TOPOGRAPHIC CONTROL OF RUN-UP VARIABILITY

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ABSTRACT

This paper presents observations of currents recorded in the swash zones of a number of morphologically different types of beaches in order to demonstrate the large variability in run-up patterns that exists primarily because of variability in beach face and surf zone configuration. Run-up spectra are shown for steep and flat beaches under low (<0.5m) and moderate (0.5-2.0m) wave energy. The longshore variability of run-up patterns on rhythmic beaches is also discussed. On reflective beaches run-up occurs only at incident wave frequency under low energy conditions and at both incident frequency and its first subharmonic under moderate energy. Low energy dissipative beaches exhibit a range of frequencies across the swash zone from incident through low frequency infragravity. As wave height increases on flat beaches, high frequency oscillations vanish leaving a concentration of energy at low infragravity frequencies. On more complex inshore rhythmic topographies under low to moderate energy conditions, alternating transverse bars and troughs give rise to a close spatial co-existence of zones of surging, reflective run-up and zones of over-running progressive bores of the type observed on flat profiles.

INTRODUCTION

In the recent literature on nearshore and surf zone processes several papers have placed considerable emphasis on the interdependence of morphologic features and hydrodynamic regimes. Of particular note are those by Chappell and Wright (1979), Chappell and Eliot (1979), Short (1979), Wright et.al. (1979) and Short (1980).

These papers point out either explicitly or implicitly that the morphologic and hydrodynamic characteristics exhibited by a beach at any one time are the result of mutual interaction between process and beach form and that many feedback loops, both positive and negative, are involved. Some (eg. Wright et.al, 1979) demonstrate quite clearly that the nature of nearshore hydrodynamics is not uniform across the range of beach types that we commonly find in nature. Others (Chappell & Eliot, 1979; Short, 1979 & 1980) discuss beach changes over time and consider how existing morphologic and hydrodynamic conditions are, to a large extent, a function of antecedent conditions.

All, however, have in common the consideration of process/form interaction and because of this they complement a large body of literature which describes various hydrodynamic and sedimentologic characteristics of sandy beaches but does not (except in a few cases) explicitly link these to beach morphology.

The reports cited above mainly confine their attention to the nearshore/inshore zone and treat it essentially as a single unit. However, smaller sub-systems can be studied in the same way and it is the intention of this paper to focus more closely on the swash zone.

Most workers addressing problems related to swash zone processes have done so either with the view of (i) extending and refining hydrodynamic theory as applied to run-up on steep beaches of uniform slope and simple morphology (see Meyer and Taylor, 1972, for a review of these studies), or of (ii) describing and explaining the nature of swash/backwash processes on real beaches (eg. Sonu et.al., 1974; Waddell, 1973). There have been few comments from either group on the relationship between beach face morphology and run-up characteristics such as swash/backwash velocity fields, swash frequency domains and sediment transport mechanisms. Huntley and Bowen's (1975) discussion of steep and shallow beaches is a notable exception.

This paper focuses on the frequency characteristics of the swash zone and presents field data which relates run-up frequencies to beach face morphology over a range of beach configurations. The aim, however, is not only to present relevant field data but, more importantly, to demonstrate the great variability of swash zone processes which hitherto, have been treated as being similar across the range of beach face types.

FIELD SITES AND METHODOLOGY

Swash zone data and observations used in this paper were collected as part of a larger study of the nearshore processes operating on the beaches of the Southeastern Australian coast. Beaches of all kinds were observed ranging from the flat dissipative extreme to the steep reflective extreme and including a number of examples with more complex types of inshore morphology (Wright et.al.,1979). Experiments were carried out under wave energy conditions ranging from low (<0.5 metre primary break) to moderate (0.5 to 2.0 metres). It is important to note that in all cases incident waves were dominated by moderate to long period swell (T>10 seconds). This contrasts with reports of nearshore experiments in other parts of the world where short period wind wave conditions predominate (eg. US Atlantic and Gulf Coasts).

Current data were collected using miniature bi-directional ducted flow meters and water surface oscillations were obtained from bottom mounted pressure transducers. Details of these instruments are discussed by Bradshaw et.al. (1978). Spectra were computed using the auto-correlation method (Bendat and Piersol, 1971) and raw spectral estimates were smoothed with a Tukey filter. Since this paper is concerned only with run-up frequencies observed on natural beaches all spectral estimates are non-dimensionalized relative to the maximum for the series.

THE OBSERVATIONS

Field observations are considered for each different type of beach morphology in turn. Data are presented for these beaches under low and moderate wave energy conditions and the effects on run-up of tidal fluctuations in water level are noted.

1. Steep Beaches

This type of beach is common on sections of the Southeast Australian coast that exhibit a high degree of compartmentization. It tends to be sheltered and coarse grained and has the morphologic characteristics of a steep linear beach face (slope>0.12), a prominant step at the breakpoint and relatively deep water immediately seaward of the step (Figure 1). Waves surge up the beach face under low energy conditions but change abruptly to plunging or collapsing as wave heights rise above about 0.5 m.

The only rhythmic features observable on this type of beach are cusps. These are regularly spaced and are of small scale but are not always present. When cusps are absent, the beach, because of its simple configuration closely resembles an artificial laboratory beach and run-up patterns, especially under low energy, are simple and uniform along shore.

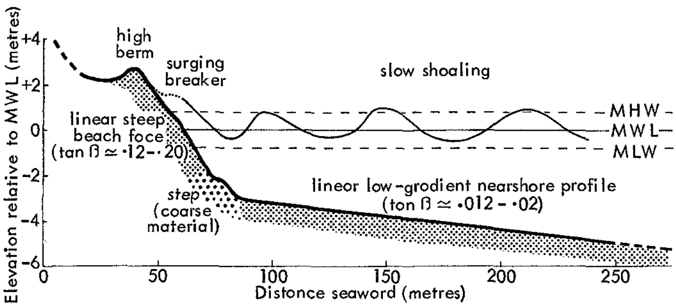

Figure 1: Typical cross section of a reflective beach (after Wright et.al., 1979)

When cusps are present however, run-up patterns generated by the longshore rhythmic undulations of the beach face are far more complex especially under high energy conditions. Data are discussed here only for non-cusped or very weakly cusped reflective beaches.

An example of a low energy reflective beach is shown in Figure 2. For most of the time waves surge up the beach face for a short distance and return completely before the onset of the next surge. Collisions at the base of the beach face between the backwash from one wave and the runup from the following wave are rare.

The spectrum of water motions on the beach face and slightly seaward of the step is shown in Figure 3. Of note is the fact that all energy on the beach face is confined solely to incident frequency oscillations with no evidence of subharmonic or infragravity peaks. This is in accordance with the suggestion by many (eg. Huntley & Bowen,1975) that the collision process at the base of the step is largely responsible for the generation of oscillations at frequencies below that of the incoming waves.

Figure 4 shows a moderate energy reflective beach. Waves now collapse or plunge on the step sending swash high up the beach face, often resulting in over-topping of the berm. The backwash almost inevitably ends in a turbulent collision at the base of the step. Under these conditions we note the emergence of water motions at twice the period of the incident waves both on the beach face and seaward of it. Figure 5 is an example of the spectrum which we consistently observe on reflective beaches under moderate energy wave attack.

The importance of tides is minimal on purely reflective beaches particularly when waves are small. Even at low tide water depth seaward of the step remains deep relative to wave height.

It should be noted that the profile shown in Figure 5 is not that of a purely reflective beach (as defined by figure 1) because of the existence of the bar seaward of the step. It is used here for two reasons: (i) the depth of water at high tide was such that no energy was dissipated in breaking over the bar and the profile was reflective, and (ii) the example illustrates the behaviour of sections of a more complex type of beach topography at high tide, a point which is discussed later in the paper.

2. Flat Beaches

Flat beaches with gradients of less than 0.02 occur mainly in high energy exposed environments or in areas where there is an abundant supply of fine grained sediments. They have a wide surf zone often exhibiting one or more linear bars (Figure 6). Waves plunge on the bar under low to moderate energy conditions with an increasing incidence of spilling breakers as the energy rises. Under all energy conditions the result is a shoreward progression of over-running, dissipative bores. Set-up is large on these beaches compared to steep profiles and has been shown to oscillate at surf beat frequencies (Sasaki et.al., 1977).

Figure 7 shows a <u>low energy dissipative</u> situation where a single plunging break results in a bore which travels inshore retaining its initial shape and velocity through most of the traverse. Only in the vicinity of the limit of uprush do successive bores begin to overrun each other.

Compared to the higher energy situations, turbulence is relatively low in the zone between the breaker line and the limit of uprush. Individual bores can often be followed across the surf zone from their originating wave to their landward limit.

Shore normal current spectra for two stations landward of the breaker line on a low energy dissipative profile are shown in Figure 8 (U-swash and U-mid surfzone). The current meters were located 5-6 metres landward of the

Figure 2: Low energy reflective beach.

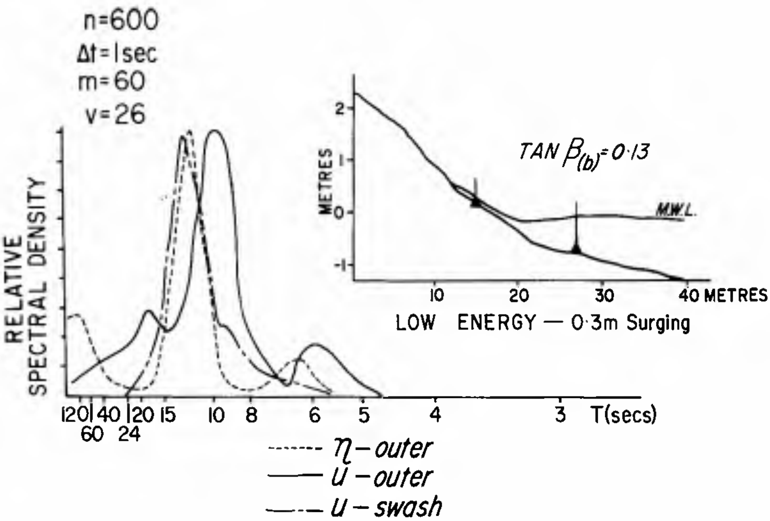

Figure 3: Typical run-up spectra from a low energy reflective beach.

Figure 4: Moderate energy reflective beach.

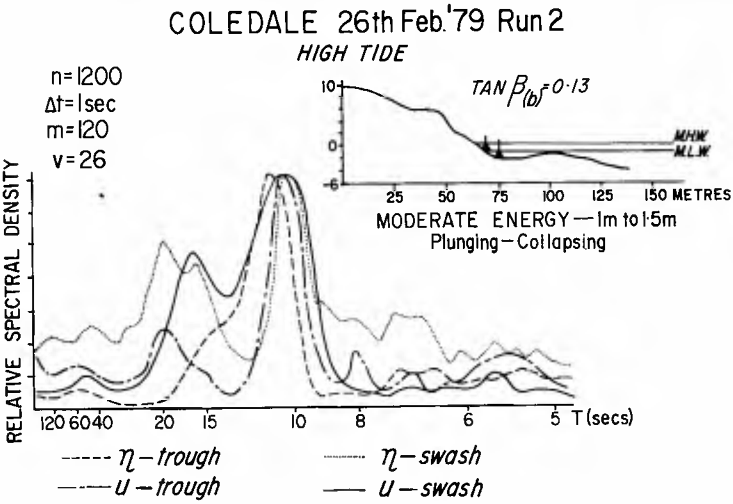

Figure 5: Typical run-up spectra from a moderate energy reflective beach.

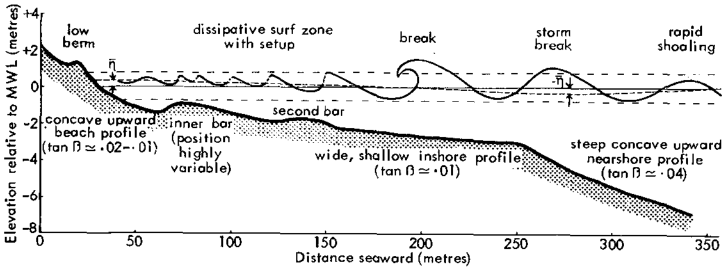

Figure 6: Typical cross section of a dissipative beach (after Wright et.al., 1979).

break point and about 5 metres seaward of the maximum run-up excursion. The figure reveals the following:
(i) expected peaks for the outer instrument at both incident and infragravity (surf-beat) frequencies and for the inner instrument at infragravity frequency;
(ii) a peak at half the incident wave frequency on both the inner and outer instrument, a phenomenon normally observed on steep beaches; and
(iii) an unexpected peak at incident wave frequency at the inner instrument.

This last phenomenon can clearly be seen from visual observation of the surf zone and suggests that when low amplitude, long period swell acts on a flat profile, the beach does not eliminate high frequencies to the extent that was first described by Emery and Gale (1951) and later by Waddell (1973), Sonu et.al.(1974) and Huntley and Bowen (1975). The appearance of incident wave frequencies at the top of the beach face can be attributed to the low turbulence in the surf zone and also to the long period of the incoming swell which gives bores time to cross the entire surf zone before they are interfered with by those following.

Discovery of the nature and extent of subharmonics on flat, low energy beaches requires more experiment replication. During the particular experiment referred to in Figure 8, swash/backwash collisions resulting in short lived hydraulic jumps (or roll waves) were occuring regularly at the top of the swash zone, about 10 metres seaward of the inner instrument station. However, even after viewing time lapse film records it was not evident what effect the collision was having on the swash period landward of it.

Figure 7: Low energy dissipative beach.

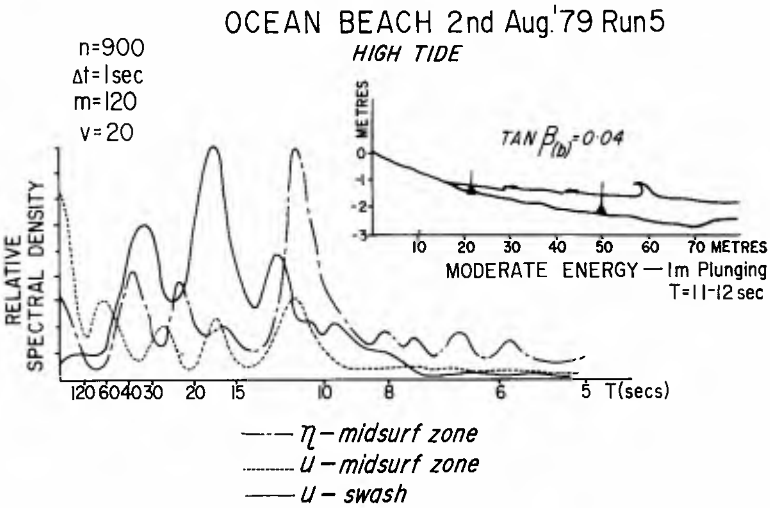

Figure 8: Typical run-up and surfzone spectra for a low energy reflective beach.

Figure 9: Moderate energy dissipative beach.

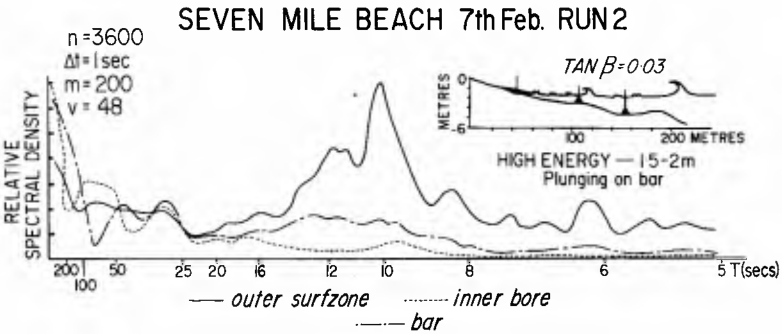

Figure 10: Typical run-up and surf zone spectra for a moderate energy reflective beach.

Figure 9 shows a dissipative profile in a much higher energy environment. Here a dual linear bar-trough system is present. Waves break on both bars and the resulting bores travel across a wide, highly turbulent surfzone. Larger bores often reform over the trough landward of the inner bar causing a secondary break higher up the beach.

The run-up spectrum for this moderate energy dissipative beach (Figure 10) shows a complete absence of energy at incident wave frequency and a dominance of energy in the low frequency infragravity domain. This is not only the case for shore normal currents at the top of the beach face but also for those over the inner bar. Compared to the low energy case these results correspond much more closely to those presented by workers such as Sonu et.al.(1974) and fit the classical view of the beach face as being an area dominated by low frequency oscillations.

Waddell (1973) presents evidence to show that the low frequencies on the beach face are not due to a simple low pass filtering effect but rather to a non-linear transfer of energy from high to low frequency, the result of collisions in the surf zone. Huntley and Bowen (1975) present similar results but suggest that the transfer is due to the interaction of many irregularly spaced breakers in the surf zone.

On the moderate energy dissipative beaches observed during the course of this study, it appeared that both mechanisms are important. It is certainly the case that there is a substantial modification of input frequencies as one moves across the lines of breakers and then into the turbulent bore zone. On moderate to high energy dissipative profiles the length of time that any one bore can travel shorewards without overrunning or being overrun by another bore is very short. However, backwashes with velocities greater than 1.5m/sec were recorded on many occasions and collision between these and shoreward moving bores resulted in roll waves lasting up to (and sometimes longer than) 10 seconds and with heights ranging to 0.5 metres. It is to be expected therefore that these are also considerably important in determining the range of frequencies operative on this type of beach.

3. Rhythmic Beaches

Many of the beaches on the Southeast Australian coast fall in between the two extremes discussed above and are characterised by complex rhythmic topography alongshore. Typically they consist of alternate anvil shaped shoals or transverse bars separated from each other and the beach face by well developed rips and feeder channels. Papers by Wright and Short (both in this volume) discuss the range of complex morphologic types in greater detail; however an example from the New South Wales coast is shown in Figure 11.

Depending on the stage of the tide, run-up patterns on this type of beach will either be uniform in the longshore direction or will show marked variation as one moves alongshore. Wave height is also important in determining the form of the run-up along the entire beach.

At high tide, under both low and moderate energy, the shoals are usually sufficiently deep that no breaking occurs over them. Instead the waves surge or plunge on the steep beach face that lies landward of the shoals. Because the sections of beach in front of rip feeders present a reflective face to the incoming waves at all times, the overall picture at high tide is one of continuous reflectivity along the entire shore. An example of this condition was presented earlier in Figures 4 and 5.

At low tide shoals emerge and become active, leaving an inactive steep beach face behind them. The longshore pattern now changes to one of alternating zones of reflective and dissipative run-up. The beach face fronting rips and rip feeders continues to exhibit reflective characteristics while the shoal regions display the characteristics of a dissipative beach. Run-up spectra taken at intervals alongshore vary accordingly.

Figure 11: An example of well developed rhythmic topography.

CONCLUSIONS

A summary of the observations discussed in this paper is presented in Table 1. The following points arise:

(i) Sandy beaches can exhibit morphologic variability both between different beach systems and also within individual beach compartments. The data discussed and summarised in Table 1 show that run-up characteristics vary as a result of these spatial differences in beach face topography. This paper considers only the frequency of run-up to demonstrate the point but the same variability can be observed in all hydraulic and sedimentary processes operating on the beach face.

Given the wide variability of the processes under consideration, account should be taken of the morphology and wave conditions for the particular beach being investigated when analysing and presenting swash zone data. This is very important for purposes of meaningful data comparison.

(ii) Understanding of swash zone processes and the nature of their interrelationship with beach morphology will ultimately come only from studies conducted over a range of sandy beach environments. The question of the swash-backwash collision process and its effect on sediment entrainment and transport on different beach slopes is significant and may be a good starting point for more specific process investigations. Initial observations show that on a steep beach the collision at the bottom of the slope bears directly on short term changes in step morphology and also influences sediment transport higher up the slope through its controlling effect on run-up and backwash velocities. On flat beaches the area of interaction is less narrowly defined and the collision results in the temporary suspension of large volumes of sediment in the roll wave. Detailed studies in this area have yet to be carried out.

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Table 1: A summary of observed relationships between surf zone and swash zone morphology and characteristic run-up spectra.

MORPHOLOGIC TYPE		WAVE ENERGY		
		LOW (<0.5m)	MODERATE (0.5-2.0m)	HIGH (>2.0m)
STEEP (REFLECTIVE)		Incident dominant No subharmonic	Incident & subharmonic	
FLAT (DISSIPATIVE)		Incident, Subharmonic & infragravity (~40-60 sec)	Attenuation of incident subharmonic frequencies	Long period infragravity (>60sec) Rapid shoreward attenuation of incident frequencies
COMPLEX MORPHOLOGY (e.g. alternating transverse bars & troughs)	HIGH TIDE	Reflective run-up incident dominant	Reflective run-up incident & Subharmonic	As above
	LOW TIDE	Alternate zones of reflective & dissipative run-up	As for low energy	As above

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