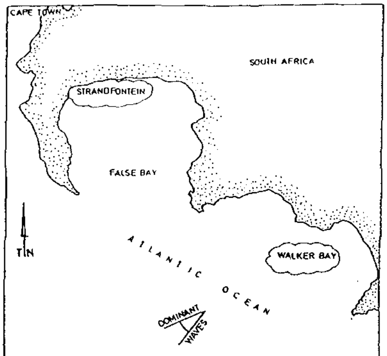

FIGURE 3: FIELD MEASUREMENT SITES

4. Field Experiments

The field measurements to quantify bottom return current as a result of a cross-shore wind were done at two sites on the south-western coast of South Africa. As can be seen on Figure 3, both of these bays face the predominant south-westerly swells although False Bay due to its dimensions is more protected than Walker Bay. Storm waves arrive at the latter nearly unabated.

In all three experiments were done, namely, in September 1986 and February 1990 in Walker Bay and in March 1990 in False Bay. The Walker Bay exercises were part of much bigger field measurement campaigns into nearshore coastal processes but the False Bay exercise was done solely for the purpose of determining wind-driven currents.

At Walker Bay the strongest wind events are from the north-west (May to August) and from the south-east during the rest of the year. Cross-shore wind events are therefore less prevalent. Nevertheless, a few useful blows in roughly the cross-shore direction did occur during the two exercises. The strongest wind events at False Bay occur from the same directions but due to the orientation of the bay and more specifically the prominent mountain ranges around it, the strong winds are nearly always roughly aligned in the cross-shore direction.

In doing the experiments during the three field programmes it was generally strived to deploy the equipment in the bottom 20 % of the water column and seaward of the dominant breaker line. Deployment water depth varied from 4 m to 20 m and in some of the shallower cases the current meters were at times inside the surf zone or very close to it, thus measuring wave-driven currents. It is easily visible on the plots of current velocity when this occurred.

As a result of the manner of deployment (location, depth, etc.) the results represent a breadth of varying influences, e.g. in incident waves (surface roughness), wave effects (rip currents, orbital velocity) and the bottom roughness (False Bay generally has a smoother bottom than Walker Bay).

Walker Bay : September 1986 Figure 4 gives an overview of the type of data gathered during this exercise. Figure 4c summarises all the available data points obtained with a vector-averaging current meter in 20 m water depth every 15 min. between 21 and 26 September 1986.

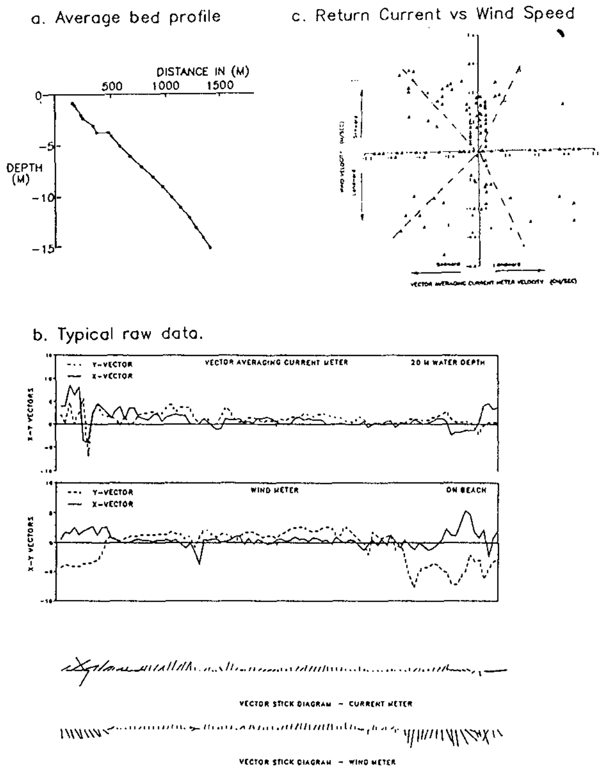

FIGURE 4: WALKER BAY DATA : September 1986

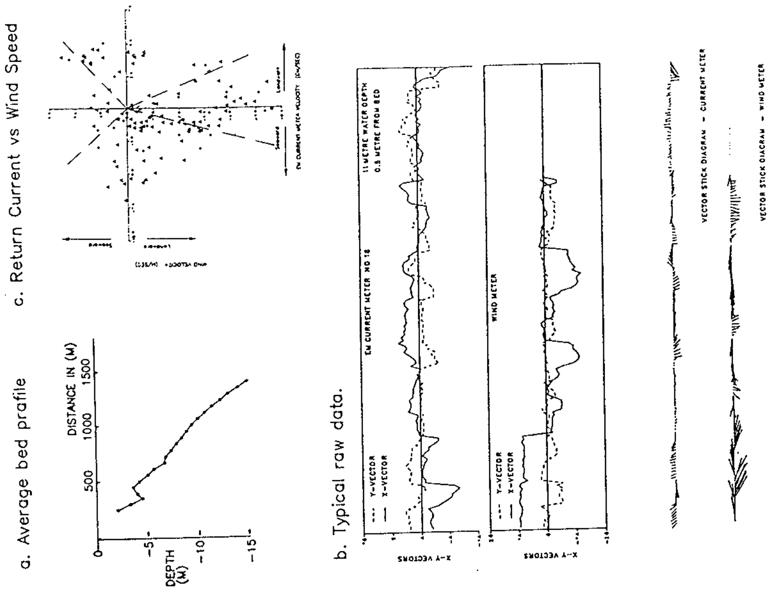

FIGURE 5 : WALKER BAY : February 1990

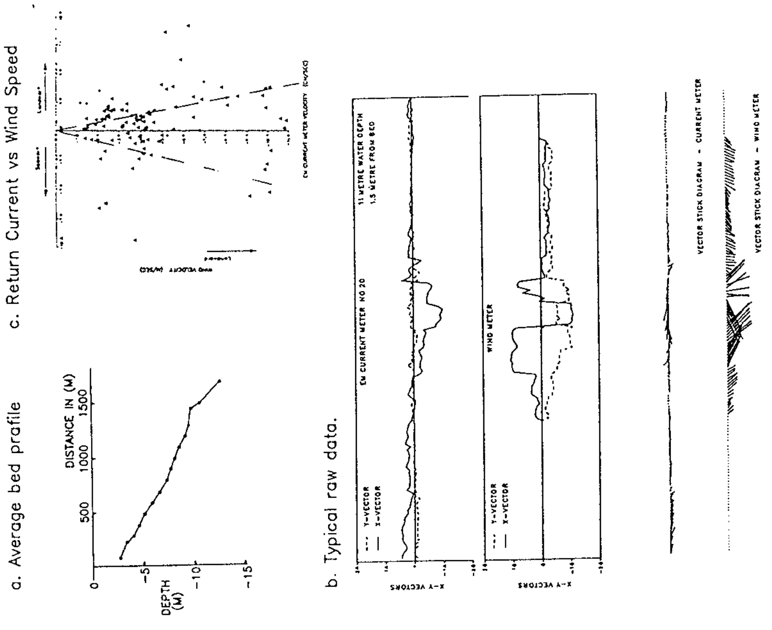

FIGURE 6 : STRANDFONTEIN : March 1990

During this period the incident, offshore wave climate varied as follows:

	Maximum	Mean	Minimum
* Significant height (m)	4,1	2,9	2,1
* Peak period (s)	15,5	12,3	7,5

The beachline was characterised by prominent cusps at 300 m centres, but the nearshore contours were nearly straight. As a result of the cuspate shoreline rip currents occurred along the beach at 300 m intervals leading to breaches in the main breaker bar at 5 m water depth, also at 300 m centres. At the position of the meter, well outside the breaker line, the contours were nearly parallel.

Walker Bay : February 1990. During this exercise 'bottom' current meters were deployed in 4 m and 11 m water depth, in each case at 0,5 m and 1,5 m above the bed. Figure 5 gives an overview of the data for the 11 m depth, 1,5 m above the bed case. The duration of the measurement campaign was from 9 to 22 February 1990, for a period of 2 hours around each day time high and low tide. Electromagnetic current meters were used for all four deployments.

During this period the incident, offshore wave climate varied as follows:

	Maximum	Mean	Minimum
* Significant height (m)	3,8	2,1	1,2
* Peak period (s)	13,5	10,3	6,6

The nearshore topography was fairly complex with no clear, well-developed breaker bar. Thus the contours were also complex, characterised by rapidly changing bars, troughs and gullies in 4 m depth but with a reasonably stable, straight set of contours in 11 m depth. The location of the breaker bar in Figure 5a in relation to the measuring stand also shows the potential for variability.

False Bay : March 1990. During this exercise the configuration of the February 1990 Walker Bay experiment was repeated, except that the deeper stand now had current meters at 0,5 m, 1,5 m and 2,5 m above the bed. Unfortunately, the meter closest to the bed at this deep stand malfunctioned and no data was obtained for that elevation above the bed.

Measurements were obtained for 2 hours around each day time high and low tide for the period 11 March to

21 March 1990. During this period the incident wave climate varied as follows:

	Maximum	Mean	Minimum
* Significant height (m)	3,0	1,8	1,0
* Peak period (s)	13,5	10,3	5,5

Figure 6 shows an overview of the data for the meter at 2,5 m above the bed in 11 m water depth. Figure 6c clearly shows some predominant wave effects, associated with a macro-rip current occurrence in the area.

This site is characterised by a very much flatter bottom profile than at Walker Bay, a very straight beach with fine sand, a smooth calcretous surface offshore and nearly straight contours at both deployment stands.

5. Verification of Schematic Representation

It was shown earlier that for a constant bed slope, which is a realistic assumption for all cases as can be seen, in Figures 4 to 6, the ratio U_r/W is proportional to the inverse of the water depth. To test this hypothesis the data in figures like Figures 4 to 6, but for all instruments, were fitted with a best-fit straight line through the origin. It is important to note that the wind condition varied between onshore and offshore, thus giving two possible data points per graph. The data, given in Figure 7a, show clearly that the correct tendency is prevalent in the plot. The scatter is to be expected, since the experiments were done under very different wave conditions and with varying seabed configurations. It is interesting that ratios between approximately 0,01 and 0,02 are found for the return current, whereas earlier studies have shown that the **surface** drift velocity varies between 3 % and 7 % of the wind speed (Kullenberg, 1976).

What is interesting, however, is that not only do those cases conform where the bottom current is a return current when compared to the wind direction, but this is also the case for those situations when the bottom current is in the same direction as the wind direction (Figure 7b). Presumably this represents cases where the whole water column is moved by wind action and continuity is achieved through horizontal water circulation.

The problem with field observations of wind-induced drift, or for that matter with laboratory observations, is that the drift takes place in a part of the nearshore area characterised by fairly vigorous currents, to mention but nearshore circulation with frequently stormy rip currents, orbital velocities and mass transport. All but the last are up to an order of magnitude higher than the wind-induced drift. Separation of the wind drift from the complex composite of currents in the nearshore area is at best a guestimate. However, the analysis done herein is not intending to provide absolute values for the drift, but rather to indicate qualitative final estimates of what appears to be the wind drift. As was shown, some clear guidelines emerged, obviously keeping the above comments in mind.

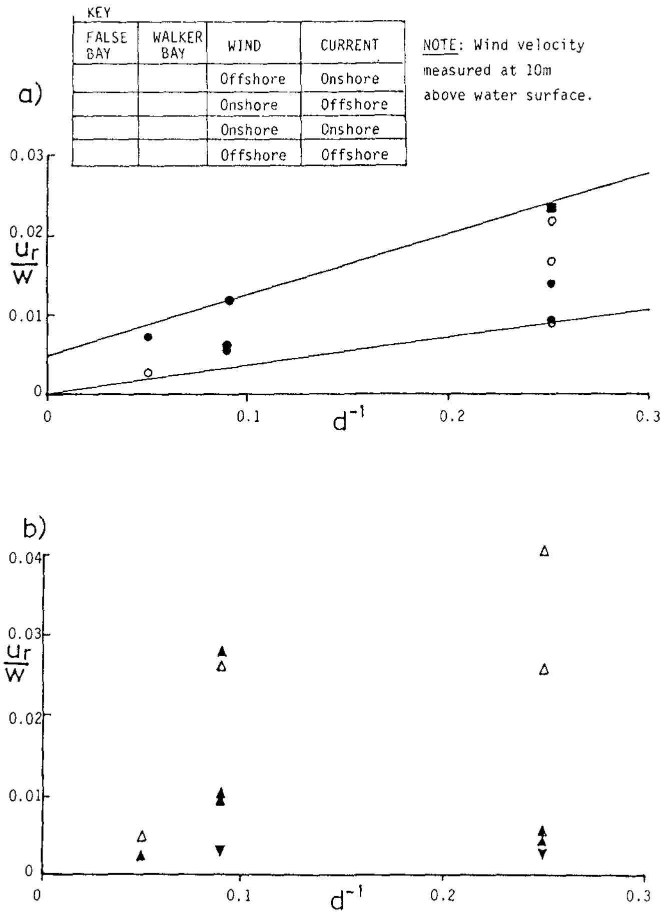

Figure 7. Schematic Framework for Prediction of Return Velocity U_r as a Function of Wind Velocity W and Water Depth d.

6. Conclusions and Recommendations

The main conclusions reached to date in this study on wind-induced cross-shore water flows are the following:

(1) The theoretical framework represented by Equations (1) to (4) is promising.

(2) The bottom 'return' layer concept seems reasonable, although the field data show that there are also cases where the return flow does not take place in the same cross-section. Presumably this latter case is strongly related to irregularities in the sea bottom and the obliqueness of the incident waves.

(3) The effect of bed slope on the results in Figure 7a and 7b appears to be fairly minimal.

(4) At present it is not sure to what extent waves will influence the results.

Therefore, with this as basis, we are taking the following approach:

- We are developing a numerical model for an arbitrary bottom profile; and

- We are further investigating the effect of varying surface roughness caused by variations in wave height.

Having made these advances, we hope to in time be in a position to predict the wind-driven cross-shore flows in a situation such as depicted below.

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CHAPTER 82

Irregular Waves on a Current

H.-H. Prüser and W. Zielke [1]

1 Introduction

In coastal areas interacting currents and waves are quite frequent. The currents are generated by the tides or the discharge of a river; the waves are irregular short crested, generated by the wind. A suitable numerical wave model for this situation is presented in this paper. It is based on the Boussinesq–Wave–Equations (BWE) which were extended to simulate the influence of a current on a wave as well as the effects of nonlinear wave–wave interaction in a propagating wave spectrum.

An analytical approach to describe wave–current interaction was given by Longuet–Higgins/Steward (1960) [3]. They investigated linear small amplitude waves in a moving medium and introduced the concept of radiation stress to determine the change of wavelength and wave amplitude as a function of the current and the direction of wave propagation. Their fundamental work was the basis for the development of various numerical models, which were reviewed recently by Jonsson (1989) [2]. Most of these models are restricted to linear (small amplitude) wave theory.

The wave climate in shallow water is generated by the influence of bottom topography as well as by nonlinear wave–wave interaction in a propagating wave spectrum, which cannot be described by linear wave theory. Instead, such weakly nonlinear waves are frequently modeled using the BWE. The development of models based on these equations first began in the late 70's. Since then, a number of studies have been carried out to verify their capabilities. It has been shown that they are able to simulate accurately combined refraction, diffraction, reflection and shoaling (see for example Madsen/Warren (1984)[4] as well as the nonlinear wave–wave interaction in a wave spectrum propagating over an uneven bed (see for example Prüser/Schaper/Zielke (1986)[7]). Boussinesq wave models have now become a practical tool for engineering applications.

In this paper, a numerical model based on an extended form of the BWE which takes into account the influence of an ambient current on waves is used to investigate irregular waves propagating and refracting on an ambient current. After presenting the equations, a comparison based upon linear (small amplitude) wave theory is conducted to illustrate the range of application. The numerical model was used to simulate irregular waves with a current in a flume and in a basin. The results were in good agreement with the solution of Longuet–Higgins/Steward.

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