Narrowneck Reef: Review of Seven Years of Monitoring

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ABSTRACT

The Narrowneck Artificial Reef is a large submerged structure constructed in 1999-2000 as a key component of the Northern Gold Coast Beach Protection Strategy (NGCBPS) implemented by Gold Coast City Council (GCCC). While primarily a coastal protection structure, its secondary objective was to improve surfing. Since its construction, comprehensive monitoring has been undertaken. To date, the reef has been a success in terms of retaining the wider nourished beach. The structural performance has been satisfactory, with ongoing improvements, and the geotextile has provided a surprisingly good substrate for development of a diverse marine community. In terms of surfing, the reef has achieved its goal and provides improved surfing conditions for a wide range of surf craft. Evaluation of the incidence of wave breaking shows that breaking is initiated on the reef for wave heights over 0.7 m to 2.0 m, depending on the tide. For an average year, waves break on the reef approximately 50% of the time. While waves tend to be more spilling than plunging in average conditions, larger swells, lower tides, and offshore winds have the potential to produce hollow, plunging breakers. The reef needs long period, clean swell to replicate the modeling. As Gold Coast wave conditions are usually bi-modal and often short-crested, there have only been a few examples where this has been the case. Bar formations around the salient also provide favorable conditions on the shore-break and the reef break often merges with the adjacent bar break to extend ride lengths. GPS data shows that recorded rides average 150 to 200 m, but have reached up to 260 to 270 m. Similarly, recorded ride times have reached up to 60 seconds. Despite being home to a number of regular and one-off surfing events, Narrowneck reef has not gained a widespread reputation as a great surf spot. Part of the reason for this appears to be that it is surrounded by world-class surfing breaks and typically these locations work in similar conditions as the reef. The fact that the takeoff area is 300 m offshore also seems to make the reef break less attractive to surfers. Media hype prior to reef construction led to unrealistically high expectations that the reef would perform in all conditions and press statements criticizing the reef before completion has also negatively impacted public perception of its success. While the objective of improved surfing has definitely been achieved, it was not well quantified. While the design has progressively evolved during maintenance works to improve surfing and safety, further improvements specifically improve surfing are not considered warranted.

The Gold Coast is a very dynamic coastal environment where beaches experience high wave energy with a net northerly sand transport rate of approximately 500,000 m^3/yr. The average significant wave height (H_S) is about 1.0 m, with recorded storm waves (H_M) reaching over 13 m every few years. Tides are semi-diurnal with tide heights over 2 m above Lowest Astronomical Tide (LAT).

ADDITIONAL KEYWORDS: Submerged breakwater, Control point, Gold Coast, Australia.

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In 1974, following an extended period of severe erosion resulting from a large number of cyclones in the 1950s and 1960s, the northern Gold Coast beaches were nourished with about 1.5 million m^3 of sand. These works formed part of the implementation of the recommendations of the Delft Report (1970). The artificially widened beach gradually narrowed, as was expected. Completion of the Nerang River training walls in 1985 (also part of the Delft recommendations) acted as a terminal groin for the northern Gold Coast beaches, progressively realigning and widening the spit. However, further southward (updrift) the beaches at Main Beach and Surfers Paradise continued to gradually narrow, and storms, such as Cyclone Nancy in 1990, cut into the narrow dunes and exposed the boulder wall at Narrowneck. By the mid-1990s, the boulder wall at Narrowneck was exposed to wave attack,

Figure 1. Photo of Narrowneck looking southward to Surfers Paradise in 1996.

with no high tide beach (Figure 1), on at least a yearly basis. The popularity of Narrowneck as a beach and/or surf destination declined.

As the wall juts some 20 m seaward of the general boulder wall alignment, the adjacent beaches and dunes at Surfers Paradise and Main Beach were very narrow during such events. The increasing occurrences of beach erosion caused dangerous conditions for beach users accessing and using them, which in turn led to a negative impact on the city's tourist image and economy. As a result, Gold Coast City Council (GCCC) coastal engineers looked at ways to restore the northern Gold Coast beaches and proposed a conceptual solution (Jackson and McGrath 1995) as follows:

"Beach widening to provide additional open space and an increased storm buffer is desirable for the Surfers Paradise area. Various schemes have been investigated. The preferred option is nourishment of the beach and dunal areas, stabilized by a low profile headland at Narrowneck (1.75 km to the north of central Surfers Paradise). The headland is to be designed to enhance surfing conditions, be visually unobtrusive and cause no adverse impacts for the beaches to its north."

The inclusion of surfing in the council's thinking was not surprising – the city of the Gold Coast grew from a small resort called Surfers Paradise and includes iconic surf spots such as Burleigh Heads, Currumbin Alley, Kirra Point, and Greenmount. Most groins on the Gold Coast are good surf areas. Structures on the Gold Coast have always been designed with a knowledge of and consideration to the fact that, if a wave breaks on it, there will be surfers trying to catch the waves. These surfers will include family and friends of the engineers and often the engineers themselves.

Surfing is not some theoretical consideration in coastal design but an inherent one, often loosely packaged with "public use and safety." Good coastal design and progressive peeling waves are compatible. The temporary sand-filled tube constructed at North Kirra in 1985 did much to expand the practical knowledge of surfing. While within the surf zone, it did not generally attract surfboard riders, but provided a great and safe platform for children, young and old, to body surf off and along.

To evaluate the state of the art with respect to being able to incorporate surfing in the design, AWACS were commissioned by GCCC to do a comprehensive literature review (AWACS 1996). This confirmed that many coastal protection structures worldwide were recognized as top surf spots and that a good scientific understanding of surf waves, particularly for short boards, had been provided by engineers such as Kimo Walker and Bill Dally. This confirmed that a more formal approach to incorporating surf amenity into the reef design would be practical.

Following storm erosion in May 1996, the urgency increased and GCCC resolved that consultants be commissioned to determine a sustainable long term strategy for the protection and improvement of northern Gold Coast beaches

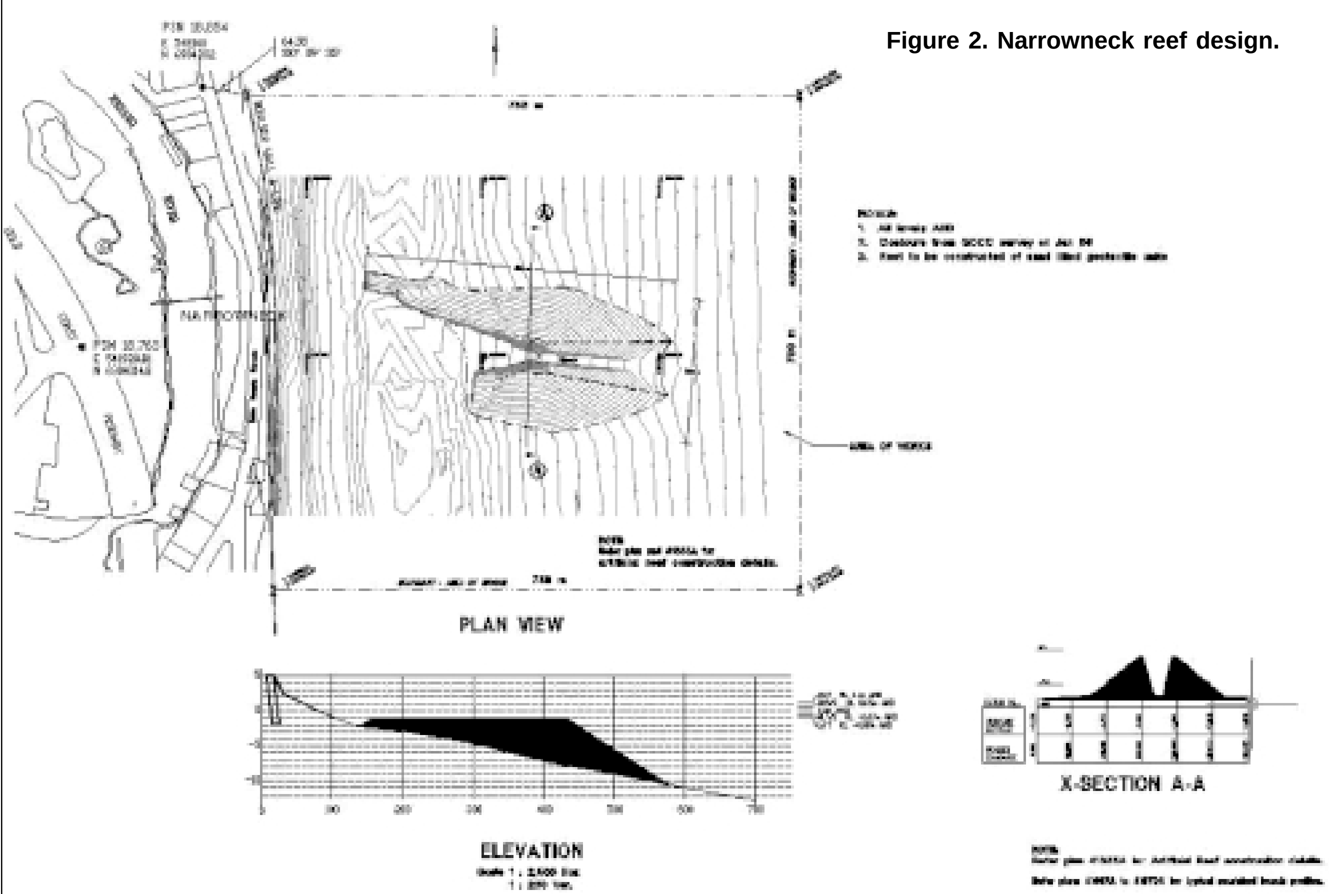

Figure 2. Narrowneck reef design.

from Burleigh Heads to South Stradbroke Island, and to widen the beaches and dunes in the Surfers Paradise area by 30 m to 50 m initially as a high priority to accommodate storm erosion and improve the recreational amenity.

The primary objective of this strategy was to widen the beach and dunes in the Surfers Paradise area to provide an increased storm buffer and additional open space. As it was considered likely that the works would involve construction of a control structure at Narrowneck, a secondary objective was to improve the surfing conditions at this popular location.

International Coastal Management (ICM) was commissioned by GCCC in October 1996 to act as project managers for the Northern Gold Coast Beach Protection Strategy (NGCBPS).

Reef Design

Because of the nature of the site and the complexity of the integrated coastal management strategy, which was to be "world best practice," widespread expertise was used in the investigations and design. As part of the approval and detailed design stage, nine study briefs were prepared and carried out by specialist consultants, coordinated by the project consultants (ICM) with input from GCCC – there was a strong interaction and cross-flow of ideas, data and findings. The studies undertaken are outlined in Table 1.

To ensure that the design objectives for the reef were achieved, numerical and physical modeling was carried out. Genesis modeling by the Water Research Laboratory and GU confirmed that the seaway works were effectively realigning and widening the beaches back from the seaway to about Narrowneck. This confirmed that Narrowneck was a good location for the next control point. 2D numerical modeling using Genesis was also carried out to evaluate the beach widening that would be associated with various selected wave transmissions. This modeling indicated that only an average 30% reduction in the wave height (70% wave transmission) was required to move the average beach line 50 m seaward and would trap approximately 100,000 m^3/yr initially in the vicinity of the reef.

The inclusion of "improved surfing" as a secondary design criterion increased the complexity and introduced an added community expectation and media focus on surfing amenity. The development of the reef shape and modeling of potential impacts was undertaken by the University of Waikato, New Zealand (UW) using a number of 2D and quasi-3D numerical models (GENIUS, 3DD and POL 3DD). The models were calibrated using measurements taken in the surf zone (UW 1998a) and run using idealized continuous crested monochromatic waves and a simplified bathymetry (flat prenourishment profile without the troughs and bars) to help ascertain the effectiveness and impacts of the reef.

To achieve the surfing aims, the reef started as a "conventional" V shape. This shape caused high seaward velocities over the crest of the reef and this was considered an unacceptable safety issue by ICM, who recommended a split V to reduce velocities and provide a longer shore parallel footprint for beach protection. A shoreward extension of the north arm was also requested to improve the submerged groin effect.

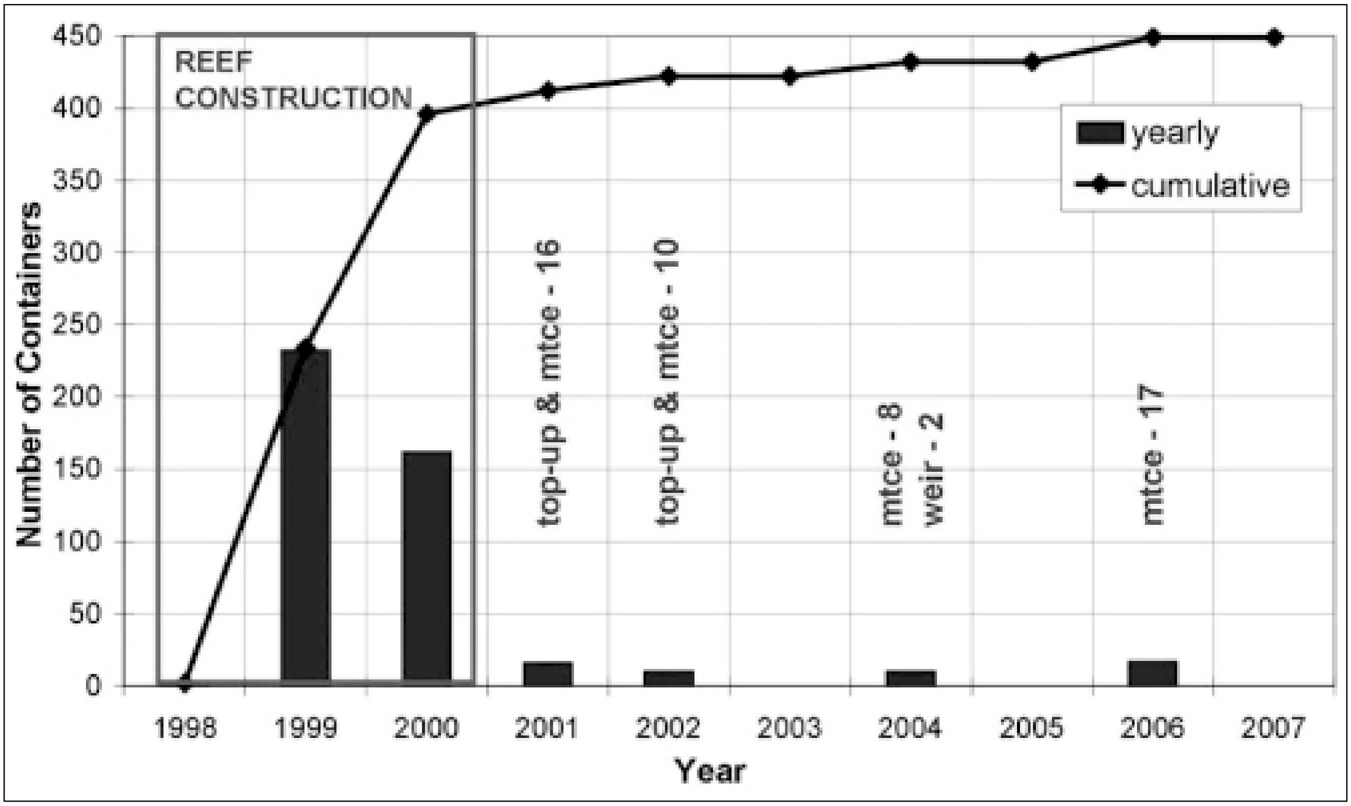

Figure 3. Construction and maintenance phases of Narrowneck reef.

The final shape (UW 1998a) was relatively complex (Figure 2). UW recommended a crest level of -1.0 m AHD (Australian Height Datum = approximately Mean Sea Level) and a large focusing area with a very smooth slope to increase wave height at the break point (UW 1998b). Even with the split shape, the model results indicated that setup and currents in the vicinity of the reef remained significant with the shallow crest at low tide.

For this shape, with the shallow crest height, a wide salient of 78 m was predicted (UW 1998c). Physical modeling (basin and flume) was undertaken by WRL (1998b; 1998c) with monochromatic waves. The results of this testing generally confirmed the numerical modeling for salient size, sediment transport, and wave breaking.

After detailed review of all of the modeling and impact assessment studies, for safety reasons and to avoid excessive sand retention ICM/GCCC adopted a crest height of RL -1.5 m AHD (-0.5 m LAT) for the initial construction contract. It was considered preferable to construct, monitor and, if then required, to raise the crest in stages to minimize risk and exposure to litigation from surfers and boat users.

Reef Construction

The reef design and construction involved the development of innovative ideas. Constructability within the project budget was a key issue. Engineering construction drawings were prepared by ICM for approval and construction. Approvals were based on the final shape modeled by UW, including the very shallow crest, but this was considered as an envelope within which the reef could be constructed and maintained.

The modified design was “replicated” using 408 very large sand-filled geotextile “bags” that were 20 m in length and ranged from 3 m to 4.5 m in diameter. For cost effectiveness, the nominated slopes were slightly truncated and more realistic slope tolerances were adopted. (Experience and modeling could not justify the ±300 mm target for all sections of the reef nominated by UW).

There has been a progressive evolution of the shape during maintenance since the major construction phase was completed in 2000 (Figure 3). These changes to shape have included:

• Where bags have been lost in the deeper sections, they have not been replaced.

• The paddle channel has been bridged to improve beach protection.

• The tail to act as a submerged groin will not be constructed as it is not required.

• The shoreward base of the reef has been flared slightly to improve linkage with the adjacent bars to maximize ride length.

Comparisons with Existing Artificial Reefs

Despite considerable interest worldwide, only four multi-functional artificial reefs, including Narrowneck, have been completed to date, and the data from these plus data from the two reefs under construction in New Zealand has been analyzed and benchmarked against Narrowneck (Jackson and Corbett 2007). The results, summarized in Table 2, show that Narrowneck has improved surf at a very reasonable unit cost compared to similar reefs.

Monitoring Overview

There has been substantial monitoring of the project since its completion in late 2000. This has included:

• Video imaging

1) “ARGUS” using multiple cameras — WRL

Figure 4. Photo of breaking initiated on the reef at low tide.

2) Webcam — GCCM/Coastalwatch

• Hydrographic and beach surveys — GCCC

• Photography

1) Aerial oblique — various

2) Beach photographs — ICM

• Surf and surf safety

1) Observations — ICM, GCCC lifeguards, GCCM/Coastalwatch

2) GPS surfing track plots — ICM, Brad Holmes Surf Coaching

• Geotextile containers

• Condition — ICM, McQuade Marine, Elco, GCCC

• Stability (pressure sensors in and on individual containers) — ICM, Elco

• Ecological surveys — ICM, National Marine Science Centre, Ian Banks

The following parameters have been evaluated:

• Beach protection — beach width and shape

• Surfing amenity — surf frequency, quality, and safety

• Marine ecology, fishing, and diving — development and overall biodiversity

• Structural performance — construction aspects, container design, placement accuracy, stability, and durability

In brief:

• Beach protection; successful (WRL 2007)

• Surfing amenity; improved as discussed in the following section

• Marine ecology, fishing, and diving; very successful (Jackson *et al.* 2004)

• Structural performance; satisfactory with successful ongoing improvements

Incidence of Wave Breaking

The specified secondary objective of the Narrowneck artificial reef was to "improve surfing." For surfing, waves need to break to be catchable. Waves break on both north and south reef (Figure 4) provided wave and tide conditions are favorable. Observations indicate incidence and initiation of wave breaking on the Narrowneck reef as per Figure 5.

In the most recent report, WRL (2007) notes that: *Wave breaking on the reef at Narrowneck continues to be commonly visible in images obtained by the coastal imaging system …"*

This report also notes that, since the additional crest containers were placed in 2002, that: *"Since that time, it has been observed that waves break across the reef structure once the significant wave height exceeds around 1m."*

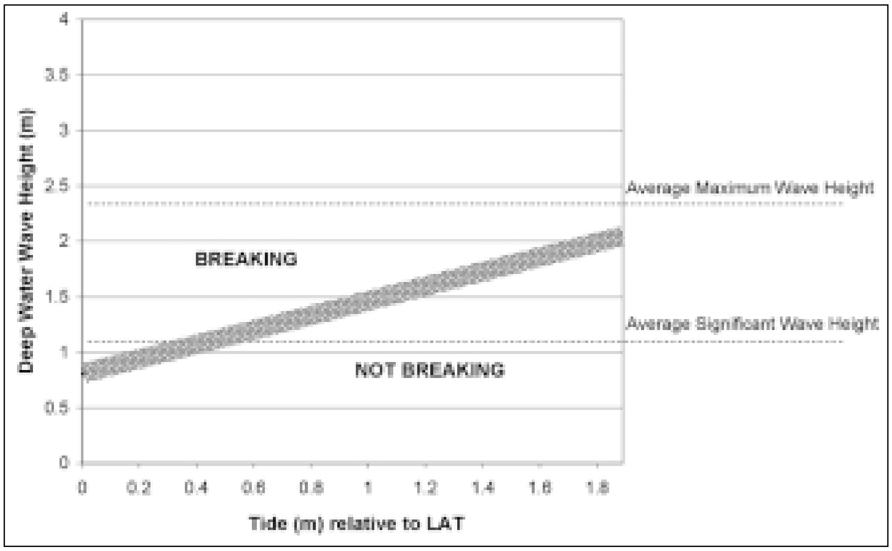

Figure 5. Incidence of wave breaking at Narrowneck reef.

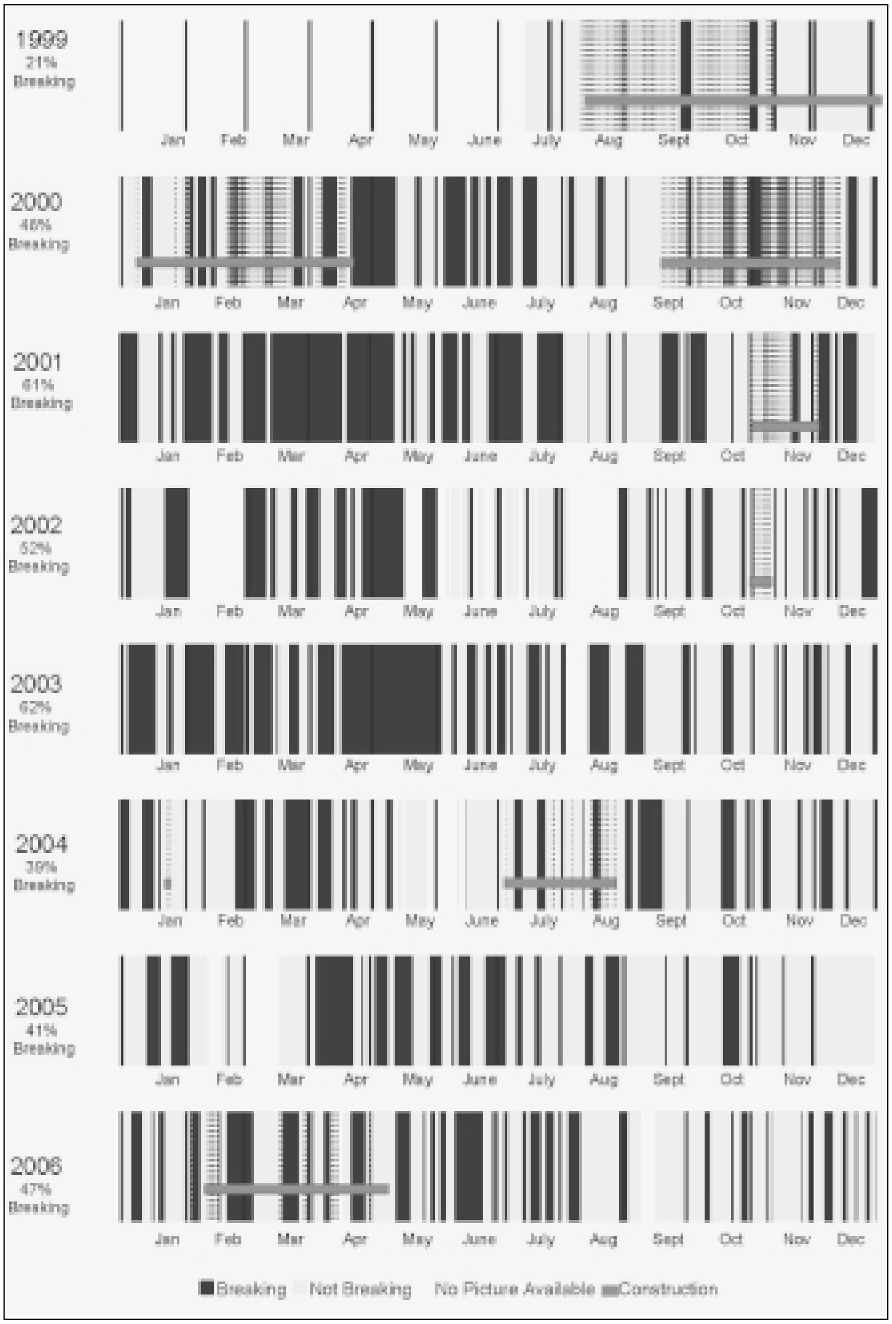

Figure 6. Frequency of wave breaking on Narrowneck reef.

This report concluded that: *"It is concluded that the reef continues to achieve the objective of enhancing potential surfing opportunities at Narrowneck."*

Frequency of Wave Breaking

To establish the frequency with which waves break on the reef, time-averaged and variance images from the WRL coastal imaging cameras were analyzed. The presence (or absence) of wave breaking on the reef was recorded for 7 a.m. each day, regardless of tide and wave conditions (Figure 6). This showed that, since construction of the reef, waves break on the reef approximately 50% of the time.

As expected, the frequency of wave breaking observed during the initial stages of construction (21%) is distinctly lower than the average frequency observed after construction as crest height is important in the wave breaking process. It is also evident from the variability in frequency that natural variability in wave conditions also has an impact on the presence of wave breaking, both seasonally and annually.

Type of Break

In average conditions (1 m to 1.5 m), the waves tend to be more spilling than plunging (Figure 7). This is preferable for safety and more inexperienced surfers, or just for a relaxed ride. In larger swells with offshore wind conditions, the waves are typically hollow, plunging breakers (Figure 8) and the crest bags can "suck dry" even with the lowered crest level. In swell conditions >1 m, particularly with a longer period, surf conditions can be very good and attract experienced surfers.

As with all reef breaks, tide level impacts on the breaker type as well as the incidence of breaking. At the top of the

Figure 7. Photos of spilling breakers on Narrowneck reef in smaller conditions.

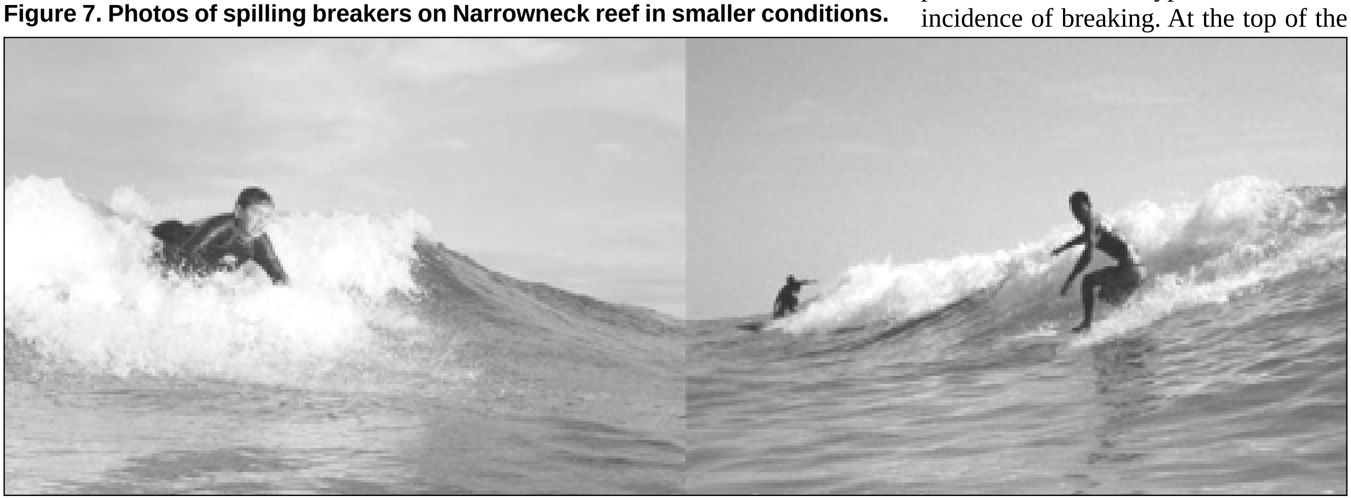

Figure 8. Photos of plunging breakers on Narrowneck reef in larger conditions.

tide, waves tend to be more spilling, even in larger swell conditions (Figure 9). While offshore winds produce the best conditions, the reef often remains surfable for a time after the onshore winds kick in when the quality on the adjacent bars quickly deteriorate.

Effect of Crest Height and Tolerances

The reef and crest level were lowered as the 1999 storm bar migrated shoreward. The crest was subsequently topped up. The change in crest height has allowed the effect of crest height on wave breaking type to be evaluated.

With the crest at or above the original design height of -0.5 m LAT, a very hollow but hazardous wave develops that often sucks dry at the breakpoint even in small swell conditions. As swell height increases, this type of wave attracts only the expert body board and short board riders. With the crest lower than -1.5 m LAT, waves tend to be spilling, attracting long boards and surf skis. The target crest height has been reduced to -1.5 m LAT (RL -2.5 m AHD) as a compromise between safety and surfing. Despite the lowered crest and acceptance of more practical tolerances (realistically, decimeter accuracy) from the original design, the reef still provides improved surfing conditions.

Figure 9. Photos of breaking during high tides with heavy swell and offshore wind.

With the top ups and maintenance, the reef crest is not smooth. However, the wave breaking tends to be unaffected by the roughness of the reef, except where there is a localised high spot and small swell conditions. Figure 10 shows wave interactions causing wave confusion before the high "slightly" displaced bag moved into its hole. Localised low spots or even missing bags (> 1.2 m) cause no significant adverse wave impacts.

Comparison with Modelling

Monitoring of the reef indicates that the reef needs long period, clean swell to replicate the modelling. The numerical and physical modelling was done with monochromatic long crested waves on a smooth (non-barred) seabed profile. In reality, the Gold Coast wave conditions are usually bi-modal and often short-crested. In the video monitoring, there have only been a few examples of the wave patterns replicating the modelling. The long period storm wave event in Figure 11 is an example. A more typical wave breaking pattern is shown in Figure 12.

This emphasises the fact that, while modeling can be a powerful tool if used correctly, it is important to recognise that it provides information for a limited number of specific conditions while actual conditions are often highly variable. While modeling can be valuable, it is important that model runs are representative of actual conditions and that results are interpreted appropriately based on independent data and past experience.

Ride Length

In the early stages of monitoring, the length of the ride achieved was evaluated qualitatively, with simple observations regarding distance and time of ride. It was noted that the surf at Narrowneck was often providing much longer rides than anticipated as the reef break merged with the adjacent bar break in favorable conditions, resulting in a ride that started on the reef and finished close to the beach.

In late 2005, monitoring was extended to include recording and analysis of surf tracks from a wrist-mounted waterproof GPS unit. Local surf coach Brad Holmes was fitted with the GPS unit while surfing at Narrowneck. At present, data has been collected and analysed from six hours of surfing — some 22 separate rides. Breaker heights during the data collection were typically <2 m.

Analysis of the data (Figure 13) shows that, while rides typically averaged 150 m to 200m, recorded ride lengths reached up to 260 m to 270 m on both the north and south reefs. This confirmed earlier observations of long rides extending significantly shoreward of the reef and close to the beach. Similarly, the longest recorded ride reached over 60 seconds, although recorded ride times averaged approximately 30 seconds. Corresponding speeds (averaged over the length of the ride) varied between 3.7 m/s and 7.4 m/s.

Figure 10. Photos of wave confusion caused by shallow misplaced container.

Figure 11. WRL image of refraction in a long period, clean swell.

During maintenance works, the shoreward end of the reef has been flared to improve linkage into the adjacent bars.

Adjacent break

There was no formal monitoring of the break prior to construction. Comparison was made with the adjacent breaks, far enough from the reef so as not to be affected by the reef. In small conditions, waves do not break on the reef. The bar formations around the salient, however, provide favorable conditions for the shore-break and it is common to find significantly more surfers directly on the bar in the lee of the reef than on the shore-breaks on either side. It is also common for the flags to be set up directly in the lee of the reef, indicating that it produces a safer swimming environment than natural conditions on the adjacent beaches.

Safety

With litigation so prevalent, safety is of particular importance. Artificial reefs present a number of hazards for swimmers and surfers (Corbett and Tomlinson 2002), including:

• Impact with the reef when surfers dive/fall off their board (relevant for surfers only) – while surfers tend to "fall" off their boards rather than diving, limiting potential for spinal damage, they also have a higher initial velocity than people who dive into a pool (and need 1.8 m water depth for safety)

• Impact with the reef due to turbulent wave action in shallow water

While breaker height and type also impact on safety, the crest height of the structure is also critical. The original design (with crest at approximately LAT) developed by the University of Waikato was intended to optimize surfing, particularly for short boards, over the entire tidal range with small waves. In 2002, the designers stated that the original Narrowneck design would have had a similar wave breaking intensity as Shark Island. As this is one of the most dangerous surf breaks in Australia, this was not desirable.

During the design process, safety was identified as a key issue. This was reflected in the lowering of the crest to -0.5 m LAT and the use of user-friendly geotextile containers. Despite this, the reef produced a very hollow but hazardous wave that often sucked dry at the breakpoint (Figure 14). The break was suitable only for very experienced surfers, even in moderate swells.

After construction, the reef crest lowered as the pre-construction storm bar migrated shoreward. During the 2001 top-up, the design crest height was restricted to -1.0 m LAT. Even at this level, the top of the crest bags is often shallow during the drawdown and has been observed to "suck dry" in larger wave heights at low tide.

In early 2002, flume testing was undertaken at QGHL by GCCM and ICM for Noosa Council (Corbett and Tomlinson 2002). The modelling confirmed the observations of water depth experienced at Narrowneck (approximately 0.3 m for crest heights of -1 m LAT and approximately 1 m for crest heights of -1.5 m LAT, see Figure 15).

Figure 12. WRL image of typical wave break.

Table 1. Summary of studies undertaken during the detailed design stage

GCCC Contract Description	CONSULTANT
Physical modeling: Wave breaking characteristics and forces at reef	WRL (Unisearch – Uni of NSW)
Numerical modeling: Wave breaking characteristics and sediment transport at reef	Uni of Waikato
Numerical modeling: Sediment movement and budget at Seaway	WRL/Griffith Uni
Numerical modeling: Estuarine hydrodynamics and sediment dynamics	WBM
Numerical modeling: Nourishment profiles/quantities and erosion due to storm and sea level rise	WRL
Assessments of impacts of dredging and nourishment on water quality and marine ecology in the Broadwater and Narrowneck	Griffith Uni
Public information/consultation Strategy	John Campbell Information and Marketing
Economic and social impacts due to changes in beach amenity	GCCC/Griffith Uni
Land tenure investigations	Michel Survey Group
UNIVERSITY/ STUDENT REPORTS	
Geotextile container design and behavior	Griffith Uni

As a result of these observations and testing, the design crest height has been reduced to 1.5 m below LAT (RL -2.5 m AHD) as a compromise between safety and surfing. To date, there have been no reports of injuries on the reef.

Range of Surf Craft

The quantification of surfing quality appears simple in theory, as considerable research has been done to determine key parameters to define surf quality. All of this research, however, relates particularly to a single type of surfing – shortboards. Importantly, there are many other types of surf craft, and the "perfect" surf for one group of surfers may not be "perfect," or even suitable, for another group of surfers. The sport of surfing encompasses a wide range of activities in the surf zone and many Australians consider themselves surfers.

The reef has provided significantly improved conditions (ride length/quality and higher surfer number capacity) for a wide range of activities including:

- Body surfing

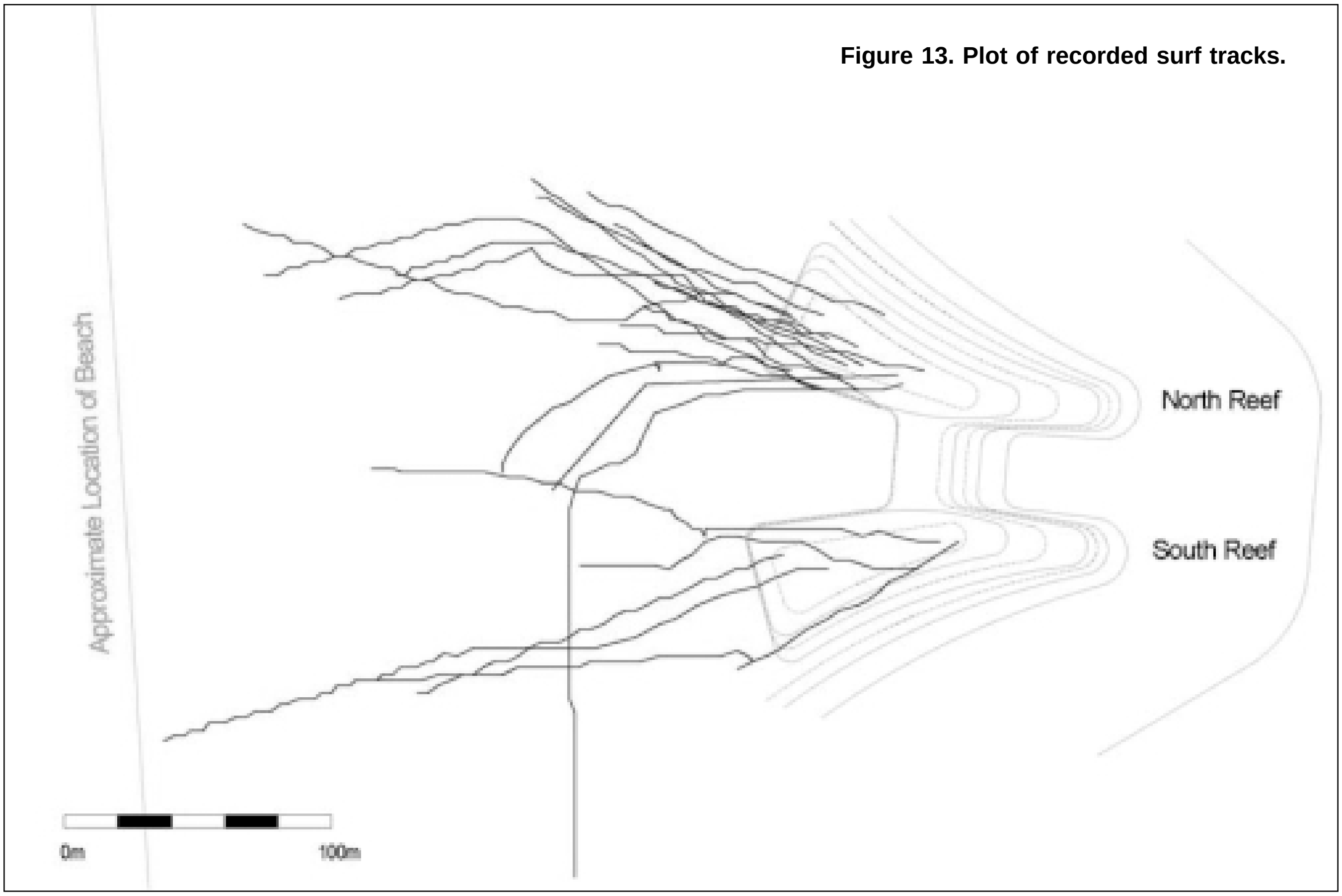

Figure 13. Plot of recorded surf tracks.

- Body boards (and mattresses)
- Surf boards – short, medium, and long
- Surf skis and paddle boards
- Surf kayaks and canoes
- Sailboards and kite boards
- Tow-in surfing

Surf Competitions

A number of regular major competitions — such as the Clean Water Teams Challenge (Figure 16), and one-off events like the National Wave-jumping Titles, Queensland State Bodyboard Championships and the National Kiteboard Championships — have been held at Narrowneck since the works were implemented.

Regular local competitions now are held at Narrowneck. The Narrowneck Long-board club and the Northend Boardriders cater to long-boards and short-boards respectively. While the competitions tend to find a quiet location not on the reef itself, the wide beach and adjacent breaks are key attractions. (The beach and surf amenity are complementary). On days with good surf conditions or multiple surf competitions, car parking is inadequate.

Public Perceptions

The Narrowneck Artificial Reef has undoubtedly improved surfing conditions and the reef does provide a quality surf wave in the right conditions. However, it has not gained a widespread reputation as a great surf spot. Part of the reason for this appears to be that it is sur-

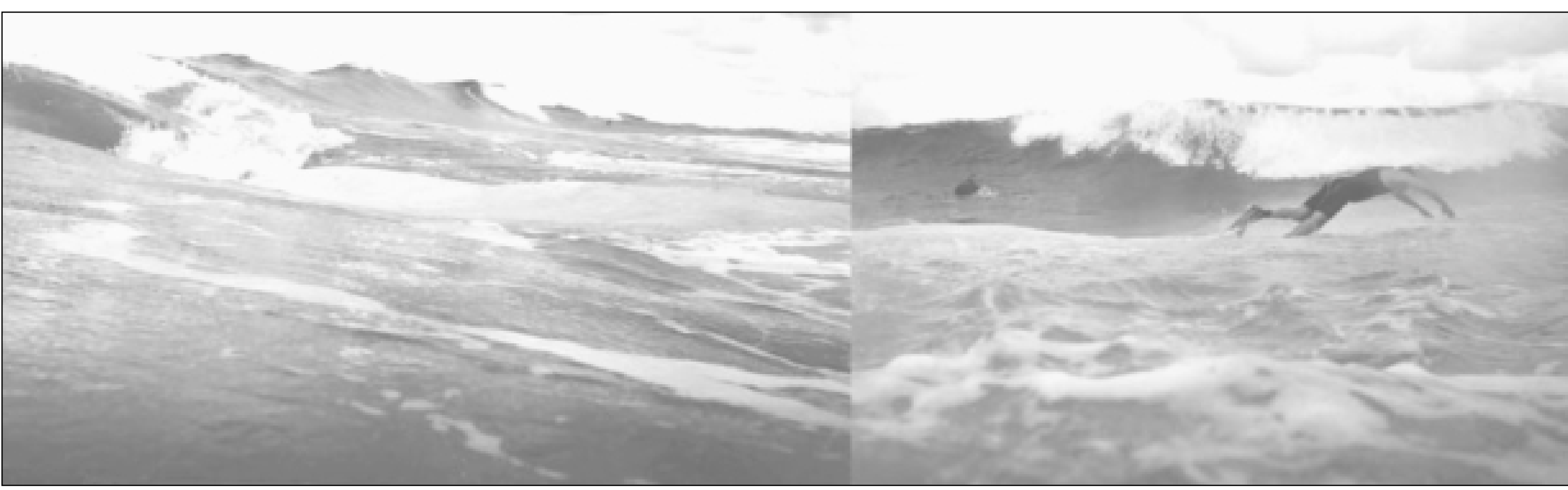

Figure 14. Photo of break with crest at -0.5 m LAT.

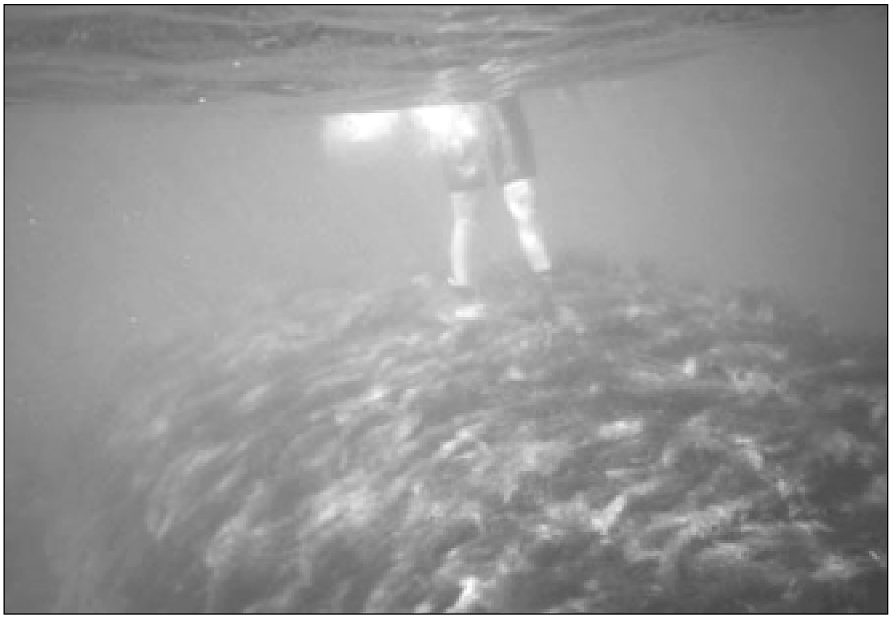

Figure 15. Photo of break with crest at -1.5 m LAT.

rounded by world-class surfing breaks, including Superbank, and typically these locations work in similar conditions as the reef.

The fact that the takeoff area is 300 m offshore also seems to have had an impact. As with many surf spots, the majority of surfers tend to congregate closer in on the beach break, even when the reef is "pumping" in the sets. However, if one "brave" surfer heads further out to the reef and starts to catch good waves, some of the crowd generally follows. While having the reef closer to shore would undoubtedly be more attractive to surfers, it may not be better overall given that distance offshore also has a significant impact on erosion protection and local currents.

Press statements damning the reef even before construction was completed gave a very negative community perception which has been lasting.

Conclusions

The Narrowneck Artificial Reef has achieved all objectives at a very competitive cost. The secondary objective of improved surfing has definitely been achieved but is very hard to measure quantitatively. In hindsight, this objective was appropriate, but needed to be more precisely defined. Promotion by the media prior to construction led to unrealistically high surfer expectations and emotions. As has been experienced with all of the artificial reefs worldwide (four completed, one substantially completed, one started), there was a belief that an artificial reef "created" surf waves and that it would perform reliably regardless of conditions.

There has been a progressive evolution of the shape since construction in 1999-2000. While further improvements for diving and fishing are recommended, no further changes specifically to improve surfing are considered warranted.

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Figure 16. Photo of Clean Water Challenge.

Table 2. Comparison of existing multi-functional artificial reefs

Reef	Bargara	Cables	Narrowneck	Pratte's	Mt Maunganui	Opanake
Location	Qld, Aust	WA, Aust	Qld, Aust	California	NZ	NZ
Started	1997	1998	1999	2000	2005	2006
Completed	1997	1999	2000	2001	Not completed	
Primary function	Surfing	Surfing	Coastal protection	Surfing	Surfing	Surfing
Material	Rock	Rock	Mega geotextile containers	Sand bags	Mega geotextile containers	Mega geotextile containers
	Rock from site reprofiled	Rock imported by barge	Sand from seabed of Broadwater	Bags brought by barge	Sand from port	Imported sand
Volume (m³)	300?	5,000	60,000	1,350	6,000	Not known
Performance	Surf OK	Surf OK — as per design	Coastal protection — OK (also surfing, fishing and diving "improved")	Surfable only several times per year (then "epic"?) — needs larger volume	Surf OK – not completed, awaiting insurance to replace damaged bag(s)?	About 10% completed? Suspended awaiting replacement of damaged bags (insurance)
Approx costs (A$/m³)	$33	$327	$54	$285	$242	Unknown

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