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NOTE ON THE POSSIBLE PERIODS OF SEICHES IN NAPIER HARBOUR

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INTRODUCTION

During storm conditions on the east coast of New Zealand, difficulties with berthed ships are often experienced in Napier Harbour - i.e., moving against the wharf fenders and the mooring lines or "ranging". The problem of "ranging" has been analysed in several reports and methods to minimise the phenomenon in future harbour developments have been suggested (e.g., Hydraulics Research 1967, 1968; Fisher 1972). It is believed that the waves producing the ship movements have periods of 30 to 60 s and are therefore not surf beats; and that the ship movements are probably induced by long waves from the open sea that are either reflected into Napier Harbour by the shores of Hawke Bay or diffracted around the breakwater (Fig. 1) into the harbour (Hydraulics Research 1967). The large response of the ships to these waves is thought to result from the mooring system rather than the harbour being resonant in this range of periods (Hydraulics Research 1968). However the possibility of resonance within the harbour did not appear to have been fully investigated, and it would therefore seem worthwhile to investigate the possible seiche periods in the harbour system in more detail (a seiche is a standing wave in an enclosed or semi-enclosed body of water). A high resolution long wave recorder (Barnes 1975) was installed in Napier Harbour in October 1974 during a period of moderately calm sea conditions. The records obtained and their interpretation are presented in this report.

OBSERVATIONS

Between 4 and 7 October 1974 sea elevations were recorded at two locations within Napier Harbour (Fig. 1). The instrument used has a full-scale range of 0.50 m of water and a resolution of 2.5 mm (Barnes 1975). Sections of the unfiltered and filtered records (wind waves are filtered out by restricting the air passage into the pressure sensing element) together with the record from the Napier Harbour Board's tide gauge over the same period are shown in Fig. 2.

DISCUSSION

Wind waves with periods of the order of 10 - 12 s and amplitudes up to 0.1 m superimposed on larger period oscillations are clearly evident in the unfiltered record. The filtered record appears to have a periodicity greater than at least 1.5 min. and there is no evidence of the 30 - 60 s period troublesome waves. A sampling interval of 0.5 min. (ΔT) has therefore been used in spectral analysis of the filtered record (Fig. 3). The Extra Fast Fourier Transform (Bice 1970) was used for this analysis with 64 (N) data points starting at 1324 h (NZST) on 4 October. The maximum period that can be discerned then is equal to the length of the record (N x ΔT) and the other periods are the first N/2 harmonics of the maximum.

The main energy is at a period of 1.78 min. with significant energy also at periods of 32, 2.7, 1.4, and 1.1 min. In the analogue record (Fig. 2) there is energy at a period of around half an hour and this energy appears at 32 min. in the spectral analysis. However, the 32 min. period should not be treated as exact for the period resolution at this end of the spectrum is very coarse.

We can examine the possibility that these periods are associated with seiches, by comparing the observed periods with those calculated from simple long wave theory. The period (T) of a seiche is given by

$$T = \frac{1}{n} \Sigma \frac{2\ell}{\sqrt{gh}} \qquad (1)$$

where ℓ is a length of water over which the depth (h) is approximately constant, g is the acceleration of gravity and n is a non-zero integer. Further $\Sigma\ell = L$, where L is the distance between the boundaries at each of which the wave reflects to form an anti-node. (For the case of a constant depth H, equation 1 reduces to Merian Formula

$$T = \frac{2L}{n\sqrt{gH}}$$

[*see* e.g., Proudman 1953]).

Within the harbour itself the periods of the first five modes of oscillations between the outer breakwater and the main wharves (line a, Fig. 1) calculated using equation 1 are

$$\frac{3.3}{3.8} : \frac{1.7}{1.9} : \frac{1.1}{1.3} : \frac{0.8}{1} : \frac{0.7}{0.8} \text{ min}$$

the upper values being for high spring tidal elevations and the lower values for low spring tidal elevations; depths were taken from the September 1973 depth soundings kindly made available by the Napier Harbour Board, with the total distance L of 875 m being subdivided into six sections in each of which the depth is approximately constant. The corresponding

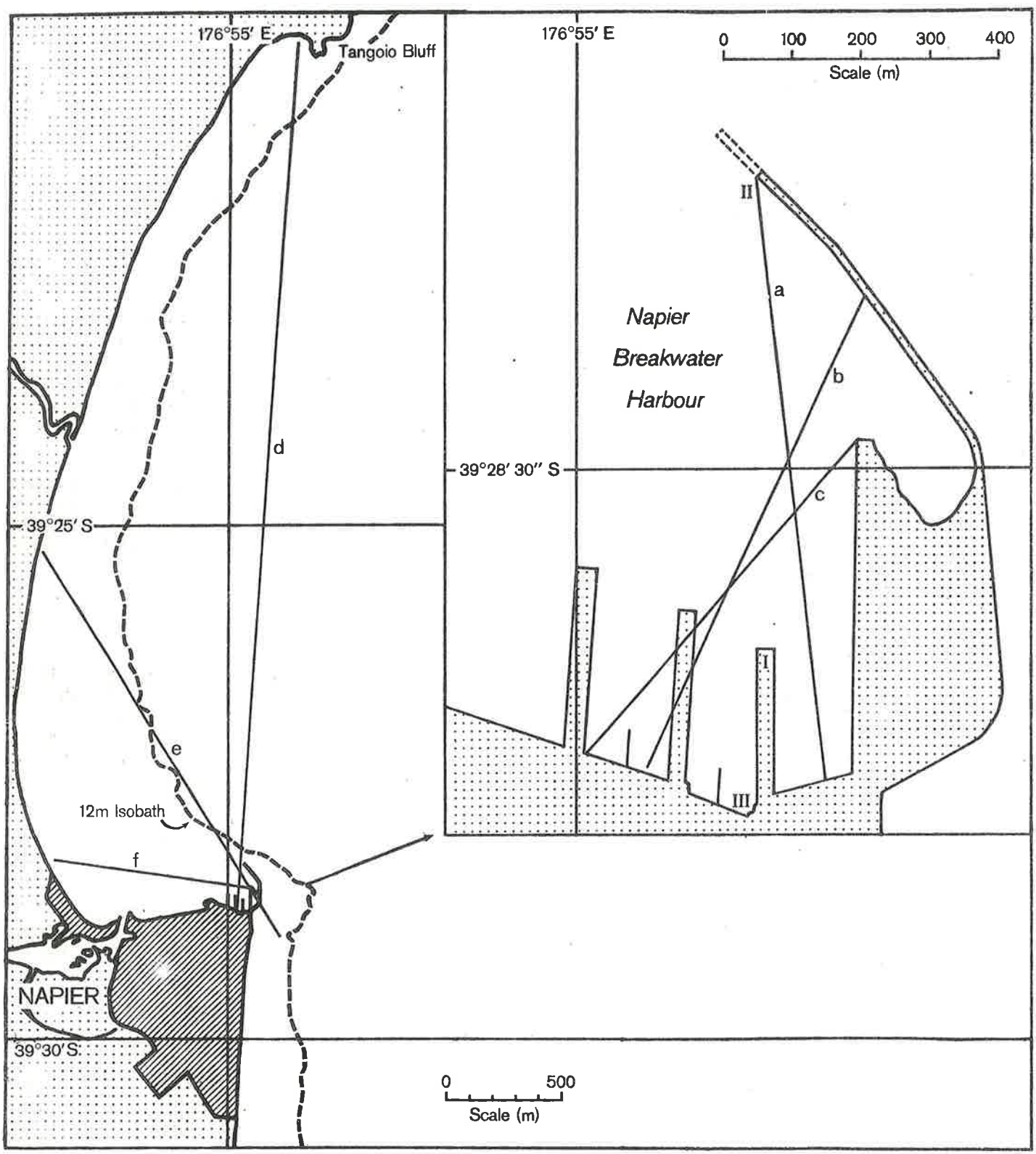

Fig. 1. Napier Harbour and the adjacent section of Hawke Bay. The theoretical seiche periods have been calculated along the lines a - f. Positions II, III are are where the seiche gauge was located, position I is where the Napier Harbour Board tide gauge is installed.

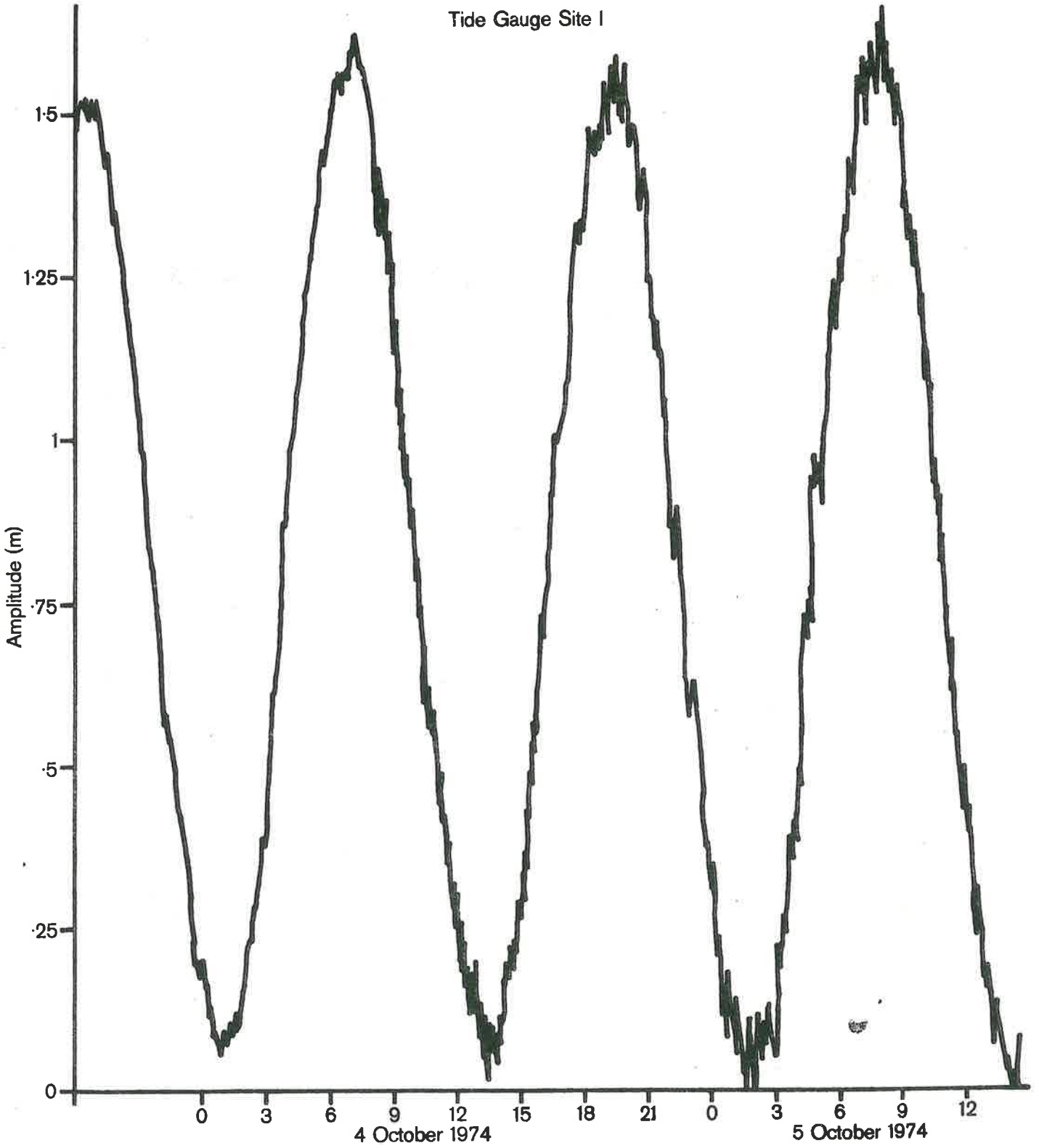

Fig. 2a.

Fig. 2, a. (above) Sea surface elevations in Napier Harbour recorded by the Napier Harbour Board (position I in Fig. 1) tide gauge.
b. (see over, P.4) Sea surface elevations in Napier Harbour recorded with a seiche gauge (positions II and III in Fig. 1).

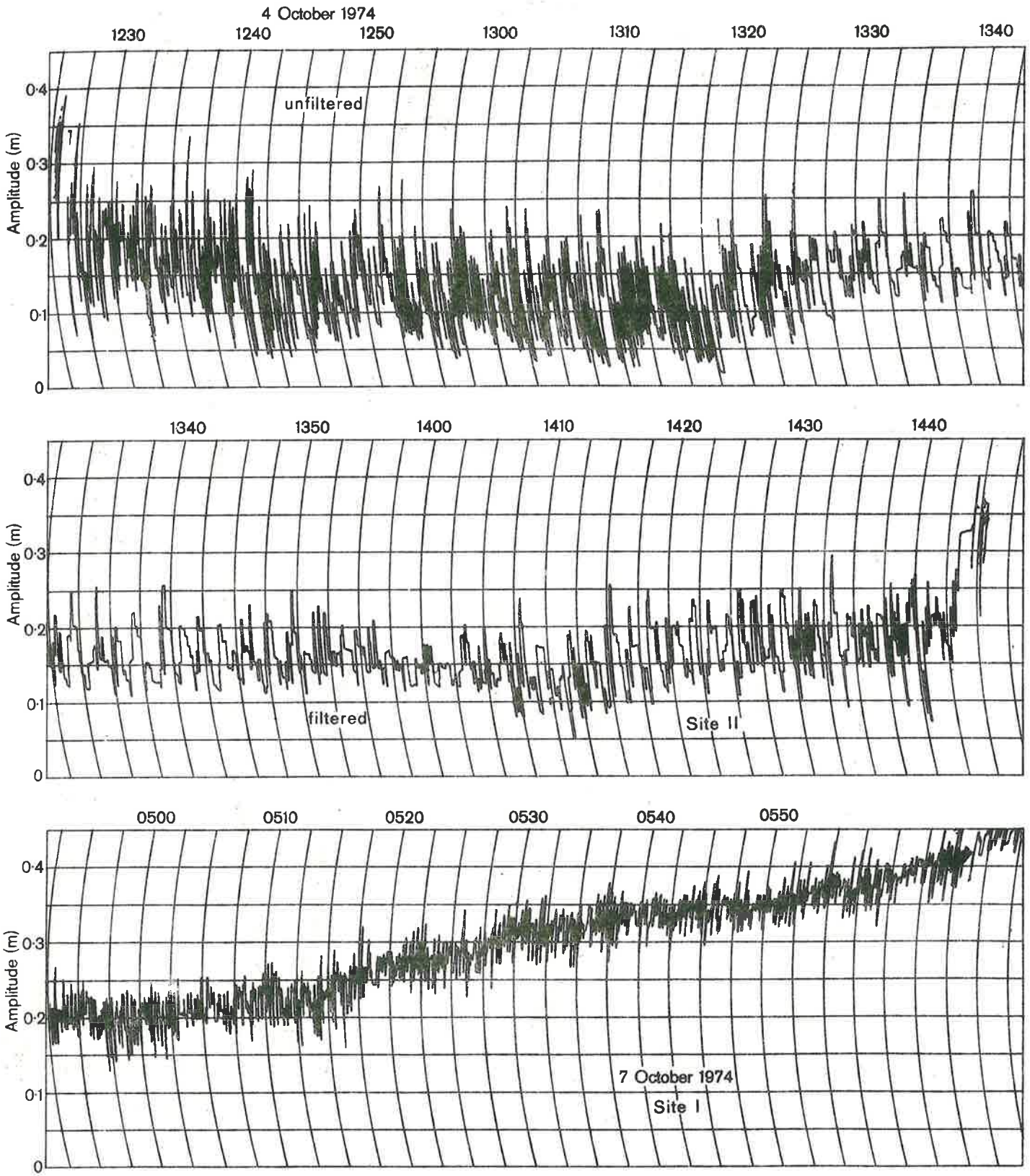
4 October 1974
1230
1240
1250
1300
1310
1320
1330
1340
unfiltered
Amplitude (m)
0·4
0·3
0·2
0·1
0
1340
1350
1400
1410
1420
1430
1440
filtered
Site II
0500
0510
0520
0530
0540
0550
7 October 1974
Site I

Fig. 2b.

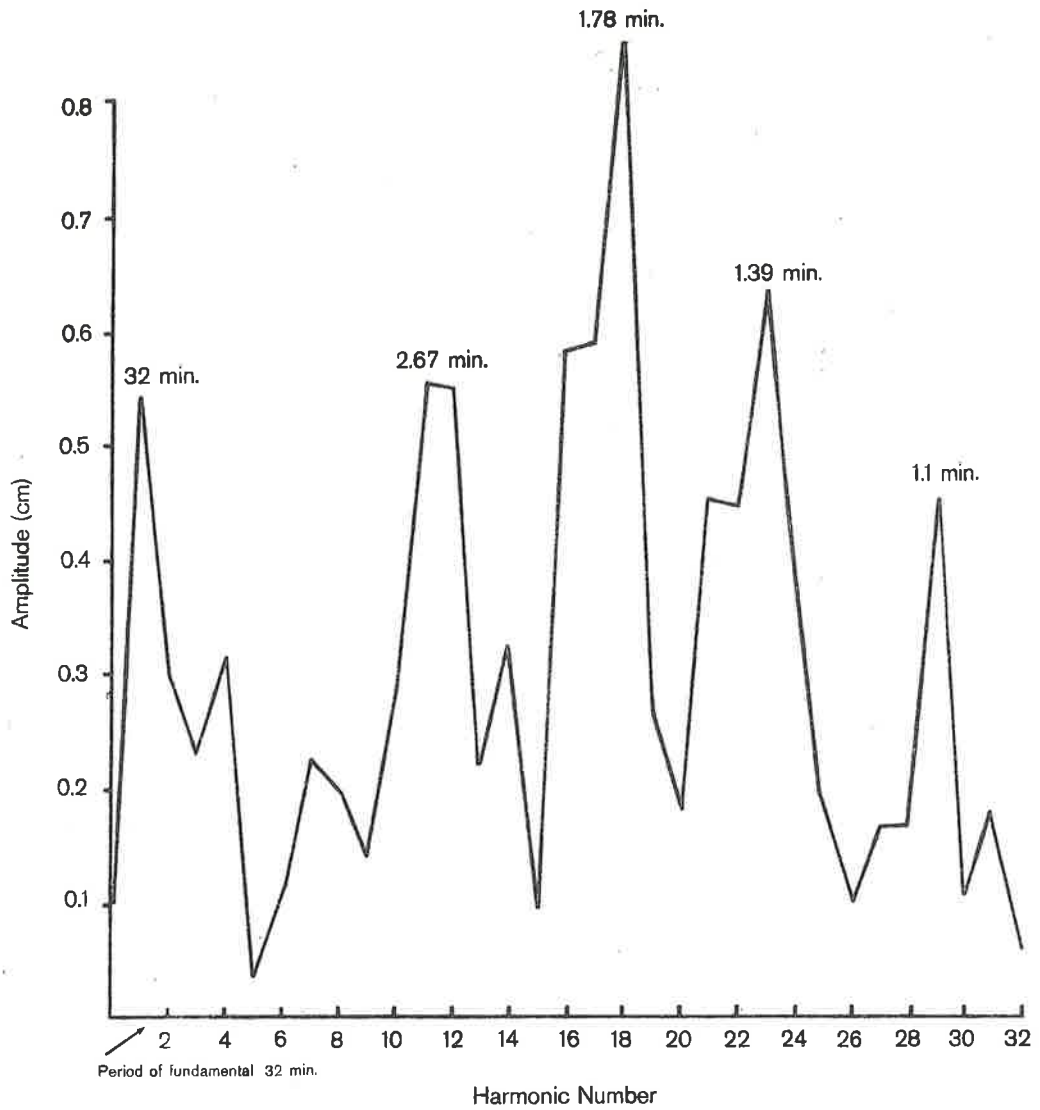

Fig. 3. Line spectra of sea surface elevations in Napier Harbour (position II in Fig. 1) on 4 October 1974. The period (minutes) of the most prominent lines are shown above the curves.

periods further within the harbour on lines b and c (Fig. 1) are

$$\frac{1.9}{2.1} : \frac{1}{1} : \frac{0.6}{0.7} : \frac{0.5}{0.5} : \frac{0.4}{0.4} \text{ and}$$

$$\frac{2.8}{3.3} : \frac{1.5}{1.6} : \frac{1}{1.1} : \frac{0.7}{0.9} : \frac{0.6}{0.7} \text{ min.}$$

Although it is not conclusive it would appear that the oscillations producing the four short-period spectral peaks (1.1, 1.4, 1.8, 2.7 min.) are those of the first modes of seiches along lines b and c.

Only the higher order modes of the seiche have periods in the 0.5 - 1 min. range of the troublesome waves. When seiches are generated by atmospheric forcing, the energy appears mainly in the fundamental (or half wavelength) mode with the relative energy in the other modes decreasing as the order of the mode increases. In this situation significant energy in the 0.5 - 1 min. period range would therefore not be expected in Napier Harbour. However if there is an external driving force (like incident long waves) with periods near that of one of the higher order modes then this mode could be preferentially excited - this possibility, the importance of a harbour resonance rather than a resonance with the ships mooring system could be checked by calculating the relative energy in the seiche modes when troublesome waves are present.

The energy at a period of about half an hour (Figs 2, 3) is clearly not due to a seiche confined within the harbour. Outside the harbour the boundaries are not distinct (or parallel) and there is always an open boundary through which seiche energy might be transmitted. Therefore the expected periods on various lines between the barrier formed by the outer breakwater and wharves in the harbour, and the main

coast of Hawke Bay have been calculated using the depths shown on hydrographic chart NZ5713 (Hydrographic Branch 1975). These periods give an indication of the probable extremes of the period of the fundamental mode.

The periods vary from 45 min. (line 3, Fig. 1) through 25 min. (line 3, Fig. 1) to only 15 min. (line c, Fig. 1). Based on these estimates it would appear that the half hour periodicity in the water elevation records is associated with the fundamental mode of a seiche between the harbour and the coast of Hawke Bay directed mainly in a north-west south-east line (i.e., in the direction of line c, Fig. 1).

CONCLUSION

Sea level elevations recorded in Napier Harbour in October 1974 show clear evidence of periodicity in the range of 1 to 3 min. Comparison of the period of the peaks evident in the line spectrum of these records with the seiche periods calculated from simple long wave theory indicates the oscillations are probably those of the lowest modes of seiches in the harbour. The significance of these seiches to the problems experienced with ships berthed in the harbour moving against the wharf fenders and mooring lines cannot be discounted although except in extreme cases the water slopes and hence the forces on the ship will be small. The significance can probably best be evaluated from simultaneous water elevation observations both inside and outside under conditions when the troublesome waves are present.

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