

Shoreline Response to an Offshore Wave Screen, Blairgowrie Safe Boat Harbour, Victoria, Australia

T.R. Atkins and R. Mocke

Maritime Group, Sinclair Knight Merz,
P.O. Box H615,
Perth 6001, Australia

ABSTRACT

A safe boating harbour was constructed in 2001 within Port Phillip Bay, Victoria, Australia. The harbour at Blairgowrie, south of Melbourne, was created by means of a precast concrete, partial depth, wave screen designed to protect the boating pens from unacceptable wave conditions during storm events. As predicted during the planning process, on completion of the boat harbour a shoreline salient has developed. The salient accretion rate has since slowed considerably, possibly returning the shoreline to new equilibrium condition. The focus of this paper is on the boat harbour, construction of protective screening and the salient formation. Finally, a comparison to the far more studied shoreline responses to natural and man made reefs and breakwaters is also undertaken as part of this paper.

BACKGROUND

Blairgowrie is located at the southern end of Port Phillip Bay, Victoria, Australia (Figure 1). Port Phillip Bay is one of the largest natural bays in the world protected by deep ocean swell waves of the treacherous Australian Southern Ocean entering the bay through the narrow entrance at the head of the bay from Bass Strait.

The area is still very exposed to winds from the northerly sector with a fetch of over 50 kilometres to the adjacent side of the bay. The longer period wind generated waves (4-5 seconds) from the north are depth limited to some extent by the shallow water depths present at the Great Sands banks just offshore of Blairgowrie.

Earlier numerical modeling at the time showed that wave conditions at the site were dominated by waves from the north and northwest with estimated annual wave climate heights less than 1.0m and peak periods generally less than 4.0 seconds (EES, 1998). Wave refraction over the Great Sands banks to the north, and the shallow nearshore water depths, causes the incident waves to be primarily shore-normal in the surf zone. A relatively low potential net easterly sediment transport rate of 2,600m³/annum was estimated for the pre-harbour condition (EES¹, 1998). EES refers to Environmental Effects Statement for Proposed Safe Boat Harbour at Blairgowrie Yacht Squadron, November 1998.

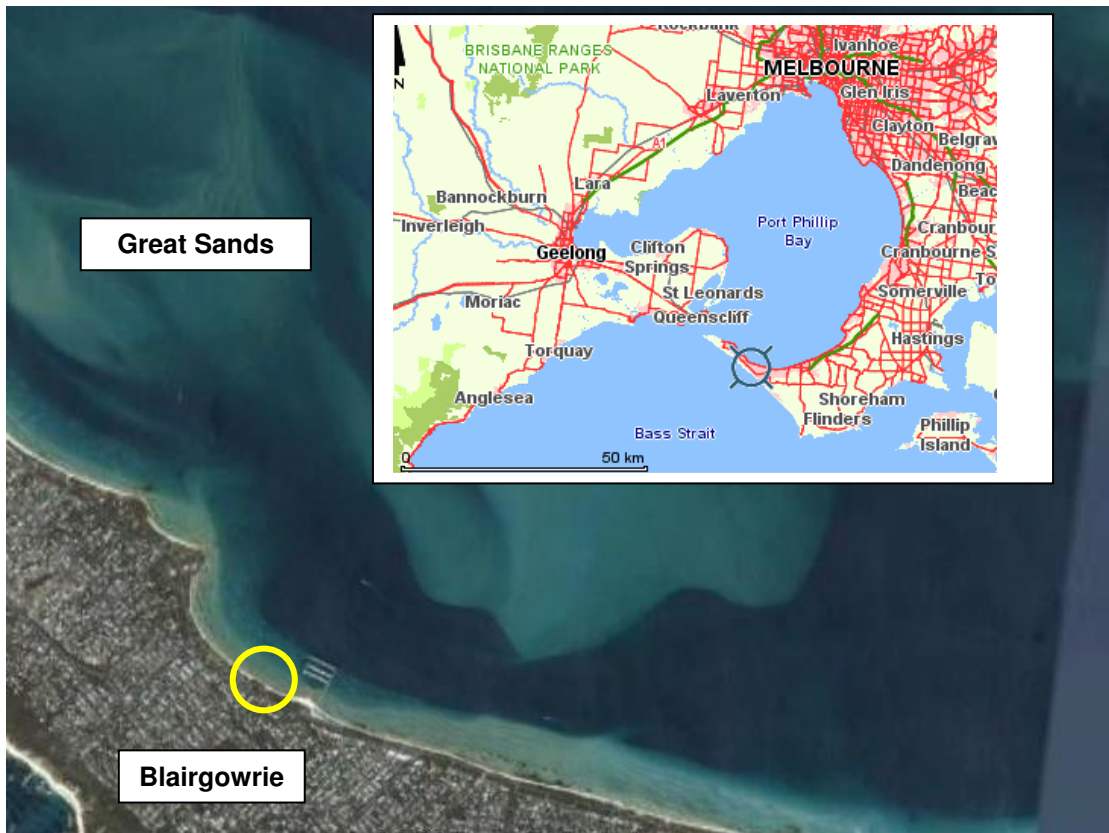


Figure 1. Boat Harbour Location

No safe haven for boat moorings existed along this part of the coastline for at least 30km and any severe weather conditions from the North would cause ongoing damage to moorings and boats. Access to the shoreline by offshore swing moorings was limited to dinghy access from a 150m long jetty (Figure 2), exposed to the elements which made for very difficult and hazardous vessel transfers.

There was considerable pressure from the boating public to create a safe harbour at Blairgowrie and in 2000 it was decided to go ahead with its construction. Blairgowrie is situated in a sensitive environmental area in pristine waters known for their clarity and fishing.



Figure 2. Blairgowrie, 1998, pre-harbour construction.

HARBOUR CONSTRUCTION

No capital dredging to create the harbour basin was permitted because of the environmental sensitivity of the location and so the berths needed to be located offshore in naturally deeper water. It was required that current flows and associated water quality also needed to be maintained at the pre-harbour conditions, and this, combined with construction difficulties associated with an offshore breakwater, meant that a rubble mound harbour was not possible at this location.

The design solution adopted was a combination of approximately 215m of partial depth wave screen with 70m of floating attenuator at the western end of the screen. The wave screen is made up of a number of precast panel units (Figure 3) which were barged to site, lifted in place over steel piled supports, and permanently connected to the supporting structure with insitu concrete construction (Figure 4).

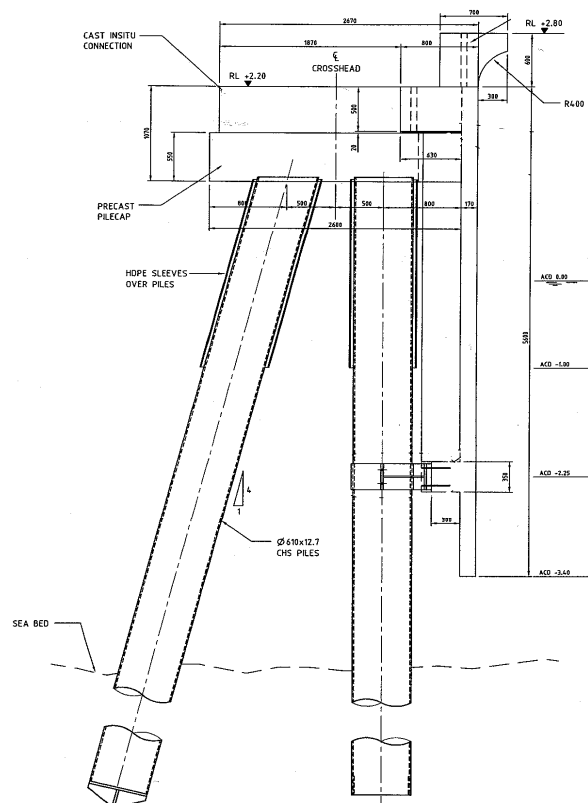


Figure 3. Typical cross section of the precast concrete wave screen



Figure 4. Construction photo showing the installation of the precast concrete panels

SALIENT FORMATION

The potential for salient formation at Blairgowrie was identified during the Environmental Effects Assessment for the project, and a sand monitoring and bypassing plan was incorporated into the planning documentation. Although the rate of sediment accumulation has been greater than expected, sand monitoring results suggest that the shoreline response could be reaching equilibrium, which is supported by the lack of any reported significant downdrift erosion. If the longshore sediment transport rate has been re-established any concerns over down-drift erosion as a result of the harbour can be eliminated and the need for any sand bypassing in the harbour can possibly be avoided.

An accurate prediction of the extent of the salient expected would therefore be of great benefit to the harbour. However, although there have been numerous investigations of the relationship between the dimensions of emergent breakwaters and the formation of salients in their lee (U.S. ARMY CORPS OF ENGINEERS, 2002), to date there does not appear to be any comprehensive studies of the shape of salients formed in the lee of permeable structures such as floating wave attenuators and partial wave screen structures. There have, however, been recent advances in the prediction of salient formation in the lee of man made and natural reefs and breakwaters (Black, 2003; BLACK and ANDREWS 2001a, 2001b) which is dealt with later in this paper.



Figure 5. Salient formation at Blairgowrie Safe Boat Harbour, December 2005

SHORELINE DATA ANALYSIS

Basic monitoring of sand movements at the site has been carried out twice-yearly since October 1998, in line with the Sand Management Plan developed in response to planning permit conditions. The sand monitoring methods have included the measurement of the beach cross-sectional profile along the Blairgowrie jetty (Figure 6) and the measurement of beach widths within a 500m zone either side of the jetty (Figure 7).

This data has been reviewed each year to determine whether an agreed trigger point has been reached and whether the implementation of a sand bypassing plan is required. The trigger point, defined as a 20m seaward movement of the high water mark at the jetty from the pre-harbour condition, has not been reached to date.

In addition to the ongoing sand monitoring program, a shallow water survey of the harbour, including the tidal zone, was commissioned in May 2006.

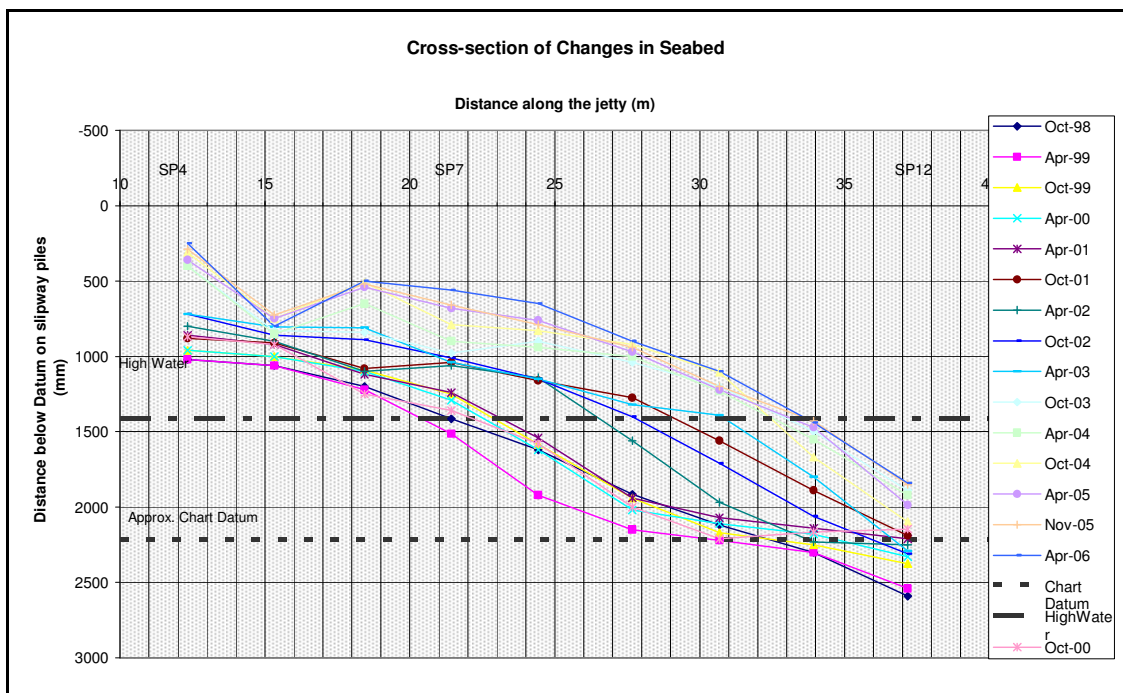


Figure 6. Beach cross sectional profile at Blairgowrie jetty, Oct 1998 to present.

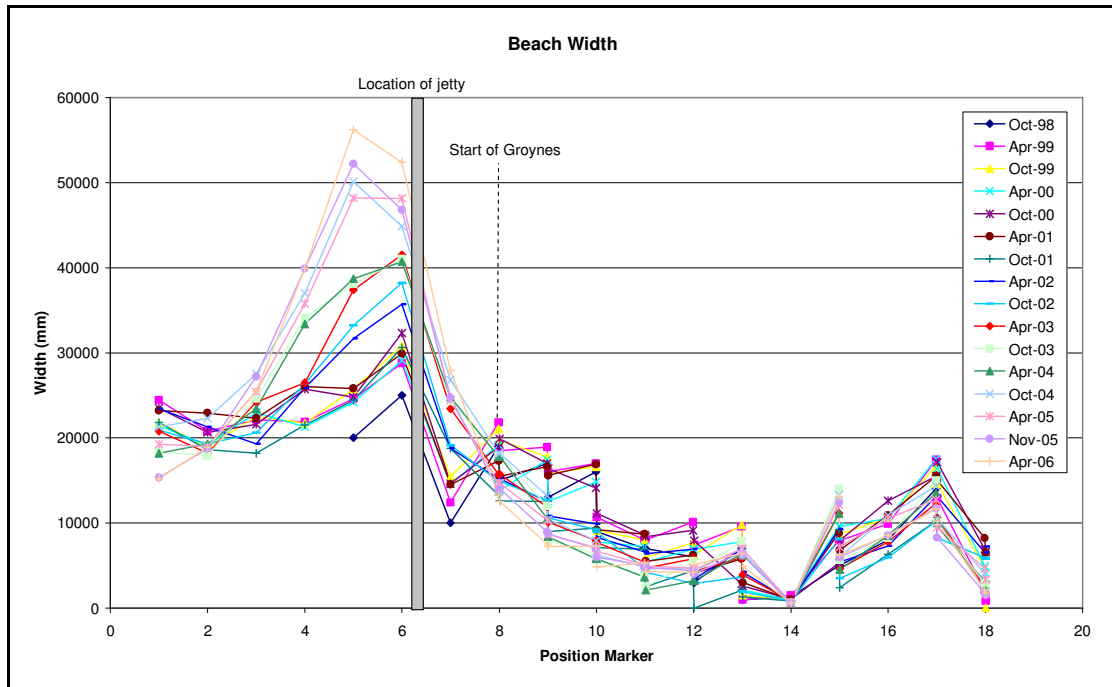


Figure 7. Beach width measurements at Blairgowrie, Oct 1998 to present

SHORELINE RESPONSE CHARACTERISTICS

An examination of Figure 6 and Figure 7 clearly shows the accumulation of sediment in the lee of the wave screen. The exact quantity of sediment contained in the salient formation is difficult to ascertain due to the lack of an accurate pre-harbour survey of the tidal zone, however, an estimation can be made based on the pre-harbour beach profile measurements taken at the jetty and the current beach profile outside the zone of influence of the wave screen that was captured in the May 2006 survey. By adopting an estimated 'undisturbed' beach profile across the width of the harbour it has been estimated that the volume of sediment contained in the salient formation is approximately $15,900\text{m}^3$, or an average of $3,180\text{m}^3$ per annum.

In terms of salient geometry, it is apparent that the salient is of a symmetrical character, as expected due to the predominantly shore normal nature of waves in the surf zone at Blairgowrie. This is further reinforced by the relatively low longshore sediment transport rate at the site.

A number of dimensionless ratios have emerged to separate salient and tombolo response (U.S. ARMY CORPS OF ENGINEERS, 2002), which are based on key geometries of the shoreline response and the offshore structure. In keeping with these established measurements and the nomenclature used in BLACK and ANDREWS (2001a), the key geometries of the salient formation at Blairgowrie are as follows:

S - Offshore distance of obstruction (distance between 315m undisturbed shoreline and obstruction)

B – Length of offshore obstruction 220m

Y_{off} – Salient amplitude (length of shore normal between 70m origin and offshore extremity of the shoreline feature)

D – Salient basal width (total length of shoreline affected) 480m

X_{off} – Distance from tip of salient to offshore obstruction 245m

It should be noted that the length of the offshore obstruction has been taken as the length of the precast concrete wave screen and does not include the length of the floating attenuator. This is because although the floating attenuator is effective against small amplitude short period waves, the wave climate at the site has proved to be of longer periods than the attenuator is capable of reducing (SINCLAIR KNIGHT MERZ, 2004). The affect of the attenuator on shoreline response has therefore been assumed to be negligible for the purposes of this study. The key salient geometries are presented in Figure 8.



Figure 8. Key salient geometries at Blairgowrie

Also of interest is the decreased growth rate of the beach profile over time. An examination of Figure 9 shows that the beach profile grew relatively quickly immediately after the completion of the harbour in 2001, but has since slowed down suggesting that coastal processes may be moving towards a new equilibrium.

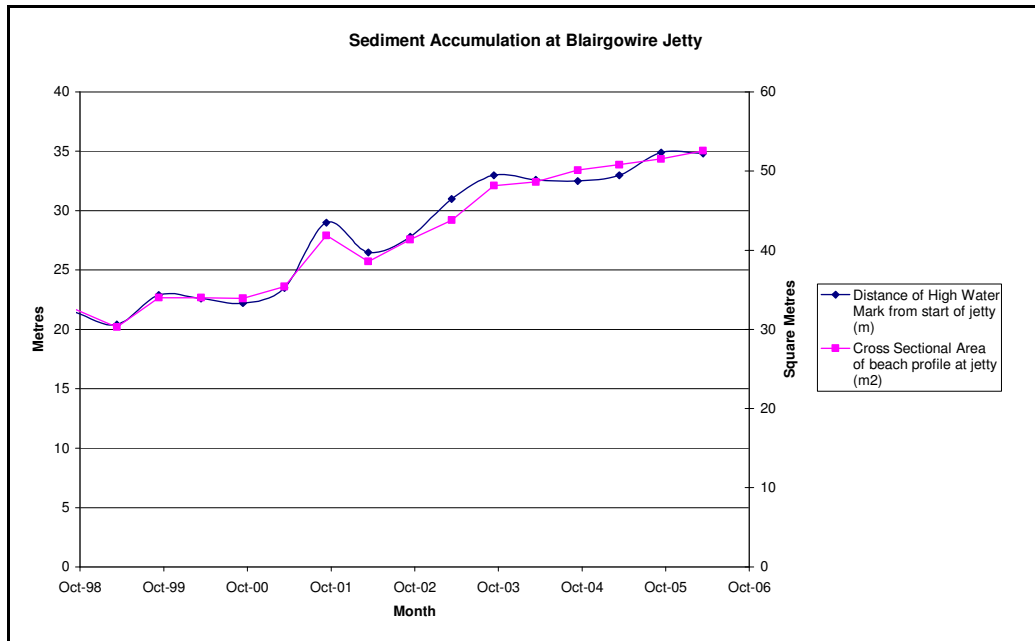


Figure 9. Growth rate of the beach profile following completion of the harbour in 2001.

COMPARISON WITH OFFSHORE REEF FORMULAE

BLACK *et al.* have made considerable progress in the prediction of shoreline response to offshore reef structures, both natural and man-made (BLACK and ANDREWS, 2001a and 2001b, BLACK 2003). This work has included the determination of relationships that predict salient amplitudes from non-dimensional variables Y_{off}/S , X/B and B/S , based on selecting and measuring salient formations behind offshore reefs and islands shown in aerial photographs of the complete coastlines of New Zealand and New South Wales (Australia).

Non-dimensional ratios of X/B versus B/S were plotted for different data sets of salient formations and power-curve relationships in the form $y=ax^b$ were identified. The following power-curve relationships for salient amplitude and salient basal width were suggested for submerged reefs.

Salient amplitude: $X/B = 0.5(B/S)^{-1.27}$

Salient basal width: $Y_{off}/D = 0.125 (\pm 0.020)$

These empirical relationships have compared favourably to numerical procedures developed to predict salient formation for offshore reefs (BLACK, 2003).

Although not directly applicable to the offshore structure at Blairgowrie, the relationship developed for salient formations in the lee of offshore reefs does represent a relationship observed in nature between a permeable offshore structure, which allows some transmission of wave energy, and the associated shoreline response. Applying these empirical relationships to Blairgowrie Safe Boat Harbour predicts the following salient formation.

Table 1. Comparison of December 2005 key salient geometries with those predicted by the power-curve relationships developed for salient formation in the lee of offshore reefs

Key Salient Geometry	December 2005 condition	Predicted formation based on power-curve relationships developed for salient formation from offshore reefs
Y_{off} – Salient amplitude (length of shore normal between origin and offshore extremity of the shoreline feature)	70m	142m
D – Salient basal width (total length of shoreline affected)	480m	979m
X_{off} – Distance from tip of salient to offshore obstruction	245m	172m

The above predictions, whilst noting that they are based on offshore reefs rather than the structures present at Blairgowrie, clearly represent a significant departure from the salient geometries currently observed for submerged structures.

This could be for a number of reasons. Firstly, although the beach profile and beach width measurements suggest that the growth rate of the salient is slowing and that the shoreline response is tending towards equilibrium, this reduction in the growth rate of the salient may be due to altered weather conditions in recent years rather than the development of an equilibrium condition. The salient may indeed continue to grow, however a growth to the extent of the predicted values seems unlikely.

There is also some uncertainty over time of day, and therefore the state of the tide, at which the December 2005 aerial photograph was taken. A close examination of the photograph shows evidence of the formation of small sandbars at the apex of the salient, meaning that the current salient amplitude may in fact be closer to 90m and that the additional growth needed to meet the predicted equilibrium conditions may not be as great as Table 1 suggests.

Alternatively, the wave energy passing through and under the wave screen is likely to be greater than that passing over an offshore reef on which waves would break. This is reinforced by a number of issues on site to do with 5 to 6 second period waves passing into the harbour. These waves have been particularly apparent during extreme storm events in 2002 and 2003, where long duration storms of up to 40 hours coincided with extreme water levels considered to be greater than a 1/50 year event. In this case the expected protection

from relative long period waves by the shallow water of the Great Sands to the north did not occur, resulting in some nominal damage to the floating pontoon system of the harbour. Significant scour, somewhat more than predicted, under the wave screen has also been observed following the completion of construction. This scour under the wave screen, and the associated increase in long period waves in the harbour as a result, could go some way to explaining the reduced salient growth rate.

CONCLUSIONS

This paper has compared the observations of salient formation in the lee of the precast concrete partial depth wavescreen at Blairgowrie with predicted salient growth based on power-curve relationships derived for salient formation in the lee of offshore reefs by BLACK and ANDREWS (2001a). Based on this comparison, it appears that the protection offered by partial depth wave screens, in terms of the transmission of energy into the lee of the structure, will be less than the protection offered by offshore reefs, particularly shallow offshore reefs where breaking waves occur. This has limited the amount of salient growth in the lee of the structure in comparison to that observed for submerged reef structures.

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