

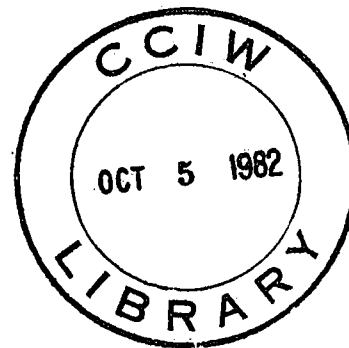
CHEMICAL CHANGES IN PORE WATER
FROM DREDGE SPOIL
DISPOSED ON THE PILOT ISLAND
MITCHELL BAY, LAKE ST. CLAIR, ONTARIO

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Alena Mudroch and Vengueot Cheam
Department of Environment, Canada Centre for Inland Waters
Lakes Research Division, Burlington, Ontario, Canada

ABSTRACT

Seasonal changes in the position of the water table and in the chemical composition of interstitial water were monitored at the site of a trial dredgings disposal area in Lake St. Clair, Mitchell Bay, Ontario, from December 1973 to July 1974. The water content within the top 1.2m layer of the sediment profile changed significantly as a result of free drainage. Only a small volume of pore water could be collected in January and no water was collected during spring and summer. On the other hand, water was easily sampled below this top layer at all times. Changes in the chemical composition of the collected pore water were very small. The concentrations of Al, Zn, Cd, Pb and Cu in the pore water and the Mitchell Bay lake water were almost identical. Pore water samples contained appreciably higher concentrations of P, N, organic C, Fe, Hg and Mn compared to Mitchell Bay water, pore water concentrations of these elements are low and consequently pose no health hazards. It is concluded that impervious pile retaining walls built at the site are needed as a protection against wave erosion but not for the retention of the pore water.

Introduction

Disposal of polluted dredged sediments into Great Lakes open water is presently prohibited. However, the large quantities of annually dredged sediments from the Great Lakes harbours and channels have caused a storage problem (U.S. Army Engineer Waterways Experiment Station, 1972). The deposition of dredge spoil on artificial islands constructed in bays or nearshore zones has been considered a feasible approach to dispose of much of these dredged sediments (International Working Group on the Abatement and Control of Pollution from Dredging Activities, 1974).

To study the suitability of this type of disposal, an experimental artificial island was constructed by the Department of Public Works in Mitchell Bay, Lake St. Clair, and termed "Pilot Island". The location and dimensions of this island are plotted in Fig. 1. The Pilot Island consists of three test bays, separated and surrounded by soldier pile walls, together with a settling basin for the displaced and excess water from the dredge disposal areas. The island rests directly on the lake bottom. The walls are made of steel and except for the first bay, all other steel walls were lined inside with teflon. Details on construction are given by Acres (1973).

Starting in November 1973, the bottom sediment was dredged by means of a clam shell dredge at different locations in Mitchell Bay, transported to the island in a scow and loaded into the first bay of the Pilot Island.

To investigate the changes in the chemistry of the pore water contained in the dredged material, during a long term disposal on the island, the pore water from various depths was collected each month and analysed for total N, total P, org. C, Fe, Hg, Al, Cd, Pb, Cu, Zn, and Mn. Simultaneously, pH, Eh and conductivity were determined. This study was not directed towards investigation of the quality of immediately released water, as occurs in the earliest phase of sediment dewatering. The investigation was begun only after sediment introduction to the test bay had ceased.

Materials and Methods

A modified lysimeter was designed and built for collection of the pore water in the Pilot Island sediments. It consisted of a porous cup and plastic tube installed in the sediment, with a couple to a moveable surface suction device.

The porous cup manufactured by Soil Moisture Equipment Corp., (Santa Barbara, California) was tightly connected to a PVC tube. This part of the apparatus was gently pushed through

the deposited sediment to a predetermined depth. Nine such lysimeters were used for sampling the pore water between a depth range of 0.3 m (1 ft.) and 3 m (10 ft.) at 0.3 m (1 ft.) intervals. The upper end of each of the plastic tubes extended about 12 cm (5 in.) above the sediment surface. A thick wall capillary glass tube with a spherical ground joint on the top was carefully placed inside the plastic tube. To prevent atmospheric water from entering, the top of the tube, above the sediment surface, was covered with a plastic cup. The dimensions of the apparatus is given in Fig. 2. To sample, the pore water collected inside the cup, was gently pumped out into a glass flask (Fig. 3) using a vacuum oil pump.

The samples were stored in PVC bottles at 4°C and analysed for above mentioned elements following methods described by Traversy (1971). The pH, Eh and conductivity were measured shortly after collection.

To obtain information on the chemical and mineralogical composition of the original and disposed sediment profile at different depths, a continuous core was obtained from a location in the middle of the first bay of the island to a depth of about 21 m (70 ft.) Subsamples from this core were taken each 0.3 m (1 ft.) starting at 0.6m (2 ft.) depth. Each subsample was

described, its Eh and pH measured following the procedure described by Kemp and Lewis (1968) and water content determined. For chemical analyses the subsamples were freeze dried and analysed for Ca, Si, Mg, Al, Fe, Mn, Ti, P by X-ray fluorescence and for Zn, Pb, Cu, Co, Cd, Cr by atomic absorption spectrophotometry after hydrochloric acid extraction.

Total nitrogen was analysed by LECO UO-14 Nitrogen Determinator and organic carbon was analysed by LECO IR-12 Analyser. Mercury in sediment samples was analysed by method developed by Agemian (1974).

Results and Discussions

The chemical composition of the pore water during the study period is shown in Figure 4 to 9. Changes in pH value are shown in Fig. 10 and conductivity changes in Fig. 11. The dredged sediment is described in Table 1, and its chemical composition is shown in Figures 12 to 15.

Rainwater and snowfall did not appear to effect the insitu water level within the dredged sediment at the Pilot Island. In January the dredged material froze to a depth of about 1.2 m (4 ft.). In the spring and summer the surface dried out and fissured, and there was evidence of surface subsidence.

In a 1.2 m (4 ft.) top layer the water in the porous cups froze during the winter and dried out after spring ablation. A hard crust formed on the surface as a result of the influence of the clay size fraction.

The changes in the chemical composition of the pore water from December 1973 to July 1974 were very small. The sampled pore water had a high content of P, N, Fe, org. C, Hg and Mn relative to the surrounding Mitchell Bay lake water. Fe and P content values appear to depend on the pH of the pore water (Figs. 4, 5 and 9). The Fe and P content values increased markedly as pH values dropped. A similar observation is reported by Chemex (1973) in a "before", "during" and "after" dredging study at Port Stanley, Lake Erie. The authors concluded the high P content found in the water column after dredging activities to be related to higher Mn and Fe content in the water column. Scavenging effects of oxides and hydroxides of these elements as noted by Dean (1970) can preferentially coprecipitate P and other elements that exist in the water column after dredging activity and also in the sediment pore water. The redox potential values of the sediment remained approximately constant to the depth of 2.7 m (9 ft.) and then increased to +235 mV. The Fe and Mn content in the pore water decreased with

depth (Fig. 5, March). Fe decreased from about 100 ppm at 2.4 m (8 ft.) to 18 ppm at 3 m (10 ft.). Mn dropped from 4.5 ppm to about 1.5 ppm.

The ratio of Mn-sediment Mn-pore water and Fe-sediment Fe-pore water at 3 m (10 ft.) depth increased about three times indicating that the decrease of Fe and Mn in the pore water has been in response to the increase in redox potential and pH in the sediment profile. The sediment at 2.7 - 3.0 m (9 - 10 ft.) horizon is probably the original lake bottom sediment on which the Pilot Island was built.

Organic carbon content in the pore water showed a conspicuous decrease at 3 m (10 ft.) depth. There was also a decrease of this parameter in the sediment profile at the same depth reflecting the inverse relationship between organic carbon content and particle size distribution (Thomas, 1969).

More than 95% of total N in the recent sediment was the form of organic N (Kemp and Mudrochova, 1972). In the Pilot Island sediment total N decreased by the same pattern as organic C. The Hg content in the pore water showed random scatter and no obvious relationship to the Hg content in the sediment profile. The Hg content of interstitial water in July sample was less than 0.05 ppb. This may demonstrate suitable conditions for

fixing of soluble Hg compounds to the sediment.

The quantities of nutrients which could be released from the pore water contained in the sediments of the Pilot Island were calculated and for the whole island, filled with sediment, the calculations are as follows:

Composition of pore water:

(highest values obtained during sampling period)

The total amount in stored sediment pore water:

Phosphorous:	2mg l	0.94 kg
Org. Carbon:	22mg l	10.0 kg
Nitrogen:	74 mg l	35.0 kg
Iron:	100 mg l	48.0 kg
Mercury:	0.5 ug l	0.25 g

The island is 45 m long, 15 m wide and has a 3 m thickness of sediment fill. The amount of dredged material stored on the island is approximately 2,000 m³, with water content about 500,000 l.

The quantities of releasable nutrients as defined by these experiments are negligible. On this basis, it appears that the waterproof walls around the dredge spoil are required only as a protection against wave erosion since no chemical treatment of the pore water from this type of sediment would be necessary to maintain water quality standards.

ACKNOWLEDGEMENTS

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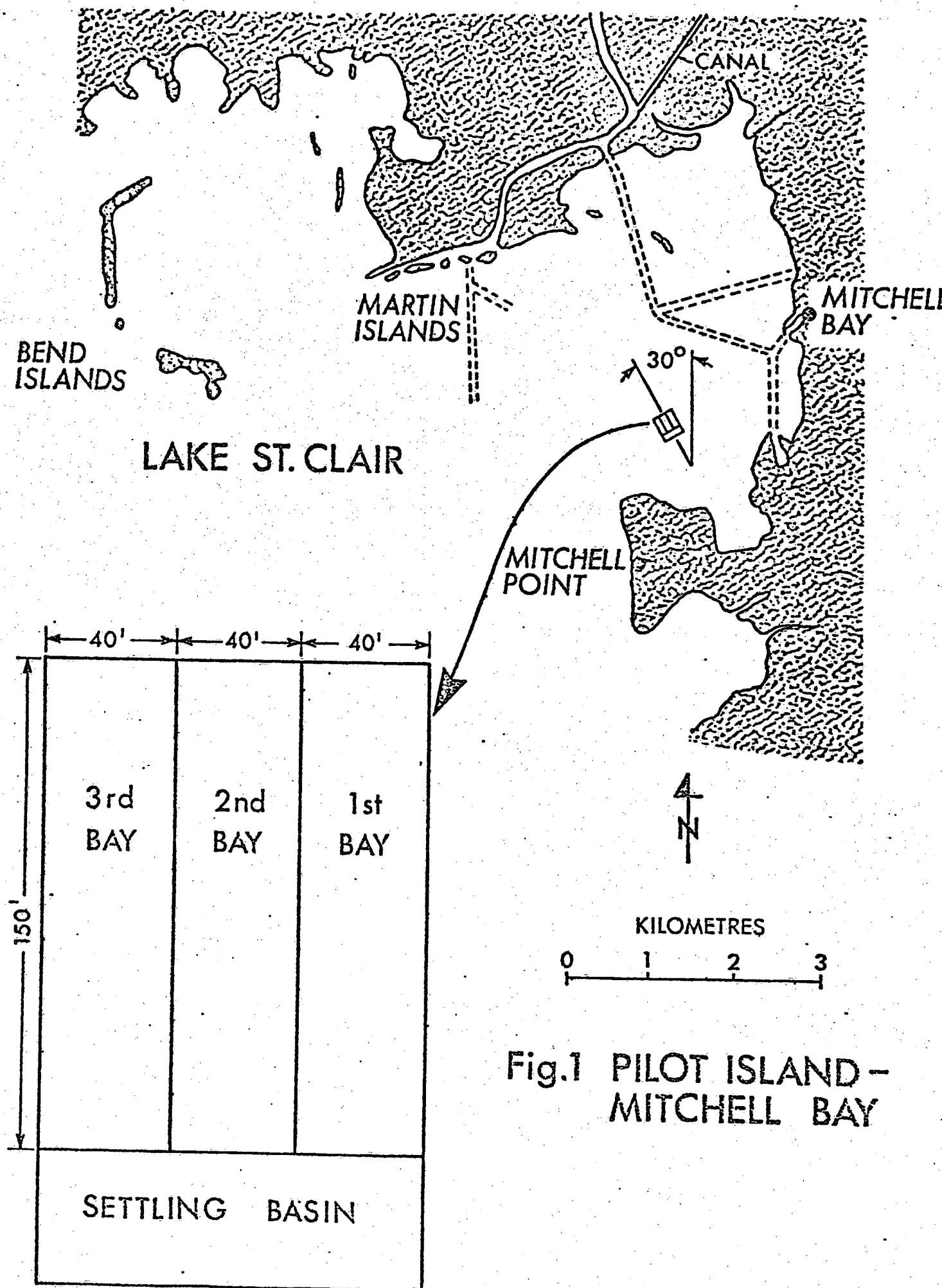
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Table 1

DEPTH m(feet)	Eh mV	pH	Sediment Description
0.6 (2)	+ 85	6.6	Stiff dark gray silt with some clay, many leaves, roots, grass.
0.9 (3)	+ 65	6.5	Same as above.
1.2 (4)	+ 50	6.5	Stiff dark grey silty clay, trace organic debris.
1.5 (5)	+ 55	6.6	Same as above.
1.8 (6)	+100	6.85	Stiff dark grey silty clay.
2.1 (7)	+ 75	6.7	Soft dark grey silt with some very fine grayish brown clay.
2.4 (8)	+145	6.75	Soft very fine greyish brown silt with some clay, organic debris.
2.7 (9)	+235	7.1	Soft to very soft dark grey fine sandy silt, black patches of decomposing organic material.
3.0 (10)	+300	7.6	Medium dark grey silt with some sand and clay.
3.3 (11)	+310	7.6	Same as above.



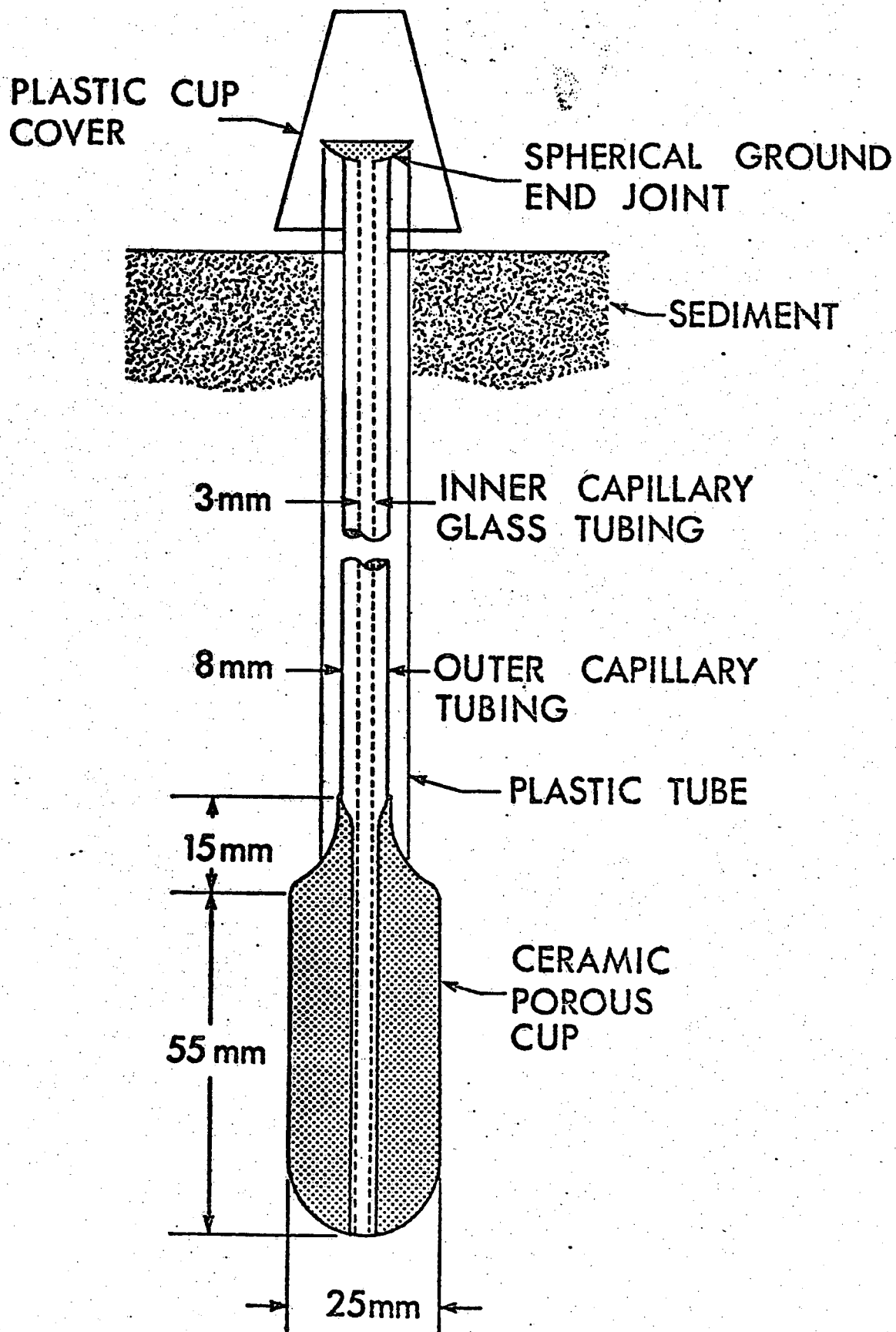


Fig. 2

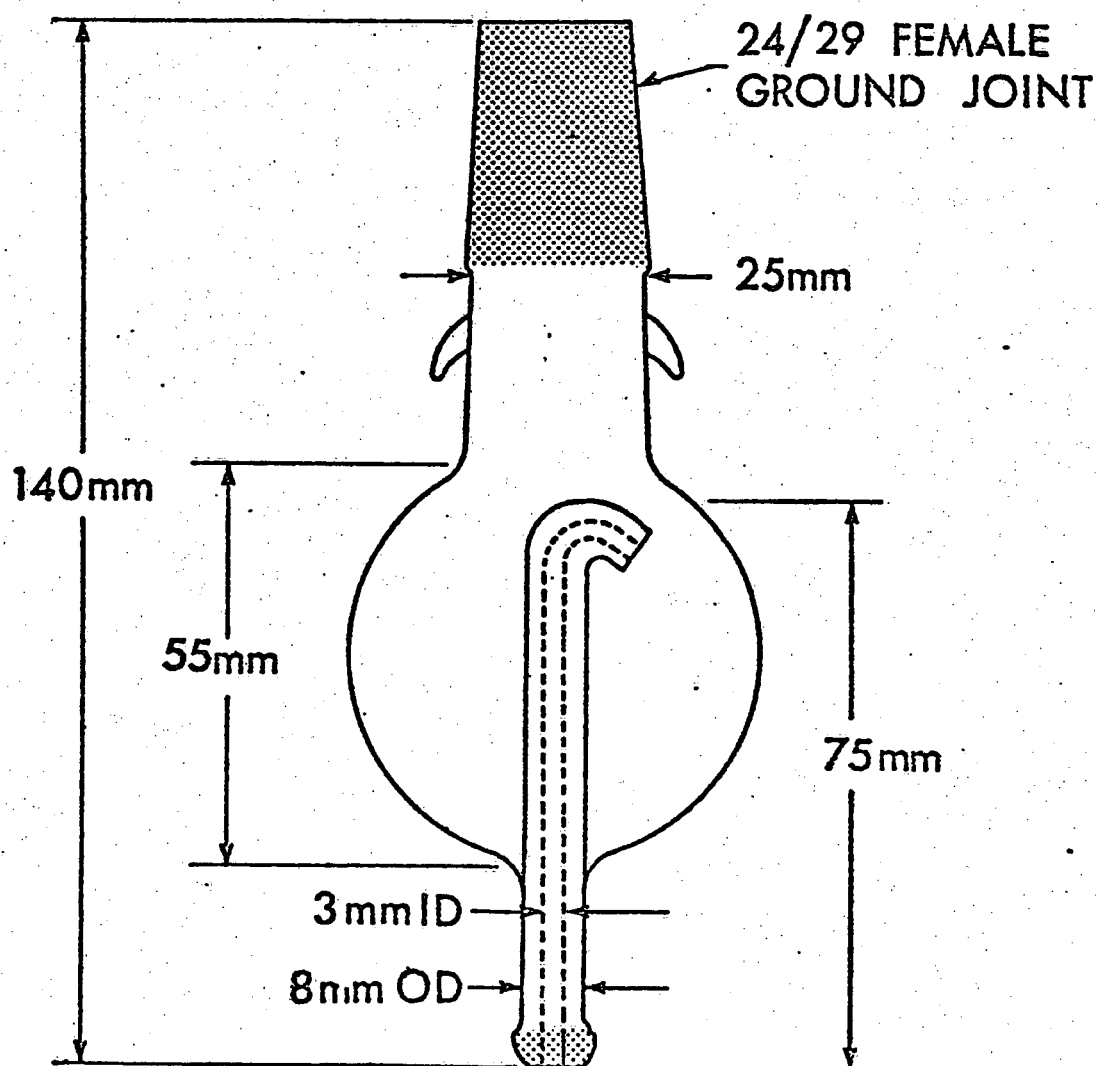
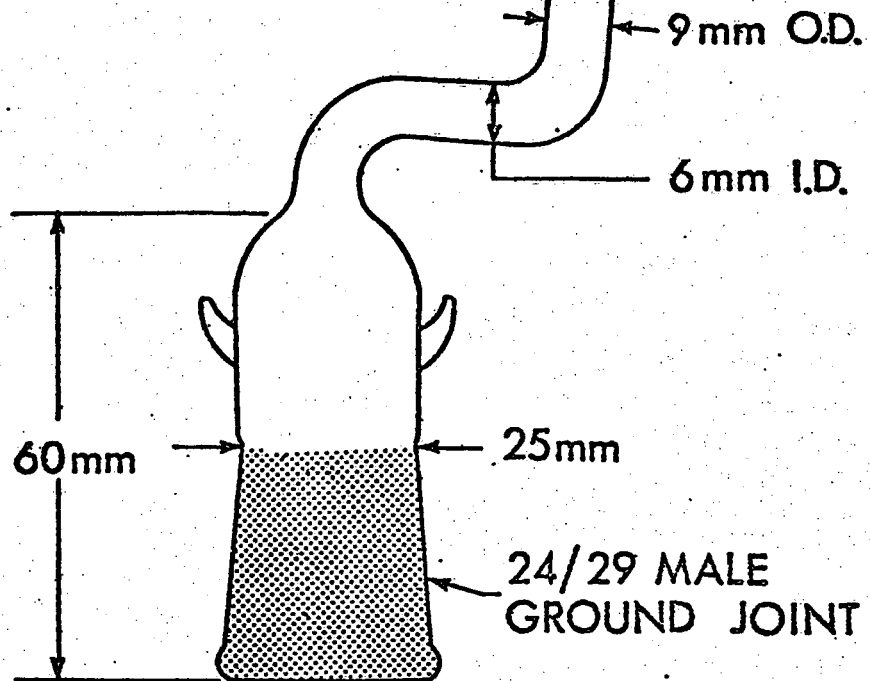


Fig. 3

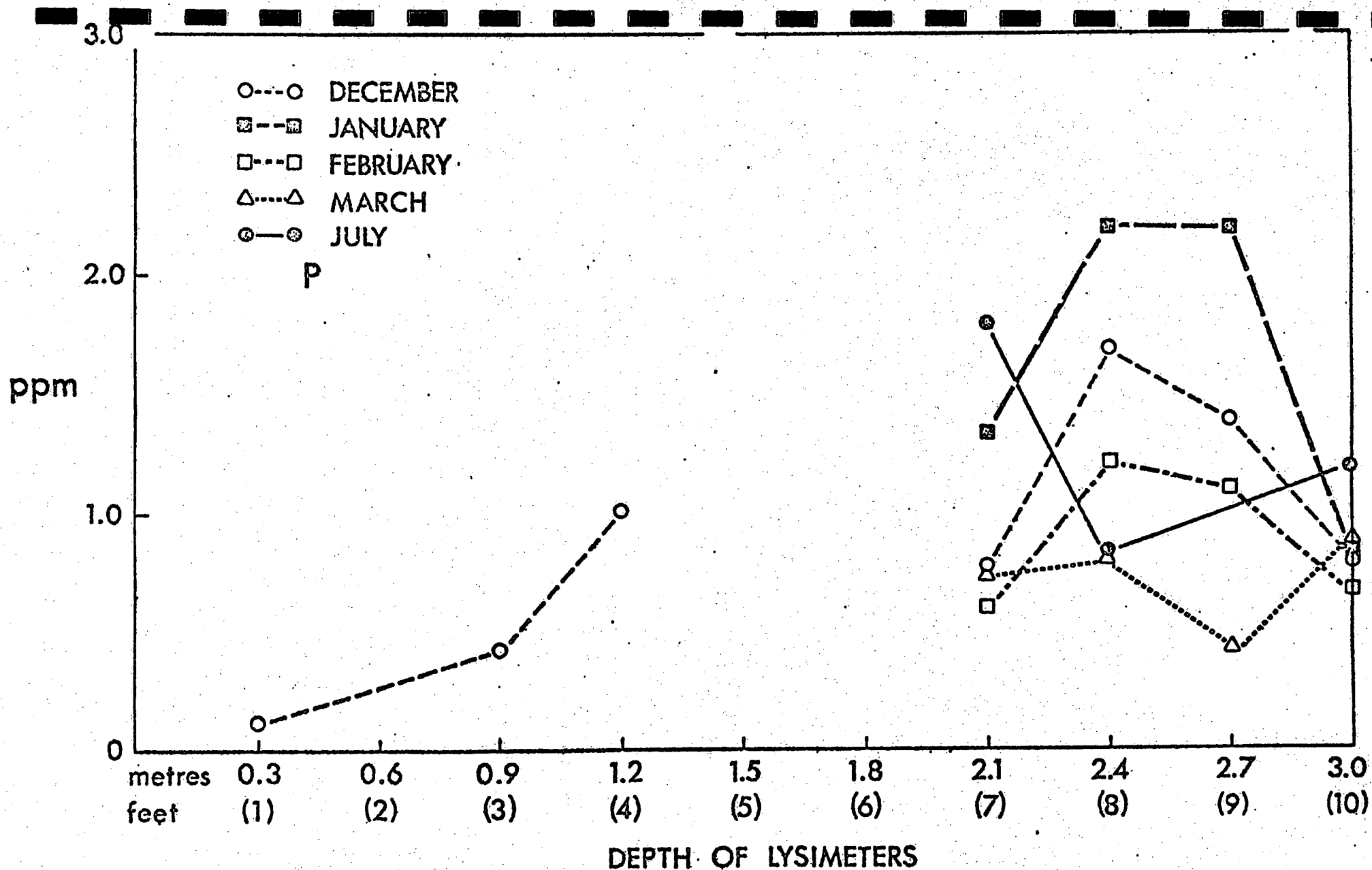


Fig.4 MITCHELL BAY WATER (1.3.74) 0.30ppm

changes in P

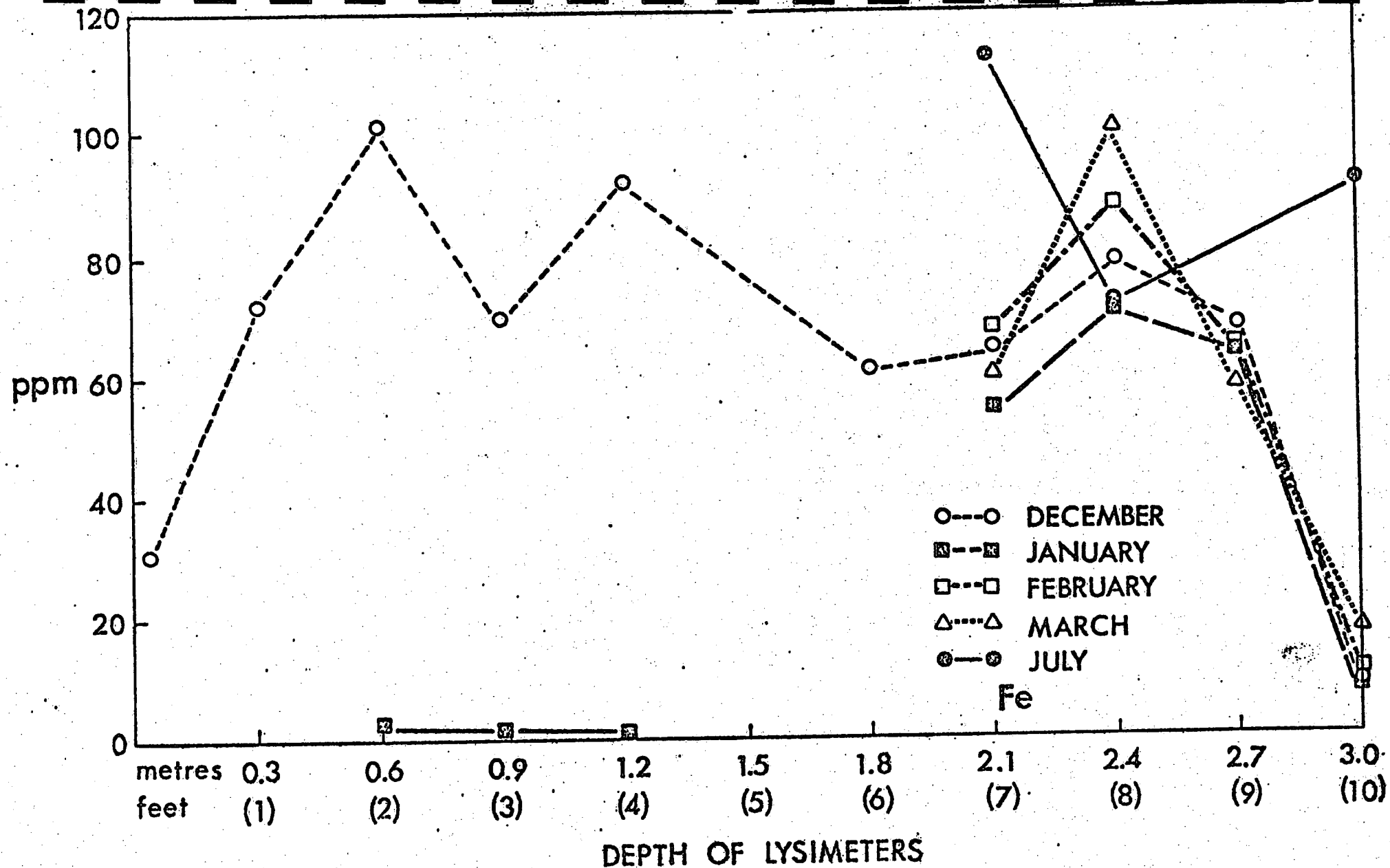


Fig.5 MITCHELL BAY WATER (1.3.74) 4.0 ppm

Changes in Fe

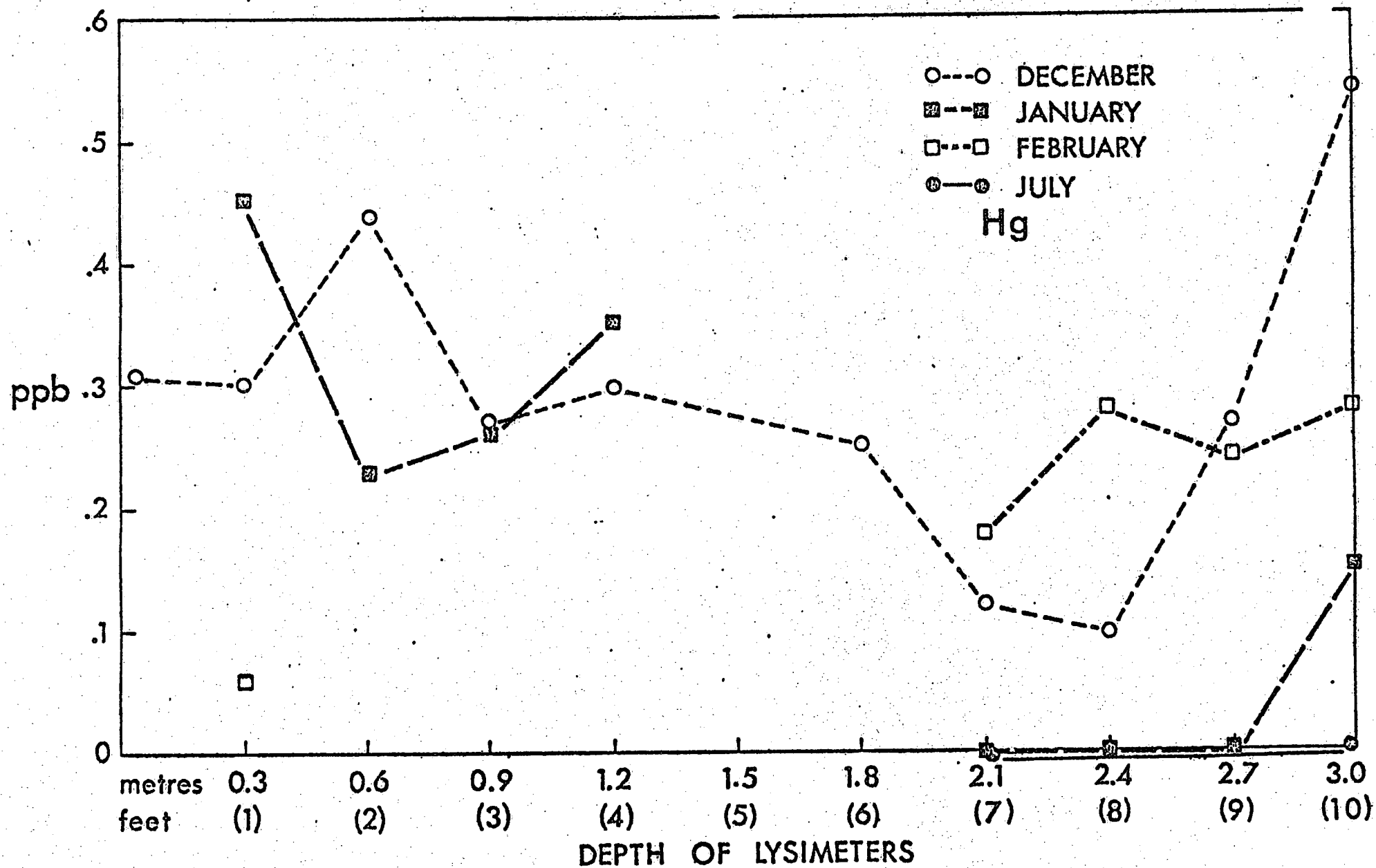


Fig.6 MITCHELL BAY WATER (1.3.74) <0.05 ppb

Changes in Hg

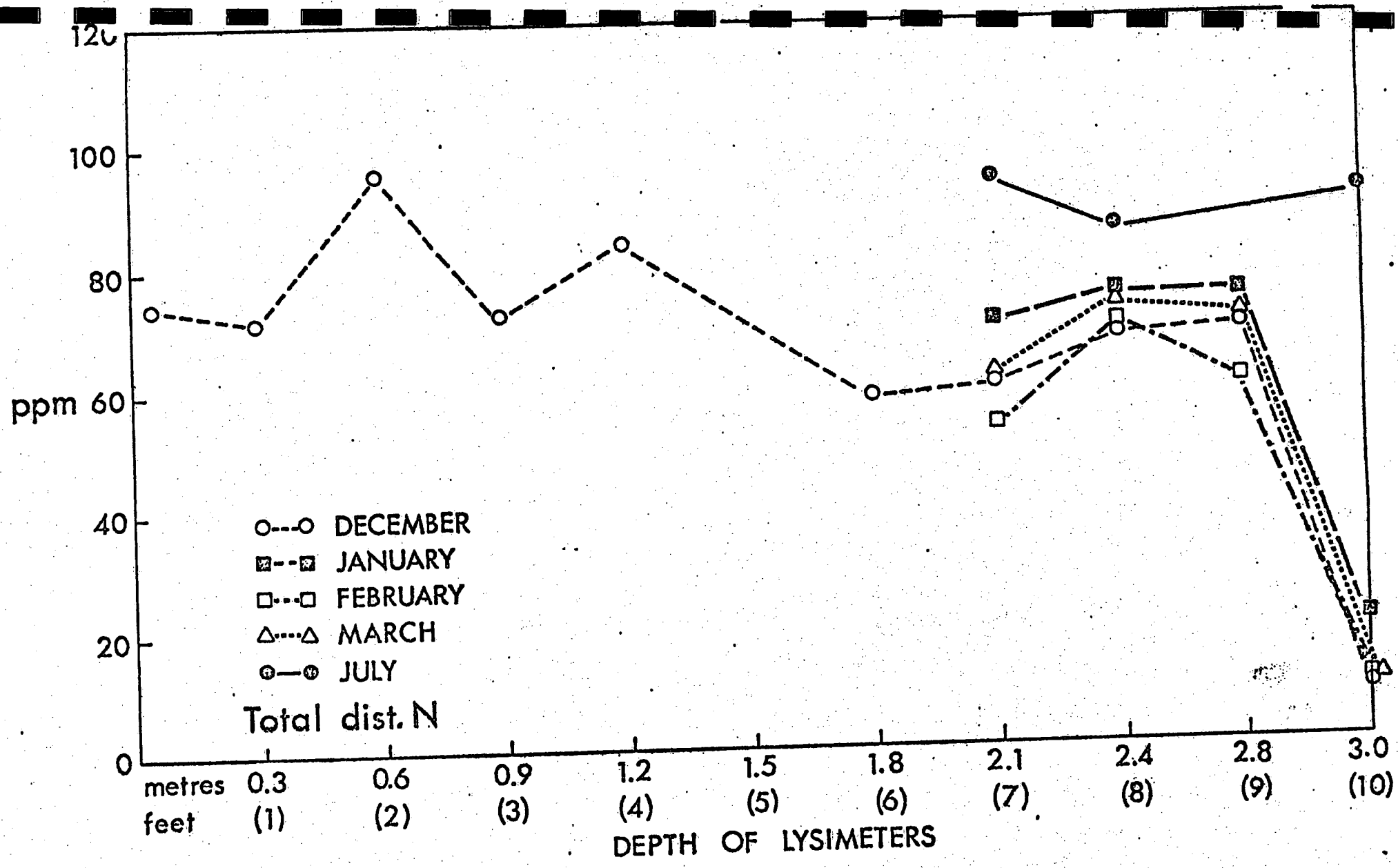


Fig.7 MITCHELL BAY WATER (1.3.74) 3.2 ppm

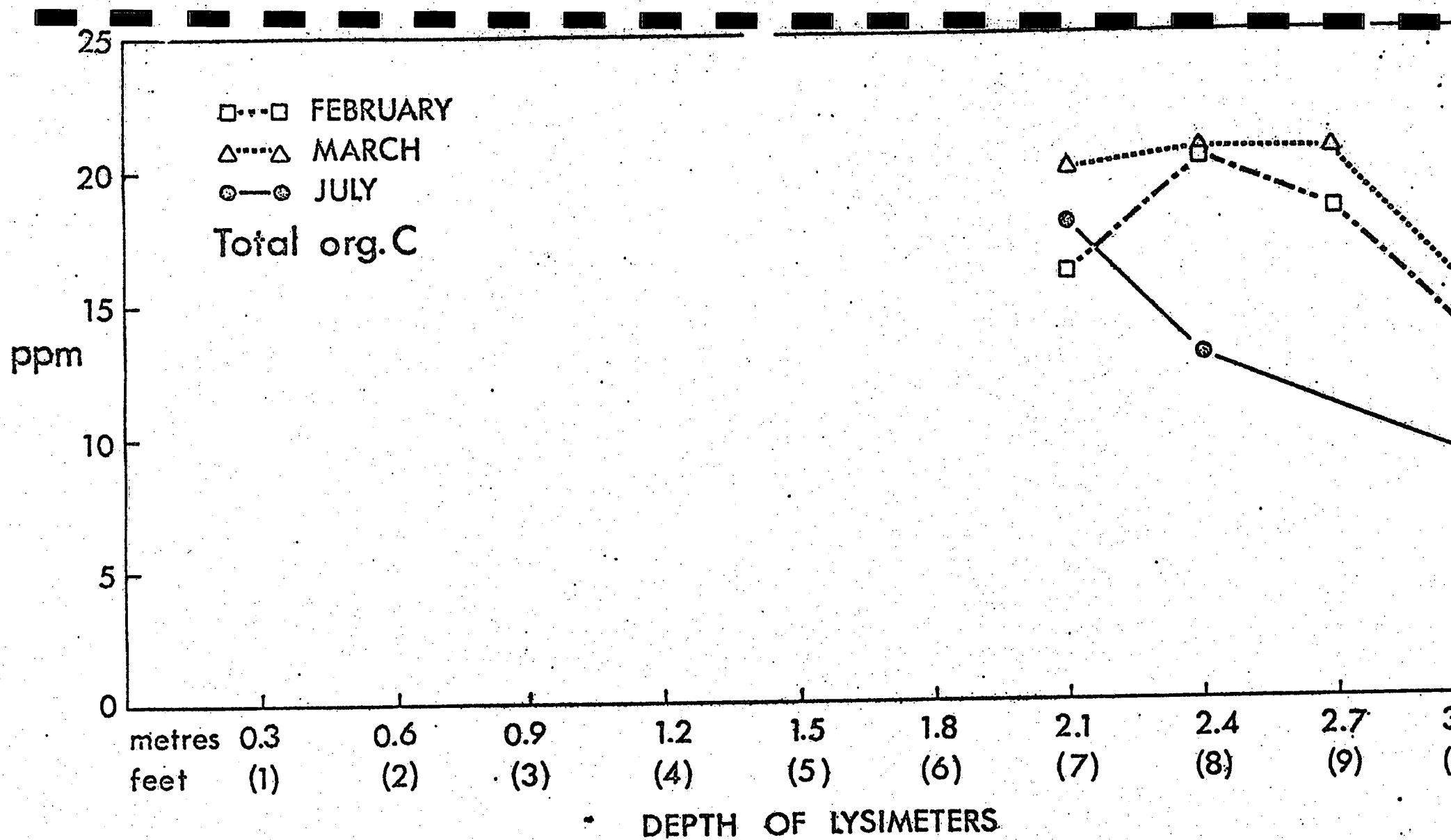


Fig.8 MITCHELL BAY WATER (1.3.74) 4.3 ppm

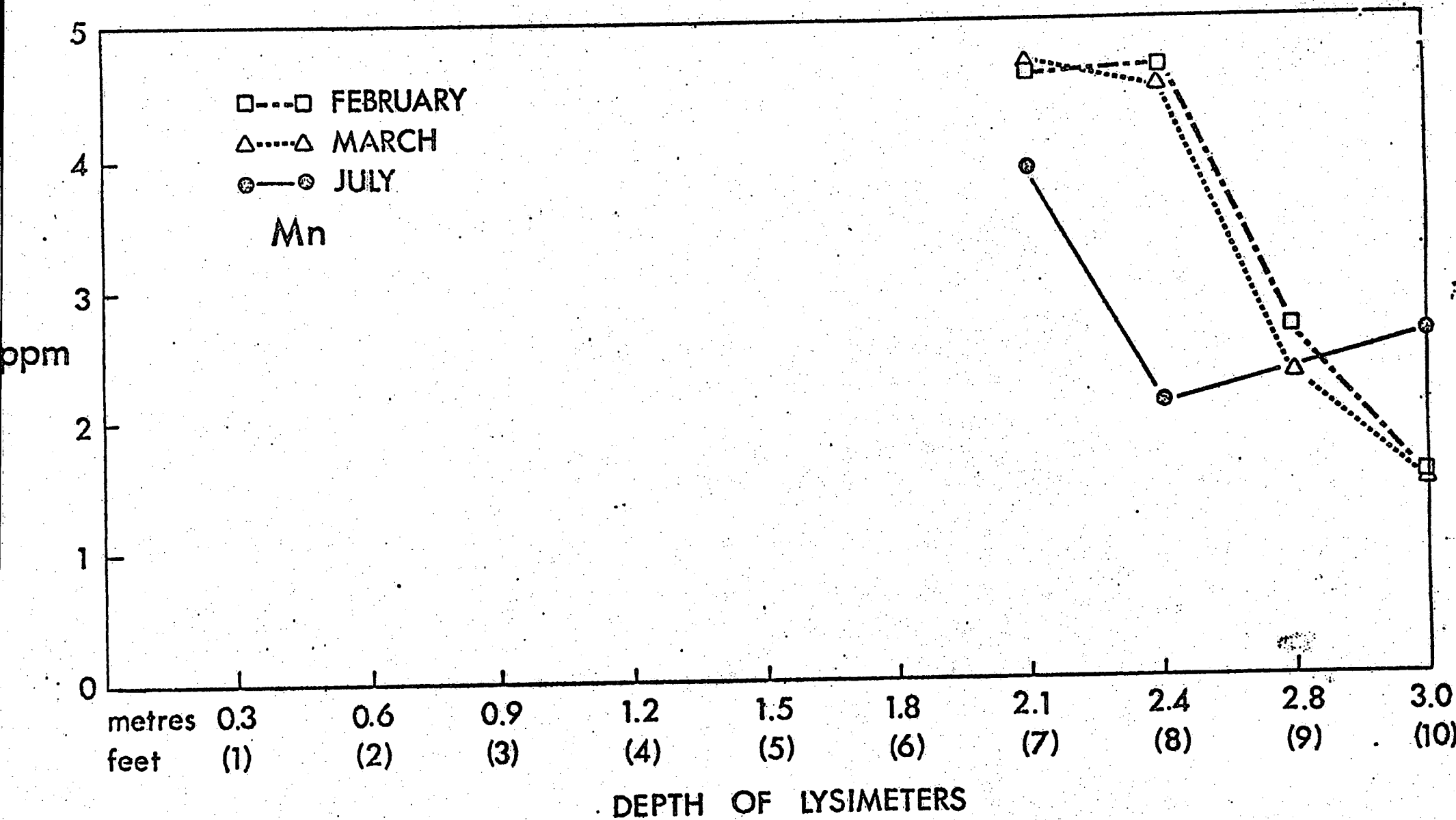


Fig. 9 MITCHELL BAY WATER (1.3.74) 0.16 ppm

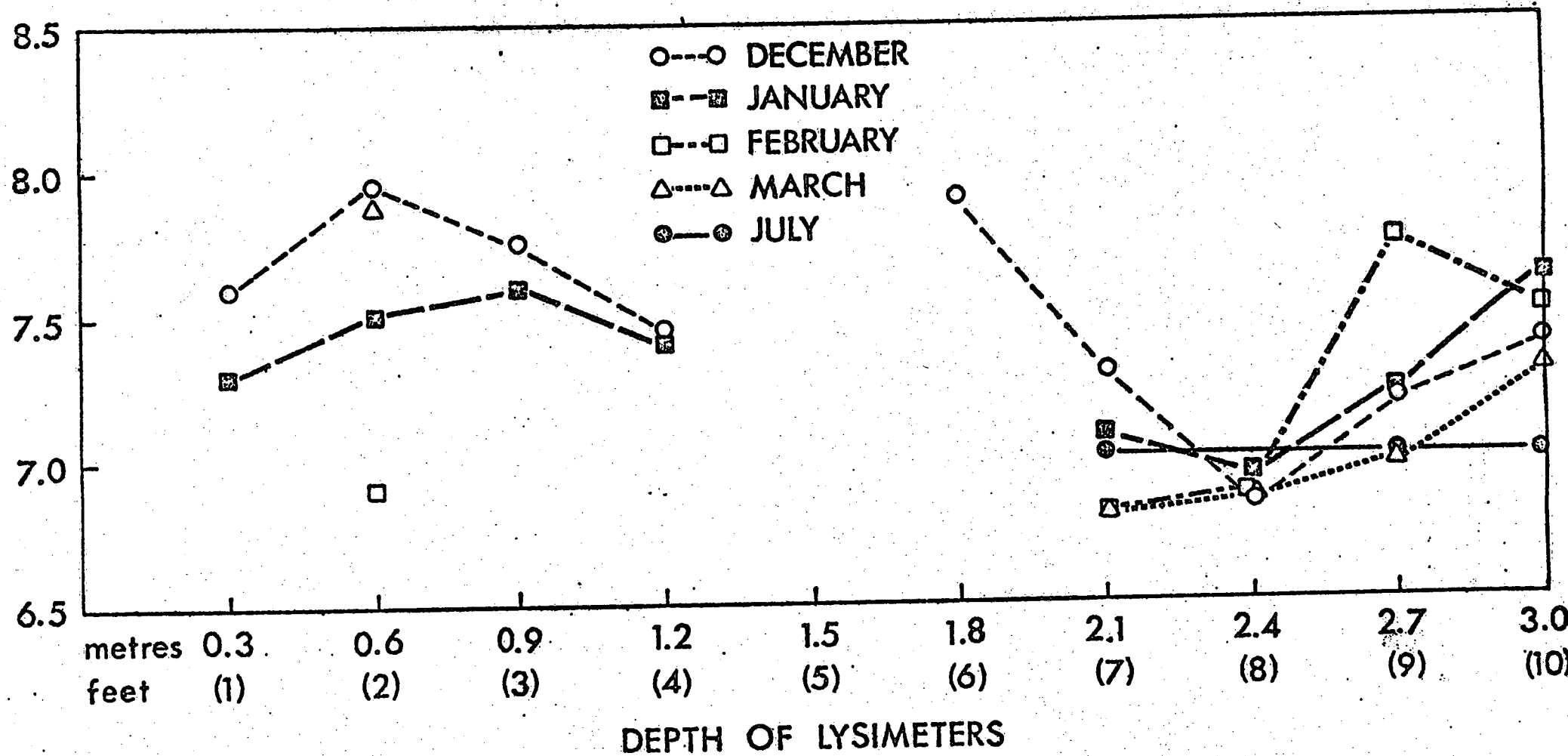


Fig.10 MITCHELL BAY WATER (1.3.74) 8.20

PH

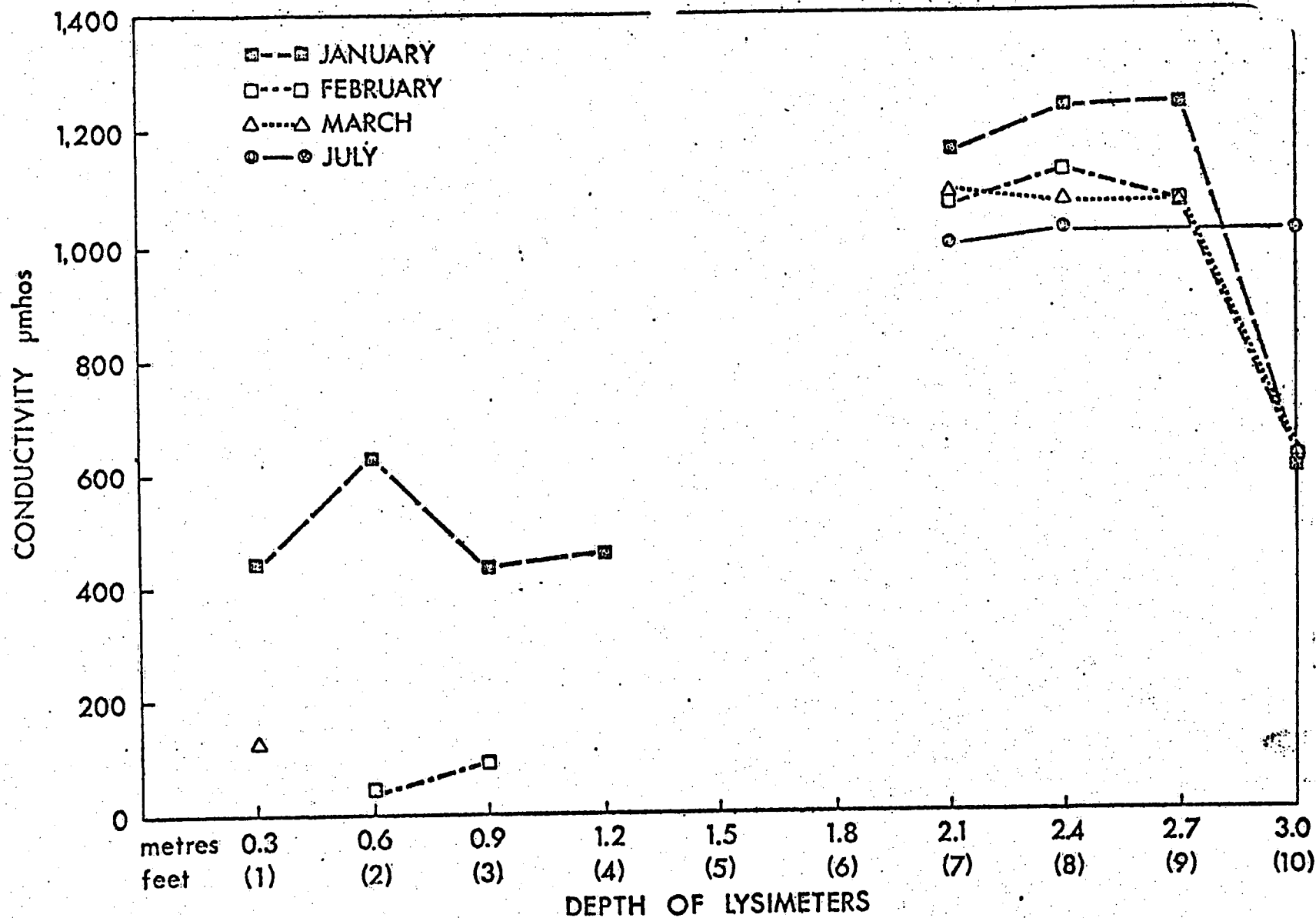


Fig.11 MITCHELL BAY WATER (1.3.74) 180 μmhos

DEPTH IN METRES (FEET)

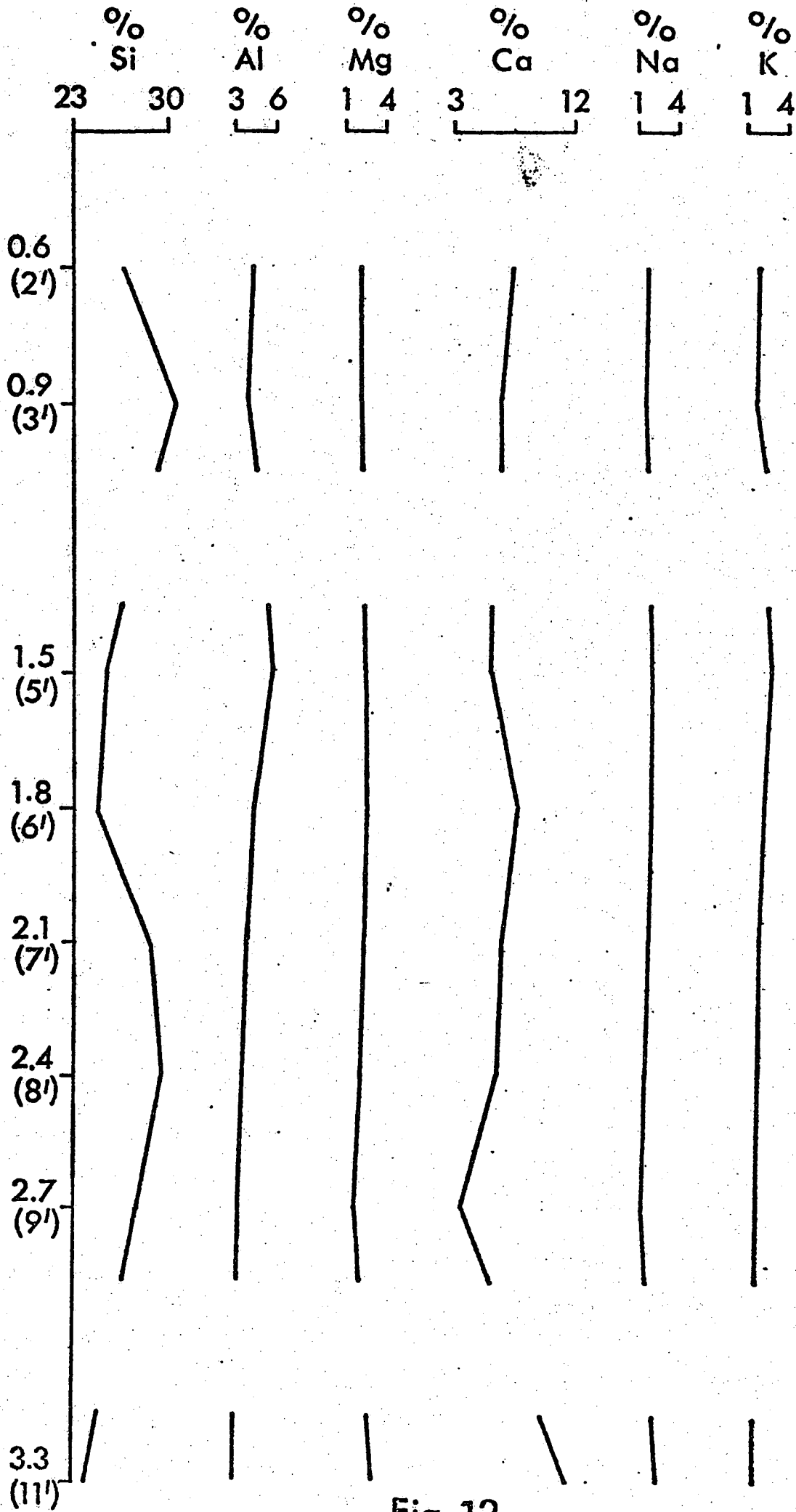


Fig. 12

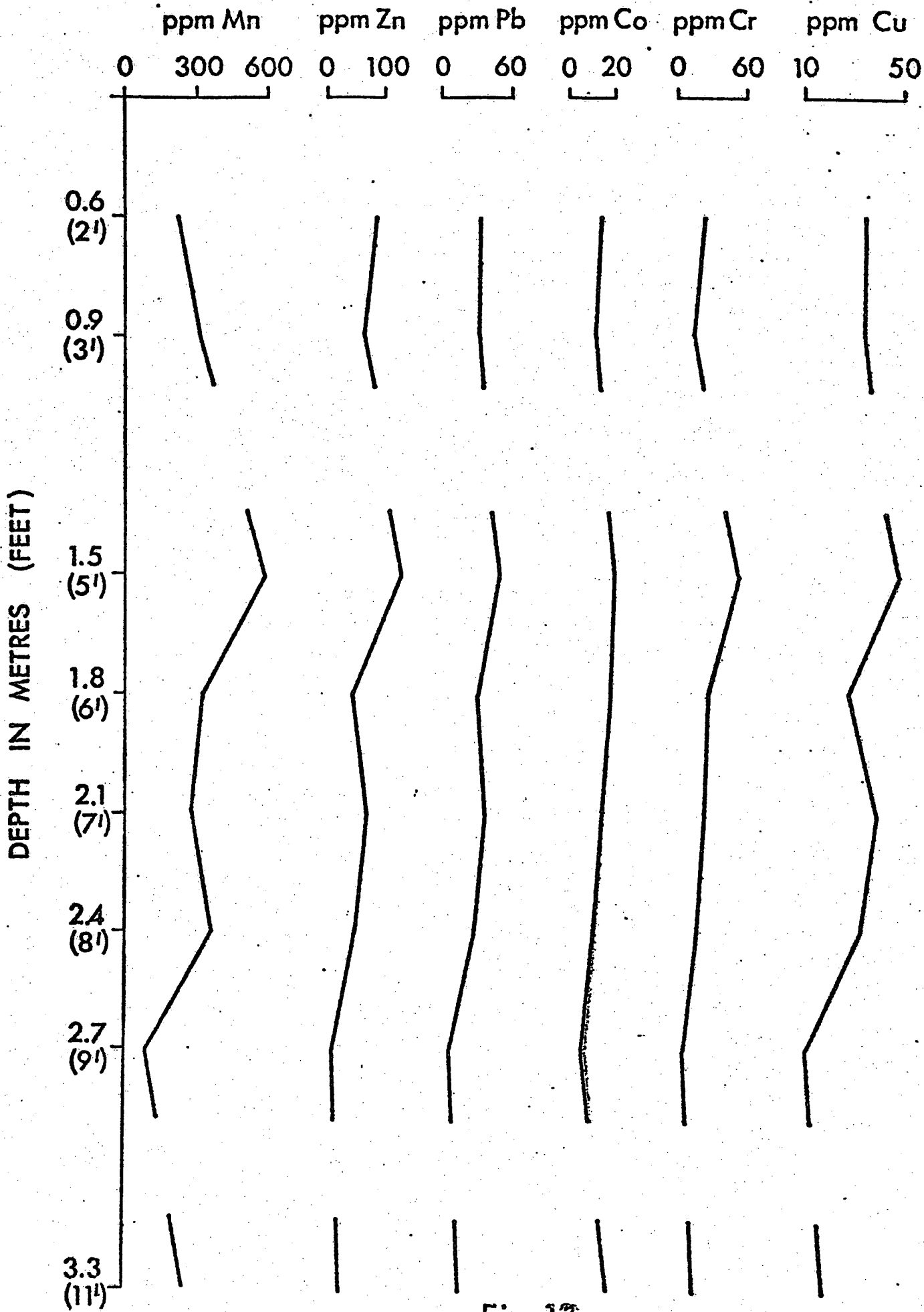


Fig.13

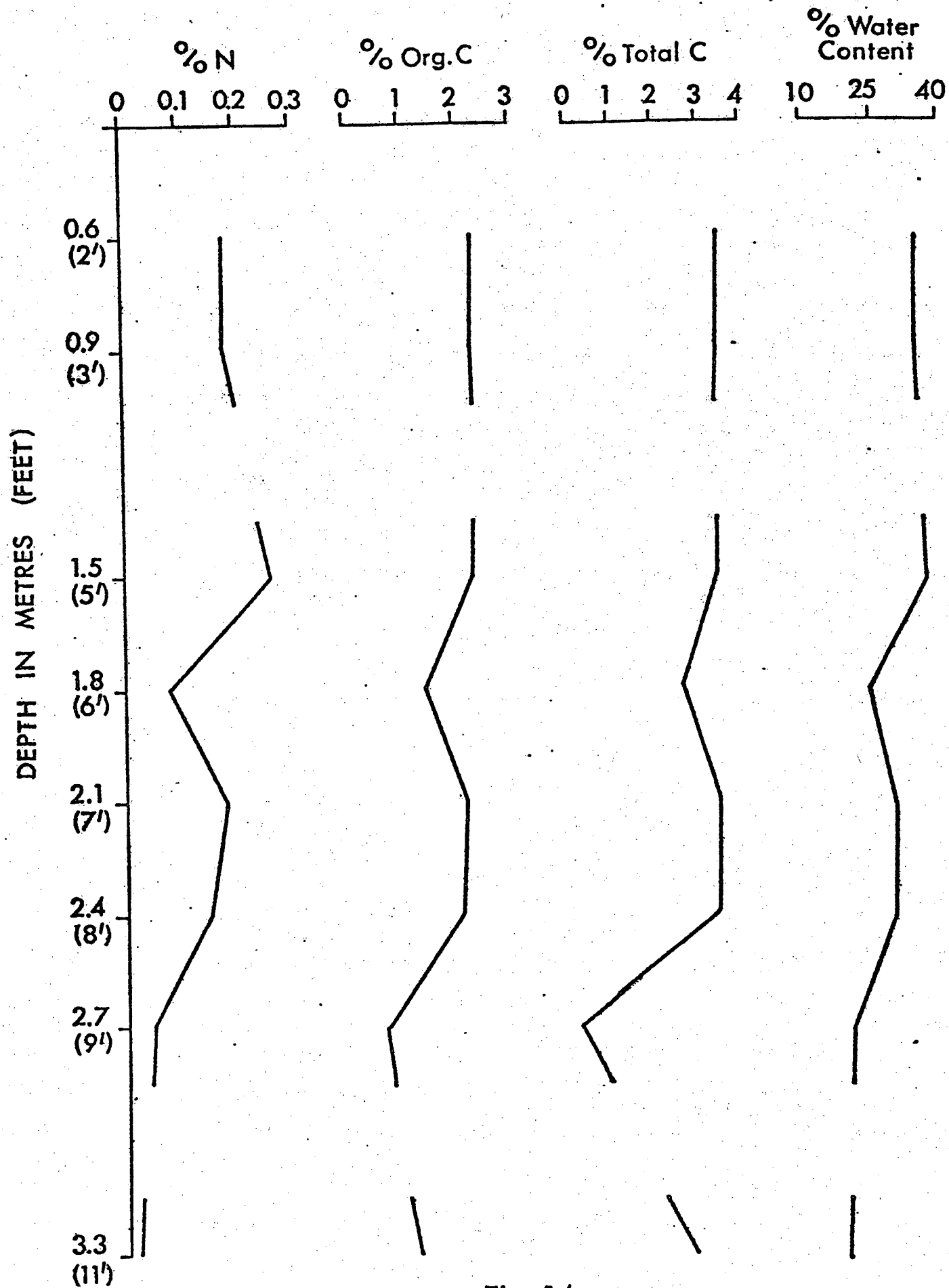


Fig. 14

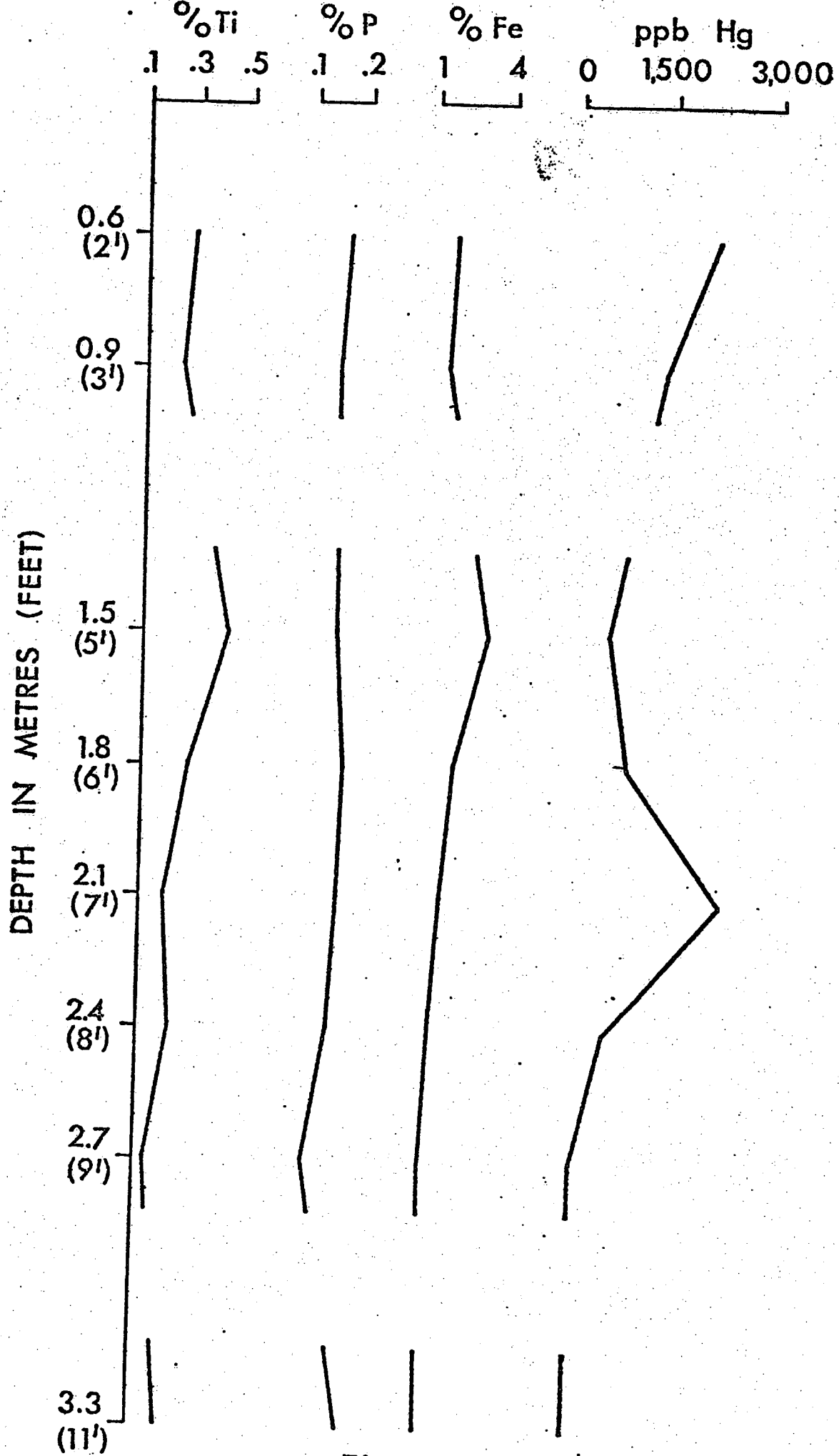


Fig. 15

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