CHAPTER ONE HUNDRED FORTY

EFFECT OF RIP CURRENT BARRIER ON HARBOR SHOALING

by

Tamio O. Sasaki*, M. ASCE and Hiroshi Sakuramoto**

ABSTRACT

Prototype experiments on rip currents and sediment transport around structures were conducted at two fishery harbors on microtidal high energy beaches facing the Pacific Ocean. The purpose of the experiments was to examine the performance and mechanism of rip current barrier structures on harbor shoaling. Based on the results of five experiments, the wave breaker heights during which varied from 1.1 m to 3.0 m, it is concluded that shore-parallel rip current barriers are effective if their length is greater than the surf zone width and if they are located outside the surf zone. When the above conditions are satisfied, the rip current barrier is a cost-effective measure against shoaling of small craft harbors.

1.0 INTRODUCTION

Two case studies are presented which demonstrate the mitigating effect of rip current barrier structures on the shoaling of small craft harbors. A rip current is a fast and narrow current that carries sediment offshore. One of the major reasons why harbor breakwaters and jetties cause beach erosion on adjacent beaches, offshore sediment loss to form rip head bars, and shoaling inside of harbors is the formation of rip currents induced by and adjacent to the structures (Fig. 1a). The construction of sand traps is often adopted as a protection measure where the longshore drift dominates, (e.g., at Channel Island Harbor, Bruno and Gable, 1976; Pointe Sapin Harbor, Pratte et al., 1982). However, the detailed functioning of a sand trap is not well understood, and a large amount of maintenance dredging may be necessary.

The present paper focuses on the role of rip currents in the shoaling process, based on field observations. Then the rip current barrier concept to block rip currents is presented as a possible cost-effective solution (Fig. 1b). The study sites, Taito Katagai Fishery Harbors, are respectively located on the southern end and middle of the Kujukuri Coast, facing the Pacific Ocean (Fig. 2).

* Chief Engineer, INA Civil Engineering Consultants, Co. Ltd., 22-1 Suido-cho, Shinjuku-ku, Tokyo, 162 Japan.

** Senior Engineer, INA Civil Engineering Consultants, Co. Ltd.

2.0 STUDY SITES AND RESULTS

Kujukuri Coast is a 55 km-long, very shallow coast bounded at both ends by eroding sea cliffs, Byobugaura and Taito Point (Fig. 3), 10 km and 2 km long, respectively. The average beach slope up to the 20 m depth is about 1/100. The dominant drift of sand is from both ends to the middle of the coast (Sunamura and Horikawa, 1977). The beach consists of fine sand (0.2 - 0.3 mm). The tidal range is 1.0 - 1.5 m.

2.1 Taito Fishery Harbor

An extreme case of harbor shoaling occurs at Taito Fishery harbor (Figs. 3 & 4). Taito Fishery Harbor originally had two shore-normal breakwaters that extended about 150 m seaward. As seen in Fig. 4, the harbor was totally filled with sediment soon after construction. To recover harbor functioning, extension of the breakwaters and construction of "wing-like" breakwaters which stop rip currents from flowing directly offshore was tried (Figs. 5 & 6). As a result, accretion at the root of the north breakwater has increased and sediment shoaling has been mitigated.

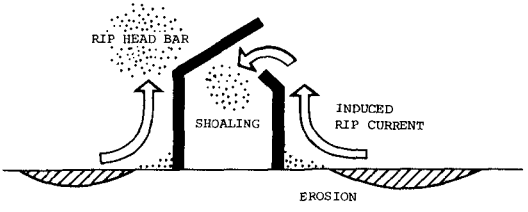

Fig. 1a Schematic diagram of induced rip current and harbor shoaling due to presence of a breakwater.

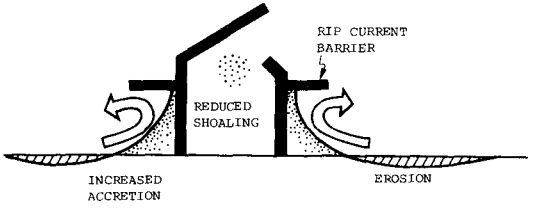

Fig. 1b Schematic diagram of a rip current barrier. Accretion at the feet of the breakwaters increased and shoaling in the harbor decreased.

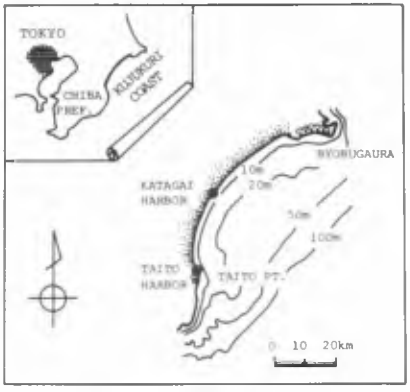

Fig. 2 Location map of Kujukuri Coast, and Taito and Katagai Fishery Harbors.

Fig. 3 Overview of Taito Fishery Harbor and the vicinity to the northwest.

Fig. 4 Taito Harbor totally filled with sediment.

Fig. 5 Recovered Taito Harbor after rip current barrier construction.

Field Observation of Rip Currents

Observations of the rip currents at the site were conducted in November and December 1979, and January 1980. The breaker heights were 3.0, 1.1 and 1.7 m, respectively. The circulation patterns shown in Fig. 7 were obtained from photographs of successive dye patch dispersion patterns (Fig. 8). The photographs were taken with a Hasselblad 500EL camera mounted on a hovering helicopter. A total of 10 - 20 kg of fluorescent dye was released at 6 - 12 points within and outside of the surf zone.

Several very regular nearshore circulation patterns and barrier-induced rip currents were found on the north side of the harbor during the Dec. 1979 and Jan. 1980 experiments (middle and bottom of Fig. 7). However, at the east side, a typical blocked rip current as shown in Fig. 1b was not found except in the Jan. 1980 experiment, due to the size and orientation of the south rip current barrier. In CASE-791124, the eastern rip current barrier was ineffective, and thus a rip current developed seaward. The wave height was large in this case, so that most of the harbor structures were inside the surf zone.

2.2 Katagai Fishery Harbor

Another example is Katagai Fishery Harbor, located about 30 km north of Taito harbor. Sediment transported alongshore on the neighboring beaches arrives at both sides of the harbor. Therefore, the entrance jetties had to be extended year by year before 1974 due to accretion (Fig. 9). The length of the jetties reached 600 m; the total entrance channel length is about 1 km. This harbor was originally built to have a common entrance with the Sakuta river. The annual rate of shoreline advance was about 6 m/year at both sides of the jetties. The annual rate of accretion estimated by Sunamura and Horikawa (1977) for the central part of the Kujukuri coast is 494,000 m^3/year.

Figure 10 shows the change in nearshore topography from 1974. Major accretion occurred at depths less than 4 - 5 m; however, significant accretion took place deeper than 6 - 7 m as well. Angled plan shape breakwater construction started in 1975. The breakwaters are connected to the jetties by piers. This structure plan shape was designed based on results of laboratory experiments to maintain the entrance by a flushing. (A similar concept and shape appear in Maza et al. (1977) as a convergent jetty.) This angled breakwater did not give a good solution under prototype conditions. As shown in Fig. 10, large accretion occurred on the lee side of the breakwater and thus the amount of required maintenance dredging increased.

Field Observation of Rip Current and Sediment Transport

Field observations of the nearshore current and sediment transport were conducted on October 1978 and March 1980 to study the underlying mechanism of the barrier (Table 1) before and after the rip current barrier construction. Several plan shape alternatives were compared by numerical modeling of the nearshore current system (Sasaki, 1975). As a result, rip current barriers as seen in Fig. 11 were finally adopted.

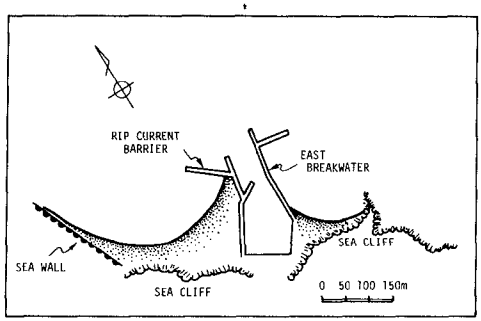

Fig. 6 Plan of Taito Harbor.

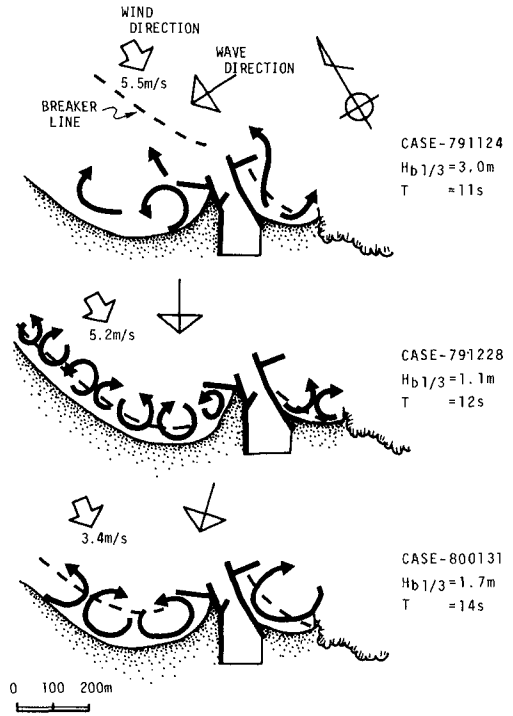

Fig. 7 Nearshore circulation patterns in the vicinity of rip current barriers.

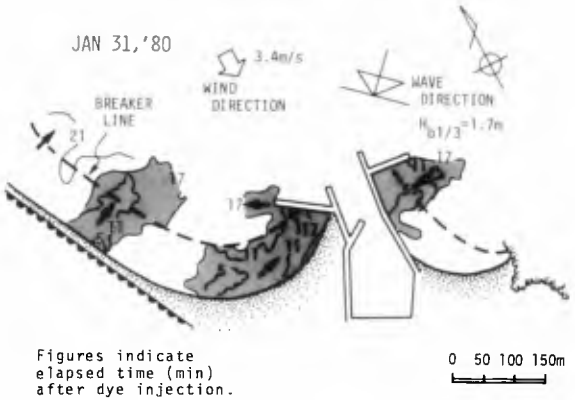

Fig. 8 Dispersion of dye patches around rip current barriers.

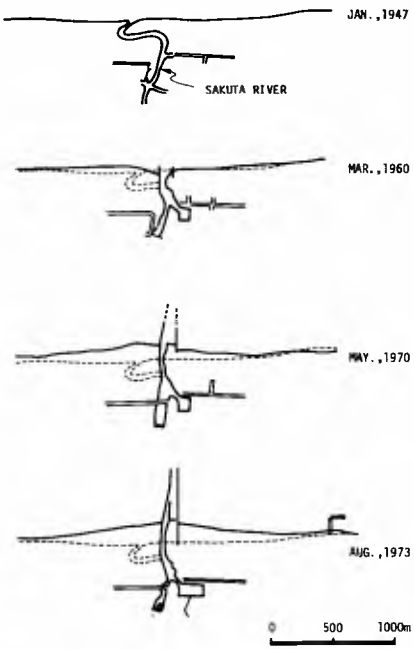

Fig. 9 History of shoreline evolution associated with jetty construction at Katagai Fishery Harbor.

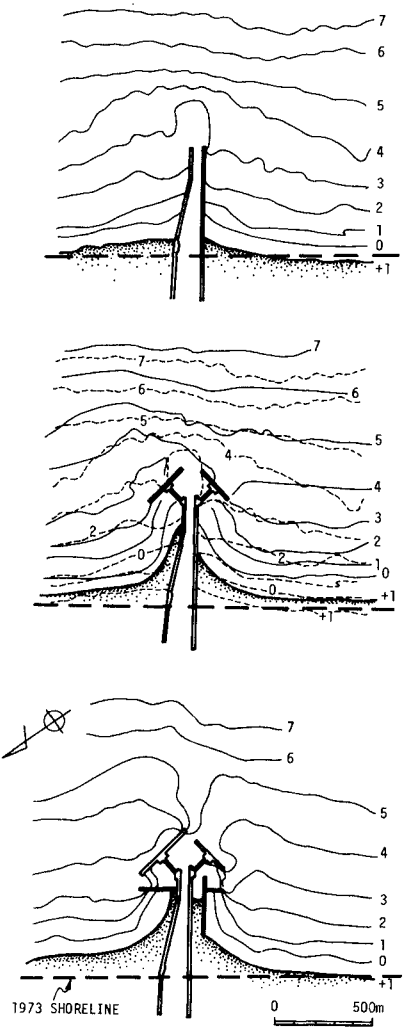

Fig. 10 History of nearshore topography around jetties and breakwaters after 1974.

Table 1 Wind and wave climates of field observations at Katagai Harbor.

Date	Time	Wind Direc-tion	Wind Speed (m/s)	Wave Direc-tion	Wave Period (s)	Signif. Breaker (m)	Surf Zone Width (m)
13 Oct. 1978	7:00	NNW	2.5	N73°E	9.6	1.5	300
	10:00	N	3.4	N75°E	10.3	1.6	300
	17:00	N	1.7	N76°E	10.0	1.8	400
14 Oct. 1978	6:30	NNW	2.4	N75°E	10.8	1.2	150
	12:30	ENE	5.0	N74°E	9.5	1.3	130
	15:30	NE	1.4	N75°E	9.6	1.3	130
25 Mar. 1980	13:10	ENE	7.2	S65°E	9.8	1.6	280

Rip currents were observed by a tethered balloon system (Sasaki et al., 1976) on 14 Oct. 1978. The dispersion of dye patches was obtained from time-lapse photography (Fig. 12). The associated current velocity is given in Fig. 13. Dye released at the foot of the north jetty moved along the jetty, then reached the harbor entrance. The dye patches on the south side also moved with the rip current then formed rip heads underway to the harbor entrance. The maximum velocity of the rip currents was 40 - 50 cm/s. The dye northward from the injection point dispersed in the bore.

Sediment movement was observed with fluorescent tagged sand tracer. One thousand kg of tracer was injected on both sides of the jetties, and samples were taken 2, 4, 6, 8, and 24 hr after injection. The distribution of tracer numbers (Fig. 14) shows very similar patterns to the current (Fig. 13). The tracer study was conducted the day before the current measurement; however, the incident wave directions were almost the same on 13 and 14 October (Table 1). The maximum drift velocities on both sides of the jetties were 7 cm/s and 1 cm/s, respectively.

One major empirical conclusion of this prototype experiment is that the sediment movement pattern is predictable based on current measurements. Thus, current measurement were conducted to determine the sediment movement after the construction of the rip current barriers.

Current around Rip Current Barrier

Nearshore current measurements were made on 25 March 1980 by using a helicopter-mounted camera instead of the balloon. Fluorescent dye was released at 7 points, 3 kg at each point in the surf zone and 2 kg at each point outside the surf zone. Figure 15 shows the dispersion of the dye patches around the vicinity of the rip current barriers. The rip current barriers block the rip currents effectively and produce forced circulation cells (Fig. 16). The velocity field is given in Fig. 17.

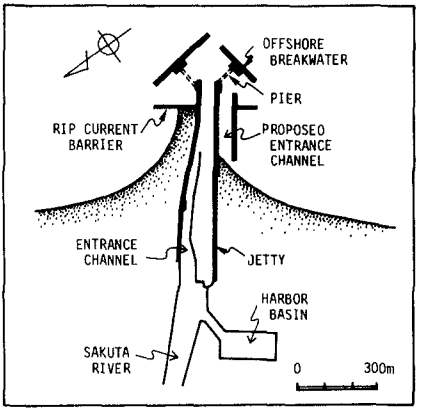

Fig. 11 Plan of Katagai Harbor. Harbor basin is located about 1 km inland from the entrance.

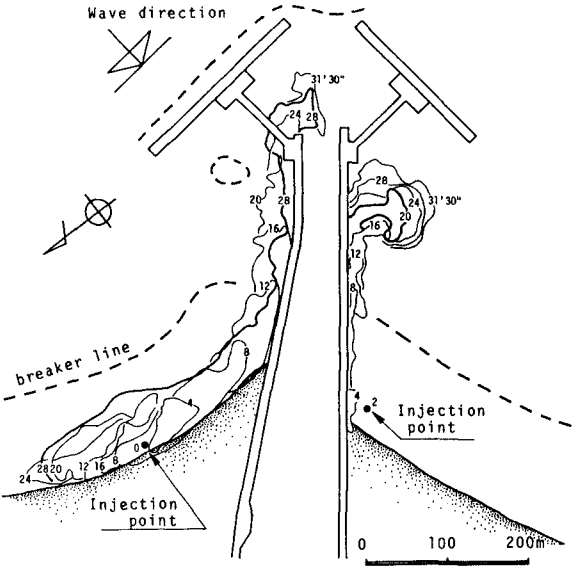

Fig. 12 Dispersion of dye released at the feet of the jetties. Numbers denote elapsed time in min. after injection. Rip heads are outlined.

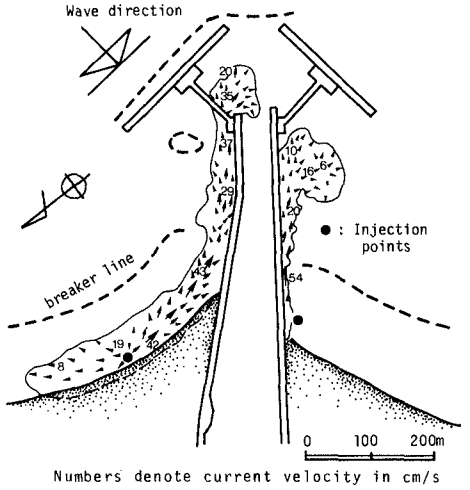

Fig. 13 Velocity distribution of rip currents derived from dye patch movement on 14 Oct. 1978.

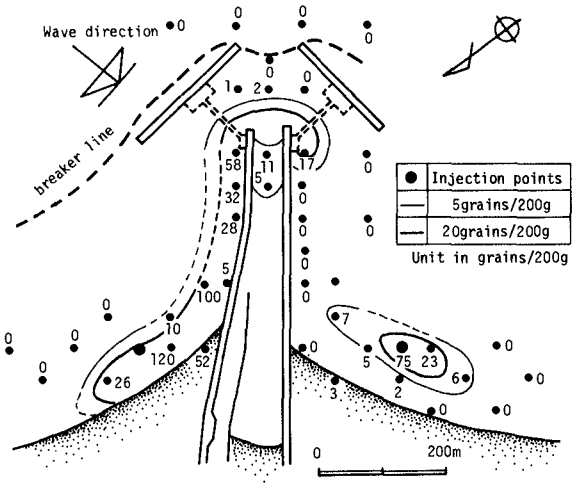

Fig. 14 Tracer movement 6 hr after injection on 13 Oct. 1978. Tracer entered the channel mouth.

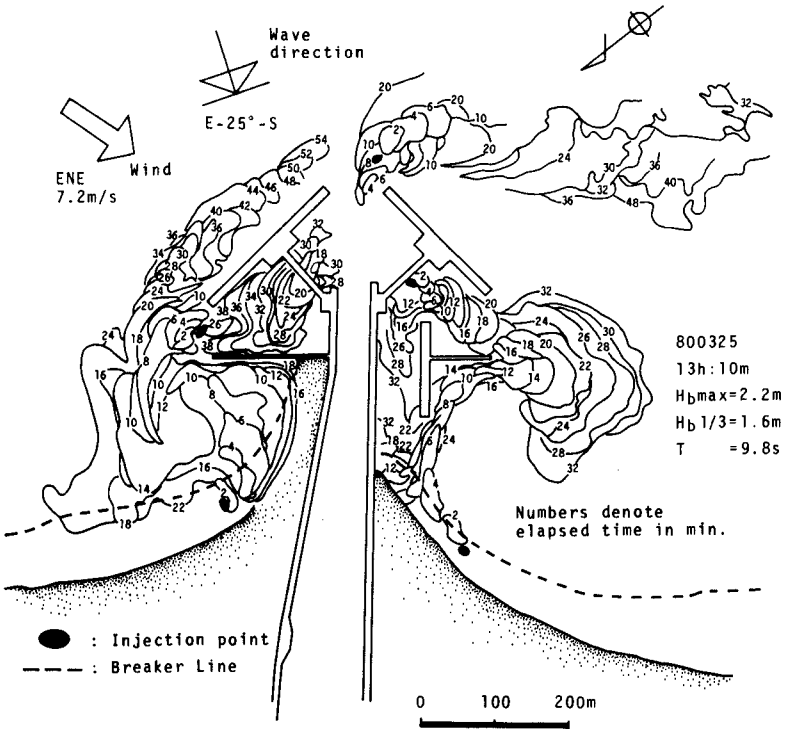

Fig. 15 Dispersion of dye patches around rip current barriers.

Because the south rip current barrier is short compared with the north barrier, the effectiveness of the barrier is limited. The shore-normal structure attached to the barrier is a portion of the proposed jetty to the separate harbor entrance channel from the Sakuta river.

Effect of Rip Current Barrier on Mitigation of Harbor Shoaling

Sounding charts were compared for surveys taken before and after rip current barrier construction (Fig. 18). General accretion is seen offshore and north of the harbor. On the other hand, an eroded area appears on the south side of the harbor. The offshore accretion may be the result of rip head bar formation during storms. Several sounding charts (e.g., bottom of Fig. 10) show huge rip channels. This tendency is consistent with the action of angled breakwaters and indicates that rip current barriers of this size are not effective in storms.

In the lee of the north barrier, accretion continues to take place, and thus the rate of accretion at the harbor entrance is decreasing. At the south, due to the geometry of the barrier, the mitigation effect is imperfect, and further extension of the barrier is deemed necessary.

3.0 CONCLUDING DISCUSSION

Prototype experiments on the rip currents and sediment transport at two fishery harbors on the Kujukuri coast, Japan, were conducted to test the effect of rip current barriers for mitigating shoaling. Rip currents are always induced along shore-normal structures, and they carry sediment offshore to form rip head bars as well as deposit sediment inside harbors to cause harbor shoaling.

To mitigate harbor shoaling and sediment loss offshore, some control of rip currents is needed. A rip current barrrier is defined as a shore-parallel structure that blocks the path of a rip current. It reduces the current velocity and turns the current direction shoreward to form a forced cellular circulation (Fig. 1b).

Field observations of the breakwater-induced rip currents at Taito Fishery Harbor under conditions of a 3 m breaker height suggest that if the barrier is outside the surf zone, it will be effective in blocking rip currents (Fig. 7). Field observations of induced-rip currents and sediment transport without a rip current barrier and of rip currents with a rip current barrier carried out at Katagai Fishery Harbor suggest that the rip current barrier is effective only under moderate wave conditions. Rip head bars under storm conditions were still formed after the rip current barrier construction.

A rip current barrier can be regarded as a cost-effective solution to mitigate harbor shoaling: however, to make it a final solution, deeper and longer structures to act as a total sand trap are required. The minimum length of a proposed rip current barrier should be greater than the radius of the induced design nearshore circulation cells, that is, approximately the surf zone width. In the case of Katagai Fishery Harbor, rip current barriers would be effective under wave conditions of 2 - 3 m breaker wave heights, which at this beach correspond to a 200 to 300-m surf zone width.

Fig. 16 Rip current barriers at Katagai Fishery Harbor. Arrows show measured rip currents.

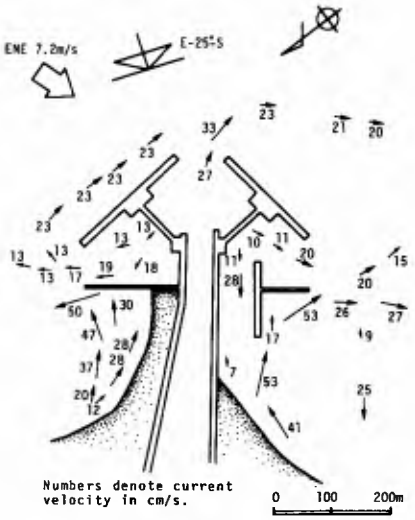

Fig. 17 Flow field derived from dye dispersion.

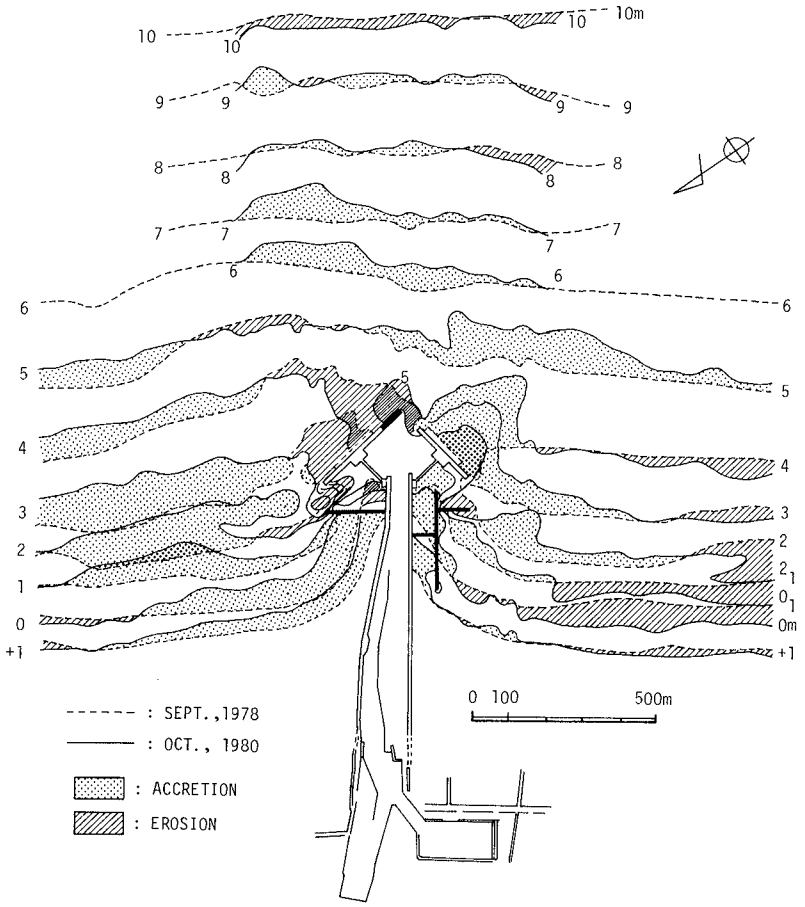

Fig. 18 Comparison of bottom contours before and after rip current barrier construction.

Because the Kujukuri coast has an exceptionally gentle beach slope, it would be very expensive to build barriers extending to the deep offshore. For such situations, an "island-type" fishery harbor has been proposed, where the harbor is located far offshore like an island and connected to the mainland by a bridge (Sakai, 1984). However, rip current barriers are feasible on moderately sloped or steep beaches.

4.0 ACKNOWLEDGEMENTS

This study was performed as part of a contract with the Chiba Prefectural Government. The authors acknowledge permission to publish given by the Fishery Harbor Division, Fishery Department of Choshi Fishery Harbor Office of Chiba Prefecture, and T. Sugawara, Chief of the Second Fishery Engineering Laboratory, Agricultural Engineering Research Station, Ministry of Agriculture, Forestry and Fishery. Also thanks are due to proofreading by Dr. N.C. Kraus of the Nearshore Environment Research Center, Tokyo.

The findings in the present paper are not to be construed as an official Chiba prefectural government position.

REFERENCES

Bruno, R.O. and C.G. Gable (1976): Longshore transport at a total littoral barrier, Proc. 15th Coastal Eng. Conf., ASCE, 1203-1222.

Bruno, R.O., G.M. Watts and C.G. Gable (1977): Sediments impounded by an offshore breakwater, Proc. Coastal Sediments '77, ASCE, 1006-1025.

Horikawa, K. and T. O. Sasaki (1972): Field observations of nearshore current system, Proc. 13th Coastal Eng. Conf., ASCE, 635-652.

Maza, J.A., M.L. Munoz and M. Porraz (1977): Jetties studies contribution, Proc. Coastal Sediments '77, ASCE, 248-266.

Pratte, B.D., D.H. Willis and J. Ploeg (1982): Harbor Sedimentation-comparison with model, Proc. 18th Coastal Eng. Conf., ASCE, 1119-1126.

Sakai, I. (1984): A proposal on island-type fishery harbor, J. Japan Soc. Civil Eng., JSCE, 69 (4), 31-35.

Sasaki, T.O. (1975): Simulation of shoreline and nearshore current, Proc. Civil Eng. in the Oceans/III, ASCE, 179-196.

Sasaki, T.O. , K. Horikawa and S. Hotta (1976): Nearshore current on a gently sloping beach, Proc. 15th Coastal Eng. Conf., ASCE, 626-644.

Sunamura, T. and K. Horikawa (1977): Sediment budget in Kujukuri coastal area, Proc. Coastal Sediment '77, ASCE, 475-487.