CHAPTER IV

SEDIMENTATION

4.1 BEACH PROFILE CHANGES

From the topographic profiles taken directly during the technical field survey, comparison is made by superimposing one series on the next as presented in Figs. 4.1-1 to 4.1-12 for profiles A to L. The repetition of topographic profile measurements along the beach in this area has given a sequence of level changes during the year. Fills and deepenings have alternated with seasonal relationship.

This chapter is concerned with beach profiles in order to understand the processes involved in beach profile development.

The beach profile is important in that it can be viewed as an effective natural mechanism which causes waves to break and dissipate their energy. The beach serves as a buffer, protecting coastal property from the intense wave action.

4.1.1 Profile Changes due to Tides

Tides produce daily flnctuations in the water level at the coast. Seasonal variations, annual variation may also be detected. The other sea level change of importance is associated with the advance and retreat of glaciers over a period of thousands of years. The detail and causes of seasonal sea level changes and the effect on beach erosion and accretion will be discussed.

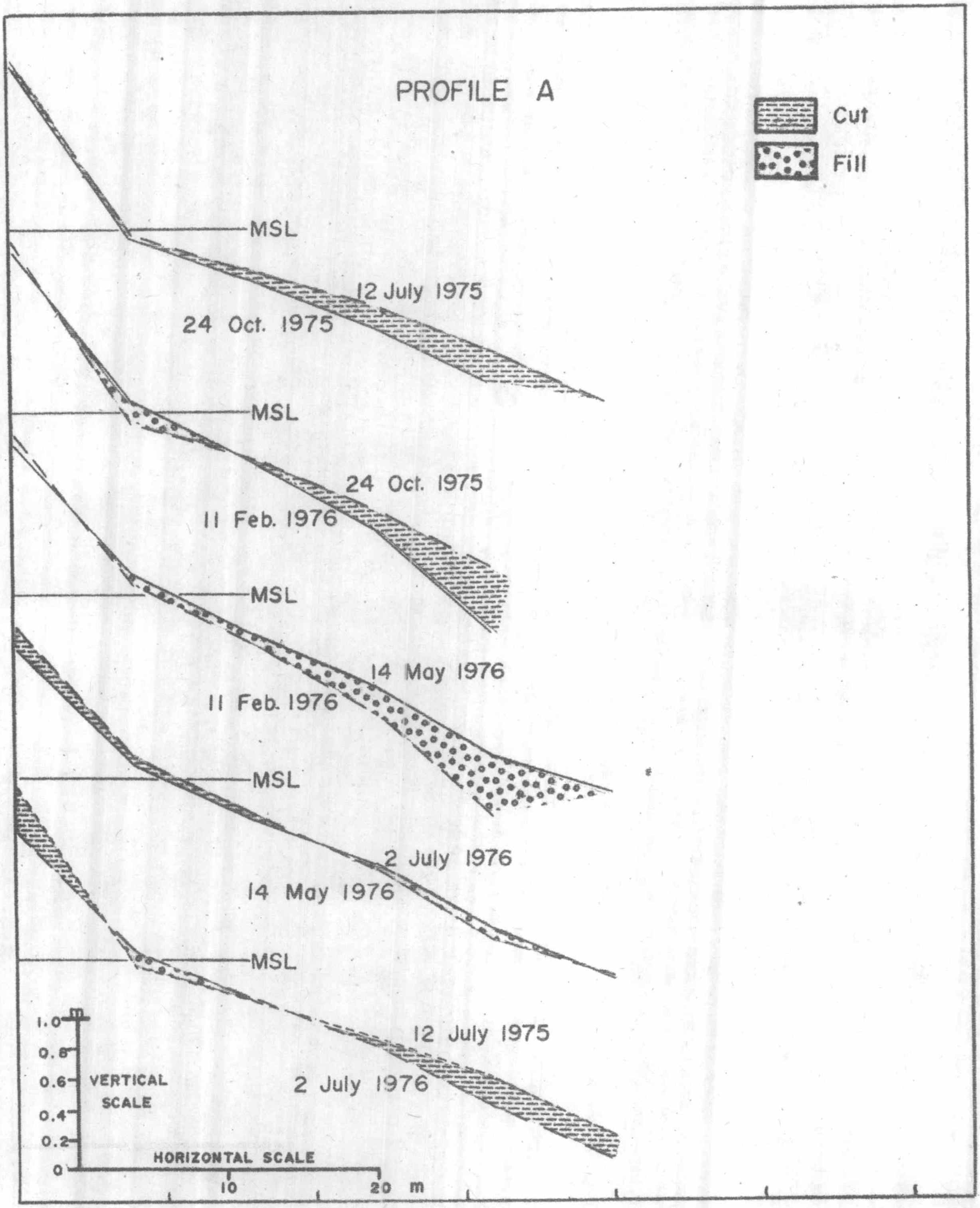

FIGURE 4.1-1. CHARACTERISTICS OF OBSERVED SEQUENCES OF BEACH PROFILE CHANGE (PROFILE A).

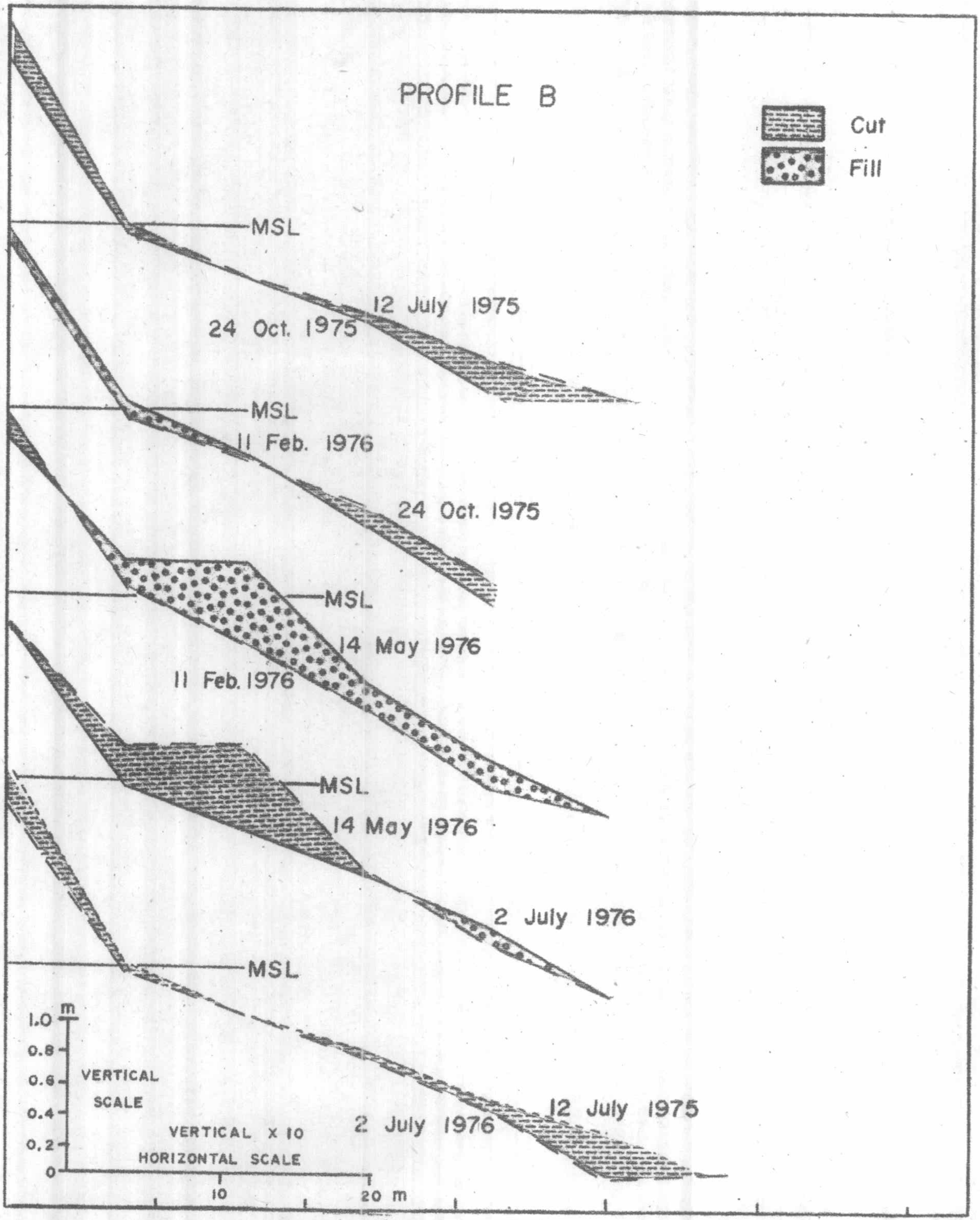

FIGURE 4.1-2. CHARACTERISTICS OF OBSERVED SEQUENCES OF BEACH PROFILE CHANGE (PROFILE B).

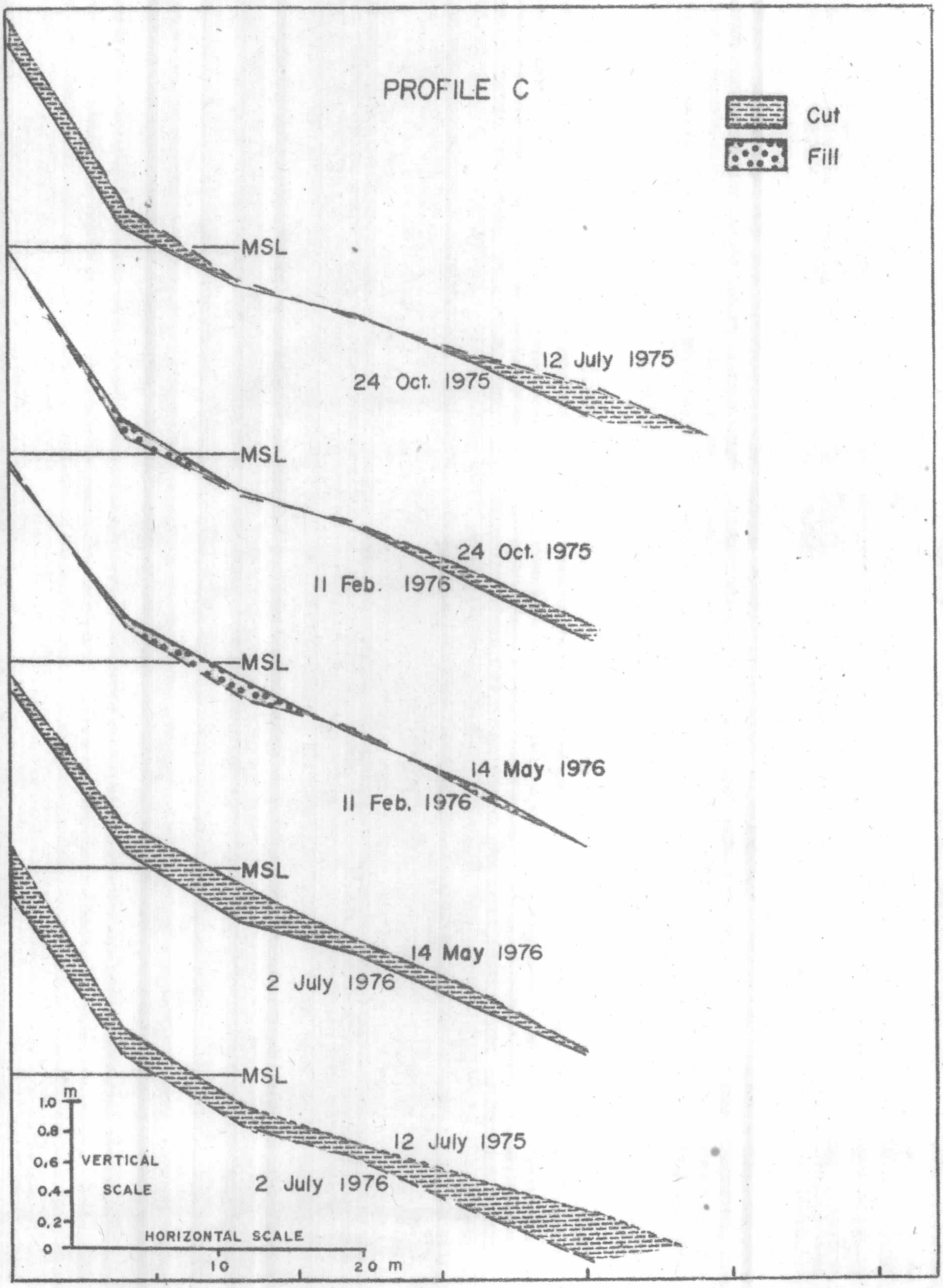

FIGURE 4.1-3. CHARACTERISTICS OF OBSERVED SEQUENCES OF BEACH PROFILE CHANGE (PROFILE C)

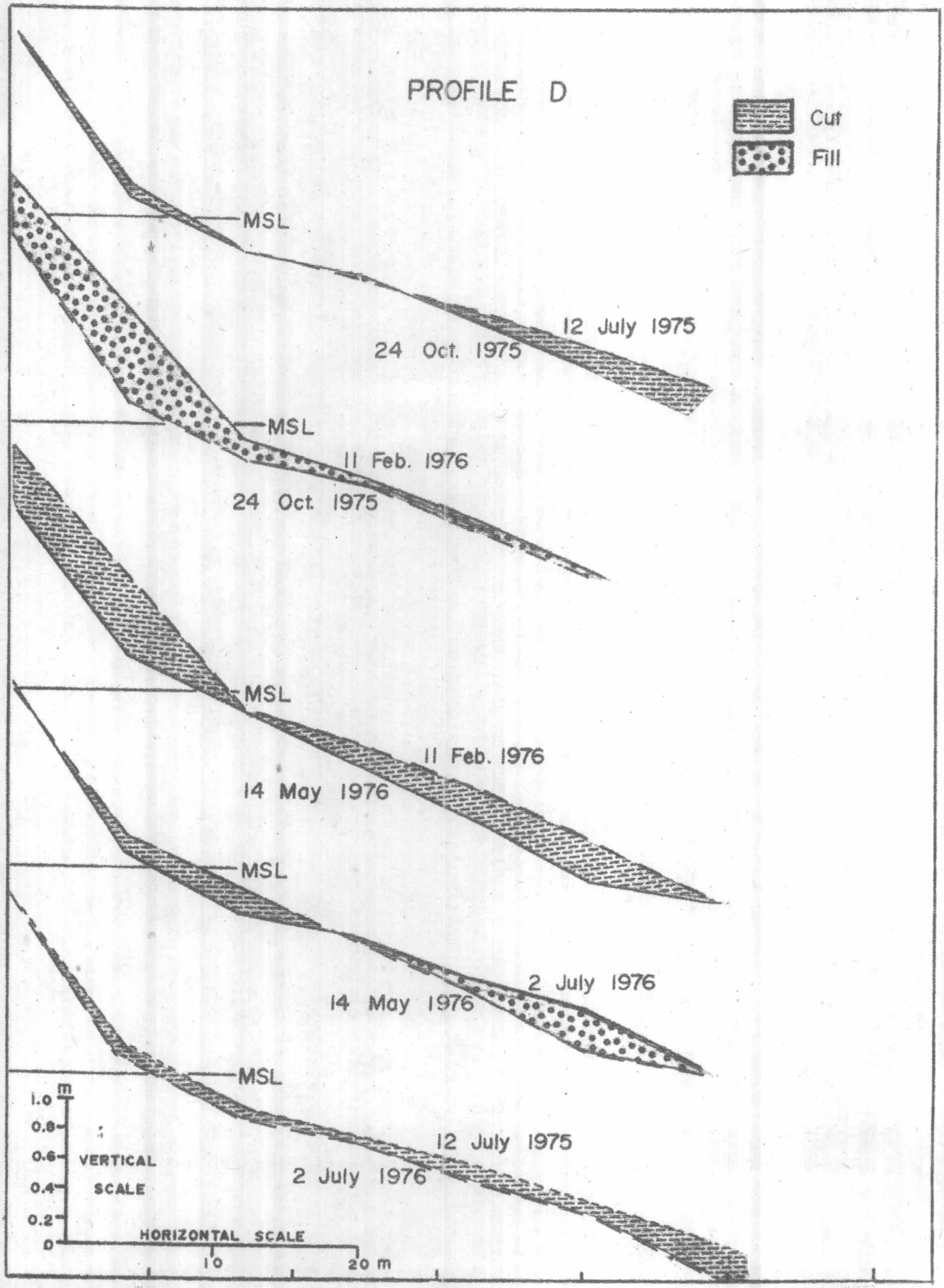

FIGURE 4.1-4. CHARACTERISTICS OF OBSERVED SEQUENCES OF BEACH PROFILE CHANGE (PROFILE D).

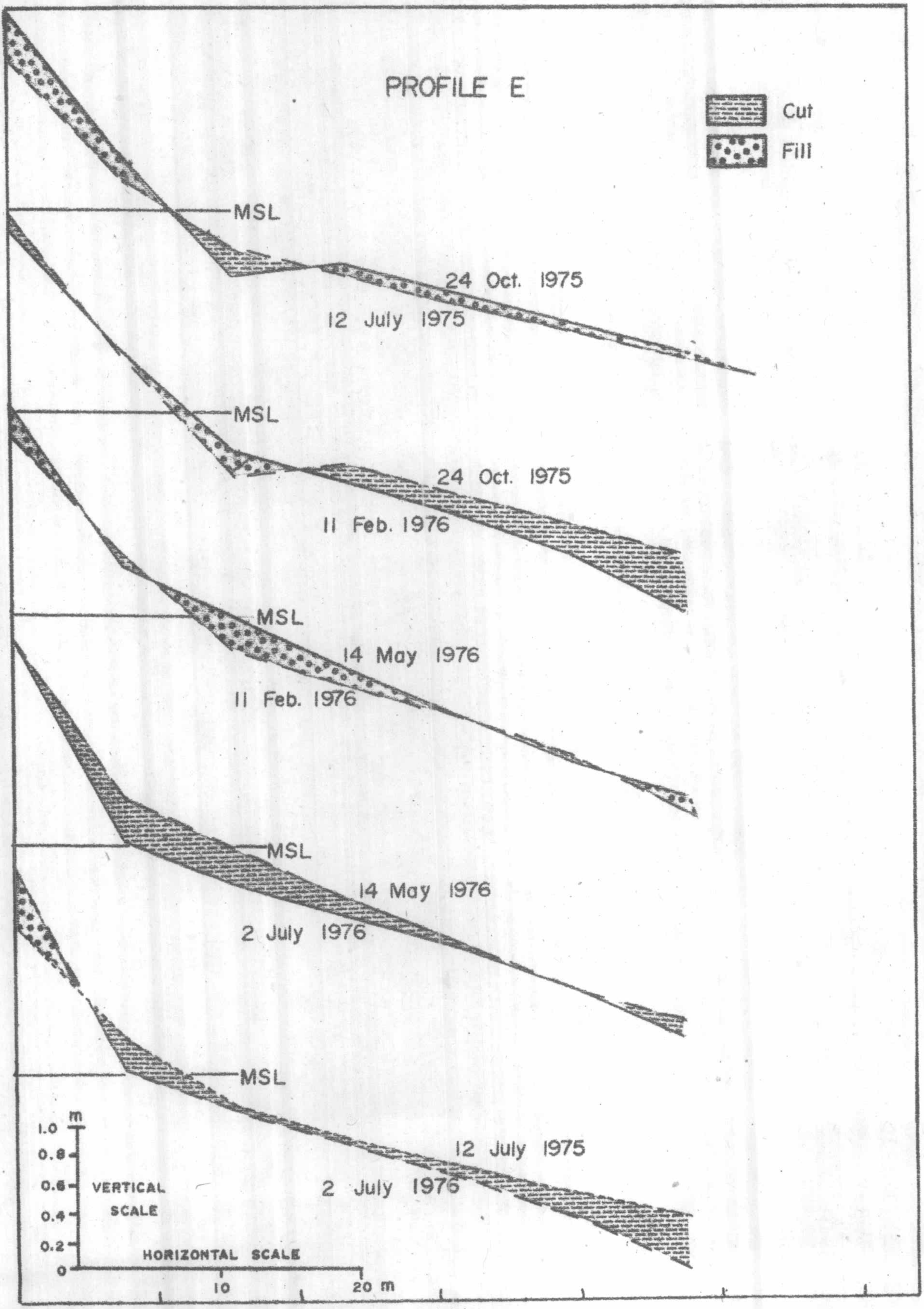

FIGURE 4.1-5. CHARACTERISTICS OF OBSERVED SEQUENCES OF BEACH PROFILE CHANGE (PROFILE E).

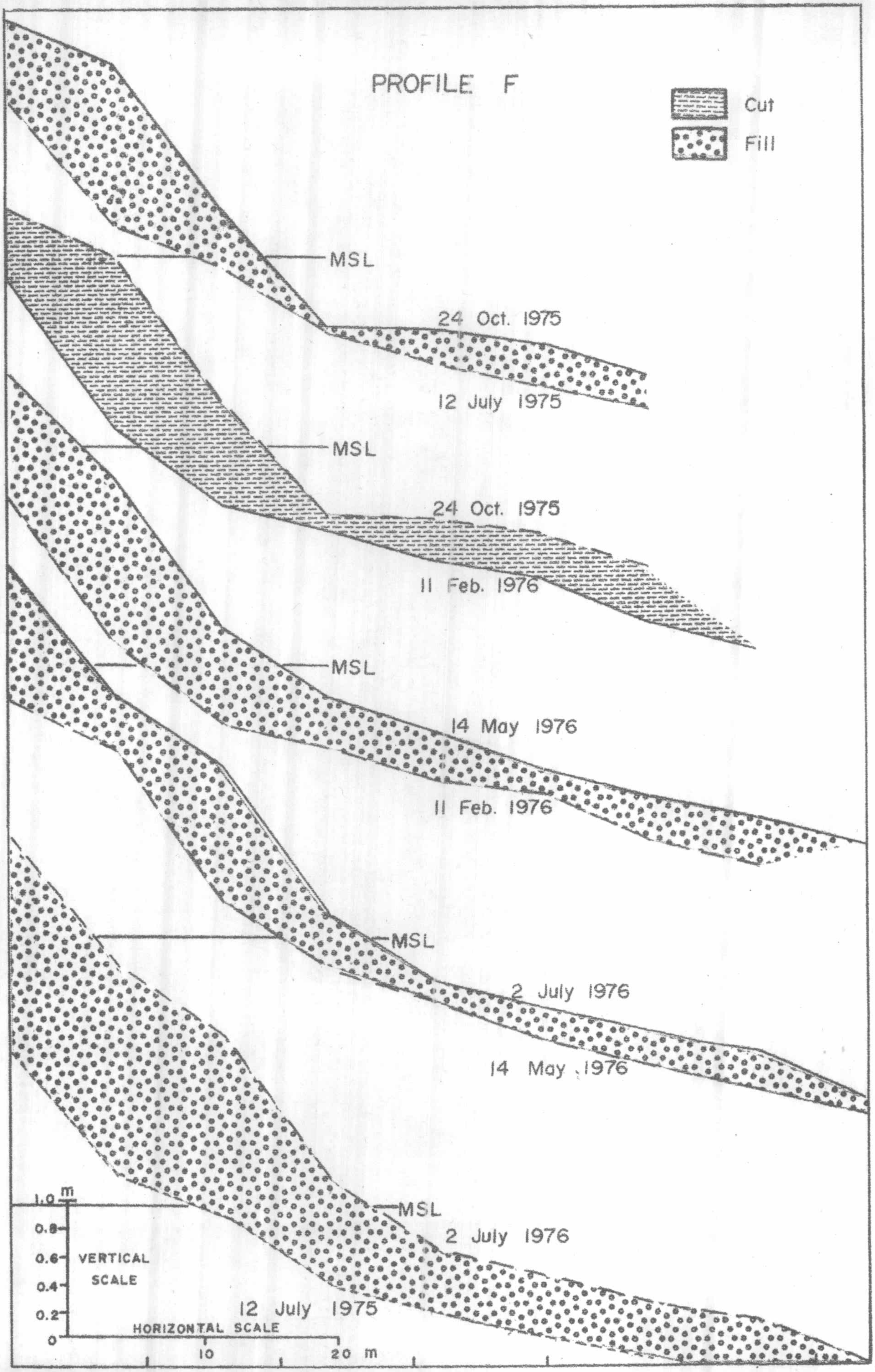

FIGURE 4.1-6. CHARACTERISTICS OF OBSERVED SEQUENCES OF BEACH PROFILE CHANGE (PROFILE F)

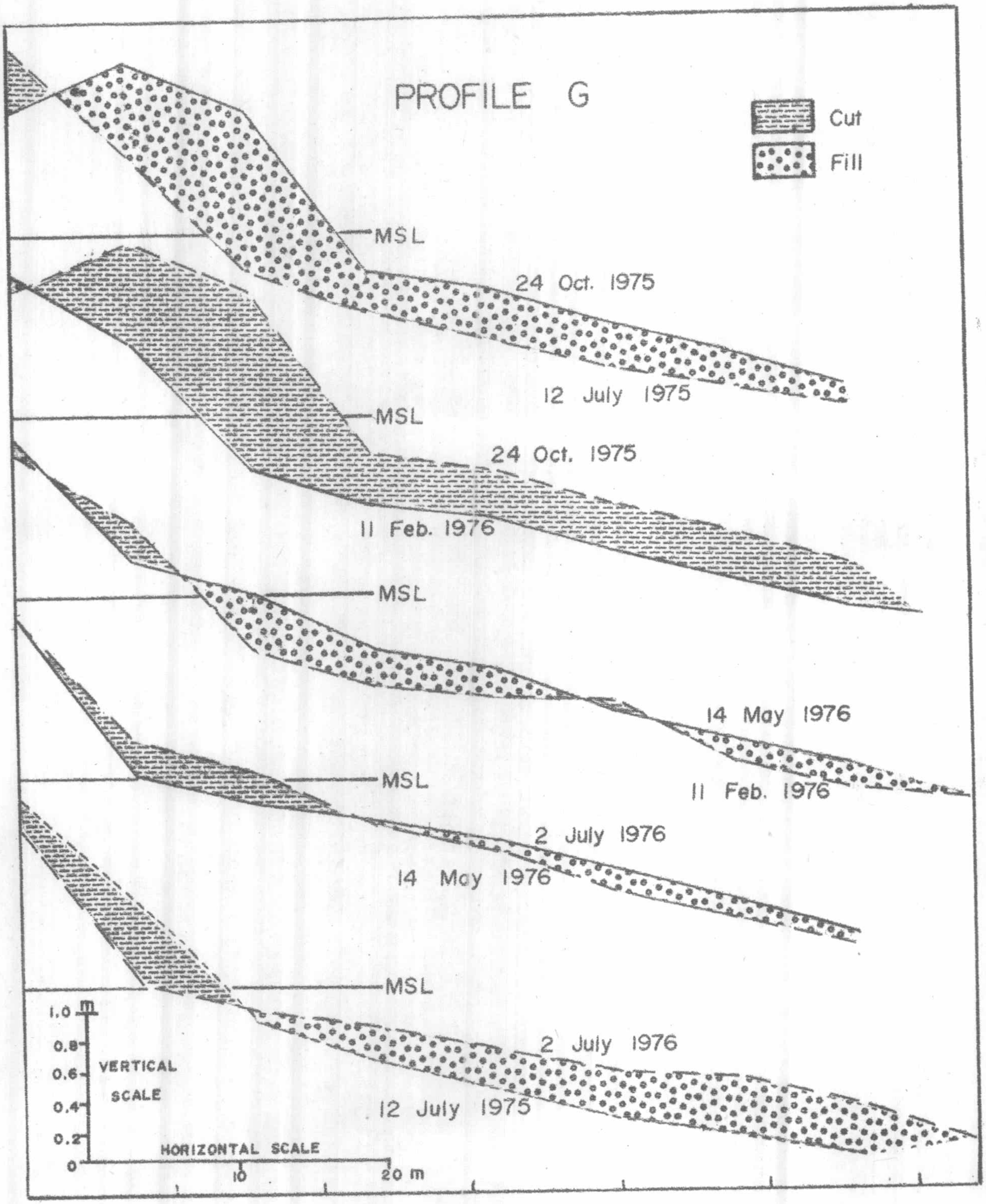

FIGURE 4.1-7. CHARACTERISTICS OF OBSERVED SEQUENCES OF BEACH PROFILE CHANGE (PROFILE G).

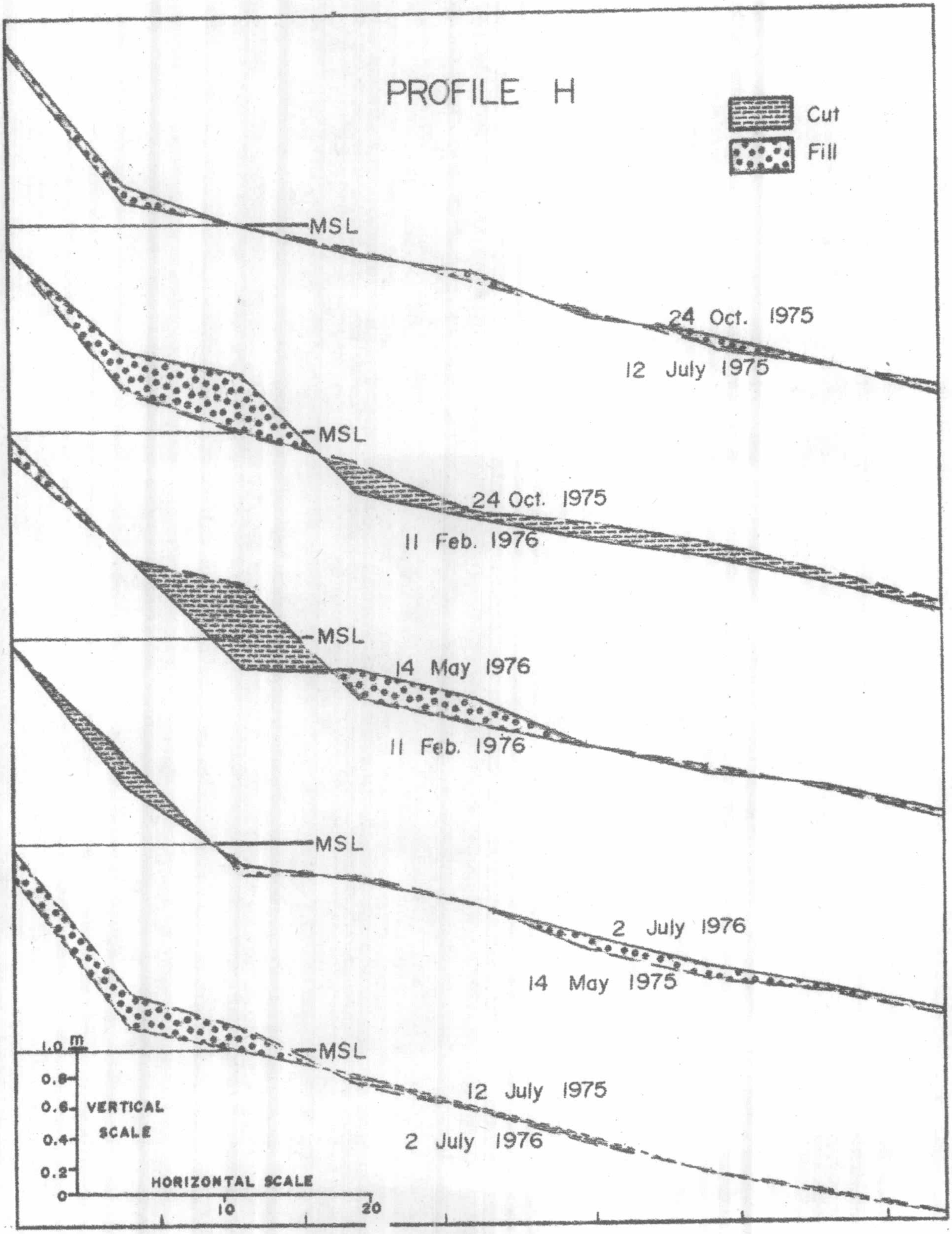

FIGURE 4.1-8. CHARACTERISTICS OF OBSERVED SEQUENCES OF BEACH PROFILE CHANGE (PROFILE H).

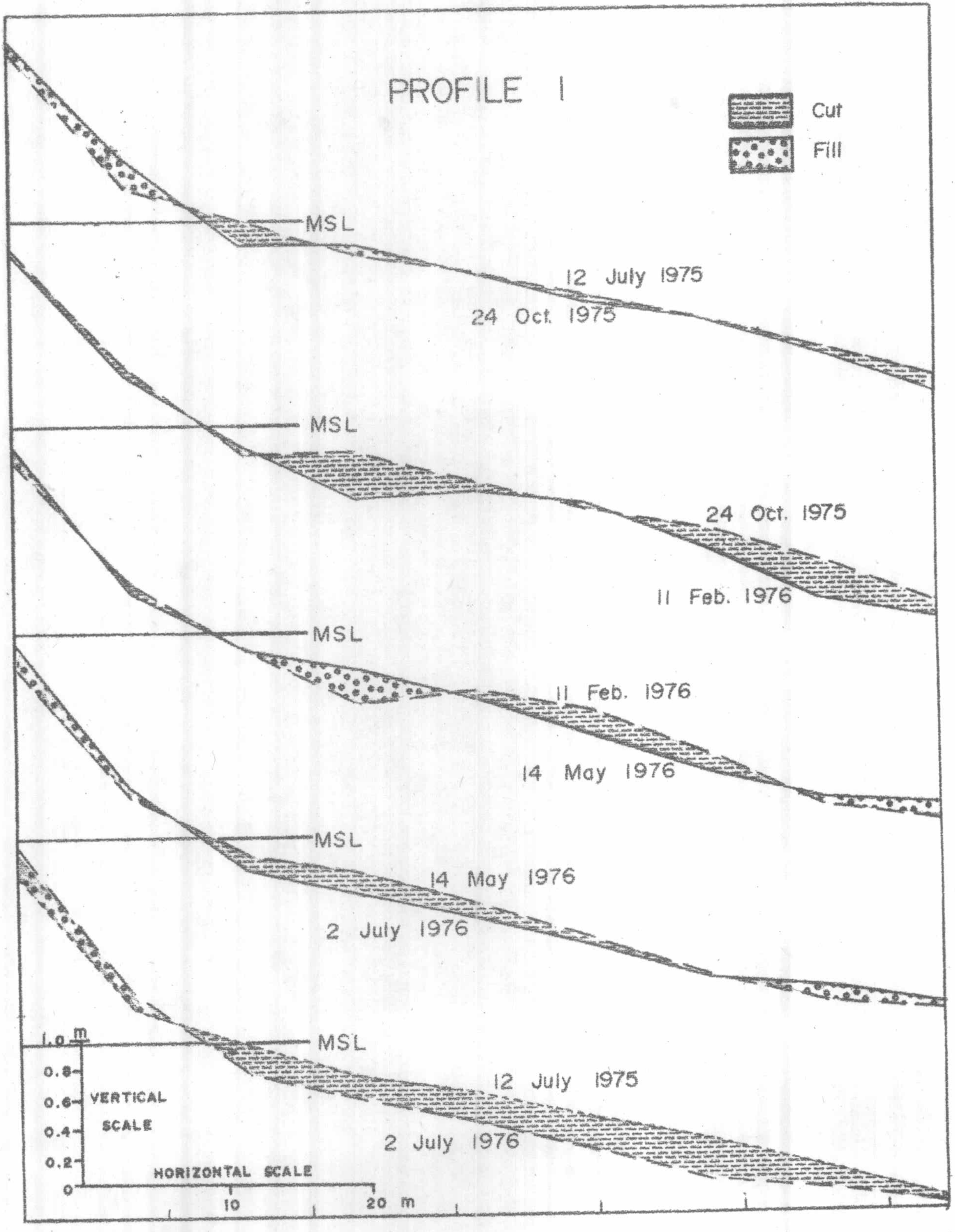

FIGURE 4.1-9. CHARACTERISTICS OF OBSERVED SEQUENCES OF BEACH PROFILE CHANGE (PROFILE I).

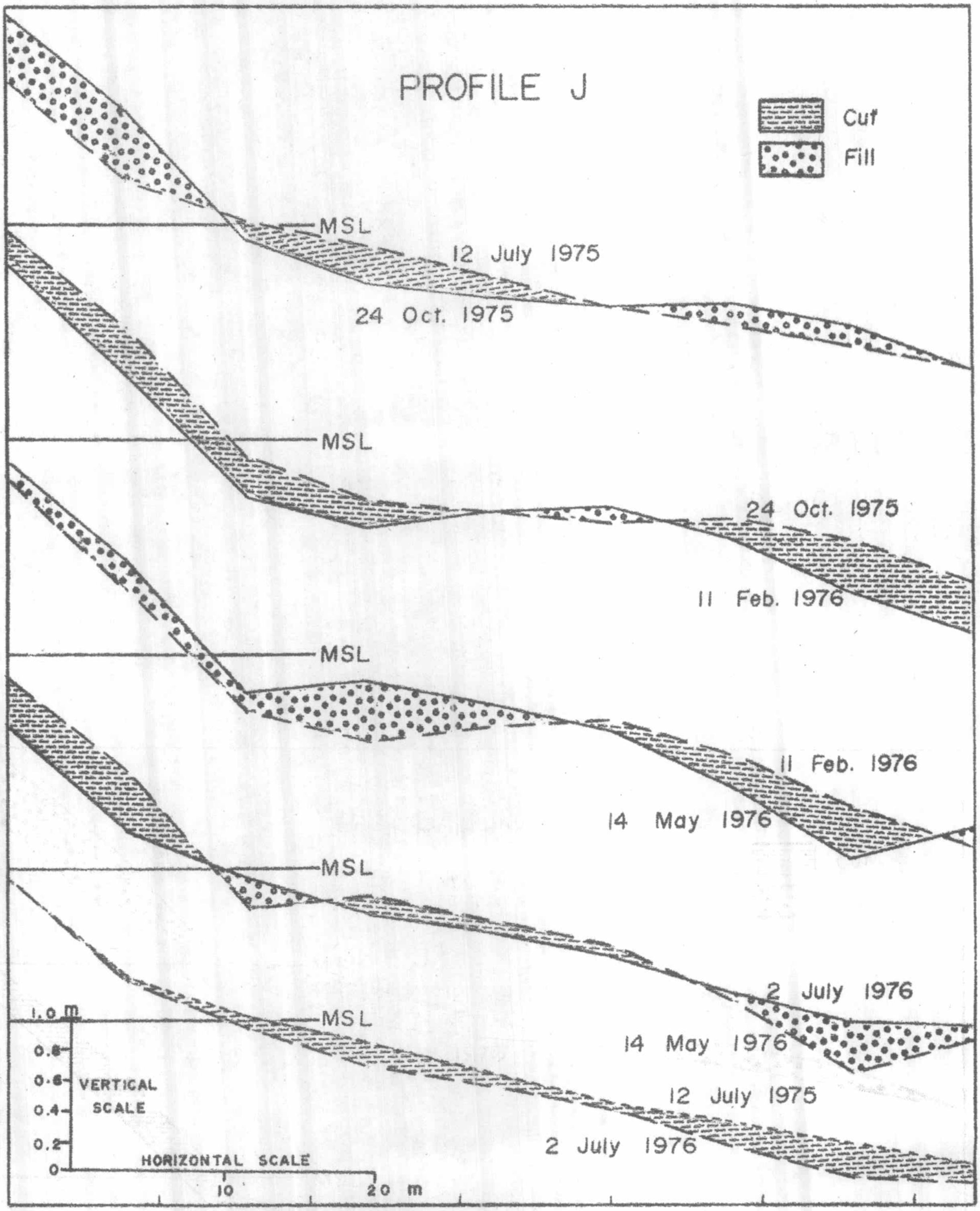

FIGURE 4.1-10. CHARACTERISTICS OF OBSERVED SEQUENCES OF BEACH PROFILE CHANGE (PROFILE J).

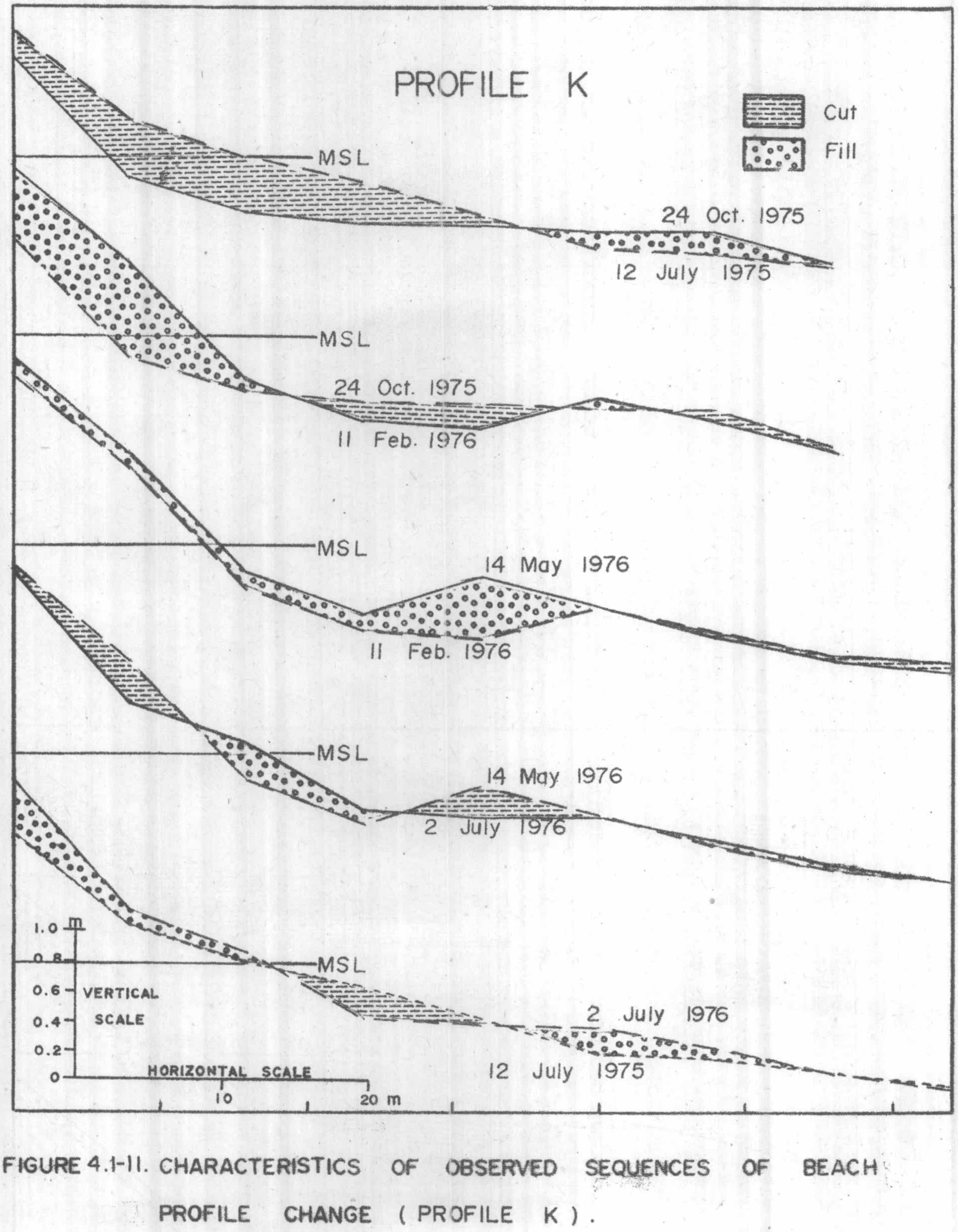

FIGURE 4.1-11. CHARACTERISTICS OF OBSERVED SEQUENCES OF BEACH PROFILE CHANGE (PROFILE K).

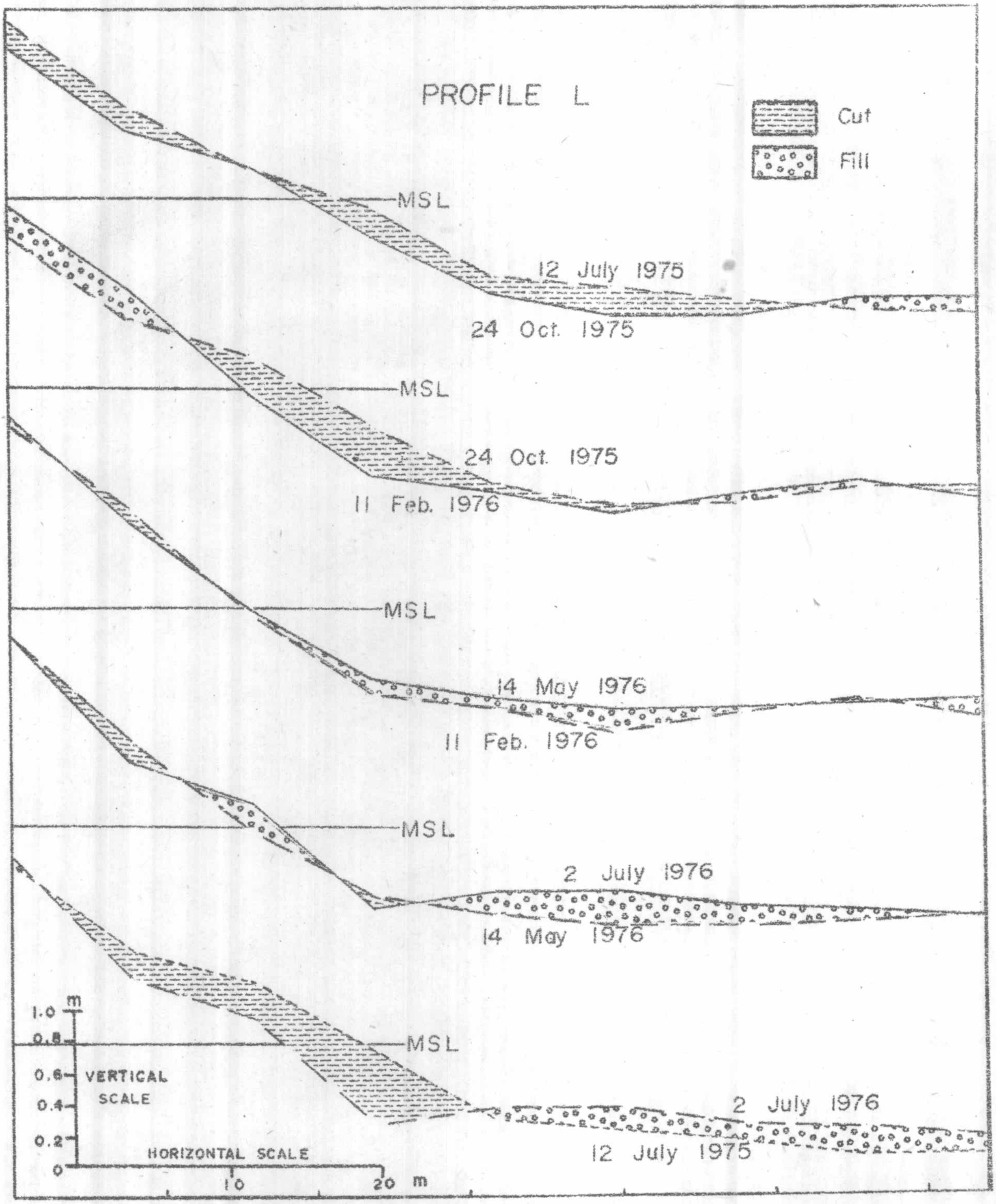

FIGURE 4.1-12. CHARACTERISTICS OF OBSERVED SEQUENCES OF BEACH PROFILE CHANGE (PROFILE L).

In addition a rise in water level nearshore is also produced by winds blowing onshore (King, 1959). Under steady-state condition the shoreward force of breaking wave should be just balanced by a rise in water level on the beach (Munk, 1949 a,. Inman and Filloux, 1960). And it is well known that a beach cycle is related to the seasonal variation in the character and direction of approach of the waves occurs along the coastlines (Shepard, 1950).

Inman and Simmons (1968) considered the negative and positive changes in mean water level due to the presence of a train of surface waves and due to the conservation of momentum flux, (Longuet-Higgins and Stewart 1960, 1962, 1963, 1964).

The response of the beach profiles to the tides would involve hourly changes resulting from the rising and falling of water level during flood tide and ebb tide that cause the changing of beach profile during the tidal cycle (Schwartz, 1967, Strahler, 1966). Also longer-term effects are due to the differences in the range of spring and neap tides. The profile changes from spring-tide conditions to neap are particularly interesting.

a) Between 12 July and 24 October 1975

The result of beach profiles change between this period in which the rising of sea level is intiated by the spring-tide. Among the 12 profiles are 3 profiles of the upbeach-fill and the foreshore-cut, 3 profiles of the overall fill, 5 profiles of all cutting and 1 profile of the cut on upper beach and the fill on the foreshore zone. The zone of interest is profile A, B and C which all of them are eroded. The cycles of fill and cut in this period are variables from place to place. It is interesting to note that, almost all profiles westward of the Pier exhibit the "cut" pattern and extraordinary "fill" pattern appear just on both side of the Pier.

b) Between 24 October 1975 and 11 February 1976

The mean tide level continues rising until reaches its maximum elevation of 36.7 dms in December. The field observations reveal that, a rising sea level deepen the water offshore and allow waves to break closer inshore. So the profiles taken over the neap and spring tide show 8 profiles of a rise in the sediment level on the beach close to the shore and the offshore were eroded. These confirmed the Lafond (1938) theory . Four profiles, F, G, I and J in Figs. 4.1-6, 4.1-7, 4.1-9 and 4.1-10 were cut over the entire length especially at profiles F and G, the alteration from fill to cut took place rapidly. Topographic changes up to a maximum of 1.28 m and 1.18 m have been observed on profiles F and G. The beach materials are certainly being carried seaward to form the submarine sand bar in the offshore zone.
A tremendous erosion has been observed in the neighbourhood of the Pier.

c) Between 11 February and 14 May 1976

This period is between falling tide, causing by withdrawal of the sea. The depth of water offshore is reduced and the attack of waves diminished in efficiency. The zone of step deposition and the zone of scour retreat down the beach (Strahler, 1966). Among 12 profiles, seven of them show the sediment accretion over the length profiles, the other 3 profiles exhibit progradation on the upper beach and the scoured foreshore. In profile F and G the previous cut in the last period has suddenly reversed to fill a series of cutting therefore indicates that such a phenomenan only occurs tempolarily.

d) Between 14 May and 2 July 1976

This short period of surveying provides the data to recover the one-year period of study. The mean tide level is continually decreased. The significant character has been observed during this period, 10 out of 12 profiles show the cutting upper beach and filling in the foreshore zone. The profiles adjusted themselves to a falling of sea level where sediment was previously shifted offshore by erosion of the upper beach. This importance of the interaction of the swash and the water tables has been further demonstrated by Harrison (1969). He provides an empirical equation for the resulting advance or retreat of the shoreline and the mean slope of the foreshore.

4.1.2 Profile changes due to longshore sand transport

In addition to onshore-offshore shifts of sand due to tides, longshore sand movement may also affect the beach profiles. The longshore movement is the result of oblique incidence of wave energy induced longshore currents. The tidal currents are effective only near the mouth of a bay where they become strong, they may become significant in sediment transport on the beach. Strong winds may also generate longshore currents that, combined with wave action (Komar, 1976).

The pattern of transport of beach material along the coast of the Royal Fleet Pier are given in Map 1. There are several areas of serious erosion along this coast particular in the western most of the study area and the two sides of the pier as shown in Map 1 a and b respectively. The mass of sediments from profile A, B, C, D and small stream is transport along the coast eastward to the pier area and deposited in profiles E, F, G and H, which have expanded eastward until reaching profile L the cut is again found, (Map 1 a) in the period between 12 July and 24 October 1975. Therefore, the transport of sand should be proportional to the product of the amount of wave emergy amd the velocity of the current especially in the surf zone when the breakers are large enough so that longshores current become dominant to cut back the beach (Inman & Frautschy, 1972, Inman, 1971, Komar, 1971), and the portion of the offshore close to the beach as shown in Figs. 4.1-1 to 4.1-4 (between 12 July and 24 October 1975).

4.1.3 Profile Changes due to Onshore-Offshore Sediment Transport

Occasionally sediments may be eroded from unconsolidated offshore sources on the continental shelf and drift shoreward onto the beach. Sediments that are too fine to remain on the beach will be placed in suspension and carried offshore into deep water and lost from the beach. The amount of transport of beach material is difficult to measure (Komar, 1976). In order to understand the profile changes the details of this transport normal to the shoreline will be disscussed. This of course depends upon the nearshore currents, wind and wave. The effect of wind therefore, had to be considered together with that of waves (King, 1972). It can be seen that the results of the effect of the onshore and offshore winds on the beach profiles are shown in the profiles drawn for 11 February to 2 July 1976 period and 24 October 1975 to 11 February 1976 period in Figs. 4.1-1 to 4.1-12.

During this period winds were blowing mainly from the south and southwest. The southwest direction winds will blow onshore normal to the shore especially near the pier. Wind roses were prepared and given in Fig. 3.4.3 a, where the maximum wind speed mostly was generally to 3 beaufort (16 km/hr). This caused erosion on the upper beach, while accretion took place on the lower foreshore. At the west end of the study area especially at profile B in which 54 cm. of sediments were removed from the top of the beach (King and Williams, 1949., Shepard and Lafond, 1940).

Offshore sediment transport seaward of the beach is illustrated in the period of the offshore wind between 24 October 1975 and 11 February 1976 in Figs. 4.1-1, 4.1-2,4.1-3, 4.1-4, 4.1-5, 4.1-8, 4.1-11 and 4.1-12. The accretion occurred on the upper beach above the mean sea level of those profiles listed, especially the maximum accretion of 65 cm. was found in Profile K (Fig. 4.1-11). Seaward of the accretion, the erosion took place. The wind directions were dominantly blowing from north and northeast with the maximum speed of 4 beaufort (24 km/hr). These give results in resonable agreement with King and

Williams (1949).

The presence of vegetables along the coast is very important in the character of the coast. They play a large part in stabilizing and promoting the coast by traping the wind blown sediments with their complex root system and thus protect the coast from erosion (Goldsmith, 1973).

4.1.4 Sediment Size and Beach Slope

Grain size, wave steepness, and wavelength have been reported by Dubois (1972), as variables affecting the foreshore slope angle and also suggested that the heavy mineral content in the mid-foreshore be accepted as an active variable that influence the foreshore slope angle.

The relation between beach slope and sediment size for various profiles is given in Fig. 4.1.4. The slope of the beach face increases with increasing sediment size. The profiles on western side of the pier were consistently steeper than those on eastern side and also with coarser sediment size. King (1951) pointed out that, the coarse grade of sediment is the factor on which the greater depth of disturbance recorded on that beach depends. A coarse sand allows water to percolate more readily. The percolation discharge decrease very rapidly as the grain size of the sediments is decreased, this is because larger materials are very permeable and permit considerable energy losses within the bed. This probably explains why the same wave attack displaces a far greater mass of large-grain materials than of small

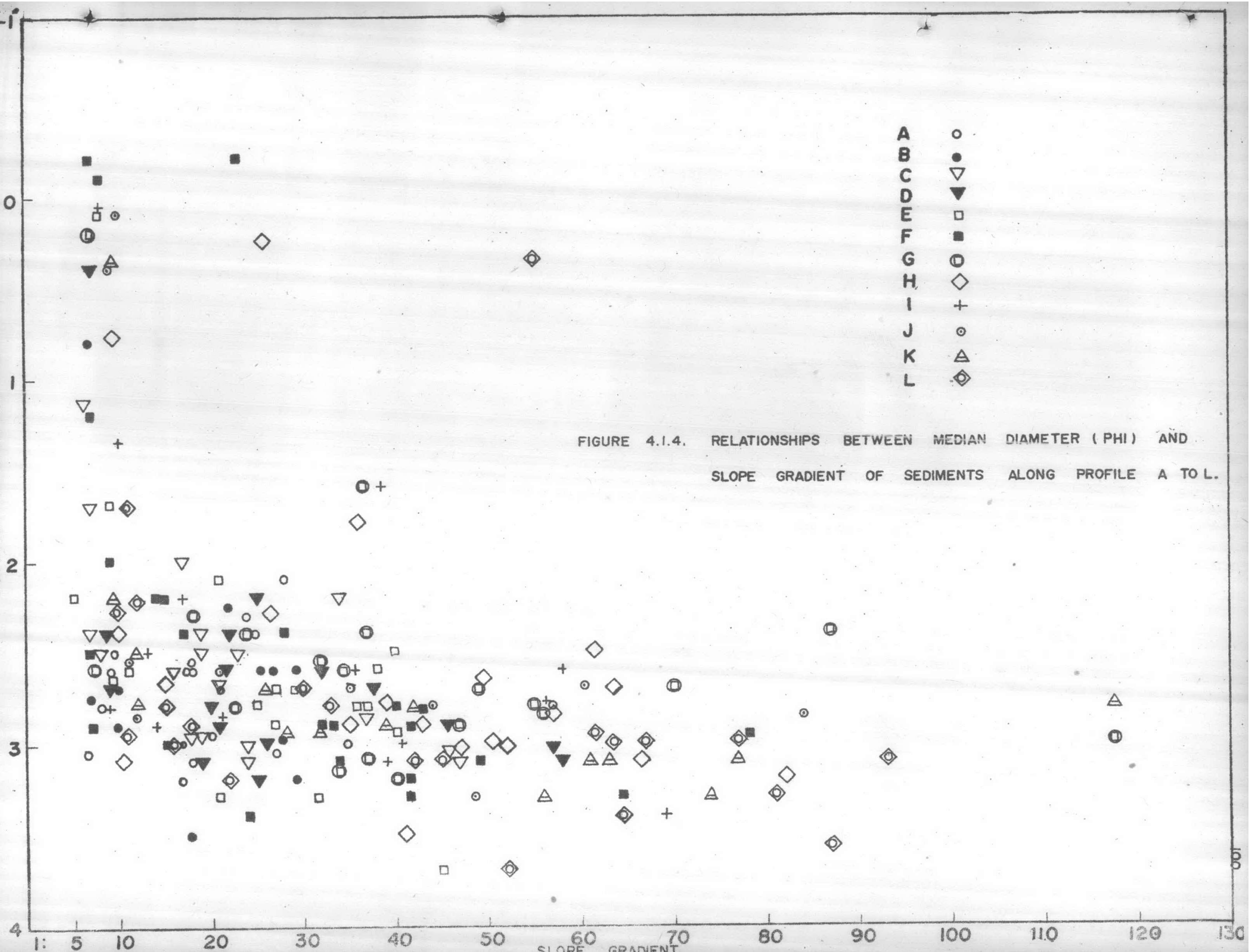

FIGURE 4.1.4. RELATIONSHIPS BETWEEN MEDIAN DIAMETER (PHI) AND SLOPE GRADIENT OF SEDIMENTS ALONG PROFILE A TO L.

(Inman and Bagnold, 1962). The waves break close inshore on a steep gradient so that the breaker and swash zones are narrow. The turbulence is concentrated in this narrow zone. King (1951) concluded that the depth of disturbance depends partly on the median diameter of the sediment, the depth of disturbance on pebbles would be larger than on a fine sand beach.

4.2 SEDIMENT CHANGES

4.2.1 Size Variation Across a Beach

On a number of beaches sediment samples were taken along the profile, the samples from the third point (16 meters seaward distance) were chosen to be the reference points. These points were in the part of the beach face at mid-tide elevation and were presumed to have approximately the same characteristics as suggested by Bascom (1951).

Other sediment samples are plotted by their percentage relationship of median diameters (mm) to the median diameters of the reference samples as shown in Fig. 4.2.1 . The largest sediment particles at any profile are found at the plunge point as in Bascom (1951), and the next largest particles are found on the top of the beaches which are carried by the maximum uprushes. Comparing among the profiles, the least variations from the reference median are in the smallest-sediment profiles A, B, C, D and the greatest variations are found at the coarsest profiles F and G.

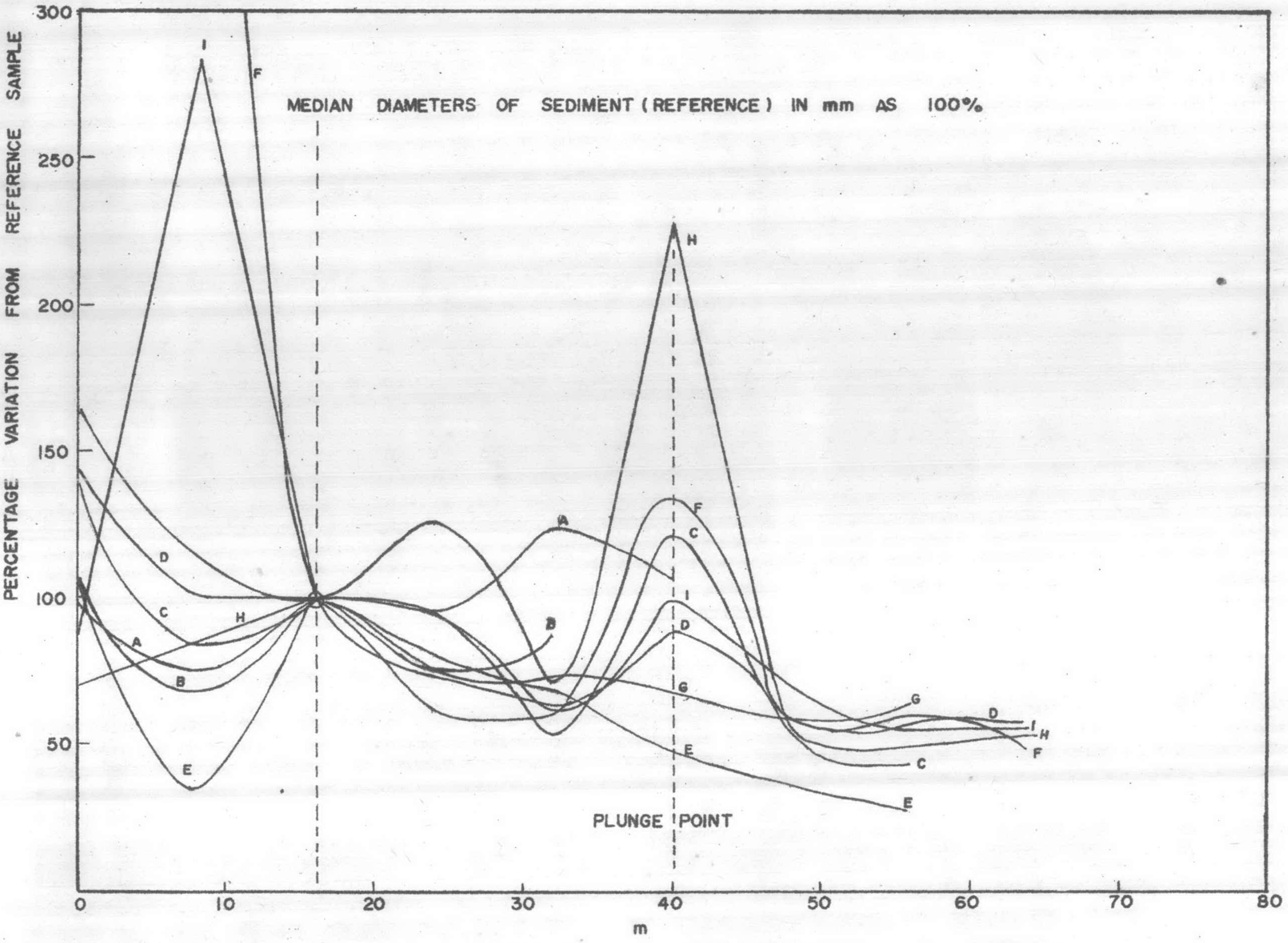

FIGURE 4.2.1. PERCENTAGE VARIATION OF MEDIAN DIAMETERS OF SEDIMENTS ACROSS A BEACH, COMPARED WITH REFERENCE SAMPLES.

4.2.2 Sediment Size and Sorting

The relationship between mean diameters and sorting is shown in Fig. 4.2.2, it shows that for sands the two values increase together, finer sands being better sorted. The sorting, hewever, becomes worse for both very coarse sediments and very fine ones, that is also the same as King (1972, p.221).

In foreshore zone just after the finer sediments with the best sort near the top of the foreshore of profile A, B and C and continuing downslope the sorting coefficient increases as size increases.

The cause of these relationships, King (1972) explained that it is probably due to polymodal sources, resulting from the common occurrence in nature of pebbles sand and clay.

4.2.3 Longshore Sorting of Beach Sediments.

It is well known that beach sediments are among the best sorted sediments. They are subjected to a progressive sorting when transported by longshore currents, and to a very effective local sorting by the oscillatory motion of the waves (Inman, 1949).

On the western side of the area where erosions were mostly found and the large sediments were dominated when compared to the most eastern area. The lateral sorting was also found along the coast as illustrated in Figs.3.3.13 to3.3.16,while the longshore variation in grain size involved. This can be explained in terms of longshore changes in the wave energy level. The progressive decrease ingrain size occur along

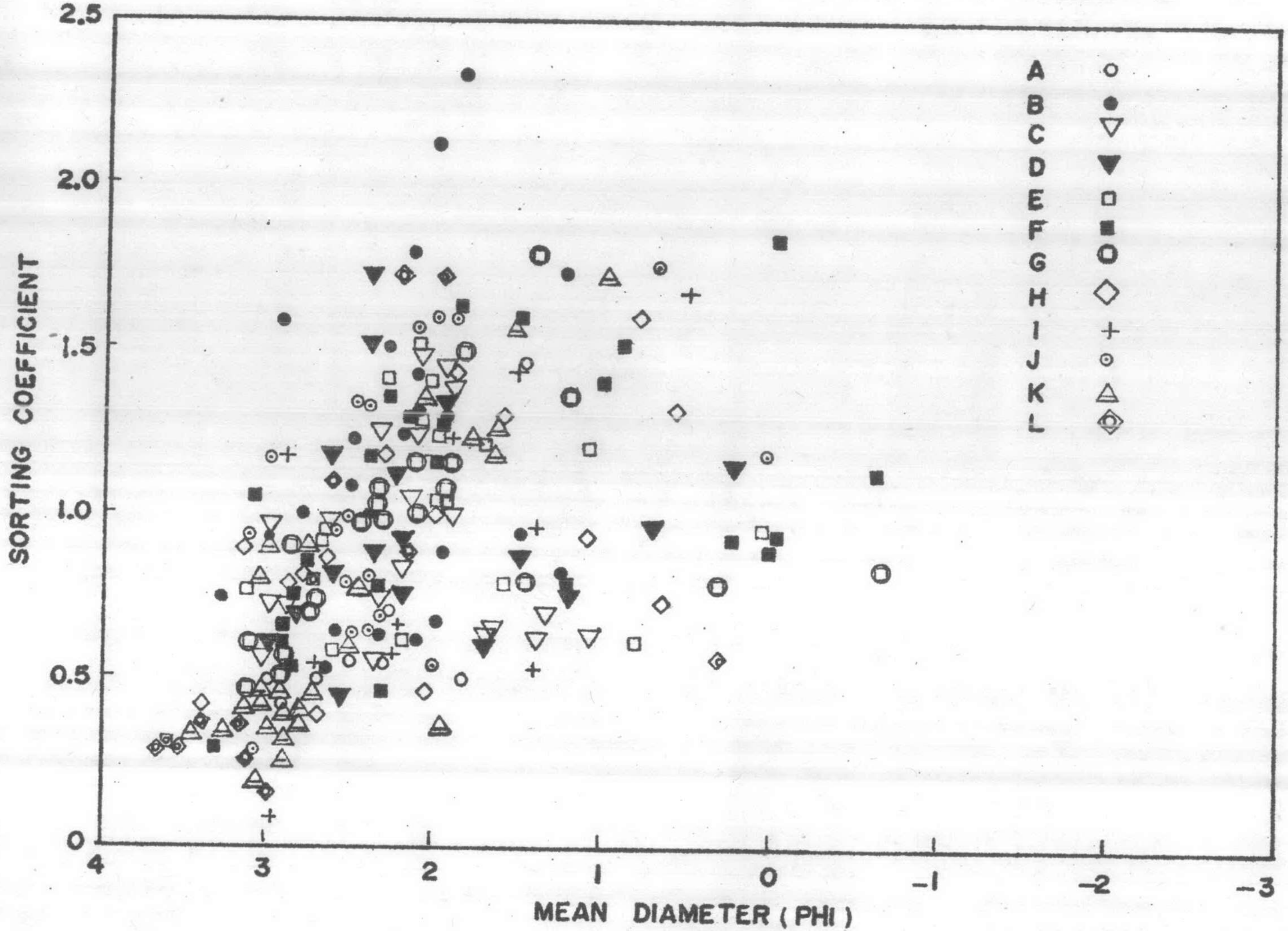

FIGURE 4.2.2. RELATIONSHIPS BETWEEN MEAN GRAIN SIZE (PHI) AND SORTING COEFFICIENT OF SEDIMENTS ALONG PROFILES A TO L.

the lengh of the beach and the finest sediment is located at the east terminal end of the beach. This selective transport attributed the smallest grain sizes moving alongshore at the greatest rate and the coarsest materials remaining close to the area near the pier, and selective removal of the finer grain sizes from the beach by waves leaving the remaining beach coarser sediments near the shore and the finer away from the shore (see Figs. 3.3.5-3.3.8).

4.2.4 Sorting across beach profile

The degree of sorting normal to the shoreline, Miller and Zeigler (1958, 1964) subdivided the beach and surf zone into several zones which are characterized by dynamic conditions of those zones. The largest sediment particles at the plunge point of the breaking waves, (Fox, Ladd, and Martin (1966) exhibit the poorest sorting due to the mixing of two modes occured (Fig.4.2.4). On the other hand, Miller and Zeigler (1958) found that, the highest degree of sorting was in the breaker zone with progressively poorer sorting on both seaward and shoreward directions.

a) Foreshore, with the graded sorted near the top of the foreshore, with the best sorted near the top of the foreshore in profiles A, B, C, J and K. Continuing downslope, a irregular contour pattern with poor-sorted (Fig. 4.2.4).

b) Breaker zone, the values of the sorting eoefficient of the sample points in this zone are either both higher or both lower than the sample in zone foreshore or shoaling waves zone (Miller and

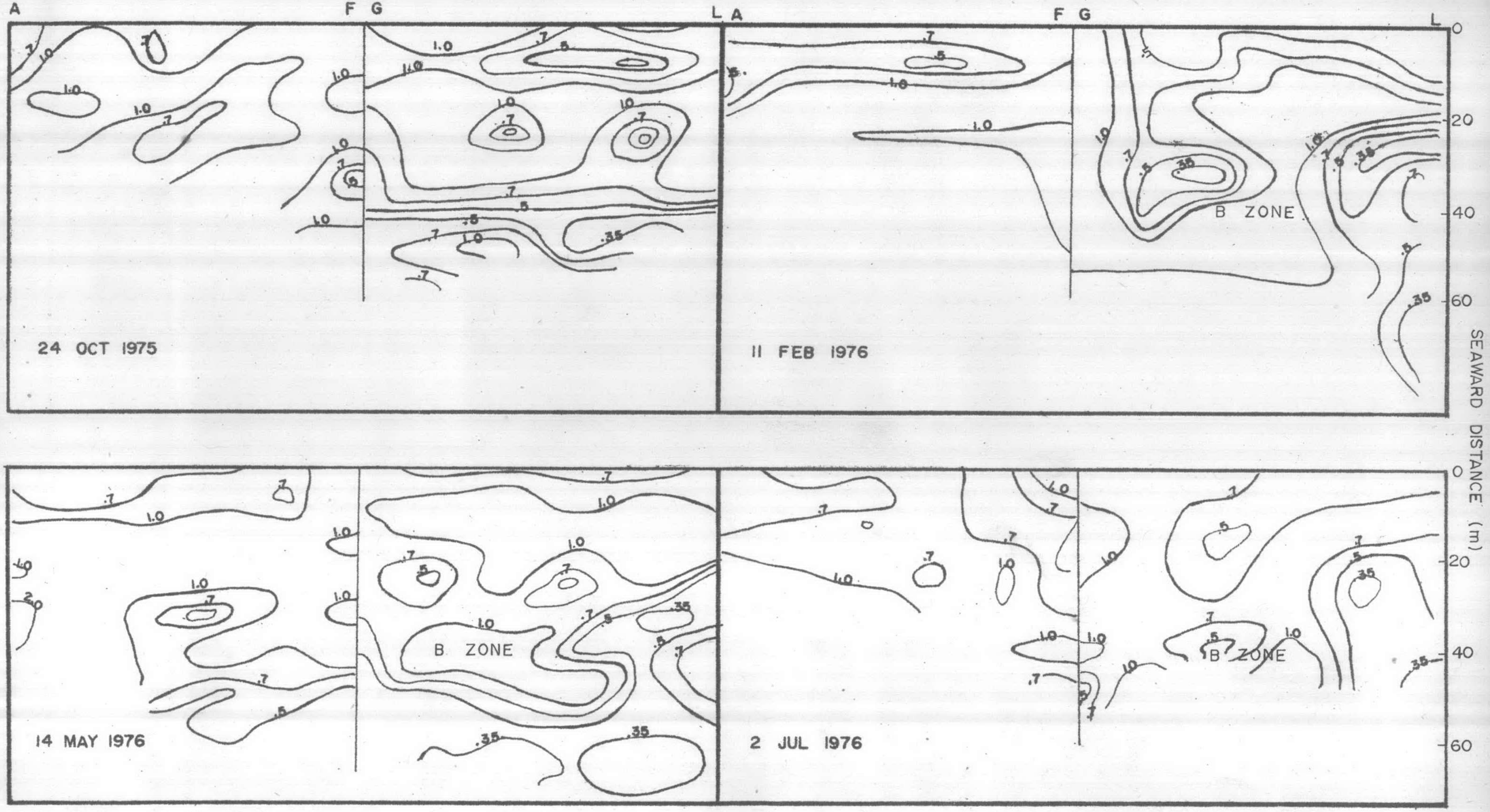

FIGURE 4.2.4. PATTERNS OF SORTING DISTRIBUTION OF SEDIMENTS IN THE FORESHORE, BREAKER AND SHOALING - WAVES ZONES, CONTOUR INTERVAL AFTER FOLK & WARD (1957).

Zeigler, 1958).

c) Shoaling waves zone, the sorting become better toward the shore with regular degree.

At two sides of the pier in profile F and G especially at the upper end of the pier, the sorting of the sediment is poor-sorted, downslope poor-sorted is alternated with moderately sorted.

4.3 OBSERVED TOPOGRAPHIC CHANGES

Map 1 indicates a series of changes in sediment level estimated as a result of the 5 surveys during the period between 12 July 1975 and 2 July 1976. These changes are in the form of isopleth maps, which give lines of equal cut or fill from one survey to the next.

The changes in sediment level shown on the isopleth maps represent the net changes that occurred during each survey period (period averaged approximately 105 days). Changes up to a maximum of + 2.57 m. have been observed against the west of the pier in one year. Fill and deepening have alternated between seasons.

In figuring the total volume of change a polar planimeter was used to obtain the area between contours and estimates were made of the average change within the contours rather than taking the mean depth represented by the two contours. The net cumulative changes in the volume of sediment in this area in one year survey period are shown in Map 1 e. The total area covered by the survey was about 120,000 square meters.

Table 4.4.1 gives in summary form, the net changes estimated between each survey. The significance of the changes can be considered to best advantage by a separate discussion of each period.

a) 12 July 1975 to 24 October 1976

During this period the net change in the up-drift side of the pier is estimated as a fill of 183 cubic metres, the zone from profile A to D shows a cut of 3,342 cubic metres and the beach has undergone a cut along the profiles. But the zone near the pier, profile E and F show a fill of 3,525 cubic meters and the zone on the down-drift side of the pier is fill of 49 cubic meters. The beach sediments appear to have shifted more in a direction parallel to the shore than in the up-drift side and there has been a small cut at the top of profile G and at profile K and L.

Deposition occurred over the top and the losses are indicated on the seaward portions of profile H, I and J.

b) 24 October 1975 to 11 February 1976

During the second period the zone of cut and fill reversed to the first period, the fill zones in the first period change to cut in this period especially at two sides of the pier show a net cut of 1,800 cubic meters at up-drift side (profile F) and 1,002 cubic metres at down-drift side (profile G).

The net cut of beach materials by erosion along the up-drift beach amounts to 3,590 cubic metres and along the down-drift Beach amounts to 6,050 cubic metres. It is of interest to note that the down-drift beach undergoes greater cut than the up-drift beach. The diagram shows clearly that the beach surface moved down vertically 0.07 to 1.18 m. These corresponding to that of in King (1972).

c) 11 February 1976 to 14 May 1976

In the third period the cut is apparent between profiles c to E and less pronounced on the eastern portion of the pier. The fill in the vicinity of the pier area is obvious. It is interesting to note the pattern of outer "fill" zone and inner "cut" zone which suggests a replacement outward of the inner sediments.

The fill of 1,473 cubic metres is calculated for profile F on the western side of the pier.

In the western part of the pier in particular the alternating bands of cut and fill roughly parallel to the shoreline is observed. As a consequence, two troughs develop in the outer zone.

The net change over this area in this third period, is the grestest fill between the seasons of the year. The western beach is greater fill than on the eastern beach, their amounts are 6,676 and 4,132 cubic metres respectively. The rapidity with which changes take place on a beach is both a blessing and on irritation.

d) 14 May 1976 to 2 July 1976

In the fourth period the cut of 3,400 cubic metres is estimated for the inner zone from profile A to E and the fill 5,290 cubic metres in the outside zone and the zone near the pier, which leaves a net fill for the up-drift area of 1,890 cubic metres and for the down-drift area of 319 cubic metres.

However, it will be observed that the cut along the shore was normal. One net effect of this cut was the development of bars and troughs in the down slope zone, the troughs representing zone of greater cut and the bars less cut. Outside the trough there is another fill which occupies about the same width. The number of bars on beach profiles depends mainly on the overall slope of the nearshore-the more gradual the slope the greater the number of bars (Komar, 1976). Off steep beaches bars are generally absent. More commonly, two bars are present in the down-drift beach of this study area.

4.4 BEACH SEDIMENTATION.

Many lines of evidence suggest that almost all of beach sediments are of organic origin. Marine productivity in the offshore area of Sattahip Bay certainly responsible for the continuous supply of skeletal debris for beach sediments. These sediments are believed to be transported landward by the tides, waves and currents where they are eventually brought about net deposition of the skeletal debris on the beach.

The supply of terrigenous sediment from small creeks in the neighbourhood appears to be negligible. Marine productivity within the warm, shallow, and partially sheltered marine environment of the Sattahip Bay is therefore dominantly responsible for the sediment supply.

The general sedimentation pattern in the area studied over the period of one year reveals that on the western side of the pier the beach materials are slightly eroded whereas the beach on the other side is an accretional one. A remarkable changes occur in the vicinity of the pier. Approximatly within the 30 metres zone from the pier on each side shows various degree of sedimentation ranging from 0-0.5 metres to 1.5-2.0 metres.

The construction and structure of the pier are undoubted responsible for the extraordinary accretion of the beach materials in the area. The structure of the pier, in particular, is believed to have a pronounced impact on the hydrodynamic regime in the area and the sedimentation is subsequently resulted.

4.4.1 Effect of the Pier on Sedimentation

The pier, breakwater and other obstruction all influence the circulation pattern and alter the direction of the current flowing along the shore or longshore currents. Shepard and Inman, 1951 suggested that, in general these obstructions determine the position of one side of the circulation cell and in places where relatively straight beach as Sattahip beach are terminated on the down current side by obstructions, a pronounced rip extends seaward.

Between October 1975 and February 1976, the rips were visually observed at low tide, they were between profile H & I, between profile I & J at down-drift side of the pier. Their effect made the all cutting along profiles I and J and the down slope cut at profile H(Bowen and Inman, 1969).

4.4.2 Suspended Solid and Tides

The tidal variations of suspended solid at two stations 1, and 2 are shown in diagram of Fig. 3.3.17 to 3.3.20. Every diagram gives for each station a curve of tides and the corresponding curves of the concentrations of suspended solid against time.

At high tide much lower sediment concentrations occurs than at low tide. Suspended solid concentrations were low at the end of the flood tide on 12 July, 25 October 1975 and 14 May 1976 (Fig. 3.3.17, 3.3.18 and 3.3.20).

The rise during the ebb in Figure 3.3.17 to 3.3.20 may be due to an inward gradient, by wave action, which therefore extended to the bottom when the water became shallower (Postma, 1961).

Very high concentrations were found in the first flood water returning from the previous ebb water which much materials was kept in suspension around low tide.

The sample, taken around the middle of the flood again shows lower concentrations, probably partly because of the increased water depth and decrease of wave action. In addition the lower concentrations are partly because of the supply of flood water with low suspended solid concentrations from farther seaward (Postma, 1961).

TABLE 4.4.1

Summary of volume changes of beach materials two sides of the pier.

PERIOD	UP-DRIFT			DOWN-DRIFT		
	Cut	Fill	Net	Cut	Fill	Net
	Cu. Metres	Cu. Metres	Cu. Metres	Cu. Metres	Cu. Metres	Cu. Metres
12 July - 24 October 1975	3,342	3.525	+ 183	5,025	5,073	+ 48
24 October 1975 - 11 February 1976	6,487	2,897	-3,590	9,230	3,179	-6,050
11 February - 14 May 1976	1,649	8,325	+6,676	2,861	6,993	+4,132
14 May - 2 July 1976	3,400	5,290	+1,890	4,458	4,777	+ 319
12 July 1975 - 2 July 1976	6,048	7,968	+1,920	5,534	5,800	+ 266

And the most conspicuous feature of the graph is the great difference between the flood-tide part and the ebb-tide part of the curve : the flood peak of suspended solid is higher than the ebb peak and the minimum preceeding the flood maximum is higher than the minimum preceeding the ebb maximum, this agrees with Groen, 1967.

The reason for the different behaviour between high tide and low tide is the fact that the time span during which current velocities are sufficiently low to permit settling of fine materials is much longer at high tide than at low tide. The cause of this difference between the two tidal phases are, first, the decrease of mean current velocities from the tidal inlets towards the coast and secondly, the asymmetrical shape of the ebb and flood curves.

The ebb peak of the suspended solid is the lower one because it has to be reached from a much lower preceding minimum (Postma, 1961) of flood water.

4.5 CONCLUDING REMARKS

There are increasing demands on the shorelines of the Gulf of Thailand for recreation, shipping, industry and marine resources of various kinds. Unfortunately, the understanding of the coastal environment has not yet advanced to the point where today's problems can be handled adequately. Therefore, it is imperative that an attempt should be made to develop the means to preserve the beaches and ports that are now available, especially for military purposes, are of greater importance. It is apparent that a relatively deep water nearshore is desirable for harbours.

In this area, the pier was constructed across the beach perpendicular to the direction of the longshore current, thus it partly interrupts the longshore transport of sediments from the west and allow the littoral sediments to pass through the pier and deposit in the down-drift site of the pier.

In order to minimize the sediment transport and protect waters for shipping, it is possible that a combined operation could be done by the following methods.

a) Groins produce a decrease in the breaker angle with the beach will decrease the wave energy, so decreasing the longshore transport rates of sediments. It should be constructed up-drift site of the pier and extend seaward from the upper beach, usually to a point some distance seaward of the breaking waves.

b) A detached breakwater constructed in some distance offshore and aligned parallel to the shore to dissipate wave energy before the wave reach the beach. If this structure is close to the shore, the wave shadow falls directly on the shore and will cause the sediments to accrete behind the breakwater. The situation offshore at Ko Phra noi is best served to construct the detached breakwater.

c) Dredging at intervals over long periods of time will assist to clear waterway for small vessels, but in shipping large deep-draft vessels it is recommended to utilize offshore islands and deep anchorages rather than dredging inland harbours areas.

d) Extension of the length of the pre-existing pier in the seaward direction, preferably further beyond the 4-metre bottom contour zone could be the economic remedial measure for the maximum utilization of the pier.