Appendix- 5 Hindcast of Design waves

Based on the record of typhoon tracks for 1971 to 1990 and cyclone tracks for 1969 to 1988, waves generated by typhoons or cyclones have no influence to Tarawa. Figures A- 5- 1(1) to A- 5- 2(20) shows typhoon tracks and cyclone tracks for above period. From view of all tracks in Figures, no occurrence or movement of typhoons and cyclones are in the vicinity of Tarawa atoll. Nearest typhoon to Tarawa atoll occurred 700 km northwestern offshore and went away to the west (see Figure A- 5- 1(12)). Generally, swell generated by strong winds far offshore have no influence to Betio Port in Tarawa atoll because waves attenuate by refraction and diffraction during long distance propagation, Tarawa atoll have only a channel in northwest corner and Betio Port is located in the north of Betio Island facing the lagoon side.

Furthermore, above, waves generated by typhoons or cyclones have no influence to Tarawa, is indirectly supported by the record of wind direction and speed for 1980 to August, 1996 in Betio weather station. Wind speed more than 20m/s are not recorded in these data. And data of wind speed more than 15m/s with the influence wind direction to Betio Port (northwest to east) are recorded only 4 times. Each data takes a few hours' duration with maximum wind speed of 18m/s.

Therefore, both the weight of wave dissipating concrete blocks and the quantity of overtopping are calculated using a design wave generated in the lagoon. The maximum fetch in the lagoon is 25km. Because waves generated in the lagoon have short periods, a deepwater wave (H_0) are regarded as an equivalent deepwater wave (H'_0) with ignorance of a refraction of incident waves. And the weight of wave dissipating concrete blocks and the quantity of overtopping are calculated considering standing and reflection of waves in the port area.

As a result, the design wave height in this study is almost same as the design wave in "The Study on Ports Development in Kiribati (JICA): FS". Both equivalent deepwater waves and design wave heights ($H_{1/3}$) are shown below:

Study in FS: H_0 = 1.20(m), $H_{1/3}$ = 1.5(m), T_0 (Wave Period) = 14(sec)

This study: H_0 = 1.24(m), $H_{1/3}$ = 1.54(m), T_0 (Wave Period) = 4 to 5(sec)

Tables A- 5- 1 and A- 5- 2 show frequency of occurrence of waves by height and direction, and height and period in FS, respectively, which are summarized to maximum of wave height and period as shown in Table A- 5- 3(1). Diffraction calculations were executed considering multiplex reflections in the harbour based on Table A- 5- 3(1), reflection coefficients of 0.9 for the wharf and 0.5 for the revetment facing the basin. The calculation result of wave height and wave height ratio are shown in Tables A- 5- 3(1) to 4(6). These tables are summarized in Table A- 5- 3(2), which was adopted as the design wave height for the weight of wave dissipating concrete blocks.

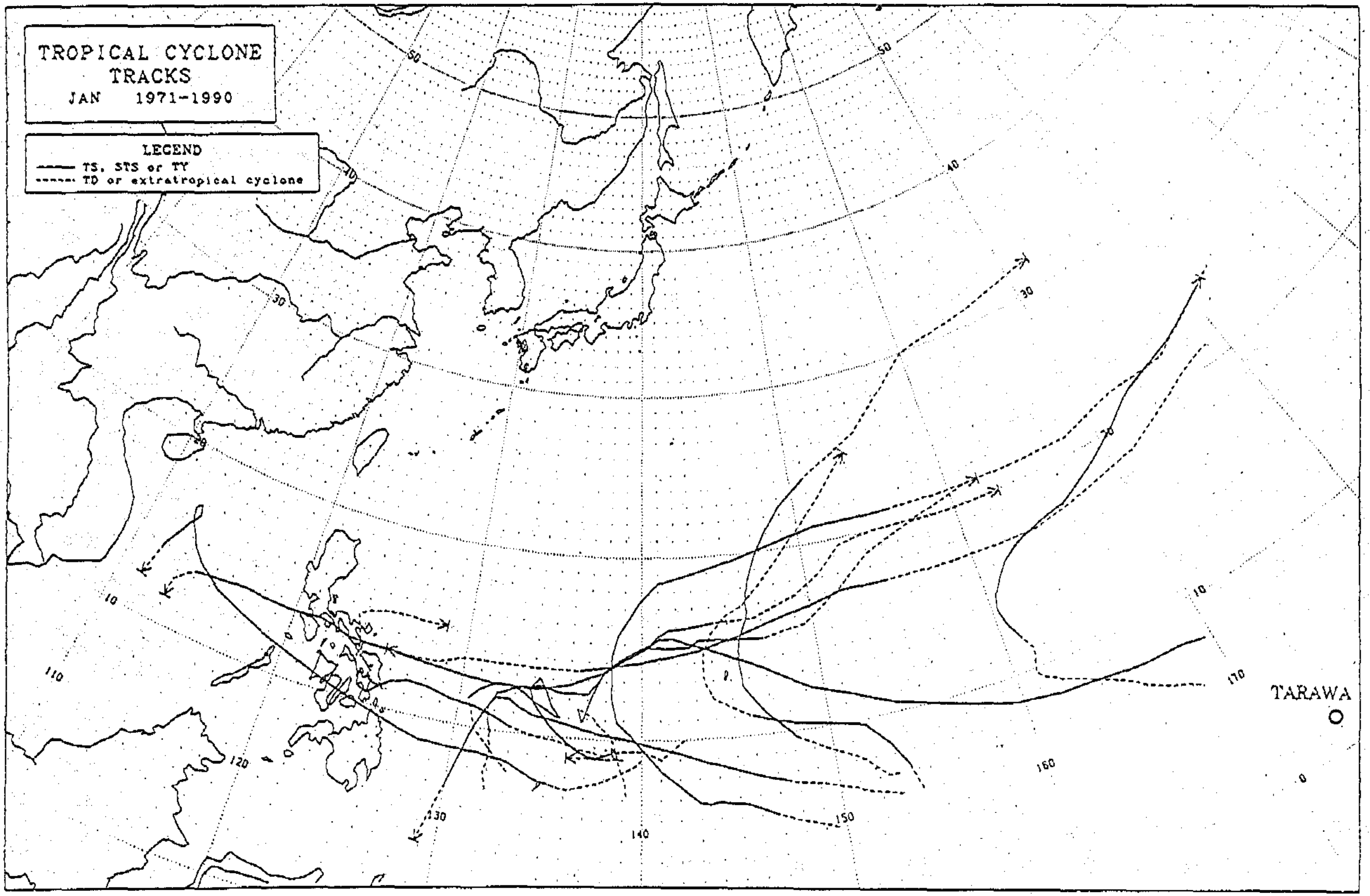


Figure A- 5- 1(1) Typhoon Track (January, 1971- 1990)

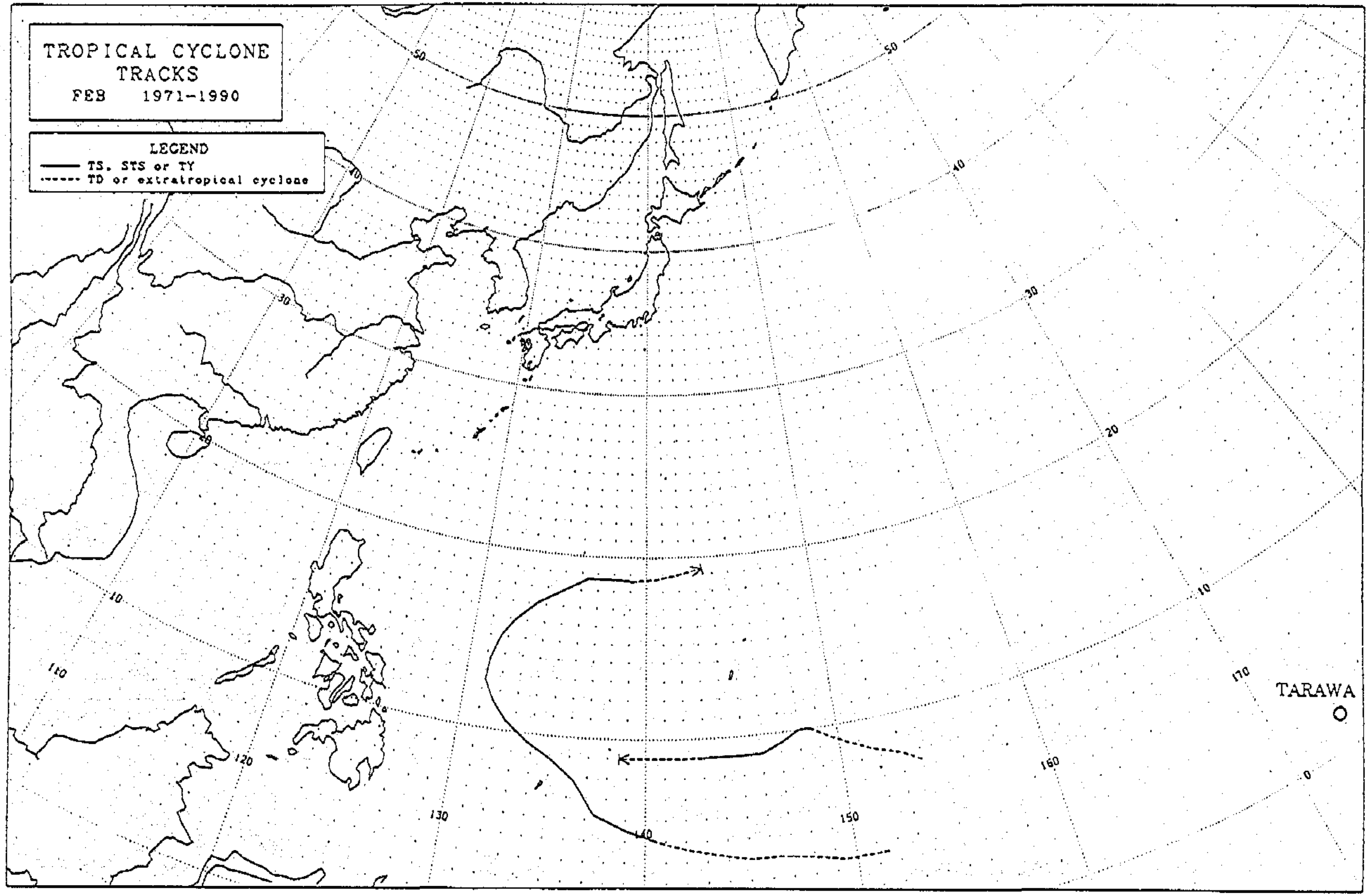


Figure A- 5- 1(2) Typhoon Track (February, 1971- 1990)

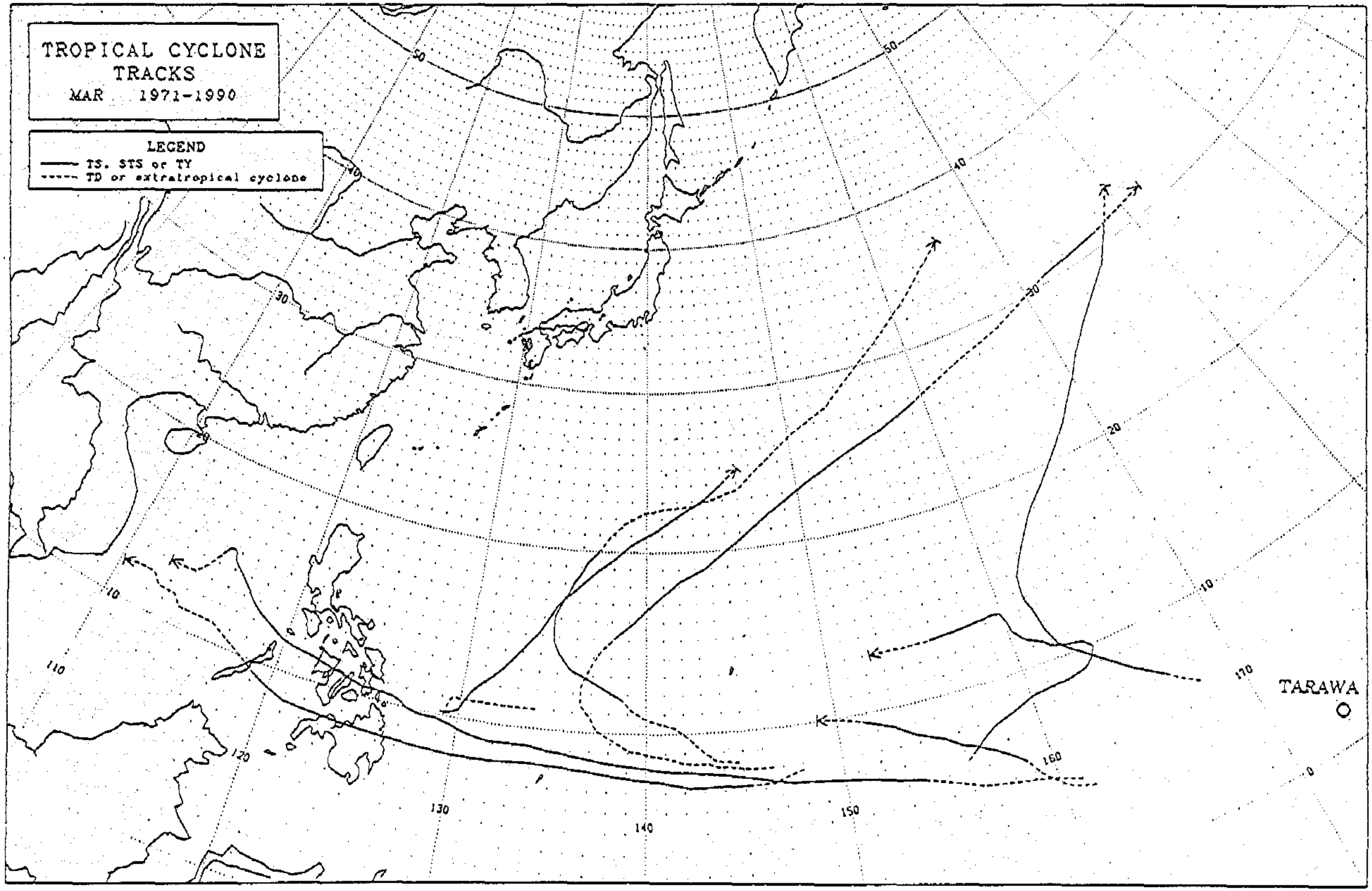


Figure A- 5- 1(3) Typhoon Track (March, 1971- 1990)

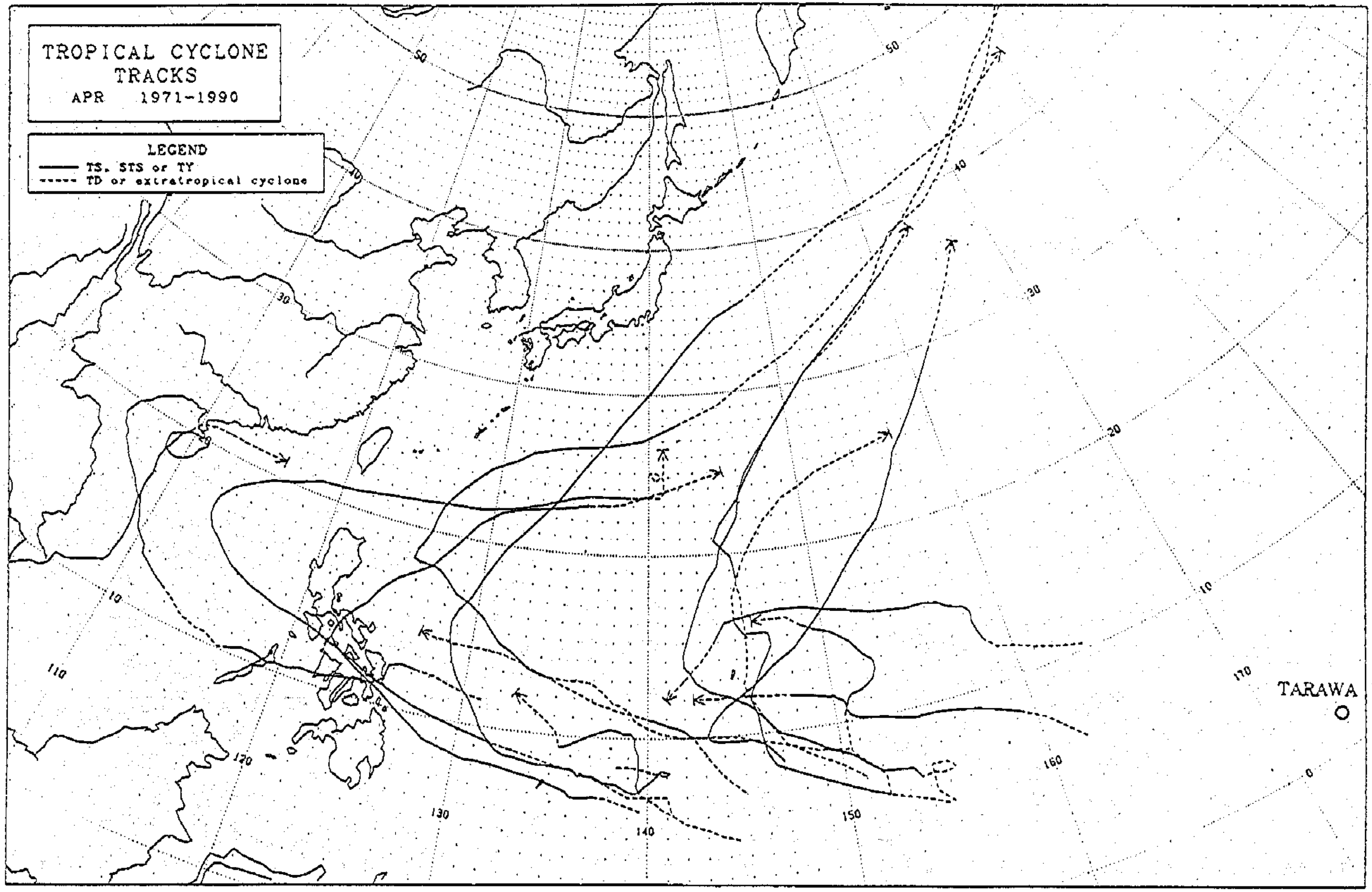


Figure A- 5- 1(4) Typhoon Track (June, 1971- 1990)

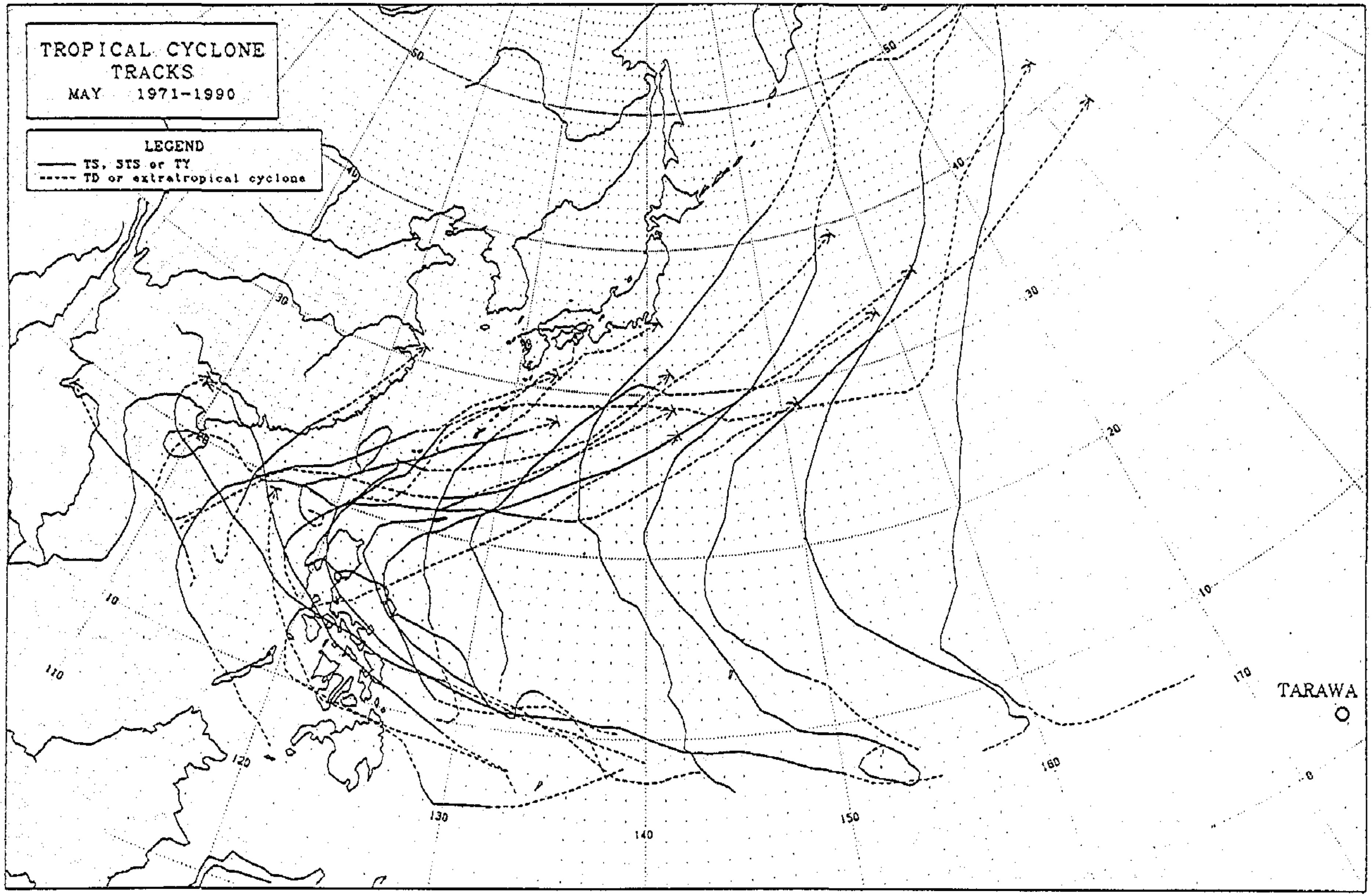


Figure A- 5- 1(5) Typhoon Track (May, 1971- 1990)

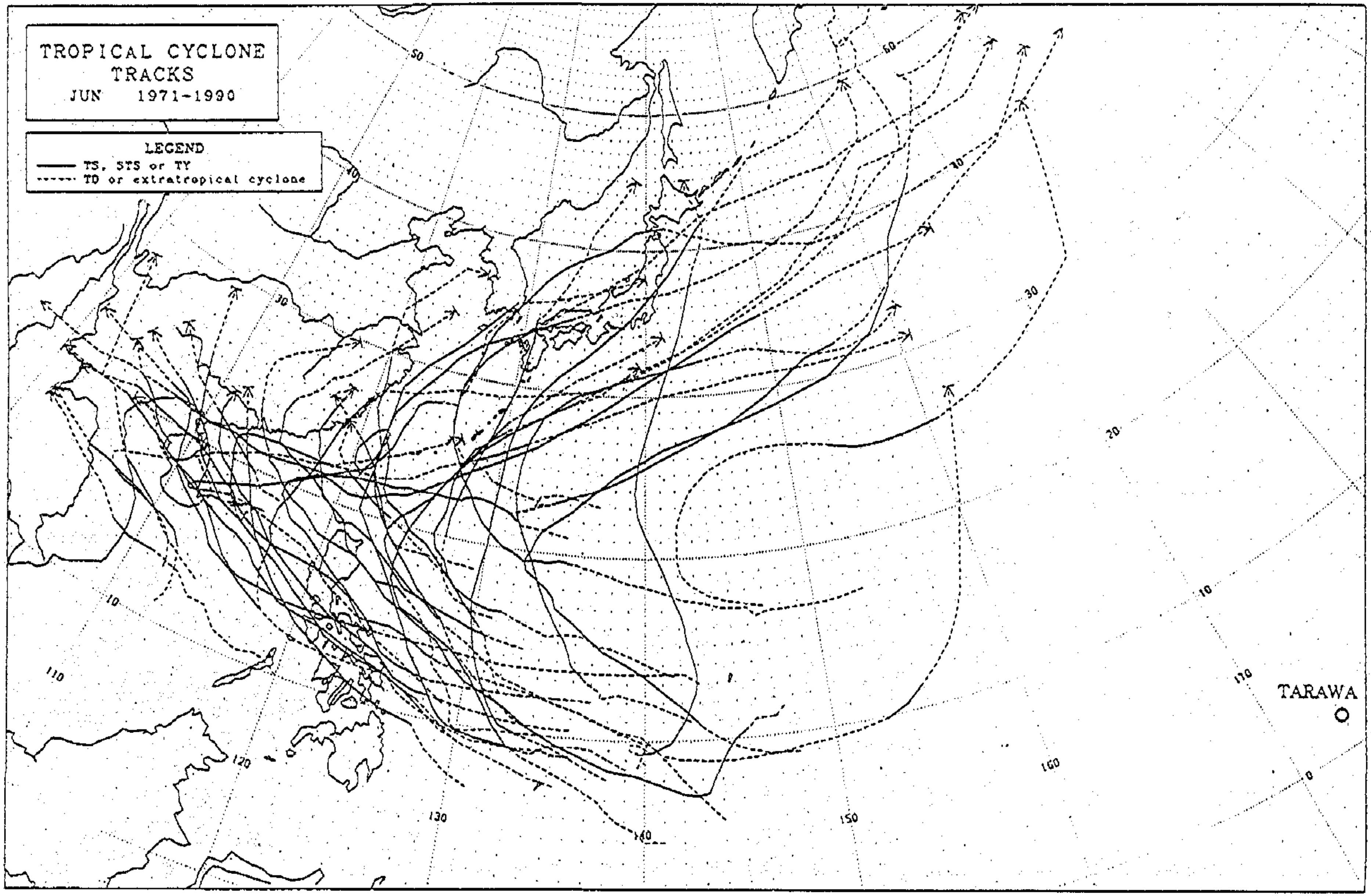


Figure A- 5- 1(6) Typhoon Track (June, 1971- 1990)

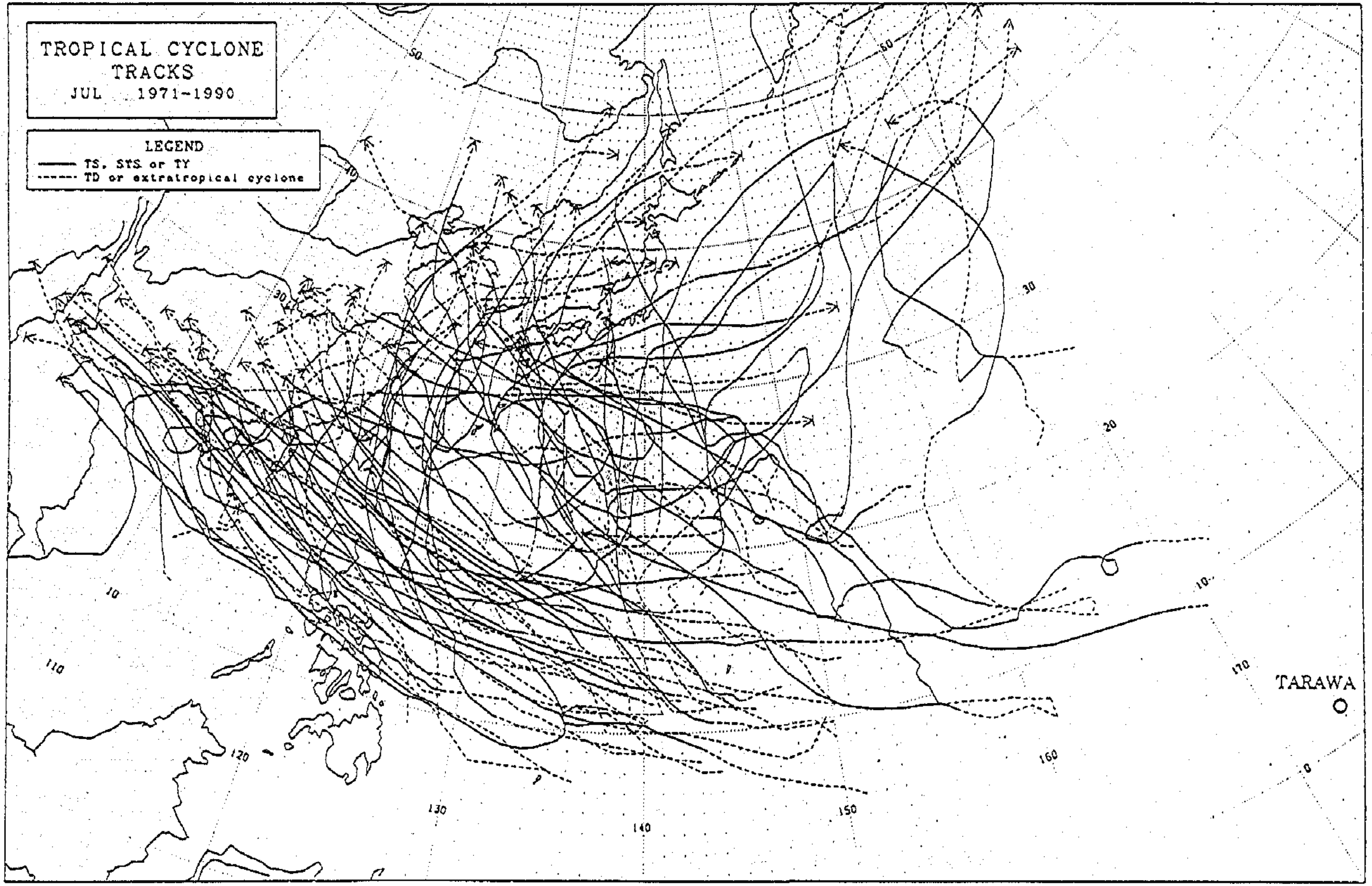


Figure A- 5- 1(7) Typhoon Track (July, 1971- 1990)

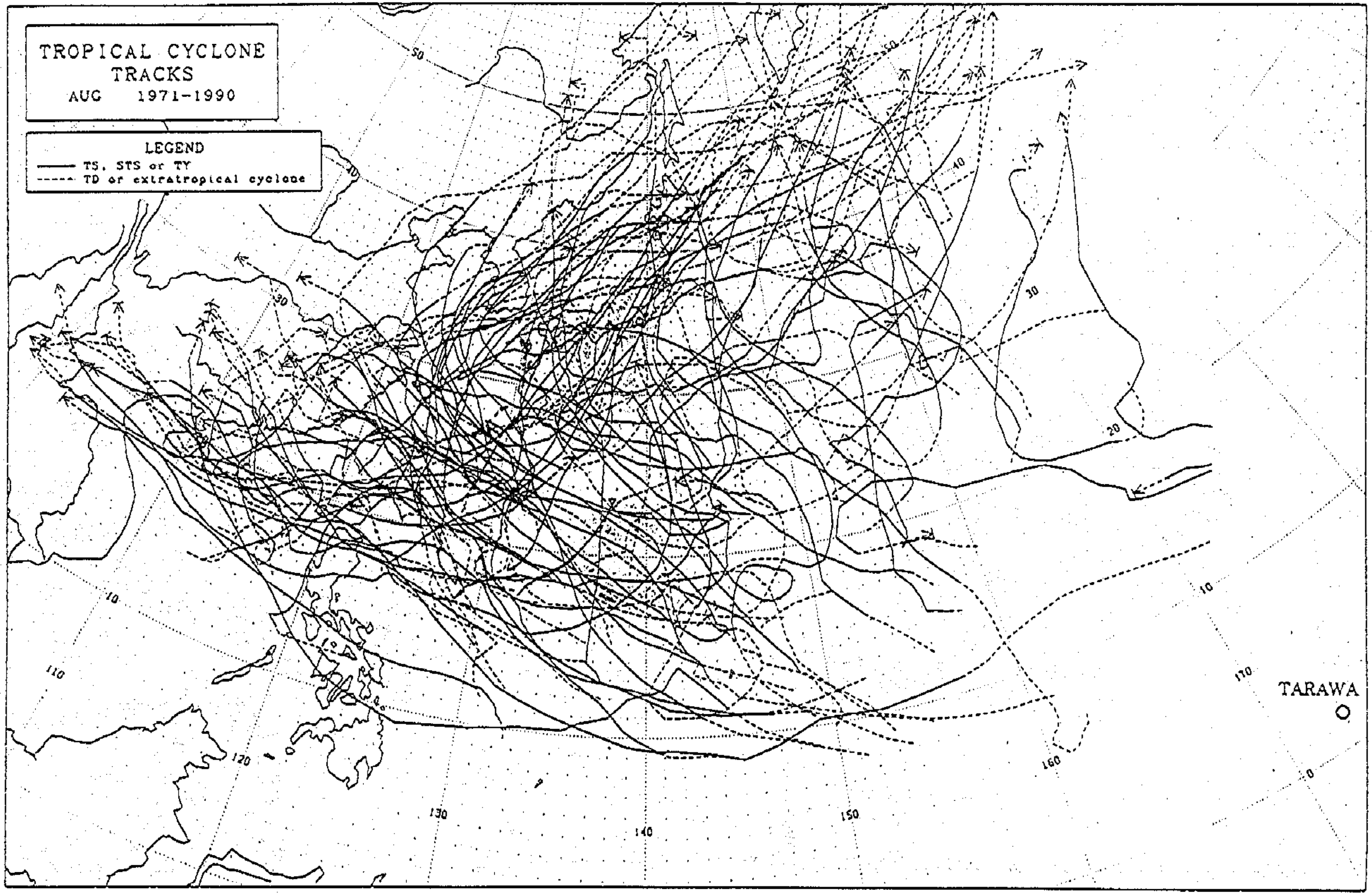


Figure A-5-1(8) Typhoon Track (August, 1971-1990)

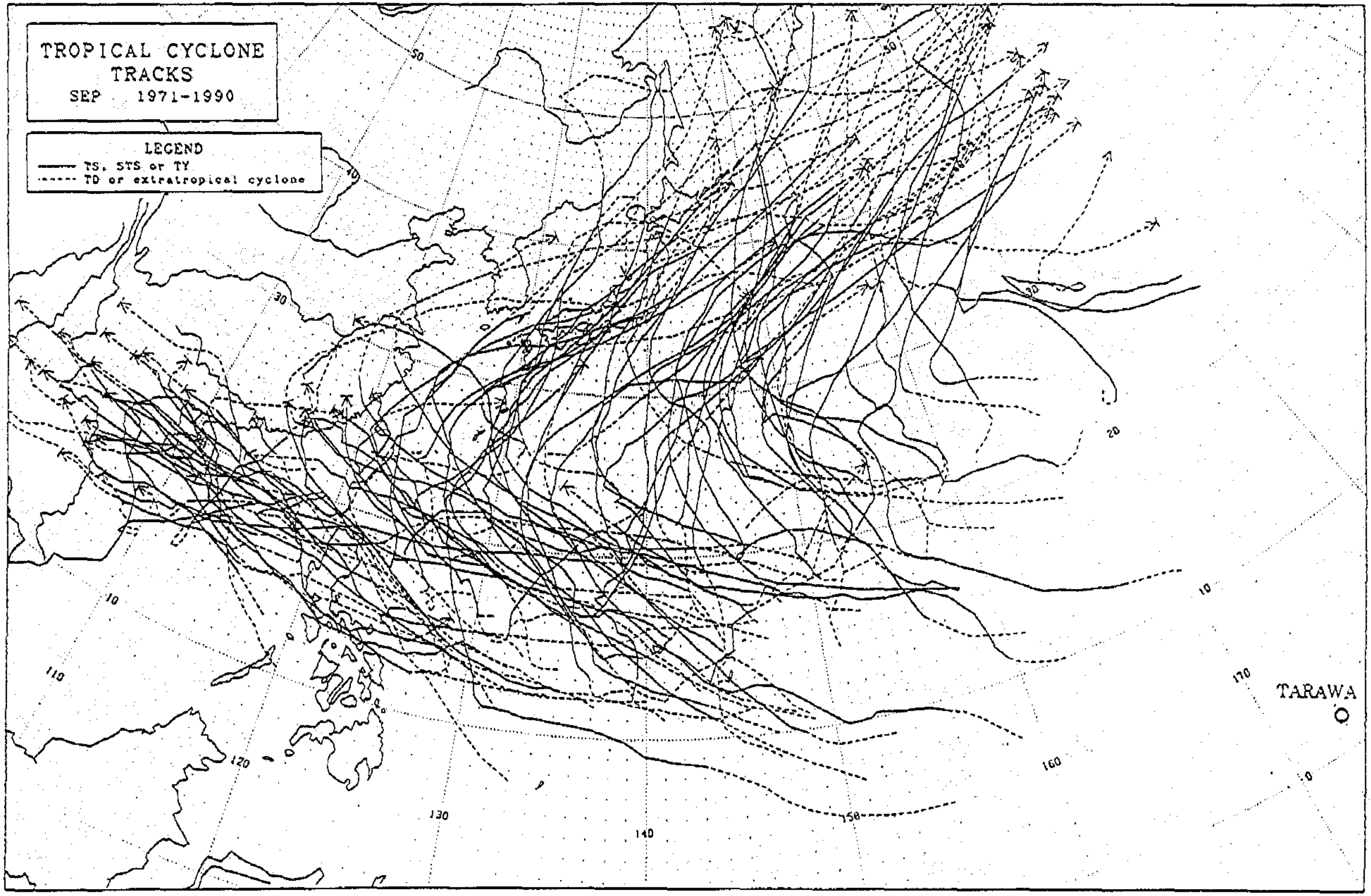


Figure A- 5- 1(9) Typhoon Track (September, 1971- 1990)

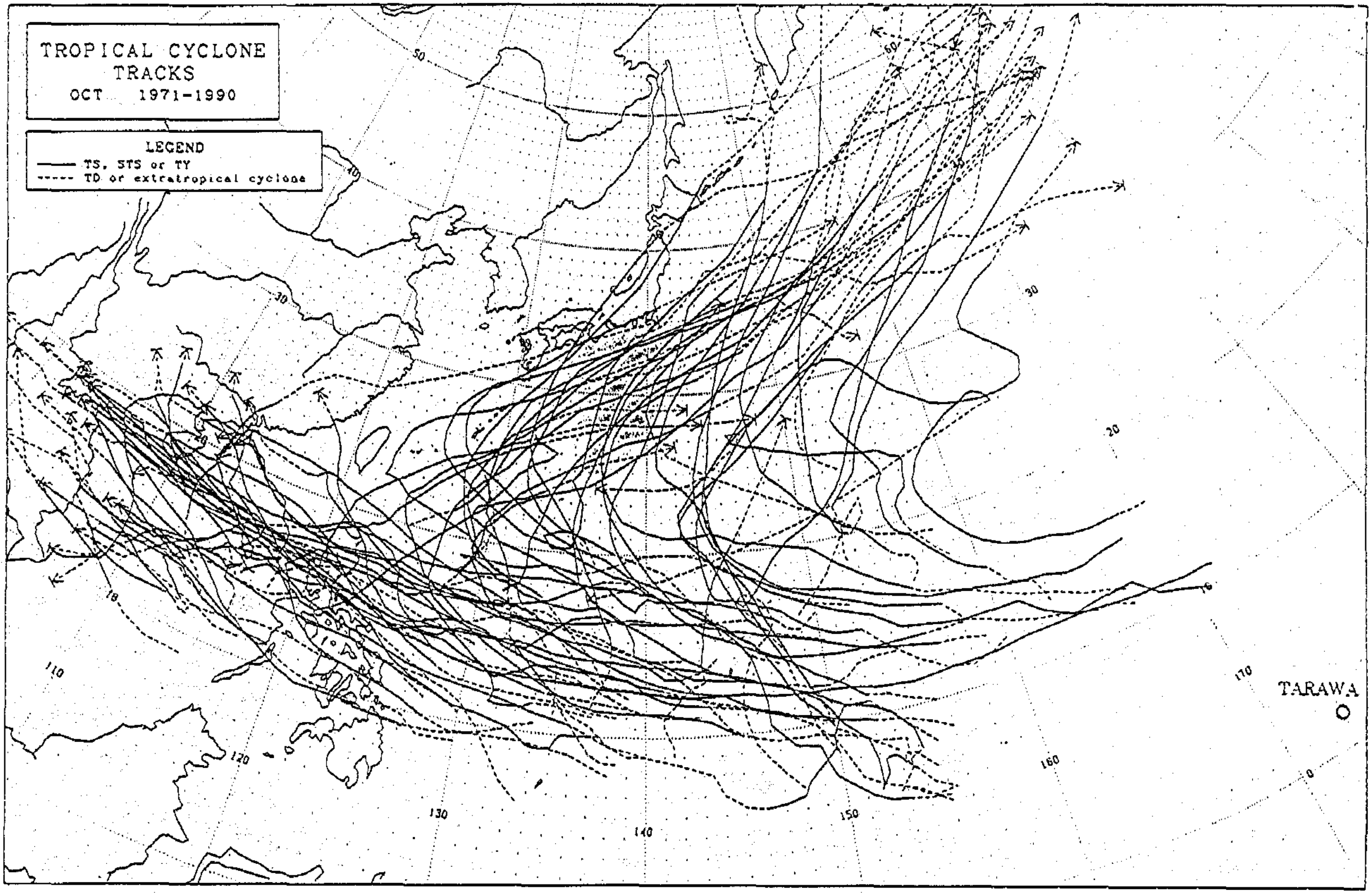


Figure A- 5- 1(10) Typhoon Track (October, 1971- 1990)

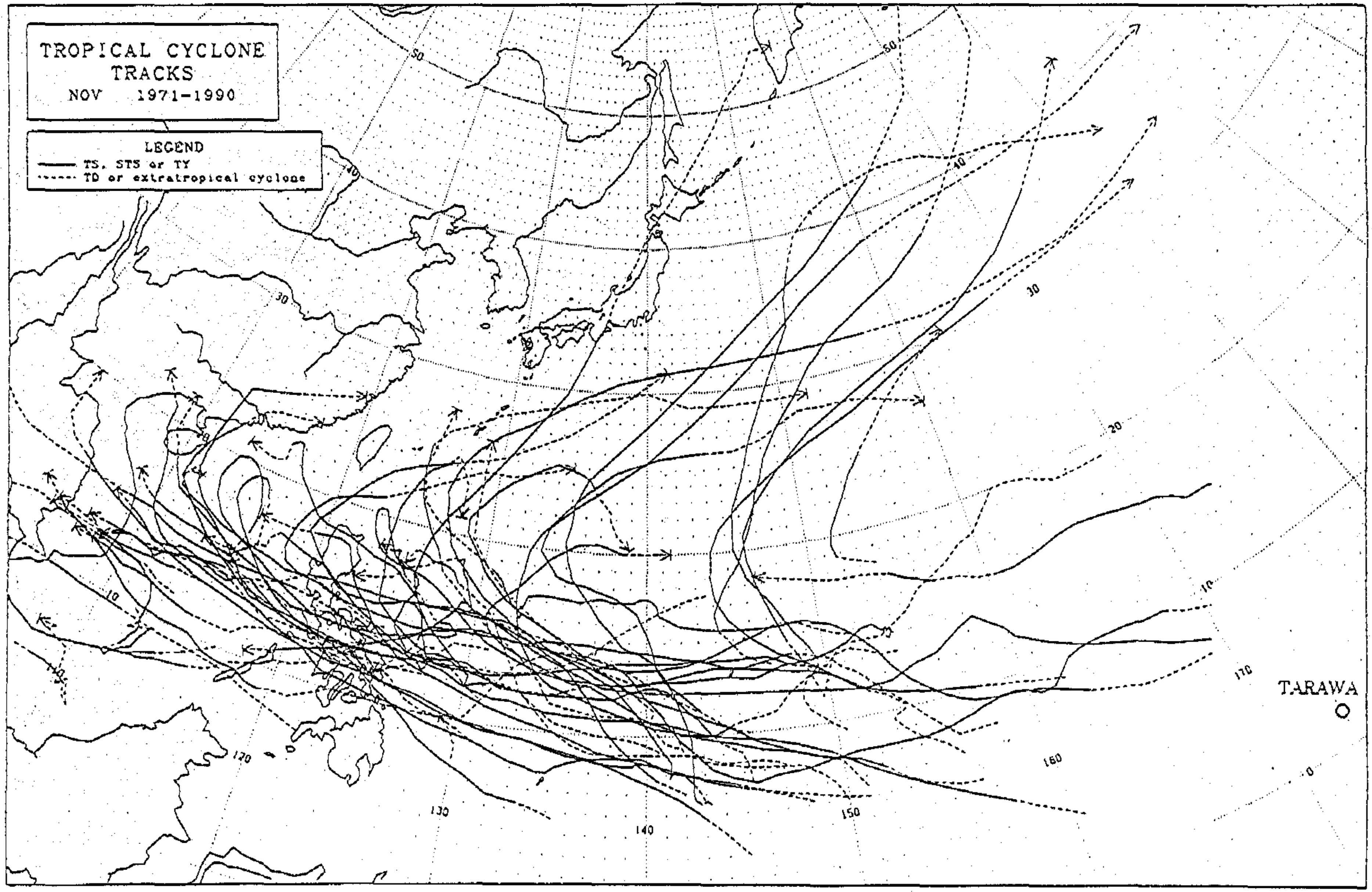


Figure A-5-1(11) Typhoon Track (November, 1971-1990)

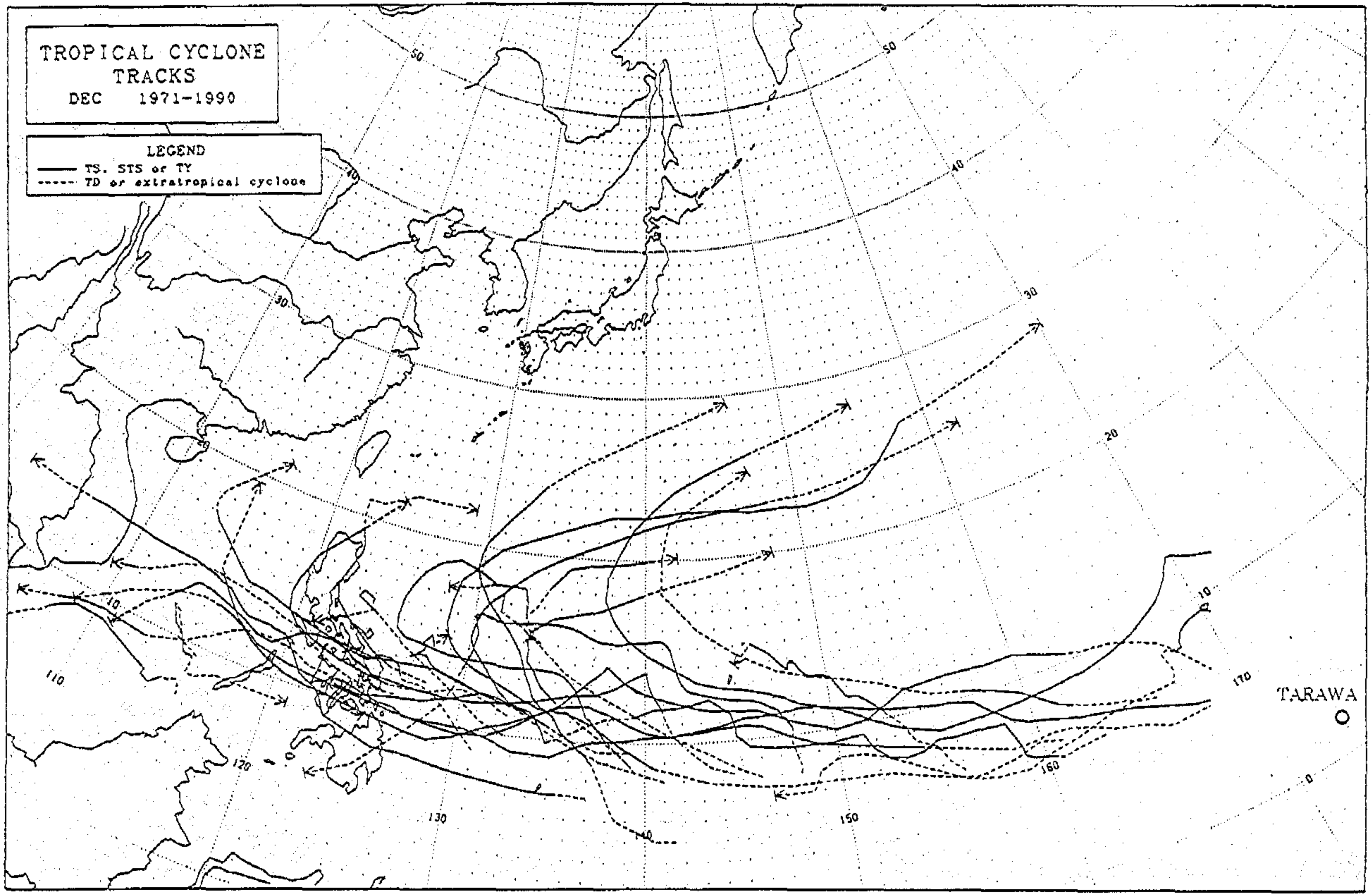


Figure A- 5- 1(12) Typhoon Track (December, 1971- 1990)

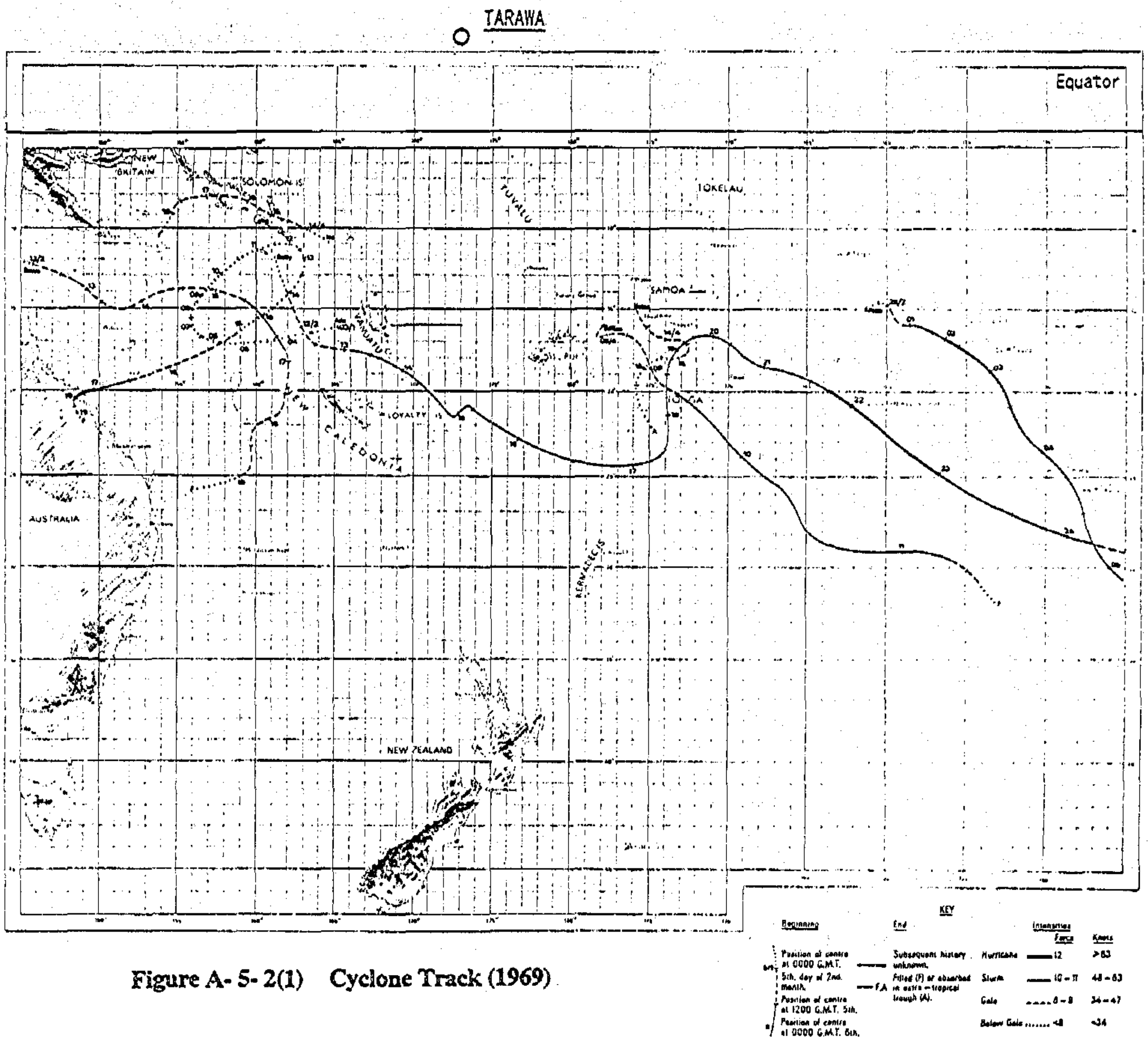


Figure A- 5- 2(1) Cyclone Track (1969)

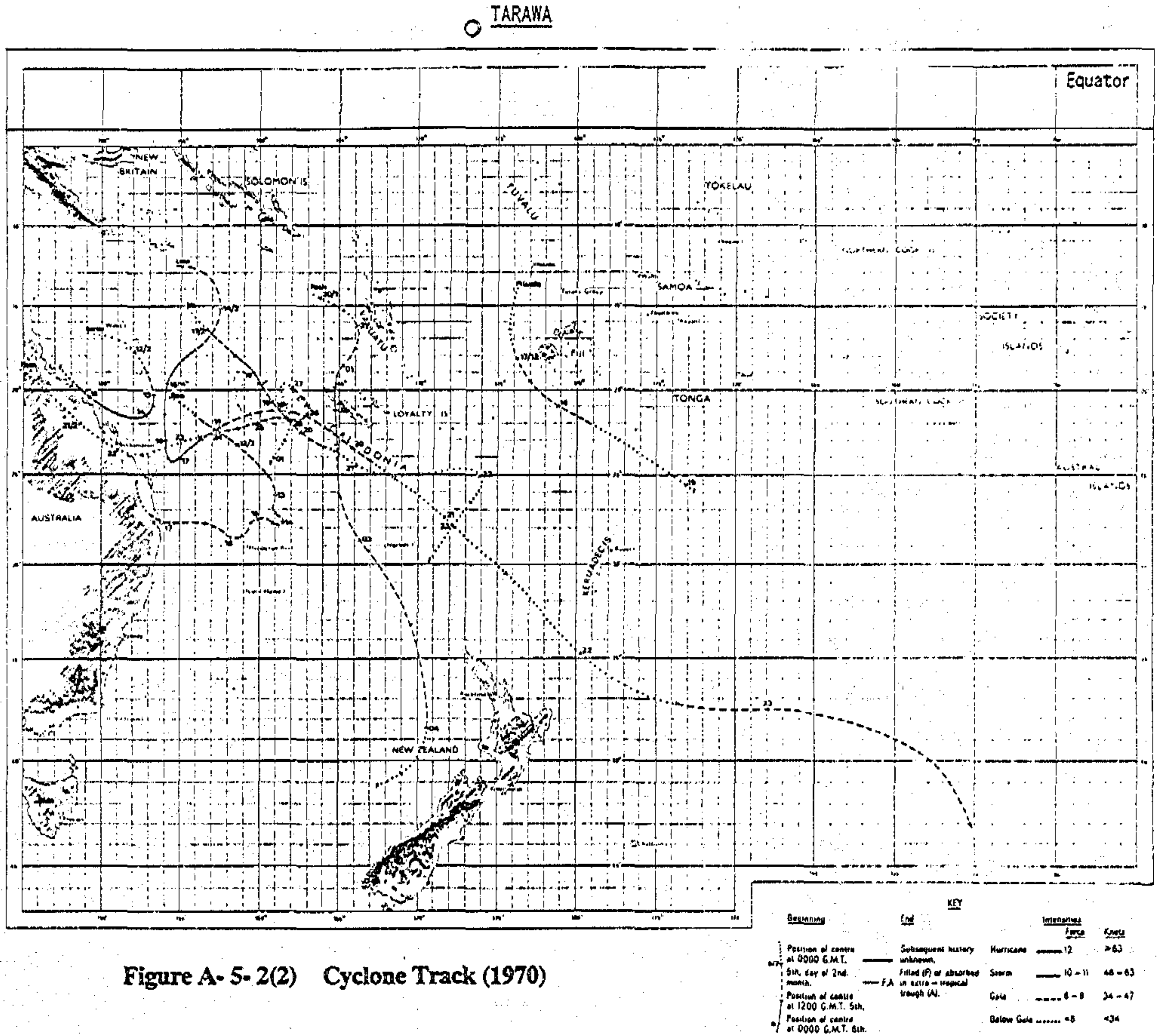


Figure A- 5- 2(2) Cyclone Track (1970)

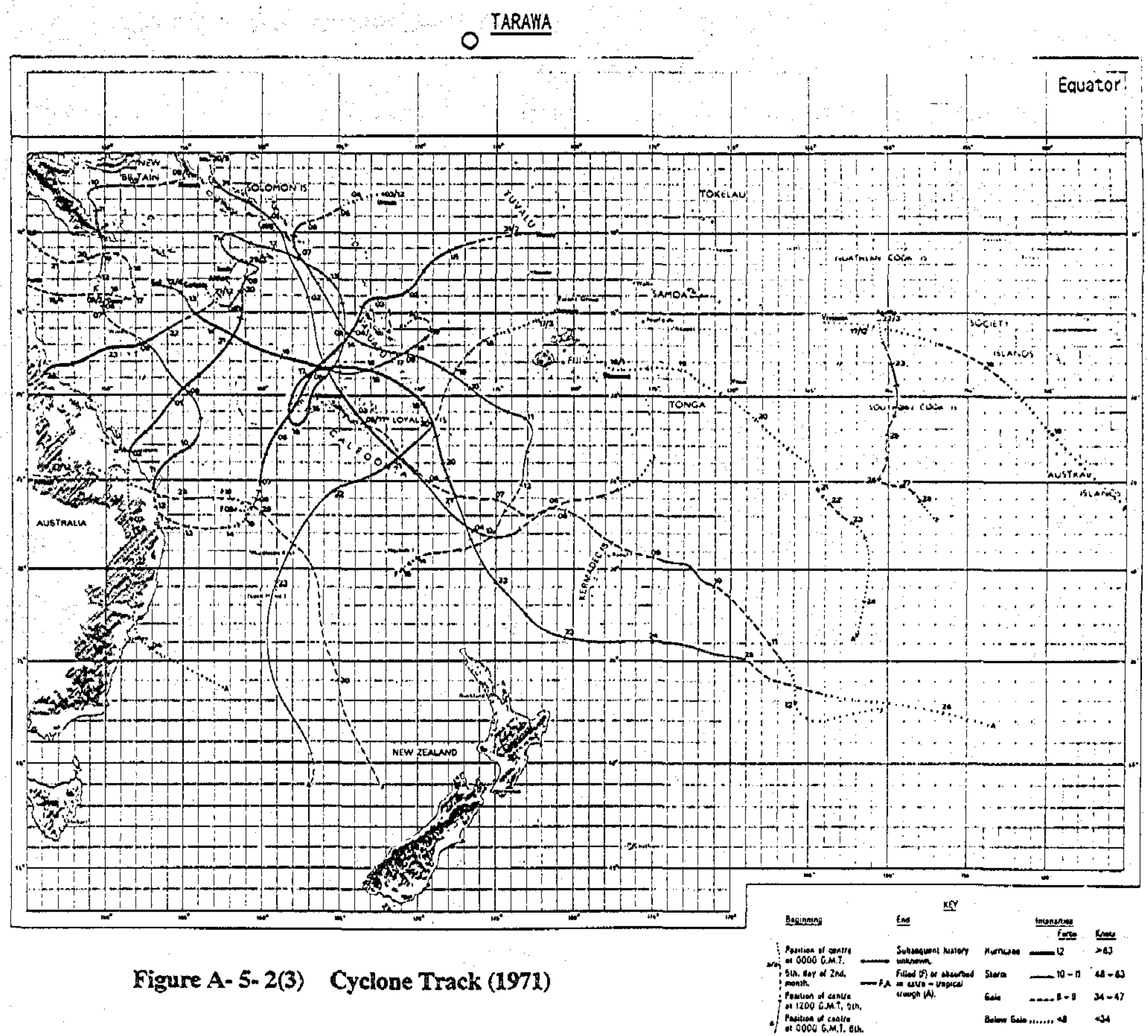
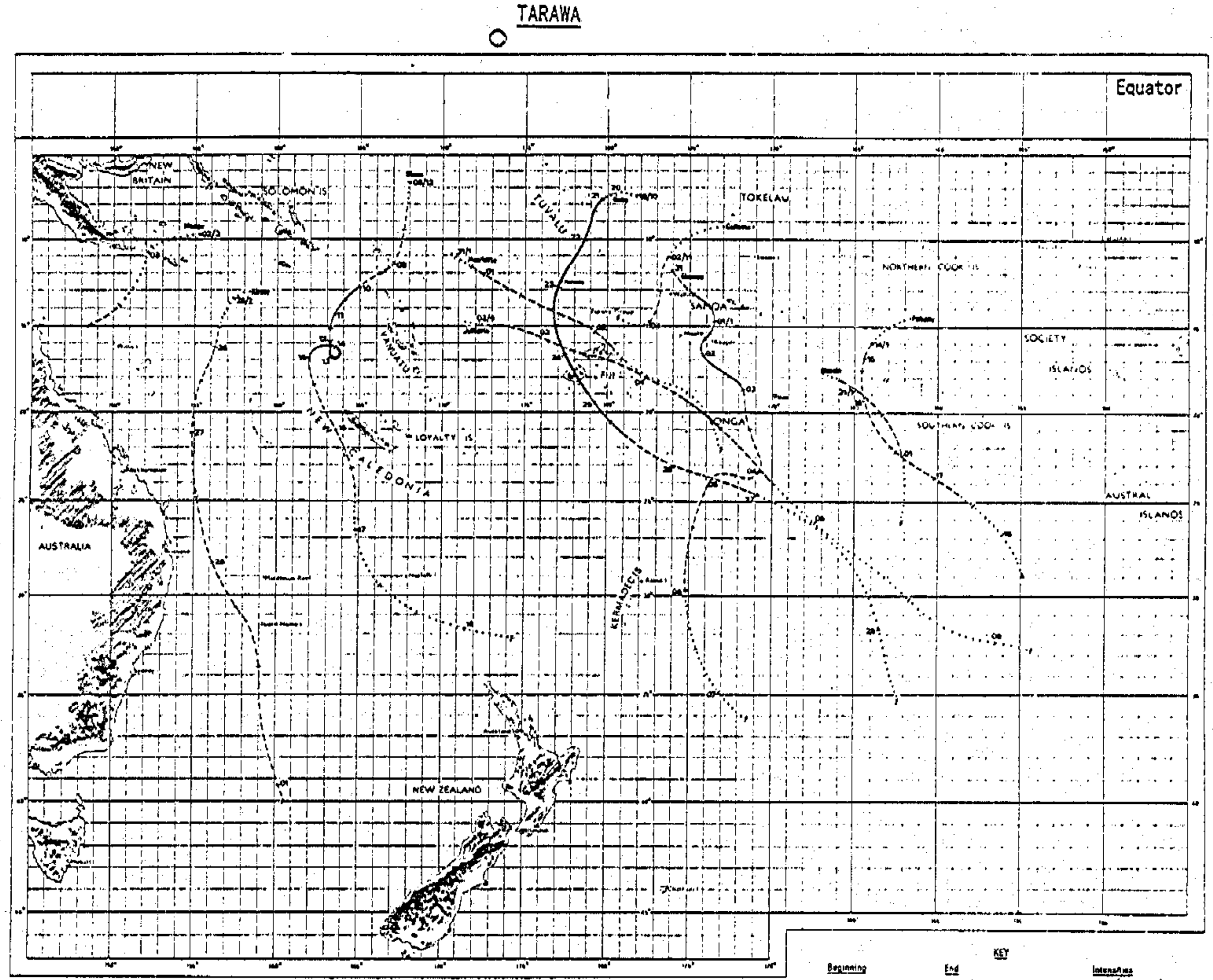


Figure A- 5- 2(3) Cyclone Track (1971)



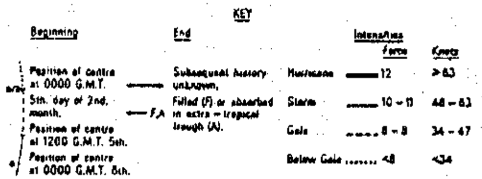
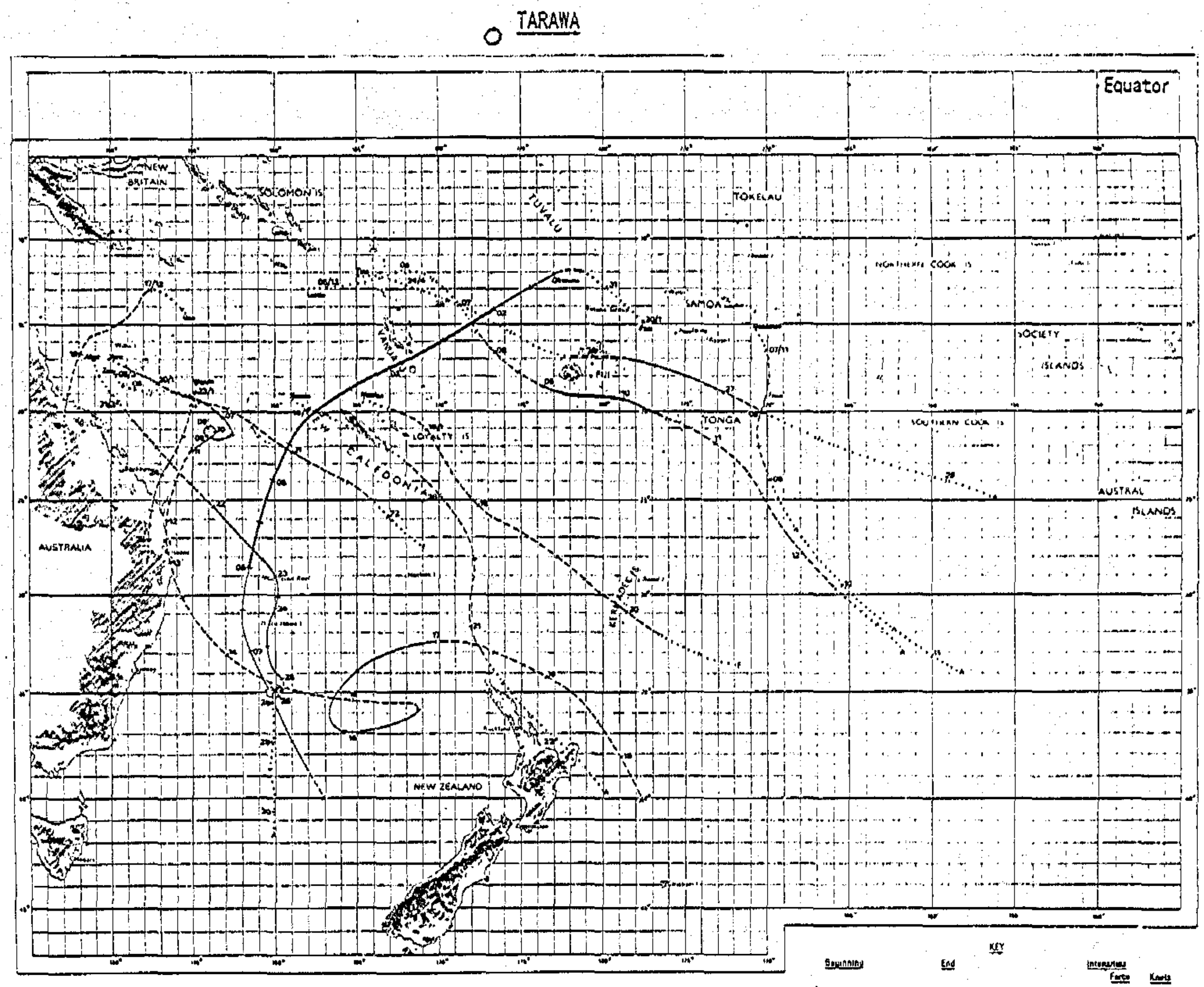


Figure A- 5- 2(4) Cyclone Track (1972)



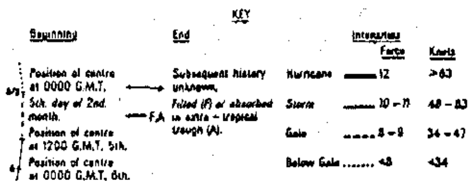


Figure A- 5- 2(5) Cyclone Track (1973)

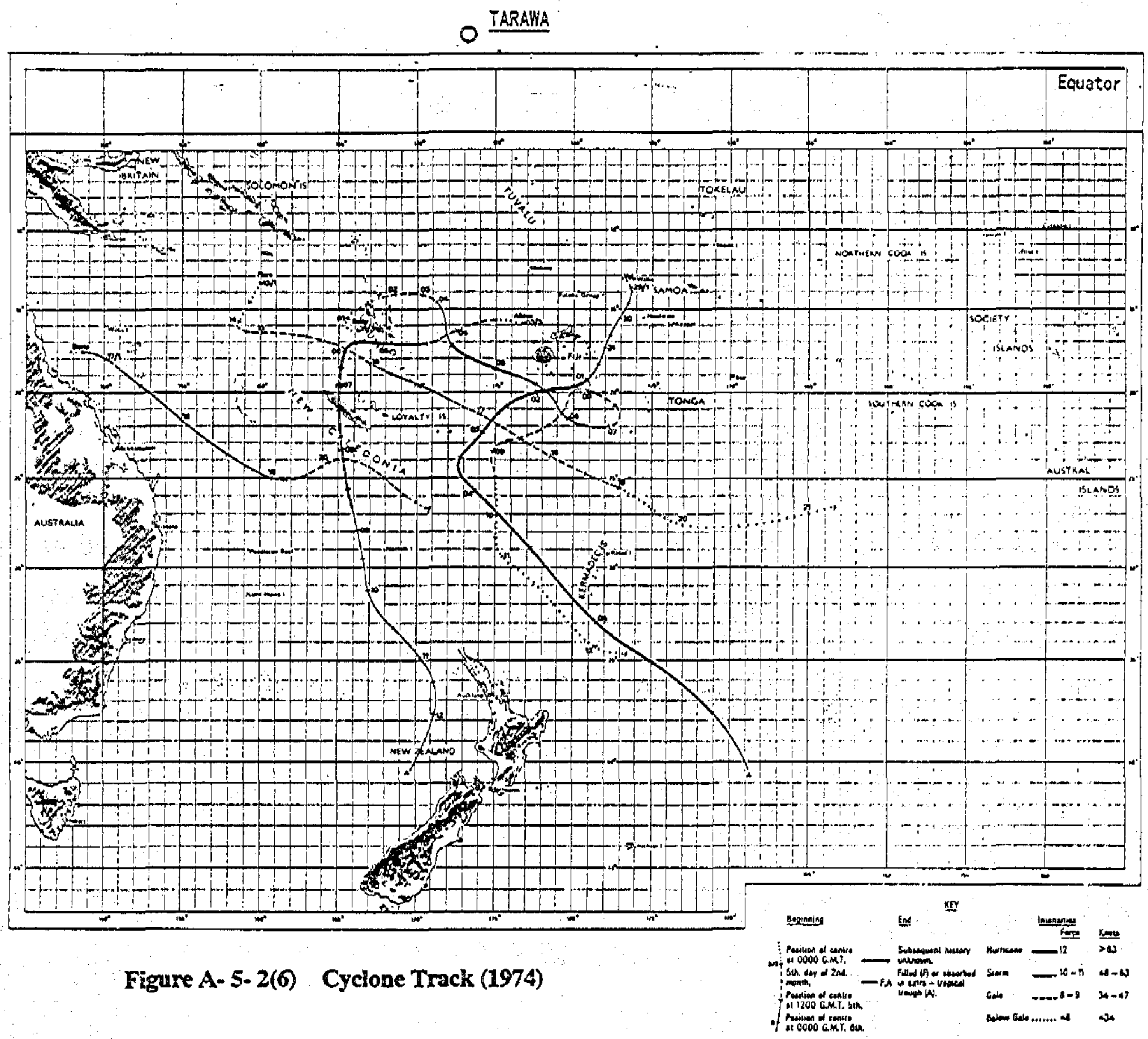


Figure A- 5- 2(6) Cyclone Track (1974)

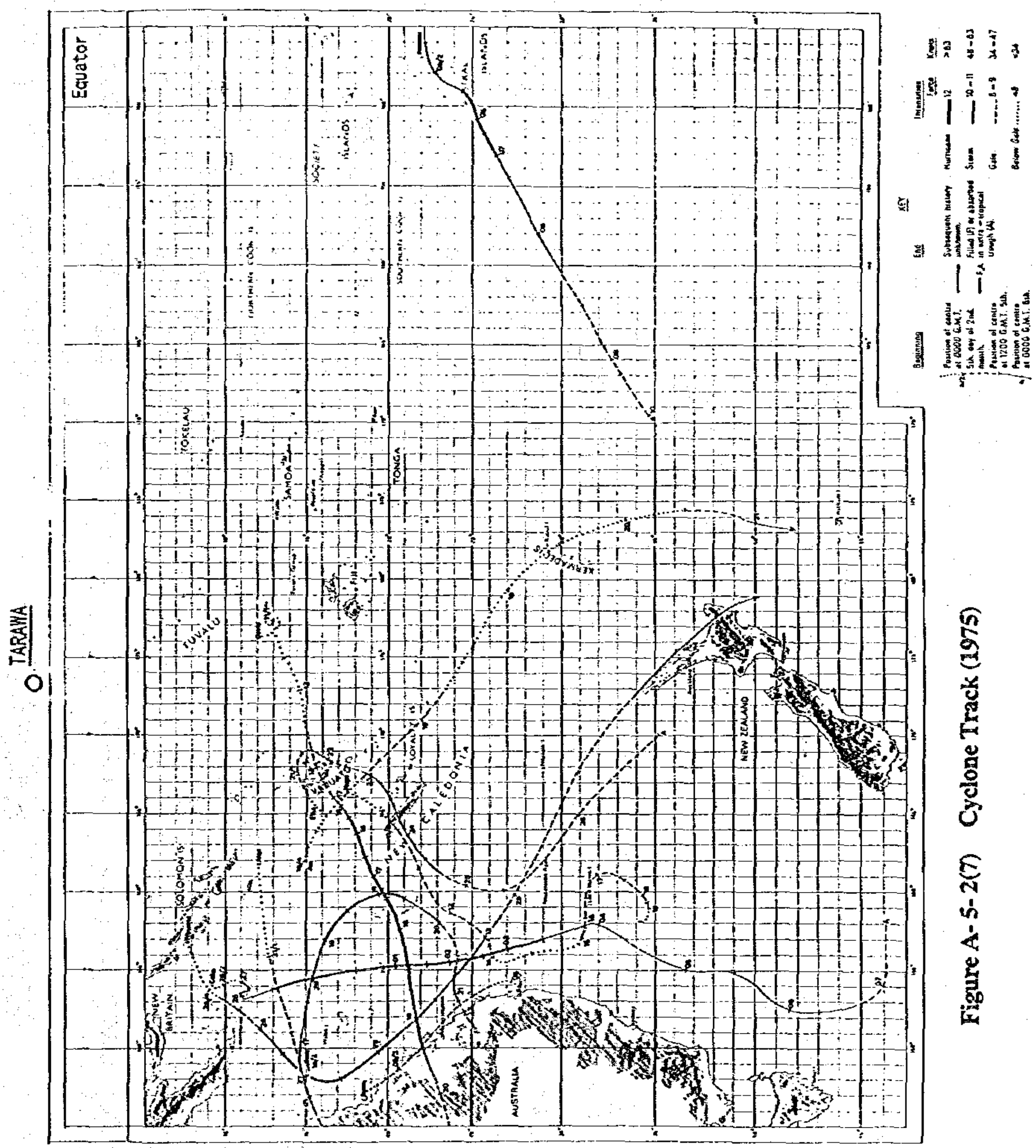
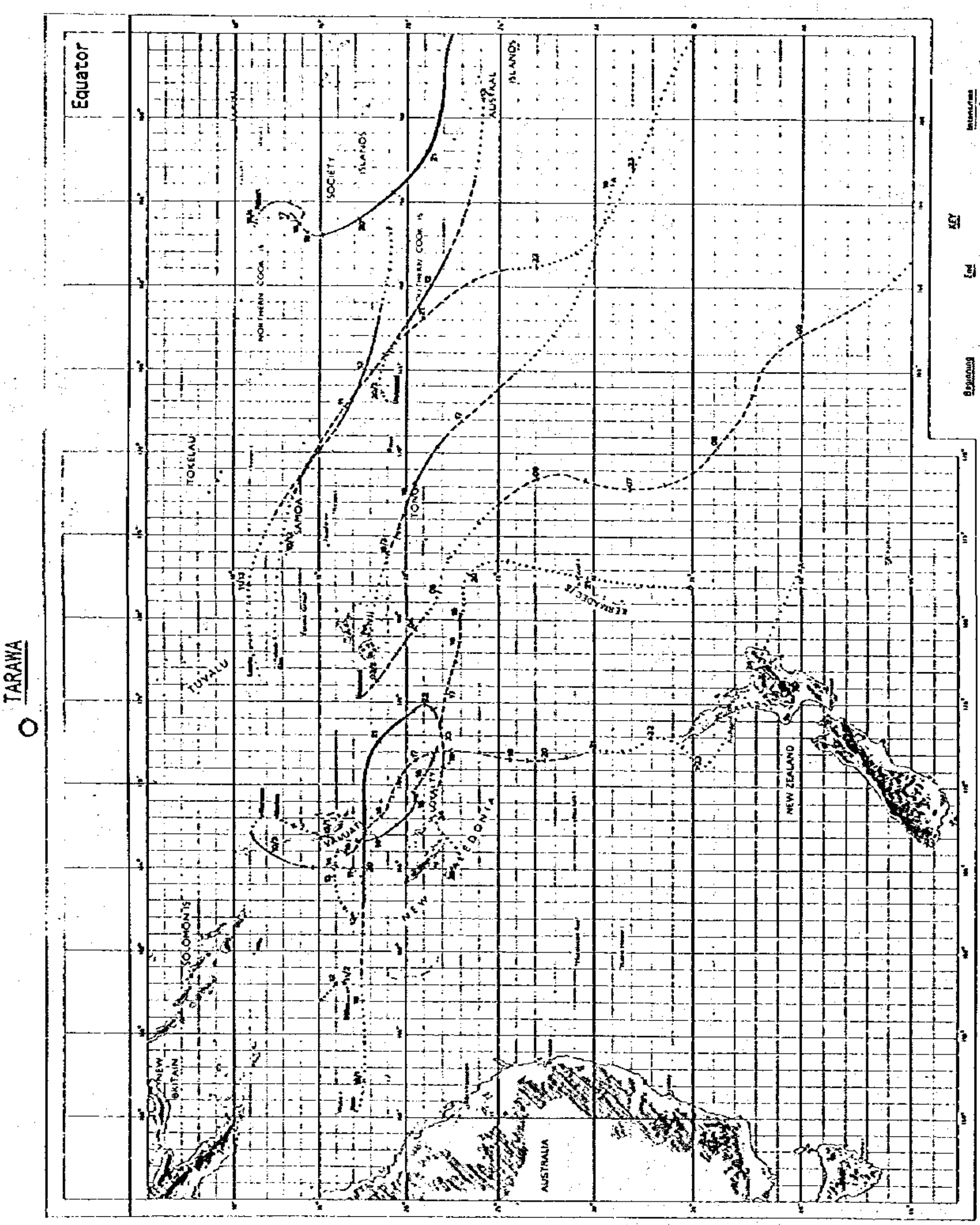


Figure A-5-2(7) Cyclone Track (1975)



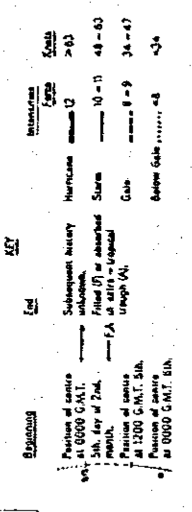


Figure A- 5- 2(8) Cyclone Track (1976)

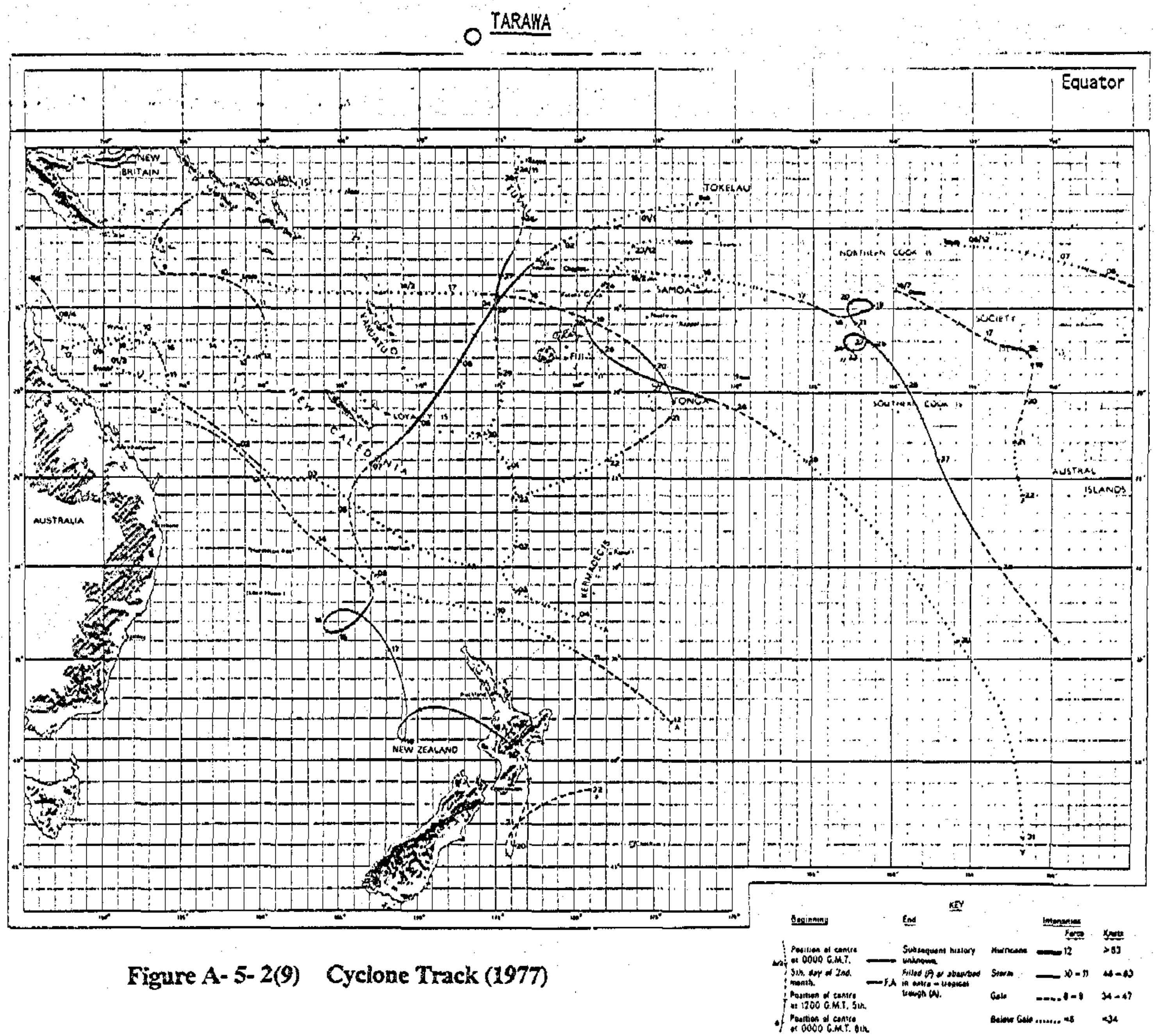


Figure A- 5- 2(9) Cyclone Track (1977)

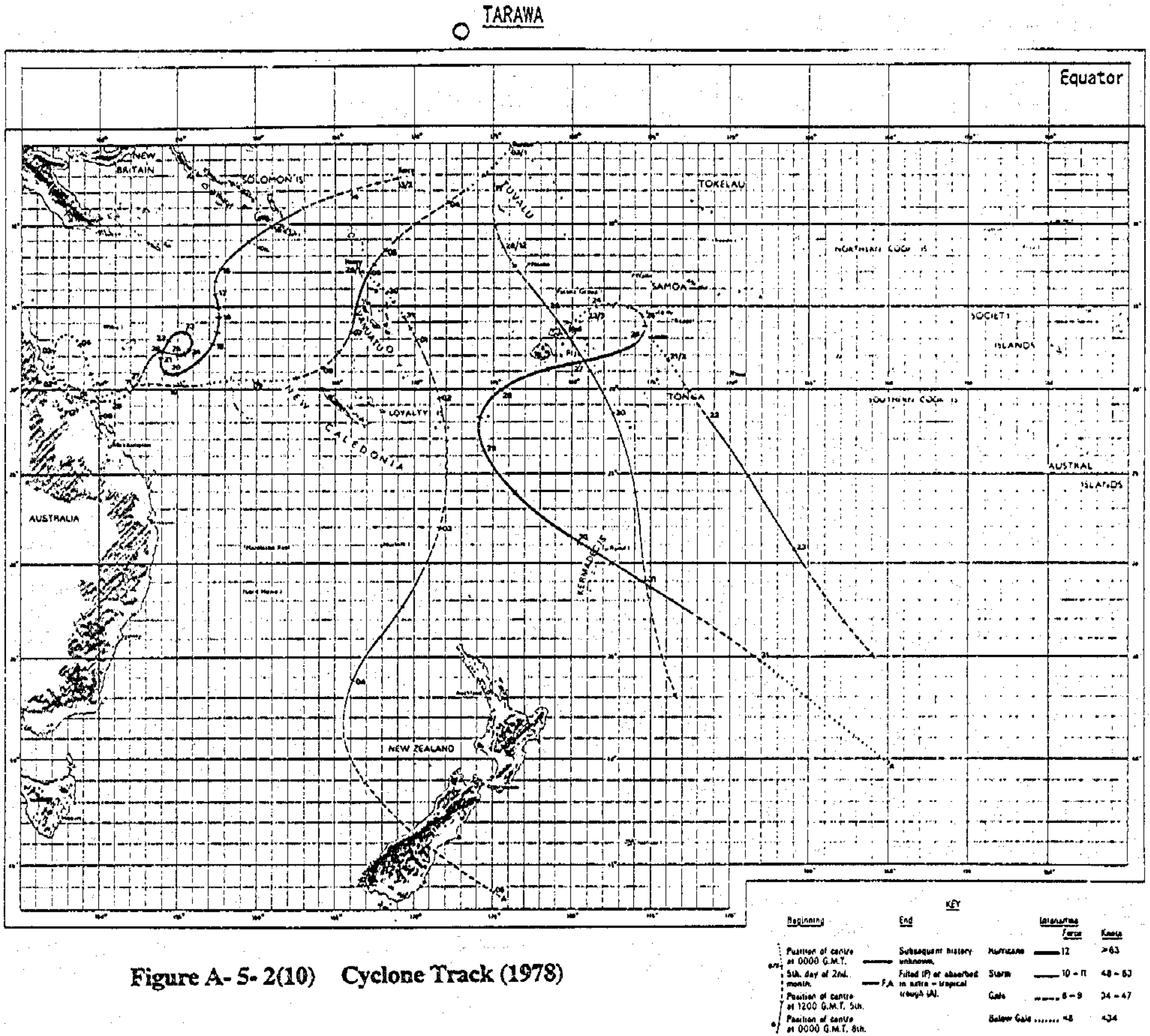


Figure A- 5- 2(10) Cyclone Track (1978)

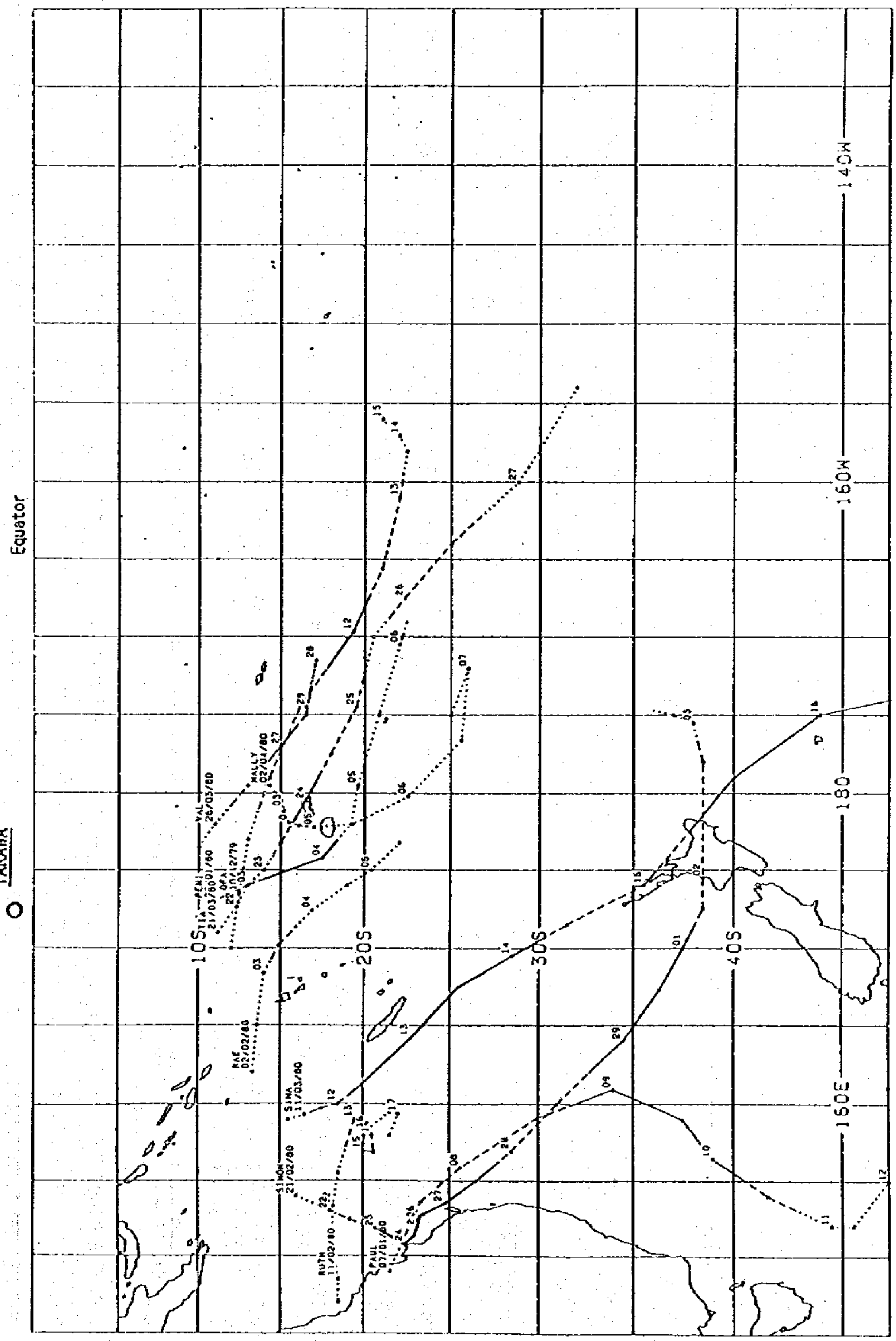


Figure A-5-2(11) Cyclone Track (1979)

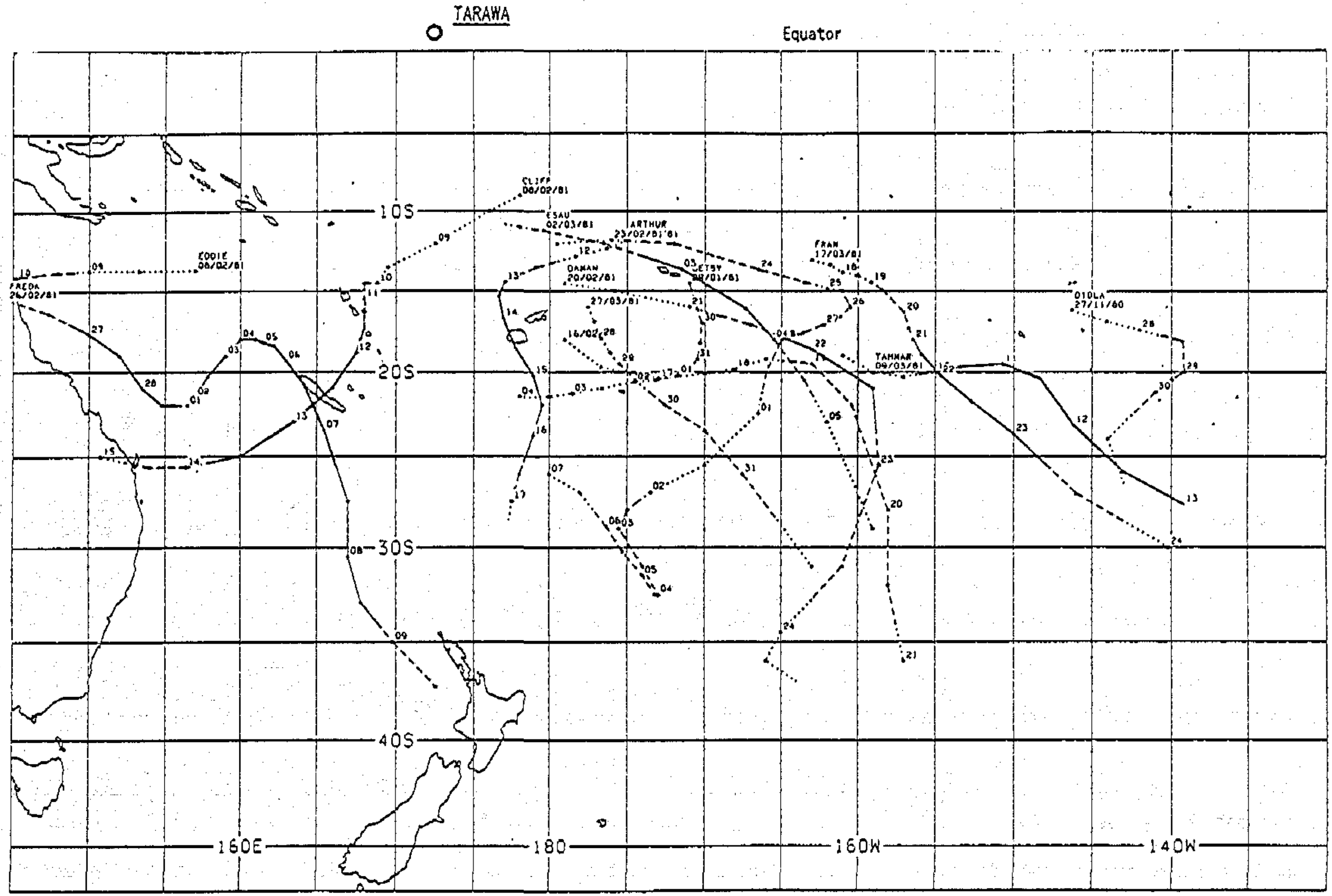


Figure A- 5- 2(12) Cyclone Track (1980)

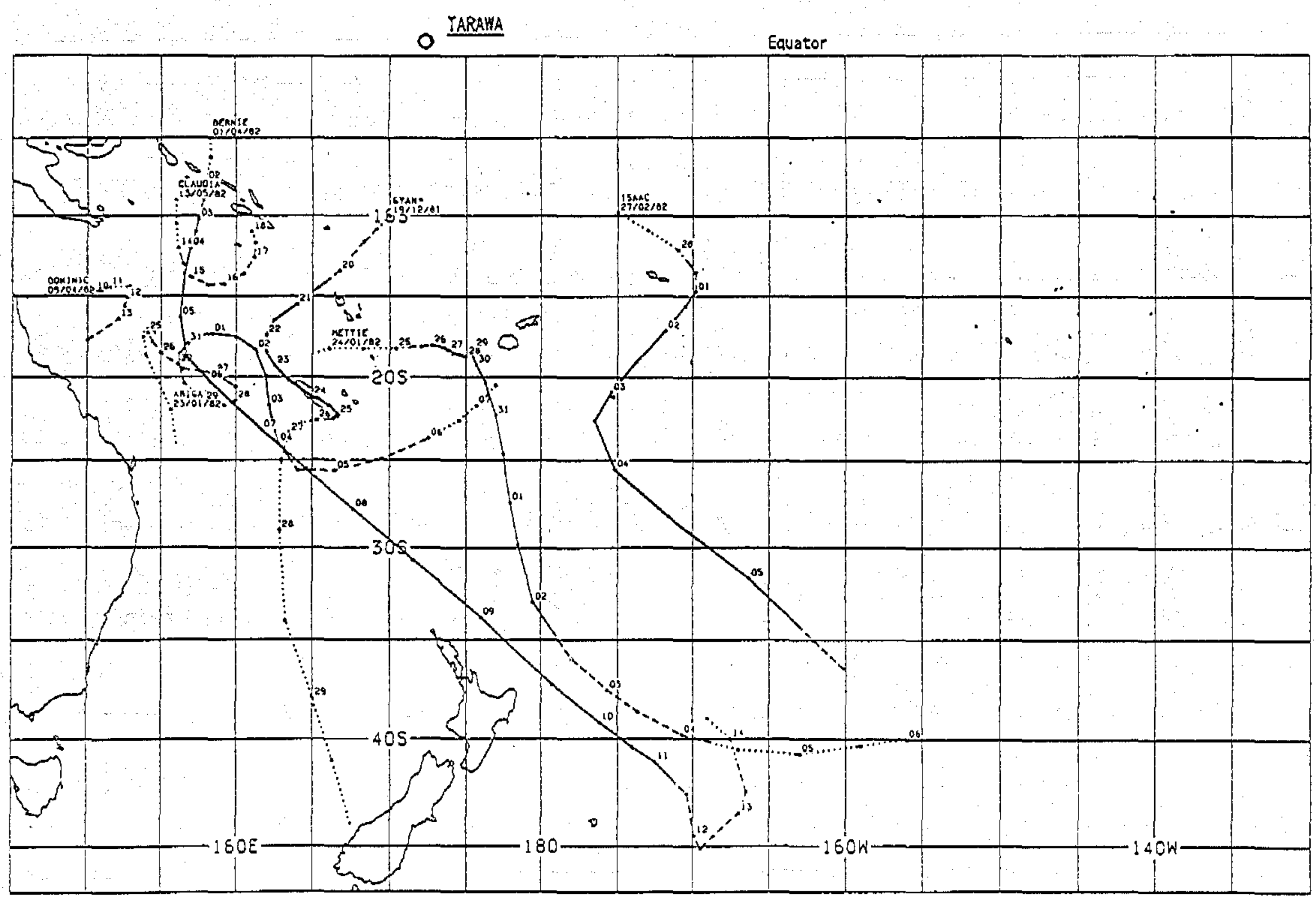


Figure A- 5- 2(13) Cyclone Track (1981)

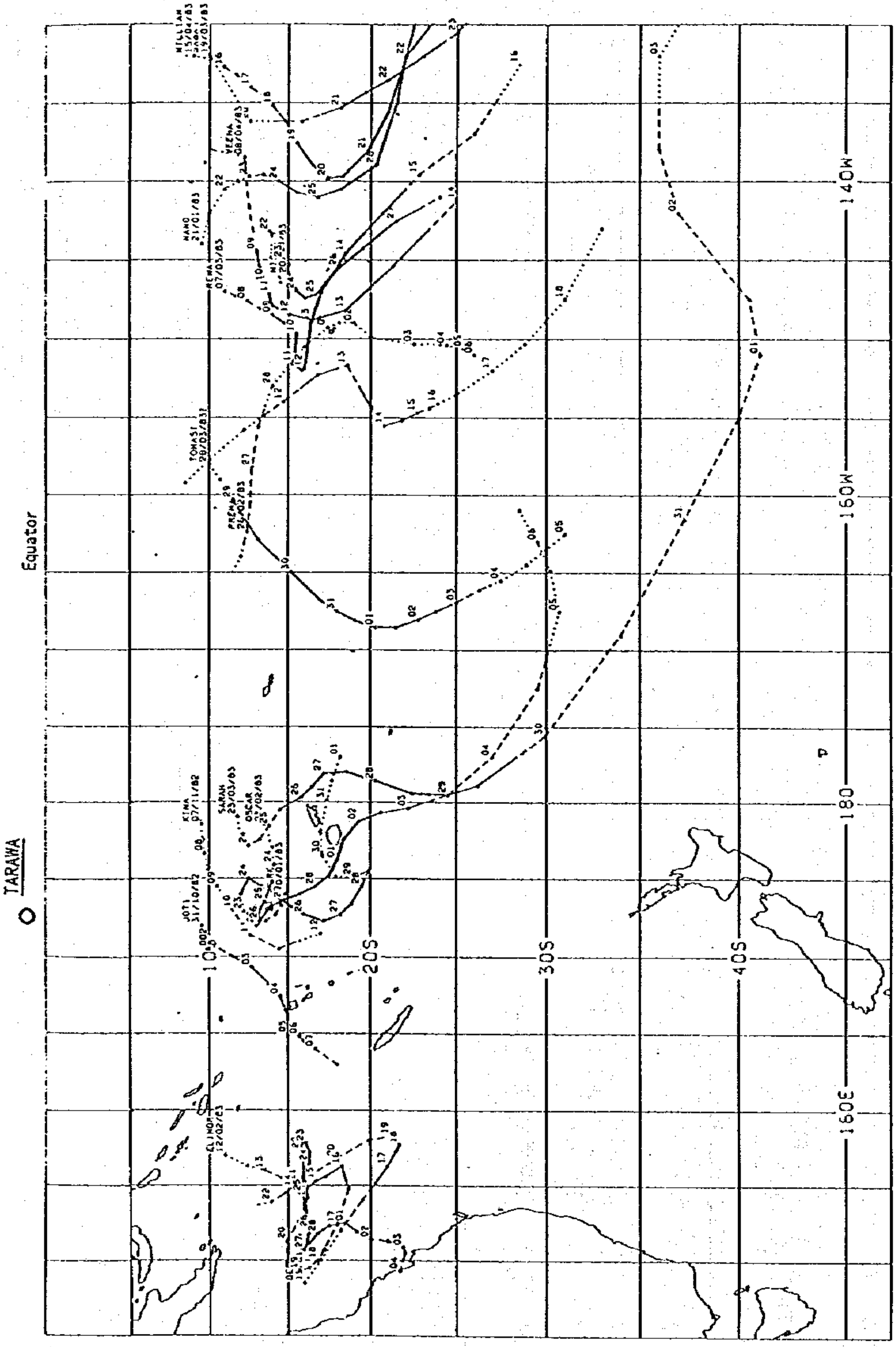


Figure A-5-2(14) Cyclone Track (1982)

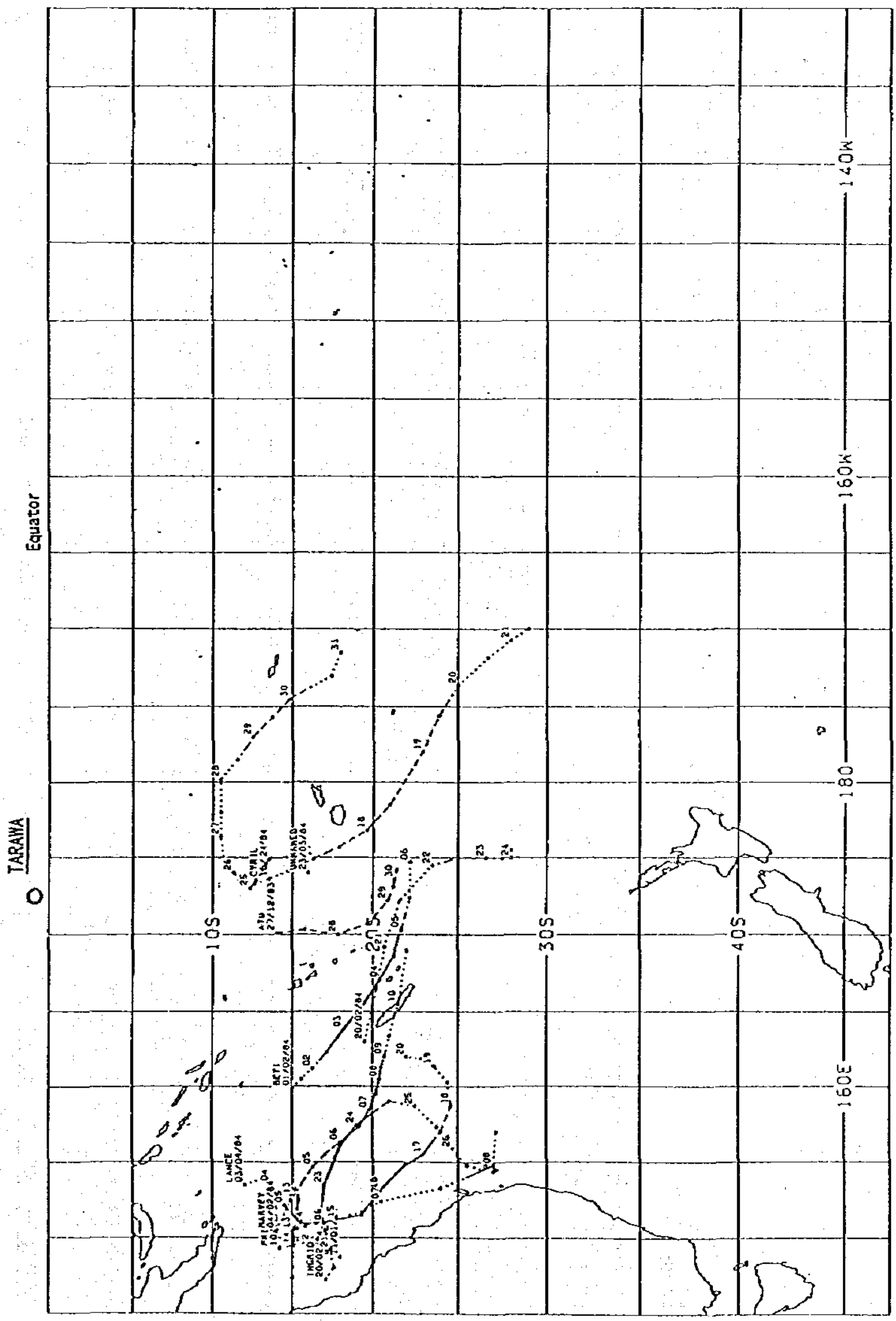


Figure A- 5- 2(15)   Cyclone Track (1983)

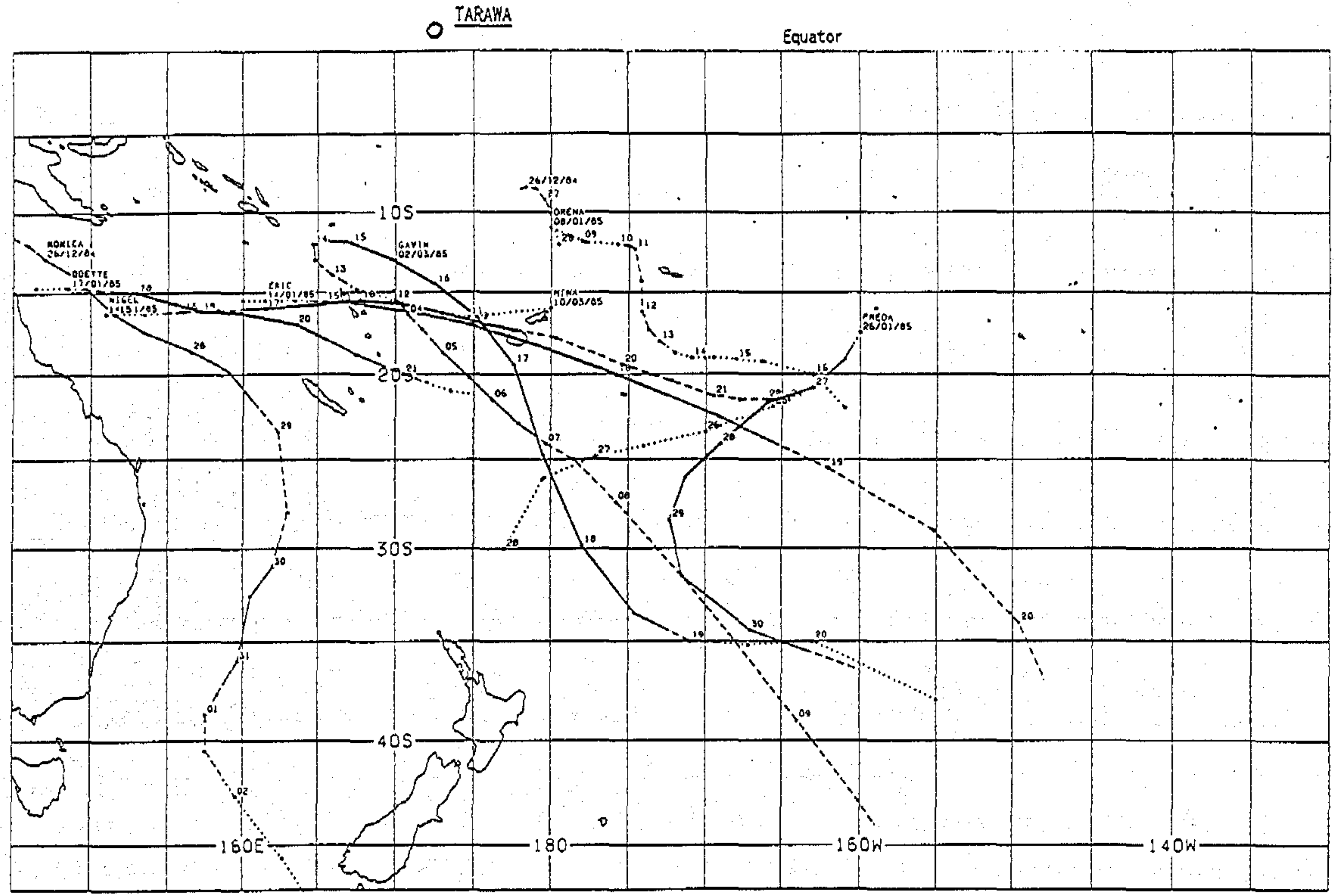


Figure A- 5- 2(16) Cyclone Track (1984)

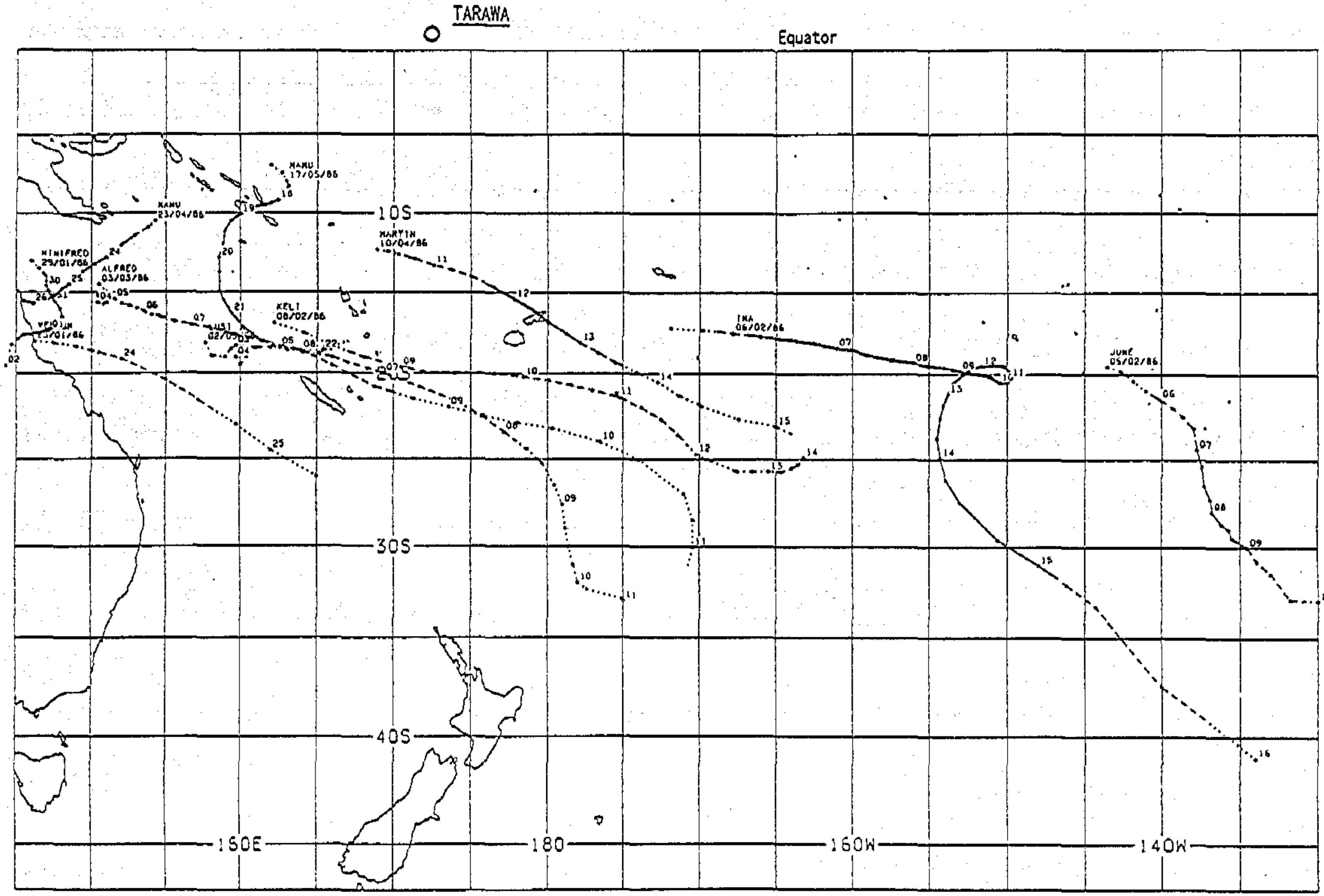


Figure A- 5- 2(17) Cyclone Track (1985)

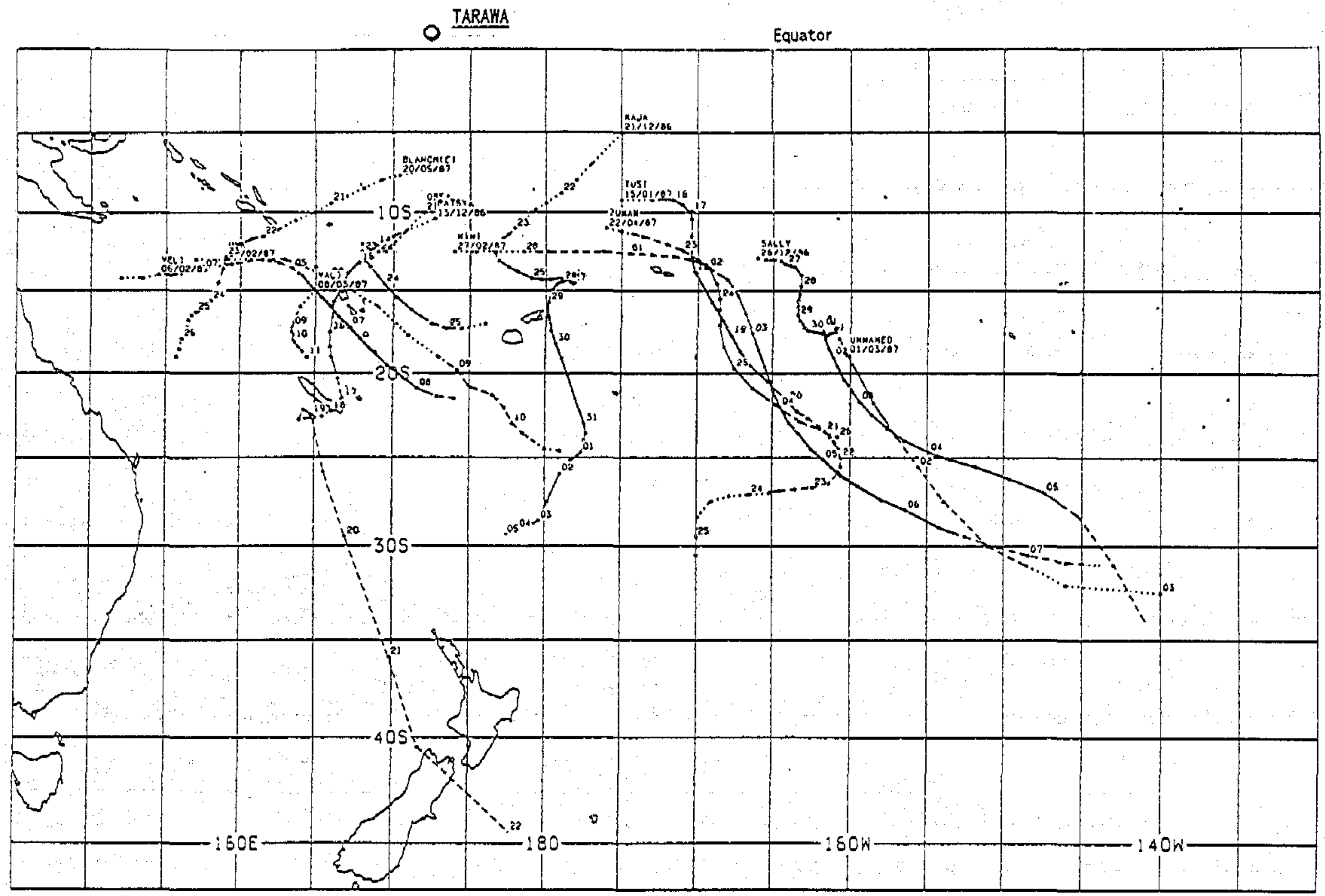


Figure A- 5- 2(18)   Cyclone Track (1986)

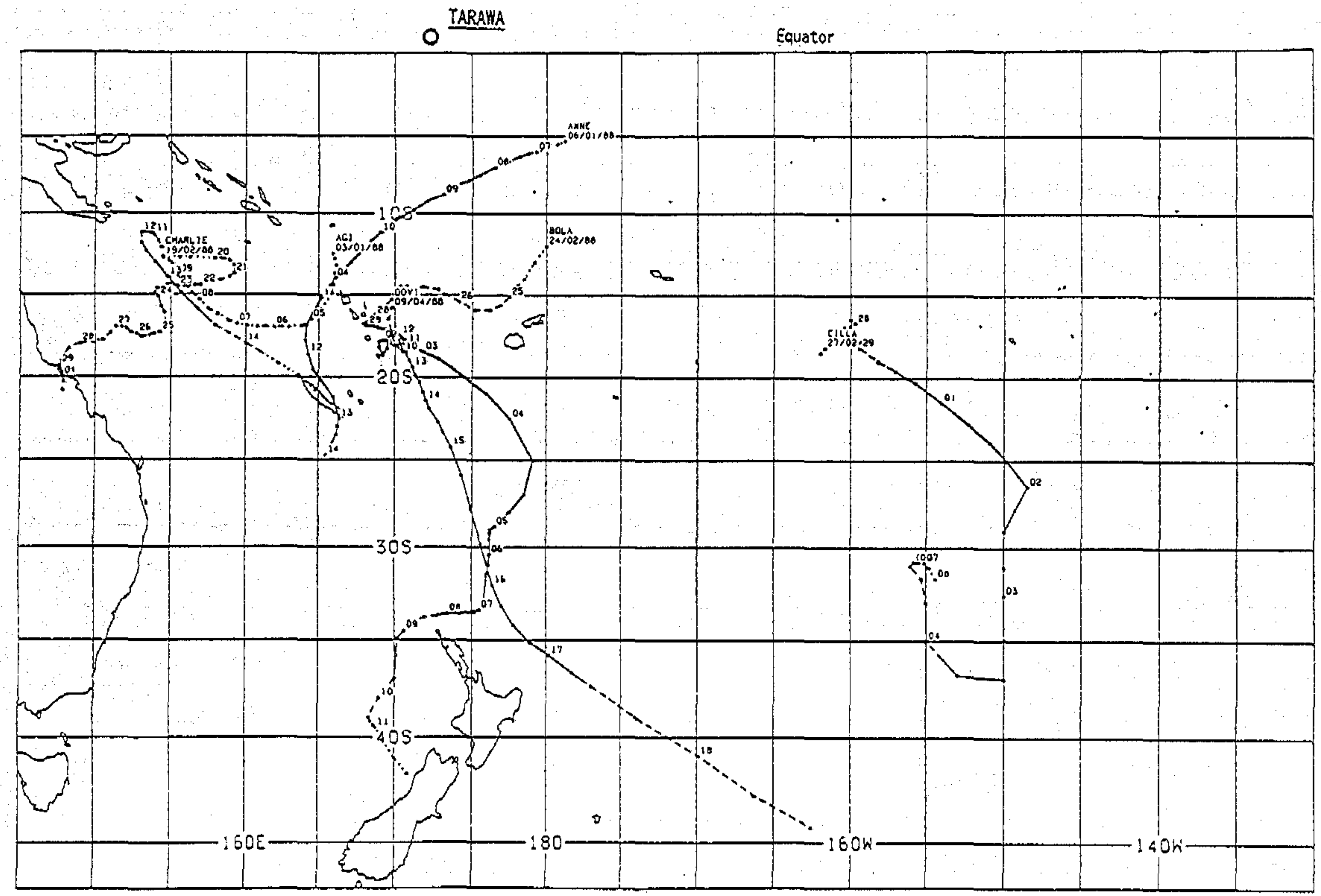


Figure A- 5- 2(19) Cyclone Track (1987)

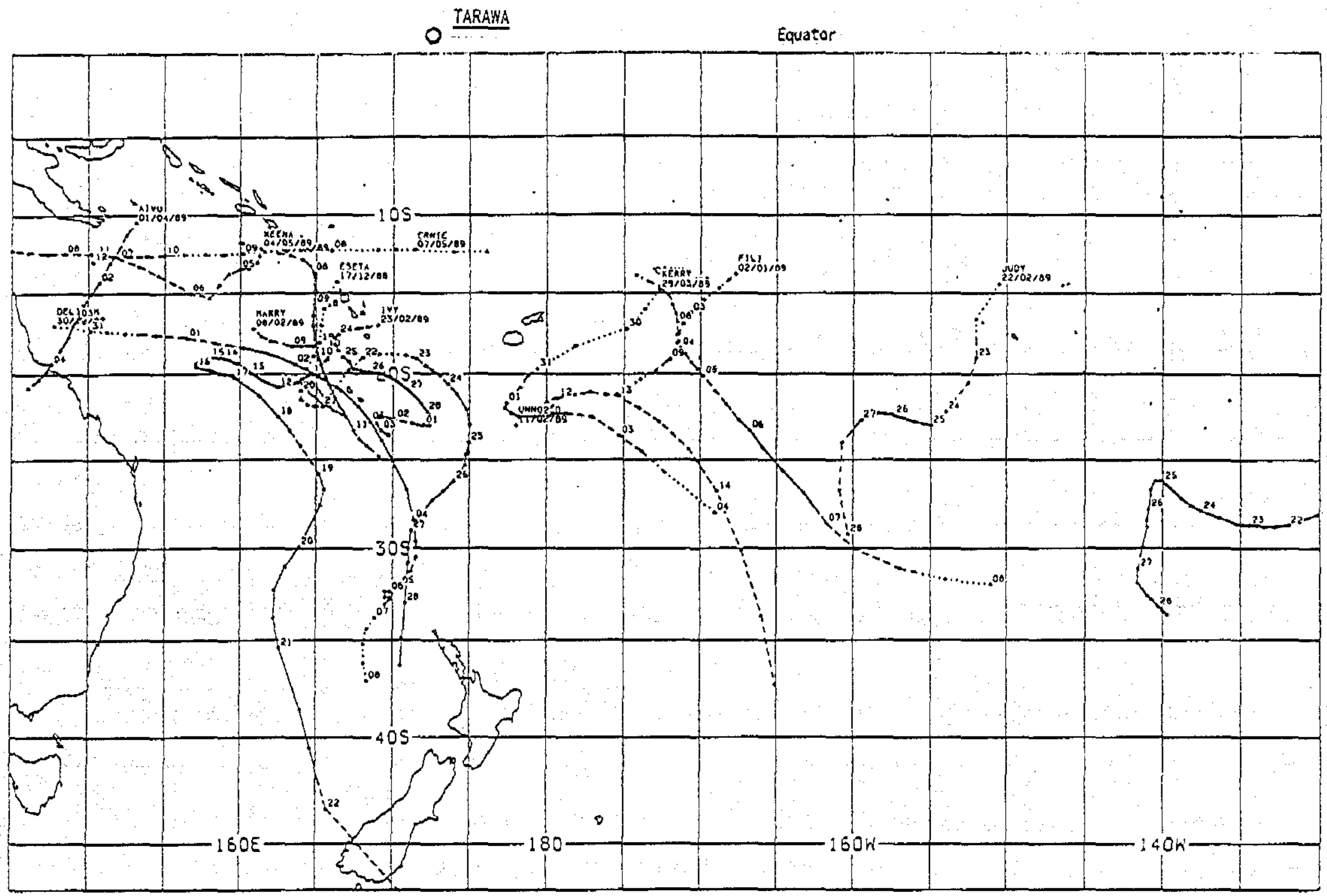


Figure A- 5- 2(20) Cyclone Track (1988)

Table A- 5- 3(1) The Maximum of Wave Height and Period

Wave Direction	NNW	N	NNE	NE	ENE	E
$H'_0(=H_0)$ (m)	0.99	1.24	1.24	1.24	1.74	1.49
T_0 (sec)	4.0	4.0	4.0	4.0	5.0	5.0
L: MSL (m)	23.75	23.75	23.75	23.75	33.67	33.67
H'_0/L	0.042	0.053	0.053	0.053	0.052	0.046
Smax	10	10	10	10	10	10

L : Wave Length, Smax: Estimation of the Spreading Paramcter

Table A- 5- 3(2) Calculation Results

Wave direction	NNW	N	NNE	NE	ENE	E
Wave Height Ratio (Revetment)	1.38	1.23	1.08	0.93	0.74	0.55
$H_{1/3}$ (m)	1.38	1.54	1.36	1.16	1.30	0.83

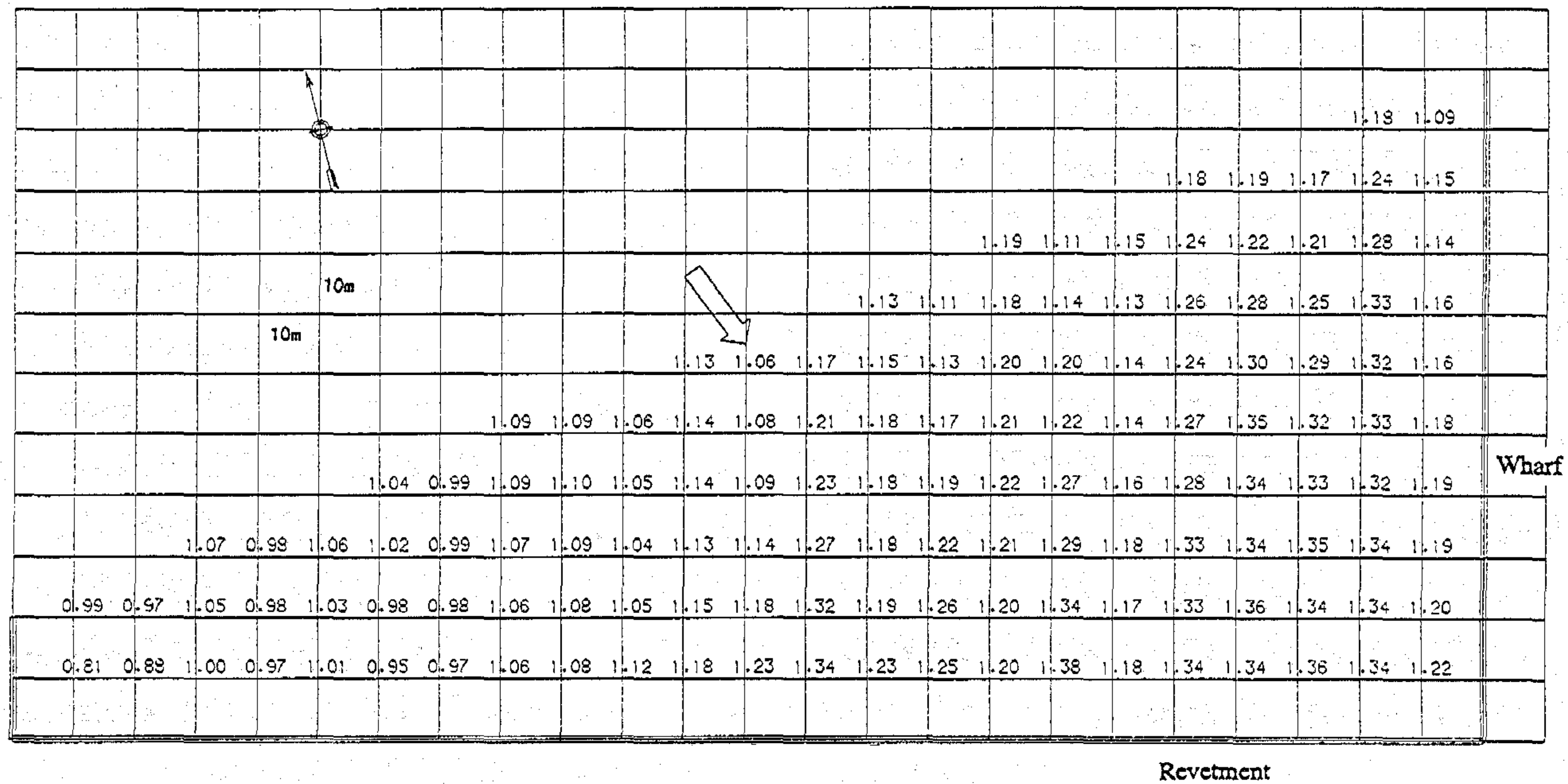


Figure A- 5- 3(1) Distribution of Wave Height Ratio (Wave Direction: NNW)

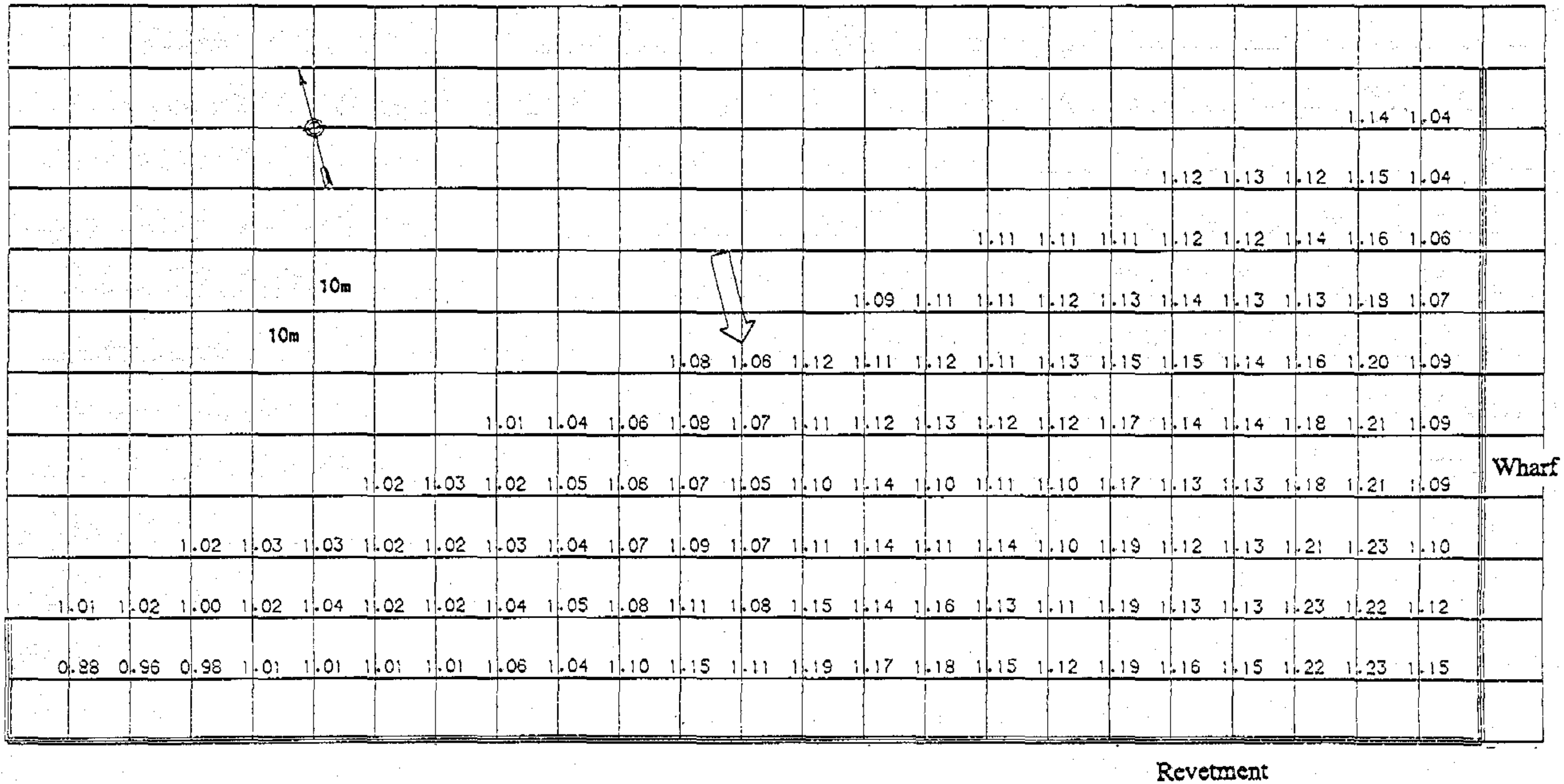


Figure A- 5- 3(2) Distribution of Wave Height Ratio (Wave Direction: N)

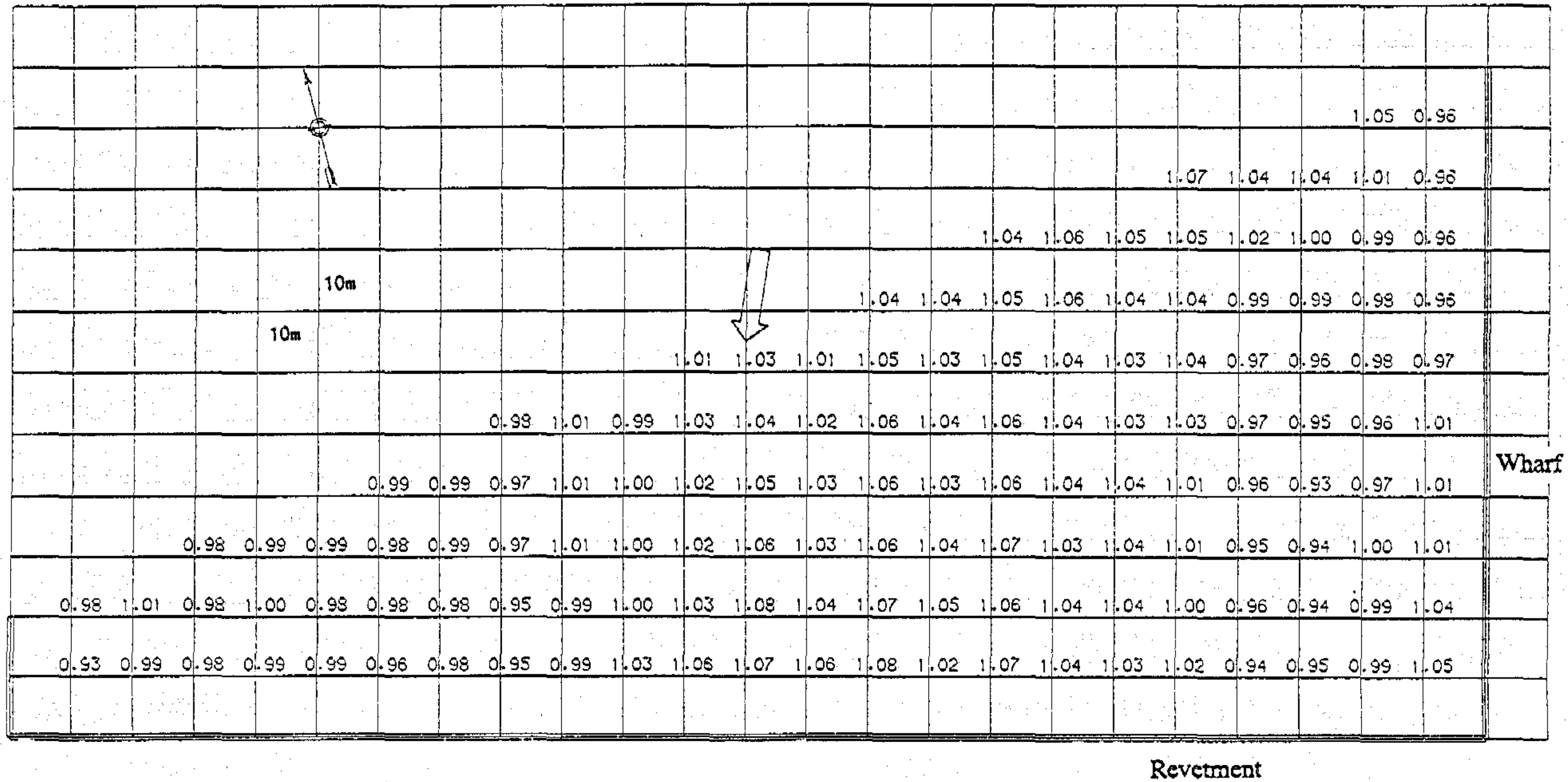


Figure A- 5- 3(3) Distribution of Wave Height Ratio (Wave Direction: NNE)

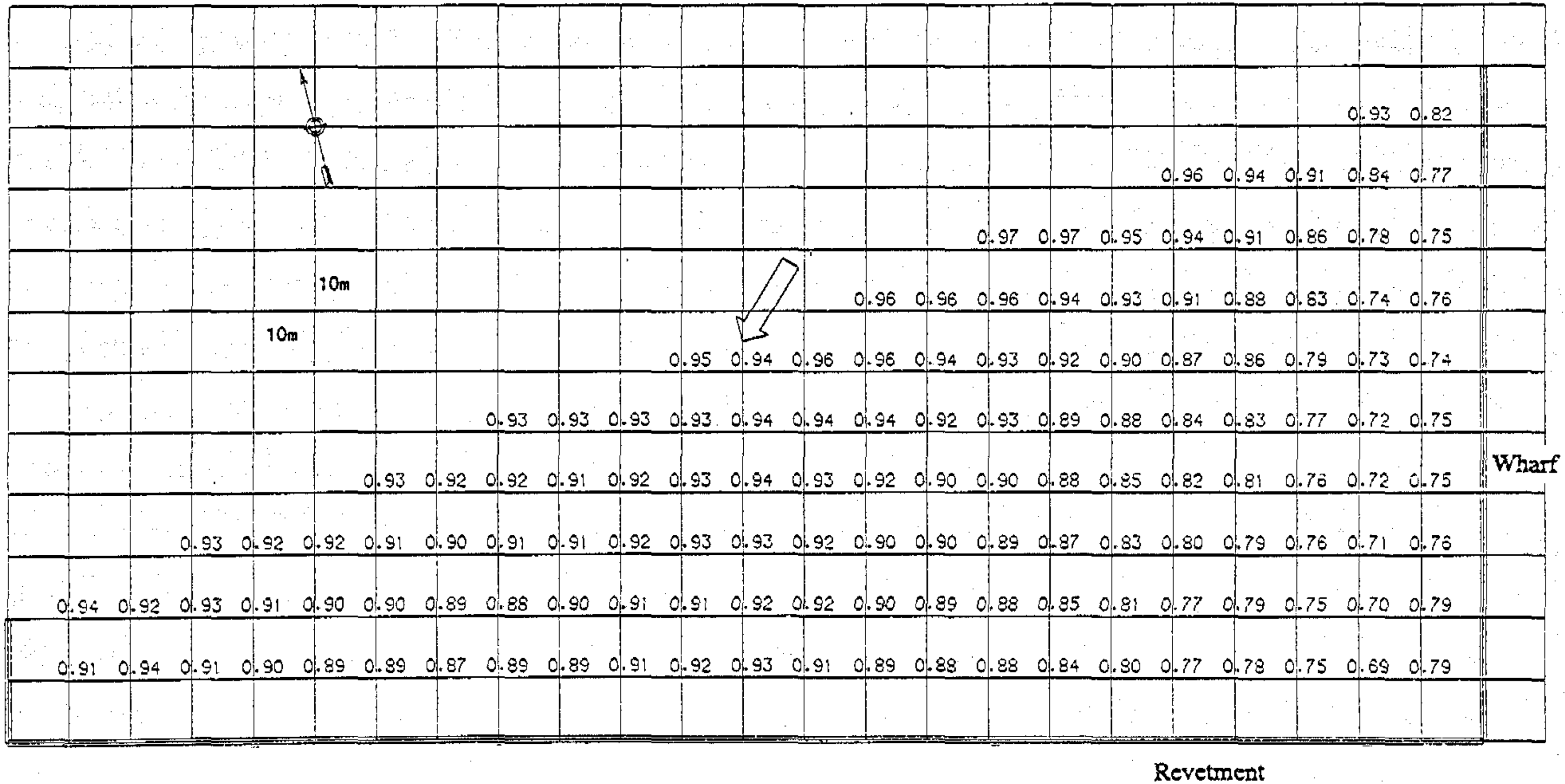


Figure A- 5- 3(4) Distribution of Wave Height Ratio (Wave Direction: NE)

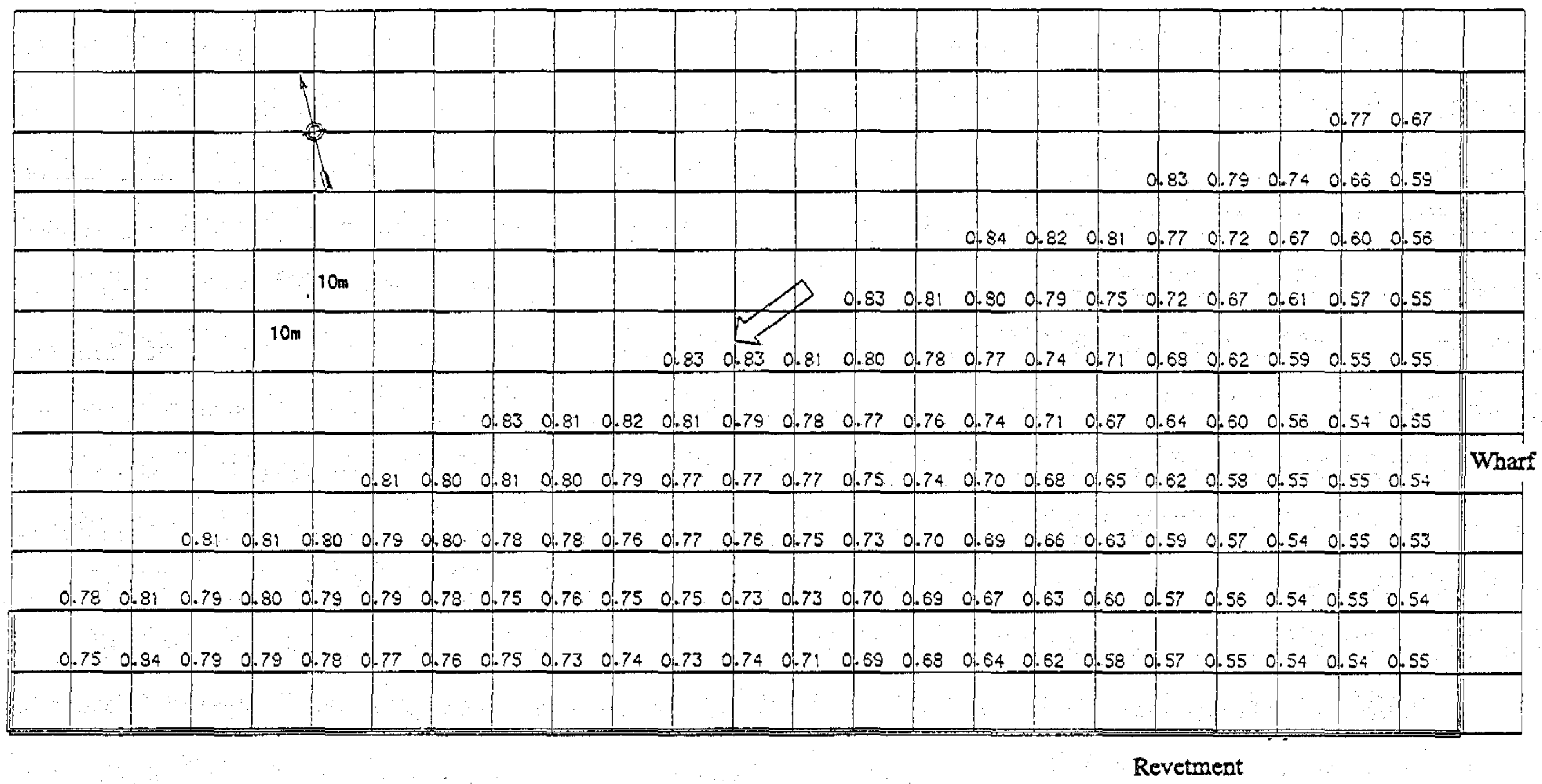


Figure A- 5- 3(5) Distribution of Wave Height Ratio (Wave Direction: ENE)

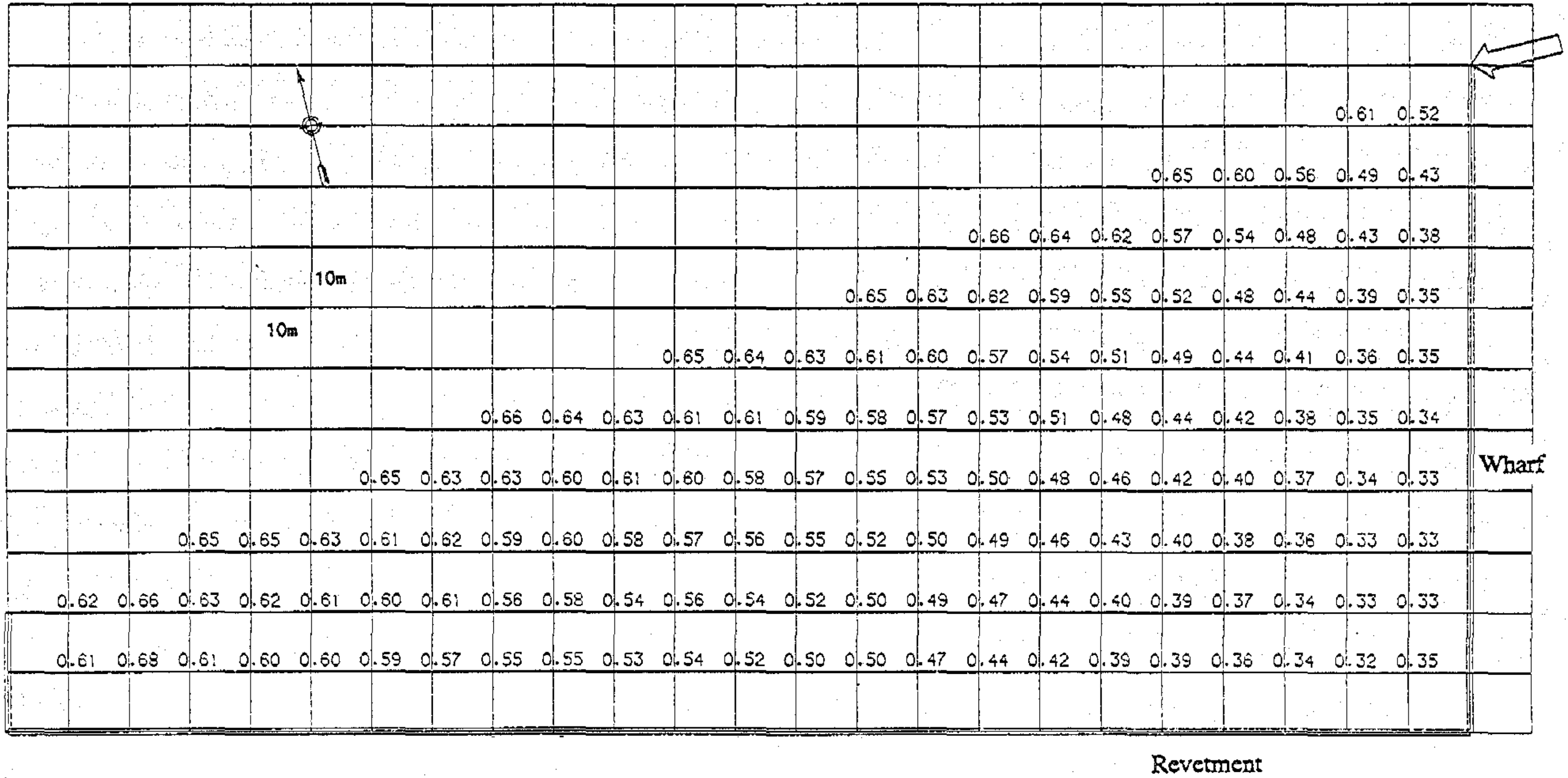


Figure A- 5- 3(6) Distribution of Wave Height Ratio (Wave Direction: E)

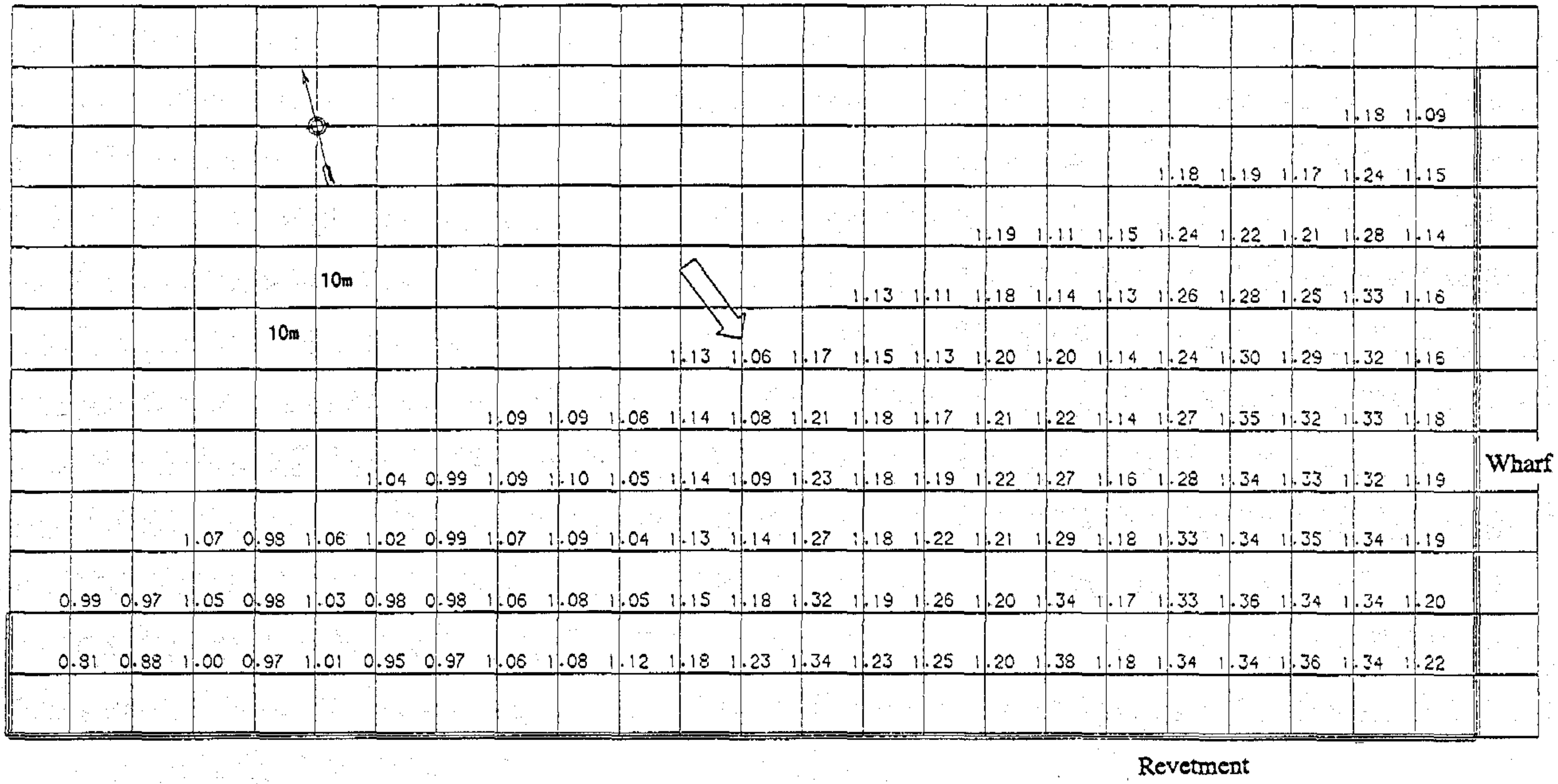


Figure A- 5- 4(1) Distribution of Wave Height (Wave Direction: NNW, Unit: m)

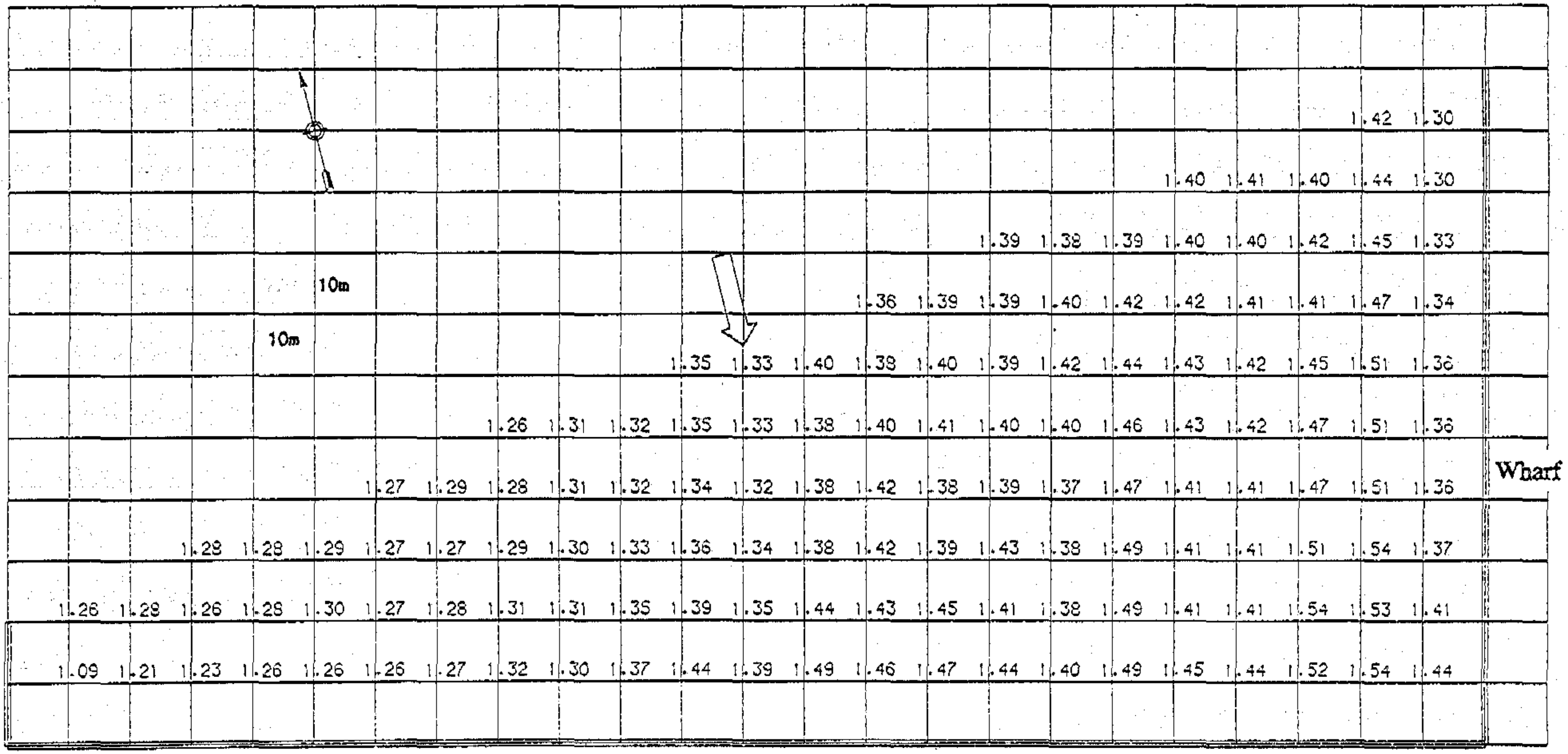


Figure A- 5- 4(2) Distribution of Wave Height (Wave Direction: N, Unit: m)

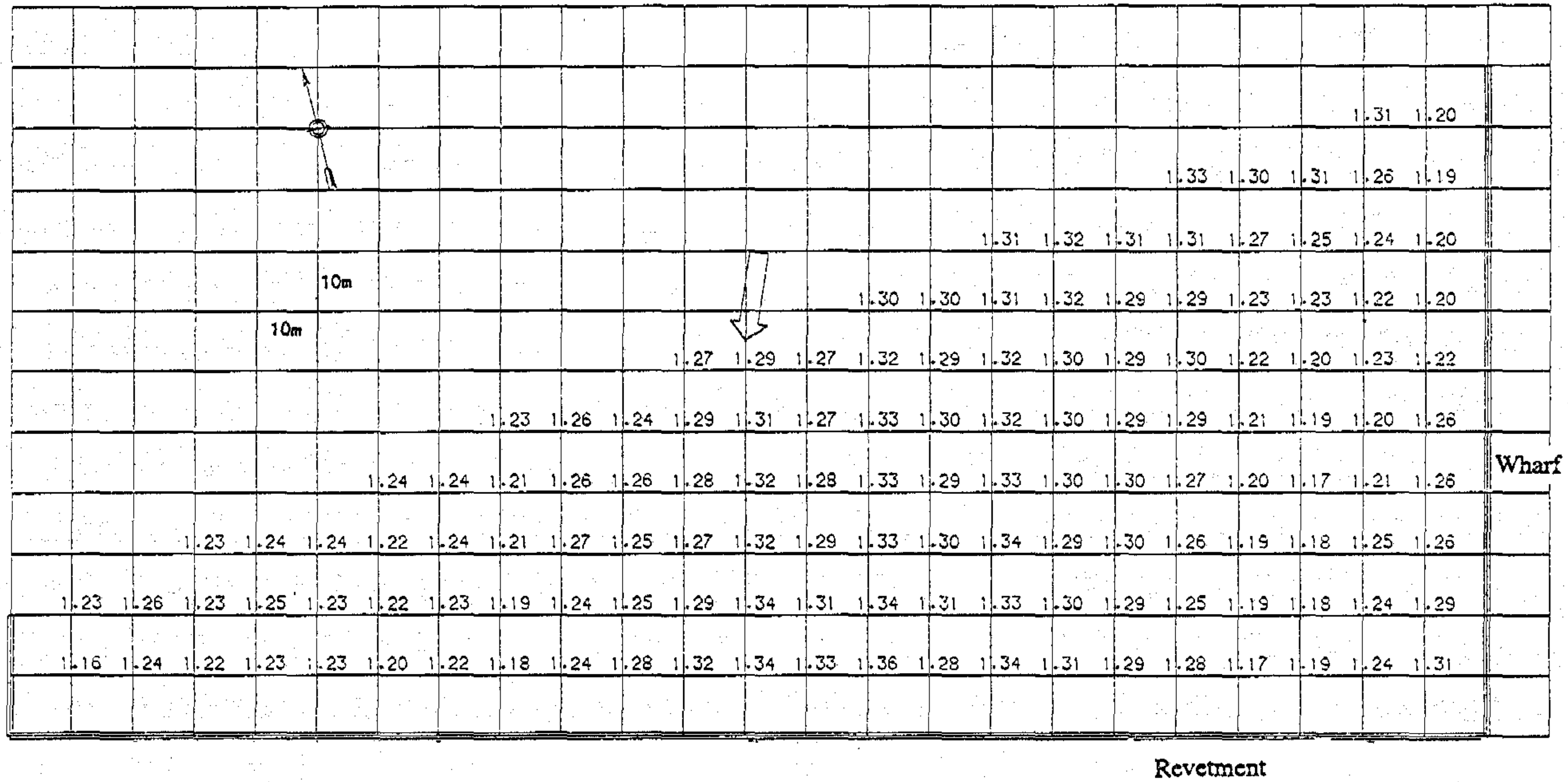


Figure A- 5- 4(3) Distribution of Wave Height (Wave Direction: NNE, Unit: m)

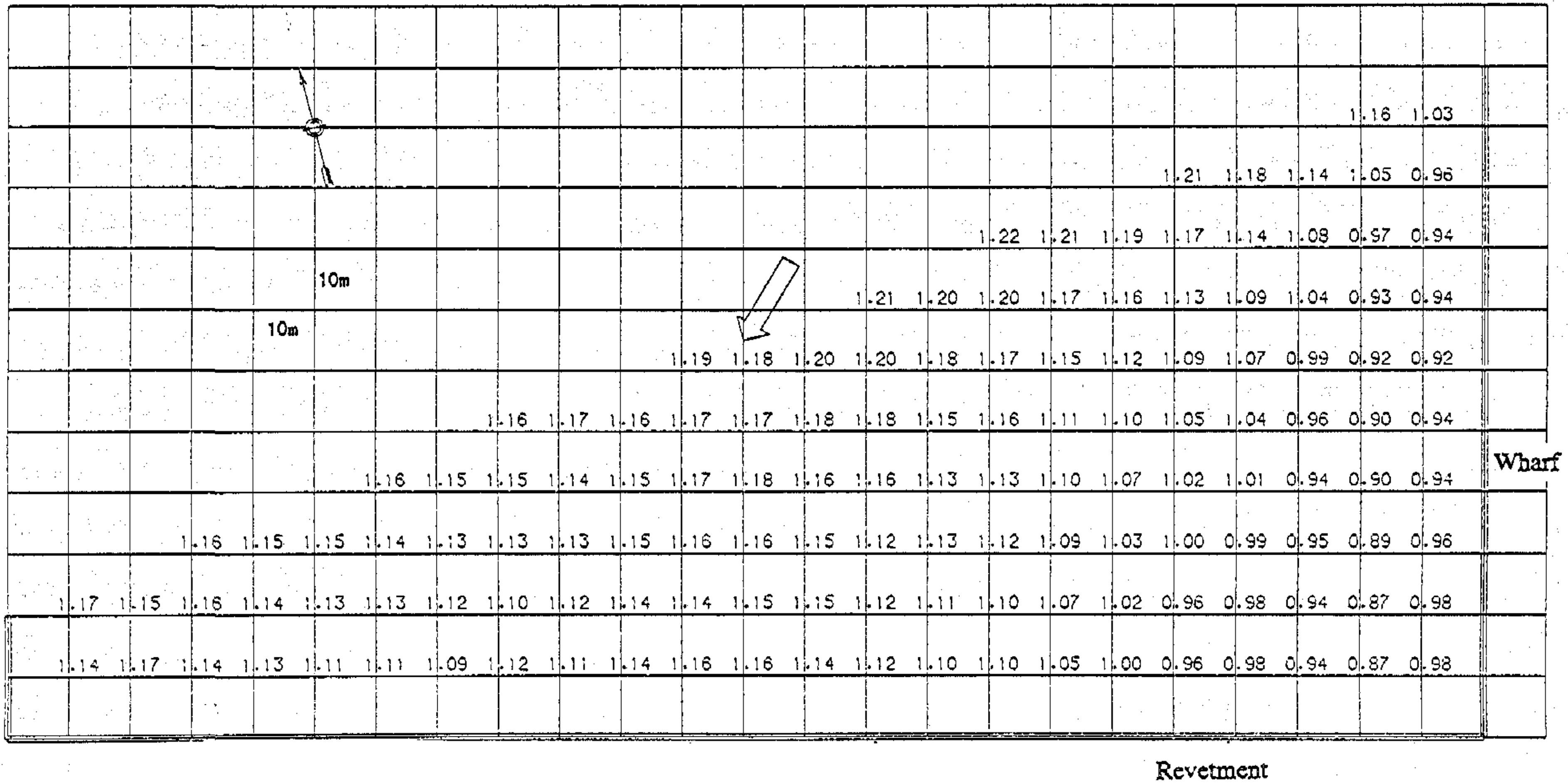


Figure A- 5- 4(4) Distribution of Wave Height (Wave Direction: NE, Unit: m)

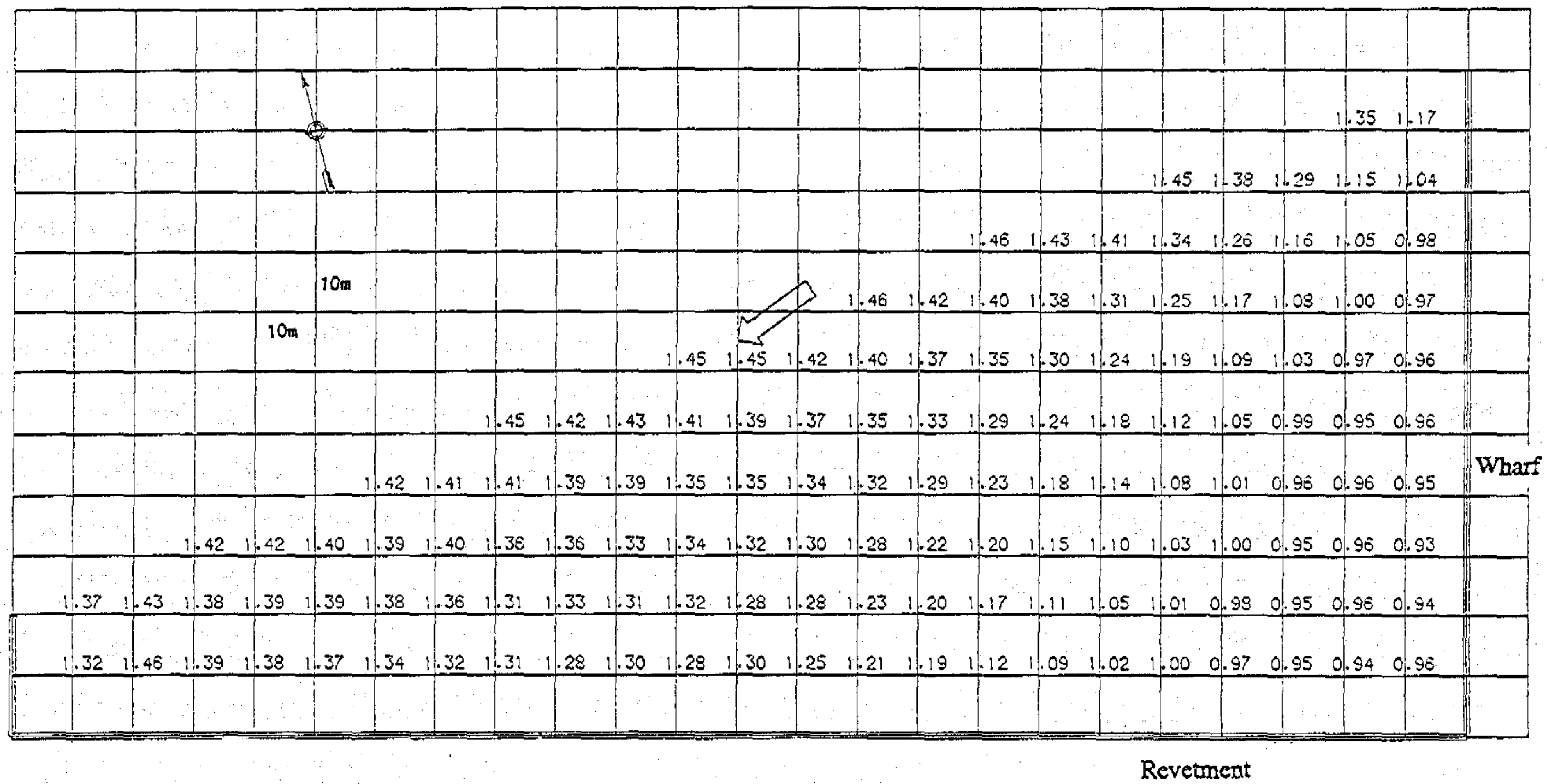


Figure A- 5- 4(5) Distribution of Wave Height (Wave Direction: ENE, Unit: m)

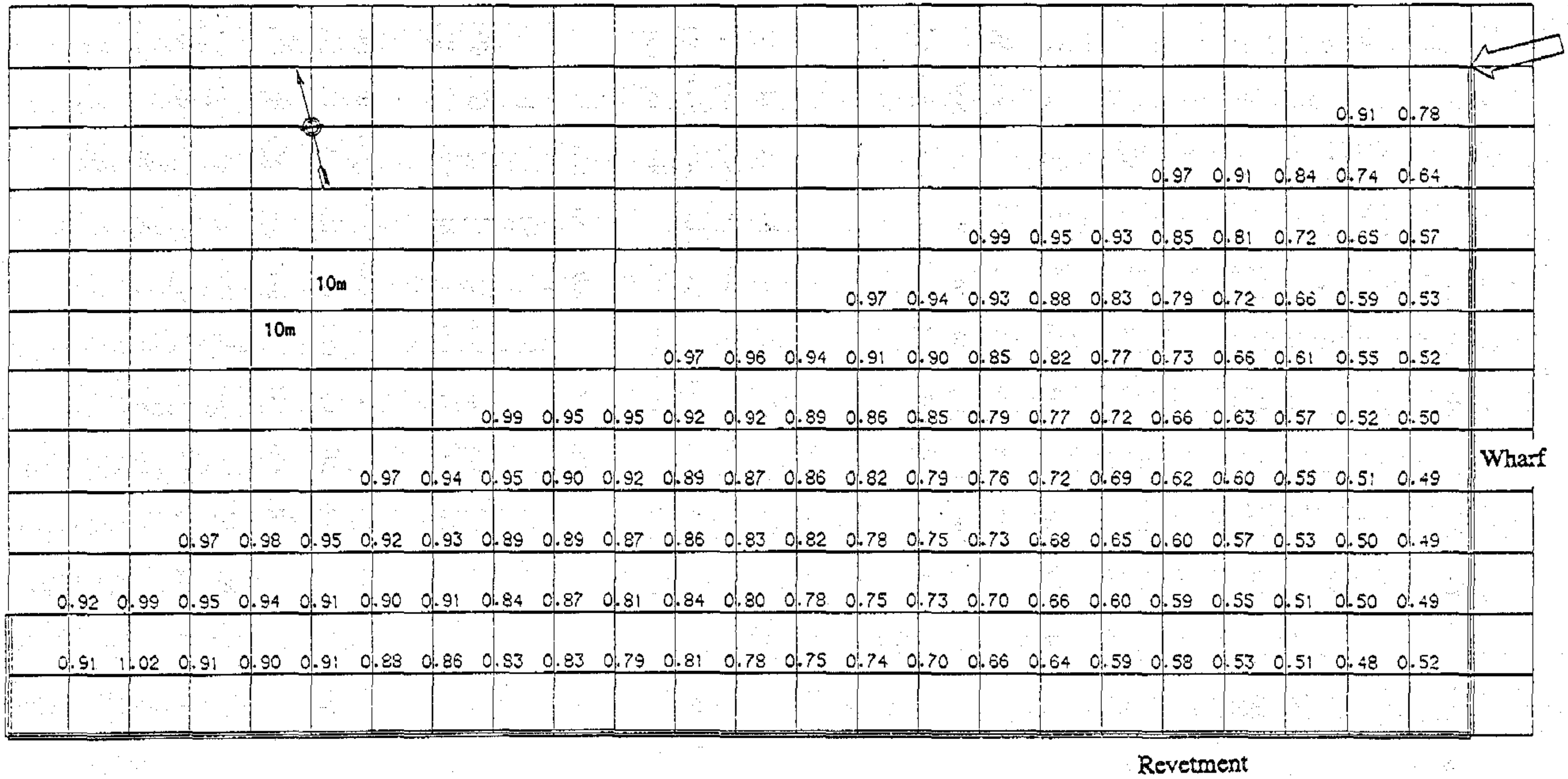


Figure A- 5- 4(6) Distribution of Wave Height (Wave Direction: E, Unit: m)

Appendix- 6 Data on Wave Agitation Analysis

(1) Cargo Handling Works Limit

Stopping cargo handling works are caused by waves, wind, rains, fogs, and so on. Considering that main cargo handling works are done by containers in Betio Port, stopping cargo handling works by rains are ignorable. No poor visibility by fogs is recorded in the vicinity of the project site.

The main reasons of stopping cargo handling works are caused by rolling of berthing vessels by waves and wind in Betio Port. Generally, cargo handling works limit by waves and wind between 500GRT and 50,000GRT vessels are shown in below:

- Limit Wave Height: $H_{1/3} = 0.5$(m), - Limit Wind Speed: $v = 10$(m/s)

Frequency of occurrence of wind speed more than 10m/s in the project site is only 1% and waves height represent the influence of wind speed. Therefore, the cargo handling works limit due to the calculation of effective working ratio in Betio Port is used the above limit wave height.

(2) Effective Working Ratio

The effective working ratio is calculated by the wave height ratio based on the wave agitation analysis in Betio Port considering multiplex deflections and refraction. From Table A- 5- 3(1) in above- mentioned appendix- 5, the maximum of wave height ratio with the incident wave is summarized according to the wave direction as shown below:

Table A- 6- 1 Calculation Results

Wave Direction	NNW	N	NNE	NE	ENE	E
Wave Height Ratio(Wharf)	1.35	1.23	1.05	0.94	0.79	0.61
Wave Height (m)	0.37	0.40	0.48	0.53	0.63	0.81

The wave height in Table A- 6- 1 are calculated by dividing the limit wave height (0.5m) by the wave height ratio as shown below equation.

0.5(m) / Wave Height Ratio (Wharf) = Wave Height (m)

The effective working ratio are calculated in Table A- 6- 3 based on the Table A- 6- 3 showing the frequency of occurrence of waves by height and direction in FS.

Table A- 6- 3 Results of Effective Working Ratio

(Unit : %)

CALM	NNW	N	NNE	NE	ENE	E	Sum.
47.1	4.7	5.9	7.4	9.2	8.8	12.1	95.2

The effective working ratio in Belio Port is calculated at 95%, which is satisfied with the criteria of "Technical Standards for Port and Harbour Facilities, and Annotations (1989: Japan Association of Ports and Harbour)".

Table A-6-2 Frequency of Occurrence of Waves by Height and Direction

(Upper: Frequency of Occurrence, Down: Percentage)

W.DIRECTION / W.HEIGHT (m)	CALM	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
CALM	3160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3160
	47.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.1
0.00–0.24	0	265	282	264	284	0	0	0	0	0	0	0	0	0	0	217	235	1547
	0.0	4.0	4.2	3.9	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	3.5	23.1
0.25–0.49	0	236	251	253	333	0	0	0	0	0	0	0	0	0	0	102	160	1335
	0.0	3.5	3.7	3.8	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	2.4	19.9
0.50–0.74	0	107	87	77	171	0	0	0	0	0	0	0	0	0	0	8	95	545
	0.0	1.6	1.3	1.1	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.4	8.1
0.75–0.99	0	19	10	9	26	0	0	0	0	0	0	0	0	0	0	1	36	101
	0.0	0.3	0.1	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.5
1.00–1.24	0	3	1	1	1	0	0	0	0	0	0	0	0	0	0	0	10	16
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2
1.25–1.49	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.50–1.74	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.75–1.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00–2.24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.25–2.49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.50–2.74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.75–3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	3160	630	631	605	816	0	0	0	0	0	0	0	0	0	0	328	536	6706
	47.1	9.4	9.4	9.0	12.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	8.0	100.0