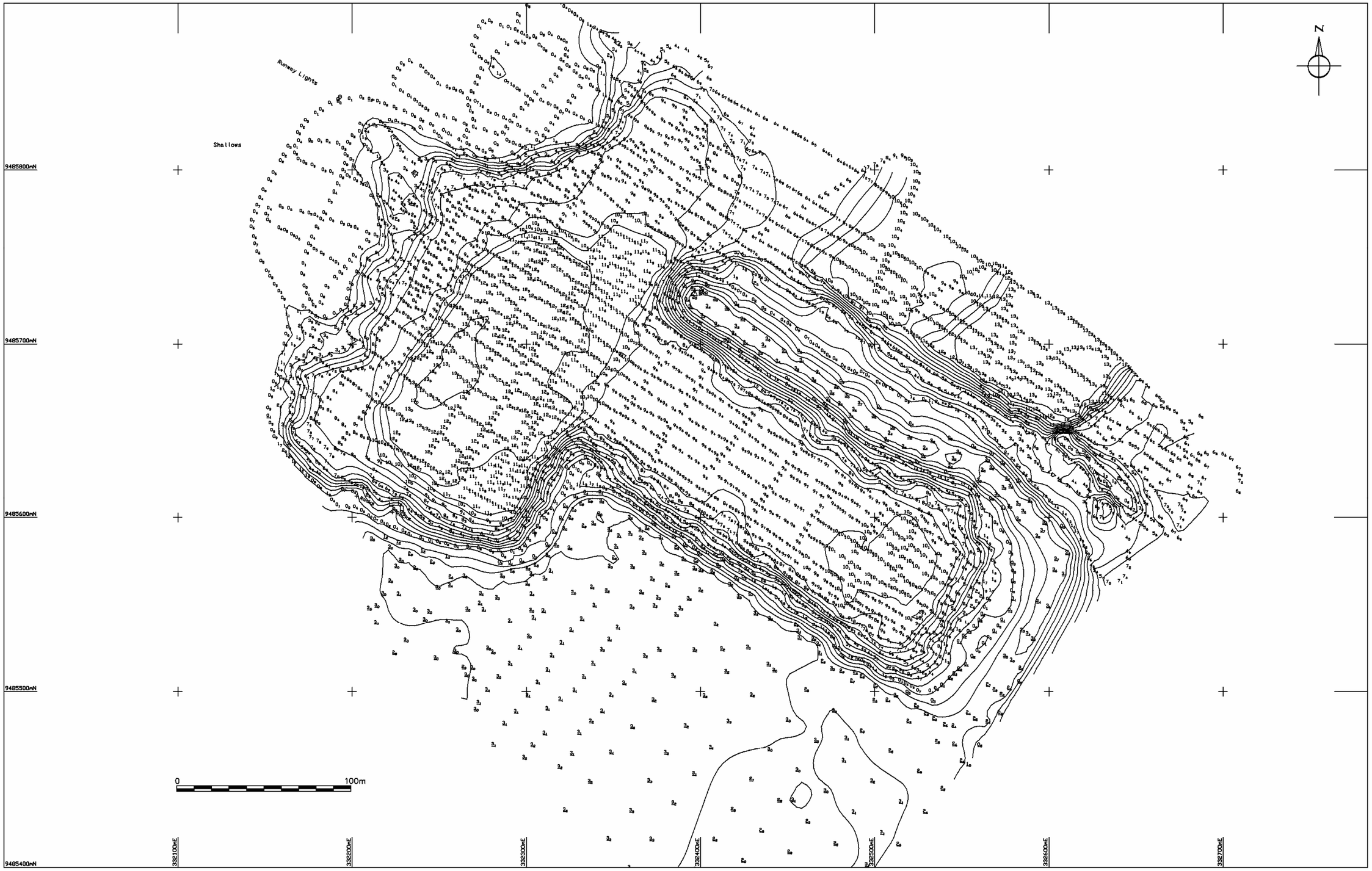
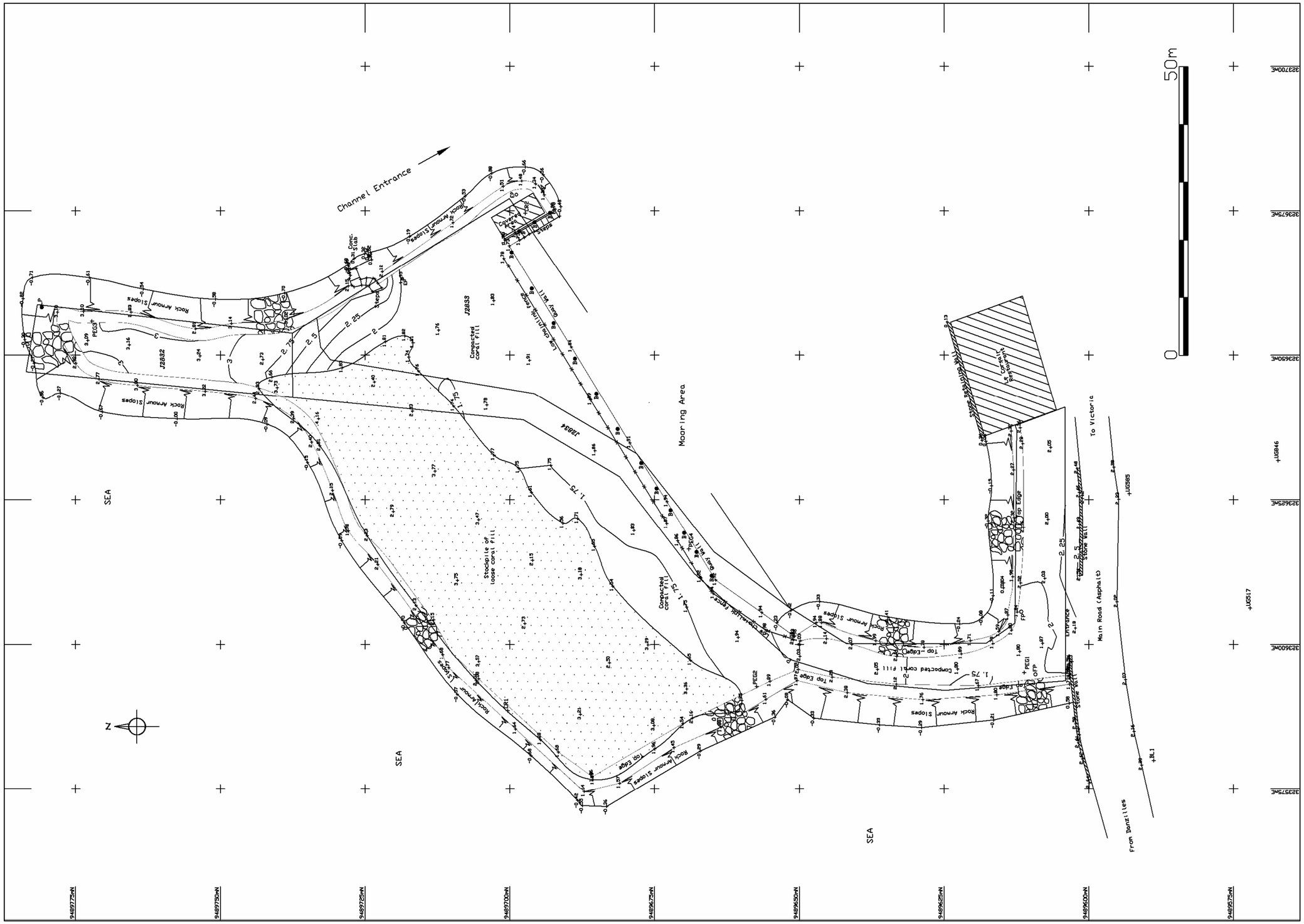
Appendix-5 Other Relevant Data

Appendix 5-1 Topographic and Bathymetric Map at Providence



Appendix 5-1 Topographic and Bathymetric Map at Providence

Appendix 5-2 Topographic Map at Bel Ombre



Appendix 5-2 Topographic Map at Bel Ombre

Appendix 5-3 Study of Design Wave for Existing Breakwater

1. Wind

Distribution of average of wind velocity (according to the data base of Meteorological Agency in Japan) in western part of Indian Ocean located in Seychelles is shown in Figure 1. In the southern area of latitude 15 degrees south, the average of wind velocity is approximately 5 m/sec so that winds are largely affected by trade winds. However, winds are relatively calm around Seychelles.

A wind rose in Seychelles and a table of frequency distribution of wind direction and speed per a year are shown in Figure 2 and Table 1. SE and SSE winds occur high frequently through a year and are account for more than 40%. Distribution of wind direction has a heavily seasonal fluctuation and Appearance ration of wind ranged from SE to SSE is high in rainy season (April to October) and wind ranged from WNW and SE is high in dry season (November to March). Appearance ratio more than wind speed 5.0 m/sec, 7.5m/sec and 10.0 m/sec are 47.8%, 17.5% and 1.7% respectively. Figure 3 and Table 2 show wind rose and frequency table of wind direction and speed based on data of Seychelles National Meteorological Services.

As compared with data of Meteorological Agency in Japan and Seychelles National Meteorological Services, though wind direction is one direction difference on 16 directions, characteristics of wind occurrence are almost same in year around and by season. As results of local observation, appearance ratio more than wind speed 5.0 m/sec, 7.5m/sec and 10.0 m/sec are 34.3%, 7.4% and 0.5% respectively. The appearance ratio of strong wind is slightly lower than data of Meteorological Agency in Japan. Since wind data of Seychelles National Meteorological Services ware observed on land, wind speed is considered to be smaller than wind speed on sea caused by effect of land surface and buildings. The wind data of Meteorological Agency in Japan are well indicated to appearance characteristics

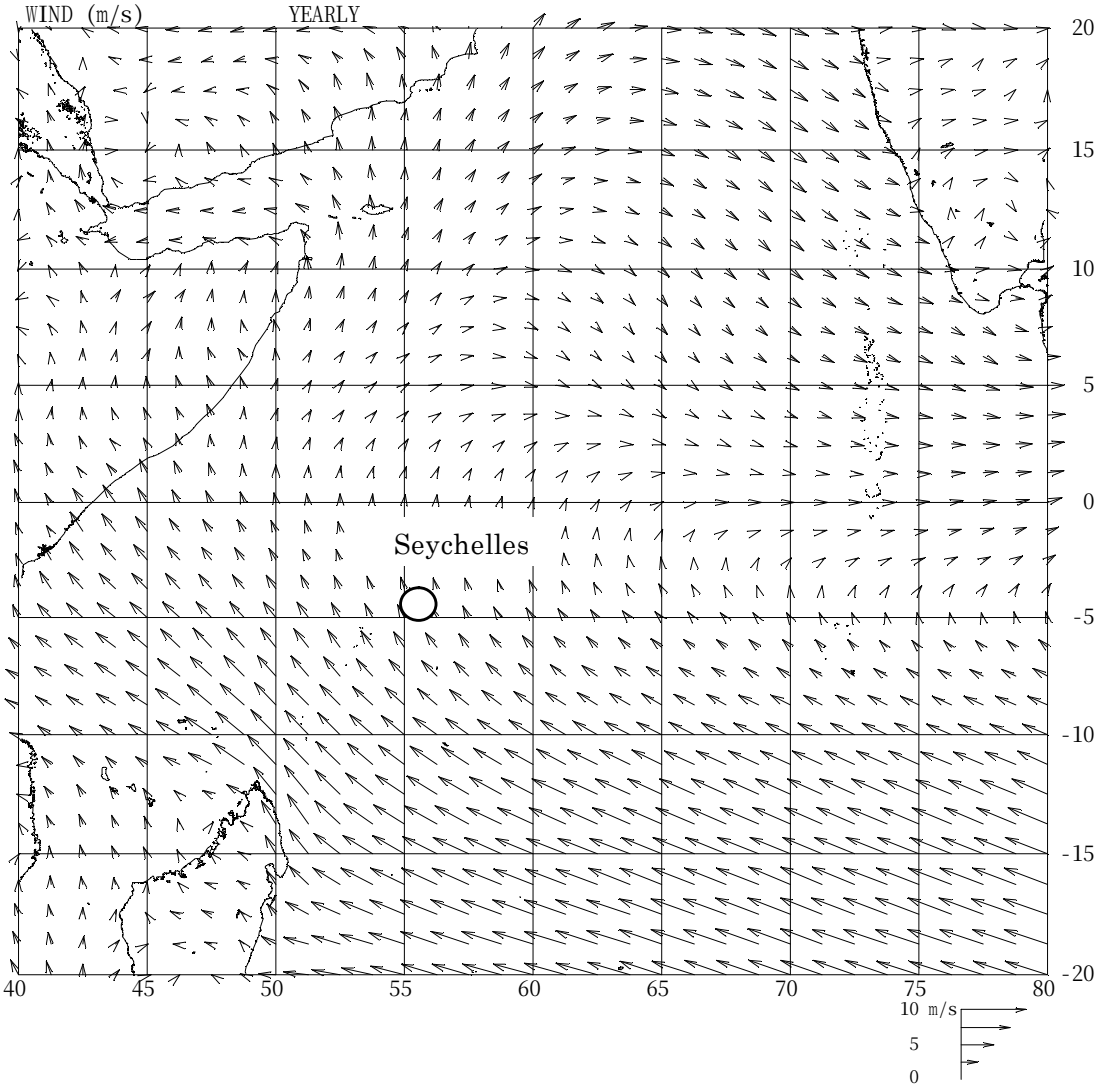
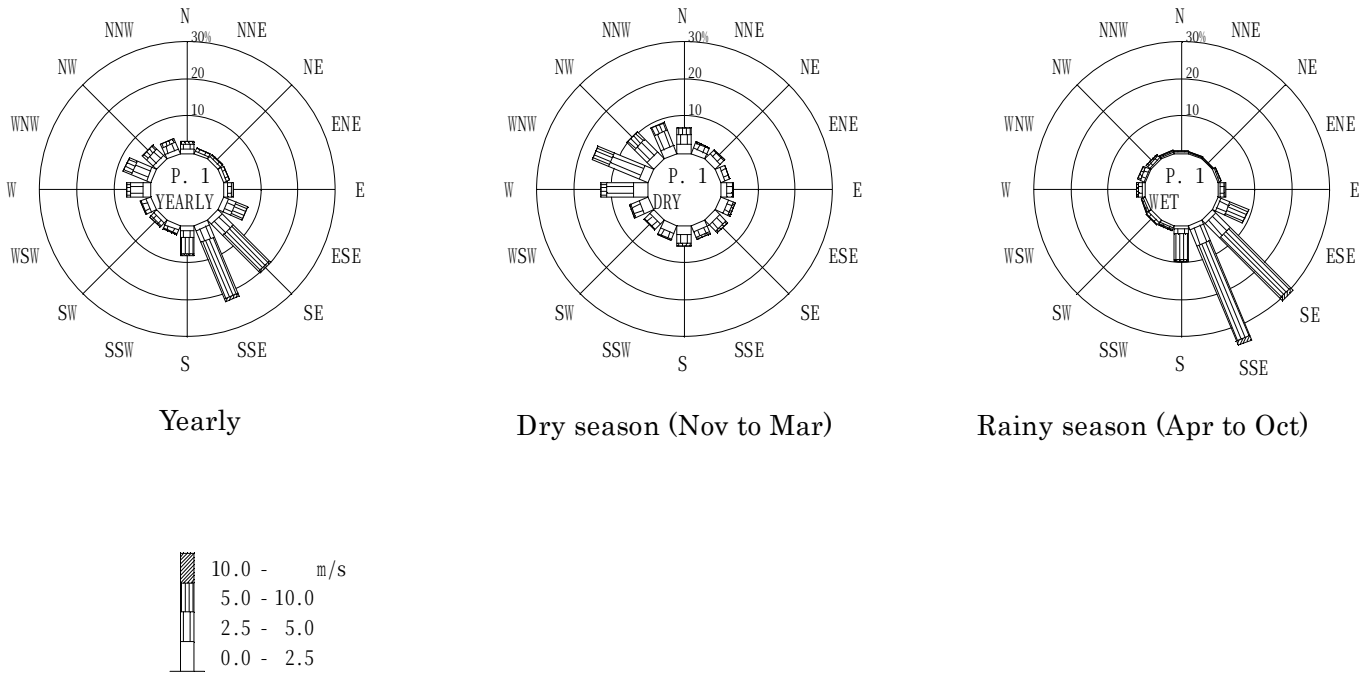
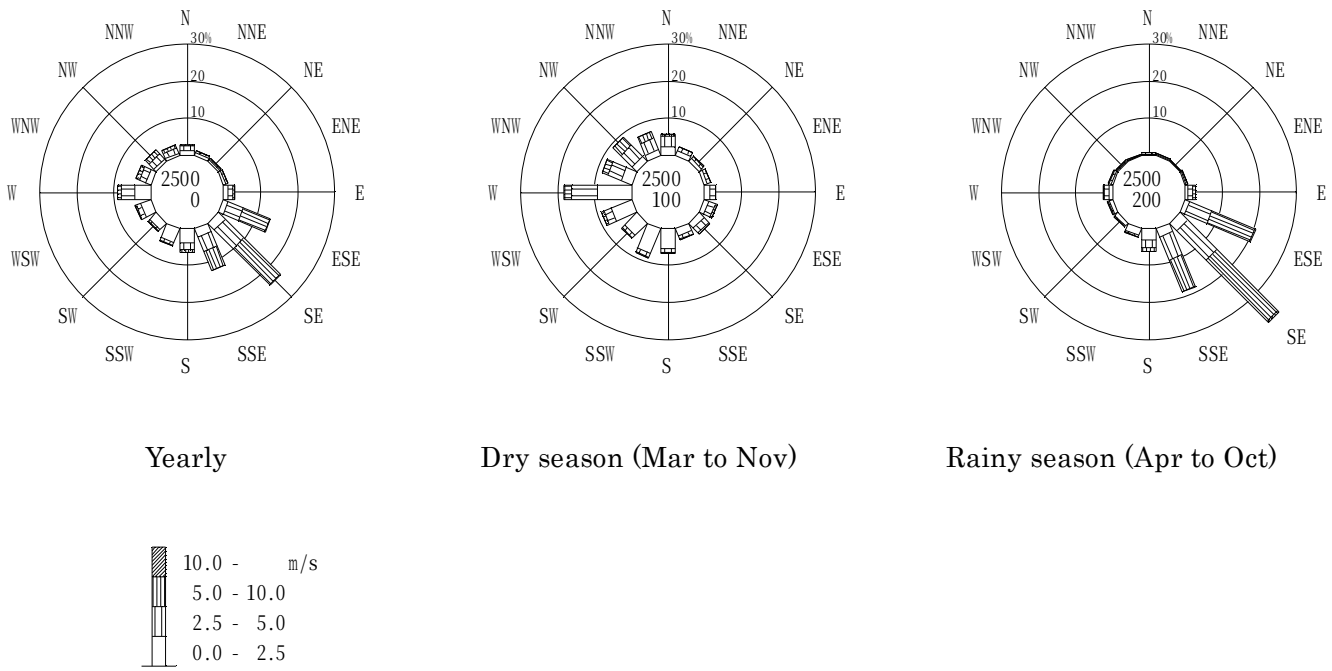


Figure 1 Distribution of average wind speed in Western Indian Ocean (Data of Meteorological Agency in Japan)



Yearly Dry season (Nov to Mar) Rainy season (Apr to Oct)

Figure 2 Wind rose in Seychelles (Meteorological Agency in Japan, (Mar 2001 to Feb 2004, observation of 4 times per day)



Yearly Dry season (Mar to Nov) Rainy season (Apr to Oct)

Figure 3 Wind rose in Seychelles (Seychelles National Meteorological Services, (1996 to 2005, observation of 24 times per day)

Table 1 frequency distribution of wind direction and speed per a year

(Meteorological Agency in Japan, Mar 2001 to Feb 2004, observation of 4 times per day)

YEARLY

Direction / U(m/s)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW		Total
0.0 - 0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1 - 2.5	48	30	38	37	50	63	64	59	60	54	44	62	87	54	52	51	2	855
	1.09	0.68	0.87	0.84	1.14	1.44	1.46	1.35	1.37	1.23	1.00	1.41	1.98	1.23	1.19	1.16	0.05	19.50
2.5 - 5.0	59	34	33	36	51	97	184	151	82	45	54	59	159	189	113	90	0	1436
	1.35	0.78	0.75	0.82	1.16	2.21	4.20	3.44	1.87	1.03	1.23	1.35	3.63	4.31	2.58	2.05	0.00	32.76
5.0 - 7.5	28	8	4	1	12	114	376	395	123	11	11	10	39	95	58	41	0	1326
	0.64	0.18	0.09	0.02	0.27	2.60	8.58	9.01	2.81	0.25	0.25	0.23	0.89	2.17	1.32	0.94	0.00	30.25
7.5 - 10.0	4	0	0	0	0	34	228	331	67	2	0	1	3	11	5	4	0	690
	0.09	0.00	0.00	0.00	0.00	0.78	5.20	7.55	1.53	0.05	0.00	0.02	0.07	0.25	0.11	0.09	0.00	15.74
10.0 - 12.5	0	0	0	0	1	0	23	33	16	0	0	0	0	0	1	2	0	76
	0.00	0.00	0.00	0.00	0.02	0.00	0.52	0.75	0.36	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.00	1.73
12.5 - 15.0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
15.0 - 17.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17.5 - 20.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20.0 - 22.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22.5 - 25.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25.0 - 27.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27.5 - 30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30.0 - 100.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	139	72	75	74	114	308	876	969	348	112	109	132	288	349	229	188	2	4384
	3.2	1.6	1.7	1.7	2.6	7.0	20.0	22.1	7.9	2.6	2.5	3.0	6.6	8.0	5.2	4.3	0.0	100.0

Upper : Number of contents
Lower : Percentage of occurrence

Table 2 frequency distribution of wind direction and speed per a year

(Seychelles National Meteorological Services, 1996 to 2005, observation of 24 times per day)

WIND DIRECTION / WIND SPEED(M/S)	U.K.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
0.0 - 2.5	20	71	56	43	31	66	77	119	182	283	295	151	168	339	110	48	61	2120
	.2	.8	.6	.5	.4	.8	.9	1.4	2.1	3.2	3.4	1.7	1.9	3.9	1.3	.5	.7	24.2
2.5 - 5.0	20	165	72	38	50	100	235	596	492	224	85	62	86	344	168	152	222	3111
	.2	1.9	.8	.4	.6	1.1	2.7	6.8	5.6	2.6	1.0	.7	1.0	3.9	1.9	1.7	2.5	35.5
5.0 - 7.5	9	53	12	6	3	37	297	1359	614	101	22	14	38	102	69	68	73	2877
	.1	.6	.1	.1	.0	.4	3.4	15.5	7.0	1.2	.3	.2	.4	1.2	.8	.8	.8	32.8
7.5 - 10.0	1	0	1	1	0	5	52	352	162	23	1	4	2	15	5	7	3	634
	.0	.0	.0	.0	.0	.1	.6	4.0	1.8	.3	.0	.0	.0	.2	.1	.1	.0	7.2
10.0 - 15.0	0	0	0	0	0	0	0	11	10	1	0	0	1	0	1	0	0	24
	.0	.0	.0	.0	.0	.0	.0	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.3
15.0 - 20.0	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
20.0 - 25.0	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
25.0 - 30.0	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
30.0 -	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	50	289	141	88	84	208	661	2437	1460	632	403	231	295	800	354	275	359	8767
	.6	3.3	1.6	1.0	1.0	2.4	7.5	27.8	16.7	7.2	4.6	2.6	3.4	9.1	4.0	3.1	4.1	100.0

2. Waves

(1) Ordinary waves

Table 3 shows results of hindcasting of offshore waves calculated by spectrum method at deepwater area in ordinary waves according to wind data in Western Indian Ocean (data source: Meteorological Agency in Japan). Table 4 shows frequency of wave height and period of offshore wave hindcasted in Seychelles. Regarding Table 13, wave direction is coordinated with wind appearance ratio and waves from E to S are account for approximately 80%. Wave height is around 5m at the maximum. Wave period distributes widely ranged from 3 to 10 sec and 6 to 8 sec is predominant. The project site is open at the direction from E to SE, waves from these directions directly come into the project site.

(2) Storm waves

Waves in Western Indian Ocean are affected by cyclone moving to west. However, since cyclones develop and move within southern area of latitude 10 degrees south, the area in the vicinity of Seychelles is not largely affected by cyclones. Figure 4 shows routes of cyclones which developed big waves affected Seychelles in 1945 to 2003. Regarding Cyclone 8307 (it means to be the seventh cyclone in 1983) and Cyclone 8908, offshore waves attacked Seychelles have been hindcasted by spectrum method. Routes and results of wave hindcasting of above two cyclones are shown in Figure 5. According to the results, largest wave height of two cyclones is 5.7m and 5.6m respectively, and wave period is from 10 to 12 sec, wave direction is ranged from SE to SW.

Regarding offshore design wave height, the largest wave height is approximately 5m in hindcasting ordinary waves. Considering the above results of hindcasting cyclone waves, the design wave height of offshore wave is set 6m. Since waves with long wave periods are dangerous for marine structure, the design wave period is set 12 sec according to results of hindcasting ordinary and storm waves. Regarding wave direction, though main wave direction is South (S) in Seychelles, since waves at E direction affects marine structure considering configuration of topography, in setting the design wave for marine structure, wave direction of the design wave is set to be ESE.

Dimensions of offshore design wave are shown as follows.

Dimensions of offshore design wave

Wave height (Ho):	6.0m
Wave period (To):	12.0s
Wave direction:	ESE to SW

(Wave deformation is calculated as wave direction of ESE.)

Table 3 Frequency of wave height and direction
(Offshore in Seychelles, yearly, Mar 2001 to Feb 2004)

WAVE DIRECTION	U.K.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
WAVE HEIGHT(M)																		
CALM	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
0.00 - 0.50	0 .0	676 2.6	450 1.7	48 .2	45 .2	65 .2	330 1.3	1090 4.1	638 2.4	68 .3	9 .0	0 .0	0 .0	0 .0	0 .0	0 .0	22 .1	3441 13.1
0.50 - 1.00	0 .0	1004 3.8	728 2.8	40 .2	85 .3	16 .1	1088 4.1	2080 7.9	699 2.7	354 1.3	35 .1	0 .0	0 .0	27 .1	107 .4	91 .3	92 .3	6446 24.5
1.00 - 1.50	0 .0	774 2.9	254 1.0	14 .1	0 .0	1 .0	635 2.4	1771 6.7	719 2.7	320 1.2	25 .1	0 .0	17 .1	0 .0	75 .3	52 .2	85 .3	4742 18.0
1.50 - 2.00	0 .0	127 .5	3 .0	0 .0	0 .0	0 .0	799 3.0	2000 7.6	584 2.2	282 1.1	2 .0	0 .0	0 .0	17 .1	6 .0	42 .2	43 .2	3905 14.8
2.00 - 2.50	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	669 2.5	1583 6.0	661 2.5	237 .9	15 .1	0 .0	0 .0	5 .0	0 .0	3 .0	27 .1	3200 12.2
2.50 - 3.00	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	328 1.2	1363 5.2	647 2.5	213 .8	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	2551 9.7
3.00 - 3.50	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	90 .3	822 3.1	321 1.2	127 .5	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	1360 5.2
3.50 - 4.00	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	5 .0	253 1.0	183 .7	91 .3	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	532 2.0
4.00 - 5.00	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	27 .1	48 .2	45 .2	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	120 .5
5.00 - 6.00	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
6.00 - 7.00	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
7.00 -	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
TOTAL	0 .0	2581 9.8	1435 5.5	102 .4	130 .5	82 .3	3944 15.0	10989 41.8	4500 17.1	1737 6.6	86 .3	0 .0	17 .1	49 .2	188 .7	188 .7	269 1.0	26297 100.0

Table 4 Frequency of wave height and period
(Offshore in Seychelles, yearly, Mar 2001 to Feb 2004)

YEAR 2500 MONTH 0 KESOK 7

WAVE PERIOD(S)	CALM	0- 1	1- 2	2- 3	3- 4	4- 5	5- 6	6- 7	7- 8	8- 9	9-10	10-11	11-12	12-13	13-14	14-15	15-	TOTAL
WAVE HEIGHT(M)																		
CALM	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
0.00 - 0.50	0 .0	0 .0	16 .1	151 .6	783 3.0	517 2.0	569 2.2	431 1.6	417 1.6	437 1.7	115 .4	5 .0	0 .0	0 .0	0 .0	0 .0	0 .0	3441 13.1
0.50 - 1.00	0 .0	0 .0	0 .0	0 .0	962 3.7	1725 6.6	1147 4.4	906 3.4	629 2.4	765 2.9	219 .8	80 .3	13 .0	0 .0	0 .0	0 .0	0 .0	6446 24.5
1.00 - 1.50	0 .0	0 .0	0 .0	0 .0	0 .0	461 1.8	1872 7.1	999 3.8	649 2.5	458 1.7	261 1.0	40 .2	2 .0	0 .0	0 .0	0 .0	0 .0	4742 18.0
1.50 - 2.00	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	977 3.7	1804 6.9	683 2.6	215 .8	145 .6	60 .2	20 .1	1 .0	0 .0	0 .0	0 .0	3905 14.8
2.00 - 2.50	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	6 .0	1550 5.9	1326 5.0	234 .9	68 .3	16 .1	0 .0	0 .0	0 .0	0 .0	0 .0	3200 12.2
2.50 - 3.00	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	181 .7	1780 6.8	543 2.1	33 .1	14 .1	0 .0	0 .0	0 .0	0 .0	0 .0	2551 9.7
3.00 - 3.50	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	557 2.1	782 3.0	21 .1	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	1360 5.2
3.50 - 4.00	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	15 .1	416 1.6	101 .4	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	532 2.0
4.00 - 5.00	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	96 .4	24 .1	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	120 .5
5.00 - 6.00	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
6.00 - 7.00	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
7.00 -	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
TOTAL	0 .0	0 .0	16 .1	151 .6	1745 6.6	2703 10.3	4571 17.4	5871 22.3	6056 23.0	3946 15.0	987 3.8	215 .8	35 .1	1 .0	0 .0	0 .0	0 .0	26297 100.0

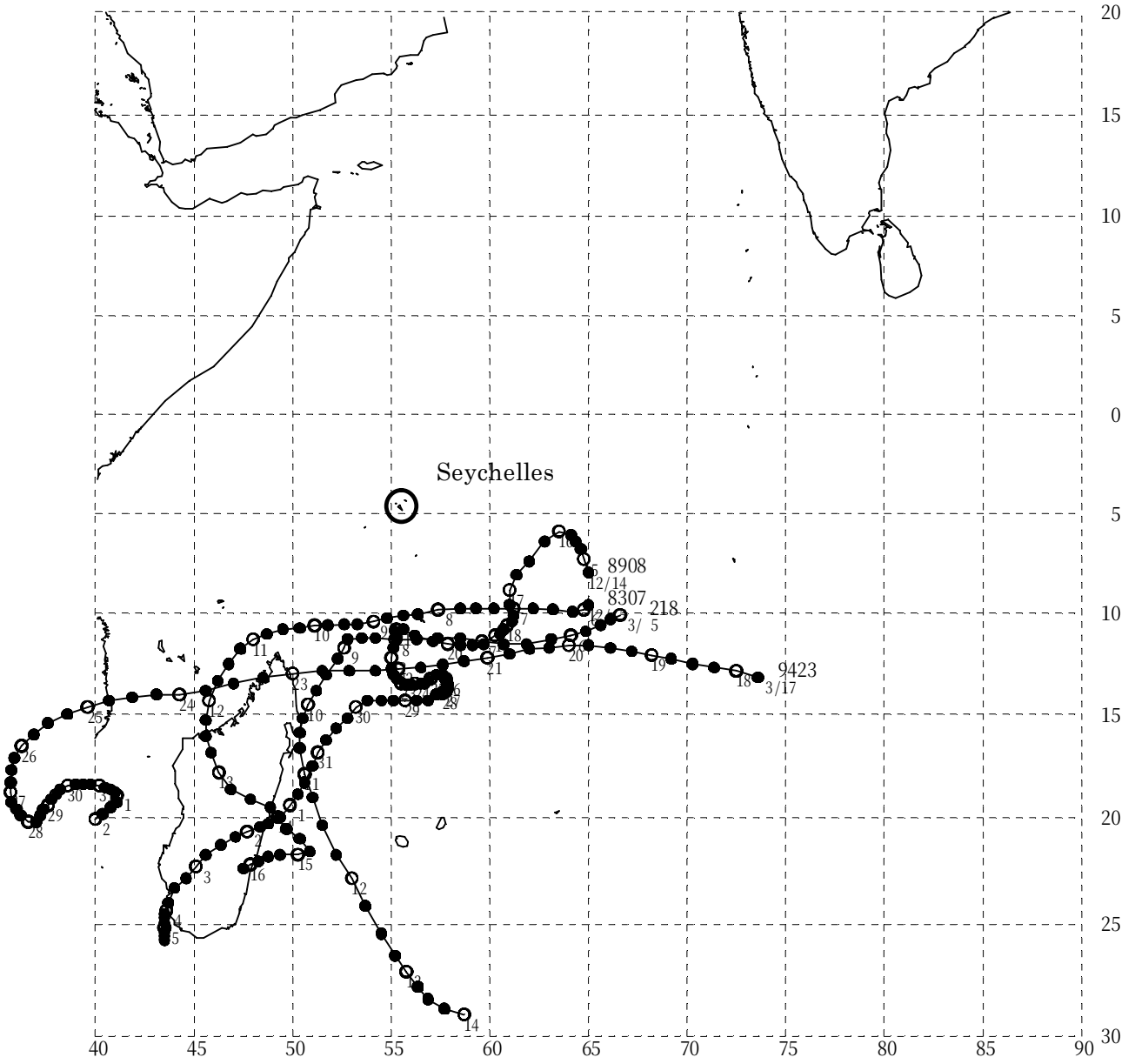
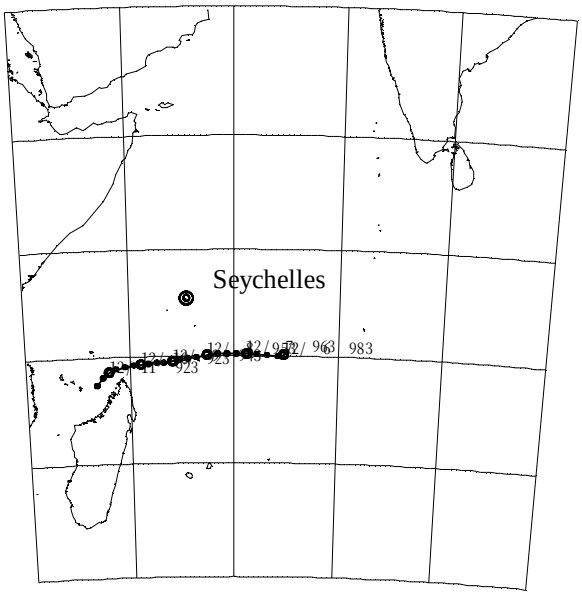
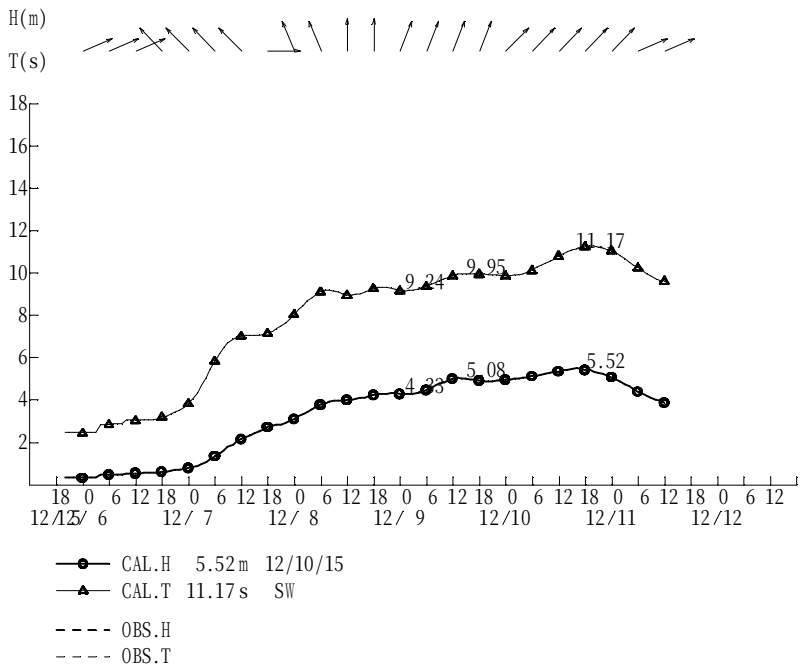


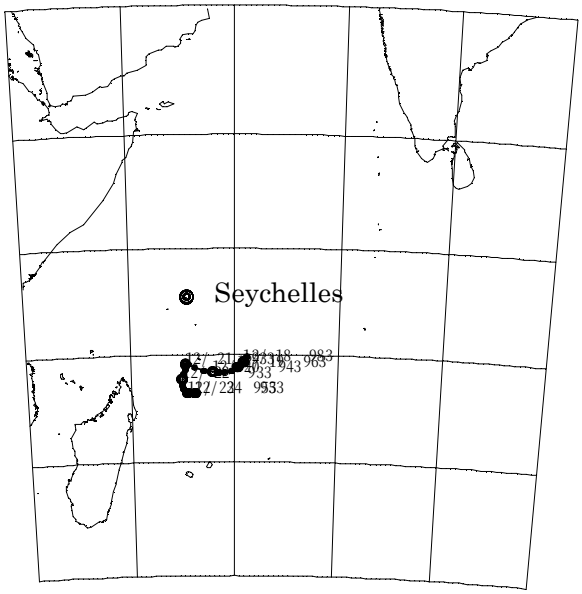
Figure 4 Routes of cyclones (1945 to 2003)

Cyclone 8307





Cyclo



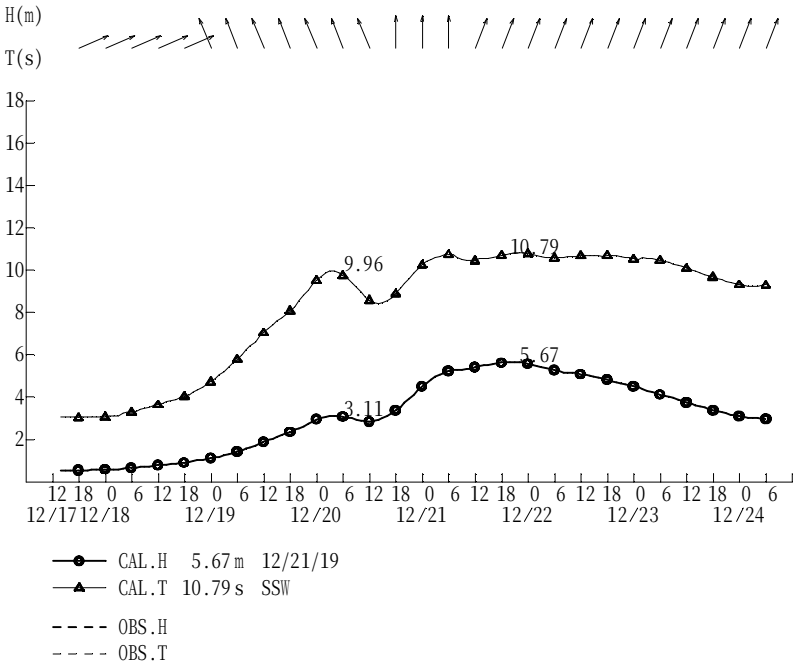


Figure 5 Route of cyclone and results of wave hindcasting (Cyclone 8307 and 8908)

3. Calculation of design wave

(1) Wave deformation in shallow water

Regarding above offshore design wave, design wave in front of the existing breakwater has been calculated by wave deformation in shallow water. This computation was done using a method that solves the energy balance equation method as irregular waves.

The range of calculation is approximately 25km between north, south, west and east as shown in Figure 6. The interval of calculation grid is 500m. The results of calculation of wave deformation are shown in Figures 7 and 8.

Table 5 shows the design wave in front of the existing breakwater in Providence. Incident wave height (Ho') is 2.64m and direction is North 53.2 degrees east.

Table 5 Design waves in front of existing breakwater

Offshore wave		Refraction coefficient	Incident wave	
Wave height (Ho)	6.0m	0.44	Incident wave height (Ho')	2.64m
Wave period (To)	12.0 sec		Wave period (T)	12.0 sec
Wave direction	ESE		Incident wave direction	N 53.2 degrees E

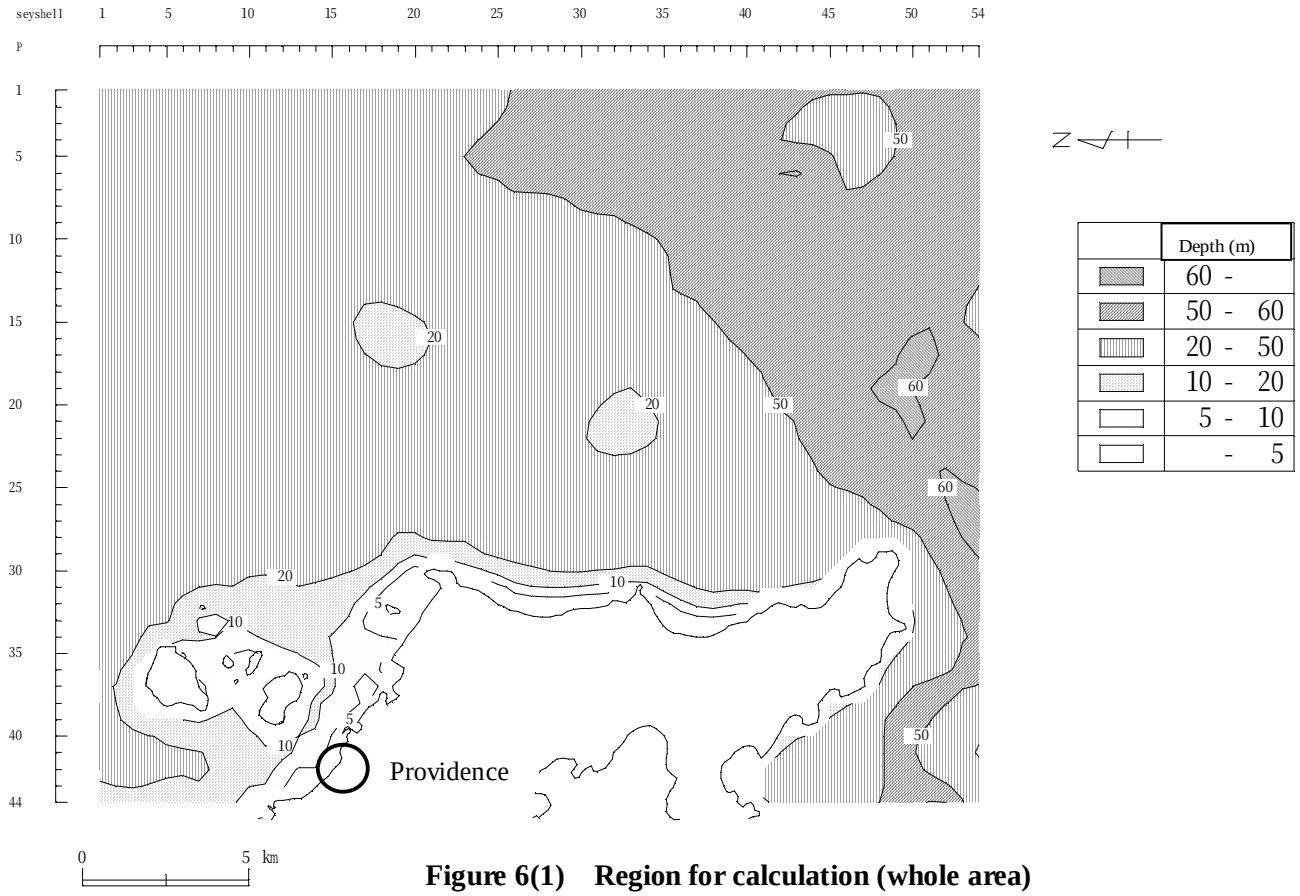


Figure 6(1) Region for calculation (whole area)

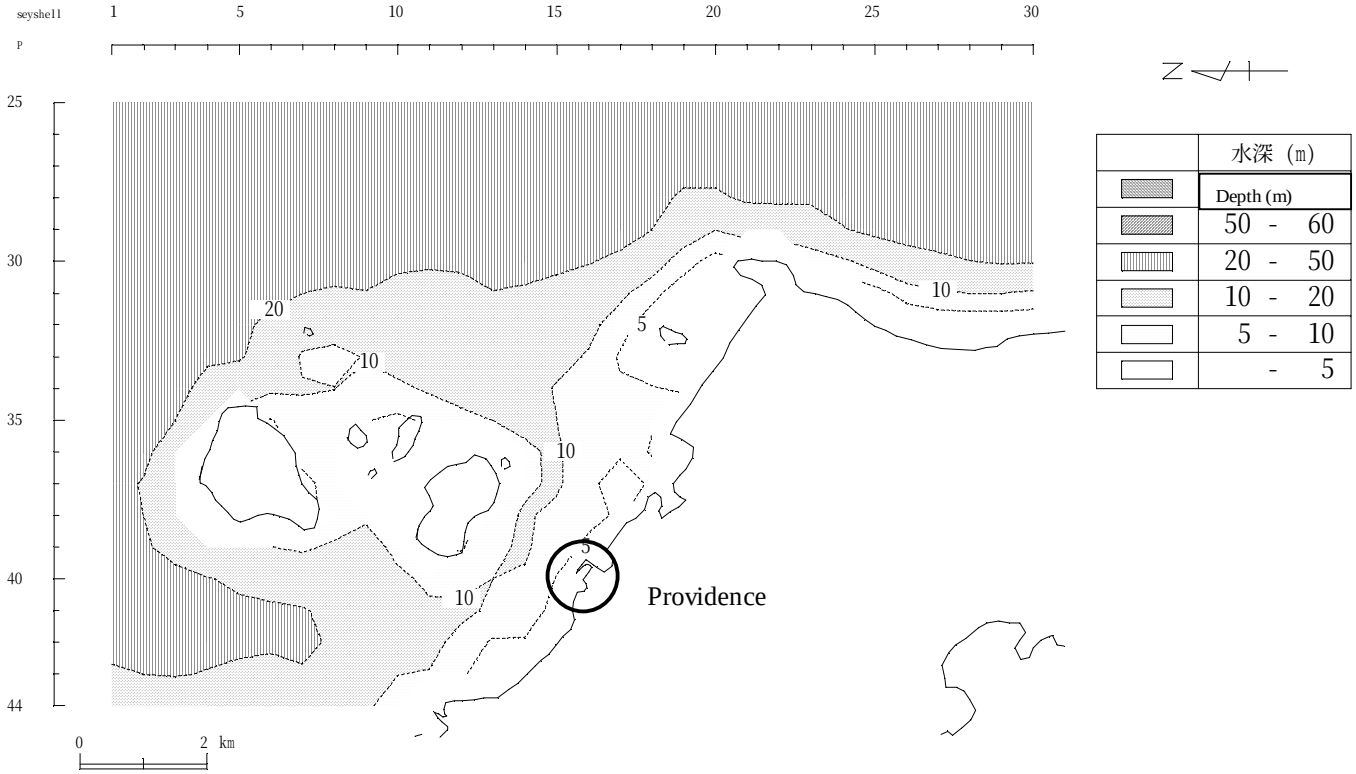
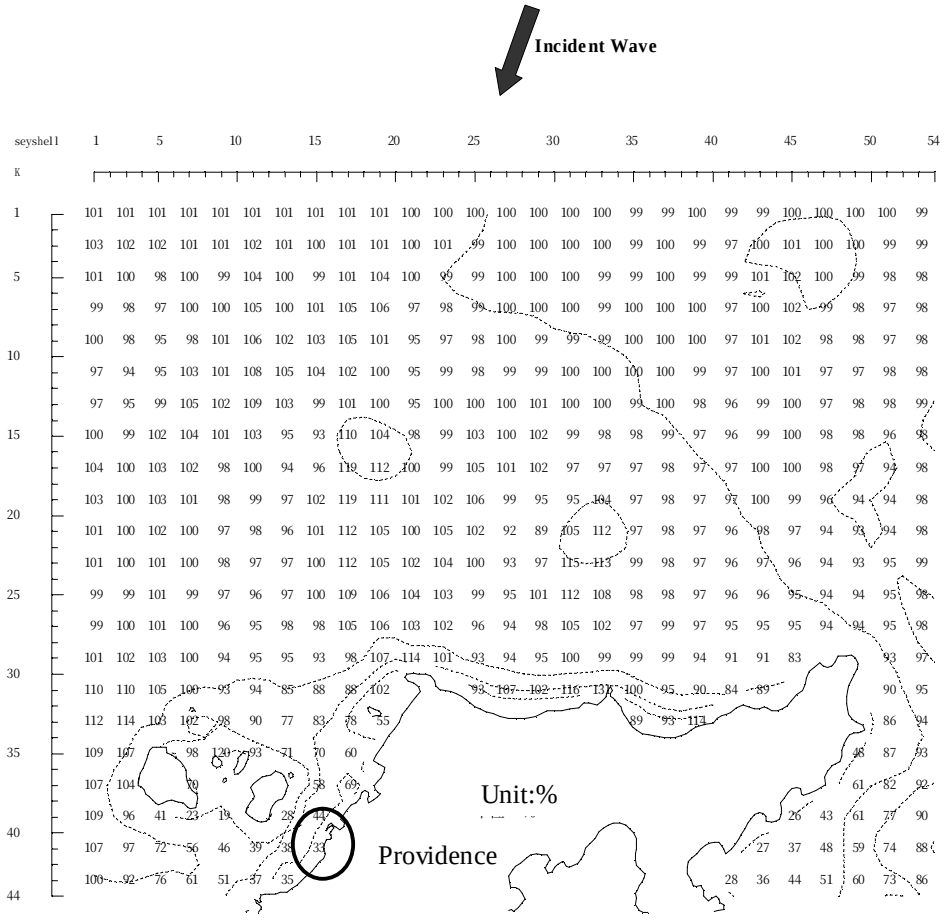
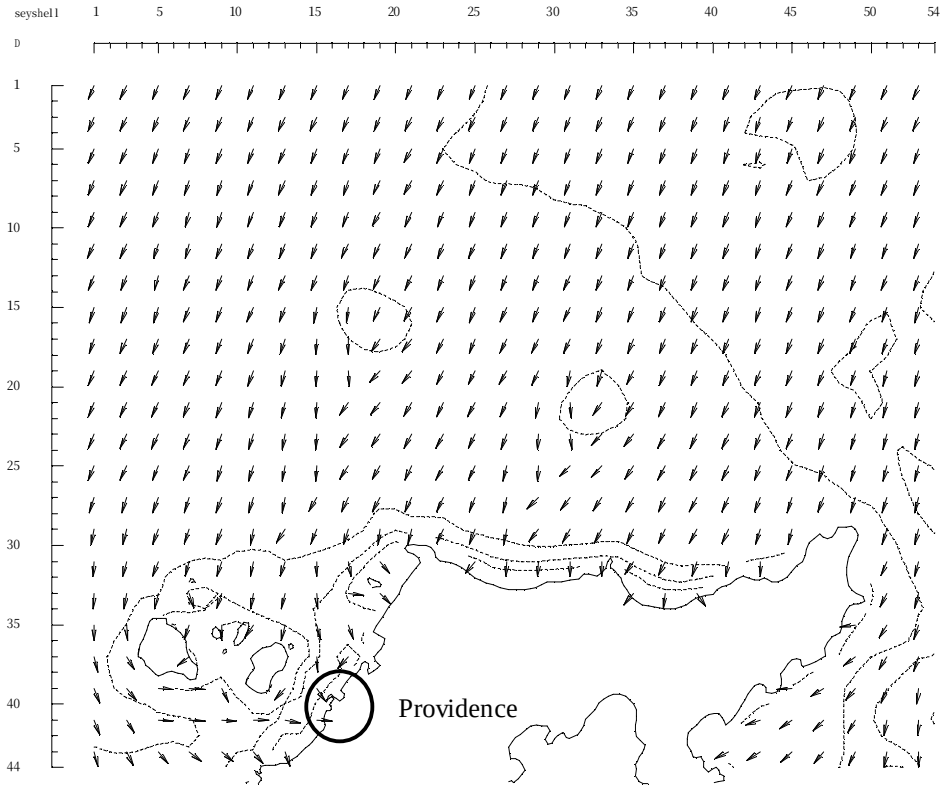


Figure 6(2) Region for calculation (enlarged area)



Refraction coefficient

Wave direction	ESE
Wave height	6m
Wave period	12 sec
Spreading patameter(Smax)	25

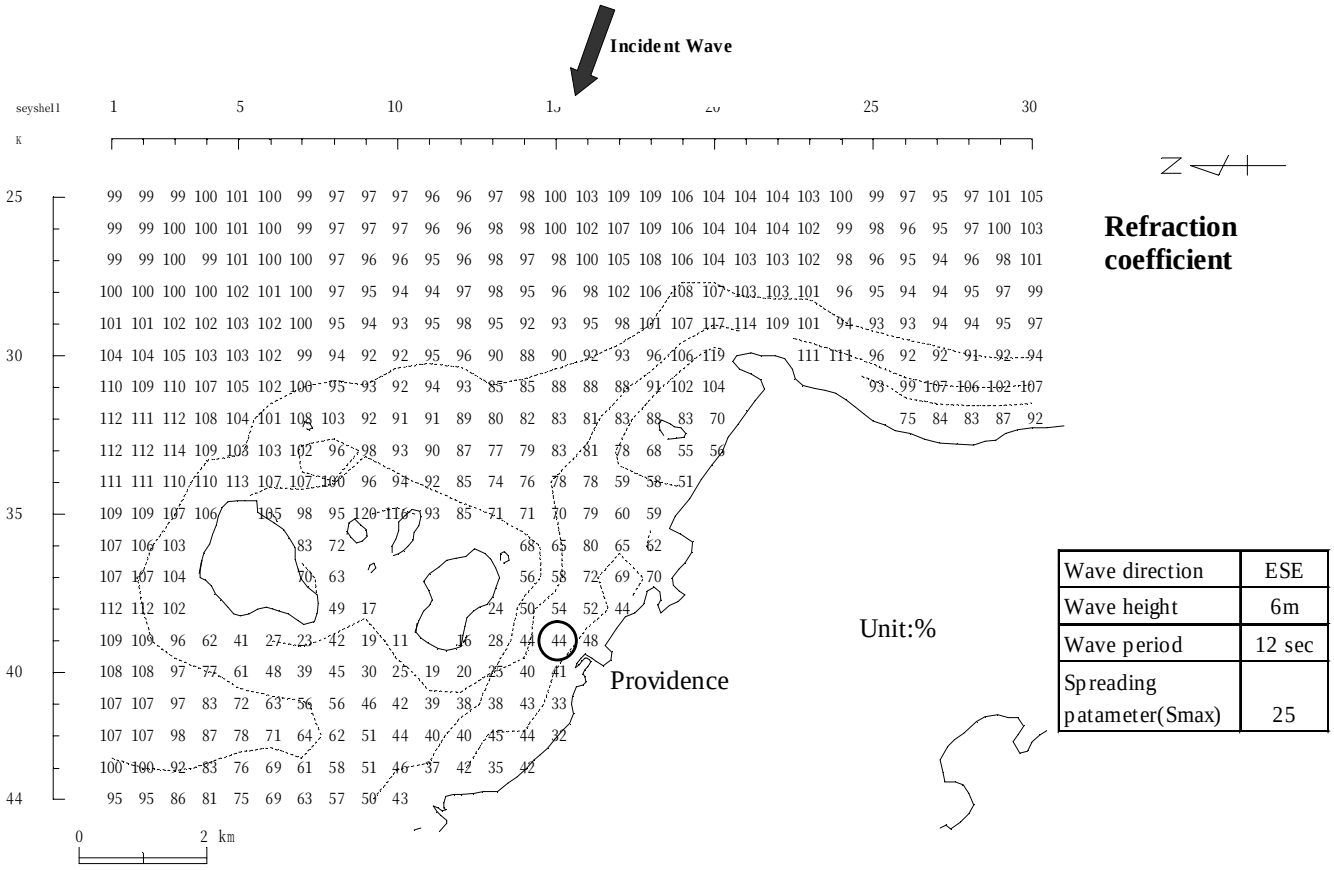


Wave direction

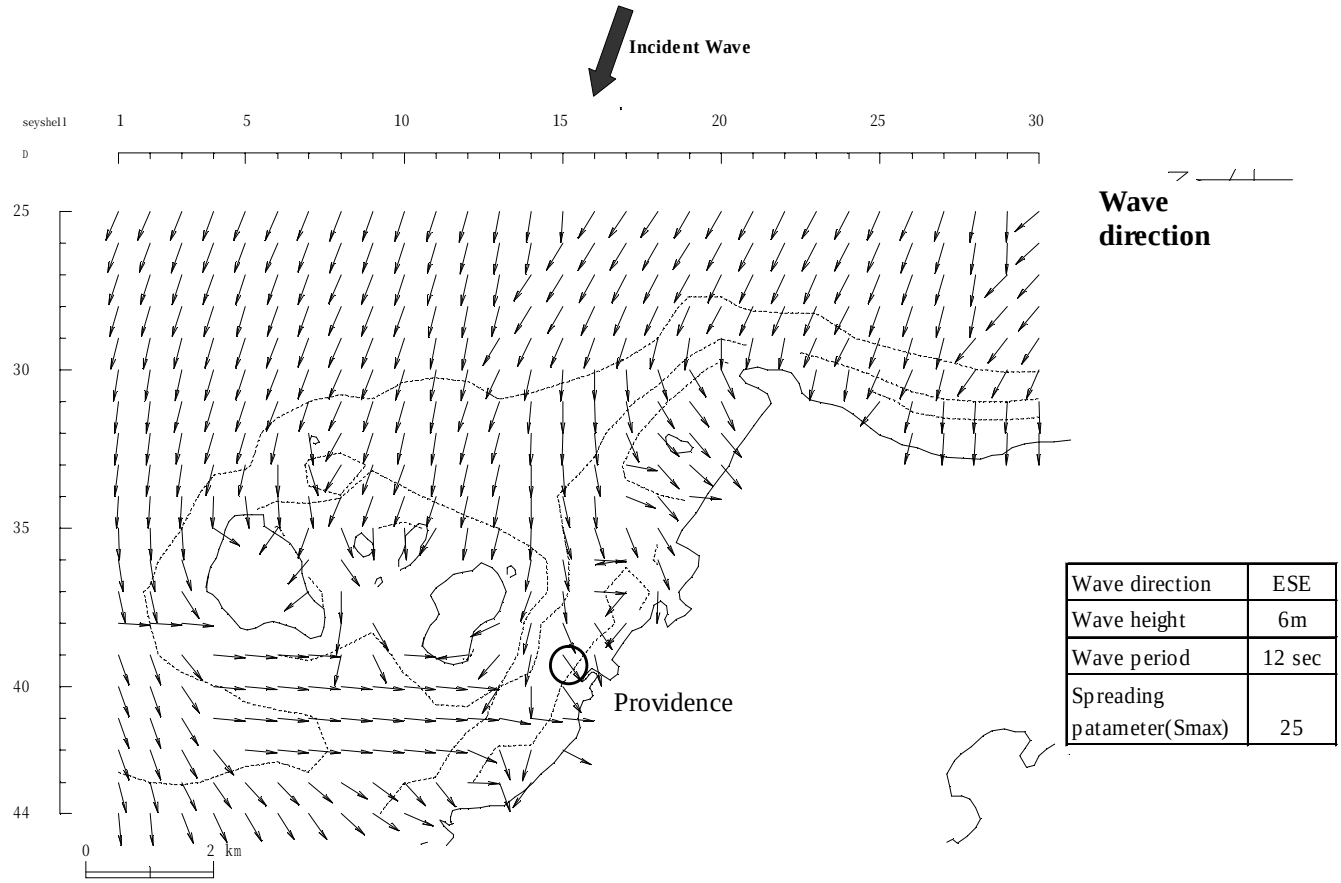
Wave direction	ESE
Wave height	6m
Wave period	12 sec
Spreading patameter(Smax)	25

0 5 km

Figure 7 Results of wave deformation (whole area)



Wave direction	ESE
Wave height	6m
Wave period	12 sec
Spreading patameter(Smax)	25



Wave direction	ESE
Wave height	6m
Wave period	12 sec
Spreading patameter(Smax)	25

Figure 8 Results of wave deformation (enlarged area)

(2) Design wave in front of existing breakwater

Regarding incident wave height 2.64m as shown in Table 5, considering change in wave height by depth (see Figure 9), design wave height (significant wave) is shown as follows.

Depth h: 9.0m + 1.45m (H.W.L.) = 10.45m

Equivalent deepwater wave height Ho': 2.64m

Offshore wave length Lo: 1.56 x To^2 = 224.6m

Slope of sea bottom: 1:30

Ho'/Lo: 2.64/224.6 = 0.012

h/Ho' : 10.45/2.64 = 3.96

According to Figure 20, H/Ho' = 1.08,

Consequently, design wave height H = 2.85m (significant wave height)

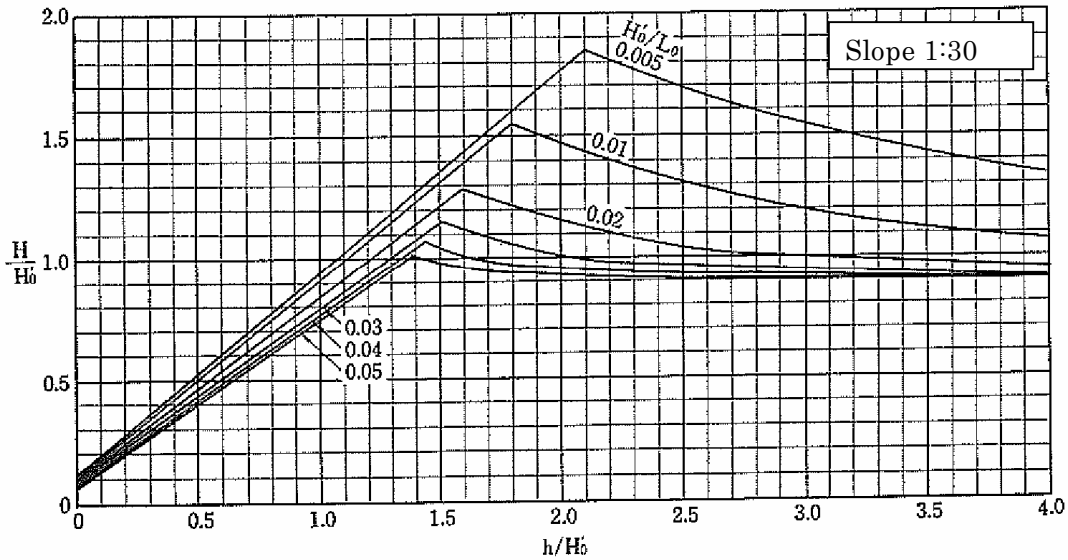


Figure 9 Change in wave height by depth