

IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of the Proposed New Zealand Coastal Policy
Statement 2008

BY SURFBREAK PROTECTION SOCIETY INC
Submitter

BY SHAW TREVOR MEAD
Submitter

TO DEPARTMENT OF CONSERVATION
Board of Inquiry

**EVIDENCE OF SHAW TREVOR MEAD
IN SUPPORT OF WRITTEN SUBMISSION AND THE SURFBREAK PROTECTION
SOCIETY INCORPORATED**

NORTH SOUTH ENVIRONMENTAL LAW

Barristers & Solicitors
PO Box 109045
Newmarket
AUCKLAND

Phone: 09 304 0043
Fax: 09 303 2427

Counsel: R A Makgill

INTRODUCTION

1. My name is Shaw Mead. I hold BSc and MSc (Hons) degrees from the University of Auckland (School of Biological Sciences), and a PhD degree from the University of Waikato (Earth Sciences). I am currently an environmental scientist and Director at ASR Ltd, which is a marine consulting and research organization. I have 14 years experience in marine research and consulting, have 34 peer-reviewed scientific papers, and have solely or jointly produced over 100 technical reports pertaining to coastal oceanography, marine ecology and aquaculture. I have undertaken hundreds of research SCUBA dives around the coast of New Zealand and led many comprehensive field investigations that have addressed metocean, biological and chemical components of the coastal environment. I am affiliated to the New Zealand Coastal Society (IPENZ) and the New Zealand Marine Science Society.
2. I have a background in coastal oceanography, marine ecology and aquaculture. I studied for my MSc degree at the University of Auckland's Leigh Marine Laboratory, undertaking subtidal research there from 1994 to 1996 directed at the fertilisation success of sea urchins as a basis for the sustainable management and development of the commercial market. The marine ecological components of my Doctorate were directed towards subtidal habitat enhancement of marine structures, while the physical oceanography component was focussed on understanding the effects of coastal bathymetry on wave breaking characteristics using field measurements and hydrodynamic numerical modelling, including the development of a database of mostly world-class surfing breaks around the Pacific and Indonesia. More recently, I have been involved in design, functional and impact assessments and monitoring of physical and ecological effects of marine construction, coastal erosion control, marine reserves, dredging, oil industry and aquaculture ventures.
3. I live and work at one of New Zealand's premier surfing breaks, Raglan. I have surfed for 26 years and during this time I have travelled to surfing destinations for business, research and pleasure all around the world including Hawaii, North and South America, Europe, South Africa, Indonesia, Australia and the Pacific Islands. Some 70% of my work is conducted overseas, which allows a global perspective on how development impacts on the coast.
4. The specific provisions of the proposed NZCS that my submission relates to are Policies 12, 20, 25 and 54, and glossary definitions:
 - Policy 12: Local authority monitoring
 - Policy 20: Surfbreaks of National significance

- Policy 25: Public or Multiple-use Structures in the CMA
 - Policy 54: Protection Structures,
 - the definition of Hard Protection Structure in the Glossary.
5. While I made my submission and am presenting my evidence as an individual, it must be noted that I am a Director of a company that helped develop and applies multi-purpose reef technology, which forms part of my submission (Policy 54 and 25) with respect to addressing other coastal management needs (i.e. Policy 6, Policy 19 and sustainability). My evidence with respect to Policy 20 is in support of the Surfbreak Protection Society. My evidence with respect to Policies 12, 25 and 54 does not directly concern surfing breaks, rather the classification of environmentally-sensitive coastal protection solutions and multiple-use structures.

POLICY 20: SURFBREAKS OF NATIONAL SIGNIFICANCE

6. I strongly support the protection of surfing breaks of national significance from inappropriate use and development. However, I believe that although the list of surfing breaks provided include some of NZ's national surfbreak treasures (all score 10/10 in the NZ Surfing Guide, with the exception of Papatowai (8/10), which is a big wave spot, there are other internationally and nationally significant surfing breaks that are more vulnerable than this list of reef breaks, i.e. surfing breaks that are natural sand features and thus more susceptible to damage than hard rock breaks. Indeed, there are a variety of factors that affect both the physical make-up of breaks and the waves that approach the breaks. Thus, protection of surfing breaks of national significance from inappropriate use and development can not only focus on the breaks themselves, but must also take into account the 'other' factors which make them nationally significant. Such factors could be integrated with local authority monitoring (Policy 12), while additional and/or separate investigations would be required to determine the factors that would need monitoring and protection to determine nationally significant surfing breaks.
7. Not all waves are good for surfing or even able to be surfed – specific types waves and conditions are required for surfing. High-quality surfing waves must peel at a 'surfable' rate and have a steep, plunging wave face (breaking intensity) to generate high board speeds and provide 'tube' rides (Figure 1).
8. As Dr. Scarfe has pointed out, high-quality surfing breaks are not common, it is rare that the various physical factors naturally come together to create them. In general, point, reef and sand-bar breaks (the latter usually due to an estuary mouth or other coastal feature) are known for producing high-quality surfing waves, while beach

breaks are generally of lower quality (although very common), unless an offshore feature has a positive influence. For example, between Raglan headland and Cape Reinga (Figure 2), some 400 km, there are 2 high-quality point breaks (Raglan and Ahipara), a couple of high-quality reef breaks and a handful of high-quality bar breaks and 100's of kilometers of beach breaks which are poor-quality or un-surfable for the vast majority of the time.

9. As with other rare natural features, high-quality, nationally significant surfing breaks need to be protected. Other submitters have and will describe the huge social and economic benefits that surfing breaks provide to the local area; many cases have been well documented in the past decade. Here, I will describe some of the other factors that must be recognized in the protection of nationally important surfing breaks, as well as advocate a second tier of importance be incorporated into the PNZCPS, that is the identification of Regionally significant surfing breaks.
10. Many of New Zealand's high-quality surfing breaks are not rocky bottomed and rely on sand, either directly (i.e. constant supply of sand on the beach), or indirectly (e.g. as an offshore deposit, or shaped by water currents (e.g. tidal currents in and out of an estuary). Whangamata Bar is a good example of a high-quality and nationally significant surfing break that relies on sand.
11. Whangamata Bar is New Zealand's most famous sand bar break (it rates 10/10 in the NZ surfing guide), with rides of up to 500 m, the lefthand break that was named the 'Jewel of the Pacific' by Hawaiian surfing legend Gerry Lopez. The Whangamata Bar is formed by the ebb-tidal delta (bar), where the estuary channel is located adjacent to the northern headland (Figure 3). The shape of the bar is governed to a great extent by the velocity of the tidal currents moving in and out of the estuary, which also move sand. Any changes in sediment supply and/or the tidal currents would likely have a detrimental impact on this break, which was one of the issues in the controversy over the marina in the Whangamata Estuary – the Minister of Conservation's decision to decline the Resource Consents for this development was overturned, even though there was no appropriate impact assessment of the effects of the new marina on the nationally significant Whangamata Bar. In addition, the monitoring conditions are focused on the ebb tidal delta (the surfing break), rather than physical processes that create the break (e.g. tidal currents, sediment supply/transport). Changes in sediment supply and current velocities at the mouth of the estuary, both due to land, coastal or estuarine activities could negatively impact on this world-class break and would need to be taken into consideration in order to protect it from inappropriate use and development.

12. Another example of the importance of sediment supply to a surfing break, with quite different processes involved, is the world-class surfing headland at Ahipara, which is classified as nationally significant in the PNZCPS. It is worth noting that the various breaks down this headland at the southern end of Ninety Mile Beach in the far north (Pines, Supertubes, Mukie 2, Mukie 1, Peaks and Shipwreck Bay all score 10/10 in the New Zealand surfing guide) are mostly sand bottomed against the shallow rocky headland (Figure 4). The majority of the sand feeding these breaks comes from the massive transverse dune system, where wind blown sand moves across the headland and into the bay (Figure 4). Any disruption to this sand supply would very likely have detrimental effects to the surfing quality along the headland. The degradation of one of South Africa's best surfing breaks, Bruce's Beauties at Cape St Francis, is a very good example of the results of stabilizing a transverse dune system.
13. Cape St Francis is known internationally as the location of "the perfect wave" discovered by two wandering surfers in Bruce Brown's seminal 1966 film "The Endless Summer". In the film the surfers literally 'stumble' upon the surf break once they crest a series of massive sand dunes. Ironically, the popular exposure Cape St Francis received from the wildly successful movie, may have hastened the demise of the beach amenity in the area. The sand dunes shown in the film are the very dunes that were stabilized to prevent the shifting sands from blowing over housing developments. These are also the dunes that provided the lifeblood (sand) to the beaches. The resulting loss of sediment supply from the wind blown sand has likely contributed to the beach erosion and also resulted in the great reduction in number of days per year of the surf break 'Bruce's Beauties' (shown in 1966 in Figure 5).
14. In the 1994 follow up film "The Endless Summer 2" – which played to huge international audiences - the travelling surfers return to Cape St Francis and are dismayed to find that the dunes had vanished, replaced with housing developments and the break that was once there was gone. Although Bruce's Beauties, "The clean, mean, green jewel of South Africa" (www.wavescape.co.za), still occasionally breaks on larger swells, this breaks decline is the legacy St Francis Bay has to the outside world. This presents an important lesson for the management of nationally significant surfing breaks.
15. There are many other examples of how interruption of sediment supply and pathways has an impact on the seabed and shape of the coast, and consequently surfing breaks. Dr. Scarfe described how down-coast erosion due to the construction of the Manu Bay boat ramp – interestingly, the pre-boat ramp Manu Bay also featured in the

original Endless Summer movie – similar impacts can be expected due to the development of breakwater ports and marinas and various forms of coastal protection structures.

16. Nearshore sand-mining has also been attributed with the demise of surfing breaks. Sand-mining has been attributed to the disruption of Mangawhai Bar and as a contributing factor (along with inappropriate development of the sand dunes) to the demise of Omaha Bar. At present, there are proposals for massive sand mining activities (hundreds of millions of cubic meters per year) on the North Island's West Coast – the impacts of sand mining on the surfing breaks in this area (including the nationally significant Raglan breaks) need to be considered as part of any applications to extract such massive volumes of sand in these areas.
17. The area of sea offshore of nationally significant surfing breaks must also be considered in order to protect them from inappropriate use and development. Long period waves start to 'feel' the seabed at the edge of the continental shelf (e.g. 16 second period waves 'feel' the seabed at 200 m deep), which means that features on the seabed influence the waves and 'condition' the waves for a break well before the waves interact with the local seabed at the break.
18. The phenomenon of wave-focussing is a well known principle, where refraction of waves causes them to build in height over submerged ridges and reduce in height where there are trenches – in very basic terms, because waves move slower in shallower water the energy is 'piled up' higher where it is shallower and dispersed where it is deeper relative to the surrounding seabed. There have been a number investigations into wave focussing of surfing breaks at a range of scales around the world that provide examples of the types and sizes of seabed features that create high-quality surfing breaks *prior to* the waves reaching the breaks themselves.
19. Focus breaks generally break with a heavy and hollow peak (A-frame) due to the height gradient established by the offshore seabed feature. Ocean ridges/canyons (e.g. Mavericks - Raichle, 1998; Centre Island, NZ - Ivamy and Mead, 2001; Blacks, Southern California) and harbour delta (e.g. Ocean Beach, San Francisco - Battalio, 1994; South Stradbroke Is, Australia; Matakana Is, NZ) are the largest features and can result in large height increases, e.g. the ~3km ridge off Centre Island in NZ increases wave heights by 4-5x.
20. Medium scale focuses such as Pipeline, Hawaii, can be the entire break (the Pipeline focus extends to some 20 m deep), or offshore systems that subtly increase wave

height and result in higher peaks and rip-cells conducive to good surfing breaks. A good example of a mid-sized focus break in New Zealand is Midway Beach in Gisborne, where the submerged ridge through the centre of the bay, the Foul Grounds, creates peaky waves of greater height than are generally present in the rest of Poverty Bay (Beamsley and Black, 2003) – Midway is an extremely popular surfing break in the centre of Gisborne.

21. Small scale focusses often represent the take-off or fast section at a surfing breaks (e.g. Lovers Cover, California; Breaker Bay, NZ). Scarfe (2002) detailed the ephemeral focus at Raglan's Manu Bay which formed due to a low reef patch on the seabed, and was often 'washed' away, and how it impacted on the wave quality and manoeuvres that could be performed. Most good surfing breaks have some focussing elements in them.
22. Recent studies of a large 'pulse' of sand that moved down the Raglan Headland between 2004 and 2006 demonstrated the large impact of changes to the offshore bathymetry can have on a nationally significant surfing break (Mead and Phillips, 2007). The presence of the sand bank had large and negative impacts on two adjacent Raglan Point breaks, Indicators and Outsides, with the impacts on both breaks being more severe in 2005 and the changes to the surfing conditions receiving comment in the New Zealand Surfing Magazine "Kiwisurf" (Hughes, 2005). This study highlights how extraction of massive volumes of sand in the nearshore zone could impact on nationally significant surfing breaks.
23. Floating structures also have the potential to affect the waves before they reach a surfing break. An example of this is the proposed mussel farm offshore of Pegasus Bay. A very large mussel farm has been proposed offshore of Pegasus Bay, directly offshore of the Christchurch city beaches when the waves are from an east to northeast direction. During the winter months, long period waves mostly originate from the south, however, during the summer months shorter period waves originate from the northeasterly quarter. While it is known that very short periods waves (wind chop) are attenuated by mussel farms, there is little if any knowledge of the attenuation due to mussel farms on longer period swells that surfers utilize. In the case of Pegasus Bay, in the absence of any information, a monitoring strategy has been developed to determine the extent of wave attenuation (Appendix 1). The results of this investigation, should it go ahead, will be very useful to apply to other areas of New Zealand, as there are presently several very large open sea aquaculture ventures planned.

24. The above brief description of some of the factors that combine to create a world-class surfing break illustrate that the successful protection of surfing breaks of national significance from inappropriate use and development must include not only the immediate vicinity of the break itself – the surfing break parameters of peel angles and breaking intensity are controlled by the shape of the seabed at the break, as well as wave influences well offshore of the break.
25. It is very encouraging to see surfing breaks given National Significance, and like many other aspects of the National Policies, I support the development of a second tier of importance being incorporated into the PNZCPS, that is the identification of Regionally Significant surfing breaks. For example, Whangapoua could be included in the Auckland Regionally Significant Surfbreaks. Whangapoua or Okiwi Bar on the east coast of Great Barrier Island is a world-class bar break (9/10 in the NZ surfing guide) at the mouth of the Whangapoua Estuary – like Whangamata Bar, changes in sediment supply would likely have a detrimental impact on this break. The protection of any level of surfing breaks from inappropriate use and development will require a structure to identify both the importance of the break and the factors that influence the existence of the break in order to be successful.

POLICY 12: LOCAL AUTHORITY MONITORING

26. I strongly support the need for local authority monitoring to apply procedures and methods that allow for comparison and collation to provide a national perspective. Indeed, I have recently worked on such cross-boundary issues in the coastal marine area of the Kaipara Harbour. However, I believe that more proactive work into understanding coastal processes is required to successfully apply many of the policies in the PNZCPS should be undertaken by the local authorities, rather than relying on other sources such as public good science and studies undertaken for resource consent applications.
27. Monitoring provides information on what is happening on the coast, but very little on what is causing it. There is a need to be proactive in understanding the processes that are operating around our coasts in order to promote sustainable management of the coastal environment (Policy 1), to be able to apply a precautionary approach (Policy 5), to ensure that amenity values are maintained and enhanced (Policy 19), to consider cumulative effects (Policy 21), to preserve the natural character of the coastal environment (Policies 30 and 32), and many of the policies directed at maintaining water quality and ensuring environmental effects are no more than minor.

28. While resource consent applications for particular developments in the coastal marine area require assessment of environmental effects to determine the various impacts on many of the policies, continually increasing the understanding of how our coasts operate. There are many examples of local authorities undertaking studies to understand coastal processes around the country, a strategic program that applies procedures and methods that allow for comparison and collation to provide a national perspective of coastal processes would be of great benefit to the managers of the coastal environment. There is an obvious link between understanding the coastal processes that make a surfing break nationally significant and what factors should be monitored in order to ensure the breaks protection from inappropriate use and development.

POLICY 54: PROTECTION STRUCTURES, POLICY 25: PUBLIC OR MULTIPLE-USE STRUCTURES IN THE CMA AND THE DEFINITION OF HARD PROTECTION STRUCTURE IN THE GLOSSARY

29. I strongly support discouraging the use of hard coastal protection structures, especially those that have detrimental impacts on the public amenity and natural character. At present, hard protection structures such as seawalls are being built in the CMA for the advantage of relatively few home owners at the expense of public amenity, e.g. the sandy beach (the Waihi Beach 1.1 km seawall is a good example of this). However, I strongly believe that artificial (multi-purpose) reefs should not be lumped into the hard protection structure category with seawalls, rock revetments, groynes, retaining walls, etc.
30. Artificial or multi-purpose reefs were developed as a response to the need for environmentally-sensitive solutions for coastal protection, driven by the Resource Management Act. The Artificial Reefs Program (ARP), was started at the Centre of Excellence in Coastal Oceanography and Marine Geology (the University of Waikato and NIWA) in 1995. The objective of the ARP as defined in 1995 was as follows:

The Artificial Reefs Program is a response to the need for positive development and environmentally sensitive solutions to coastal protection and to the continued growth in recreational usage of our beaches. By unifying senior scientists and experienced industrial partners, the Program, operating jointly within the Earth Sciences Department of the University of Waikato and the National Institute of Water and Atmospheric Research, aims to:

- enhance the coastal amenity value of the New Zealand shoreline by evaluating multiple use options (surfing, diving, recreational and commercial fishing, navigation and swimming safety) for incorporation into coastal constructions
- focus and further develop expertise within the research community, and within industry, while providing a sound basis for senior student education.

31. This objective is strongly associated with Policies 6, 19 25 and sustainability in general.
32. More than a decade since its instigation, the primary aim of the ARP has been achieved. Indeed, in addition to numerous research theses, individual journal and conference papers and consulting reports, Special Issue No. 29 of the Journal of Coastal Research (Winter 2001), "Natural and Artificial Reefs for Surfing and Coastal Protection" includes more than a dozen scientific papers on the design, impacts and construction of multi-purpose reefs (a second multi-purpose reef JCR Special Issue is currently in press).
33. The public's demand for beaches for recreation, combined with the increasing value society places on the natural environment, has led to a dramatic increase in the development of submerged reef projects world-wide (e.g. Ahren and Cox, 1990; Hsu and Silvester, 1990; Pilarczyk and Zeidler, 1996; Hall and Seabrook, 1998; Black et al., 1998; Harris, 2001; Mead et al., 2003; Babbie, 2003), and more recently independent research is strongly supporting the findings of the initial ARP (e.g. Nielsen, 2001; Houston, 2002; Pilarzyck, 2003; Ranashinge and Turner, 2004; Jackson et al., 2005).
34. Policy 54 and 25 are linked through the definition of a "Hard Protection Structure" in the Glossary, which includes 'artificial reef' as a hard protection structure, which is incorrect and contradictory to Policy 25. Artificial, or 'multi-purpose' reefs are located offshore of the beach and are submerged – unlike hard protection structures, they are not built on the beach and are designed and built to address the causes of coastal erosion rather than the effects. Another important distinction is that they can and are usually built from sand-filled geotextile containers, which can be easily emptied and removed if needed, unlike rock or concrete structures they are not 'hard'. Indeed, in the State of Florida, sand-filled structures on the beach for coastal protection have recently been classified as *soft protection* structures and are the only type of structure that can be applied on the beach by home owners. Some of the basic principles and examples of multipurpose reefs are shown in Figures 6-12.
35. Policy 25 encourages the requirement for the multiple-use for public benefit of structures in the marine environment – artificial or multipurpose reefs are designed to be multiple-use structures that incorporate coastal protection through the widened of the beach (added amenity, unlike the loss of beach caused by a seawall, which results in lost public amenity), surfing breaks (the 1998 Hillary Commission study indicated that surfing/body boarding was the 14th ranked sport and leisure activity for

people of the age of 18, higher than rugby, netball and cricket – in the last 10 years that number is likely to have increased significantly) and fishing/diving/snorkeling opportunities (structures offshore and underwater quickly become colonized by marine organisms, unlike structures on the beach). By lumping artificial or multi-purpose reefs in with hard protection structures, there are less opportunities for Policy 25 to be implemented.

36. Further reasons why multi-purpose reefs should not be categorized as hard protection structures include the interactions with Policy 6, Policy 19 and sustainability. Policy 6 calls for integrated management of natural and physical coastal resources. Multi-purpose reefs are part of the integrated management of beaches which includes the combination of renourishment, retention of the renourishment (by the offshore multi-purpose reef) and stabilization of the beach (through the planting of native dune species such as spinifex and pingoa). Multi-purpose reefs are an integrated beach solution that support Policy 19, the maintenance and enhancement of the coastal amenity values, unlike many hard protection structures that are aimed at protecting the land and infrastructure, reefs are aimed at enhancing the beach (the best form of coastal protection is a healthy beach).
37. Beach renourishment is being applied more and more often in order to protect the coast (with a wide healthy beach) while providing the beach amenity. However, renourishment is designed to fail (i.e. the sand will be washed away after a time), which leads to issues of the sustainability of continually finding new sources of sand, as well as the environmental impacts where the sand is taken from.
38. More and more often these days, beach renourishment is being implemented with coastal structures to maintain the sand on the beach of a longer period of time to make it more cost effective and sustainable – using multipurpose reefs for this (as has been done overseas – See Appendix 2; the Gold Coast Beach Protection Strategy won the 2000 Queensland State Environmental Award) also provides added multiple use benefits.
39. Internationally, submerged structures (i.e. artificial or multi-purpose reefs) are being held up as *environmentally-sensitive solutions* to coastal protection. In the last decade the research and application of submerged reefs as environmentally-sensitive solutions for coastal protection has greatly increased. For example, “Environmentally Friendly Coastal Protection: Proceedings of the NATO Advanced Research Workshop on Environmentally Friendly Coastal Protection Structures Varna, Bulgaria

25–27 May 2004” includes the descriptions of the application of a variety of reef structures:

- Performance of Submerged Breakwaters as Environmental Friendly Coastal Structures. Sevket Cokgor and M. Sedat Kapdasli
 - Low-Crested Structures: Boussinesq Modeling of Waves Propagation P. Prinos, I. Avgeris and Th. Karambas
 - Interaction of Waves and Reef Breakwaters. Valeri Penchev
 - Flow Measurements and Numerical Simulation on Low-Crested Structures for Coastal Protection. Pedro Lomonaco, Cesar Vidal, Iñigo Losada, Nicolas Garcia and Javier Lara
 - Performance of Submerged Breakwaters as Environmental Friendly Coastal Structures. Sevket Cokgor and M. Sedat Kapdasli
40. DoC has supported artificial surfing reef resource consent applications around New Zealand due to the local enhancement of biodiversity (Figure 13).
41. By including artificial or multi-purpose reefs, environmentally-sensitive coastal protection measures, in the hard protection category, the PNZCPS is taking a step backwards. Multipurpose structures support Policies 6, 19 and 25, and are contradictory to ‘hard coastal protection solutions’. I can only assume the list of hard protection structures was developed without considering coastal dynamics or understanding the application of submerged multi-purpose reef structures.
42. The Glossary provides a list of Hard Protection Structures, but not of Soft Protection Structures, which are referred to in Policy 54. A Glossary list of Soft Protection Structures, which includes offshore multi-purpose reefs should be included in the NZCPS.

CONCLUSION

43. In summary, I strongly support the protection of surfing breaks of national significance from inappropriate use and development, and point out the factors that need to be considered, but also the variety of factors that influence the break and the waves that approach it. I also advocate a second tier of surfing break protection and believe that framework will need to be developed to both identify and monitor significant surfing breaks. In Policy 20, “White Rock, Wairarapa”, should be amended to “The Spit and White Rock, Wairarapa” and Whangamata Bar, Coromandel and Whangapoua/Okiwi, Great Barrier should be added to the list of surfbreaks of national significance.

44. I strongly support the need for local authority monitoring to apply procedures and methods that allow for comparison and collation to provide a national perspective. In addition, Policy 12 should include of collection of data that leads to a better understanding of coastal processes and the causes of the change that monitoring measures.

45. I strongly support discouraging the use of hard coastal protection structures, especially those that have detrimental impacts on the public amenity and natural character. However, artificial or multi-purpose reefs are not hard coastal protection structures and should be removed from the Glossary Definition of Hard Protection Structures and from Section 1.3. A new category of soft engineering options (e.g. renourishment, multi-purpose offshore reefs, dune stabilization, sand bypassing/back passing, etc) should be incorporated into the PNZCPS.

Dr Shaw Mead

References:

- Ahrens, J. P., 1984. Reef Type Breakwaters. *Coastal Engineering - 1984*, B. L. Edge, ed., 1985. pp. 2648-2662
- Battalio, B., 1994. Estimating braking wave height at Ocean Beach, San Francisco. *Shore and Beach* (October) pp. 33-36.
- Beamsley B., and K. Black, 2003 . The Effect of Offshore Reefs on Inshore Surfing Conditions. Proceedings of the 3rd International Surfing Reef Conference. ISBN 0-473-09801-6 2003.
- Black, K.P. 1998. *Narrowneck Reef - Report 3: Sediment transport*. Joint Centre of Excellence in Coastal Oceanography and University of Waikato report prepared for Gold Coast City Council, 1998.
- Hall, K. R. and Seabrook, S.R., 1998. "Design Equation for Transmission at Submerged Rubblemound Breakwaters." *Journal of Coastal Research*, SI(26), pp. 102-106. Royal Palm Beach (Florida).
- Harris, L., 2001. *Submerged reef structures for habitat enhancement and shoreline erosion abatement*. U.S. Army Corps of Engineers Coastal & Hydraulic Engineering Technical Note (CHETN), Vicksburg, MS.
- Houston, J. R., 2002. *The Economic Value of Our Beaches*. US Army Engineer Research and Development Centre.
- Hsu, J. R. C., and R. Silvester, 1990. Accretion Behind Single Offshore Breakwaters. *Journal of Waterway, Port, Coastal and Ocean Engineering* 116(3); 362-381.
- Hughes, L. (2005). Barrel Bulletin. KIWISURF magazine.
- Ivamy, M., and S. T. Mead, 2001. An Investigation of 'Big Wave' Surfing Breaks: Potential For Artificial Reef Application. Report for the Foundation of Research, Science and Technology, Wellington, New Zealand, Feb 2001.
- Jackson, L. A., R. Tomlinson, I. Turner, R. Corbett, M Daggata and J. McGrath, 2005. Proceedings of the 4th International Surfing Reef Conference, Manhattan Beach, Californai, 12-14 January 2005.
- Mead S. T., and D. J. Phillips, 2007. Temporal and Spatial Variation of a Large Offshore Sandbar at Raglan, NZ. *Proceedings of the 17th Australasian Coasts and Ports Conference*, Melbourne 2007.

- Mead S., K. Black †, B. Scarfe †, J. Frazerhurst, 2003. The Effects of Wave Focussing on Surfing Reef Site Selection, Surfing Wave Quality and ASR Design at Scales of Inner Continental Shelf to Sub-Tidal Reef. Proceedings of the 3rd International Surfing Reef Conference. ISBN 0-473-09801-6 2003.
- Mead, S. T., K. P. Black, C. Blenkinsopp and P. McComb, 2003. *Reef Design and Physical Processes*. For the Lyall Bay Surfing Reef Charitable Trust, Wellington, March 2003.
- Nielsen, L., 2001. *Newcastle Coastal Zone Management Plan: Coastal Engineering Advice*. Technical report for Umwelt (Australia) Pty Ltd, March 2001.
- Pilarczyk, K. W. & R. B. Zeidler, 1996. *Offshore Breakwaters and Shore Evolution Control*. Published by A. A. Balkema, Rotterdam. 560p.
- Pilarczyk, K. W., 2003. *Design of Low-Crested (Submerged) Structures – An Overview*. Proceedings of the 6th International conference on Coastal and Port Engineering in Developing Countries, Colombo, Sri Lanka, 2003.
- Raichle, A. W., 1998. Numerical Predictions of Surfing Conditions at Mavericks, California. *Shore & Beach*, April, 1998, 26-30.
- Scarfe, B. E., 2002. *Categorising Surfing Manoeuvres Using Wave and Reef Characteristics*. Unpublished MSc Thesis, University of Waikato, Hamilton, New Zealand.
- West, A. S., P. Cowell, J. A. Battjes, M. J. F. Stive, N. Doorn and J. A. Roelvink, 2002. *Wave-Focusing Surfing Reefs – A New Concept*. Proceedings of SASIC 2, Ventura California, 9 Nov 2002.

Appendix 1

Monitoring Strategy to Determine Influence of Pegasus Bay Joint Venture Farm on Short Swell from Northeast.

Discussions between Craig Stevens & Shaw Mead
14 September 2006

We suggest that in order to clarify for all the likely impact of the proposed farm on the shorter swell from the north-east the following monitoring be conducted:

Prior to Development

Install 2 wave sampling devices

- one off shore and one inshore of the proposed location.
- installed for a period of 2 months
- same device*
- the device be able to resolve waves with periods of 3 seconds and longer
- the device be able to resolve directionality
- same depth beneath the surface
- during "summer" – say mid jan – mid march – when northeasterly winds dominate
- data analysed to check for consistent difference

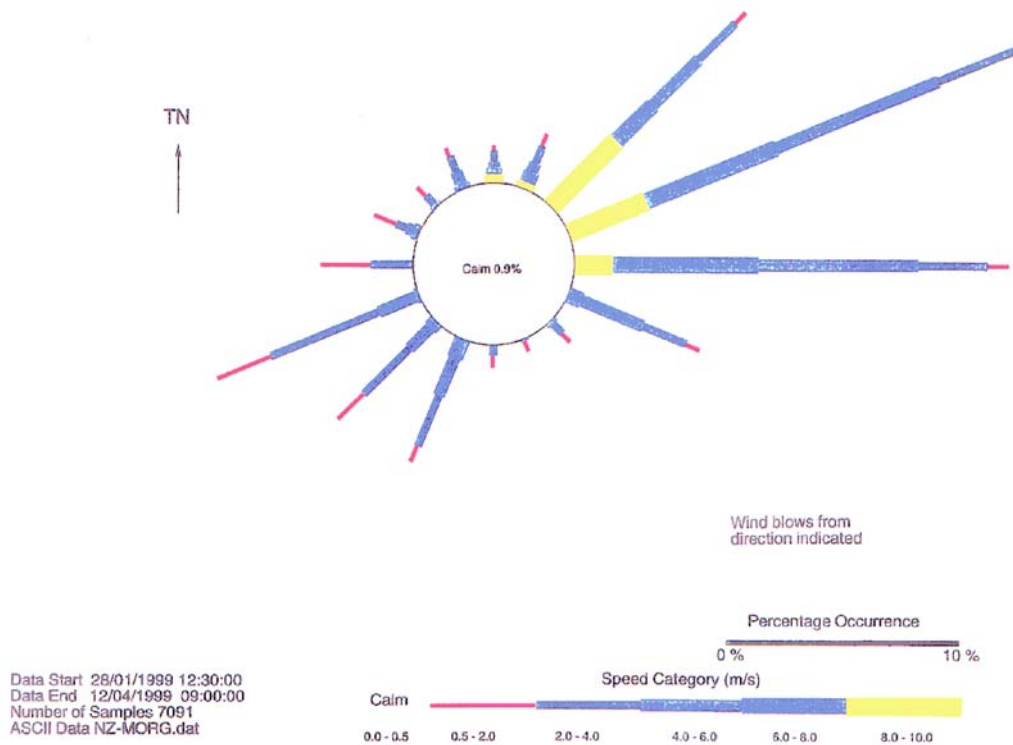
Upon installation of Stage One:

Once the farm stage one development is at full normal operational stocking density, if there is no directional difference in attenuation based on direction identified in wave data then repeat above.

If there is a clear difference in attenuation based on direction then repeat above but with THREE devices.

- The offshore device in same location as above but the two inshore devices be spaced to the north and south based on discussion and the data.

* suitably mounted (taut mooring) aquadopp, Vector, aquapro, ADCP-waves, directional waverider.



Christchurch Ocean Outfall Wind Data 28th January to 12th April 1999 (Cox, 1999)

Appendix 2

Example Project – The Narrowneck Submerged Reef, Queensland, Australia

The erosion problem at Narrowneck, 1 km north of Surfer's Paradise on the Gold Coast, in Queensland. The Gold Coast is Australia's primary tourist destination, with the wide sandy beaches being a major attraction. The erosion problem on the Gold Coast was confined to a hotspot at Narrowneck, where only the coastal road separates the Broadwater from the sea. This causeway was breached several times in the previous century and coastal protection was proposed as part of the Gold Coast Beach Protection Strategy to address this problem. The wave climate and sediment transport regime at the Gold Coast is dominated by SE swell, which results in large net sediment transport in one direction ($\sim 500,000 \text{ m}^3/\text{yr}$).

Traditional coastal protection methods were considered (e.g. groynes, rock rip-rap, etc.). However, a socio-economic assessment found that for every dollar spent on enhancing the beach, \$60-80 was returned via tourism (Raybould and Mules, 1997). Consequently, an offshore submerged reef was proposed and design works were undertaken by ASR consultants (Black *et al.*, 1998).

The aims of the project were:

- to widen the beach and dunes along Surfers Paradise Esplanade.
- to improve the surfing climate at Narrowneck.

A comprehensive field program was undertaken, with the results being utilised for reef design and sediment transport modelling (i.e. to assess the functional performance of the reef). The resulting final design was a $128,000 \text{ m}^3$ submerged reef (Figs. 1 and 3). The main purpose of the Narrowneck reef is to retain sand nourishment material that was pumped onto the beach from the Broad water. Figure 3 demonstrates how successful the Narrowneck submerged reef has been at retaining nourishment material on Surfer's Paradise Beach. Argus coastal imaging has shown that wave energy is dissipated by the reef for up to 90% of the time and that Narrowneck reef is an erosion control point on the coast (Turner *et al.*, 1999).

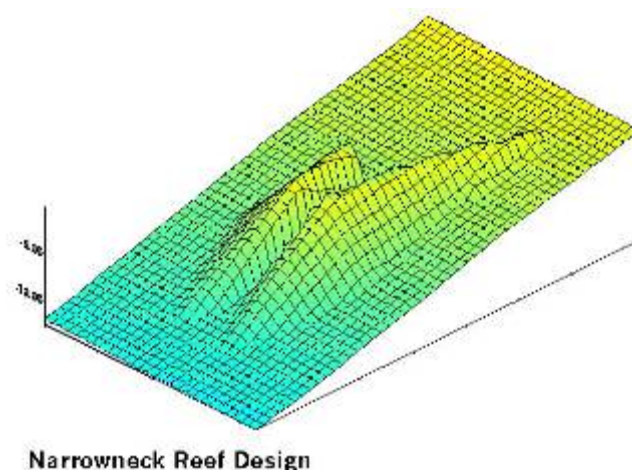


Figure 1. 3-dimensional representation of the Narrowneck multi-purpose reef.

The Narrowneck reef was built using over 400 Terrafix 1200/1209RP geotextile containers, with standard 20 m long by 5 m diameter units. Terrafix 1200RP sand filled containers (SFC's) can be custom designed to suit the required purpose by sewing or ultra-sonically welding large sheets of

material together to form enclosed units. A wide range of sand-filled geotextile construction units in a variety of shapes and sizes have been used for coastal projects around the world. At Narrowneck, the ~300 tonne SFC's were filled inside a split-hull dredge, sealed and then positioned with GPS before dropping to the seabed. The resulting reef can be seen in the aerial photograph (Fig. 3), with recently added SFC's still sand-coloured, while SFC's that were placed at an earlier date are colonized by marine life and are much darker (like a natural reef) as a result.



SPLIT HULL HOPPER DREDGE FILLING SANDBAG



SPLIT HULL HOPPER DREDGE PLACING SANDBAGS

Figure 2. Terrafix 1200R SFC's being filled and placed during construction of the Gold Coast reef.



Figure 3. The view of Surfer's Paradise with the multi-purpose reef in the foreground. The lighter coloured containers had only just been deployed, while the darker containers are colonised by marine life.

The Gold Coast reef has been a huge success, not only in terms of coastal protection (Fig. 4), but also providing a surfing facility (recent reports describe the reef as the 'best surfing spot on the coast') and a 'natural' reef ecosystem that supports a dive trail (Fig. 5). An important outcome of the project was the confirmation (via beach profile monitoring and Argus coastal imaging) of no downdrift impacts on the coast. In 2000, the Narrowneck reef project won the prestigious Queensland State Environmental Award. Recent re-assessment of the economic impacts of the reef have confirmed a benefit:cost ratio of 70:1 (McGrath, 2002).



Figure 4. Coastal protection with the Narrowneck submerged reef. Top to Bottom: Before reef construction (construction commenced in August 1999); After reef construction; The view looking south showing the wide salient in the lee of the reef.

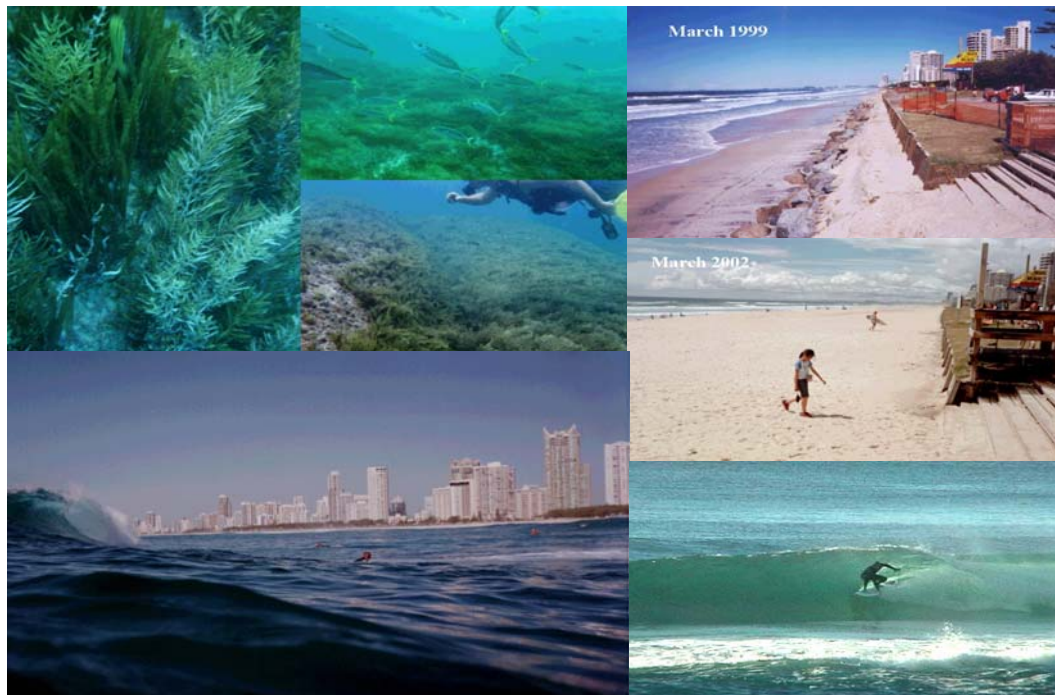


Figure 5. The Narrowneck multi-purpose reef. Clockwise from top left, colonization of the reef has resulted in a dive-trail; before and after reef construction (construction commenced in August 1999); surfing on the reef; the view from the surf.

Narrowneck Reef Monitoring Report Summary:

"North of the reef construction site, the beach in the vicinity of Narrowneck can be seen to have widened by 20 – 25 m through the latter part of 1999, stabilised in the first months of 2000, and then evolved to a generally erosional state from April to August 2000. Accretion then occurred up to December 2000, followed by modest erosion again in January 2001. The net result by this time had been an increase in beach width of the order of 40 – 50 m. The beach then eroded through the first half of 2001, resulting in a net gain in beach width since the start of monitoring period of approximately 10 – 20 m. During the six month period August 2001 to January 2002 the beach recovered fully, regaining some 30 – 40 m beach width, of which some 20 – 30 m was removed again during February 2002 – July 2002. From August 2002 the beach again recovered some 40 – 50 m, then receded again during the period February 2003 to July 2003, followed again by a general trend of beach recovery during August 2003 to January 2004. During the present monitoring period February 2004 to July 2004, a distinct erosion trend was measured, followed by recovery to the conditions that prevailed at the end of January 2004.

By the end of the present six month monitoring period the beach immediately north of the reef Narrowneck was typically of the order 20 m wider than at the commencement of monitoring in 1999. It should be noted that extensive sand nourishment had commenced in this area prior to the commencement of monitoring (refer Section 2.3), so the actual increase in beach width since implementation of the NGBPS is likely to be somewhat greater than this figure. At the centre of the reef construction site and the two transects to the south (all located in deposition area A3), beach widening of 50 – 60 m was observed through to early 2000 in response to ongoing nourishment during this time. At the centre of the reef construction site and 150 m south, this was followed by a period of erosion through to March then accretion to May, after which time a general accretionary trend persisted. At the transect 300 m south the beach continued to increase in width at a generally steady rate through 2000. Again, the net result had been an increase in beach width of the order of 50 – 60 m. Storms in March, April and July 2001 resulted in recession of the shoreline, with the beach in mid 2001 approximately 30 m wider than at the commencement of the monitoring program.

Through August 2001 to January 2002 the beach in the lee of the reef and to the south recovered to the conditions of January 2001. During the period February 2002 to July 2002 the beach width decreased by 20 – 30 m, then recovered through to the end of 2002 and continue to accrete some 30 – 40 m, mirroring the shoreline erosion–accretion changes observed north of the reef. Through to July 2003 recession again occurred, followed by accretion to January 2004. As was observed to the north of the reef, a period of erosion followed by recovery was measured from February 2004 to July 2004.

By the end of the present monitoring period the beach to the south (up-drift) of the reef was of the order of 40+ m wider than at the commencement of monitoring. In the lee of the reef, an additional 30 m had been maintained.

Wave breaking on the reef at Narrowneck is commonly visible in images obtained by the coastal imaging system (photo 8). In previous monitoring reports completed during the initial construction phase of the reef, the progressive increase in the occurrence of wave breaking was documented and quantified as additional geocontainers were added. Further geocontainers were placed on the reef crest in late 2001 and again in November 2002.2). Since that time it has been observed that waves break across the reef structure once the incident significant wave height exceeds around 1 m. It is concluded that the reef continues to achieve the objective of enhancing potential surfing opportunities at Narrowneck."

Turner, I.L., 2004. **Analysis of Shoreline Change: February 2004 to July 2004. Report 10: Northern Gold Coast Coastal Imaging System.** WRL Technical Report 2004/07, Water Research Laboratory, University of New South Wales.