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EMA-T 8805

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REPORT ON THE DYNAMICS OF THE KLEINEMONDE WEST AND EAST ESTUARIES (CSE 13 AND 14)

by

P Badenhorst

August 1988

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REPORT ON THE DYNAMICS OF THE KLEINEMONDE WEST AND EAST ESTUARIES (CSE 13 AND 14)

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ABSTRACT

The data report on the Kleinemonde East and West estuary contains as far as possible all relevant data which can have an influence on the physical processes taking place in the estuaries and mouth area.

Also included is a survey of part of the Kleinemonde West estuary and the mouth area of the Kleinemonde West and East estuaries.

The effects on sedimentation processes taking place in the lower reaches of the estuaries are discussed with the aim to resolve whether the bridge caused sedimentation rates to increase.

1. INTRODUCTION

The aim of this report is (a) to provide all relevant data which can have an influence on physical processes taking place in the estuaries and the mouth area, (b) to describe the present and historic dynamics of the mouth area and (c) to discuss the effects of artificial changes on the physical processes.

A survey of part of the system is included to serve as a base for future reference and to throw some light on the effects of artificial changes such as the road bridges. The survey was carried out on 27 and 28 February 1986 by Messrs P Badenhorst, L van der Merwe and J P Möller. Mr L van der Merwe produced Figures 9 and Miss J B Crowley produced Figure 10.

The basic data is discussed in Chapter 2 with the historic and artificial changes in Chapters 3 and 4, respectively. A summary of the characteristics and dynamics of the mouth area and the effects of artificial changes is given in Chapter 5.

2. BASIC DATA

2.1 General

The Kleinemonde East and West estuaries are situated about 11 km north of Port Alfred (see Figure 1). The coastal road from Port Elizabeth to East London crosses the estuaries about 750 m from the mouth.

The two rivers reach the sea together on coordinates 33°33'S and 27°02'E. The mouth is usually closed with a sandbar on part of which overwash during high tides can take place. On the rest of the bar mobile dunes are formed.

2.2 Hydrology

The simulated mean annual run-off for the Kleinemondes East and West (MAR) from the respective catchment areas of 46,3 km^2 and 93,7 km^2 is $2x10^6m^3$ and $4,04x10^6m^3$ (see Tables 1 and 1a).

The monthly simulated run-off for the Kleinemondes East and West is shown on Figures 2 and 2a with the simulated annual respectively run-off in Figures 3 and 3a. The cumulative run-off is shown in Figures 4 and 4a (all values calculated from Pitman **et al.,** 1981 revised).

From Tables 1 and 1a it can be seen that the mean run-off is higher than the median run-off which means that the run-off is very erratic. In the Kleinemonde West monthly run-off events bigger than the MAR occurred ten times between the years 1921 to 1977, that is 1,5 per cent of the time. None of these flood events occurred in the months of December, January, February, July and August.

2.3 Wind Data and Aeolian Transport

2.3.1 Wind

The wind frequencies and directions for the area 1°block, calculated from VOS - data (VOS - Voluntary Observing Ships), are shown in Figure 5, Observed data for the Great Fish Lighthouse is shown in Figure 6.

From these figures it can be concluded that prevailing southwesterly and westerly winds occur most frequently with winds from the northeastern sector occurring occasionally all year round.

2.3.2 Aeolian (wind-blown) sediment transport

The aeolian transport calculations for the area are shown in the form of a creep diagram in Figure 7 (Swart, 1986).

From the "all year" diagram the potential aeolian sand transport rates (cubic metres per kilometre width perpendicular to the prevailing wind) can be calculated.

TABLE 3: Potential aeolian drift at Kleinemonde Beach

Component	Aeolian Drift Rate m^3/yr/km
Eastbound	24 000
Westbound	6 000
Northbound	2 000
Southbound	600

From Table 3 and the creep diagram it can be seen that the net sediment movement is towards the north east, which is in agreement with the aerial photograph interpretation (see Section 3).

2.4 Waves

No measured wave data is available for the area. The yearly wave data from VOS (Swart and Serdyn. 1981) is shown in Figure 8.

Waves approaching the coast obliquely generate a longshore current in the surfzone which flows in the down-wave direction. Owing to the orientation of the coastline and due to the screening off of swells by Cape Padrone to the west and Great Fish Point to the east, only deep sea swells within a sector between 60° and 250° can reach the area of the Kleinemondes.

The swell roses show a predominance from the SE sector (200° to 250°) which indicates a predominantly eastbound longshore current and longshore sediment movement.

Variations in the wave climate cause short-term on/offshore sediment transport and in general beach erosion takes place due to storm waves while the beach accretes during calm sea conditions.

2.5 Survey

A survey of the Kleinemonde East and West mouth and about 1 km of the west estuary was carried out on 27 and 28 February 1986. The spot heights and general layout is shown in Figure 9 with the contour map in Figure 10. To quantify any sedimentation in the estuary it is now surveyed annually as part of an estuarine monitoring programme. Four surveys have already been done and a data report is being compiled.

Cross-sections of the February 1986 survey are shown in Figures 11a, 11b and 11c with a long section of the estuary in Figure 11d. The cross-sections show that the estuary bed is generally above mean sea level (MSL) with the sandbanks nearly on

MSL+1 m. This means that with an open mouth at low tide very low water depths will be present.

2.6 Mouth Dynamics

In 1938 the Kleinemonde West and East had separate mouths but since then the rivers usually flowed out to see through a single mouth. The predominant northeasterly going aeolian and longshore sediment movements both contribute to the process of mouth closure when the river flow dropped after rainy periods. The mouth usually closes from southwest to northeast leaving an overflow channel for some period of time. Normally overwash takes place during high tides but the mouth area can become totally plugged by northeasterly moving transverse dunes. For flood-time dominated estuaries such as these, a net movement of sand generally takes place into the estuary, resulting in the formation of sandbanks.

The overflow channel at the time of the survey of February 1986 was on a level of about MSL+1,8 m which means that this is the maximum water level in the estuary. Although the mouth can become totally plugged with a resulting higher sandbar level the lowest part in the road on the right bank of the Kleinemondes West estuary is on a level of MSL+2,3 m. It is therefore clear that the maximum permissible water level in the estuary is about MSL+2,3 m at which the mouth will have to be opened. With the sandbank formation in the estuary downstream of the Kleinemonde West bridge it is very important that in the event that the mouth is artificially breached it should be done at the maximum water level in an effort to flush some of the sand out of the estuary and to keep artificial breaching to an absolute minimum.

3. HISTORIC CHANGES

To obtain an idea of the recent (later than 1938) changes of the estuarine areas near the mouth six sets of aerial photographs were studied (see Table 2). On all the photographs the mouth/s of the estuaries are closed. Channels in the mouth areas on the photographs of 1979 and 1981 seem to indicate that they were open in the period shortly before the photographs were taken. Knowledge of these small estuarine systems, evidence of locals and the aerial photographs indicate that the mouths of the estuaries are usually closed with an open system for only a short period after floods.

The following observations can be made from the aerial photographs: (The mouth areas are shown in Figures 12 to 16)

1938 (Figure 12) : The mouths are closed and dune ridges in the mouth areas and further towards the northeast can clearly be seen. Houses already exist at the south side of the Kleinemonde West estuary on the edge of the vegetation near the mouth.

1955 (Figure 13) : The mouths are closed and the channels are towards the northeastern side which is due to the effect of the predominant southwestern and western winds that blow most of the year. Further towards the northeast the dune ridges are clearly visible. Sand banks were formed on both sides of estuary mouths. The salt marsh areas in the estuaries at the top of the Figure are increasing in size. Two sandbanks are forming in the Kleinemonde West river.

1979 (Figure 14) : The mouths are closed and the wetline is clearly visible on the photograph. Two bridges with openings of about 20 m were constructed over the estuaries in 1974. More sandbanks are visible downstream of the bridge on the West Kleinemondes. The salt marsh areas are bigger and a new area is forming downstream of the bridge on the East Kleinemondes. It is interesting to note that the bridge in the Kleinemonde West is sited on the sandbanks seen in Figure 13.

1981 : (Figure 15) The mouths are closed and dune ridges, lying in a northeasterly direction, can be seen on both sides of the estuaries. The salt marsh and sandbanks are fairly similar in size compared with those seen on the photograph 1979 (Figure 14).

1987 : (Figure 16) Although the mouth is closed the wetline, connecting the river with the sea, is visible. Dune ridges along the coastline can clearly be seen. A parking area has been established on the beachfront between Kleinemonde West and East. The saltmarsh areas are slightly bigger especially downstream of the East Kleinemonde bridge. There are fewer sandbanks downstream of the West Kleinemonde estuary probably due to a flood shortly before the photograph was taken. Evidence of such a flood is the fact that an overflow channel is still present.

The aerial photographs show that a slow process of sedimentation was present since the earliest photograph of 1938. This is a natural process present in most estuarine systems. This process was probably locally accelerated by the building of the bridges. Evidence of this can be seen in the formation of sandbanks downstream of the West Kleinemondes bridge and the formation of salt marsh areas downstream of the East Kleinemondes bridge. It must however be kept in mind that sandbanks were already present in 1955 at the position where the bridge was later built. Most probably this is the reason for siting the bridge at this position.

The aerial photographs also indicate a sediment movement across the mouth area from southwest to northeast which supports the aeolian sediment movement and longshore transport calculations.

4. ARTIFICIAL CHANGES

From the aerial photographs the conclusion was made that a slow process of sedimentation was taking place, probably locally accelerated since the building of the bridges. In an effort to further quantify the effect of the bridges cross-sections and vibracores were taken. An attempt was also made to run a computer model on the estuary to try and calculate the pre and post bridge levels and scour.

Computer Model

The computer model could not easily handle the specific case but with a few assumptions it indicates that the bridge opening on the West Kleinemonde can handle flood flows although it predicts a slight build-up of water level upstream of the bridge. Scour calculations indicate no major change in potential scour for pre and post bridge conditions. However, because of a lack of calibration data and other programming problems more specific answers are not possible at this stage.

The fact that some damming-up is shown by the model is quite possible because the sediments on the bed is much finer, even muddy, upstream of the bridge when compared to downstream.

Cross-sections and Vibracores

For the purpose of positioning and leveling of the vibracores further cross-sections were taken on 17 November 1986. The position of the cores and sections are shown in Figure 17a with the cross-sections in Figures 17b to f. As expected when comparing these cross-sections with the ones of February 1986 no difference can be seen. The long-term monitoring programme should be able to over a few years quantify the sedimentation rate.

The three vibracores taken are shown in Figures 18a to c. Core 1 (Figure 18a) is to a depth of MSL-2,4 while Cores 2 and 3 (Figures 18b and c) are to a depth of MSL-1,3 m. Core 1 indicates a coarse layer at MSL-1,5 and it can be assumed that Cores 2 and 3 were not able to penetrate this layer. When comparing the three cores above MSL-1,3 there is no major difference between them except that Cores 2 and 3 are slightly finer at the top than Core 1 which support on-site observations.

In the event that the bridge had played a major role in sedimentation a marked difference in Core 1 (downstream of the bridge) and Cores 2 and 3 (upstream of the bridge) would have been obtained as a result of the marine source of sand downstream of the bridge as compared to the fine fluvial source of sediment upstream of the bridge.

It is therefore most unlikely that the bridge played a major role in sedimentation except for locally accelerating the process by the faster growth in salt marshes and formation of sandbanks. The sandbanks in the West Kleinemonde which is up to a height of MSL+0,8 m further decrease the already shallow water depths in the area downstream of the bridge.

5. SUMMARY

From the above discussion the following conclusions are drawn:

1. The predominant sediment movement is from southwest to northeast resulting in relatively short periods of mouth openings because the sediment supply and movement quickly closes the mouth when the river flow dropped.

2. The mouth's are usually closed with openings only after major river flows after which the mouth closes relatively quickly leaving an overflow channel for some period of time. Overwash normally takes place during high tides but the mouth area can become totally plugged by northeasterly moving transverse dunes from time to time.

3. The Kleinemonde West estuary is in general very shallow with bottom levels in the channels of about MSL and the top of the sandbanks on about MSL+0,8 m.

4. Levels of the road and some buildings on the right bank of the Kleinemondes West estuary control the maximum permissible water level in the estuary at about MSL+2,3 m. In February 1986 the overflow channel was surveyed at MSL+1,8 m.

5. Due to the fact that in these flood tide dominated estuaries there is in general a net gain in sediment during times of mouth openings it is important to keep mouth openings to a minimum and should an artificial breaching be necessary the water level must be the maximum permissible.

6. A slow process of sedimentation has been taking place in both estuaries since the earliest available aerial photographs of 1938. This is a natural process taking place in most estuaries.

7. From the available data the building of the bridges in the Kleinemondes East and West has had no major influence on the sedimentation rates of the estuaries. It seems, however, likely that the bridges have had some local effect on sedimentation in that there was a marked increase in salt marsh area downstream of the Kleinemonde East bridge and the formation of sandbanks downstream of the Kleinemonde West bridge. It must however, also be kept in mind that the 1955 aerial photograph already show sandbanks in the Kleinemonde West estuary at the position of the present bridge.

8. Although the aerial photographs indicate that sedimentation seems to take place quantification of this will only be possible by surveying of cross-sections over a period of years. Such surveys are being under-taken since February 1986 and these should in time give some indication of the sedimentation process.

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YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	%M.A.R.
1921	.00	.51	.23	.03	.00	.00	.01	.04	.37	1.78	.55	.02	3.54	177.57
1922	.01	4.76	1.59	.23	.09	.01	.00	.00	.00	.01	.00	.00	6.69	335.55
1923	.01	.01	.00	.01	.01	.00	.00	.00	.00	.00	.00	.01	.06	2.84
1924	.00	.00	.04	.02	.00	.41	.18	.02	.04	.01	.00	.06	.79	39.70
1925	.02	.00	.01	.00	.00	.02	.01	.01	.01	.00	.00	.01	.11	5.36
1926	.07	.08	.02	.00	.00	.00	.00	.01	.00	.00	.00	.00	.18	9.24
1927	.00	.00	.00	.00	.00	1.89	.63	.00	.00	.00	.00	.08	2.61	130.64
1928	.16	.05	.01	.00	.00	.01	.00	.00	.09	.06	.02	.87	1.27	63.65
1929	.53	.08	.00	.00	.01	.45	.15	.00	.02	.01	.03	.03	1.31	65.47
1930	.36	.12	.03	.04	.01	.01	.11	.03	.00	.18	.06	.02	.97	48.67
1931	.39	.13	.37	.27	.05	.00	.00	.00	.00	.01	.00	1.47	2.70	135.20
1932	.60	.16	.04	.00	.02	.01	.15	.05	.00	.00	.16	.06	1.26	63.23
1933	.00	.07	.04	.12	.10	.36	.11	.00	.00	.51	.17	.00	1.49	74.44
1934	.04	.04	.01	.00	.00	.00	.33	4.23	1.38	.00	.08	.04	6.15	308.45
1935	.02	.02	.01	.00	.01	.02	.01	.01	.00	.00	.00	.00	.11	5.48
1936	.40	.64	.17	.00	.00	.03	.01	.00	.00	.00	.00	.00	1.24	62.38
1937	.00	.06	.29	.12	.02	.08	.06	.01	.00	.00	.00	.00	.64	32.22
1938	.05	.38	.13	.01	.95	.72	.14	.00	.00	.01	.01	.06	2.45	123.02
1939	.19	.06	.00	.00	.34	.80	.23	.00	.00	.00	.00	.02	1.64	82.43
1940	.01	.14	.05	.00	.02	.01	.42	.14	.00	.00	.00	.00	.78	38.94
1941	.74	.25	.16	.11	.02	.02	.01	.03	.01	.00	.00	.00	1.36	67.96
1942	.13	.05	.00	.04	.01	.00	.04	.01	.04	.01	.01	.00	.36	18.15
1943	.00	.23	.21	.05	.03	.54	.18	.38	.13	.00	.00	.20	1.95	97.88
1944	.07	.00	.00	.01	.01	.00	.00	.02	.06	.02	.00	.00	.19	9.61
1945	.04	.01	.00	.00	.00	.20	.07	.00	.00	.00	.00	.00	.32	16.16
1946	.04	.02	.00	.01	.00	.32	.11	.00	.02	.03	.01	.00	.55	27.71
1947	.01	.04	.02	.00	.06	.02	1.22	.41	.00	.00	.00	.00	1.78	89.44
1948	.10	.03	.00	.00	.01	.00	.00	.00	.00	.00	.00	.00	.15	7.38
1949	.00	.94	.31	.00	.00	.00	.00	.05	.02	.01	.01	.00	1.35	67.72
1950	.25	.35	.72	1.11	.30	.01	.00	.00	.00	.01	.00	.63	3.37	169.12
1951	.21	.00	.00	.02	.19	.06	.00	.01	.00	.00	.00	5.77	6.28	314.66
1952	1.92	.00	.00	.00	.02	.01	.00	.00	.01	.00	.19	.21	2.36	118.34
1953	6.25	2.73	.22	.00	.00	.48	.16	.14	.05	.00	.01	.01	10.05	503.49
1954	.00	.06	.02	.01	.05	.03	.01	.00	.00	.00	.00	.00	.19	9.75
1955	.00	.21	.07	.00	.00	.01	.00	.03	.01	.00	.00	.48	.81	40.62
1956	.16	.04	.09	.03	.16	.11	.02	.00	.00	.00	.00	.05	.67	33.46
1957	.02	.00	.00	.00	.00	.01	.01	2.08	.69	.00	.00	.00	2.82	141.46
1958	.02	.01	.13	.10	.02	.08	.09	.03	.00	.12	.04	.00	.64	32.03
1959	.00	.00	.00	.04	.01	.00	.01	.03	.01	.00	.00	.05	.16	8.18
1960	.10	.05	.01	.01	.01	.04	.02	.10	.03	.01	.01	.00	.38	18.90
1961	.00	.01	.00	.00	.01	.73	.27	.01	.00	.00	.00	.00	1.03	51.61
1962	.20	.08	.00	.26	.09	3.45	2.57	.48	.00	.02	.01	.00	7.15	358.34
1963	.02	.01	.01	.00	.32	.11	.00	.00	.12	.04	.00	.46	1.10	55.37
1964	.15	.00	.00	.00	.00	.00	.00	.03	.04	.01	.00	.01	.25	12.52
1965	.39	.48	.12	.01	.01	.01	.00	.01	.00	.00	.04	.01	1.08	54.04
1966	.00	.06	.02	.00	.01	.13	.09	1.20	.40	.03	.01	.00	1.96	98.10
1967	.00	.00	.00	.00	.00	.04	.06	.02	.87	.29	.00	.09	1.36	68.26
1968	.03	.00	.00	.00	.10	.31	.09	.00	.00	.00	.00	.00	.54	27.03
1969	.01	.00	.00	.00	.01	.00	.00	.00	.00	.00	1.95	.66	2.62	131.56
1970	.22	.07	1.77	.59	.07	.03	.07	.03	.00	.01	.50	.17	3.54	177.37
1971	.03	.01	.02	.02	.06	.02	.00	.00	.00	.00	.00	.00	.16	8.18
1972	.00	.02	.01	.00	.04	.02	.01	.00	.00	.00	.02	.01	.14	6.79
1973	.00	.17	.09	.16	.18	4.85	1.60	.22	2.71	.88	1.47	1.03	13.37	670.19
1974	.18	.05	.02	.01	.02	.01	.00	.00	.00	.00	.00	1.97	2.27	113.65
1975	.66	.00	.10	.03	.01	.81	.27	.00	.00	.25	.08	.00	2.21	110.67
1976	.17	.09	.01	.00	.25	.08	.02	.42	.14	.00	.00	.01	1.19	59.79

KLEINEMONDE WEST

SIMULATED RUN-OFF - 1921 TO 1976

Kleinemonde East

CSIR - EMA

TABLE 1

CSIR - EMA

SIMULATED RUN-OFF - 1921 TO 1976

Kleinemonde West

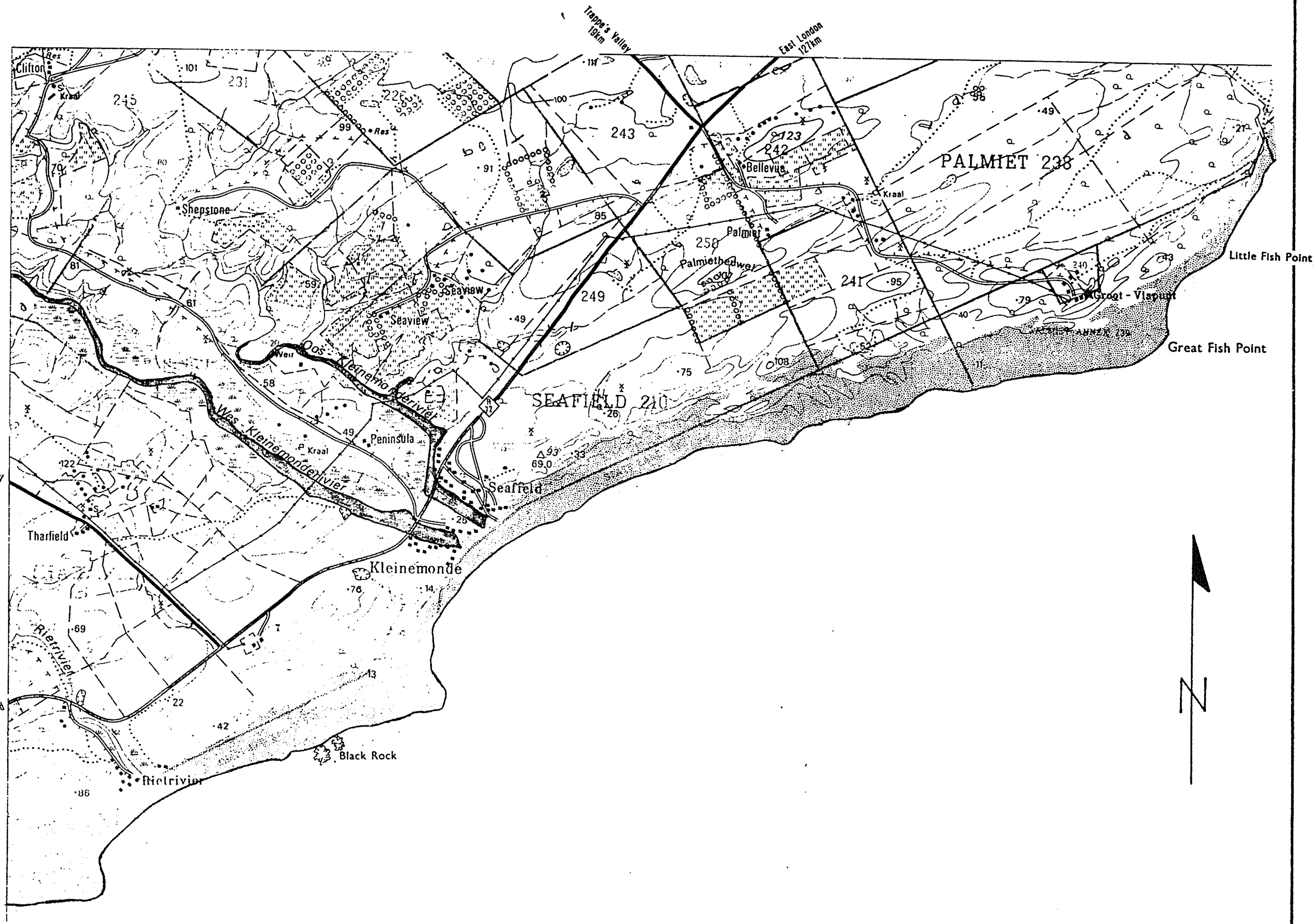
KLEINEMONDE WEST

TABLE 1 A

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	%M.A.R.
1921	.00	1.03	.47	.05	.01	.01	.02	.07	.75	3.60	1.12	.04	7.17	177.57
1922	.01	9.63	3.21	.46	.18	.01	.00	.00	.00	.02	.01	.00	13.54	335.55
1923	.03	.01	.01	.03	.01	.00	.00	.00	.00	.00	.00	.01	.11	2.84
1924	.00	.00	.08	.05	.01	.83	.37	.04	.08	.03	.00	.12	1.60	39.70
1925	.05	.00	.03	.01	.00	.05	.02	.02	.01	.00	.00	.03	.22	5.36
1926	.15	.15	.04	.00	.00	.01	.00	.02	.01	.00	.00	.00	.37	9.24
1927	.00	.00	.00	.00	.00	3.83	1.28	.00	.00	.00	.00	.16	5.27	130.64
1928	.32	.10	.02	.00	.00	.02	.01	.00	.17	.13	.03	1.76	2.57	63.65
1929	1.08	.16	.00	.01	.03	.90	.30	.00	.04	.01	.05	.05	2.64	65.47
1930	.73	.24	.06	.08	.02	.01	.22	.07	.00	.37	.12	.04	1.96	48.67
1931	.79	.26	.75	.54	.10	.01	.00	.00	.00	.02	.01	2.97	5.46	135.20
1932	1.22	.33	.08	.00	.05	.02	.31	.10	.00	.00	.33	.11	2.55	63.23
1933	.00	.14	.07	.25	.20	.72	.23	.00	.00	1.04	.35	.00	3.00	74.44
1934	.09	.08	.02	.00	.00	.00	.66	8.56	2.79	.00	.15	.09	12.45	308.45
1935	.03	.05	.02	.00	.01	.04	.01	.03	.01	.01	.00	.00	.22	5.48
1936	.82	1.28	.34	.00	.00	.06	.02	.00	.00	.00	.00	.00	2.52	62.38
1937	.01	.12	.58	.25	.04	.16	.12	.02	.00	.00	.00	.00	1.30	32.22
1938	.10	.77	.26	.02	1.92	1.45	.28	.01	.00	.01	.03	.12	4.97	123.02
1939	.38	.11	.00	.00	.69	1.62	.47	.00	.00	.00	.00	.05	3.33	82.43
1940	.02	.28	.09	.01	.03	.01	.84	.28	.00	.00	.00	.00	1.57	38.94
1941	1.51	.51	.33	.22	.04	.05	.02	.06	.02	.00	.00	.00	2.74	67.96
1942	.26	.10	.01	.08	.03	.01	.07	.02	.09	.03	.03	.01	.73	18.15
1943	.00	.46	.43	.10	.06	1.10	.36	.77	.26	.00	.00	.40	3.95	97.88
1944	.15	.00	.00	.03	.02	.00	.00	.04	.11	.03	.00	.00	.39	9.61
1945	.09	.03	.00	.00	.00	.40	.13	.00	.00	.00	.00	.00	.65	16.16
1946	.09	.03	.00	.01	.00	.65	.22	.00	.04	.06	.01	.00	1.12	27.71
1947	.01	.09	.04	.00	.12	.05	2.47	.82	.00	.00	.00	.01	3.61	89.44
1948	.20	.07	.00	.00	.02	.01	.00	.00	.00	.00	.00	.00	.30	7.38
1949	.00	1.91	.64	.01	.00	.00	.00	.10	.03	.02	.02	.00	2.73	67.72
1950	.50	.72	1.45	2.24	.61	.02	.01	.00	.00	.01	.00	1.27	6.83	169.12
1951	.43	.00	.00	.04	.39	.13	.00	.03	.01	.00	.00	11.68	12.70	314.66
1952	3.89	.00	.00	.00	.03	.01	.00	.00	.02	.01	.38	.43	4.78	118.34
1953	12.64	5.52	.45	.00	.00	.98	.33	.27	.09	.00	.02	.02	20.32	503.49
1954	.01	.12	.04	.03	.11	.07	.01	.00	.00	.00	.00	.01	.39	9.75
1955	.00	.42	.14	.00	.00	.02	.01	.06	.02	.00	.01	.96	1.64	40.62
1956	.33	.09	.19	.05	.33	.22	.04	.00	.01	.00	.00	.10	1.35	33.46
1957	.04	.00	.00	.01	.00	.02	.02	4.21	1.40	.00	.01	.00	5.71	141.46
1958	.04	.02	.26	.20	.04	.16	.18	.05	.00	.25	.09	.00	1.29	32.03
1959	.00	.00	.01	.08	.03	.00	.01	.07	.02	.00	.00	.10	.33	8.18
1960	.21	.10	.01	.01	.02	.08	.03	.19	.06	.03	.02	.00	.76	18.90
1961	.01	.02	.01	.00	.02	1.47	.54	.02	.00	.00	.00	.00	2.08	51.61
1962	.40	.15	.01	.53	.18	6.97	5.21	.96	.00	.03	.01	.00	14.46	358.34
1963	.05	.03	.02	.01	.65	.22	.00	.00	.24	.08	.01	.93	2.23	55.37
1964	.31	.00	.01	.00	.00	.00	.00	.06	.08	.02	.00	.02	.51	12.52
1965	.78	.96	.23	.03	.01	.01	.00	.03	.01	.00	.08	.03	2.18	54.04
1966	.00	.12	.04	.00	.03	.27	.18	2.43	.80	.07	.02	.00	3.96	98.10
1967	.00	.00	.00	.00	.00	.07	.13	.04	1.76	.59	.00	.18	2.75	68.26
1968	.06	.00	.00	.00	.20	.63	.19	.00	.01	.00	.00	.00	1.09	27.03
1969	.02	.01	.00	.00	.01	.00	.00	.00	.00	.00	3.94	1.33	5.31	131.56
1970	.44	.14	3.59	1.20	.14	.05	.14	.07	.01	.02	1.02	.34	7.16	177.37
1971	.05	.02	.04	.03	.13	.04	.00	.00	.00	.00	.00	.01	.33	8.18
1972	.00	.03	.01	.00	.09	.04	.03	.01	.00	.00	.05	.02	.27	6.79
1973	.01	.34	.19	.33	.36	9.81	3.24	.44	5.48	1.78	2.98	2.09	27.05	670.19
1974	.37	.10	.04	.03	.04	.02	.00	.00	.01	.00	.00	3.99	4.59	113.65
1975	1.33	.00	.20	.07	.02	1.64	.54	.00	.00	.50	.17	.00	4.47	110.67
1976	.35	.18	.02	.00	.51	.17	.04	.84	.28	.00	.00	.02	2.41	59.79

TABLE 2: Available aerial photographs

Date	Job No.	Photo No.	Scale	Flown by
1938	134/38	14015	1:25000	Dept of Land Surveying, Mowbray
1955	360	9199	1:36000	"
1973	721	3585	1:50000	"
20/4/1979	326	198	1: 8000	Dept of Surveying, University of Natal
12/1980	374	82	1:20000	Dept of Land Surveying, Mowbray
12/1981	391	172/4	1:20000	Dept of Surveying, University of Natal



CSIR - EMA

LOCALITY PLAN

KLEINEMONDE WEST

FIGURE 1

KLEINEMONDE WEST

SIMULATED MONTHLY RUN-OFF
Kleinemonde East

CSIR - EMA

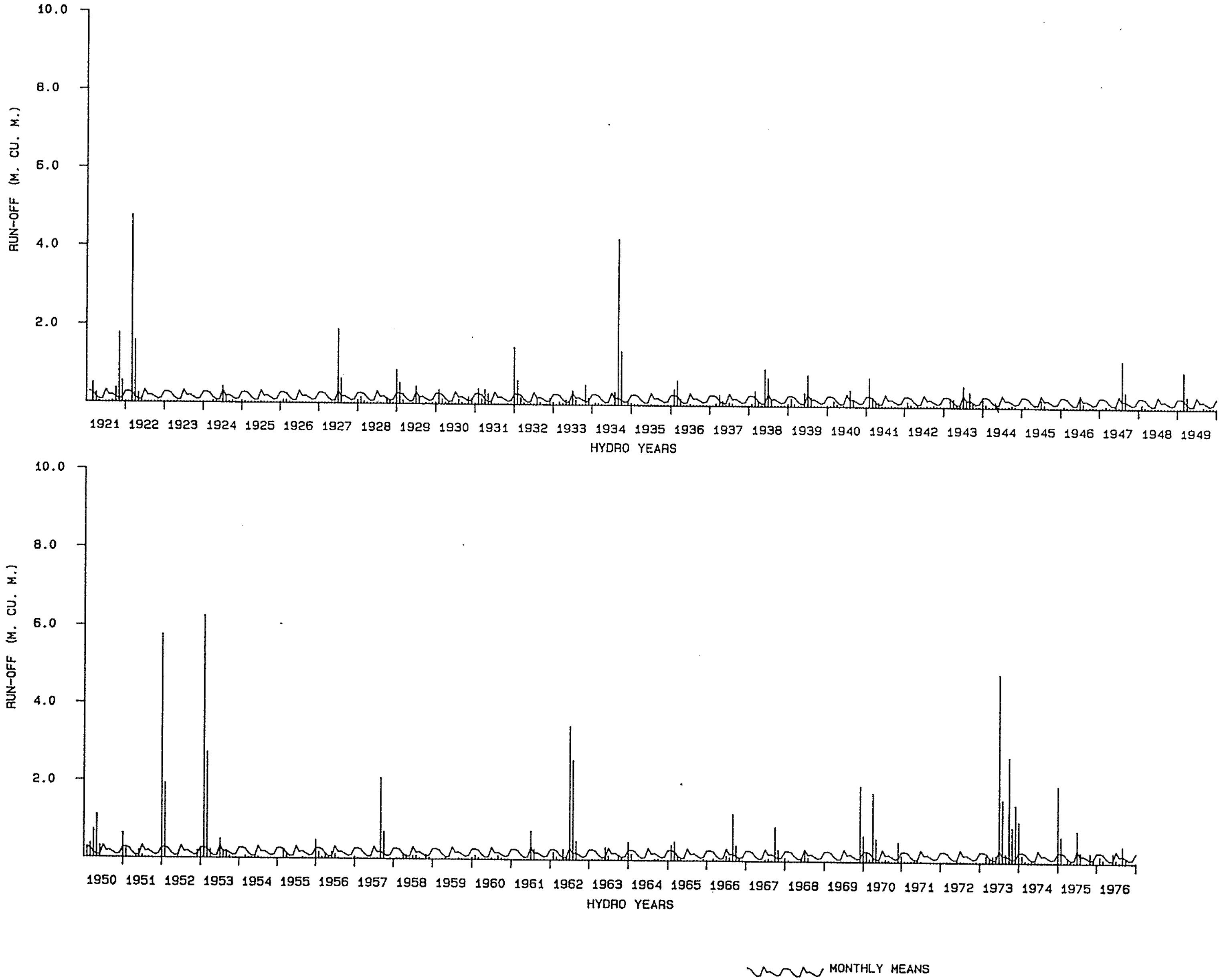
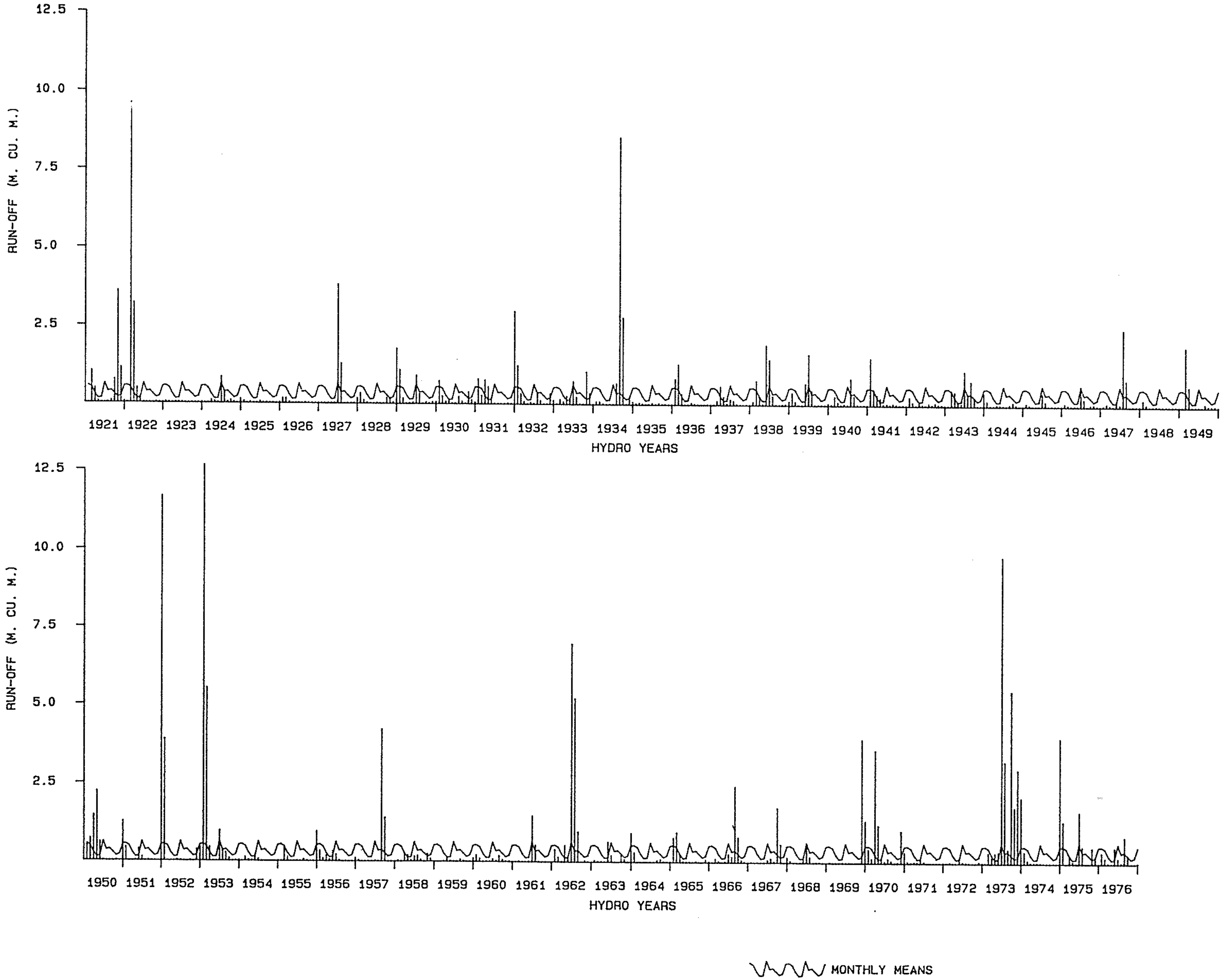


FIGURE 2

KLEINEMONDE WEST

SIMULATED MONHTLY RUN-OFF
Kleinemonde West



CSIR - EMA

FIGURE 2a

SIMULATED ANNUAL RUN-OFF
Kleinemonde East

KLEINEMONDE WEST

CSIR - EMA

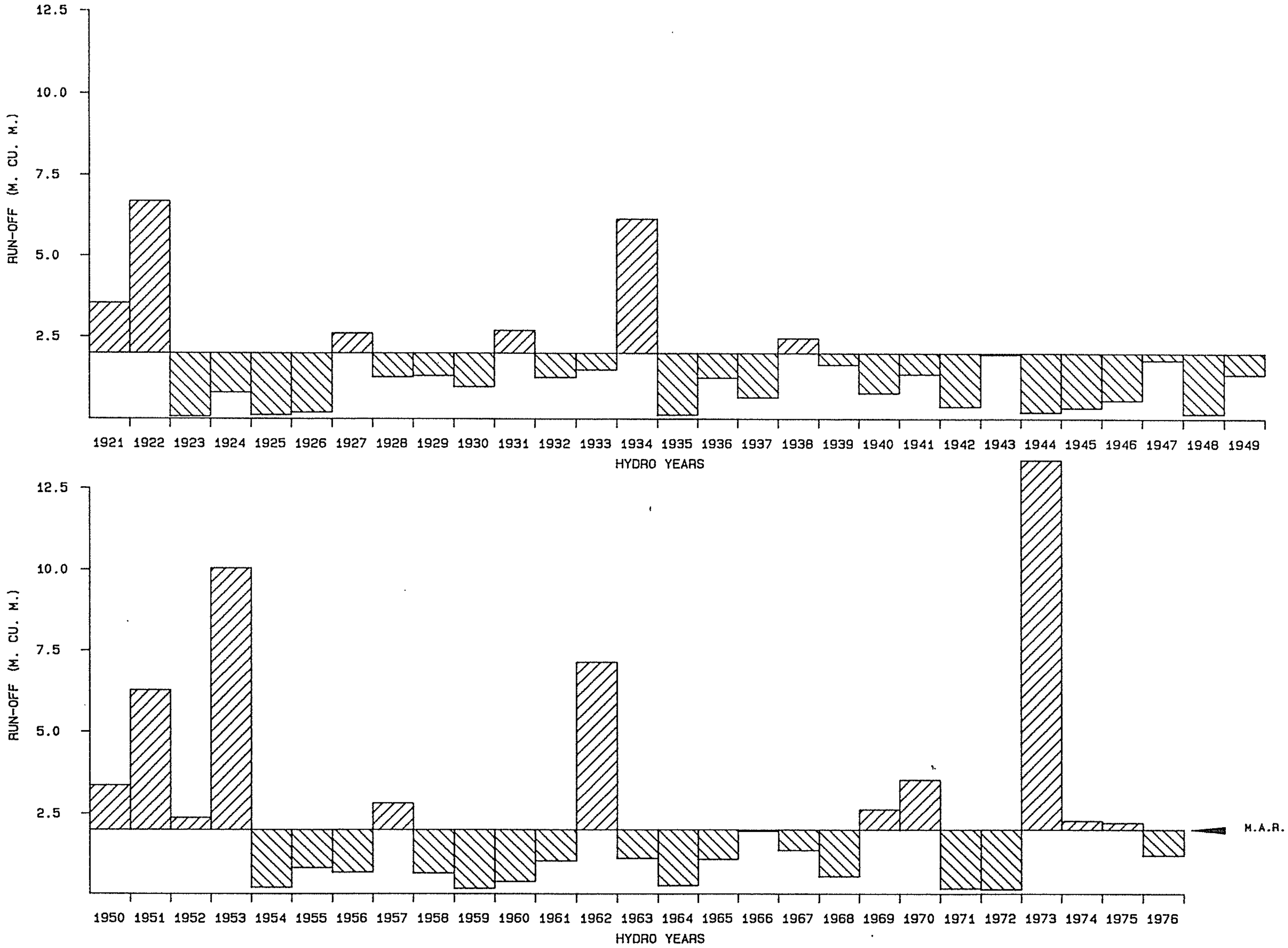
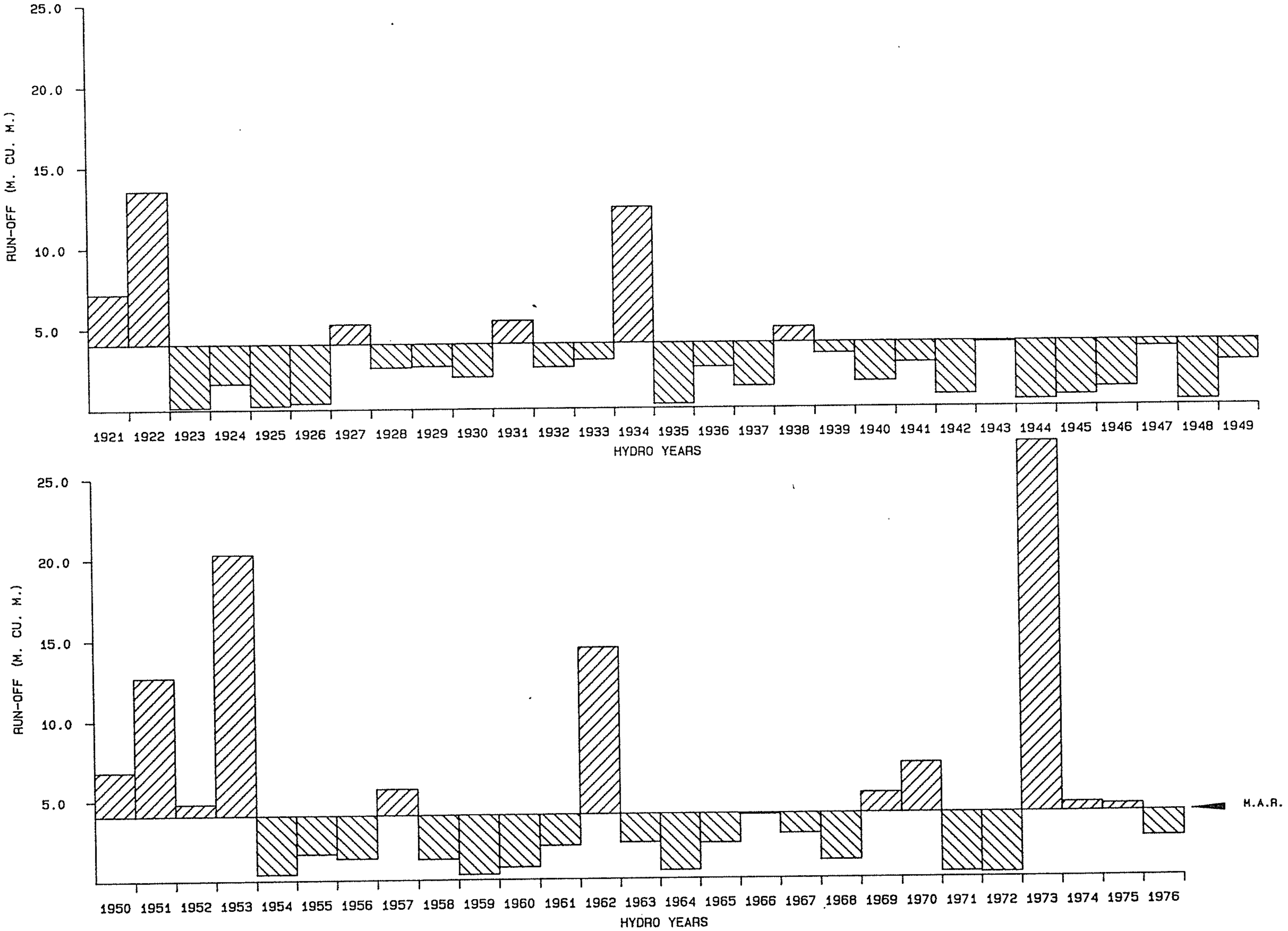


FIGURE 3

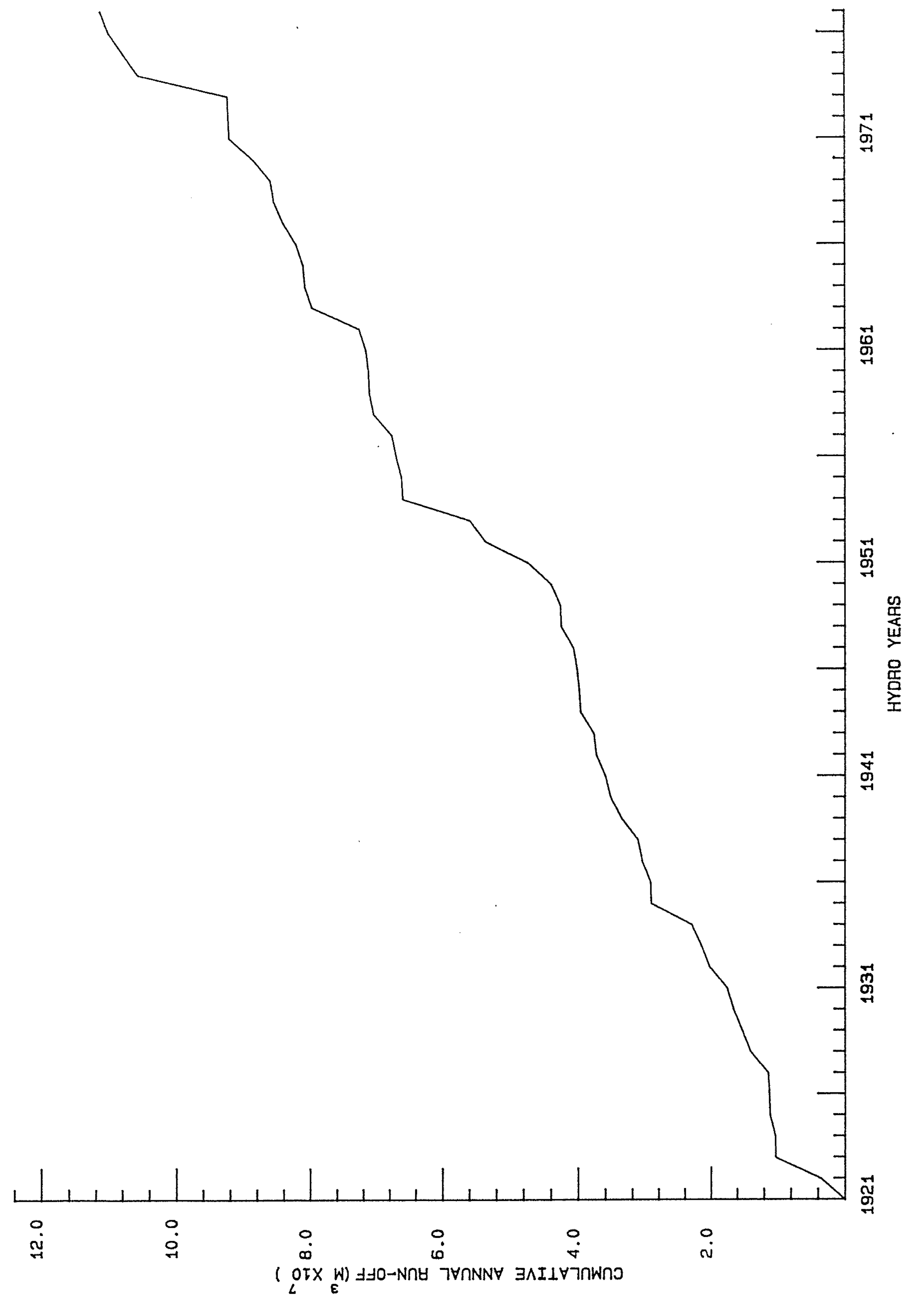
KLEINEMONDE WEST

SIMULATED ANNUAL RUN-OFF
Kleinemonde West



CSIR - EMA

FIGURE 3a



KLEINEMONDE WEST

CUMULATIVE ANNUAL RUN-OFF

Kleinemonde East

FIGURE 4

CSIR - EMA

CSIR - EMA

CUMULATIVE ANNUAL RUN-OFF
Kleinemonde West

KLEINEMONDE WEST

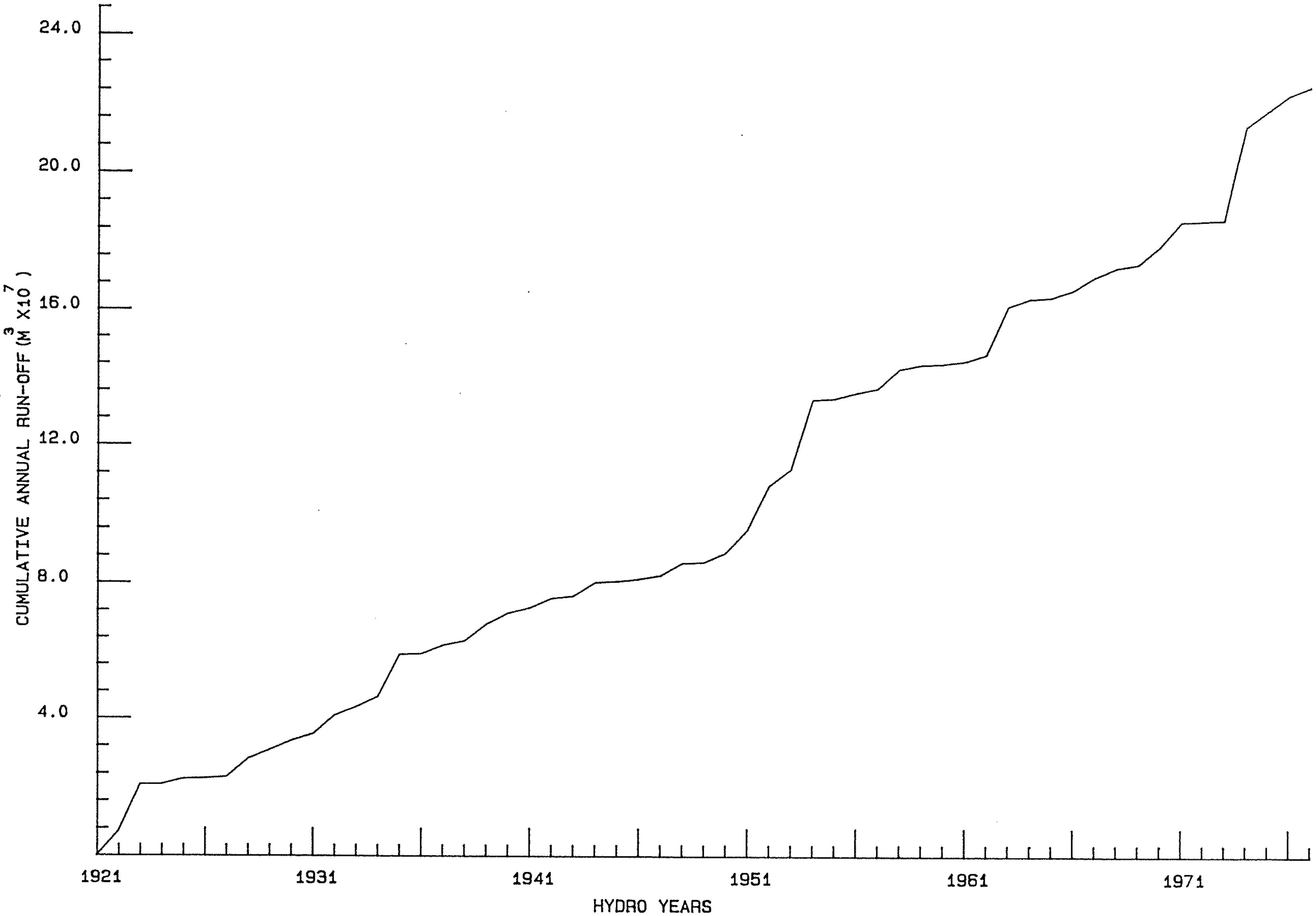


FIGURE 4a

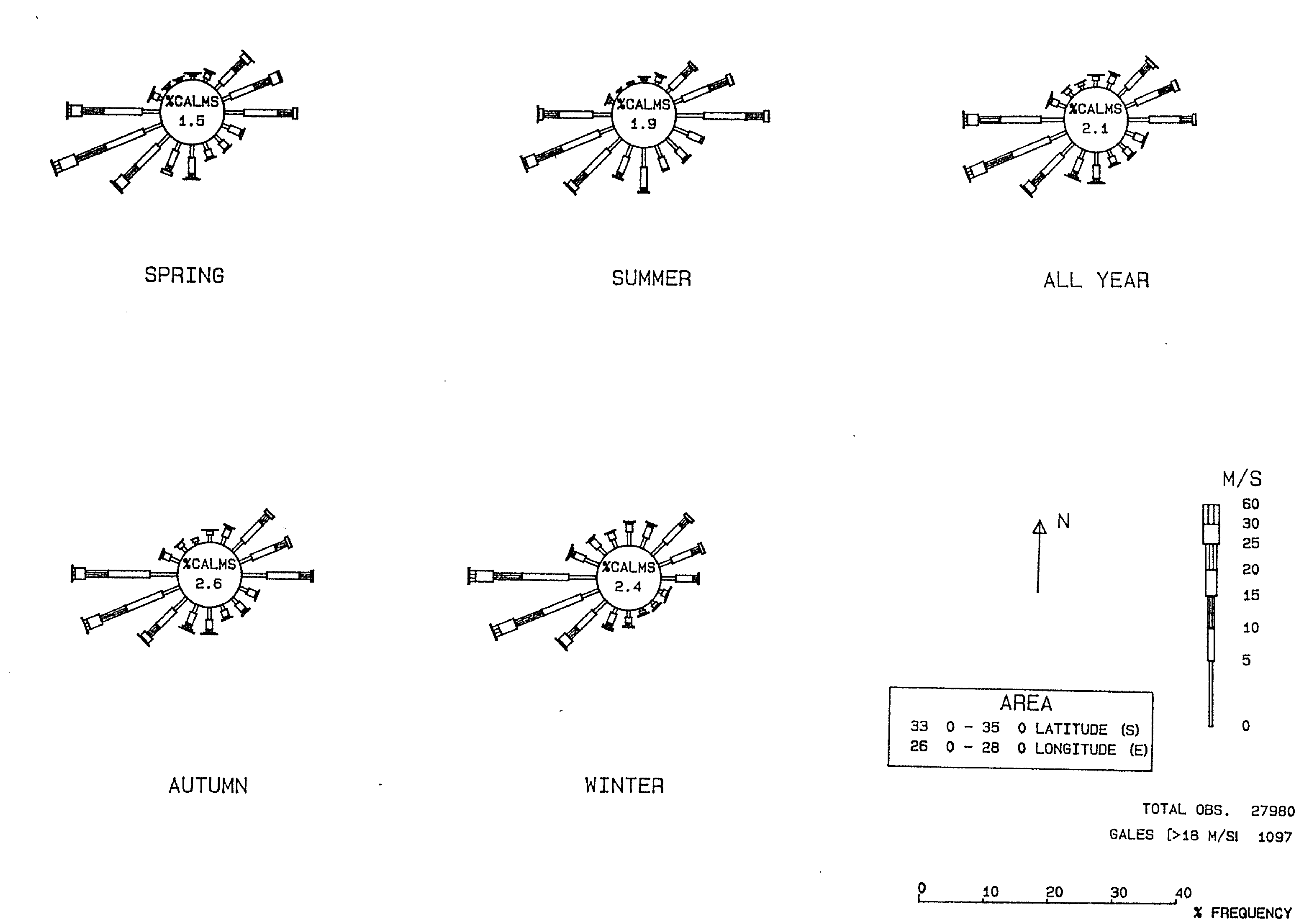
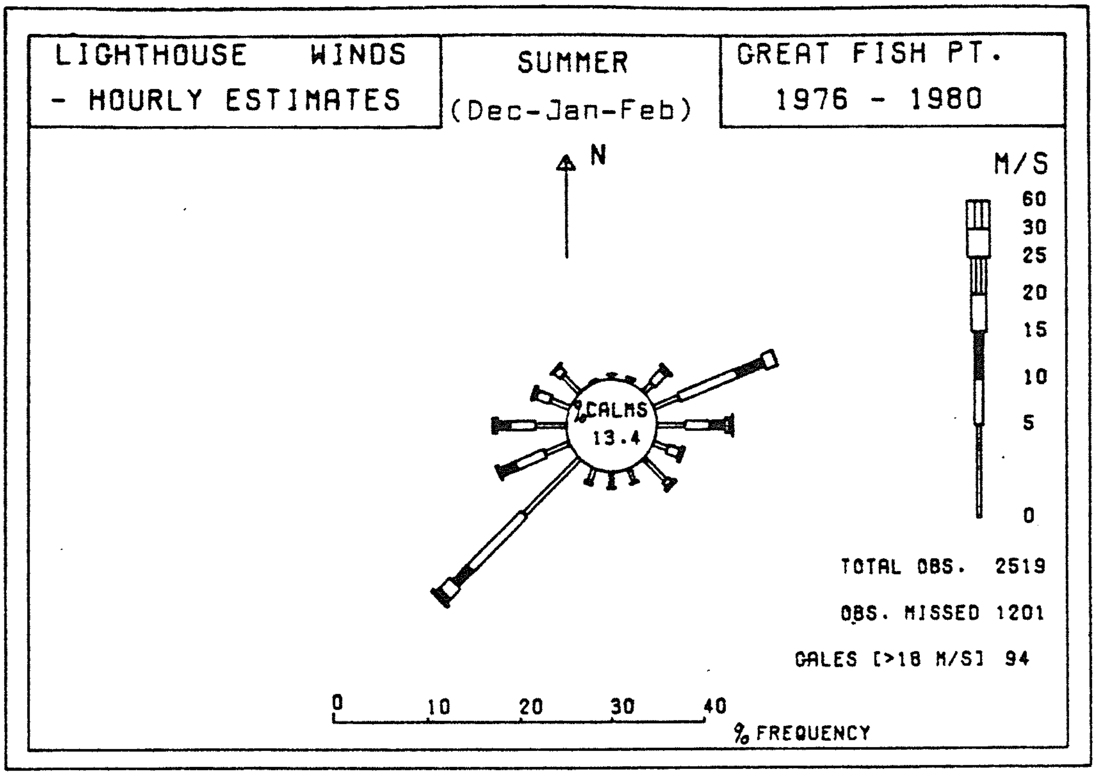


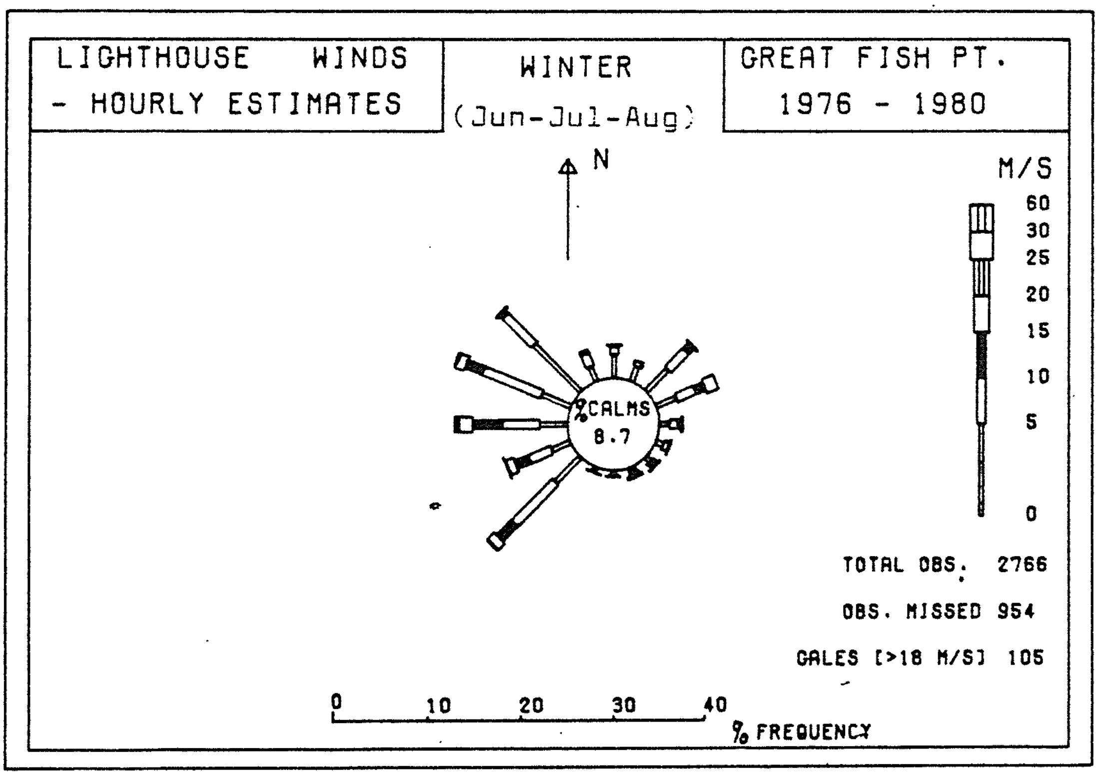
FIGURE 5

VOS WIND FREQUENCIES AND DIRECTIONS

KLEINEMONDE WEST

CSIR - EMA





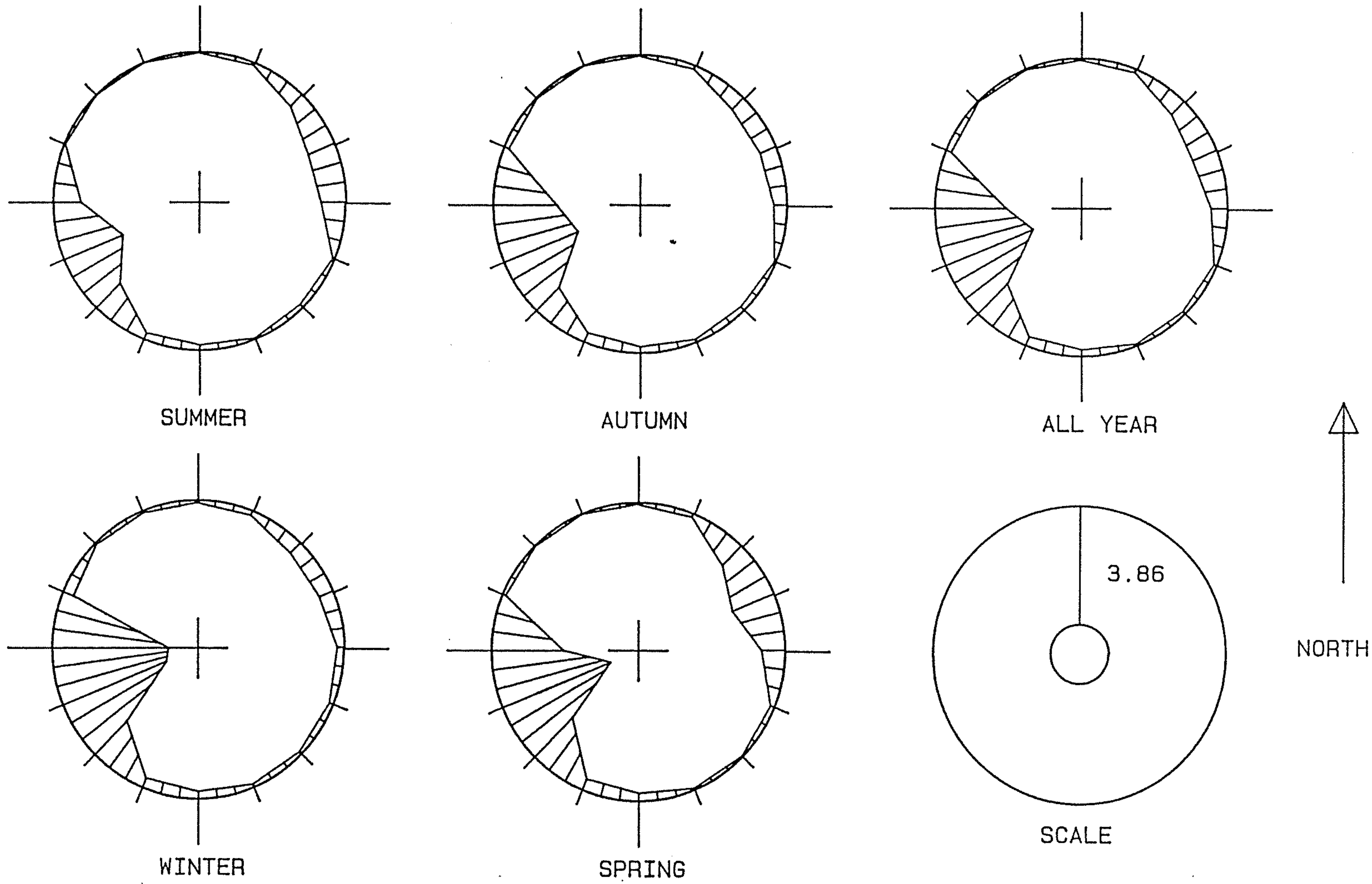
PERCENTAGE FREQUENCY WIND ROSE (After Hunter, 1985)

	KLEINEMONDE WEST WIND DATA Great Fish Lighthouse	FIGURE 6

CSIR - EMA

CSIR

AEOLIAN CREEP DIAGRAM



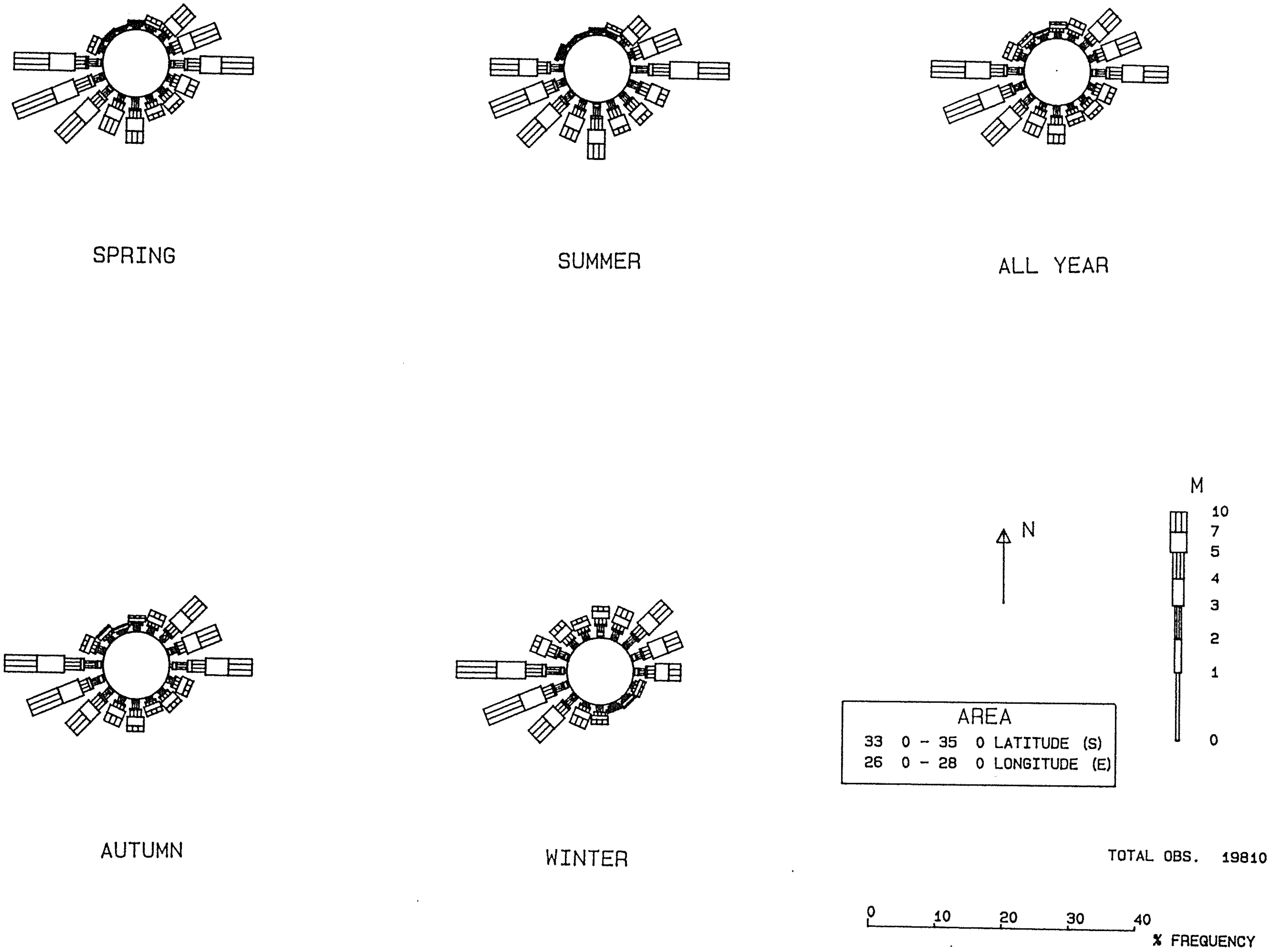
AEOLIAN TRANSPORT RATES ARE GIVEN IN FRACTIONS OF 10000 CUBIC METRES/YEAR/KILOMETRE WITH DUE COGNIZANCE FOR FREQUENCY OF OCCURRENCE OF WIND EVENTS

KLEINEMONDE WEST

AEOLIAN CREEP DIAGRAM

CSIR - EMA

FIGURE 7



VOS SWELL ROSES

KLEINEMONDE WEST

CSIR - EMA

FIGURE 8

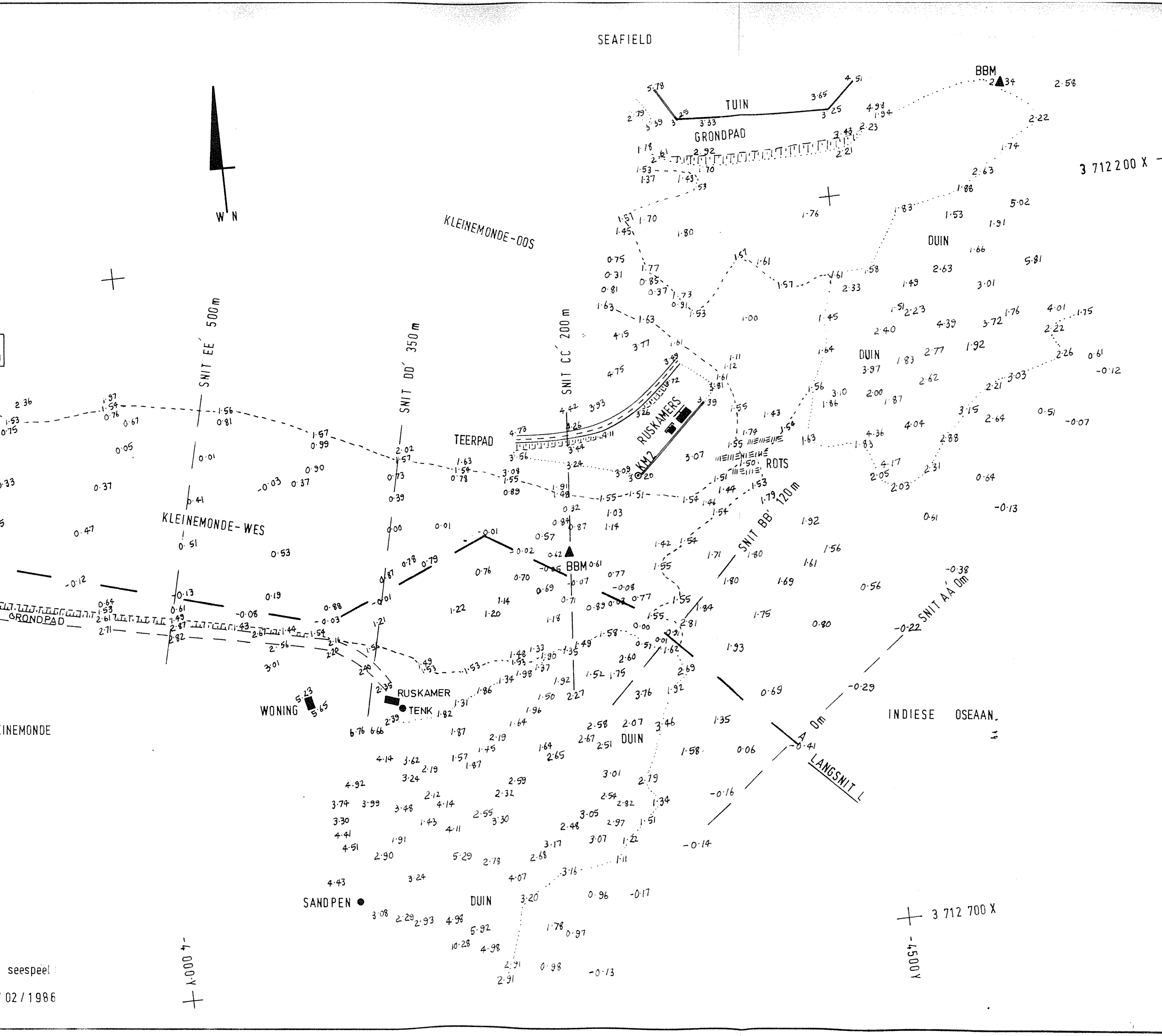
OPM. L V D M PLAN. L V D M	KLEINEMONDE WEST SURVEY LAYOUT	FIGURE 9

CSIR-EMA

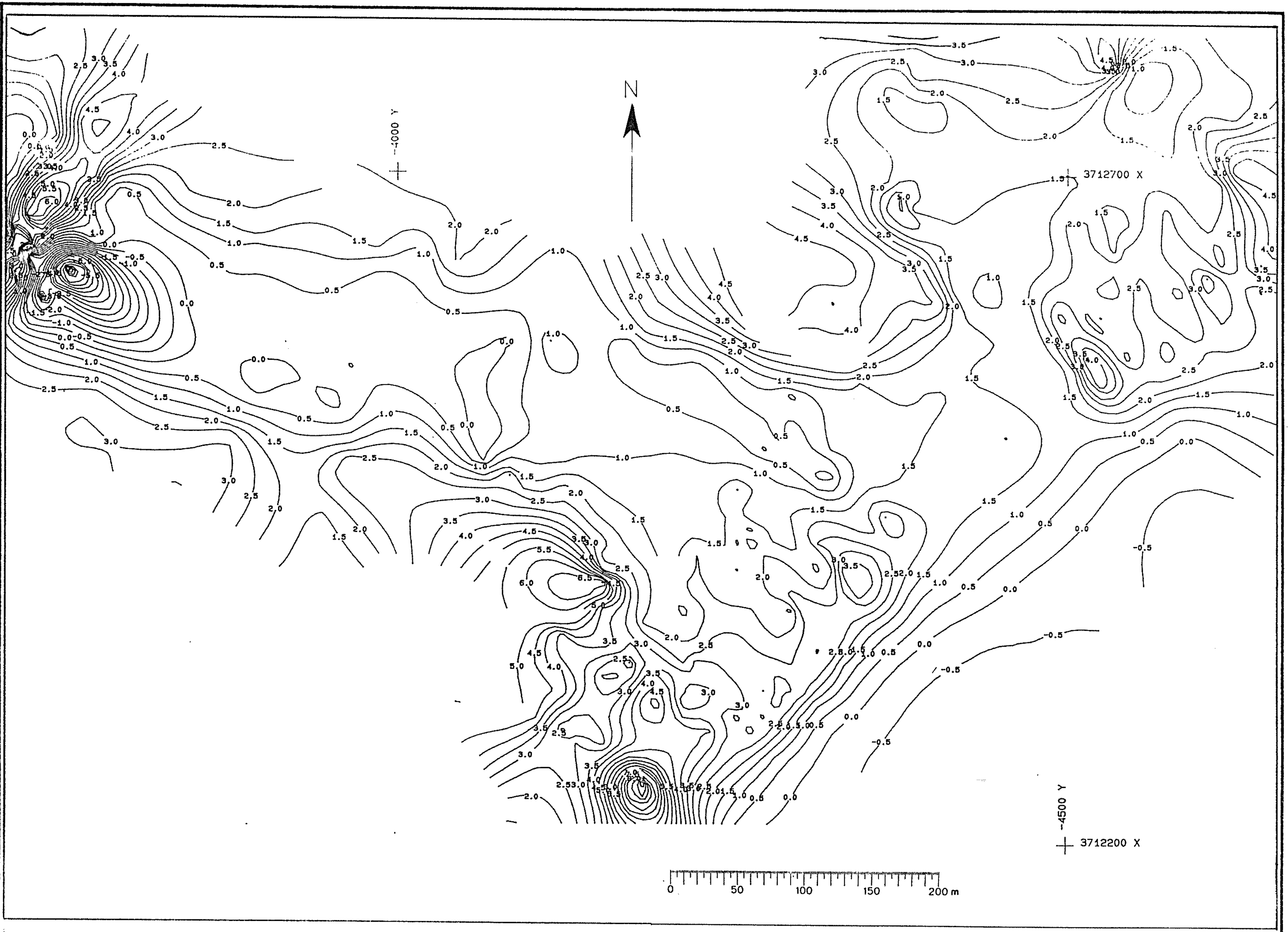
Hoogtes vanaf baken 93 SEAFIELD = 70,2 m (gemiddelde seespeel

L°. 27°

OPGEMEET OP 28 / 02 / 1986



SEAFIELD
TUIN
GRONDPAD
BBM
3 712 200 X
W N
KLEINEMONDE-OOS
DUIN
SNIT EE' 500 m
SNIT DD' 350 m
SNIT CC' 200 m
TEERPAD
RUSKAMERS
KM2
ROTS
SNIT BB' 120 m
KLEINEMONDE-WES
BBM
SNIT AA' 0m
GRONDPAD
RUSKAMER
TENK
WONING
DUIN
A 0m
LANGSNIT
INDIESE OSEAAN
KLEINEMONDE
SANDPEN
DUIN
3 712 700 X
-4 000 Y
-4 500 Y
seespeel
02 / 1986

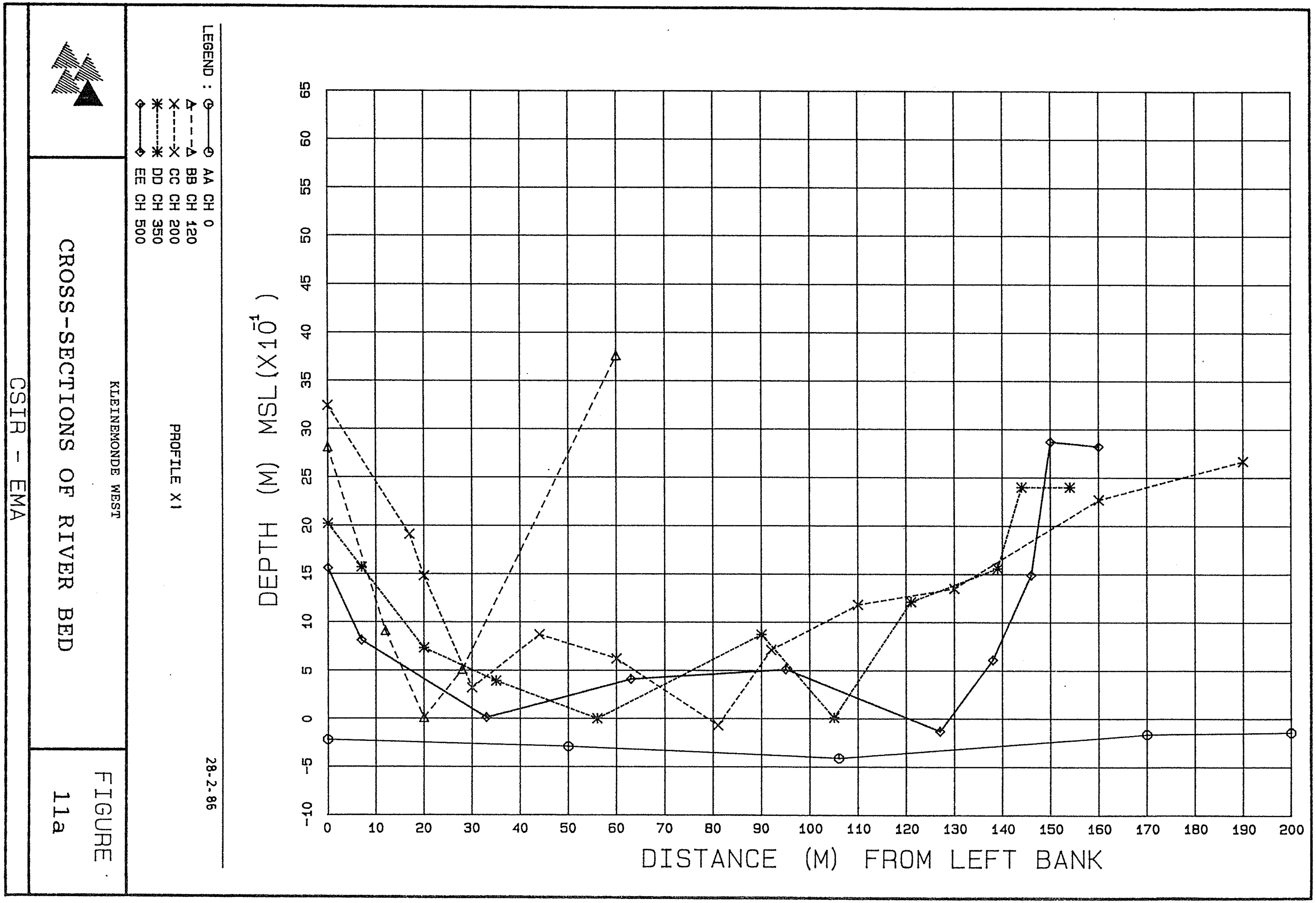


KLEINEMONDE WEST

CONTOUR PLAN Kleinemonde West

CSIR - EMA

FIGURE 10


CSIR - EMA
CROSS-SECTIONS OF RIVER BED
KLEINEMONDE WEST
PROFILE X1
28-2-86
LEGEND :
AA CH 0
BB CH 120
CC CH 200
DD CH 350
EE CH 500
DEPTH (M) MSL (X10⁻¹)
DISTANCE (M) FROM LEFT BANK
-10
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
FIGURE 11a

CSIR - EMA

CROSS-SECTIONS OF RIVERBED

KLEINEMONDE WEST

PROFILE X 2

28-2-86

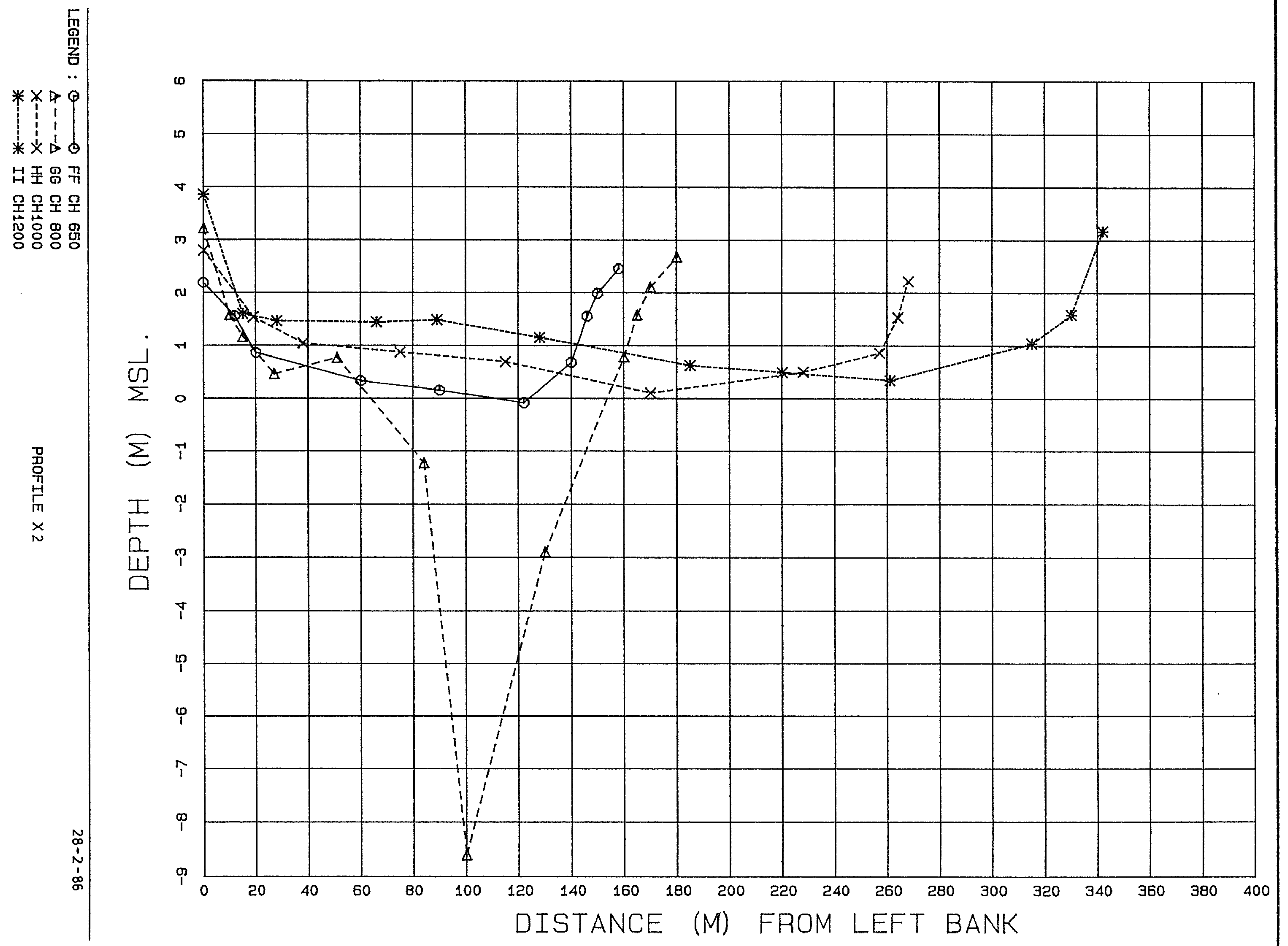


FIGURE 11b

CSIR - EMA

CROSS-SECTIONS AT BRIDGE

KLEINEMONDE WEST

PROFILE X3

28-2-86

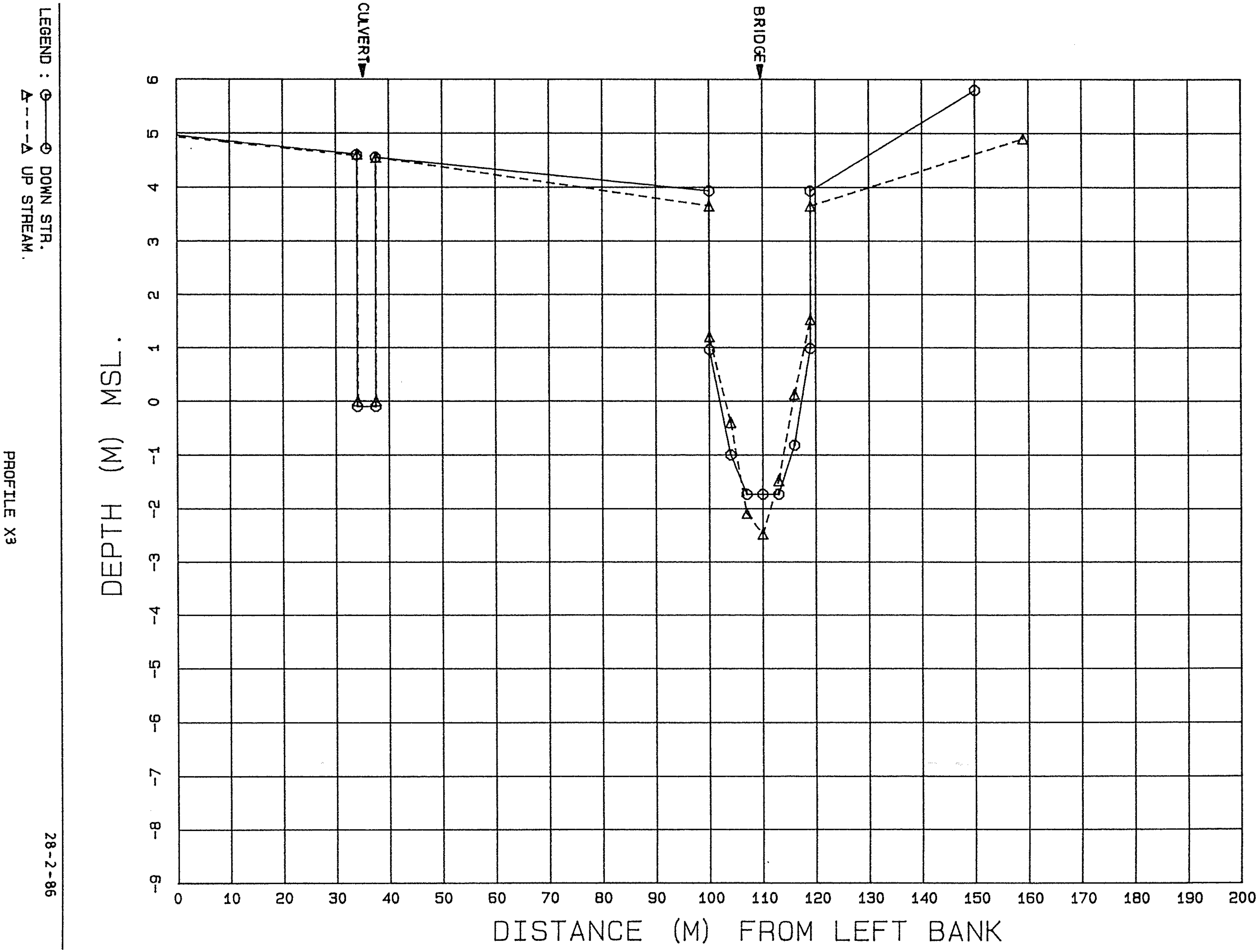


FIGURE 11c

CSIR - EMA

LONG-SECTION OF RIVERBED

KLEINEMONDE WEST

PROFILE L

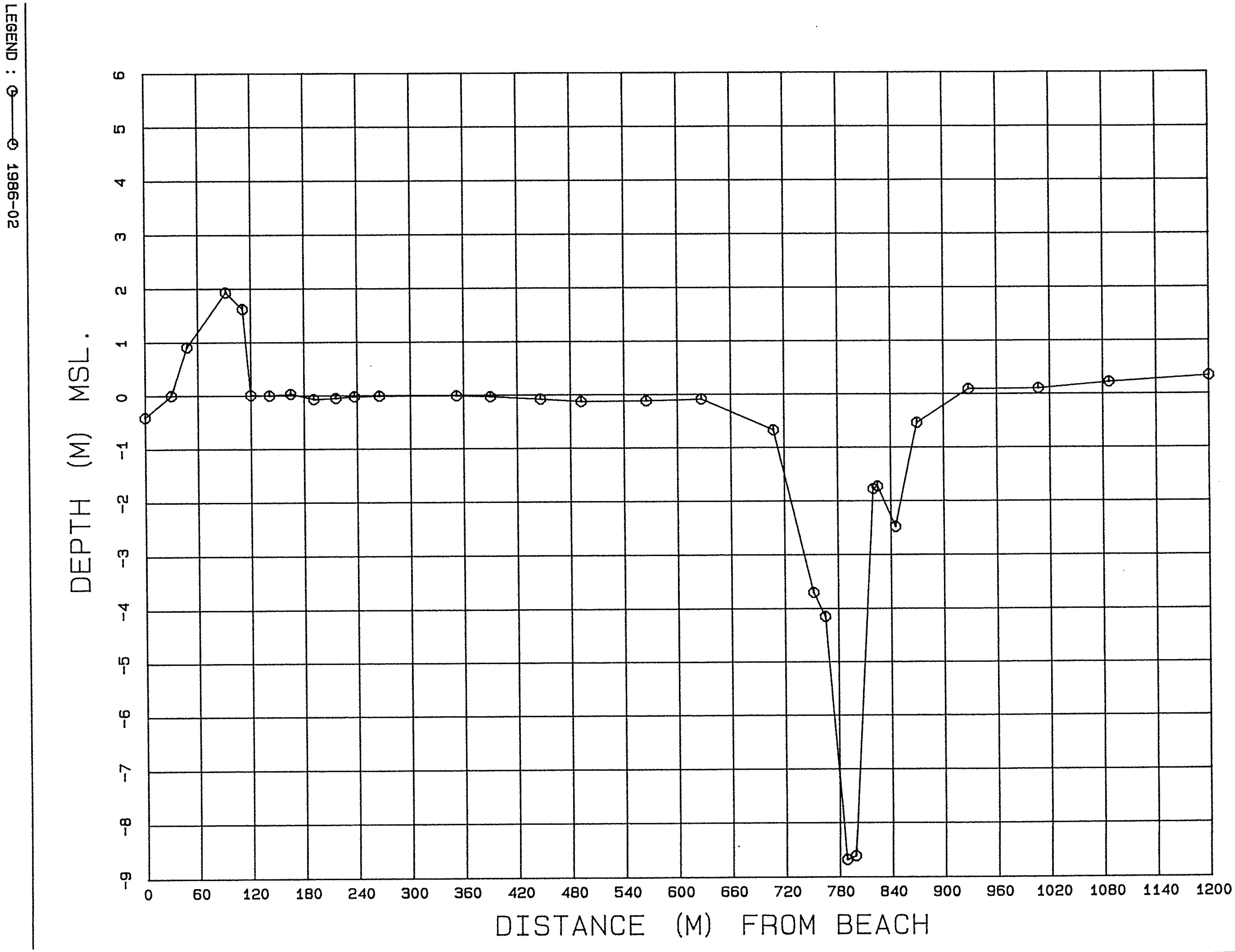
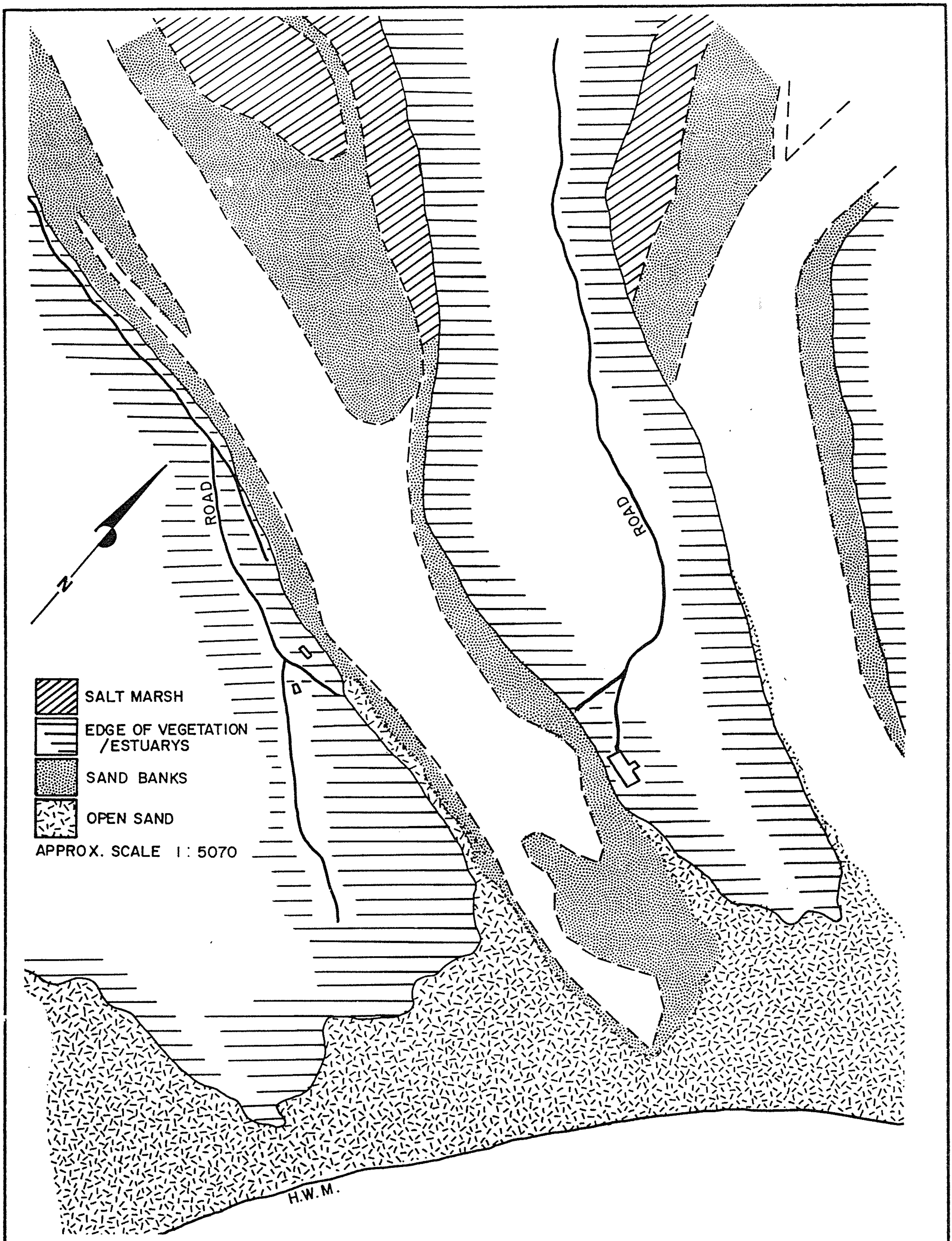


FIGURE 11d

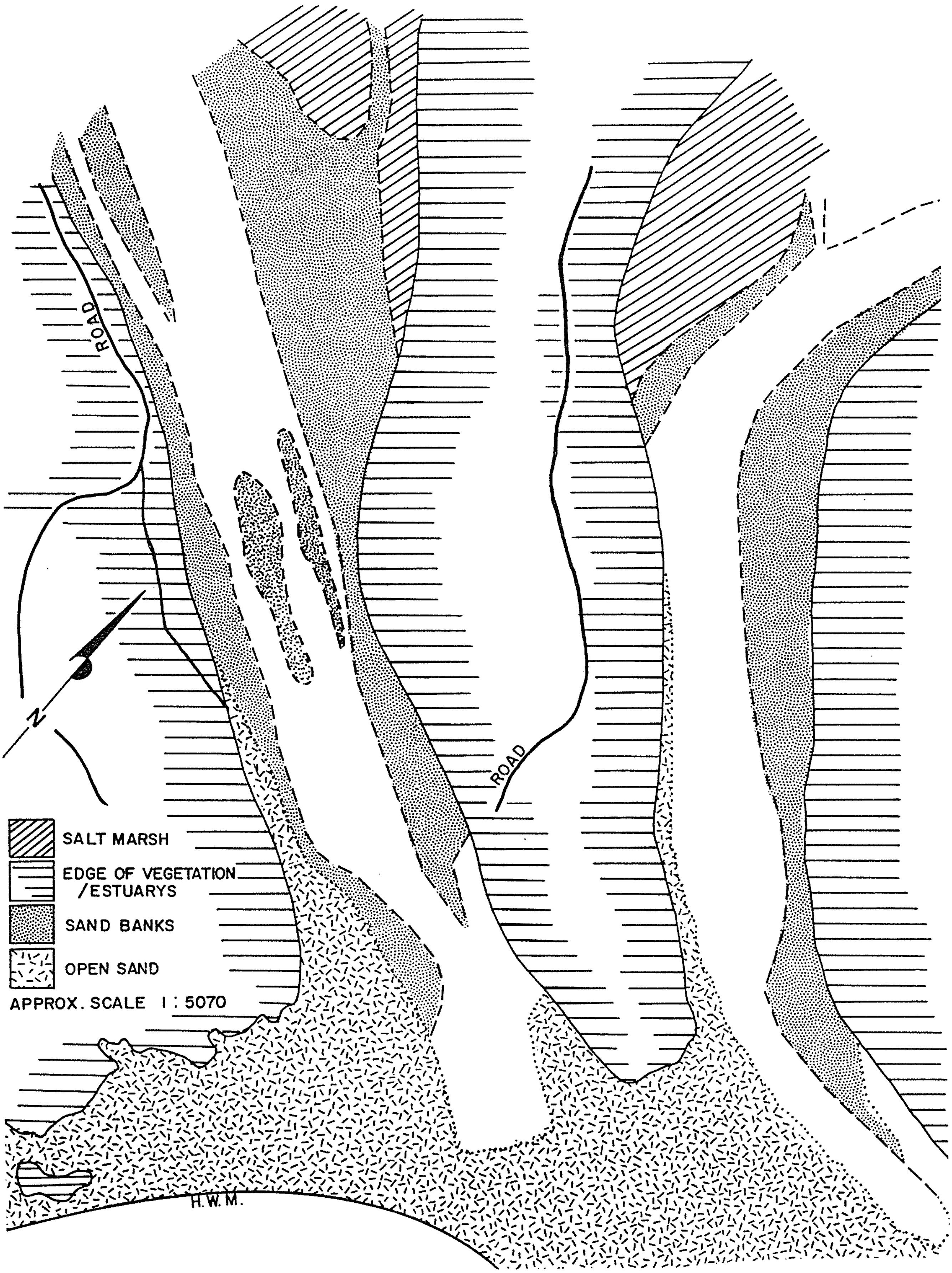


KLEINEMONDE WEST

LANDBANKS AND CHANNELS 1938

FIGURE 12

CSIR - EMA

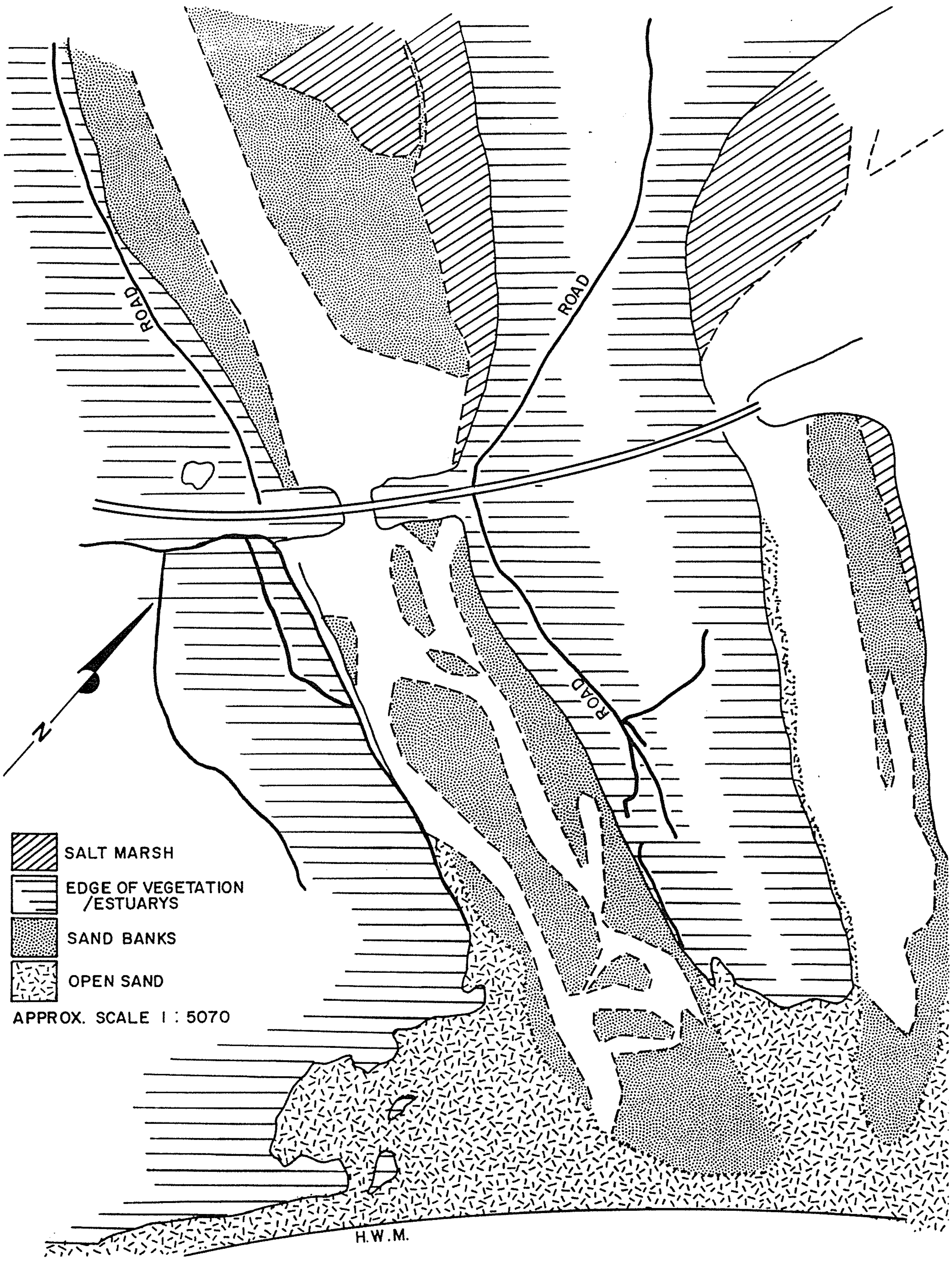


KLEINEMONDE WEST

LANDBANKS AND CHANNELS 1955

FIGURE 13

CSIR - EMA

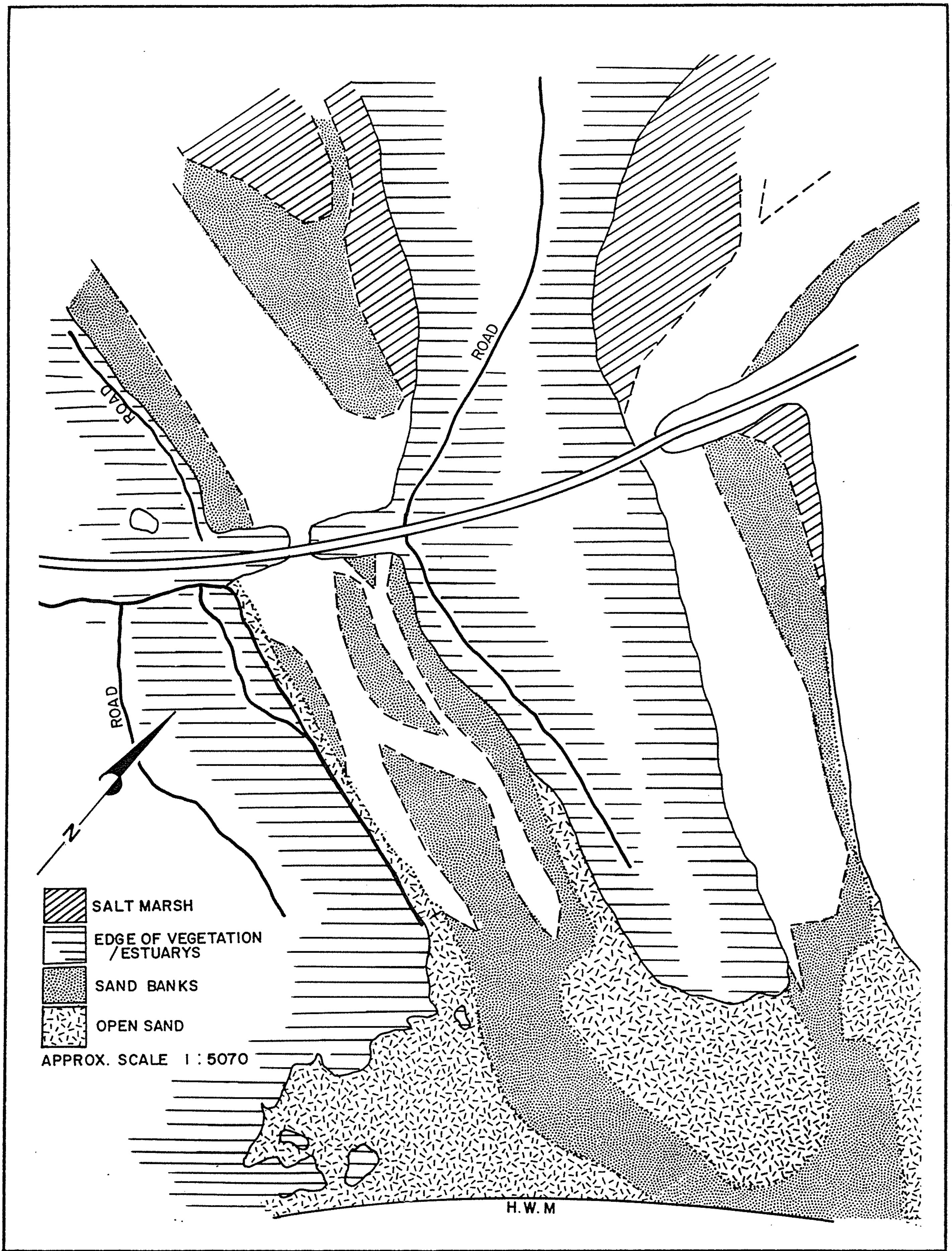


KLEINEMONDE WEST

LANDBANKS AND CHANNELS 1979

FIGURE 14

CSIR - EMA

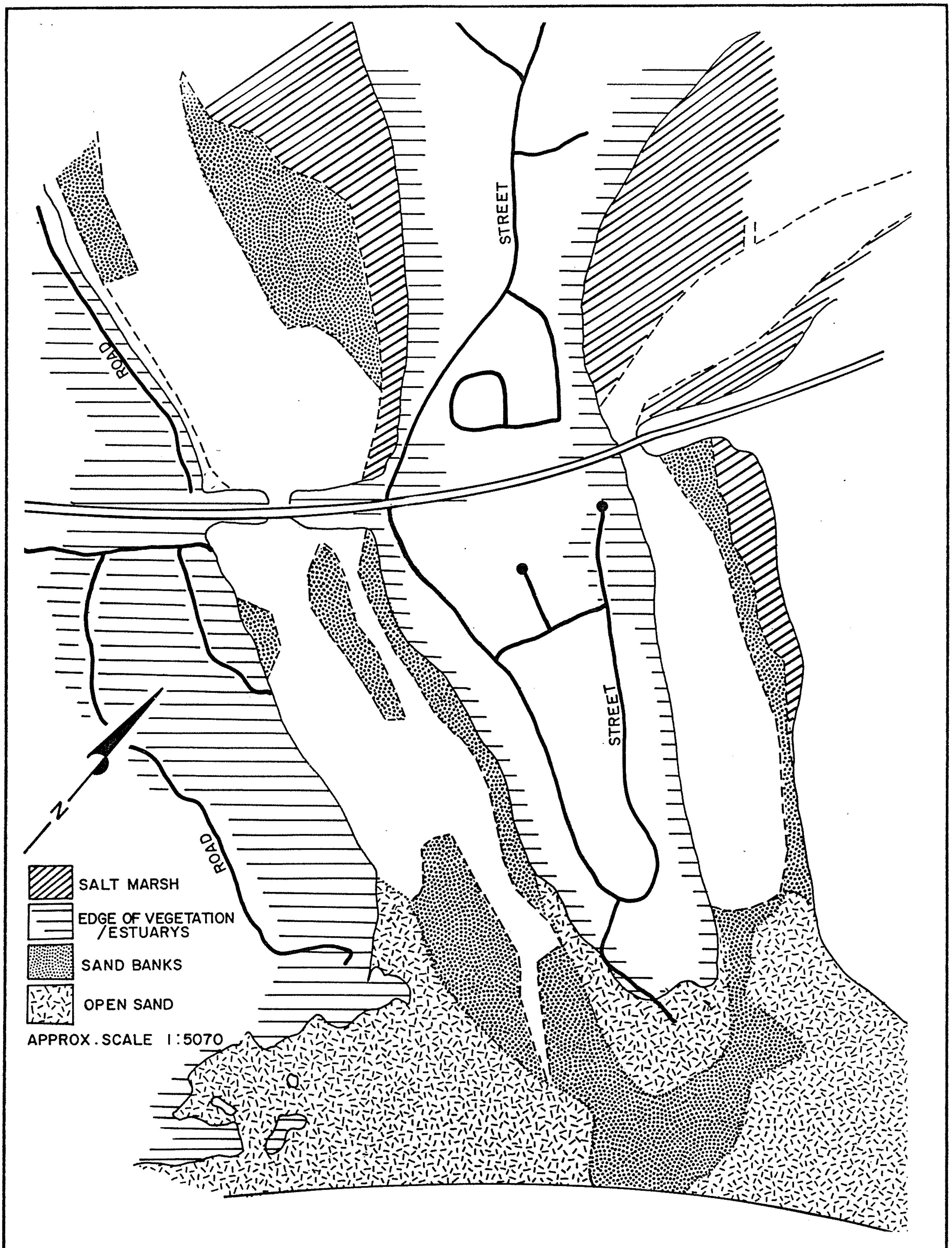


KLEINEMONDE WEST

LANDBANKS AND CHANNELS 1981

FIGURE 15

CSIR - EMA

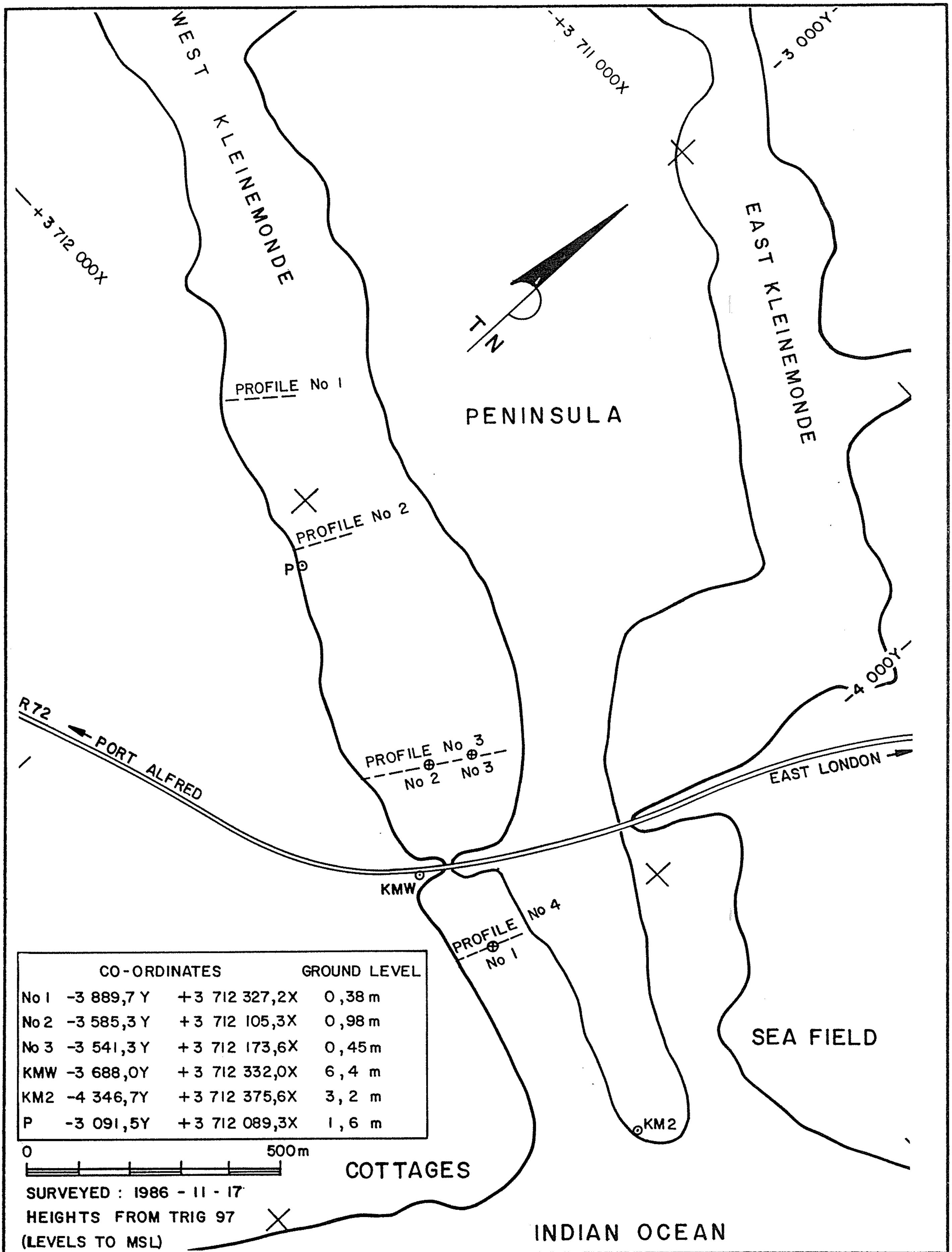


KLEINEMONDE WEST

LANDBANKS AND CHANNELS 1987

FIGURE 16

CSIR - EMA



	CO-ORDINATES		GROUND LEVEL
No 1	-3 889,7 Y	+3 712 327,2X	0,38 m
No 2	-3 585,3 Y	+3 712 105,3X	0,98 m
No 3	-3 541,3 Y	+3 712 173,6X	0,45 m
KMW	-3 688,0Y	+3 712 332,0X	6,4 m
KM2	-4 346,7Y	+3 712 375,6X	3,2 m
P	-3 091,5Y	+3 712 089,3X	1,6 m

KLEINEMONDE WEST

VIBROCORE POSITIONS AND CROSS-SECTIONS

FIGURE 17a

CSIR - EMA

CSIR - EMA

CROSS-SECTIONS OF RIVERBED

KLEINEMONDE WEST

PROFILE 1

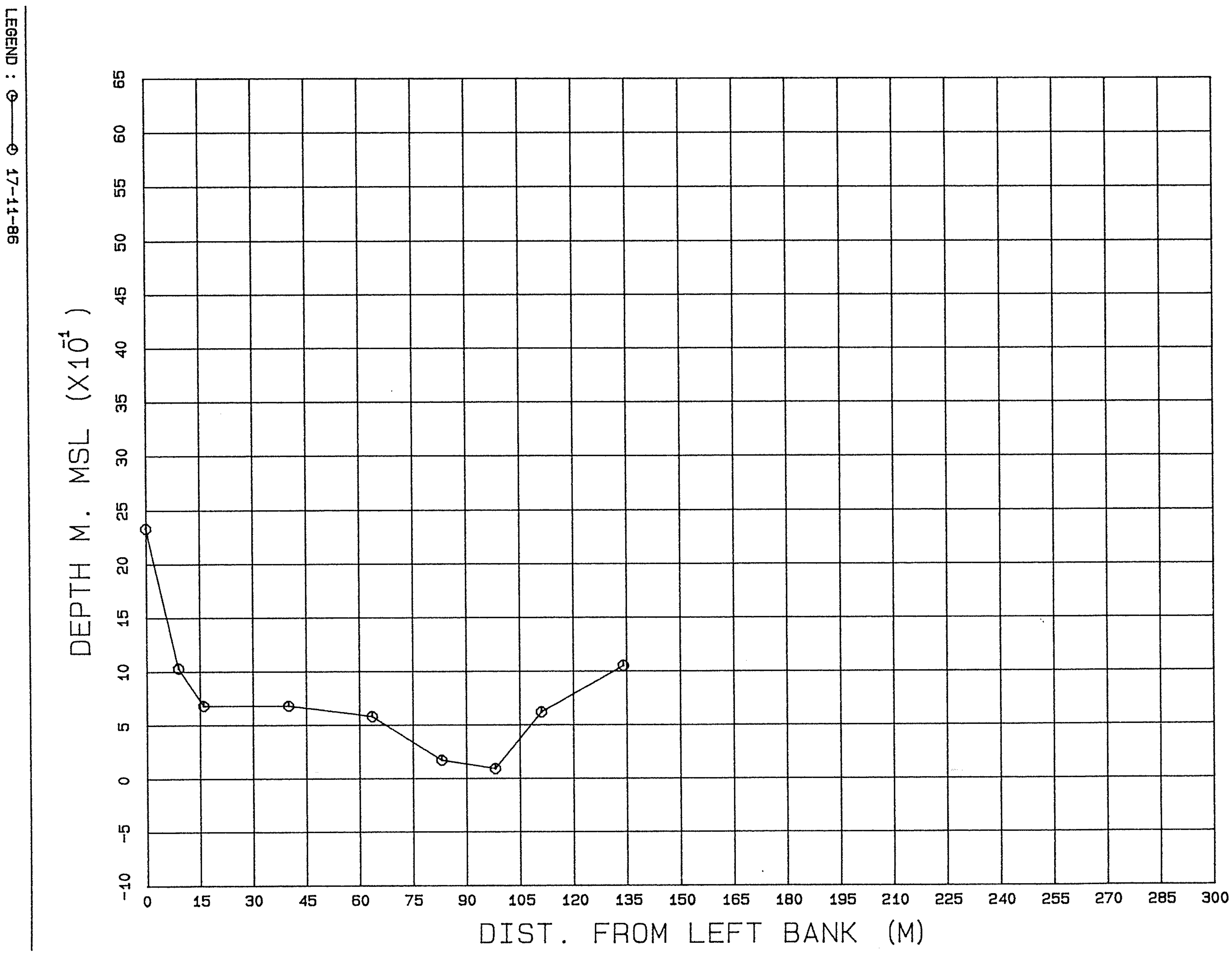
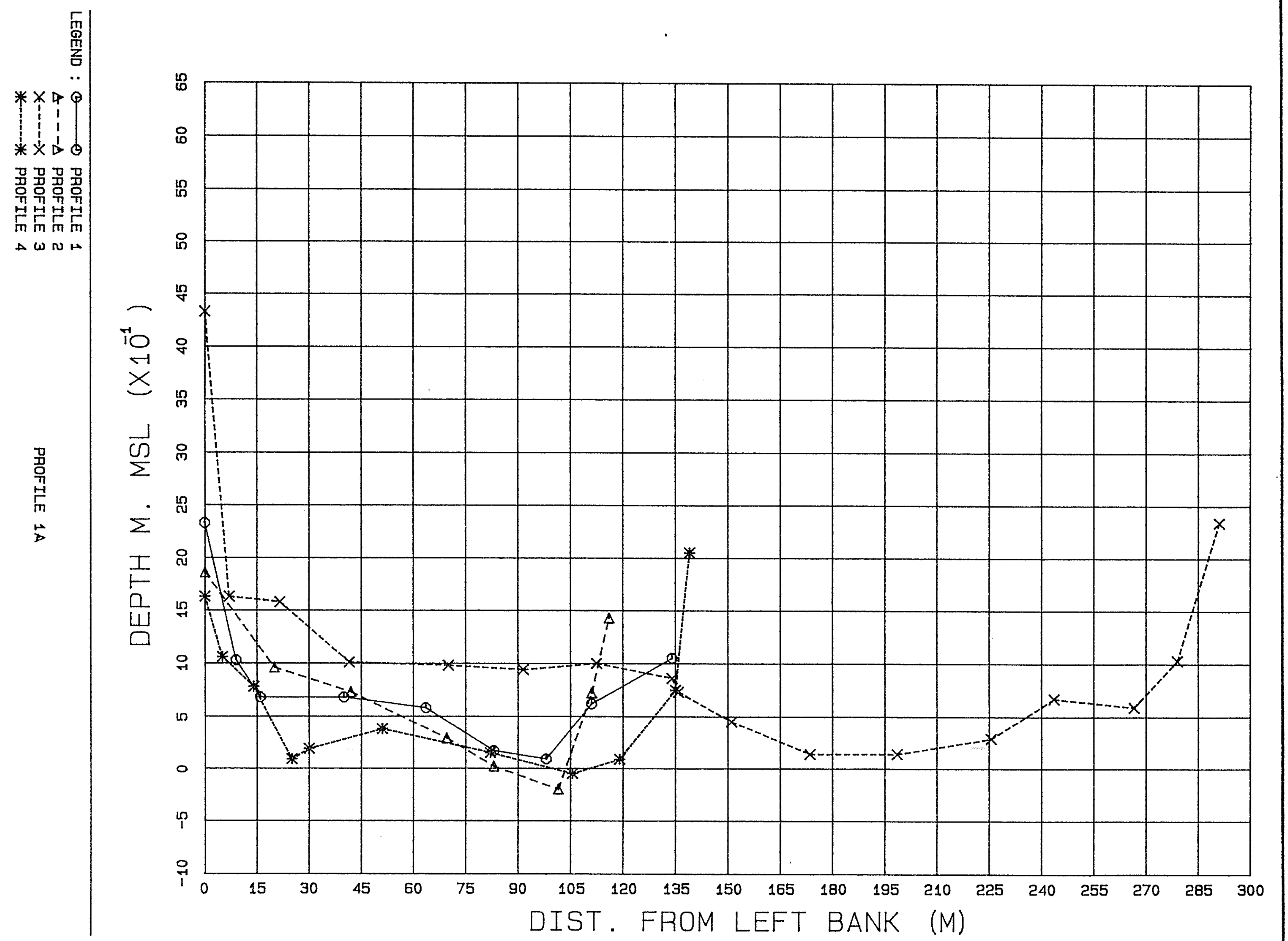


FIGURE 17b



KLEINEMONDE WEST

CROSS-SECTIONS OF RIVERBED

17-11-86

CSIR - EMA

FIGURE 17c

CSIR - EMA

CROSS-SECTIONS OF RIVERBED

KLEINEMONDE WEST

PROFILE 2

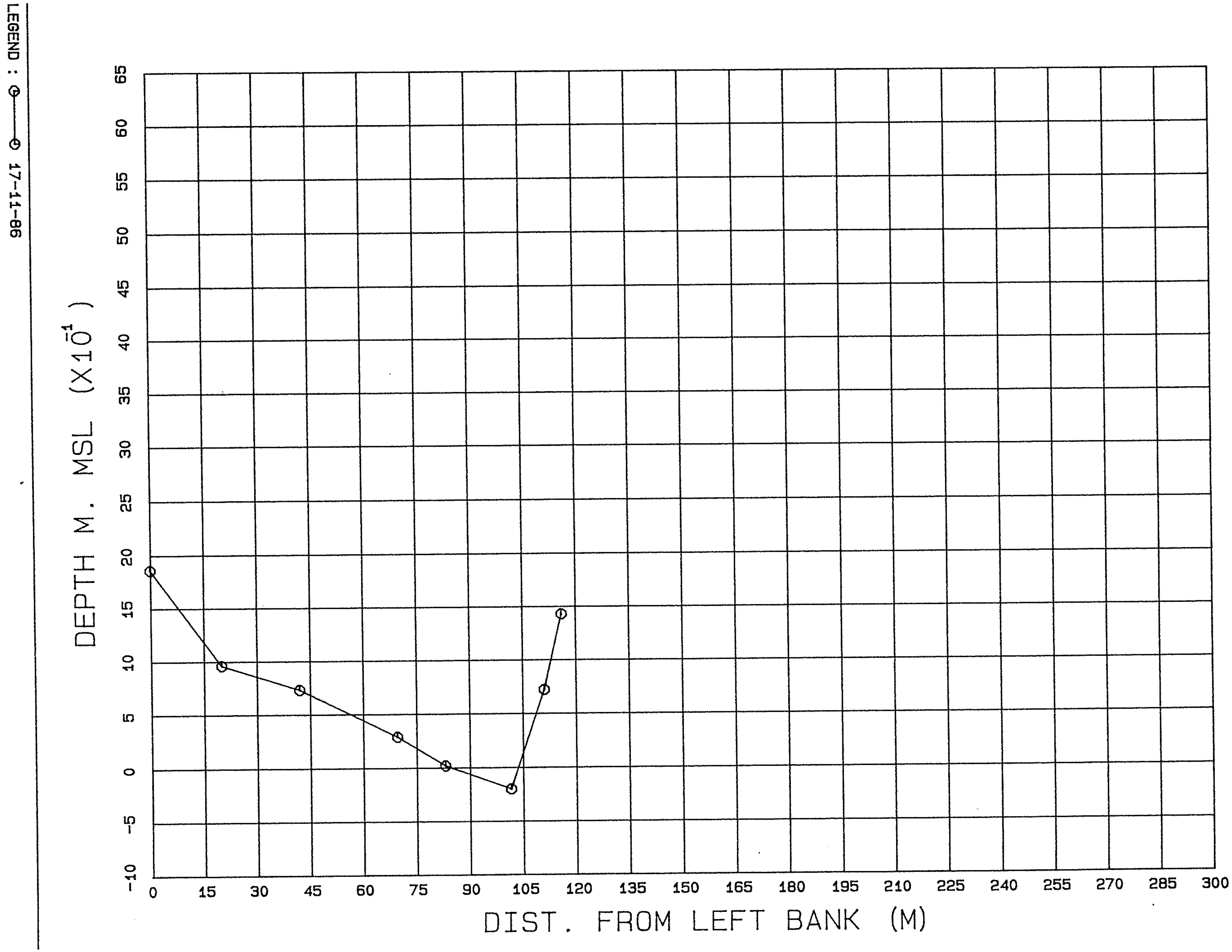
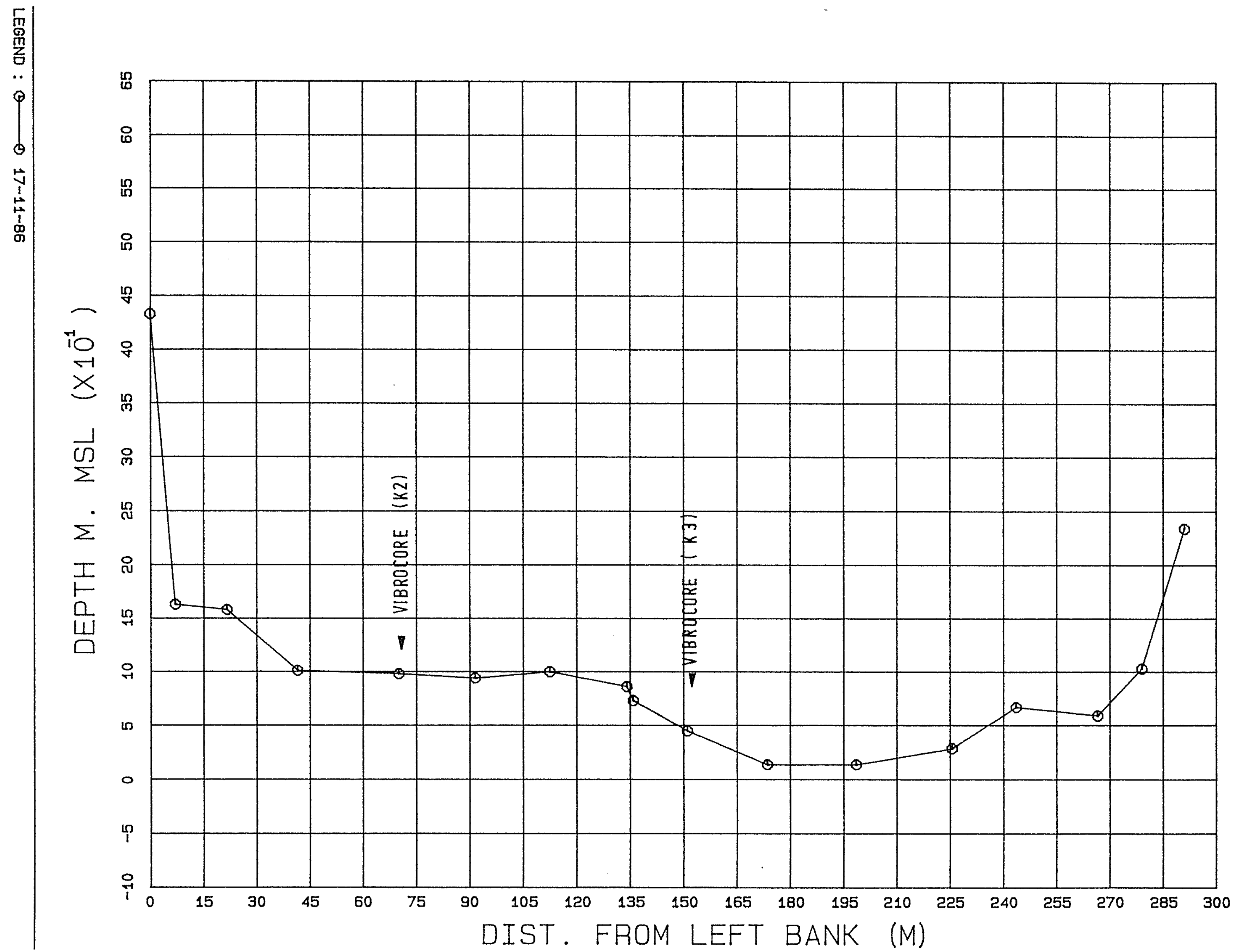


FIGURE 17d



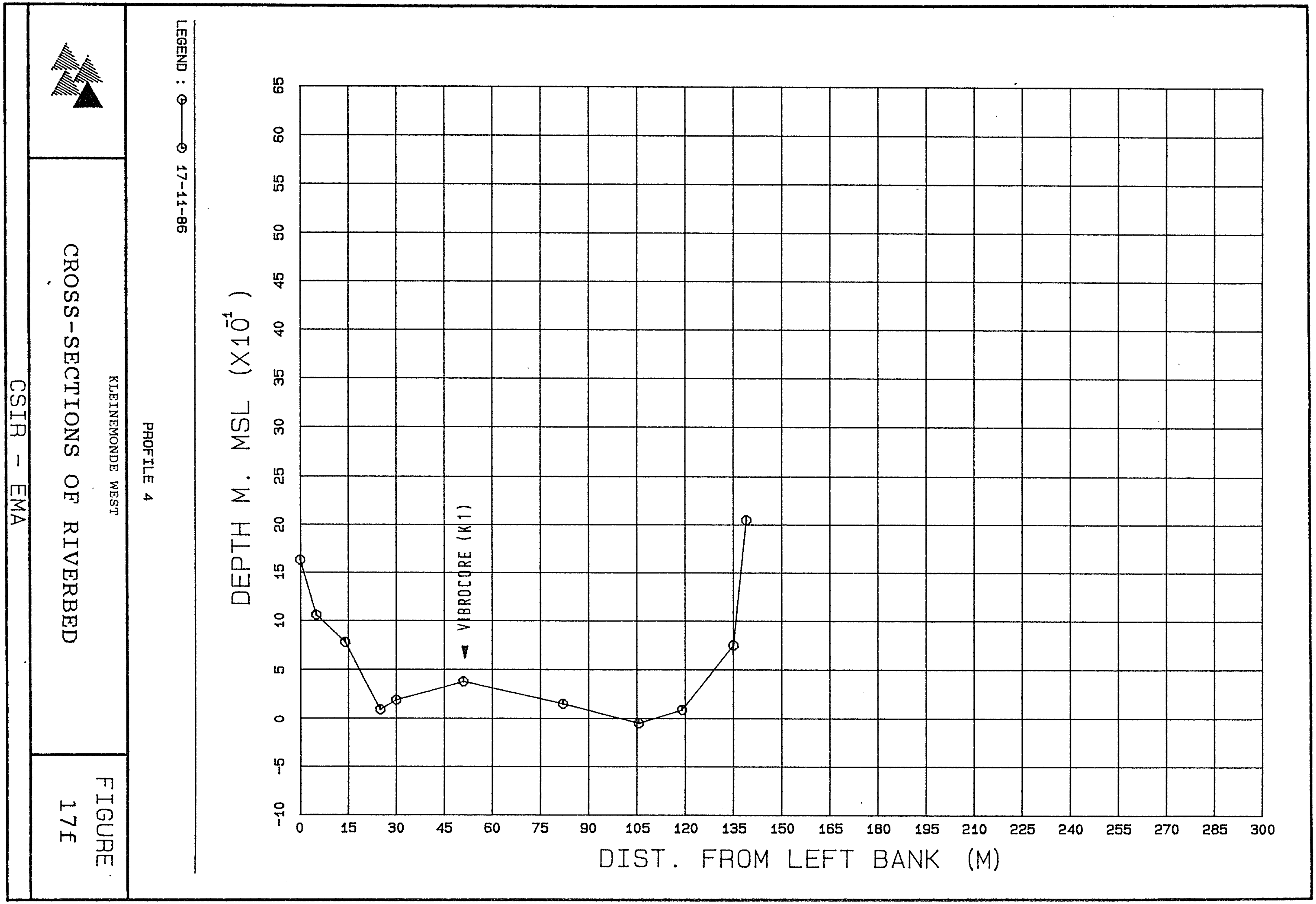
PROFILE 3

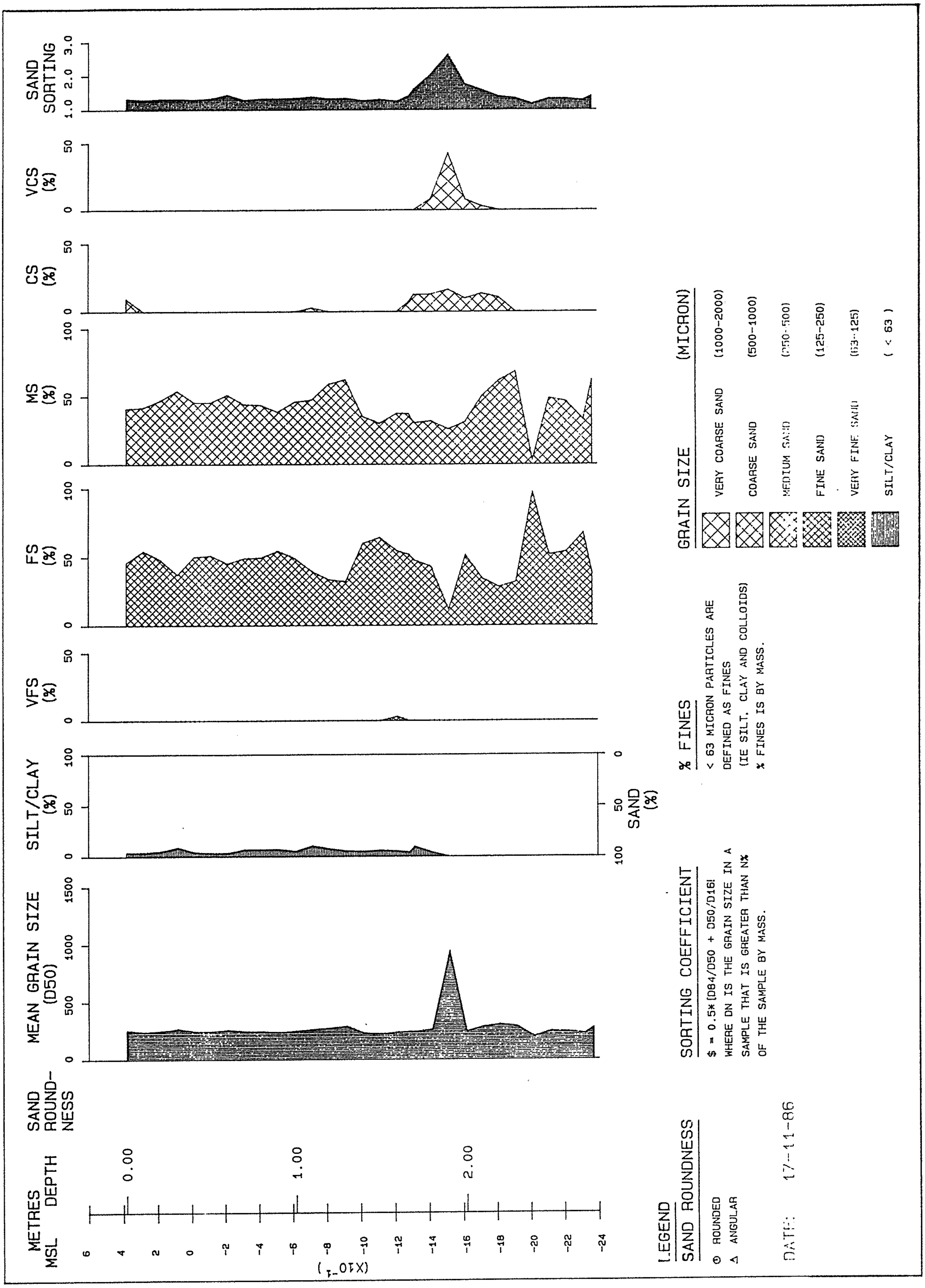
KLEINEMONDE WEST

CROSS-SECTIONS OF RIVERBED

CSIR - EMA

FIGURE 17e


CSIR - EMA
CROSS-SECTIONS OF RIVERBED
KLEINEMONDE WEST
PROFILE 4
FIGURE
17f
LEGEND : 17-11-86
DEPTH M. MSL (X10^-1)
VIBROCORE (K1)
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300
DIST. FROM LEFT BANK (M)

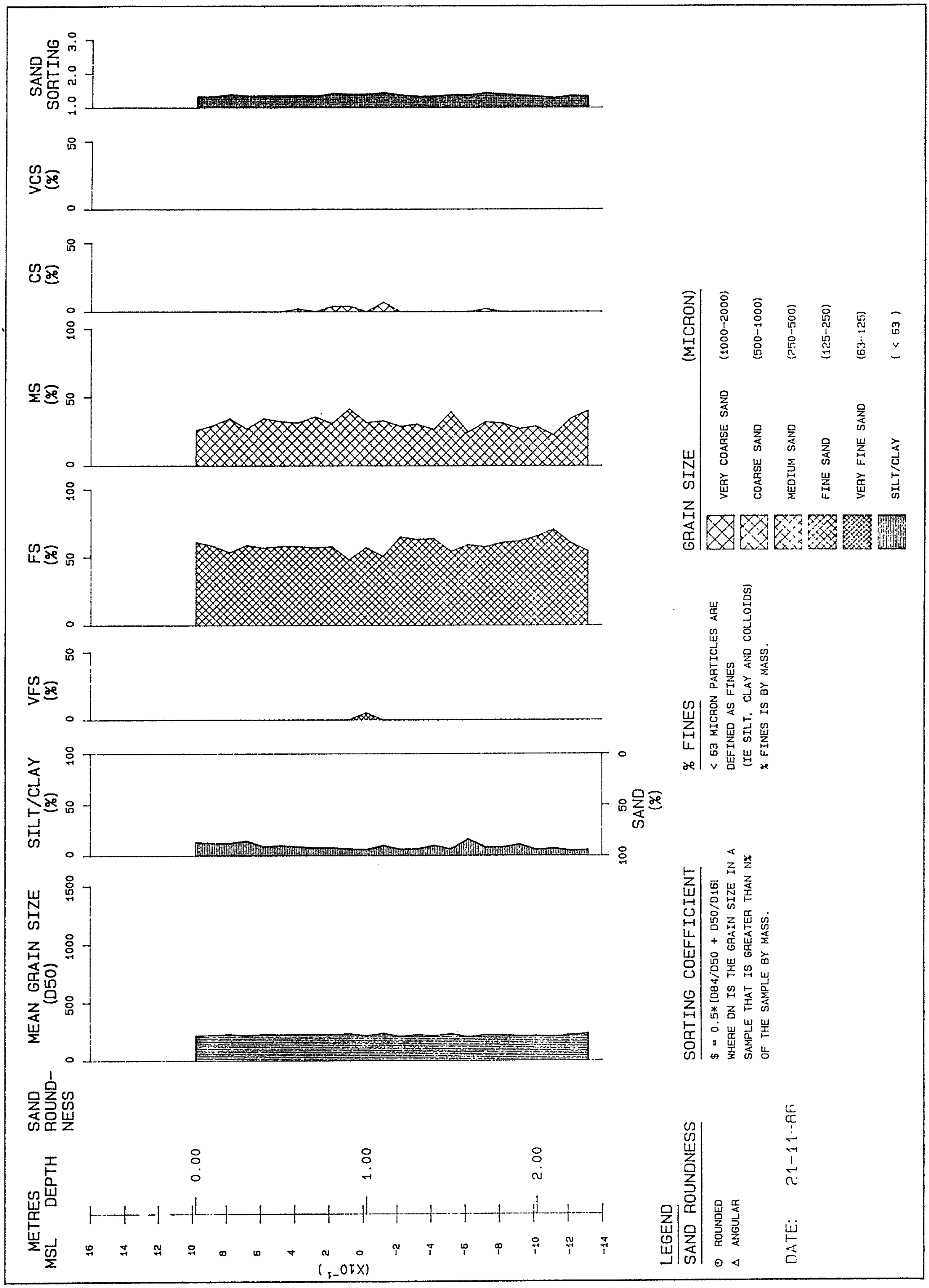


KLEINEMONDE WEST

SEDIMENTOLOGY-IV
Kleinemonde West

FIGURE 18a

CSIR - EMA



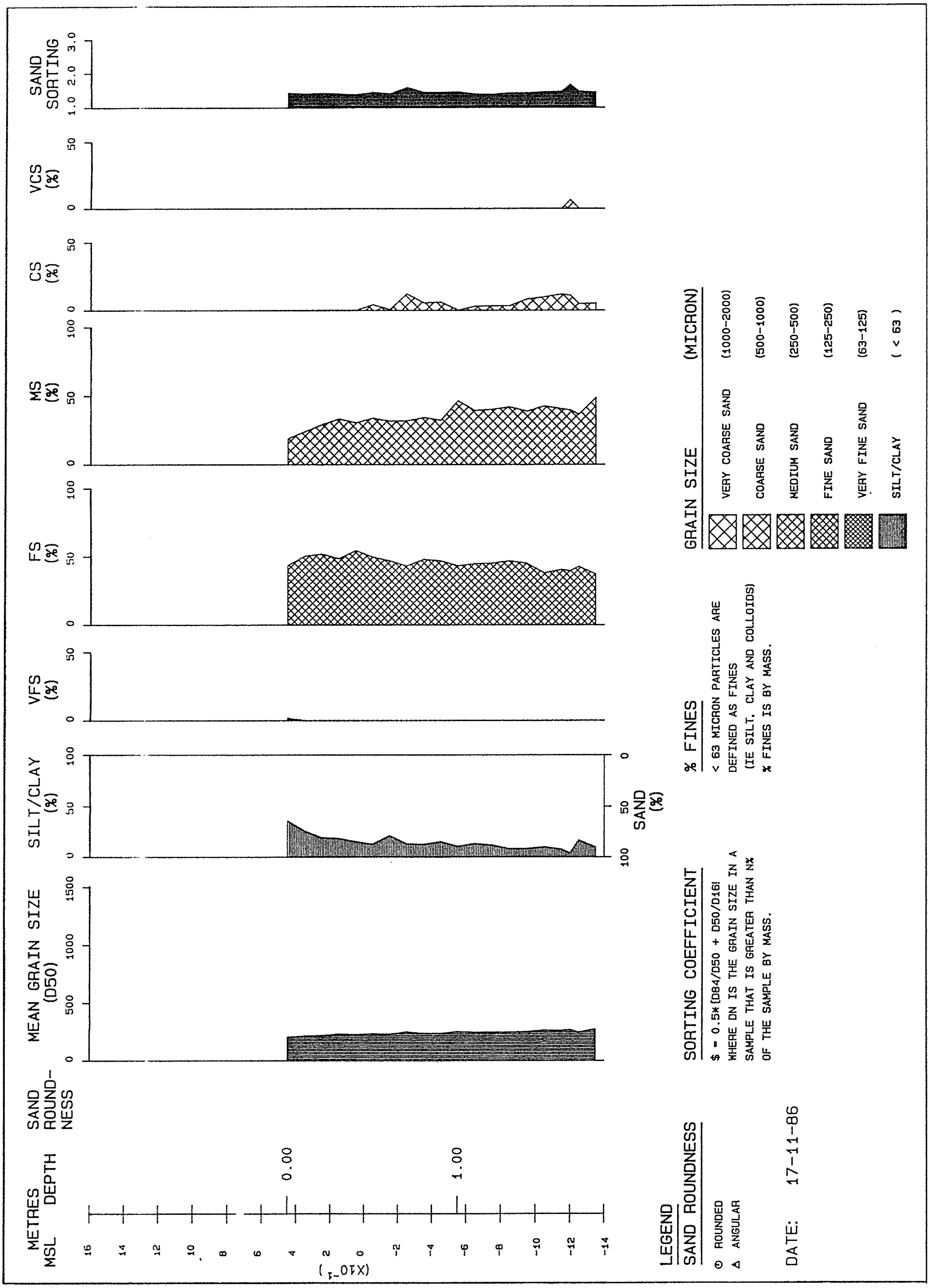
KLEINEMONDE WEST

SEDIMENTOLOGY-2H

Kleinemonde West

FIGURE 18b

CSIR - EMA



KLEINEMONDE WEST

SEDIMENTOLOGY-3H
Kleinemonde West

FIGURE 18c

CSIR - EMA