

# Waves and Rip Currents on a Caribbean Pocket Beach, Jamaica<sup>1</sup>

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## ABSTRACT



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Using relatively simple methods, the wave and current patterns in Engine Head Bay, Jamaica, a remote arcuate bay exposed to incident swell, have been investigated. A wave refraction program shows that convergence of incident waves occurs at the mouth of the Bay creating relatively large, and spatially varying, wave heights. A one-week field programme in the Bay used a fixed pressure sensor to monitor incident wave conditions, and a combination of float and dye tracking to describe and quantify the currents. A persistent central rip current was found, with a maximum strength of  $65 \text{ cm s}^{-1}$ . The variation of rip current strength was found to be directly related to variations of incident wave height over periods of a few minutes. This is consistent with the observations of rip currents by Mackenzie (1958) but is inconsistent with the rip currents on an open coast described by Shepard *et al.* (1950), perhaps indicating that long wave motion, on the scale of the bay, may determine rip current strength.

The results of this project indicate what can be achieved in a remote environment where manpower skills and resources are limited.

**Additional Index words:** *Caribbean, Jamaica, rip currents, pocket beach.*

## INTRODUCTION

In small tropical island economies, the coastal zone is an important resource particularly for tourism and as a local amenity. It is important therefore that this zone be developed with care, making the best use of scientific predictions of possible impacts on the environment. In most coastal zones a knowledge of the nearshore wave and current conditions and the related sand transport patterns is a minimum requirement for informed development. In small economies, however, the trained manpower skills and technology needed to gain this information about the coastal zone are very limited. This paper describes a seven day study of waves and currents on a remote beach near Kingston, Jamaica in April 1985 and is presented as an example of what can be achieved with relatively simple equipment and methodology, of a kind which should be available to those with limited financial and technical resources.

The presence of rip currents also makes the measurement site interesting scientifically. Despite their obvious importance, these strong, narrow, seaward flowing currents have rarely been measured quantitatively in the field. Rip currents are generally highly irregular both in strength and precise location, and are therefore difficult to study with the fixed, Eulerian sensors commonly used for quantitative measurement of nearshore flows. The Lagrangian techniques used in the present study, on the other hand, have proved successful in determining rip current strengths, pathways and variability. Our results show a clear relationship between rip current strength and incident wave amplitude, and are therefore important for the accurate modelling of rip currents.

## GENERAL BACKGROUND TO THE PROJECT

The project described in this paper forms part of the Caribbean Coastal Management Study, described by BACON & HEAD (1985). This study is a collaborative venture by the University of the West Indies at Kingston, Jamaica

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and Dalhousie University in Halifax, Nova Scotia, Canada, and is funded by the International Development Research Centre, Canada. The study seeks to train and equip a team of Caribbean-based scientists, through joint studies, in skills related to coastal zone research and management. The overall approach is focussed on measurements (biological, chemical, geological, and physical) in the waters and coastal zone east of Hellshire, Jamaica (Figure 1), where a Government development scheme is in the initial phases of converting virgin land into a residential and tourist area.

The site for the project described in this paper was Engine Head Bay, on the Hellshire coast. The need for work in this Bay was clear. Several deaths by drowning have occurred on this beach, with reports of bodies being carried considerable distances offshore, suggesting the presence of rip currents. Moreover, the natural beauty of the site is attracting investors and the Bay is a potential site for hotel development.

## STUDY AREA

### General Physiography

The Hellshire Hills form a salient along the south central Jamaican coast (Figure 1). They are underlain by well-lithified and extensively faulted Tertiary limestones. Semi-arid acacia and cactus scrub typify the flora, belying the name 'Healthshire' which appears on early maps of the region.

Along the eastern coast, dissected rocky headlands separate numerous pocket, or com-

partmented, beaches. The offshore platform is generally graded to a -40 meter level, but a number of erosional features, products of Pleistocene low stands, are evident, including residual mounds that emerge from the platform as the Port Royal Cays, now fringed by Holocene reef growth (STEERS, 1940; GOREAU & BURKE, 1966).

Bathymetrically the shelf adjacent to the study area is divided into two distinct regions. To the north of Half Moon Bay reef-capped eminences form a semicontinuous barrier, sheltering the coastline from incoming swell. South of this the shelf opens out, grading at an angle of about 2-3° towards the shelf edge, which is marked by a possibly drowned, early Holocene sill reef (GOREAU & BURKE, 1966) some 5-6 km from the coast. Over this southern part of the shelf, several steep-sided projections are evident, but in contrast to the cays further north, do not reach to sea level (Figure 2).

Tidal effects in the region are small (HENDRY, 1980). The tidal range in Kingston harbour is typically only 0.23 cm, resulting in tidal currents which are very small compared to currents driven by the wind and the flow of fresh water out of the harbour.

### Engine Head Bay

Engine Head Bay is an arcuate bay formed by erosion behind coastal cliffs.

Dunes, some lithified, others younger and partially vegetated, rise steeply behind an attractive white sand beach. The foreshore is relatively steep, reaching angles of 10-15°

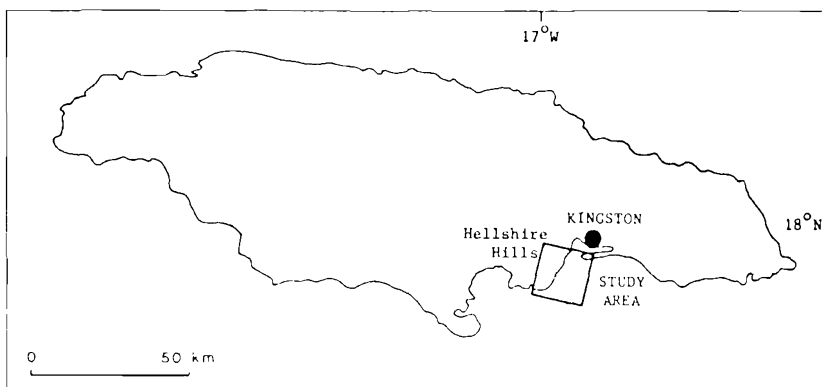


Figure 1. Location of the study area.

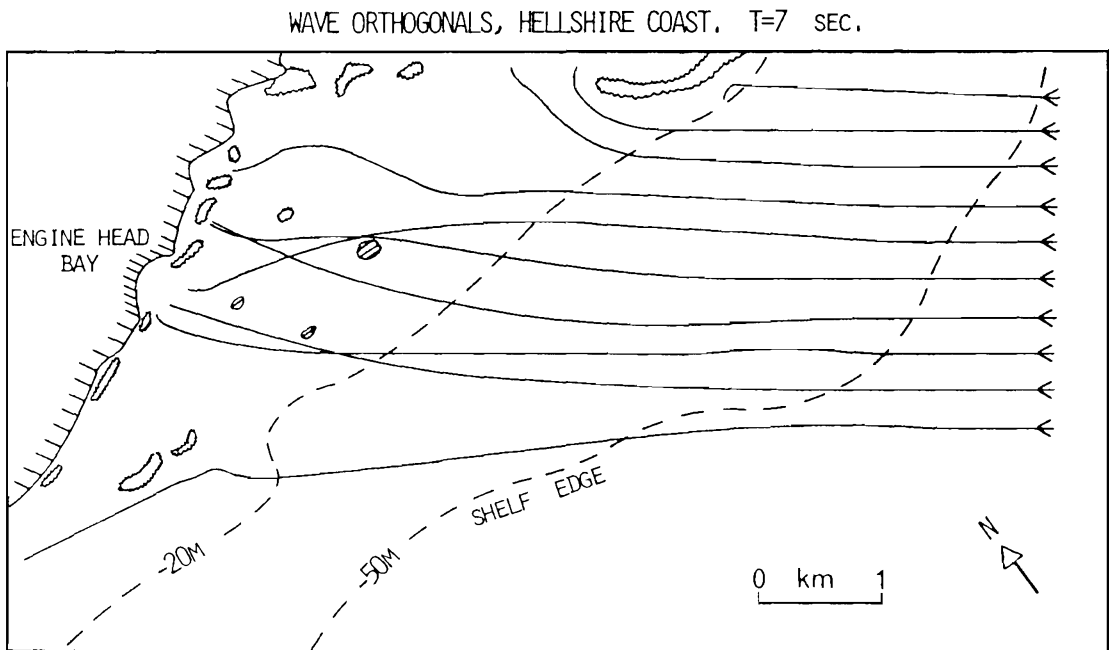


Figure 2. Bathymetry and wave refraction on the shelf adjacent to Engine Head Bay. Wave period is 7 seconds, and orthogonals are approaching from the east-south-east. Cross-hatch shading offshore represents knolls on the shelf, that do not reach to sea level. Jagged motif represents reef at sea level.

towards the southern and northern ends, where just offshore eroded limestone and modern reef growth projects in towards the center of the Bay.

The inshore region was surveyed from a number of markers established above the active beach, within the dunes. Each datum was levelled in to the baseline marker at 0C (Figure 3). The tops of 6 cm diameter poles, driven about 1 m into the ground, served to relocate each station on subsequent surveys. Profiles were measured normal to the orientation of the shoreline at each site using a theodolite and taken as far offshore as safety would permit.

Two major surveys were conducted, one at the beginning and one at the end of the study period. The results given in Figure 3, show that the inshore region was very shallow to a distance of between 60-80 meters offshore. A narrow runnel was evident on both occasions at the base of the foreshore, particularly in the region of 120S and between about 60N and 120N. At the seaward edge of the bar, where wave breaking and strong currents prevented surveying,

snorkelling indicated the presence of an abrupt drop-off to depths of about 3 meters. Mesoscale bedforms, not reproducible at the scale used in these diagrams, included sand waves with wavelength of 1-1.5 m and amplitude of 10-15 cm at the seaward edge of the bar, oriented parallel to the bar, and rhomboid interference ripples, particularly noticeable at 60-120N and 60S, apparently caused by the interaction between incoming waves and waves reflected from the steep foreshore at these locations. Wave breaking and strong current motion produced clearly observable oscillatory traction and suspension of sands across the bedforms of the inshore area.

## WAVE CLIMATE

### Waves Approaching the Bay

Information on wave conditions offshore of Jamaica is scanty, and mainly to be found in the shipboard observations of the Summary of Synoptic Meteorological Observations prepared by

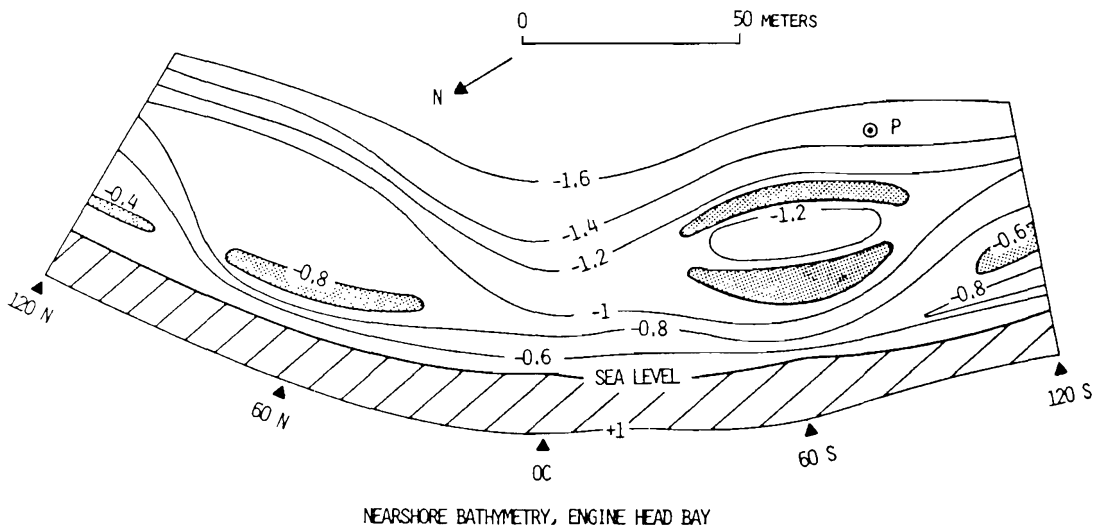


Figure 3. Nearshore bathymetry, Engine Head Bay. The survey shown is that of April 5th, as only minor changes occurred between this and the survey of April 11. Shaded regions represent bars or ridges. 'P' indicates the position of the pressure sensor used to record the incident wave heights and periods.

NOAA. These and other wave data for the south east coast of Jamaica were summarised by HENDRY (1980, 1983). Longer period waves are generated by the trade winds and distant storms, the majority of these waves approaching Jamaica from the east or north-east.

Sheltering by the Island and some refraction during passage along the south coast results in a dominant east-south-easterly approach direction for the swell at the shelf edge off Hellshire (HENDRY, 1980). Periods of 7-9 seconds appear to be characteristic of swell waves approaching this coast.

In order to estimate wave conditions at the entrance to Engine Head Bay, a wave refraction program developed by KEELEY (1977) was adapted for use on a microcomputer and applied to the refraction of waves over the island shelf adjacent to Hellshire. As discussed earlier, the topography of the shelf is complex, with exposed reefs to the north and south of Engine Head Bay. Offshore from the Bay itself, however, waves from the shelf edge have a relatively clear approach over a width, parallel to the shore, of about 6 km. Figure 2 shows the wave refraction diagram for waves of period 7s approaching from E-S-E.

The ray patterns off Engine Head Bay are clearly very complex, as might be expected for

a shelf region with variable topography. However, the tendency for wave rays to focus into this region is striking, particularly when compared with the divergence of the waves to both the north and south. This focussing appears to be due primarily to a large shoal region, rising to within 12 m of the surface from a background depth of about 20 m, about 4 km offshore from Engine Head Bay. This shoal is flanked to north and south by somewhat deeper regions. Unfortunately, persistently rough conditions have so far precluded collection of sufficient information on bathymetry within Engine Head Bay, in the region of rapidly shoaling waves, to allow continuation of the wave refraction scheme in to the shoreline. This, and the absence of measurements of waves outside the Bay during our field project, make it difficult to relate offshore wave refraction patterns directly to our measurements inside the Bay. However, Figure 2 suggests that large and spatially variable wave heights and directions should be expected outside the Bay, and these are likely to create a complex current pattern, sensitive to the approach angle of the incident waves. Our current measurements near the mouth of the Bay (Figure 6) suggest a predominantly southerly current, and there is evidence that this is a more permanent feature than the complex wave

refraction might suggest. For example, those drowned within the Bay have been frequently picked up along the shore to the south of the Bay. It is possible that the surface flows along the Hellshire coast are driven primarily either by freshwater flows from Kingston Harbour or by larger scale wind circulation over the adjacent continental shelf, with wave effects contributing only to local variability. Measurements being made in the nearshore waters off the Hellshire coast will help to clarify the nature and driving mechanisms of the currents.

### Waves Within the Bay

In order to measure the wave conditions within Engine Head Bay during our field program, a pressure sensor was deployed 80 m offshore from survey line 60S (Figure 3). We used a piezoelectric sensor mounted in an oil-filled plastic tube. The tube was terminated at one end with a light plastic finger stall, which acted as the interface to the seawater pressure. The sensor was mounted about 0.7 m above the seabed on a metal support oriented with the sensitive end facing downwards to prevent accumulation of sand. Armoured cable connected the sensor to its power supply, two 12V car batteries, and a chart recorder at the top of the beach. Static calibration of the sensor was achieved by lowering it known distances below the surface of a swimming pool and measuring the resulting output voltages.

Figure 4 shows examples of the time series obtained on the three days when current measurements were made. On each day the sensor was approximately at the breaker line of the largest waves, and each time series illustrated here was recorded at close to 1300 hrs local time.

Wave heights did not vary greatly between these three days, but there is a marked difference in the average wave period; the record for the 9th April shows relatively long period regular waves, characteristic of open ocean swell, while the 8th and 10th April records show a much higher frequency wave motion superimposed on the longer period waves. These observations are borne out by more detailed analysis of the wave records. Three or four runs of ten minutes each, taken during the morning (0900-1300 hrs) on each day have been analysed to give average wave heights and zero-upcrossing

periods (DRAPER, 1967). The results are given in Table 1. It can be seen that although wave height itself does not vary significantly from day to day, the mean wave period is significantly larger on 9th April, tending towards the estimated swell period of 7-9 s. The variance of wave period is also smaller on the 9th, further evidence that regular swell was dominant over irregular shorter period waves on that day.

A diurnal pattern of shorter period waves becoming superimposed on incoming swell is caused by a strongly diurnal wind field, the local sea and land breeze system. Onshore sea breezes set in rapidly during mid to late morning, and can persist until late in the day. For example on April 10th the wind speed at 0830 hrs was less than 5 knots from 106 degrees Magnetic. The onshore breeze began at around 1115 hrs, and by 1300 hrs was blowing steadily at around 18 knots from 133°. On the adjacent beaches of the Palisadoes this diurnal wind field and the seas that it generates have a noticeable impact upon onshore-offshore sediment transport (HENDRY, 1983).

In order to estimate the changes in the wave conditions resulting from this diurnal pattern of winds we have plotted in Figure 5 the changes of average wave height and period through the day. The values displayed are averaged over all three days and points within an hour of each other have also been averaged together. Unfortunately only one run was made after 1400 hrs (on 10th April). Nevertheless there is a clear trend towards decreasing wave period as the day proceeds, as expected. Again, surprisingly, there does not appear to be a corresponding trend in the wave heights, although the value at 1530 hrs may suggest an increase towards the end of the day.

Clearly these results do not fully clarify the range of changes in wave climate that may occur from day to day or during any single day. A full spectral analysis of the wave records would be interesting, but was considered to be outside the scope of the present study.

## RIP CURRENTS

### Introduction

As mentioned earlier, a major reason for choosing to study Engine Head Bay was the suspected presence of rip currents within the Bay.

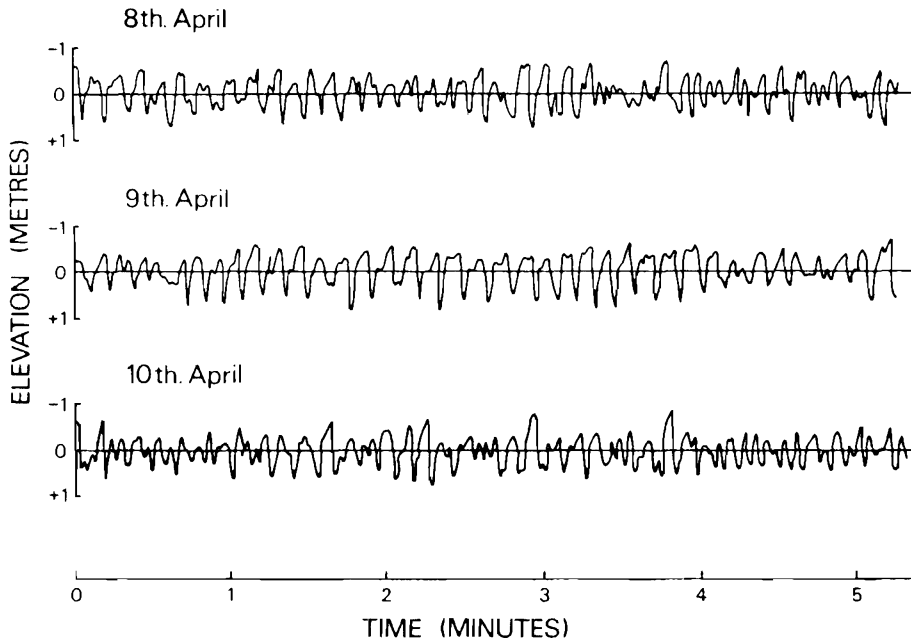


Figure 4. Example time series of water elevation on each of the days on which current measurements were made. The time series were measured using the pressure sensor deployed out-side the surf zone directly offshore from survey range 60S (Figure 3).

TABLE 1. *Average Wave Heights and Periods.*

Date (1985)	Mean Wave Height (m)	Mean Wave Period (s)
April 8	$0.52 \pm 0.10$	$6.15 \pm 0.12$
April 9	$0.50 \pm 0.121$	$7.10 \pm 0.06$
April 10	$0.47 \pm 0.08$	$6.20 \pm 0.50$

Hence a major effort during our field study was devoted to identifying and measuring the currents within the Bay.

Rip currents, first clearly identified by SHEPARD (1936) are strong seaward flowing currents originating in the surf zone and extending seawards well beyond the point where incoming waves begin to break. They are relatively narrow and are generally thought to result from alongshore variations in the height of the incoming waves (BOWEN, 1969).

Despite their obvious significance, not only for swimmers but also as factors effecting beach topography (SHEPARD *et al.*, 1941), and despite theoretical work (TAM, 1973; BOWEN, 1969), there have been relatively few field

observational studies of rip currents (SHEPARD *et al.*, 1941; SHEPARD & INMAN, 1950; MCKENZIE, 1958; COOK, 1964).

This must in large measure be due to the difficulty of observing such a strong and yet often transient phenomenon in the presence of steep and breaking waves. The most complete study to date still appears to be that of SHEPARD & INMAN (1950) for the shoreline in the vicinity of Scripps, Southern California. Floats, drogues and dye were used to trace nearshore water motion, and visual observations and pressure sensor measurements were used to characterize wave conditions. More recent attempts have been made to measure rip currents with more sophisticated equipment particularly fixed current sensors but these have proved generally unsuccessful, primarily because of the difficulty of placing a fixed Eulerian sensor within a narrow rip current which may meander back and forth along the beach. We therefore chose in this study to use Lagrangian drifter techniques very similar to those used by SHEPARD & INMAN (1950).

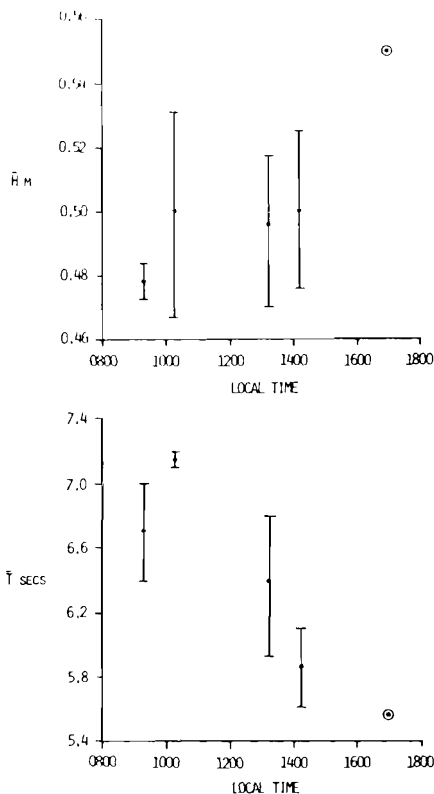


Figure 5. Diurnal changes in wave height (a) and wave period (b) Error bars are standard deviations of the means. The points near 1700 hrs have no error bars since they are single observations. They have been circled for clarity.

## Method

Dye tracking proved to be the most successful technique for measuring rip current velocities. Rhodamine-B dye was placed in the water at fixed locations and times and tracked from the headland at the northern end of the beach using a single theodolite (see also DRAPER & DOBSON, 1965). When tracking dye the leading edge of a dye patch was taken to represent the advective velocity of the water surface. The leading edge motion must have some diffusive component but in strong rip flows this component will probably be small compared to the advective component. Theodolite readings of vertical angle were made to 1 sec of arc corresponding to a sensitivity of about 2 m in the radial direction, but the actual accuracy of horizontal positioning was estimated to be nearer 8 m, in view of the difficulty of taking rapid

readings. This error could be reduced by using two theodolites at different locations and triangulating to the dye patch using only horizontal angles, but unfortunately it did not prove possible at this site to find a second location with sufficient elevation for a second theodolite.

In addition to theodolite tracking, some dye deployments were also filmed with a time lapse movie camera and photographed by a series of slide photographs taken every 30 or 60 s. With the help of theodolite measurements to scale the field of view these film records were subsequently analysed to give estimates of dye tracks and velocities.

We also tried a variety of floats as current tracers. Surface floats (plastic bottles brightly painted and filled with water until just buoyant), floats with drogues suspended about a half meter below the surface, and, to increase ease of tracking, floats designed to release small amounts of dye as they drifted, were all tried. However as found also by SHEPARD & INMAN (1950) these were unsatisfactory as tracers for rip currents because they tended to 'surf-board' inshore even in the presence of relatively strong rip currents. Floats were therefore primarily used here only to measure shore-parallel feeder currents close to the shore.

## Observations

Observations of currents were made on April 8, 9 and 10th. Figure 6 shows the most complete tracking of currents, from the afternoon of 10th April. The rip current clearly shown in the centre of the beach was tracked using theodolite positioning of dye movement and the shore-parallel feeder currents close to the shore were measured by float tracking.

Although the rip current was much less persistent on this day than on the previous day, apparently ceasing to flow completely at some times, the dye clearly revealed the motion when the rip was well developed. The currents in the rip itself average  $42 \text{ cm s}^{-1}$ , over more than 5 minutes, by which time the leading edge of the dye had reached about 150 m, or two to three surf zone widths, offshore.

There was then a decrease in velocity to  $19 \text{ cm/s}^{-1}$  after 22 minutes. The direction of the rip current was essentially directly offshore from OC initially but was apparently caught up in a northerly drift just outside the surf zone. At

about 180 m offshore this drift reversed, and the dye path drifted towards the south as it moved offshore. This final direction is consistent with a southerly drift along the Hellshire shoreline outside the Bay discussed earlier. Feeder currents are the shore-parallel currents leading into the seaward flowing rip current. On Engine Head Bay beach these currents were strongest within a narrow runnel between the shoreline and a low-relief shore-parallel bar about 10 m offshore. On 10th April, when the measurements in Figure 6 were made these feeder currents were predominantly towards the southwest, probably reflecting a somewhat oblique angle of approach of the incident waves. The location of the central rip current is marked by a sharp reduction in the strength of the alongshore current but no reversal of its direction. A divergence of the flow can also be seen between 90N and 120N. The currents in this region showed strong variability, suggesting that the precise location of the divergence may be due to a focussing of wave energy at this location due to refraction of the incident waves, or may be due to a change in the general trend

of the shoreline associated with a very broad promontory at the shoreline near the location of the divergence, so that longshore currents generated by obliquely incident waves reversed in direction from one side of the promontory to the other. At the northern end of the Bay the northward flowing alongshore current weakened considerably and turned seawards in a weak rip current.

The wave field at this extreme end of the Bay was very complex, with reflection from the shoreline creating a confused pattern of crossing waves, and a correspondingly confused pattern of bottom topographic features. At the far southern end of the beach a rocky reef about 15 m offshore, with its top at about the mean sea level, isolated a pond of water from all but the inflow due to breaking waves offshore. The northerly flow out of this pond joined the current near the main branch to create a strong and persistent offshore rip current near the end of the reef. A distinct circulation pattern was observed here, with the offshore end of this rip flowing northwards and circulating back shorewards towards the feeder current between

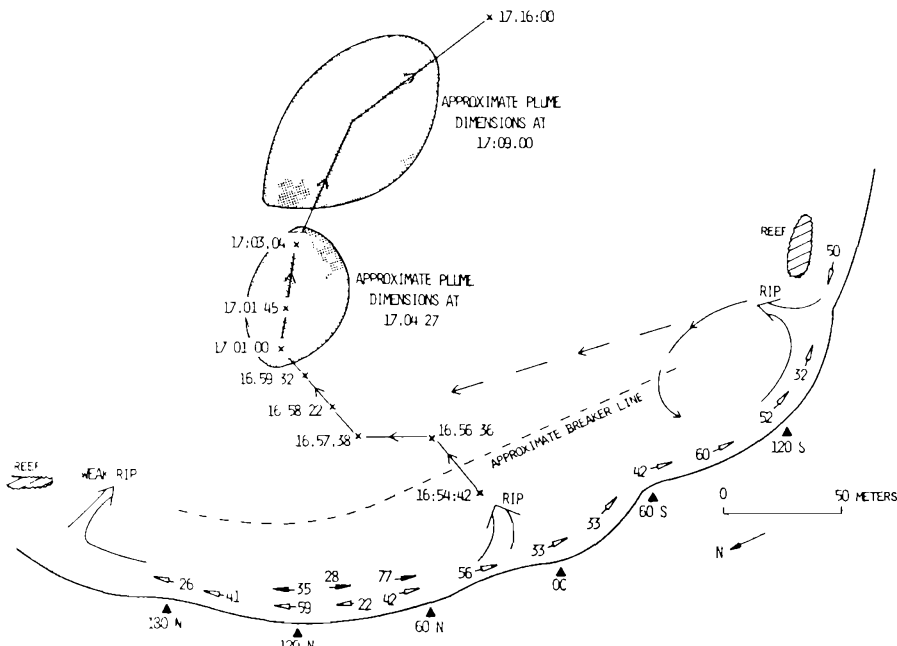


Figure 6. Observations of dye trajectory in the central rip current and of float speeds and directions in the inshore feeder currents (April 10th 1985).



60S and 120S. At times, this rip fed directly across the Bay to join the central rip running out from 0C.

The central rip current and the rip current at the southern end of the Bay were apparently permanent features of the circulation, in that they were observed on all the days of the present study, and appear to coincide with previous visual observations of currents in this beach throughout the year by two of the present authors and other observers. Other features appeared on some days, notably a weak rip current near 60S and another weak rip current between 60N and 90N. The direction of the feeder currents was also variable from day to day. Unfortunately there is insufficient information about offshore wave conditions and too few days of study for these transient features to be linked to particular features of the incident wave field.

### Rip Current Variability

SHEPARD & INMAN (1950), MCKENZIE (1958) and others found that rip current strength varies on many time scales, and the rip currents in Engine Head Bay are no exception. Again there are too few observations for definitive conclusions, but the mornings of 9th and 10th April form contrasting conditions. On 9th April the central rip current was clear, persistent and the maximum measured current was  $66 \text{ cm/s}^{-1}$ , while on 10th April the rip was rather ill-defined and sporadic. We have seen previously (Table 1) that the incident wave climate was significantly different on these two days, and the stronger currents on 9th suggest that longer period swell waves play a major role in rip current generation. This suggestion is also consistent with the apparent lack of diurnal variation in rip current strength despite the diurnal changes observed in the incident wave field (Figure 5).

On a shorter time scale it was obvious visually and to anyone working in the water that the rip circulation strength was variable, ranging from weak to strong and back to weak again over a period of a few minutes.

Both SHEPARD & INMAN (1950) and MCKENZIE (1958) found similar variability and related it to the group structure of the incident waves. However their conclusions are apparently contradictory, with SHEPARD &

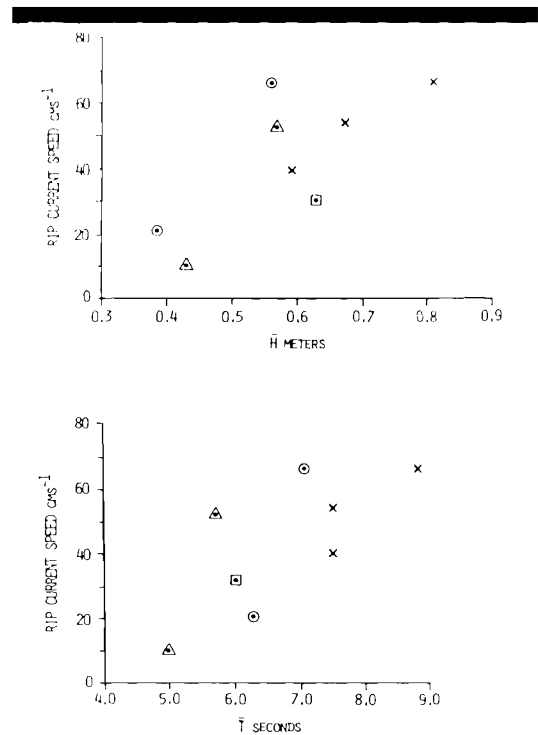


Figure 7. Mean wave height (a) and wave period (b) plotted against rip current speed.  $\times$  8th April 1430 hrs;  $\circ$  9th April 1000 hrs;  $\triangle$  10th April 1330 hrs;  $\square$  10th April 1654 hrs.

INMAN (1950) finding minimum rip current strength associated with high waves while MCKENZIE (1958) reports strongest rip currents at times of highest waves.

In order to assess the influence of wave height on rip current strength at Engine Head Bay we have compared our measurements of rip current strengths when the leading edge of a dye patch passed through the rip current with simultaneous measurements of wave conditions at the pressure sensor. Wave heights and periods were estimated, as before, as 30 s or 60 s averages. The data for 8th and 9th April were obtained by using sequences of slides taken of the movement of dye patches, while the measurements on 10th April were made by theodolite tracking of the dye. The results are shown in Figure 7.

Obviously there are very few measurements, and there is some difficulty, which could only be resolved subjectively with these data, in defining when the dye patch is in the rip current. However the results do suggest that the stronger rip currents are associated with higher waves and waves of longer period.

Our results are therefore consistent with the observations of McKENZIE (1958) but not with those of SHEPARD & INMAN (1950). It is not absolutely clear why this should be, but a possible explanation may be associated with the fact that SHEPARD & INMAN (1950) were observing large scale rip currents on an open coast while our observations, and many of those reported by McKENZIE (1958) were made in relatively enclosed bays. The rapidity of response of the rip current to changing wave conditions suggests perhaps that large bay-scale motion is responsible for rip current generation. Other studies have reported the presence of long period, large scale surf-beat motion associated with wave groupiness and suggested that this motion may in some way be related to rip current generation (SHEPARD & INMAN, 1950; BOWEN, 1969; BOWEN & INMAN, 1969). However our wave records (Figure 4) show little evidence of significant long period motion on any day.

The persistent shoaling swell waves inside the Bay make conditions generally too rough for small boat work and it has proved impossible to make detailed measurements of the bathymetry in the Bay. Unfortunately this has prevented us from calculating wave refraction diagrams and so assessing the importance of converging and diverging incident waves in generating the rip current.

## CONCLUSIONS

Despite the simplicity of approach and the short duration of this project, considerable progress has been made in describing the wave and current patterns in Engine Head Bay. In particular the dye and float-tracking experiments have proved very successful, and provide the best means of making quantitative measurements of rip currents and feeder currents in the nearshore zone.

Using a single, inexpensive (\$200) pressure sensor, connected by cable to a battery and recorder on the beach, we have shown the diurnal character of the wave climate in the Bay, revealed in the decreasing average wave period as the diurnal onshore breeze generates short period waves. There is surprisingly little evidence, on the other hand, for a change in wave height during the day.

A central rip current appears to be a persist-

ent feature of the Bay. Its strength was found to vary both from day-to-day and on a time scale comparable with the variation of amplitude of the incoming waves (groupiness). The day-to-day variation in rip current strength appears to depend upon the amplitude of the incident swell waves, there being no evidence for a diurnal variability in rip current strength. The highest velocity recorded during our three days of measurements was about  $65 \text{ cm s}^{-1}$ , much smaller than the  $1.5 \text{ m s}^{-1}$  rip currents measured by DRAPER & DOBSON (1965) in Cornwall, England, but much higher velocities might be expected on days of high incident swell.

On the time-scale of the incident wave groupiness (typically a few minutes) comparison of the measured rip current strength and the incident wave amplitudes, measured by the pressure sensor, shows a clear trend towards higher rip current strength with increasing incident wave height and period (Figures 7a and b). This observation is in agreement with that of McKENZIE (1958) but contrary to that of SHEPARD *et al.* (1950) who found decreased rip current strength when incident waves were largest. Our observations suggest a rapid response of the rip current circulation pattern to changing incident waves. This might indicate that long wave motion, on the scale of the Bay may determine rip current strength but no such long wave motion was obvious visually on the pressure sensor record of the wave motion.

The results described here are primarily descriptions of the conditions inside the Bay. We do not yet know in detail the nature of the forcing mechanism for the currents in the Bay. As we have already discussed, the central rip current is related to the incident wave conditions perhaps through long wave motion. However, the role of wave refraction in the Bay is still unknown. Long-crested waves normally incident at the mouth of a simple arcuate bay will refract to approach the shoreline in the bay at an oblique angle everywhere, except at the centre of the bay. This obliquity will drive feeder currents, inside the surf zone, towards the centre of the bay, where the convergence might be expected to create a seaward-flowing rip current. This simple model of a central rip current might be operating in Engine Head Bay, but much more detailed bathymetry within the Bay will be needed before wave

refraction diagrams can be drawn to evaluate the relevance of this model.

Prediction of the strength of the rip circulation system from day to day will also need further work. We have suggested that the rip current strength is related to the amplitude of swell motion incident on the Bay. A full evaluation of this will require concurrent measurements of incident swell, preferably near the edge of the shelf off Hellshire, and of rip current circulation inside the Bay. Measurement of the wave climate outside the Bay will be a much more complex activity than any undertaken in the project so far, but should not be ruled out if prediction of rip current strength is important.

The current project has not addressed the question of sediment pathways inside the Bay, though these would be of some interest in view of the strong currents. Determination of sediment transport pathways and a sediment budget for the Bay would be vital before any development took place which might interfere with the natural processes in the Bay. Some degree of modification will be necessary to render the bay safe for swimming whether it remains as a local amenity or becomes the focus for tourist development.

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#### □ ZUSAMMENFASSUNG □

Eine Forschung der Wellen- und Strömungsmuster Eingine-Head-Bays, Jamaika, die eine entfernte, geschweifte und den vorkommenden Schwellen ausgesetzte Bucht ist, wurde mit relativen einfachen Methoden durchgeführt. Ein Wellenbrechungsprogramm zeigt, dass vorkommende Wellen sich der Buchtöffnung nähern; die folgende Wellenhöhe unterscheiden sich räumlich und sind relativ gross. Ein wochenlange Feldprogramm in den Bucht überwachte die Wellenumstände mit einem festen Druckempfindungsgerät; Schwimm- und Farbebeobachtungen wurden benutzt, um die ständige Reissströmung mit einer Maximalstärke von  $65 \text{ cm s}^{-1}$  wurde gefunden. Veränderungen der Reissströmungstärke standen mit Bezug auf Veränderungen der vorkommenden Wellenhöhe Luber Perioden ein paar Minuten. Diese Beachtung ist mit den Reissströmungenbeobachtungen von MACKENZIE (1958) übereinstimmend, sondern sie ist mit der von SHEPARD et al. beschriebenen Reissströme auf einer offenen Küste nicht so. Diese Situation zeigt vielleicht, dass lange Wellenbewegung (im Masstab de Bucht) die Reissströmungenstärke bestimmen. Die Folge dieser Forschung zeigen auch, was man mit begrenzten Arbeitskräfte und Materialien machen könnte.—Stephen A. Murdock, Charlottesville, Virginia, USA