Mount Maunganui Reef – Assessment of Management Options

Prepared for the Bay of Plenty Regional Council

December 2013

focus
resource management group

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Report submitted:

December 2013

Citation:

FOCUS, 2013: Mount Maunganui Reef – Assessment of Management Options. Prepared for Bay of Plenty Regional Council by the Focus Resource Management Group. Focus Report No. 131

EXECUTIVE SUMMARY

The Mount Maunganui Reef Trust gained resource consent in August 2000 to construct a pilot offshore submerged reef at Mount Maunganui ("the Reef"), approximately 250 m offshore from the junction of Tay Street and Marine Parade. The Reef was primarily intended to form the basis for continuing research into artificial reef development as well as aiming to provide the community with a high class surfing break. The five year consent term has now lapsed and the Bay of Plenty Regional Council (BoPRC) as the RMA regulator must now consider options for future management of the Reef. This report considers the performance and effects of the reef and provides a recommendation for Council regarding the Reef's future management.

This review has considered the performance of the Reef in terms of the expected gains in research, shoreline protection and surfing amenity. It also considered the effects of the Reef on beach and nearshore processes, swimmer safety, navigation safety, surfing values, cultural values and ecology.

The expected positive impacts on surfing amenity and beach width have largely not been realised. The failure of the reef to deliver these benefits can be attributed partly to problems with construction, experienced also with many other similar reefs. Other factors are also likely to have played a role.

The Reef has also generated some unforeseen impacts on nearshore processes and morphodynamics, including the creation of a large scour hole in the lee of the structure. The size of the scour hole and its effects on waves and currents is greater than the direct physical impact of the reef itself. The reef structure and associated scour hole alter waves and currents and have increased the frequency and intensity of rips and other complex offshore currents in the immediately vicinity, aggravating risk to swimmers in the popular Tay Street area. This beach is a popular use area and growing in importance because of the facilities available (i.e. boardwalks, BBQ areas, toilets and change facilities, parking, and café/shops) and the difficulties with parking on the main Mount Maunganui beach. The impacts of the reef on swimming hazard at Tay Street is therefore of serious concern, particularly as the beach does not currently have lifeguards stationed at the site over the peak summer period and is only protected by periodic roving patrols.

The review evaluated three options for Reef management, including Status Quo, reef removal and reef repair/restoration. On the basis of this review, it is recommended that Council undertake removal of the reef structure in a staged manner. Initial efforts would focus on removing the largest geotextile containers making up the reef. With careful management, partial removal will involve estimated costs in the order of $55-60,000 and is likely to be adequate to eliminate the health and safety and environmental issues. Full removal would be considerably more expensive and might well cost >$100,000 – but on the basis of existing information is unlikely to be required. However, periodic ongoing monitoring (relatively low cost) will be required to confirm the adequacy of the partial removal option and assess whether complete removal of the structure is warranted.

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1 INTRODUCTION

The Mount Maunganui Reef Trust gained resource consent in August 2000 to construct a pilot offshore submerged reef at Mount Maunganui ("the Reef"), approximately 250 m offshore from the junction of Tay Street and Marine Parade.

The resource consent was sought and obtained for a five year period as part of ongoing research linked to the University of Waikato. The Reef was primarily intended to form the basis for continuing research into artificial reef development as well as aiming to provide the community with a high class surfing break (Rennie et al., 1998a; Mead et al., 1998).

The Reef was ultimately constructed over a three year period between 2005 and 2008 and a range of research investigations and monitoring were undertaken to assess the effects of the structure.

The five year consent term has now lapsed. The Mount Maunganui Reef Trust has communicated to Council that they would ultimately like to see the Reef completed to achieve the original intent – but are not currently in a financial position to maintain, manage, re-consent or complete the Reef (Luke Faithfull, BoPRC, pers. comm., April 2013). The Bay of Plenty Regional Council (BoPRC) must now consider options for future management of the Reef. A key issue for Council is to determine whether the Reef can safely be left in the current state, or whether there are hazard and/or environmental issues which necessitate that the Reef be repaired or removed.

As part of this consideration, BoPRC have commissioned the Focus Resource Management Group to conduct a review of the state of the Reef in relation to its design objectives, and the effects that the Reef may be having on public safety and the environment. We also consider the likely method, impacts and potential costs associated with retaining or removing the structure.

A draft report was submitted to the Council in April 2013, which outlined some further work that was required to provide a more definitive recommendation, including a diver and video inspection. This further work has been completed and the draft report has been updated to reflect this additional information, and to give clearer guidance to council on a recommended course of action.

2 THE MOUNT MAUNGANUI SURFING REEF

2.1 Location and Dimensions

The Reef was constructed on the seabed adjacent to the intersection of Tay Street and Marine Parade, Mount Maunganui (Figure 1). The resource consent application specifies the location as at or about map reference NZMS 260 U14:9260-903 and approximately 250-300 metres from the shoreline. The Reef is composed of sand filled geotextile “megacontainers”.

The original proposed dimensions were approximately 50 m in width (shore parallel measure) and just less than 100 m in length (perpendicular to shore). However, in 2005, just prior to commencement of construction, a change to the resource consent was obtained to alter the shape of the structure from a “wedge” shape to a “delta-wing” design. As finally built, the structure is approximately 80 m in shore-parallel length and about 70 m in cross-shore width.[1]

The resource consent application notes that the structure would be located in an area with (pre-reef) water depths of 3.7-4.6 m. This broadly coincides with the final location of the Reef shown by Scarfe (2008) superimposed on his August 2004 baseline survey – in which the Reef is shown in an area with (pre-reef) depths of approximately 3-5 m depth (relative to Moturiki MSL datum) (see Figure 8.3 on p 262 of Scarfe, 2008).

The maximum proposed design height of the Reef was about 0.4 m depth (below lowest astronomical tide, which is approximately equivalent to Chart Datum). The most recent survey suggests at its highest point, the reef is approximately 0.2 m below chart datum, or approximately 0.1 m below the lowest astronomical tide. Crest elevations over the majority of the reef are approximately 1.0 m below chart datum.

2.2 Reef Construction

Construction commenced in November 2005 but there were several delays during reef construction, due to weather conditions and other factors (detailed in Mead, 2011). Consent was granted to extend the construction period and the work was completed in mid-2008.

Mead (2011) notes that the basic reef design incorporated 6 geotextile containers on each side of the structure, 3 large crest containers and 3 smaller base-containers (see Figure 4 in Mead, 2011). In the constructed reef, shorter containers were used for the smaller base containers, so that the as-built structure has 6 lower containers on each side. In addition, Mead (2011 notes that one of the larger crest containers (on the more northern arm) split during construction and was eventually replaced with 2 shorter containers.

[1] Scarfe (2008, p271) gives the reef dimensions as 79 m by 67 m.

Figure 1: Aerial view of Mount Reef (arrowed). Photo supplied by BoPRC.

2.3 Maintenance

Resource consent conditions were included to ensure the safety and ongoing maintenance of the reef structure. In particular, these conditions required that the Reef be maintained in good structural condition and that a safety survey be undertaken every three months and after any major storm event. Any necessary repairs identified by the safety survey were to be completed as soon as practicable. The consent holder was required to report findings of these surveys and any repairs to the Regional Council.

2.4 Monitoring

Consent conditions included a range of monitoring requirements, including beach profile monitoring, bathymetric surveys and ecological surveys. Table 1 provides a brief summary of the monitoring required by the consent conditions.

Table 1: Monitoring required by Mount Reef consent conditions.

Monitoring	Description	Frequency
Bathymetric Surveys	Full coverage of area bounded by low tide, 11 m contour and 300 m each side of the reef.	3 monthly for first year Annually after first year
Beach Profile Surveys	14 sites defined adjacent to the reef and on nearby beach.	Fortnightly for first year Monthly for duration of consent.
Ecological Surveys	Survey of intertidal benthic fauna.	Annually between September and November
Safety Survey	Diver survey to ensure user safety.	3 monthly and after major storms.

2.5 Consent Term and Removal

The resource consent for the Reef was first granted in September 2000, for a period of five years. There were delays in obtaining funding, and reef construction actually commenced in November 2005. Several modifications were subsequently made to the consent timeframe and the associated conditions (e.g. working hours and completion date).

The consent anticipated that the removal of the Reef would be achieved by gradual release of the sand in stages and subsequent removal of the bags from the coastal marine area.

3 DATA AND INFORMATION USED IN REVIEW

This section briefly outlines the available site specific data and other information used in this review.

3.1 Beach Profile Surveys

Consent conditions required beach profile monitoring to assess any effects of the Reef on beach erosion or accretion relative to adjacent areas removed from the influence of the Reef. The consent conditions required that beach profile monitoring be undertaken at fortnightly intervals for the first year following reef construction and thereafter monthly as well as after major storm events.

The beach profile monitoring was designed to measure beach changes in the lee of the Reef in relation to beach behaviour in adjacent areas removed from the influence of the Reef and involved 16 beach profile sites in total. Consent conditions required that the Reef would be removed if a significant increase in erosion was observed in the lee of the Reef compared with beach profile sites distant from the Reef.

The data available for this review included 32 surveys at 17 sites between August 2005 and March 2007. This data covers the period from approximately three months prior to commencement of construction until approximately five months after completion of construction of the second half of the Reef. However, there were further significant changes made to the Reef after this time, including the removal and subsequent replacement of a major geotextile bag and the additions of the Reef "focus". This work was completed between May and August 2008. Accordingly, the data does not provide reliable long term information on the effect of the Reef on the adjacent shoreline. Nonetheless, it provides useful indicative information on initial effects of the Reef.

Additional shoreline monitoring was also undertaken and reported by Scarfe (2008) and Weppe (2010), as described in Section 3.2.

3.2 Bathymetric Surveys

Consent conditions required full bathymetric surveys of the area, extending from the low tide line out to the 11 m contour and 300 m each side of the Reef. These surveys were to be taken every three months for the first year after construction, and annually thereafter.

The data held by BoPRC and provided for this review included a total of 15 surveys conducted between mid-2005 and February 11, 2009; each covering an area of approximately 800 m x 800 m. Mead (2011) also presents and discusses two additional bathymetric surveys (Table 2).

Table 2: Bathymetric Surveys of the Mount Maunganui Reef as listed by Mead (2011)

Date of Survey	Survey Number	Comment
June 2005 (?)	0	Baseline survey
23 December 2005	1	One month after initial reef placement
05 April 2006	2	
19 May 2006	3	
28 July 2006	4	Second half of reef constructed between these two surveys (4&5)
10 October 2006	5	
20 October 2006	6	
13 November 2006	7	One of the geotextile containers removed between these two surveys (7&8) because it was pierced
20 February 2007	8	
30 May 2007	9	
08 August 2007	10	
13 May 2008	11	Missing geotextile container replaced between Survey 11&12 and focus added.
06 August 2008	12	
11 February 2009	13	
July 2010		From Mead (2011)
April 2011		

Mead (2011) provides no date for the first survey ("Survey 0") but raw data supplied by Bay of Plenty Regional Council suggest it was undertaken in June 2005, six months prior to the first post-construction survey.

In addition, nine surveys of the surf zone, offshore bar, beach and reef structure were conducted by Scarfe (2008) in the period from August 2004 to May 2007 (see Table 8.1 on p259 of Scarfe, 2008). For various reasons, discussed by Scarfe (2008), not all of the surveys covered the entire study area and it was also generally difficult to obtain coverage in the area with depths between -1 to -2 m below MSL (Moturiki Datum). Nonetheless, Scarfe (2008) notes that the datasets still clearly show the evolution of the beach and reef structure. Weppe (2010) also undertook and analysed a further post-construction survey in March 2009.

A multibeam survey of the reef and immediate surrounds was undertaken by the University of Waikato in July 2013. This survey data gives a detailed picture of the current reef structure and has been utilised to compare changes in the reef since the earlier data and reporting of Scarfe (2009), Weppe (2010) and Mead (2011).

3.3 Other Monitoring Data

3.3.1 REEF ECOLOGY

Consent conditions included a requirement for annual biological surveys of the Reef. There has been no information provided to the authors to indicate that this ongoing ecological monitoring has occurred. However, a survey of the Reef ecology was undertaken in October 2007, comparing ecological assemblages present on the Reef with those on nearby natural subtidal rocky reefs at Moturiki Island (Green, 2009).

3.3.2 INTERTIDAL ECOLOGY

Consent conditions required that the consent holder carry out an annual ecological assessment of the intertidal benthic fauna between September and November, in accordance with methodology set out in the consent conditions. There has been no information supplied to the authors in relation to the fulfilment of this consent condition and so we are unable to comment definitively on the impacts of the Reef on beach ecology.

3.3.3 REEF CONDITION AND SAFETY

Consent conditions for the Reef required regular (3-monthly) diver checks to monitor the physical condition of the Reef and any damage that may pose a risk to the safety of reef users.

A brief memo supplied by the Regional Council suggests that nine diver surveys were carried out between November 2006 and April 2007 (BoPRC, 2007). We were not provided with any information suggesting there have been any inspections of the Reef since this time.

As part of the present investigation, an underwater inspection of the reef was conducted on 25 November 2013 using a video and divers to assess the physical condition of the reef, including damage to the geotextile material and extent of marine growth. The inspection also considered methods for removal of the reef should this be required.

3.4 Other Information

Other information used in the review included:

- Reports and papers on the Reef
- Anecdotal reports and discussions – particularly in regard in to use of the Reef and beach safety, where information was otherwise limited.
- Reports and papers on similar structures elsewhere
- Written advice from the Omanu Surf Life Saving Club (letter to Bay of Plenty Regional Council dated 9 November 2013), the Mount Maunganui Lifeguard Service (letter to Bay of Plenty Regional Council dated 11 November 2013) and the Eastern Regional Office of Surf Life Saving New Zealand (Email to BoPRC dated 16 October 2013) providing feedback on the reef, particularly in relation to swimmer safety.
- Discussions with experienced marine industry and construction divers in regard to potential removal of the reef, including an indication of likely costs.

4 EFFECTS OF REEF

This section briefly reviews the effects of the Reef. The review adopts the following structure:

- Brief outline of the effects as anticipated by the designers and/or the consent evaluation
- Actual outcomes as assessed based on monitoring data, previous studies/reports, field and reef inspection, and other information.

4.1 Morphologic Change Beach State and Nearshore Processes

4.1.1 DESIGN EXPECTATIONS

The assessment of the likely effects of the Reef on sediment transport and shoreline movements included field measurements (bathymetry, grain size analysis, diver bedform observations, and deployment of an S4 current meter in the approximate location of the Reef), used in conjunction with numerical model simulations of wave refraction, wave induced circulation and sediment transport (Mead et al., 1998).

These investigations assessed that:

- Wave transformation and attenuation over the Reef was likely to form a salient in the lee of the Reef, increasing the buffer zone against erosion in storm conditions. Empirical relationships available at the time suggested maximum predicted salient dimensions of 450 m alongshore by 58 m across shore. This anticipated beneficial effect was to be temporary due to the five year term of the consent. The application emphasized that while a salient was expected to form, the Reef was not intended to be a coastal protection activity.
- The volume of sediment required to form the anticipated salient (estimated at approximately 6,670 m^3) would be insignificant relative to the large volumes in the beach system and the large volumes of gross longshore transport, so any effects on other shoreline areas would be negligible (Mead et al., 1998).

The assessment of effects also noted that the beach is highly active with banks migrating cross-shore in response and observed that the "*efficacy of the reef for enhancement of beach stability cannot be fully determined in the absence of the proposed long-term pilot study*" (Chapter 7 of Application, p44). Accordingly, the application included shoreline change criteria for reef removal developed using analysis of available beach profile data – in case the predictions proved incorrect and the Reef caused unanticipated serious erosion (Mead et al., 1998).

A peer review commissioned by BoPRC (DTec, 2000a,b) concurred that the Reef was likely to form a salient (seaward projection of the beach) and was unlikely to have any significant adverse effect on coastal sediment transport and shoreline movements. The peer review agreed that the proposed criteria for reef removal (with minor proposed alteration) provided adequate safeguard if the Reef were to generate unforeseen adverse effects.

4.1.2 OUTCOMES

The available beach profile monitoring only covers the period to August 2008, about five months after construction of the second half of the Reef. This data is not sufficient to provide reliable information on the long term effect (positive or negative) of the Reef. However, the effect of the Reef on coastal morphology has been considered in some detail in field and modelling investigations by Scarfe (2008) and Weppe (2010).

Scarfe (2008) assessed the effect of the Reef on surf zone morphology using nine accurate and dense multibeam echo sounding surveys dating from 19 August 2004 to 15 May 2007, modelling of wave transformations offshore and around the site, and analysis of morphologic changes. Construction of the Reef was only 70% complete at the completion of his study. He found there was no persistent salient formed in the lee of the Reef, and concluded that "*It is clear when comparing the average preconstruction to post construction shorelines ... that the shoreline is undulating around the mean preconstruction shoreline, rather than a salient accreting above the mean position*."

Weppe (2010) reanalysed the data used by Scarfe, together with an additional survey conducted after completion of the Reef (March 2009). He similarly concluded that the shoreline response to the Reef was dynamic and there was no evidence of a persistent salient. He did however note evidence of possible transient localised shoreline advance related to the structure. We have also examined this change and note that it may also relate to a period of natural shoreline accretion as it appears to occur over a significant length of shoreline.

Scarfe (2008) also found that a significant scour hole has developed on the landward side of the Reef, with an area over three times the surface area of the Reef and eroded to depths of -4.0 m to -5.0 m (MSL), about 1.75 m deeper than ambient bed levels. This significant feature was not anticipated in the original application. The scour hole links with the existing longshore trough, which in the vicinity of the structure is compressed between the Reef and the shore. Scarfe (2008) argued that the scour hole is likely to be formed by strong wave induced currents over the Reef.

The large scour hole caused wave divergence in the lee of the Reef, with wave refraction over the scour hole more significant than wave rotation over the Reef under average wave conditions (Scarfe, 2008). This could be a significant factor in the absence of the persistent salient originally anticipated.

The analysis by Scarfe (2008) and Weppe (2010) also indicated other complex hydrodynamic and morphologic responses to the presence of the Reef, including:

- **A submerged groyne effect on the offshore bar (which naturally forms offshore of the beach)** causing a change in the nearshore erosion/accretion patterns updrift and downdrift of the Reef. Both Scarfe (2008) and Weppe (2010) observed that the offshore bar was slightly elevated on the updrift side and extended further offshore and slightly lowered on the downdrift side relative to the baseline survey. Despite these subtidal effects, both studies found that no significant shoreline erosion was evident on the bathymetric surveys or shoreline data available at the time. Both authors noted that the current effects could become more significant if the Reef was larger. This potential effect is important when considering any future proposed repair or upgrade of the present structure.

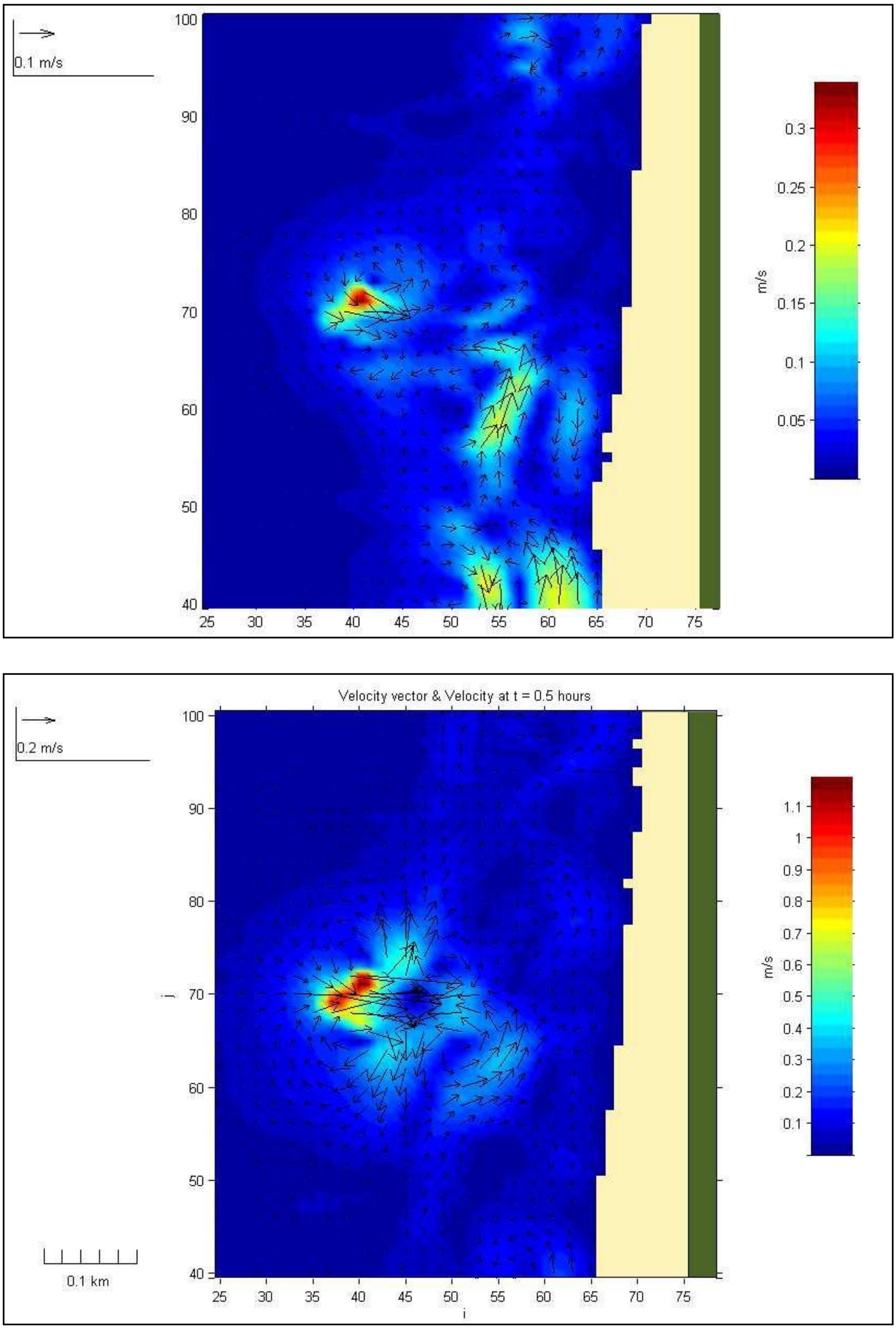

Figure 2: Predicted hydrodynamic circulations in the vicinity of the reef for wave height of 1.0 m (top) and 2.0 m (bottom), at shore-normal incidence. Note the complex current patterns in the lee of the reef. (from Weppe, 2010).

- **Evidence of greater shoreline irregularities associated with bars and rips subsequent to reef construction**, with rip eroded features and accreted bars appearing rhythmically around the Reef site after construction. Scarfe (2008) attributed this to a change from an intermediate to a more reflective and rhythmic beach state arising from the impact of the Reef on surf zone hydrodynamics. He considered that the impact of the Reef on natural rip and bar formation was significant. However, Weppe (2010) observed a more linear beach state in March 2009 and noted that both rhythmic and linear beach states were recorded in two pre-construction surveys. This aspect is further discussed in Section 4.2 below in relation to swimmer safety.

Weppe (2010) modelled waves and currents in the vicinity of the reef and observed that the hydrodynamic circulation can be significantly disturbed when wave heights are sufficient to break on the reef. In these conditions, a strong onshore flow is generated over the reef, and an associated set-up of the water level in its lee. This generates a circulation pattern in the lee of the reef that includes return currents on the reef sides. The increase in current velocities and complex changes in current direction can be seen in Figure 2. While these wave and current patterns change significantly under different offshore wave conditions, strong onshore water fluxes over the reef, and associated high velocity return currents are common in the modelling results.

It is our view that the analyses by Scarfe (2008) and Weppe (2010) indicate the effect of the Reef on hydrodynamic processes and morphology has been more significant and complex than anticipated. This appears to be related in part to the Reef being located within the active beach system. Scarfe (2008) found that the longshore bar and trough consistently covered the entire study site before and after reef construction. He assessed the seaward edge of the active beach system as about 6 m depth based on profile analysis, whereas the Reef is located in an area with (pre-construction) depths of 3-5 m. This assessment is further supported by a photograph taken during the July 2007 storm event which shows waves breaking well seaward of the Reef (Scarfe, 2008). Scarfe (2008) noted that the Reef may have benefited from being located further seaward, where sediment mobility is less significant.

There is also still some uncertainty as to how the Reef might (positively and/or negatively) influence shoreline response during rare and severe storm erosion events, with modelling clearly showing the Reef dissipating wave energy and rotating waves during a moderately severe event in July 2007 (Scarfe, 2008).

Overall, the studies and available evidence (e.g. bathymetric surveys) indicate that the reef has had unanticipated and significant adverse effects on nearshore morphology and dynamics, including formation of a large scour hole inshore of the reef and significant currents. In addition, the beneficial effects originally anticipated through formation of a salient increasing the buffer against coastal erosion have not been realised.

4.2 Swimmer Safety

4.2.1 DESIGN EXPECTATIONS

The original application recognised that the adjacent Tay Street beach and backshore were popular for recreational use, including swimming during summer (Black et al., 1998). The safety of beach users was not considered in any detail in the environmental impact assessment but it was expected that the Reef would generate a safer swimming environment in its lee, reducing the level of danger while maintaining most of the natural character of flows of sand and water. The application anticipated that the presence of surfers for an increased period of time was also likely to increase swimmer safety as surfers often assist swimmers in difficulty (Rennie et al., 1998).

An independent audit of beach users conducted as part of the preliminary design work found that most beach users interviewed did not believe that the proposed reef would affect their beach use (Lancaster, 1998).

4.2.2 OUTCOMES

The draft report considered a range of anecdotal reports including newspaper and web articles with comments on the effects of the reef by experienced lifeguards and local surfers – complemented by telephone conversations with experienced local lifeguards. These reports suggested considerable concern in regard to the impact of the reef on swimmer safety. Accordingly, Bay of Plenty Regional Council sought formal comment from the two local surf lifesaving clubs that patrol this area of the coast and also from the Eastern Office of Surf Life Saving New Zealand – with responses received from all of these parties (see Section 3.4).

4.2.2.1 **View of Local Surf Clubs**

The feedback from both the Mount and Omanu surf lifesaving clubs indicates they are firmly of the view that the reef has increased the hazard posed to swimmers in the popular Tay Street area and that the reef should be removed.

In the response from the Mount Maunganui Lifeguard Services, senior lifeguards quoted note that the reef:

- has formed new rips (either side of the reef) and exacerbates existing rips,
- has caused rips to form in unusual ways, with many inexperienced lifeguards struggling to read the Tay Street conditions and swimmers generally unaware of the dangers,
- can result in very fast changing conditions

The Omanu Surf Lifesaving Club notes while there have always been holes and rips in the area, the rips in the vicinity of the reef have become more severe since establishment of the reef. The Club considers that the reef has exacerbated swimmer hazard for about 300-400 m to both the north and the south of the structure.

The Omanu Club note that when surf conditions exist, "*a large scour hole rapidly forms on the inside of the reef which acts as a magnet for developing longshore and rip currents*". In particular, they note: "*Often, a very strong rip will develop inside the reef sweeping through the scour hole and exiting to seaward north of the reef. It is this rip that is responsible for a number of incidents.*" These observations are consistent with bathymetric survey data, which confirms that a large scour hole in the lee of the reef can extend close inshore to the beach (see Figure 4).

Of particular concern, the formal response from the Omanu Club notes that they believe that the reef played a significant contributing role in at least one drowning (possibly two) and a number of (largely unreported) serious incidents. The role of the reef in these incidents is a judgment call and it is difficult for us to comment on whether or not any of these events would have occurred had the reef not been present. Nonetheless, the firm view of experienced surf lifeguards from both clubs that the reef has significantly exacerbated swimmer risk at this popular site is in our opinion reason for concern.

4.2.2.2 **Incident Statistics and View of Eastern Office of SLSNZ**

The BoPRC also contacted the Eastern Region of Surf Life Saving NZ (SLSNZ) to provide comment and available statistics for incidents at Tay Street. A response was obtained in the form of an email and further detail gathered in a telephone conversation with the lifeguard responsible for the response. The lifeguard has worked in the area for up to five years in the past.

The eastern office response noted that "*From a lifesaving point of view the reef doesn't have a massive impact on the water. Like most beaches they all get rips and current's which change most days*." However, in a subsequent telephone conversation the representative noted he was also of the view that the reef does accentuate risk on occasions, with the seriousness depends on surf conditions.

The representative from the Eastern Office also indicated that preference should be given to the views of the local clubs who do the patrols. When also asked for the names of experienced local lifeguards we should approach to discuss the matter further, the names given were individuals already consulted in the earlier stage of this study – both of whom expressed firm and serious concerns.

The statistics provided by the Eastern Office on recorded incidents at Tay Street of SLSNZ cover the period since the summer season of 2004-05 inclusive and are shown in The Eastern Region notes that the statistics are based on callouts rather than patrolled beach statistics as SLSNZ currently do not patrol at Tay Street. They note "*The only cover we can provide is a roaming patrol who drive past every 40min to warm public of any dangers and in the odd chance perform a rescue if they are in the right place at the right time*."

The formal response from Omanu Surf Club notes that there have also been a number of other serious incidents related to the reef and that "... *the true extent of incidents is not being fully recorded. SLSNZ Eastern Region statistics only encompass incidents recorded by lifeguards or passed on by their respective SLSC. We have been made aware of several other incidents where swimmers (mostly children) have been assisted from the water at Tay Street by concerned parents or other beachgoers. Unfortunately, most of these incidents never get reported at the time.*"

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Table 3: Statistics from Surf Lifesaving NZ for recorded incidents at Tay Street.

Season	Lives Saved/Rescues	First Aid	Searches	Total Incidents
2013-14	3	0	1	4
2012-13	4	1	0	5
2011-12	4	1	1	6
2010-11	7	3	1	11
2009-10	2	2	0	4
2008-09	3	0	2	5
2007-08	6	3	6	15
2006-07	5	0	0	5
2005-06	8	1	0	9
2004-05	0	0	0	0

In addition, the statistics only cover one summer season (2004-05) before construction of the reef. There were no recorded rescues or incidents of any kind at Tay Street in that year (The Eastern Region notes that the statistics are based on callouts rather than patrolled beach statistics as SLSNZ currently do not patrol at Tay Street. They note "*The only cover we can provide is a roaming patrol who drive past every 40min to warm public of any dangers and in the odd chance perform a rescue if they are in the right place at the right time*."

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Table 3). In the summer seasons since initial construction of the reef in 2005 there have been a number of recorded rescues each year, varying from 2-8 (The Eastern Region notes that the statistics are based on callouts rather than patrolled beach statistics as SLSNZ currently do not patrol at Tay Street. They note "*The only cover we can provide is a roaming patrol who drive past every 40min to warm public of any dangers and in the odd chance perform a rescue if they are in the right place at the right time*."

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recorded. SLSNZ Eastern Region statistics only encompass incidents recorded by lifeguards or passed on by their respective SLSC. We have been made aware of several other incidents where swimmers (mostly children) have been assisted from the water at Tay Street by concerned parents or other beachgoers. Unfortunately, most of these incidents never get reported at the time."
Table 3). In addition, since the reef was constructed, the total number of recorded incidents has varied from 4-15 (The Eastern Region notes that the statistics are based on callouts rather than patrolled beach statistics as SLSNZ currently do not patrol at Tay Street. They note "*The only cover we can provide is a roaming patrol who drive past every 40min to warm public of any dangers and in the odd chance perform a rescue if they are in the right place at the right time*."

The formal response from Omanu Surf Club notes that there have also been a number of other serious incidents related to the reef and that "... *the true extent of incidents is not being fully recorded. SLSNZ Eastern Region statistics only encompass incidents recorded by lifeguards or passed on by their respective SLSC. We have been made aware of several other incidents where swimmers (mostly children) have been assisted from the water at Tay Street by concerned parents or other beachgoers. Unfortunately, most of these incidents never get reported at the time."*
Table 3), with an average of 7. While this data tends to suggest that the reef has had a significant effect on the number of rescues and other incidents, it is not possible to draw any definitive conclusions given the limited data (i.e. only one season) for the period prior to reef construction. The data does however indicate that there are a number of rescues required at Tay Street every year.

4.2.2.3 **Modelling and Other Investigations**

Scarfe (2009) and Weppe (2010) both considered the effect of the reef on bed morphology, waves and currents, and commented on possible changes in the intensity and frequency of rip currents in the area (see Section 4.1.2). These investigations tend to support the anecdotal reports that the reef has aggravated swimming risk.

Scarfe (2009) concluded (p 304) that "*the morphodynamic beach-state was found to be significantly modified and this has the potential to change surfing conditions and swimming safety around the reef*". On the basis of his findings, he recommended further monitoring and research on the impact of reefs on changes in beach state, including effect on swimmer safety.

Both studies indicate that the reef has a range of effects on nearshore currents, which depend on conditions, but do have the potential to generate strong offshore return currents.

Weppe also noted that "*Based on the WRIGHT and SHORT (1984) model, a decrease in wave height in the lee of a structure would result theoretically in a shift of the sheltered beach towards a more reflective state. This includes the development of more rhythmic features such as rip/bar systems, and these have indeed been observed in the vicinity of constructed reef prototypes*..." and that fragmentation and changes in the longshore bar "*...is consistent with numerical modelling simulations by GARNIER et al. (2008) who demonstrated that a single bathymetric perturbation on an idealized uniform long-shore bar was sufficient to induce the bar onshore migration and its fragmentation into a bar/rip systems, through coupling between hydrodynamics and morphology. This further highlights the relevance of rip systems formation around narrow submerged structures. They pose potentials problems since increased rips* *currents can deteriorate swimming safety and may transport significant volumes of sediment offshore (e.g. AAGAARD et al., 1997)."*

In addition to the direct influence of the reef structure, the steepening of the beach profile in the lee of the reef (due to the large scour hole which occurs in its lee) supports the development of rhythmic surf zone features such as rip/bar systems.

It is also be relevant to note that during periods of moderate to high wave energy, waves are attenuated over the reef and therefore wave height is reduced in the lee of the reef. This area may therefore appeal to swimmers as it may appear safer. Unfortunately modelling studies by Weppe (2010) suggest the strongest and most complex current patterns generated by the reef occur in this area under these conditions.

4.2.2.4 **Summary**

Overall, it is our view that the investigations by Scarfe (2009) and Weppe (2010) indicate that the reef alters wave action and generates complex currents between the reef and the shore. These effects are likely to aggravate swimmer hazard on Tay Street Beach, particularly under moderate to high surf (i.e. 1-2 m height) conditions. This is consistent with the views of the lifesaving clubs and experienced lifeguards. For the same reasons, there is considerable hazard to swimmers who venture out to the reef.

Tay Street Beach is a popular use area and growing in importance because of the facilities available (i.e. boardwalks, BBQ areas, toilets and change facilities, parking, and café/shops) and the difficulties with parking on the main Mount Maunganui beach. The Omanu Surf Life Saving Club note that "*On most busy summer days, our lifeguards are recording significantly higher numbers of beachgoers and people swimming at Tay Street than at the nearest patrolled beach at Omanu*."

Accordingly, any impact of the reef on hazard to swimmers at Tay Street is a serious concern, particularly as the beach does not currently have lifeguards stationed at the site over the peak summer period and is only protected by periodic roving patrols. In addition, as noted by the Omanu Beach SLSC there is currently no additional funding currently provided for patrolling Tay Street, so that any demands on lifeguard services from this area stretches available resources.

4.3 Navigation and Reef User Safety and Reef Integrity

4.3.1 DESIGN EXPECTATIONS

The application identified potential water users in the area to include surfers, boogie boarders, swimmers, small water craft and (during calm conditions) divers (Section 7.5 of Application).

The assessment of effects noted that the Reef could be a boating hazard to those unaware of its presence, depth and size. Accordingly, the applicant agreed to mark the structure in accordance with the standard NZ system of buoyage and beaconage, with the location of the Reef posted at nearby boat launching sites and the use of lighted buoys to mark the Reef.

The risk to surfers using the Reef was assessed to be low as the reef face was relatively flat and also soft relative to natural rocky reefs. It was noted that surfers rarely hit the seabed due to the depth in which waves break and when they do it is usually not with great force due to cushioning provided by the water column.

It was expected that diving would occur around the Reef during calm periods and there could be a risk of entanglement with strapping. However, the application argued that measures proposed to control the use of strapping eliminated the possibility of entanglement.

The design life of the Reef was not discussed in the original application, probably because of the short term of the consent sought. However, the application provided for reef diving inspections approximately every three months and after major storms.

4.3.2 OUTCOMES

4.3.2.1 **Navigation and Reef User Safety**

The reef is presently unmarked, with no buoys or lights marking the location of the structure. Buoys were installed on the reef at the time of construction, as required by the consent. However, difficulties were experienced in maintaining the buoys due to the periodically high energy surf conditions. The first few times the buoys were lost they were replaced but ultimately this practice ceased - presumably due to the frequency of damage and resource limitations.

Both the Mount and Omanu surf clubs express concern that the now unmarked reef poses a hazard to IRBs and other (particularly fast moving) marine craft, due to its location some distance from the foreshore and being barely submerged at low water.

The most recent survey of the reef conducted in July 2013 indicates that the shallowest areas of the reef are most typically in the range of 0.8-1 m below Chart Datum (approximately lowest low tide), though there is also an isolated area on the southern arm where depths get as shallow as 0.2 – 0.4 m below Chart Datum (Figure 3). These depths are not likely to pose a serious hazard to most shallow marine craft in calm conditions but may pose a risk during wave conditions when depths between waves may get very shallow, or the reef may be exposed. Boat collision with nearshore artificial reefs of this nature has occurred elsewhere (e.g. damage to the Boscombe reef in the UK was attributed to propeller impact).

The Mount Surf Club also notes that swimmers periodically swim out to investigate the reef and "*end up in difficulty either on their way out to the reef, upon reaching the reef or on their return to shore. This happens often*". They also report that, at lower stages of the tide in large surf, powerful and unpredictable dumping waves pose a danger to swimmers who are near to or are standing on the reef.

To our knowledge there have been no reports of significant injury to surfers or body boarders using the Reef. Moreover, with use of the Reef now very infrequent (see discussion in Section 4.5), this risk is probably relatively low.

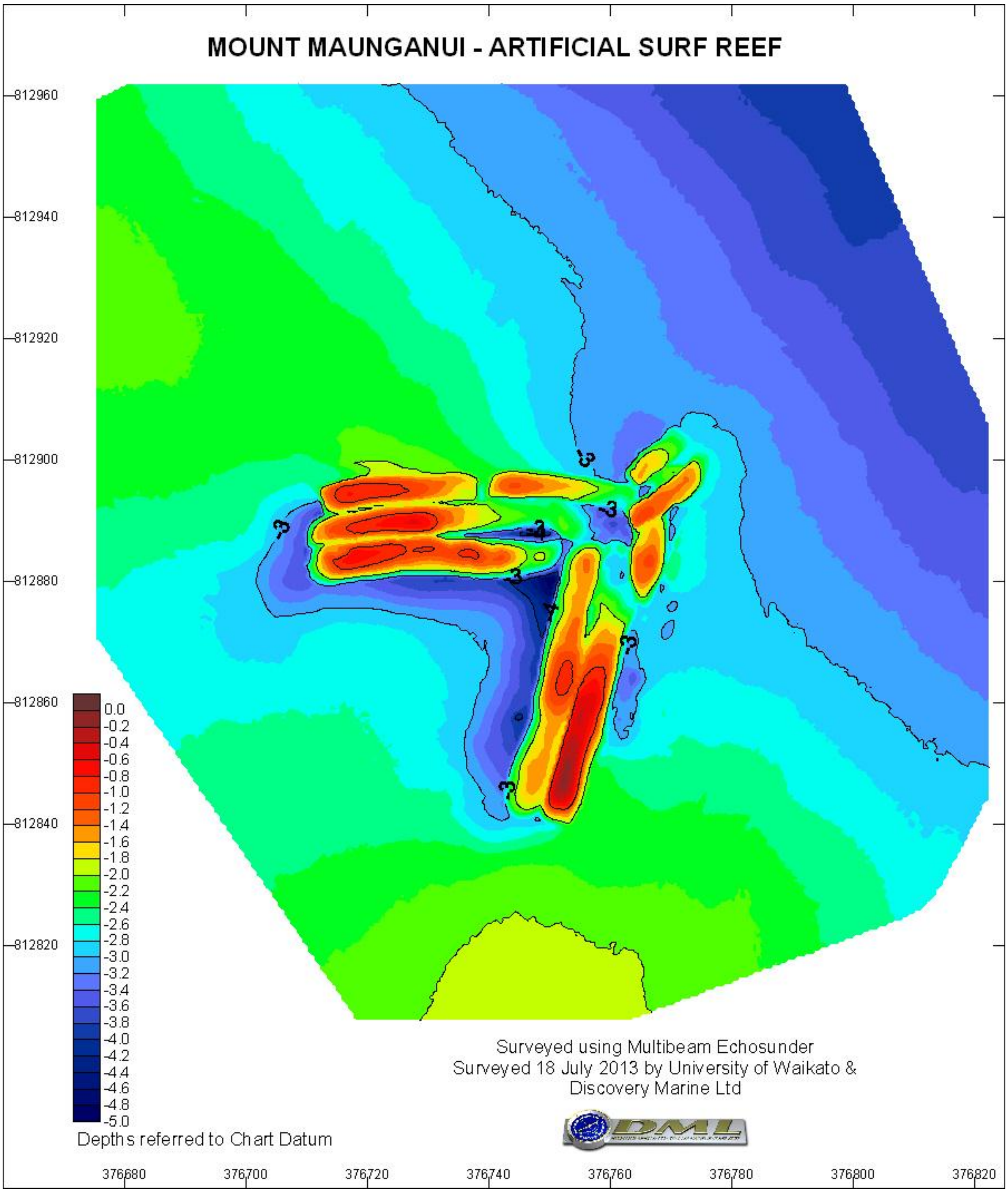

Figure 3: Most recent survey of Mount Reef conducted on 18 July 2013.

4.3.2.2 Reef Condition and Integrity

Diver inspections of reef integrity were conducted in the first few months following reef construction (but prior to reef completion in 2008). The data held by Council and provided to us includes only brief observations associated with such inspections. There is also no record of any diver inspections since April 2007.

The inspections indicate that one of the major bags (T4) was damaged during installation and eventually had to be removed following an unsuccessful repair (see Figure 4). Slumping of part of the structure was also reported by Mead (2011), which he attributed to the lengthy period between removal and replacement of the bag.

Mead (2011) notes differences between the present "as built" and design dimensions, which he attributes largely to construction issues. However, bathymetric surveys also suggest some loss of reef crest elevation and volume since construction. Scour is evident around the structure in most surveys (e.g. Figure 3 and Figure 4) and subsidence and scour have also been noted around similar structures elsewhere (NCCOE, 2012). Mead (2011) argues that there is no evidence of ongoing subsidence of the Reef since 2010.

In terms of the structural integrity of the Reef, we have made observations based on:

- comparison of detailed multibeam surveys conducted in 2008 and 2013, and
- a video and diver inspection of the reef conducted on 25 November 2013.

Initially, it was also planned to also look at changes in the reef and adjacent environment over time using the surveys completed as part of the consent monitoring (Table 2). However, examination of this data by an experienced hydrographic surveying specialist revealed significant inconsistencies and other issues, including evidence that the surveys were done in a vessel without motion sensing or poor vertical controls – these various matters precluding useful analysis and comparison (Greg Cox, DML, pers. comm., October 2013).

Comparison of the 2008 and most recent 2013 surveys suggest that the crest levels of the main large reef bags have not changed significantly over this time.

There is however, very clear evidence of damage to the bags near the apex of the structure (see Figure 3). In particular, upper bags on both arms appear to have deflated suggesting sand leakage. This damage was evident in 2008 (Figure 4) but appears to be more extensive in the latest 2013 survey (Figure 3). If sand leakage has occurred, it is difficult to be certain that this will not continue in the future, particularly during severe storms. Over time, any ongoing sand leakage would pose a serious threat to the structure. The main large bags appear to be otherwise intact and retaining volume.

There is severe scour immediately landward of the structure (Figure 3), but this has been present since soon after the initial construction and does not appear to have resulted in structural failure or collapse, though it may have contributed to initial settlement of the reef.

There is also clear evidence that bed levels in the vicinity of the structure fluctuate considerably. For instance, the deepest bags on the northern arm of the structure evident in the 2008 survey (e.g. Figure 4) are not visible in the July 2013 survey (Figure 3). Seabed depths adjacent to the northern arm were typically 3.0-4.0 m in 2008, but only 2.25-2.75 m in the latest 2013 survey (Figure 3). This suggests that the small bags on the edge of the northern arm are most likely still intact but buried underneath the sand.

Bed level fluctuations of this nature could clearly result in settlement of the structure, particularly if construction occurred when bed levels were elevated. Natural fluctuations would also make it difficult to predict physical conditions at the time of construction and therefore to construct to design specifications – though it is not clear if this factor played a role in the failure to construct the reef to design dimensions.

Divers involved in construction also advise there was trouble in achieving the desired levels of bag infilling with sand. Underfilling of some bags was also noted by Mead (2011). This appears to have been a factor in the variation in elevations along the length of some containers and is also likely to complicate any potential for future upgrade of the structure.

In terms of durability of the bags, Rendle and Davidson (2012) note that modern geotextiles are durable materials with a postulated life of up to 100 years when submerged in a challenging marine environment, but the guaranteed life of the geotextile will depend on the fabric used. Jackson et al (2012) noted that the nominated guaranteed lifetime of the standard and reinforced geotextile used on the Narrowneck Reef were 15 and 25 years, respectively. They note that the lifetimes were primarily driven by UV and therefore should be significantly lengthened by the presence of marine growth.

Regardless of the durability of the fabric under wave conditions and sand movement/abrasion, the structures appear to be vulnerable to damage from various other causes (NCCOE, 2012). For instance, the comparable Boscombe Reef has suffered significant damage in recent years (Richards, 2009; Rendle & Davidson, 2012; Daily Echo, 2013). That Reef is still closed to the public due to safety concerns surrounding the damaged area and the potential for trapping of swimmers or surfers (Rendle & Davidson, 2012). Similarly, a recent inspection of the Narrowneck Reef noted that 42 containers had been placed as part of maintenance campaigns and that specific inspections of these 42 containers indicated 8 containers either damaged or missing entirely, with a further 2 containers known to have failed previously (Jackson et al., 2012). Damage has also been reported from other geotextile reefs (NCCOE, 2012).

Past inspections also indicate that the Mount reef is extensively colonised by biota. The biota is likely to provide some protection to the fabric (e.g. from UV exposure), but the long term effect of reef biota over time is unknown. The video and diver inspection of the Tay Street Reef conducted in November 2013 indicated biological growth over much the structure but no evidence of any significant damage to the geotextile fabric. Overall, the fabric appeared to be in good condition with no evidence also of general deterioration or abrasion damage. A small section of the geotextile was also cut from a damaged bag to examine more closely and appeared in good condition.

Overall, there is significant uncertainty as to the longer term integrity of the structure, particularly in regard to the existing sand leakage from some bags. There may be potential for the geotextile bags to also deteriorate over time from various forms of physical and/or biological damage, though there is no present evidence of any such damage. The sand loss from some containers and the improper filling of some are also both factors which are likely to complicate any potential future upgrade of the structure.

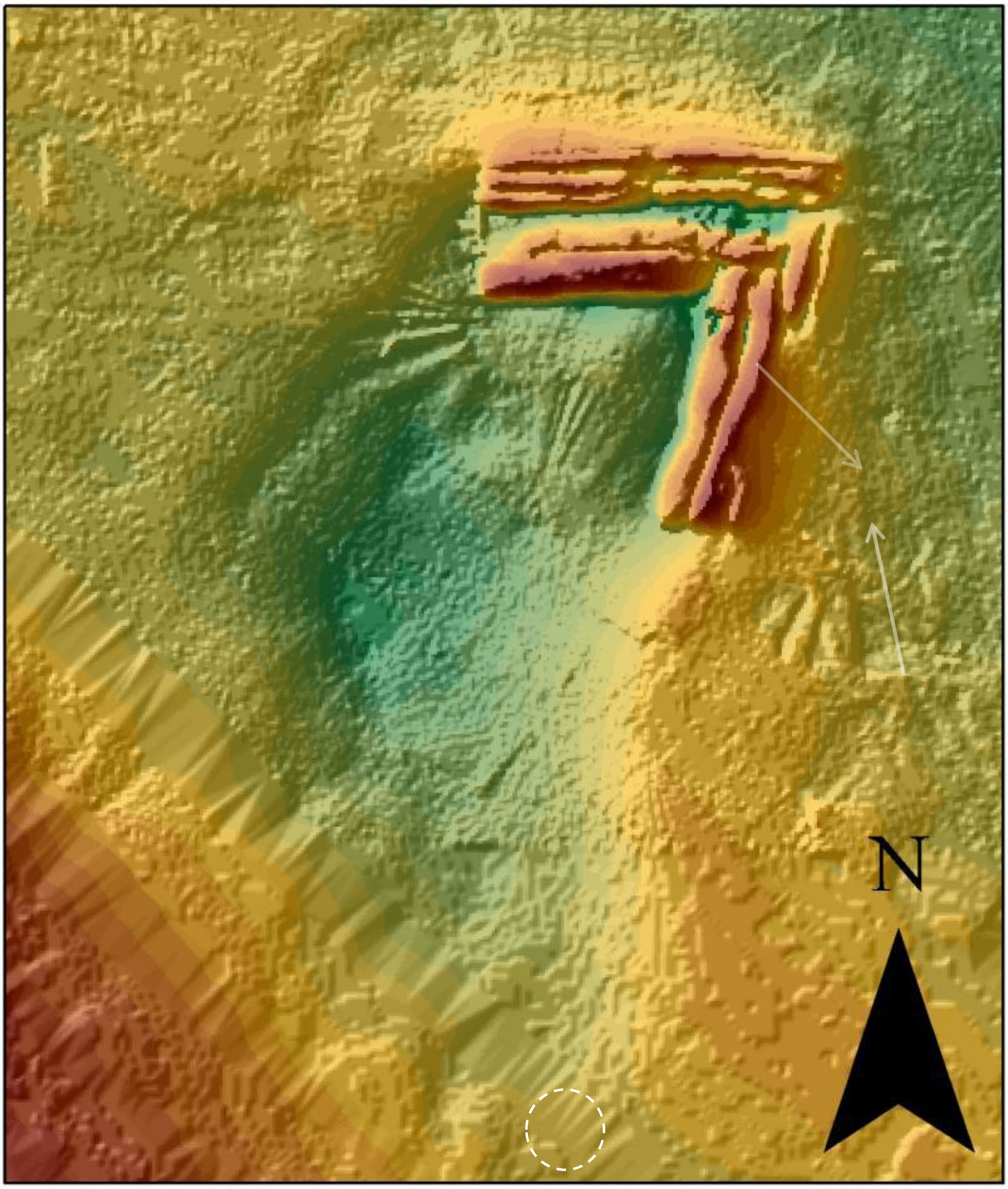

Figure 4: View of the Mount Reef from a multibeam survey conducted in January 2007, when the reef was 70 % complete (from Scarfe, 2009). Note the large scour hole on the landward side of the reef. The (then) missing bag is also clearly visible on the northern arm of the reef. This bag was replaced in 2008. Note also the smaller lower bags on the northern arm which are buried in the July 2013 survey (see Figure 5).

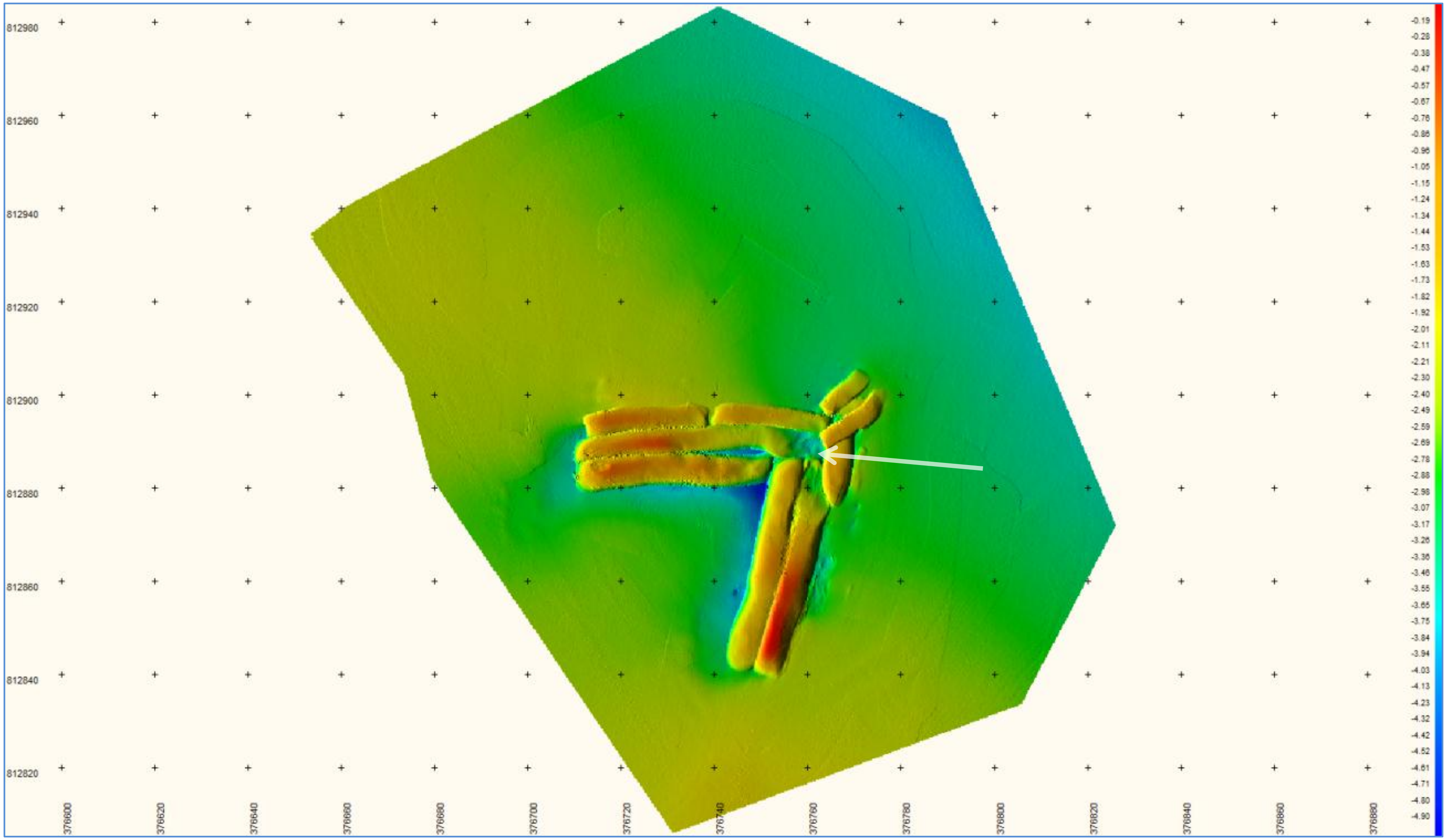

Figure 5: View of July 2013 multibeam survey with colour-coded depths. Note apparent bag deflation near apex (arrowed).

4.4 Research

4.4.1 DESIGN EXPECTATIONS

The application noted that the primary purpose of the proposed reef was to enable University staff and post-graduate students to undertake research including effects of the Reef on coastal protection, amenity enhancement (especially surfing but also diving, fishing and beach recreation), biological enhancement and social and economic impacts of the Reef (Rennie et al., 1998). This was presented as a five year research programme.

4.4.2 OUTCOMES

The Reef has been the subject of wide range of research and investigations, both prior to and following construction. Mead (2011) provides a useful though not exhaustive list of the pre- and post-construction studies, not all of which were available for the present review.

The investigations following construction focussed primarily on:

- Field and modelling investigations looking at the impacts of the Reef on nearshore hydrodynamics and morphology (Scarfe and Healy, 2005; Black and Mead, 2006 & 2007; Scarfe, 2008; Weppe, 2010).

  An MSc thesis by Issertes (2006) is also noted by Mead (2011). This work was not available to this review but a subsequent and detailed investigation on the same subject by Weppe (2009) was available.

- Ecology of the Reef (CAS & ASR, 2008; Green, 2009)

There has not yet been any detailed analysis and investigation in relation to surfing aspects. However, Mead (2011) notes that use and performance of the Reef was briefly monitored by video and provides some limited comment on this aspect based on that data (see Section 4.5). There is also widespread anecdotal assessment of the performance of the Reef in relation to surfing amenity by local surfers on a range of surfing blogs. Mead (2011) also provides an assessment of why the Reef is not performing as anticipated in relation to surfing.

Various social science, economic, legal and planning aspects of the Reef were also investigated (e.g. Makgill, 1998 & 2005; Gough, 1999; Rennie et al., 1998). This work largely relates to pre-construction assessments. It is probable that if the anticipated surfing amenity gains had been realised, there would have been further research and monitoring in many of these areas.

Papers have also examined aspects related to construction and stability of the Reef (Mead et al., 2007; Mead, 2011).

Various other investigations not available to this review were also noted by Mead (2011) including internship reports (largely conducted through ASR Ltd) and both undergraduate and Master's studies - including De Shipper (2005), Gue (2005), Marzilli (2008), Skroski (2009), Spher (2010), Thiebot (2007) and Wandres (2010).

Overall, it is clear that the Reef has provided the stimulus for a wide range of useful investigations and research, both prior and subsequent to construction.

4.5 Surfing and Other Amenity

4.5.1 DESIGN EXPECTATIONS

The application anticipated that the Reef would *".. create world class surfing waves under optimal conditions. … This will be a significantly improved surfing amenity"* (Section 3.6, p 13 of Black et al., 1998). Specifically, it was anticipated that higher quality surfing wave would be experienced in conditions of 1-3 metre swell which it was noted occurred about 30% of the time under the El Nino conditions prevailing at the time of the application (Black et al., 1998).

4.5.2 OUTCOMES

To date, there has been no detailed analysis and investigation of the performance of the Reef in regard to the anticipated gains in surfing amenity. However there is general agreement that the Reef is not presently achieving the anticipated gains in surfing amenity. There is a greater difference in opinion however as to whether the Reef ever achieved any useful improvement in the surfing amenity.

Strong and typically negative views are expressed on surfing blogs and by local surfers. The most objective assessment by local surfers that we were able to find was that presented by Estrada (2009) who posed the five questions about the Reef to seven of the "most successful and respected" local (i.e. Mount Maunganui) surfers. The responses indicate that the Reef has only rarely produced waves conducive to surfing, though it was noted that the Reef was occasionally used by body boarders. The performance of the Reef in this regard has generally fallen short of the expectations of the local surfing community. Similar experiences have been observed with artificial surfing reefs elsewhere to date (Shand, 2011; NCCOE, 2012).

Mead (2011) expresses the view that the Reef worked for a short period when it was first built. In a 2011 interview, Dr Mead argued that the Reef delivered high quality surfing waves when it was installed in 2006 but problems since had led to it being dangerous (Nous, 2011). He argued that the difficulties started when the biggest sand bag used to construct the Reef split and was removed.

Mead (2011) presents evidence of reef use by surfers from six months of remote video monitoring between April and September 2008. He noted that this data indicated there were surfers at the beach surfing adjacent to the Reef on 28 of the 102 days sampled, with surfers surfing on the Reef on 10 of these days. This indicates that at least for this period of time, the Reef was used less often than the natural adjacent areas. It is also not clear whether the monitoring was able to differentiate between surfers and body boarders on the reef.

Mead (2011) acknowledges that the Reef is now fickle and rarely breaks with waves that are conducive to surfing. He notes that the as built reef is significantly different from design; with the crest level generally being 0.5-1m lower than design (apart from specific areas) and the "as built" reef volume (2,800 m^3) significantly less than the design volume (6,500 m^3).

Mead (2011) attributes the problems to construction issues, including the protracted construction time, incomplete filling and a prolonged period between removal and replacement of one large container. However, difficulty with replicating design in practice has also been experienced elsewhere (Shand, 2011; NCCOE, 2011; Jackson et al., 2012) and so construction difficulties appear to be widespread and are probably multi-faceted.

For instance, it is clear from comparison of the recent July 2013 and the earlier (2007) multibeam surveys that bed levels in the vicinity of the reef can fluctuate by over 1 m (see discussion in Section 4.3). Variations in bed level of this scale make it difficult to reliably anticipate the topography at the time of installation and therefore to construct the reef to the desired design dimensions. It seems that these fluctuations were not anticipated or provided for in the design and construction of the reef. Jackson et al (2012) note that scour was anticipated with the Narrowneck Reef and therefore initial placement heights were approximately 0.5 m above design level to provide some compensation. However, they note that since placement these containers have experienced lowering of up to 2m, resulting in present levels some 1.5 m below design.

It also appears from examination of bathymetric surveys of the Mount Reef that some scour and subsidence was experienced following construction, which is also a common feature with these structures (NCCOE, 2011; Jackson et al., 2012).

Overall, there appear to be considerable difficulties in constructing these features to design specifications and this would appear to be an area that requires more attention.

We concur with Mead (2011) that the present dimensions of the Reef differ significantly from the design and that this would undoubtedly have a major influence on surfing amenity. However, given the widespread failure of artificial surfing reefs to match the design expectations from numerical modelling (Shand, 2011; NCCOE, 2012) other factors may also play a role. For instance, the significant bed level fluctuations noted in Section 4.3 will not only affect construction of the reef but also probably wave shoaling and transformation seaward of and around the reef. These changes may well affect performance, even if the reef could be constructed to design profiles. Accordingly, future modelling design should examine the influence of anticipated bed level fluctuations on reef performance. Obviously, this also requires monitoring of bed level variations for some time prior to design.

In his review, Shand (2011) notes that "*the future of artificial reefs intended primarily to enhance surfing amenity remains uncertain*". In the light of this knowledge (which has only come from hard-earned experience with real life structures such as the Mount Reef) it is important to ensure public expectations are appropriately managed with future structures of this nature (Shand, 2011; NCCOE, 2012).

4.6 Ecology

4.6.1 DESIGN EXPECTATIONS

Three ecological assessments of sub-tidal habitat were undertaken prior to the construction of the Reef. These assessments showed a range of species commonly found in harbour, sheltered beach and open coast environments The Reef was not expected to adversely impact the existing benthic fauna (with the exception of the footprint of the structure itself) as the existing communities are well adapted to a highly dynamic environment (Black et al., 1998).

A small salient was expected to form in the lee of the Reef as a result of the increased protection from wave energy. The application anticipated that the seabed in this area was therefore likely to become more stable than the more exposed coastline and as a result ecological productivity and diversity may increase. Annual tua tua monitoring at the beach was proposed at the time of the consent application.

The Reef itself was expected to be extensively colonised and to have enhanced biodiversity relative to the surrounding mobile sea bed.

4.6.2 OUTCOMES

Post reef construction, ecological investigations have focused on the Reef, most notably the work by Green (2009). To the knowledge of the authors, there has been no post-construction monitoring to examine changes in benthic fauna on the sandy seabed in the vicinity of the Reef or on the beach in the lee of the structure.

Green (2009) compared the ecology of the Reef with a natural rock reef on the offshore side of nearby Moturiki Island. She found that the species distribution on the Reef was quite different to the natural reef, being dominated by macroalgal communities, which accounted for 54% of total species. There were some species present on the artificial reef that were not seen on the natural reef nearby, but the overall biodiversity was lower on the artificial reef. This has been shown to be normal at other artificial reefs in the first years following construction and is considered to represent an early successional phase in benthic community development. To our knowledge, there has been no ongoing monitoring of the ecology of the Reef since this survey. Mead (2011) notes however that the Reef is colonised by seaweeds, sponges, bryozoa, crustacea, cepholapods, bivalves and a variety of reef and schooling fish compared to the sandy seabed dominated by polychaete worms, amphipods, isopods and biscuit stars documented in (Mead et al., 1998).

The recent (25 November 2013) video inspection also confirms that the Reef has been extensively colonised by marine biota. The dive survey was undertaken in poor visibility and did not include a detailed assessment of biota. However, observations included extensive algae and sea weed over the surface, common mussels (small and mature) and accumulation of sea lettuce in the lee of the structure. Juvenile crayfish seen in previous inspections (Mead, 2011) were not noted but octopuses were relatively common.

Rapid and extensive colonisation has also been noted at other geotextile reefs, including Boscombe, Narrowneck and Prattes (the latter since removed), with Narrowneck Reef reported to be popular for both diving and fishing. There has also been a recent proposal to incorporate the Boscombe Reef in a local dive trail as part of the UK’s first Coastal Activity Park (Broderick, 2012).

The effect of the Reef on shellfish used for kaimoana is unknown as this aspect has not been monitored or investigated. However, given the relatively limited effect on the shoreline (i.e.

the absence of either a persistent salient or aggravated erosion) we would expect any effect to be minimal.

Overall, the reef has been extensively colonised by marine biota as anticipated in the original design and consistent with experience at other geotextile reefs.

4.7 Maori and Cultural Values

4.7.1 DESIGN EXPECTATIONS

The application noted that the Reef "may also boost the presence of shellfish, of particular importance to Maori, on the foreshore" (Section 3.6, p 13 of Rennie et al., 1998). It was also anticipated that "Tangata whenua will have the opportunity to augment their traditional knowledge through direct involvement in the monitoring programmes and associated training opportunities made possible by the presence of the Reef" (Section 3.5, Rennie et al., 1998).

At the time of the consent application, the Ngaiterangi Iwi Management Plan was evaluated against the likely effects of the Reef. The applicant acknowledged that the Mount Maunganui foreshore is considered culturally significant, but also that the Reef site is distant from any site of particular significance.

During consultation with iwi, the applicant recorded concerns of iwi about the impact on natural processes and in particular on kaimoana. The applicant therefore proposed an ecological monitoring programme to examine this effect.

4.7.2 OUTCOMES

It appears that the proposed monitoring of shellfish was never undertaken. However, as discussed in Section 4.6, the available evidence suggests any adverse effect on shellfish beds used as kaimoana is likely to have been negligible. In addition, the overall effect of the Reef on local ecology is likely to be positive. Given the mature mussels noted in places in the November 2013 inspection, it is also possible that, over time, the Reef might even become a local source of kaimoana. However, the potential significance of the reef in this respect is unknown and the difficulty of access is a consideration. Obviously, any value as kaimoana will depend on whether the reef is retained and the nature of ongoing management.

5 OPTIONS AND RECOMMENDATIONS

5.1 Options for Management of Mount Reef

There are essentially three options for the future management of the Mount Reef:

- Status Quo
- Complete or Partial Removal of the Reef
- Restoration and/or Upgrade of the Reef

These options are briefly evaluated below on the basis of the review in Section 4.

5.1.1 STATUS QUO

5.1.1.1 Effects

This option involves leaving the Reef in its current state. The considerations relevant to this option include:

- **Coastal Erosion:** There is no evidence in the data and studies to date that the Reef has had significant effects on erosion or accretion of the upper beach or dune (see discussion in Section 4.1). Accordingly, the risk of seriously aggravated dune erosion is assessed to be low, though there is still some uncertainty in relation to extreme events. On the basis of existing information, this is not a significant consideration.
- **Nearshore Hydrodynamics:** The Reef has caused unforeseen complex and locally significant effects on nearshore morphology and hydrodynamics (see discussion in Sections 4.1 and 4.2). These effects will persist with the Status Quo option.
- **Swimmer Safety:** Overall, the available evidence suggests the reef has formed new rips and considerably exacerbated existing rips, significantly increasing swimmer hazard on the popular Tay Street Beach. It has also complicated risk assessment at this site and put an added strain/demand on existing lifeguard resources (Section 4.2). This is judged to be an extremely serious complication for the Status Quo option. The risk would need to be significantly mitigated for the Status Quo option to be viable.
- **Reef User and Navigation Safety:** With the current unmarked location, there is some risk to IRBs and other small water craft - but these are low probability risks. This risk is probably limited to low stages of the tide and will be greatest when there is significant wave action. There is however a more serious risk to occasional swimmers enticed to swim out to the reef. This is judged to be a moderate consideration for the Status Quo option.
- **Structural Integrity:** There is uncertainty in regard to the medium to longer term integrity of the structure with this option, particularly in respect to apparent sand leakage from some of the bags. This is judged to be a minor consideration for the Status Quo option in the short-medium term. Nonetheless, periodic ongoing monitoring of reef condition (probably at least once every five years and after rare and

severe storms) is likely to be required and the potential for damage in the medium-longer term is unknown.

- **Research:** It is clear that the existing structure has promoted significant research. However, in its present state, ongoing research value is relatively limited – except perhaps in relation to ecological succession and durability of the structure over time. This is considered a minor consideration for the Status Quo option.
- **Surfing Amenity:** The Reef presently provides little or no additional surfing amenity and therefore this is a minor consideration for the Status Quo option in the short term. However, the option preserves the potential for future upgrade of the reef and thereby preserves the significant public investment to date. Overall, we judge this to be a moderate consideration, limited by uncertainties around the potential to upgrade the structure to achieve useful surfing amenity and to also adequately avoid or mitigate adverse effects.
- **Ecology:** This option would retain and may over time enhance the ecological benefits of the Reef, unless the Reef begins to physically deteriorate. We regard this as a minor consideration given the limited scale of the reef in the context of the wider environment.
- **Cultural:** There are presently limited, if any cultural benefits though the reef may become a minor local source of kaimoana over time (e.g. mussels) (Section 4.6). At present, this is a minor consideration given the limited values and difficult access.

The primary benefits of this option are that it avoids loss of the community investment to date and retains the potential for future upgrade or recovery of the Reef (e.g. as proposed by Mead, 2011). Given the present level of uncertainty around the ability of this technology to achieve significant gains in surfing amenity (Shand, 2011; NCCOE, 2012), this option has the advantage of giving reef proponents time to further develop the technology. However, higher levels of certainty in terms of reef performance and effects are likely to be required before an upgrade would be supported. The option also preserves the ecological benefits.

This option avoids the costs of removal in the near future, though these costs may still be required in the longer term if the Reef begins to deteriorate, or the adverse effects become more severe. There will be some ongoing costs in the interim associated with periodic monitoring of reef condition.

The primary concerns with the Status Quo option relate to swimmer safety and resource consent requirements.

5.1.1.2 Approach and Costs

In terms of swimmer safety, it is our firm view that the issues are sufficiently serious that they need to be avoided, remedied or mitigated. With the Status Quo option, the risks cannot be avoided and therefore would have to be remedied or mitigated. Options in this regard include:

- **Improved signage and public information on the risks:** Adequate signs to warn beach users of the risks associated with the reef would be critical for the Status Quo option but have been ignored in the past and would not be adequate in isolation to mitigate the risk.

- **Funding support for provision of appropriate surf life-saving facilities at Tay Street over summer:** At present, the beach does not have a permanent patrol over summer and is only protected by roaming patrols from the Omanu and Mount Maunganui surf lifesaving clubs or callouts (i.e. situations where police or public identify the need for a rescue and volunteer or contact lifeguards in the area are called upon to undertake a rescue).

  Omanu SLSC advised they are currently in communication with Surf Lifesaving New Zealand to formalise the patrolling arrangements for the Tay Street site and considered it imperative that urgent consideration be given to the need for a more comprehensive lifeguard presence at Tay Street, and the additional funding that such a service would require. We were advised by SLSNZ that Tay Street and/or Papamoa East are “on the radar” for patrols but funding was not likely in the near future. Omanu SLSC are planning to monitor use at Tay Street over summer as part of developing the case for improved patrols in this area but it appears that such patrols are not likely to be in place over the coming summer.

  Accordingly, the Status Quo option would require funding for the patrols. SLSNZ advise that a patrol could be provided at Tay Street but would require funding for contract lifeguards, probably costing at least $3000 per week for the 8 week period from 16 December 2013 to 7 February 2014 (i.e. the same period that contract lifeguards are used for week day patrols at Omanu and Mount Maunganui). SLSNZ felt there were probably sufficient volunteer patrols to cover the weekends for the main summer period (these patrols operate at Omanu and Mount Maunganui over weekends for the period from November-March inclusive). In our view, this would be the minimum requirement if the Status Quo option were to be adopted.

  A weakness with the option is that the risks would not be mitigated for swimmers using the area outside the period of the patrols. Outside of the period during which volunteer and contract guards are available, the rescue situation depends entirely on a call out when either the public and/or police alert local surf lifesaving contacts of the need for a rescue.

5.1.2 REMOVAL OF THE REEF

5.1.2.1 Effects

This option involves sufficient removal of the Reef to eliminate serious adverse effects. The considerations relevant to this option include:

- **Coastal Erosion:** This option would have no significant effect on coastal erosion but would eliminate the (probably low) risk of severe erosion being caused by the reef during a major storm. There could also be temporary and localised beach accretion with the release of sediment from the geotextile bags. Overall, this would be a minor but positive consideration.
- **Nearshore Hydrodynamics:** The locally significant effects on nearshore morphology (including the large scour hole landward of the reef) and hydrodynamics (e.g. effect of the reef on waves and currents) would be eliminated with this option. Overall, this would be a moderate-significant positive consideration. Staged removal would probably be required to reduce any potential temporary effects with release of the sand.

- **Swimmer Safety:** This option would eliminate the adverse effects of the reef on swimmer safety. In our view, the elimination of these risks is a very significant and positive consideration for this option.
- **Reef User and Navigation Safety**: Any risk to reef users or small craft would be eliminated with this option. There would also be no reason for swimmers to swim out to the area and risks currently associated with the reef in this respect would also be eliminated. While these are relatively low probability risks, the consequences could be serious. Accordingly, we believe the elimination of these risks would be a moderate and positive effect.
- **Structural Integrity:** This option would eliminate any concerns about the structural integrity of the Reef and any costs of ongoing monitoring and maintenance, a positive consideration for this option.
- **Research:** Given the limited ongoing value of the structure in relation to research in its present condition, removal of the structure is not likely to have a significant adverse impact on research. In our view, the option would have a negative but minor effect.
- **Surfing Amenity:** In view of the limited if any surfing amenity value of the present reef, the option would have no significant adverse impact on surfing values. Given the view expressed by some parties that the reef has actually reduced surfing values in the area (see Section 4.5) any effect on surfing amenity is likely to be positive. Accordingly, loss of the reef will have only a minor but probably positive effect on surfing amenity. However, all hope of upgrade of the structure to achieve the originally desired surfing benefits would be eliminated and the public investment to date would be lost. Overall, while the reef was consented as a temporary research reef, we believe the general expectation of at least some of the funding bodies was that it would be a permanent feature.
- **Ecology:** This option would result in loss of the biological communities that have colonised the Reef, and return the area to the less diverse biota typical of mobile sandy sediments. However, given the relatively small size of the Reef, the fact that it was consented as short-term feature and there are questions around longer term integrity, this is not a significant adverse effect. However, it is a negative effect.
- **Cultural:** There are presently limited, if any cultural benefits apart from its potential to become a minor local source of kaimoana over time.

Overall, this option would have major positive benefit as it would eliminate environmental and safety concerns associated with the Reef in what is a very popular and increasingly significant area for use. It also avoids ongoing costs of monitoring and maintenance of the Reef. The only significant negative effect of the option would be the elimination of any potential for future upgrade – which aspect is examined further in Section 5.1.3. .

5.1.2.2 Approach and Costs

The major issue with this option is the financial cost of removal. The experimental nature of the Reef and the intention to ultimately remove the structure was reflected in the choice of materials, and it was envisaged the structure could be readily removed when the consent expired or if adverse effects occurred (see Section 6.2 of Rennie et al., 1998). Removal was to be effected by cutting the geotextile bags to release the sand at the site. The bags and other removal substrate units would then be removed from the marine environment (Rennie et al., 1998). This was to be carried out in a staged manner to avoid an excessive “slug” of sand being released at any one time.

However, on the basis of other experience with removal of similar structures, we believe the actual situation is more complex and that a well-designed removal process would be required to avoid high costs.

For instance, Leidersdorf et al. (2011 and 2012) note that a key lesson learned from the removal of Pratte’s Reef was the difficulty and cost of removing geotextile containers from the nearshore environment. This reef was a small artificial surfing reef constructed in 2000 in Santa Monica Bay, US. The structure was removed in two phases in 2008 and 2010. The total cost of removal approximated the structure’s capital cost of $US550,000 (Leidersdorf et al., 2012). The reef was significantly smaller than the Mount Reef and comprised of geobags, though less durable materials (Borrero, 2008). Leidersdorf et al (2012) suggest that as geotextile-based structures are inherently temporary, a feasible plan of removal that includes a reliable source of funding should be developed prior to installation and similar thoughts are expressed by NCCOE, (2012). This is something to consider with future structures of this nature in New Zealand. NCCOE (2012) also note that removal or modification of the structures can incur costs similar to initial construction.

In another relevant case, Tasman District Council has recently (2012-2013) removed a geotextile groyne from Motueka Spit, with about one-third (approximately 200 m) of the length of this structure being subtidal. Council engineers involved with the project indicated that removal of the subtidal section accounted for around two-thirds of the approximately $700,000 cost (including staff and contractor costs). Tasman District Council engineers did comment on useful lessons from their experience that could reduce costs, and we have discussed these further below.

In view of the potential for costs we have discussed the removal with two experienced commercial underwater construction dive firms. A representative of one of these firms was also present during the video inspection and dived on the reef to assist in their assessment of what would be involved in removal.

The firms advise that complete removal of the Reef is likely to be very expensive if it had to be completed in a short period, as this is likely to:

- require use of expensive techniques (e.g. pumping sand off and/or out of the bags),
- involve a lot of weather disruption,
- have significant stand-by or similar costs.

The firms consulted agreed that the original proposal to cut the bags and allow time for waves and currents to wash the sand out of the bags was likely to be the cheapest approach and remained practical despite the extensive biological colonisation of the reef. Diver tests on damaged containers indicated the bags can be reasonably readily cut despite the various growths on them.

Staged removal, focusing on the accessible and highest bags is likely to be the most appropriate approach. This will enable the relief of the reef (and therefore the most significant adverse environmental and safety effects) to be markedly reduced while minimising both costs and risks (i.e. loss of geotextile materials to the marine environment and release of excessive volumes of sand in a short period).

Importantly, staged removal would also enable ongoing evaluation of effects. If partial removal was found to satisfactorily address the key concerns (particularly swimmer safety), then the smaller lower bags (which appear to be buried under the sea floor on many occasions) may be able to be to be retained. This would reduce removal costs while also eliminating the significant environmental effects.

In maintaining part of the structure, it might also maintain the option of upgrading the reef at some future date – though we believe this is not a major consideration given the significant uncertainties and costs associated with that option and the questions around the appropriateness of the present location.

Progressive removal could also make it more affordable for Council as the cost could be spread over a number of years.

We therefore recommend staged removal – with each stage of the removal process involving the following steps:

- Divers cutting flaps off the top over the full length of each container to allow sand to disperse, with these flaps winched onto a suitable craft and removed to land for disposal (probably to landfill). This work needs to be conducted carefully to avoid hazard to the divers as some of the bags are relatively high and if the flaps are cut too low on the bags there may be hazard to the divers from collapsing sand. The process also needs to ensure that all flaps cut from the containers are removed.
- Allowing a suitable period for waves to wash sand out of the cut containers. This period will depend on wave conditions but is likely to be at least 2-3 weeks.
- Return to the site to remove the exposed bags and to monitor and report on conditions. The monitoring would include diver inspection and a simple bathymetric survey of the remaining reef and immediate locality (including the scour hole immediate landward). If necessary and practical, flaps would also be cut from further exposed bags and removed to the supporting craft.

The process requires suitably experienced commercial divers and a small craft with a crane capable of winching up the flaps cut from the bags. It is important that each removal episode documents which bags have been cut or removed and which have not. Any bags that are cut will need to be fully removed over time. The monitoring will also require use of an experienced hydrographic surveyor with suitable craft and equipment to reliably survey the reef and locale. Various companies with the requisite skills and equipment are available locally.

With partial removal, the above steps would be repeated until the accompanying monitoring indicated that the remaining reef was either buried or of very low relief and there was no evidence of the large scour hole landward of the reef. At this stage, it is very unlikely that the reef would be having any significant effects on swimmer safety or the environment. With partial removal, it would be useful to have a site inspection and survey at a suitable time some months after the work had ceased to ensure the effects had been adequately addressed. This survey should be conducted when the sea bed is likely to be lowered rather than a built up stage (e.g. probably not during winter or after large storms when sand may have been transferred offshore to the site).

With the full removal option, the work would be continued until all bags had been removed. As many of the lower and lesser diameter bags are often largely buried, full removal could be considerably more time-consuming and expensive than partial removal. This additional expense may have little to no benefit. Accordingly, it is recommended that the best approach would be to conduct removal progressively with monitoring, with the work designed so that partial removal is practical if found to adequately address adverse effects. In particular, this requires careful management and monitoring of the cutting process – as any bags that are cut will need to be fully removed from the marine environment.

Design of the work should also take into account various other factors required to facilitate efficient, safe and cost-effective removal including:

- Conducting the work in calm conditions with good visibility and being prepared to wait for such conditions, while also having the ability to act promptly when they arise. This will maximise diver efficiency and safety. Working in turbid and/or swell conditions is likely to considerably increase costs and difficulties and the risk of accidents.
- Having contracts that avoid the need for standby costs
- Timing expensive work such as diver and barge mobilisation to coincide with periods when bags are likely to be best exposed (e.g. based on understanding of beach and nearshore morphology and dynamics)
- Timing work to minimise the risk of weather and wave disruptions
- Avoiding periods when conditions (e.g. water temperatures, weather, waves, and water clarity) are likely to limit daily productivity.

In terms of costs, even a minimum partial removal option is likely to require at least three removal episodes:

1. Cutting of the large central container on each arm – essentially removing a large flap off the top of the container. Divers advise that the sand spilling from this large bag is likely to preclude useful work on the adjacent large bags – though work could be conducted at the same time on the focus structure at the apex. A boat with a small crane would be required to lift the cut geotextile from the sea.
2. Cutting open the remaining two large containers on each arm and any remaining exposed bags on the focus structure – with removal of the geotextile flaps cut from the containers.
3. A third trip to retrieve the remains of the bags. A follow-up hydrographic survey (single beam is fine) would also be required at this time to quantify changes in bed levels around the reef – accompanied by a diver inspection to ensure no loose geotextile materials remained to be removed.

On the basis of indicative costs provided by the commercial divers who conducted the inspection, we estimate that total cost of this partial removal option (including disposal) is likely to be in the order of $50-60,000. If further cutting and removal were required, then costs would rapidly escalate. For instance, each additional cutting and removal operation required is likely to add $10-20,000 depending on the scale and scope of the work required.

The above costing assumes that each stage is timed to coincide with conditions that maximise productivity. Otherwise, costs could be considerably higher.

There would also need to be at least 2-3 weeks between each of the above stages to ensure enough time for sand to be dispersed from the cut bags and the local sea bed morphology to adjust to the loss of the reef – though the time requirement will vary according to wave conditions.

If the follow-up hydrographic survey and diver inspection indicated that the above work eliminated the most serious environmental effects and risks, then the remaining smaller bags (which are quite often completely buried) could be left in the interim.

However, periodic inspections would still have to be conducted – including a hydrographic survey and diver inspection. These inspections are likely to cost about $1500-2000 (2013 costs). These inspections should be conducted annually for at least 2 years, and timed to occur when bed levels in the vicinity of the reef are likely to be low (i.e. not soon after major storms when bed levels may be elevated by sand carried offshore). If there were no significant issues noted by these inspections, the frequency of the inspections could probably be reduced to 5-yearly. Any loose geotextile material noted during inspections should be removed.

If the follow-up surveys indicate ongoing issues (e.g. persistence of a large scour hole landward of the reef), then further container removal is likely to be required. This work would need to be timed very carefully to coincide with periods when the bed levels around the reef were likely to be at their lowest – to enable the bags to be most efficiently and cost-effectively removed. Otherwise, significant costs may be incurred. However, given that the small lower bags are frequently completely buried (e.g. Figure 5) and are of relatively low relief even when exposed, we believe it is unlikely that these containers will cause any significant adverse effects. Accordingly, these containers will probably only ever need to be removed if the periodic inspections indicate they are badly damaged and may wash away and pose a hazard.

Overall, partial removal is likely to eliminate the major environmental and health and safety risks. If well designed and managed, the option is likely to cost $55-60,000 – with additional ongoing costs of periodic inspections (probably costing $1500-2000 for each of the two years following removal, with inspections reduced thereafter if judged appropriate).

If full removal is required, costs would probably be considerably higher. These costs are very contingent on unpredictable factors and cannot be reliably estimated. However, the costs could well exceed $100,000 and, with poor management and design, may be considerably higher.

5.1.3 REPAIR OR UPGRADE OF THE REEF

5.1.3.1 **Effects**

This option involves repair and/or upgrade of the Reef to achieve desired surfing amenity gains.

For instance, Mead (2011) proposes a three stage plan to recover surfing amenity based on physical modelling. This proposal centres on increasing the dimensions of the Reef to the original design dimensions. He argues that the proposal would create evenly peeling waves on the Mount Reef but otherwise provides little detail on the improvement in surfing amenity likely to be achieved. Given the now-known difficulties in achieving surfing amenity gains (Shand, 2011; NCCOE, 2012) it is important that any plan for repair or upgrade establishes clear and realistic expectations.

The considerations relevant to this option include:

- **Coastal Erosion:** Changes to the size and/or shape of the Reef have the potential to affect the adjacent shoreline. Further detailed investigations and modelling would be required to assess these effects. On the basis of existing information, serious dune erosion caused by the reef is assessed as a low risk.
- **Nearshore Hydrodynamics:** Given the relatively significant and unforeseen effects of the existing reef on nearshore morphology and hydrodynamics, this matter would be a critical consideration for any restoration or extension of the Reef. On the basis of existing information, it is likely that the significant effects of the reef on nearshore currents and morphology would continue with this option. Accordingly, this is assessed as serious negative effect of the option.
- **Swimmer Safety:** It is probable that upgrade of the reef would not eliminate the serious adverse effects of the reef on swimmer safety, and may exacerbate the hazard. This is assessed as a serious negative effect of the option.
- **Reef User and Navigation Safety:** The effect of this option on the risk to reef users (including board riders and curious swimmers enticed to swim out to investigate) and small water craft would depend on the design of the upgrade. Current crest elevation is typically 0.8-1 m below Chart Datum or deeper except for limited areas where it is as shallow as 0.2-0.4 m. A restoration such as that proposed by Mead (2011) increases the crest height of the reef by 1.0 m in many areas. This would bring the reef very close to or above the water surface during low stages of the tide. Accordingly, the option is likely to increase the risk to reef users and to navigation safety. If the upgrade was successful in achieving enhanced surfing amenity it would also increase use.
- **Structural Integrity:** The option would involve periodic ongoing inspections to determine damage and, if damage occurred, periodic maintenance. It would also require repair of existing problems with sand leakage. We assume that in any upgrade of the structure, construction would be managed by an experienced marine engineer and would include design to ensure structural stability. If so, these aspects will involve significant initial and some ongoing costs, but would provide a reasonable level of certainty provided the monitoring and maintenance was conducted. Accordingly, this is assessed as a significant cost but otherwise a minor issue.
- **Research:** If the repair or upgrade of the Reef was successful in achieving enhanced surfing amenity, it is likely to stimulate further research and would be a positive effect of the option. Even if the upgrade was not successful, it is likely there would be positive gains in terms of research and understanding. The option is therefore likely to have a positive effect on research.
- **Surfing Amenity:** Mead (2011) argues there is potential for surfing amenity to be significantly improved by an upgrade/repair of the current reef. If so, this would be a

significant positive effect of the option. However, given the difficulties associated to date with achieving significant gains in surfing amenity and the remaining uncertainties around the technology, there is no certainty that the gains would be realised. We also believe there are significant questions as to the appropriateness of the present site for a reef. Accordingly, we believe caution is required and that gains in surfing amenity are best viewed as a potential rather than a likely benefit of the option.

- **Ecology:** The placement of further bags to achieve design dimensions would have a short term adverse impact on the existing biota, but the area would rapidly recolonise. The overall impact on ecology would be positive over time as the option would maintain and enhance the existing reef.
- **Cultural:** The effects on cultural values are likely to be minimal, but if the reef were to be used as a local source of kaimoana the overall effect would be positive rather than negative.

Overall, the key potential benefit of an upgrade of the Reef would be an improvement in local surfing amenity. This would also preserve community investment to date. If realised, these would be significant benefits of the option.

We believe a number of other wider benefits would also accrue if the work was successful in significantly enhancing surfing amenity. Notably, these would include a recovery of confidence in artificial surfing reefs – in which New Zealand based firms and expertise have played a significant role internationally. It would also assist relevant NZ firms and specialists in promotion of the technology and could have employment and export earning benefits for New Zealand, as well as useful training and research opportunities for local tertiary institutes. The continuing and growing international interest in this technology, despite the difficulties experienced to date, tends to suggest a wide range of experienced scientists and engineers believe there is potential. While the weight of focus locally is currently on the problems and failures experienced to date, this is not uncommon experience with emerging technology.

However, these potential benefits need to be balanced against the fact that surfing amenity design expectations have so far failed to be met with structures of this nature (Shand, 2011; NCCOE, 2012), the significant difficulties with constructing to design dimensions and the questions around the suitability of this site for a reef.

5.1.3.2 Approach and Costs

The potential adverse effects associated with maintaining and upgrading the reef are significant and would require detailed consideration. Accordingly, we believe detailed (and relatively expensive) modelling and field investigations are likely to be required for any major repair or upgrade of the reef. In our opinion, the design and consenting phase is likely to cost any applicant at least $0.25-0.5 million and could be considerably more expensive, with uncertain outcomes.

There would be difficulties in making reliable predictions at this site located well within the active beach system, where wave transformation may vary significantly from numerical model predictions due to dynamically changing topography, wave-current interactions and other factors (e.g. unanticipated effects of the structure on hydrodynamics and morphology).

Experience to date indicates that it is very difficult to reliably predict the outcomes of the complex interactions between reefs and these dynamic environments.

The cost of the Reef upgrade itself would also be significant. Mead (2011) estimates the cost of the proposed recovery plan at approximately $408,000 for purchase and installation of the containers alone (i.e. excluding any consideration of design and consenting costs). We believe these costs are optimistic and that significant engineering and construction costs would be required for repair of the existing reef before the upgrade can proceed. In our view, this work, combined with proper engineering of the upgrade to ensure structural stability and the desired design profile and dimensions, is likely to be considerably more expensive – with these works very unlikely to cost less than $0.75-1 million, depending on the details of the design.

Ongoing monitoring and maintenance costs would also be required. These costs are uncertain and could be relatively minor (probably averaging $5000-$10,000 per year) if the structure was well engineered. We believe this is the only basis on which the option is likely to be consented.

There are also likely to be significant difficulties and costs associated with remedying or mitigating the adverse effects of the reef. For instance, the key issue of swimmer safety at Tay Street is likely to involve an ongoing cost of at least $25-30,000 per year to upgrade surf patrol at Tay Street. As discussed with the Status Quo option, this action would also not fully remedy the risk and there would be a residual risk to swimmers outside of patrol periods. There are also difficulties with mitigation of other adverse effects. For instance, in regard to navigation safety, it is unlikely to be practical or cost effective to maintain location buoys at this site.

Overall, we believe the total costs associated with the option are:

- Design and related costs of at least $0.25-0.5 million
- Construction and engineering management costs of at least $0.75-1 million
- Ongoing monitoring and maintenance costs (probably $5,000-$10,000 per year)
- Ongoing costs associated with mitigation of environmental effects of at least $25-30,000 per year.

Collectively, the total cost of the option is likely to be at least $1-1.5 million and quite possibly higher.

There are also significant uncertainties with this option, including:

- likelihood of achieving the desired surfing amenity,
- the nature and scale of adverse environmental effects and the ability to adequately mitigate or remedy such effects,
- the public acceptability of the option, particularly given the adverse effects of on swimmer safety in the popular Tay Street area and the opposition of local surf lifesaving clubs,
- the ability to raise the required funding for design, consenting, construction and ongoing monitoring and maintenance, particularly given the current levels of scepticism around this technology in the local and wider community. Significant community and stakeholder engagement would be required.

It is our opinion that for a reef recovery plan to have any chance of implementation, a number of conditions would need to be met, including:

- A general scientific consensus among surf scientists (including rigorous and reliable independent peer review) that the upgrade is likely to achieve useful gains in surfing amenity.
- Confirmation by field and modelling investigations (including an independent peer review) that the upgrade will not adversely impact swimmer safety and will avoid significant adverse effects on beach or nearshore morphology and hydrodynamics.
- Review of the design and management of the reef construction process by suitably qualified and experienced marine engineers to ensure design outcomes and tolerances are able to be realistically achieved and maintained with a high level of confidence.
- Ongoing maintenance strategy appropriately considered and costed based on real life experience with similar reefs to date.
- Provision of insurance or bond to ensure the Reef can be fully removed should unforeseen adverse effects be experienced, together with appropriate monitoring for such effects.

Overall, we believe there are considerable obstacles facing this option. It may be many years before there is sufficient information and proof of concept to overcome the present level of disillusionment and scepticism in the local community – if in fact the difficulties can be overcome. Of particular significance, there are no parties currently willing and able to fund this.

5.2 Recommendation

In the short to medium term we believe there are only two realistic options for Council:

- Status Quo option
- Full or partial removal of the reef

As noted above, the Status Quo option retains the potential for future restoration but involves significant costs associated with ongoing mitigation of effects (at least $25-30,000/year) and monitoring. There are also residual risks to swimmers at Tay Street even if additional patrol was provided. Adverse environmental effects would also remain.

Partial removal of the reef, sufficient to eliminate significant health and safety and environmental issues, is likely to cost at least $55-60,000 but would need to be well designed and managed to avoid significant cost over-runs (see detailed discussion in Section 5.1.2).. Partial removal would also involve ongoing costs associated with periodic diver and bathymetric surveys – probably $2000 each time and conducted once every 1-2 years or after severe storms. If 3-4 episodes of such monitoring indicate no ongoing effects are likely then the monitoring could be significantly reduced in frequency and possibly even eliminated.

Full removal is considerably more uncertain as the lower containers are frequently buried and may be time-consuming and require expensive approaches to fully remove. It is not possible to reliably estimate the costs of this option because of the various associated uncertainties.

However, we believe that costs could well exceed $100,000. However, on the basis of existing information full removal is very unlikely to be required to adequately address the environmental and swimmer safety issues with the reef.

We believe that in view of the serious nature of the risk to swimmers at the popular Tay Street Beach and the major uncertainties and costs around any potential to upgrade the reef in the future, that removal of the structure is the only appropriate option.

Accordingly, we recommend that Council undertake staged, partial removal of the reef with monitoring as discussed in Section 5.1.2. In our view, it is probably that partial removal will be sufficient to address the adverse effects of the reef but this can only be confirmed as the work is undertaken.

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