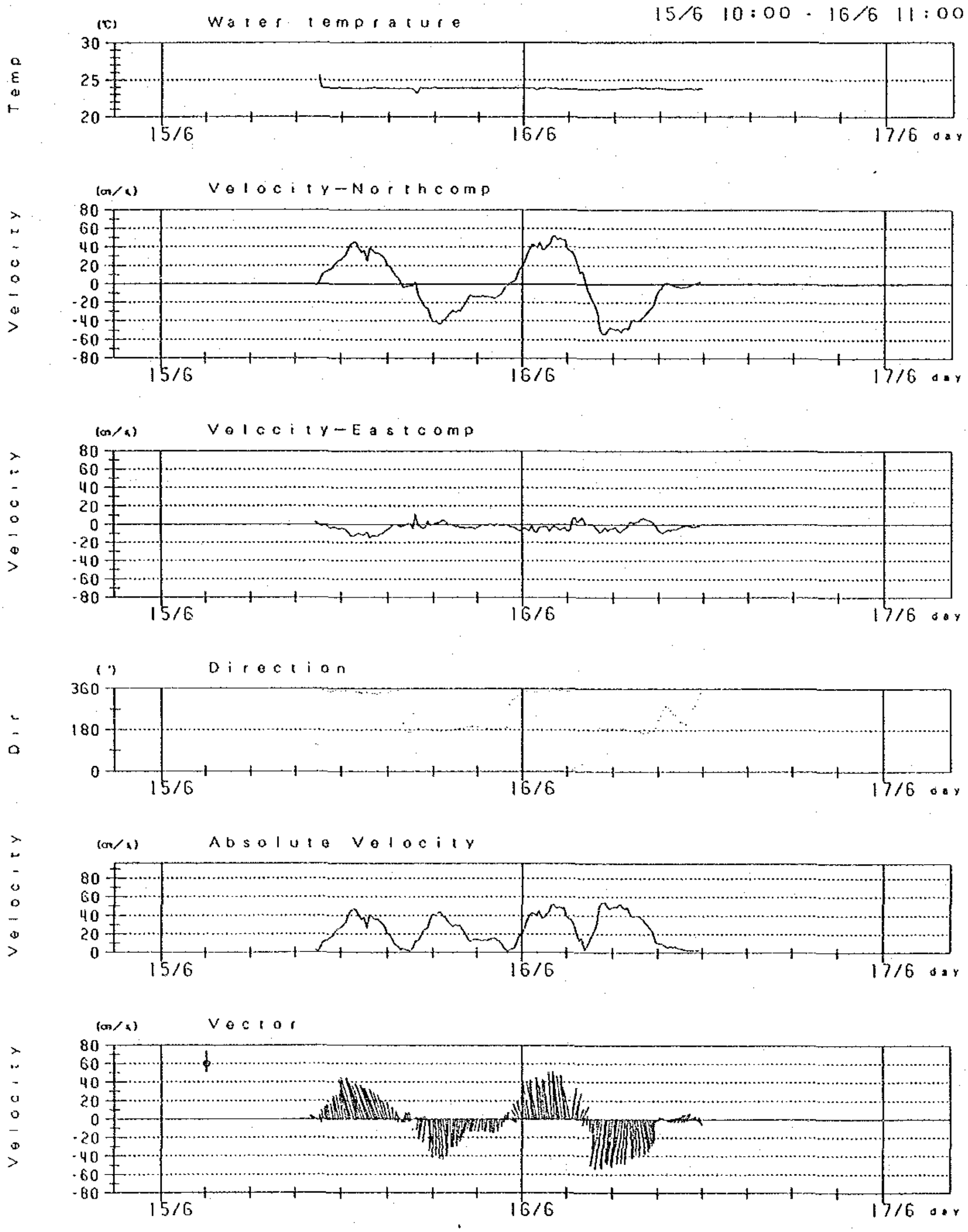
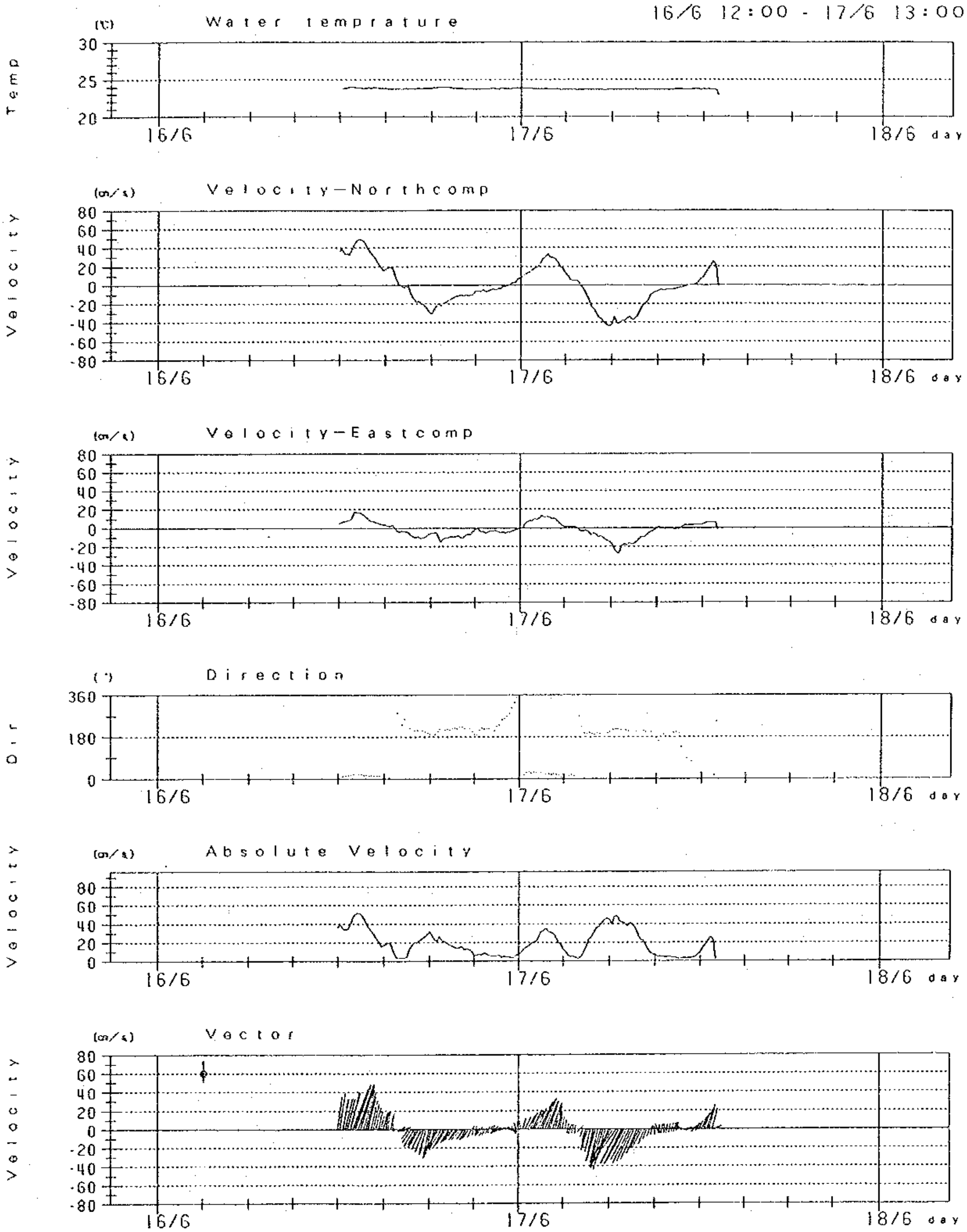
St.B (lower)

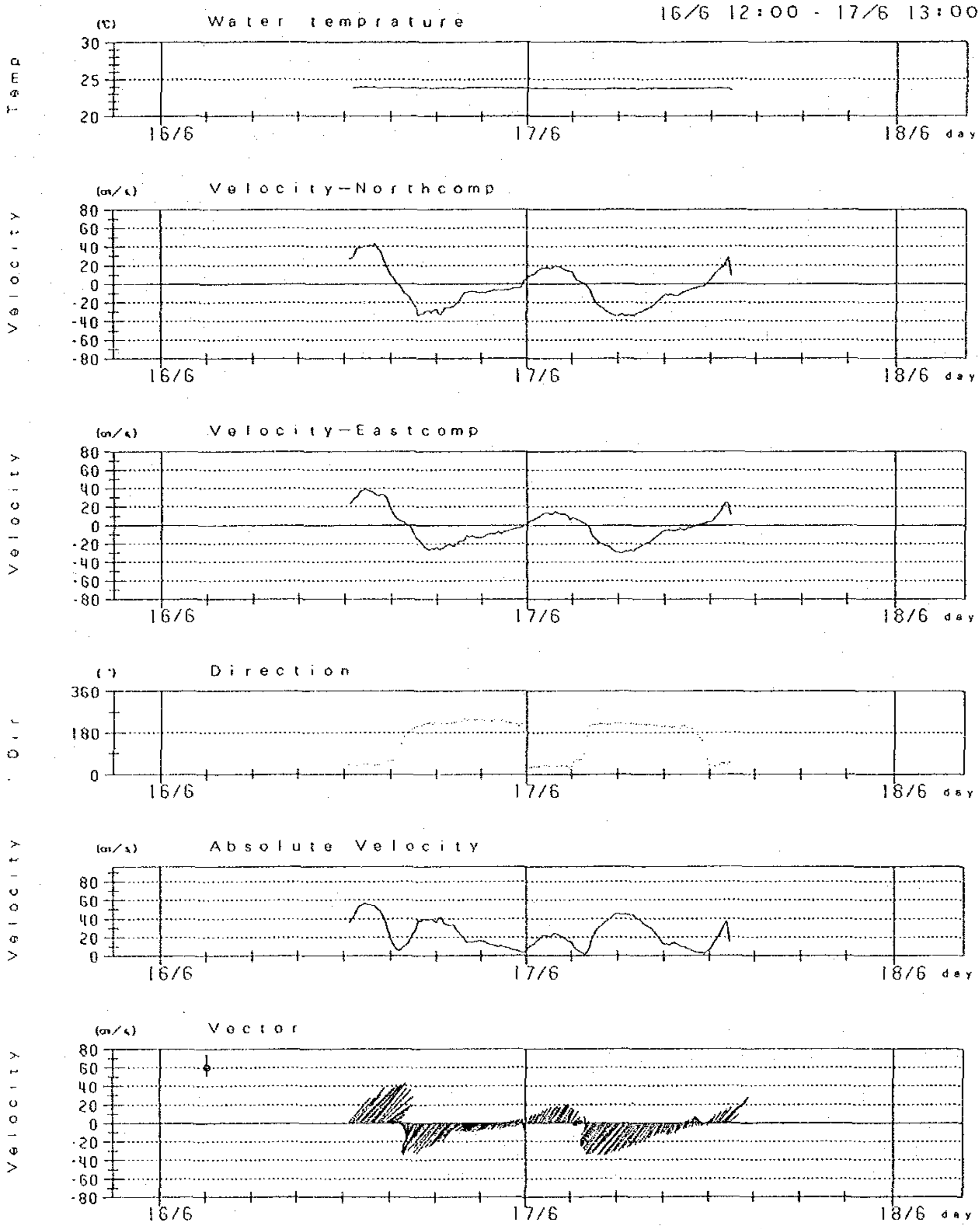


15/6 10:00 - 16/6 11:00
(℃) Water temprature
Temp
30
25
20
15/6
16/6
17/6 day
(cm/s) Velocity—Northcomp
Velocity
80
60
40
20
0
-20
-40
-60
-80
(cm/s) Velocity—Eastcomp
(°) Direction
Dir
360
180
0
(cm/s) Absolute Velocity
(cm/s) Vector

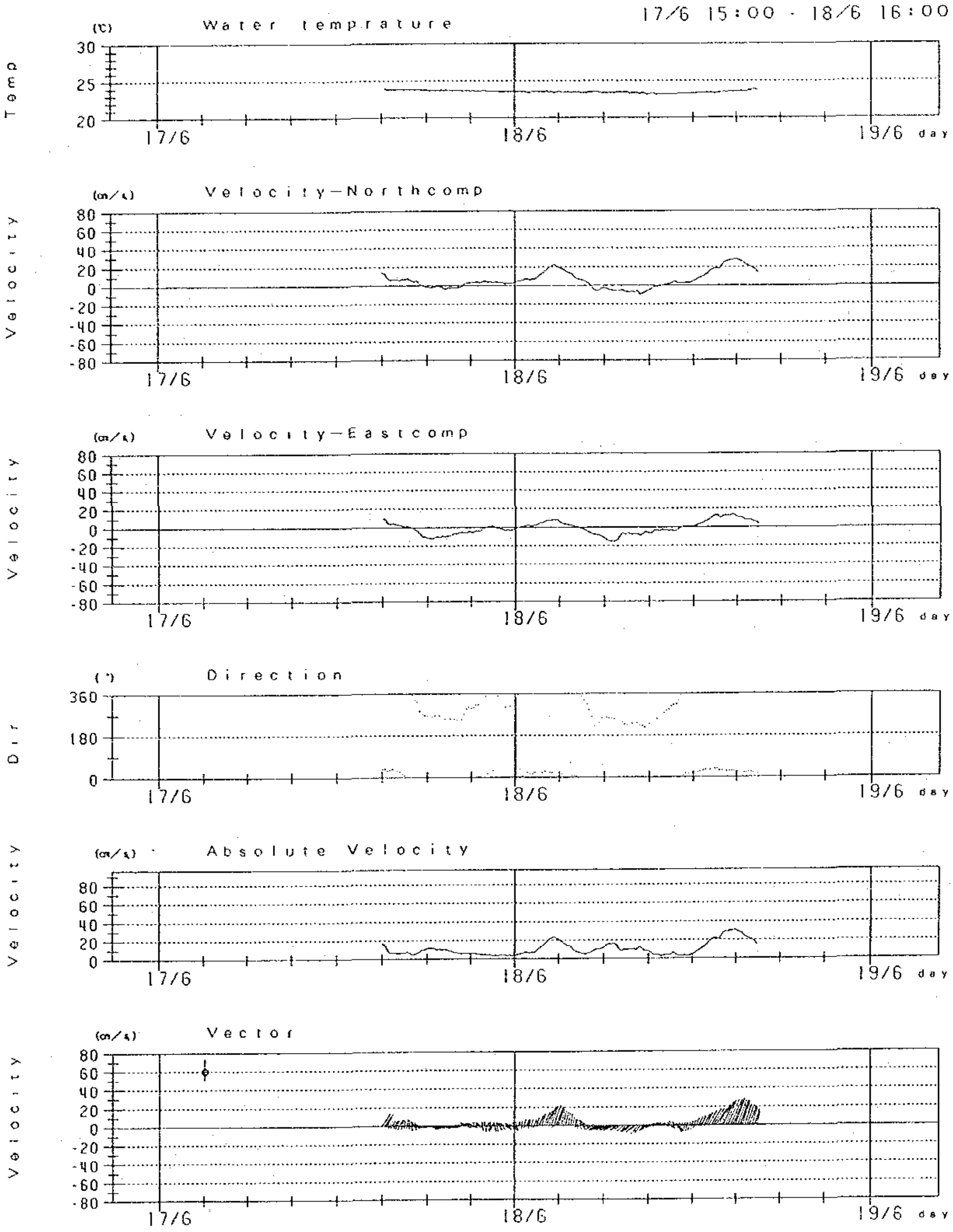
St.C


16/6 12:00 - 17/6 13:00
Water temprature
(℃)
Temp
30
25
20
Velocity-Northcomp
(cm/s)
Velocity-Eastcomp
Direction
(°)
360
180
0
Dir
Absolute Velocity
Vector
Velocity
80
60
40
20
0
-20
-40
-60
-80
16/6
17/6
18/6
day

St.D


16/6 12:00 - 17/6 13:00
Water temprature
(℃)
Temp
30
25
20
16/6
17/6
18/6 day
Velocity-Northcomp
(cm/s)
Velocity
80
60
40
20
0
-20
-40
-60
-80
Velocity-Eastcomp
Direction
(°)
Dir
360
180
0
Absolute Velocity
Vector

St. F


17/6 15:00 - 18/6 16:00
Water temprature
(℃)
Temp
Velocity-Northcomp
(cm/s)
Velocity
Velocity-Eastcomp
(cm/s)
Velocity
Direction
(°)
Dir
Absolute Velocity
(cm/s)
Velocity
Vector
(cm/s)
Velocity
17/6
18/6
19/6 day

Phase 2

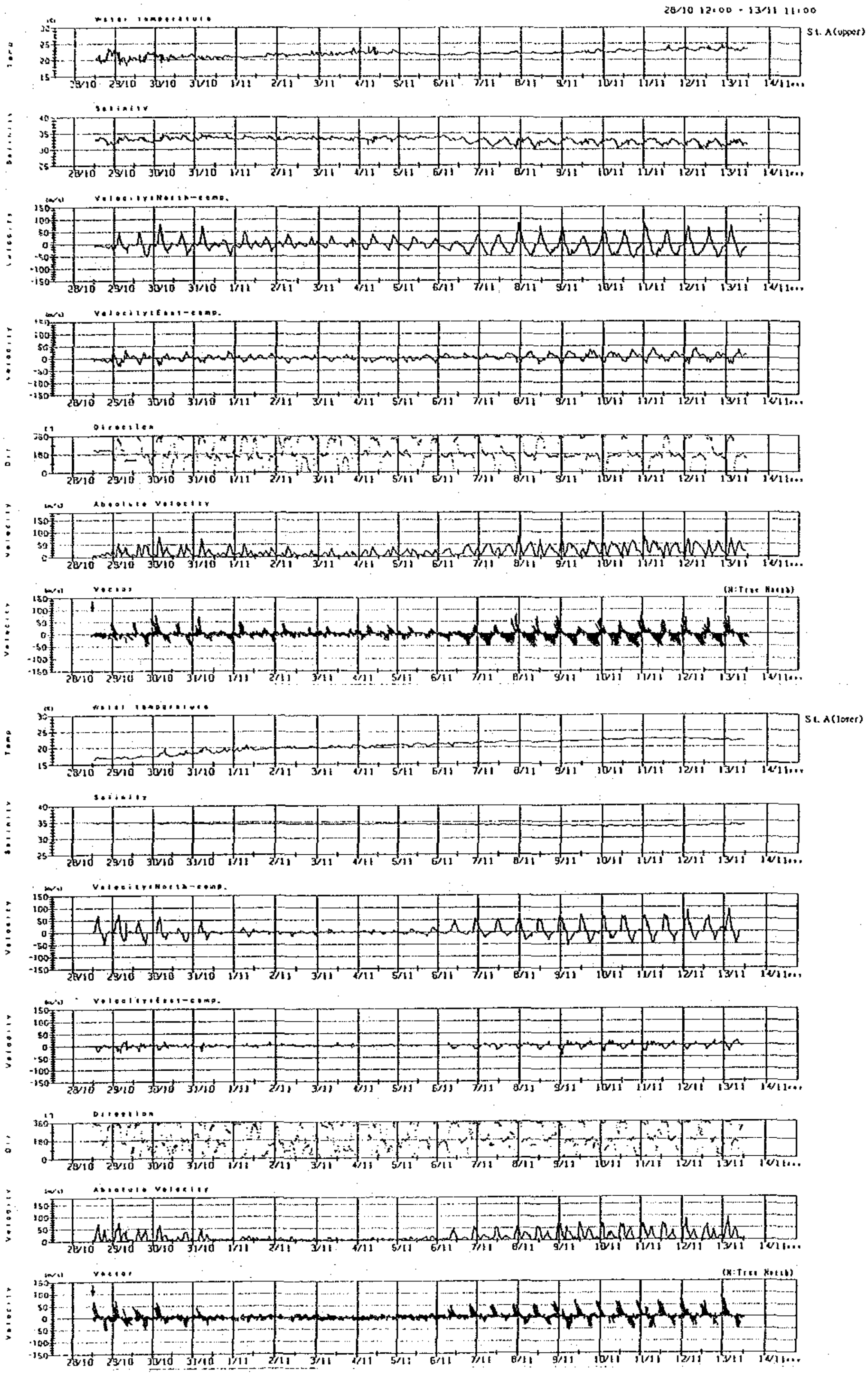
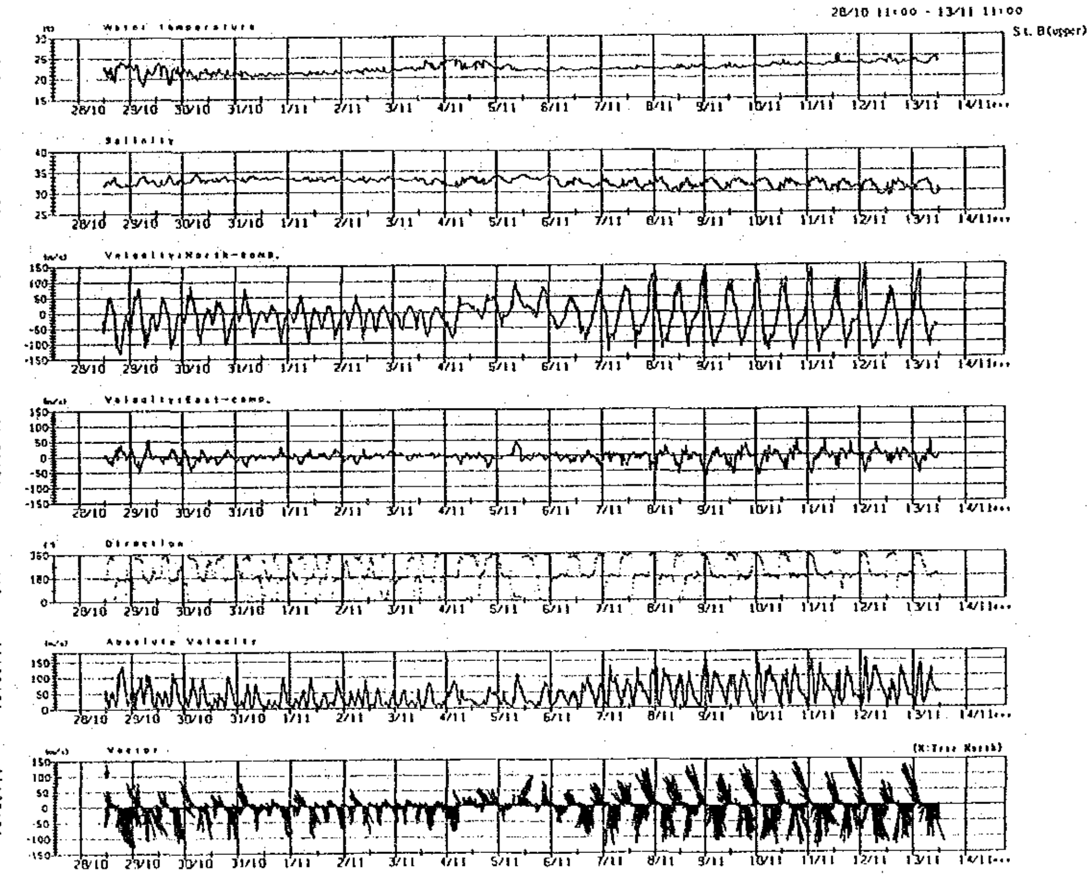
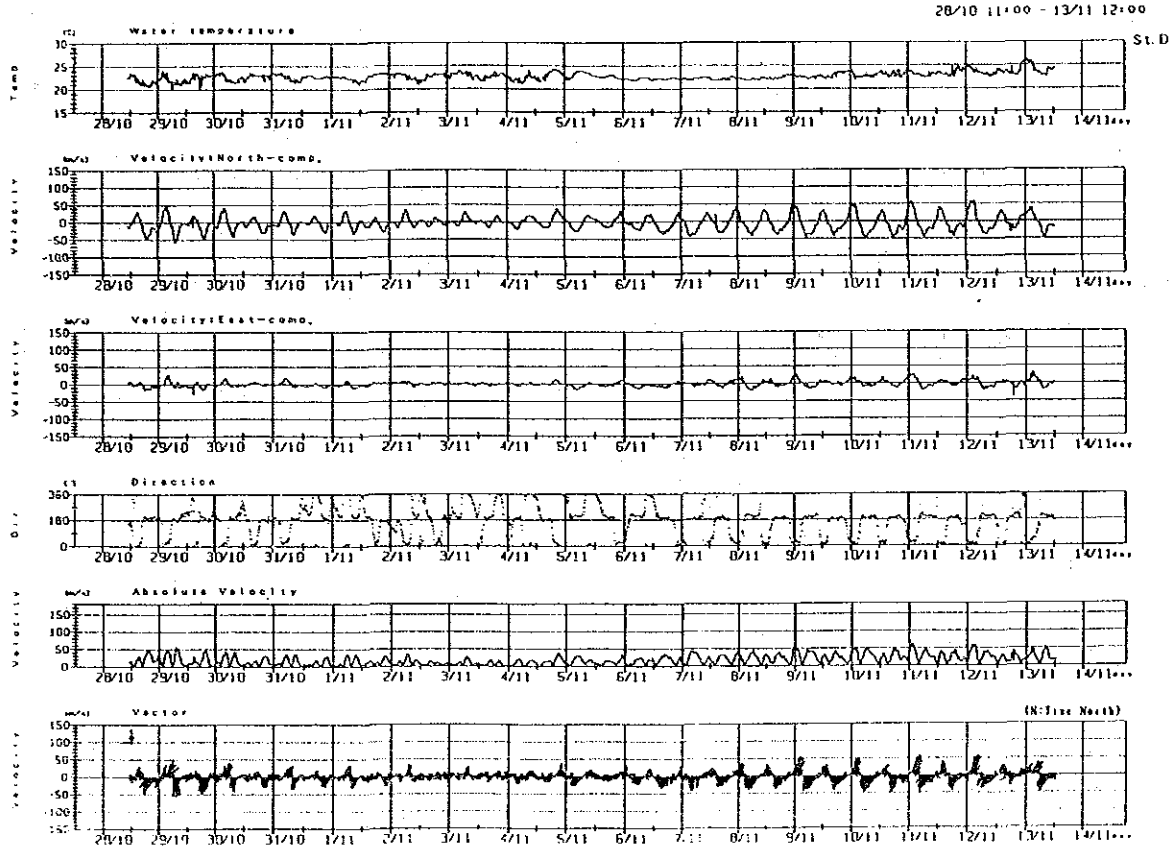


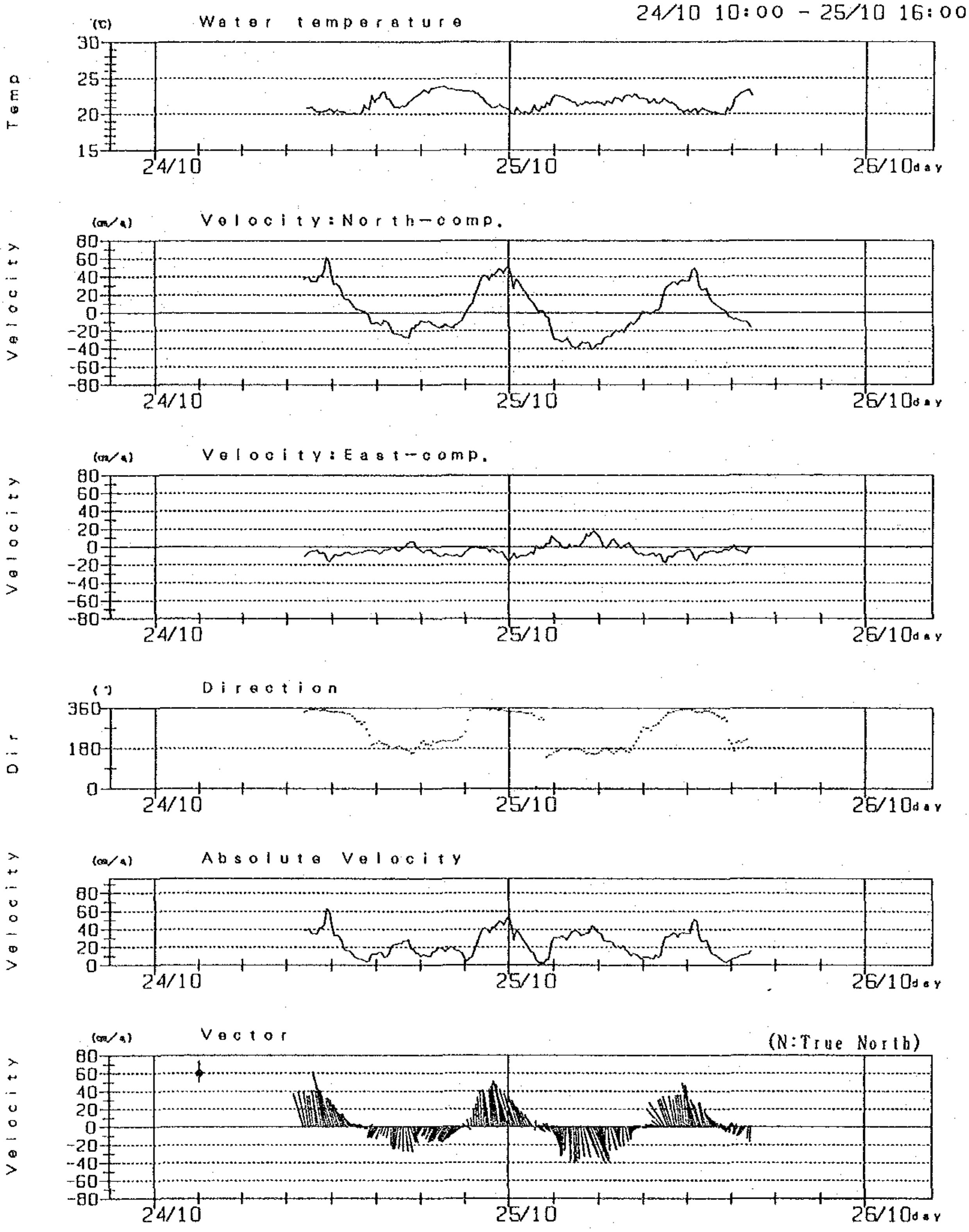
Fig. 6.2 -2 Tidal Current Curves


28/10 11:00 - 13/11 11:00
St. B(upper)
Water temperature
Salinity
Velocity:North-comp.
Velocity:East-comp.
Direction
Absolute Velocity
Vector
(N:True North)


St. B(lower)
Water temperature
Salinity
Velocity:North-comp.
Velocity:East-comp.
Direction
Absolute Velocity
Vector
(N:True North)

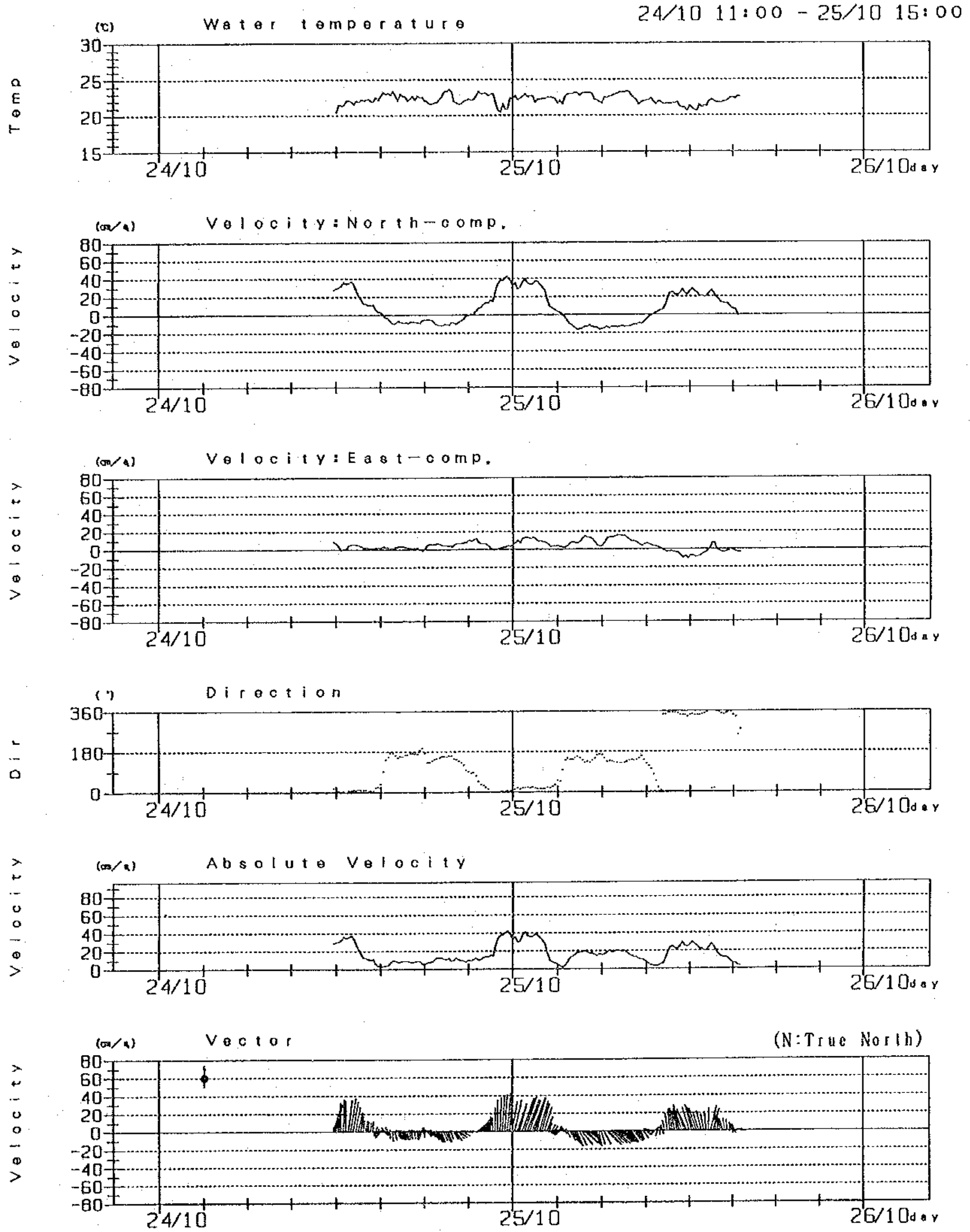

28/10 11:00 - 13/11 12:00
St. D
Water temperature
Temp
Velocity:North-comp.
Velocity:East-comp.
Direction
Absolute Velocity
Vector
(N:True North)
28/10 29/10 30/10 31/10 1/11 2/11 3/11 4/11 5/11 6/11 7/11 8/11 9/11 10/11 11/11 12/11 13/11 14/11

St.C


24/10 10:00 - 25/10 16:00
Water temperature
(℃)
Temp
30
25
20
15
Velocity:North-comp.
Velocity:East-comp.
(cm/s)
Velocity
80
60
40
20
0
-20
-40
-60
-80
Direction
(°)
Dir
360
180
0
Absolute Velocity
Vector
(N:True North)
24/10
25/10
26/10day

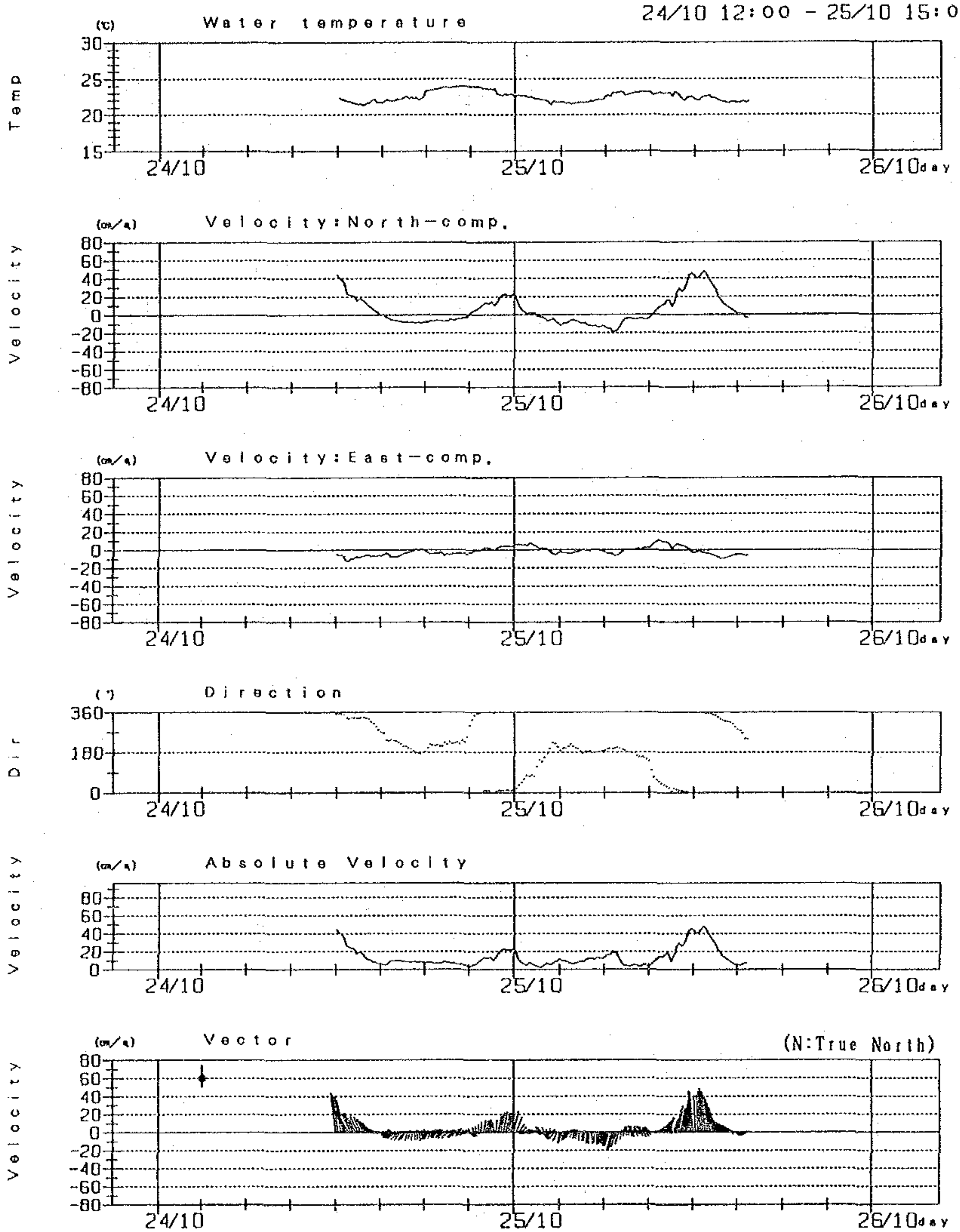
St. E

24/10 11:00 - 25/10 15:00

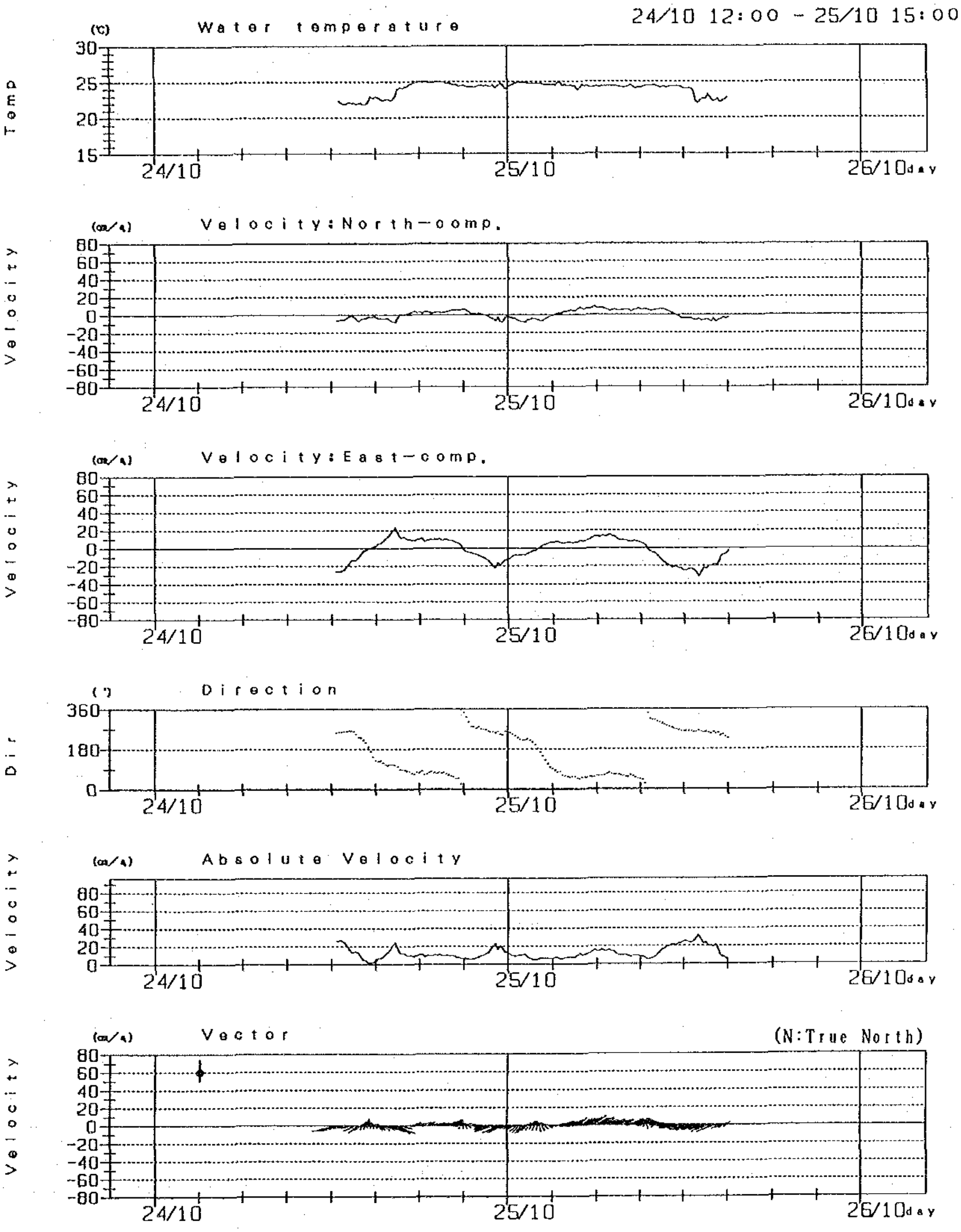


St. F

24/10 12:00 - 25/10 15:00

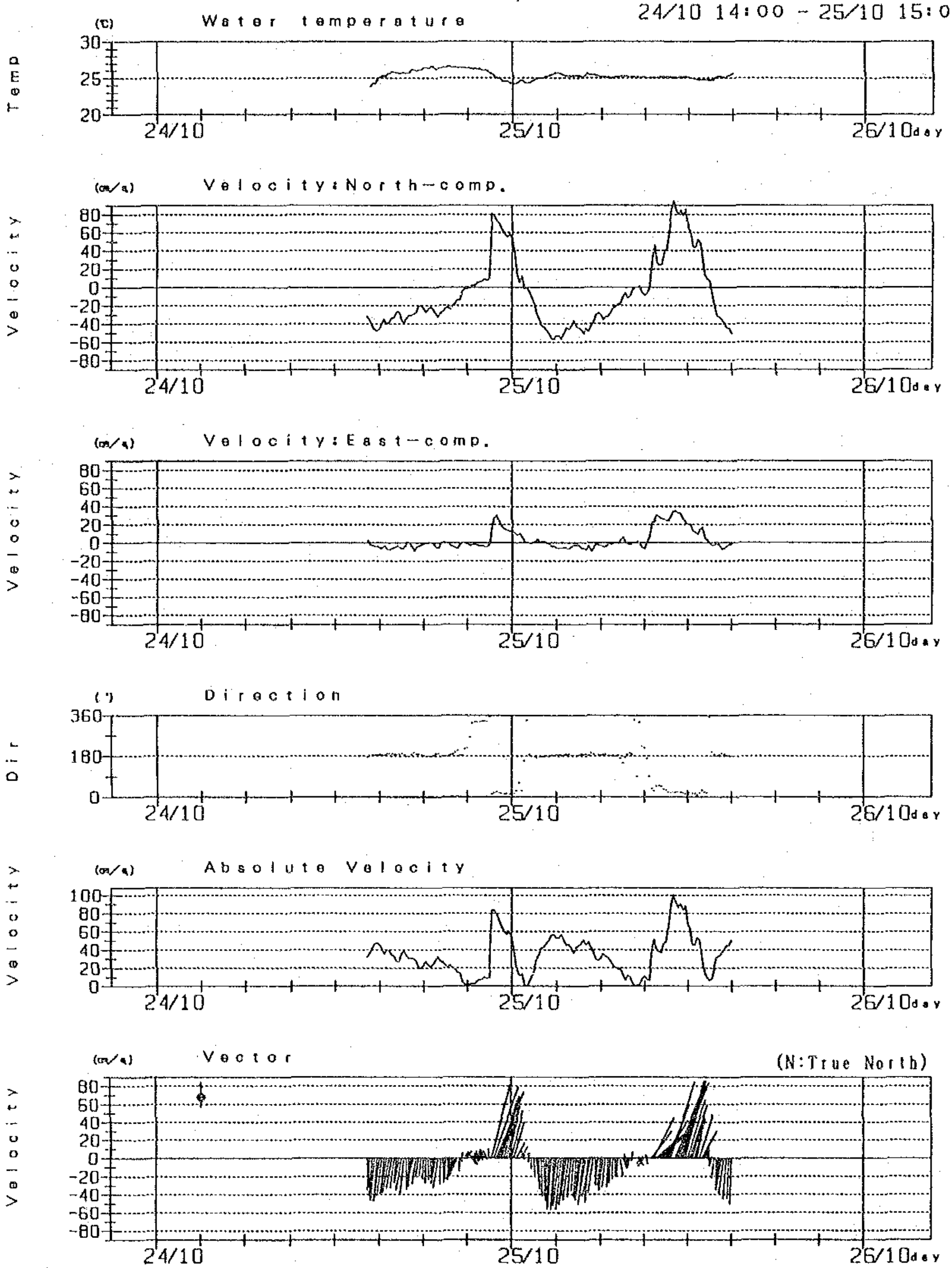


St.G

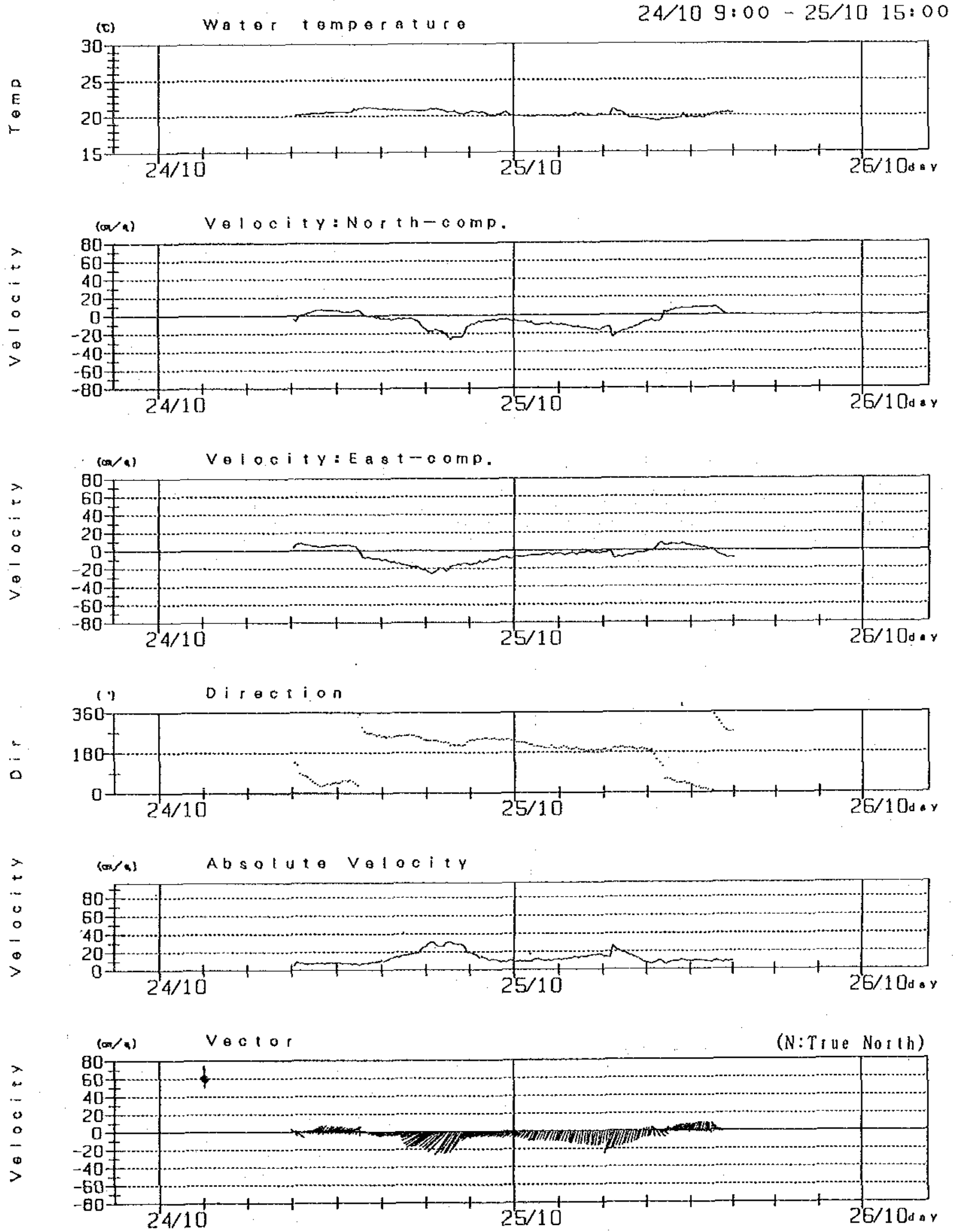

24/10 12:00 - 25/10 15:00
Water temperature
(℃)
Temp
Velocity:North-comp.
Velocity:East-comp.
Direction
Dir
Absolute Velocity
Vector
(N:True North)
Velocity
(cm/s)
24/10
25/10
26/10day

St.H

24/10 14:00 - 25/10 15:00



St. I


24/10 9:00 - 25/10 15:00
(℃) Water temperature
Temp
30
25
20
15
24/10
25/10
26/10day
(cm/s) Velocity:North-comp.
Velocity
(cm/s) Velocity:East-comp.
Velocity
(°) Direction
Dir
360
180
0
(cm/s) Absolute Velocity
Velocity
(cm/s) Vector
(N:True North)
Velocity
80
60
40
20
0
-20
-40
-60
-80

Phase 3

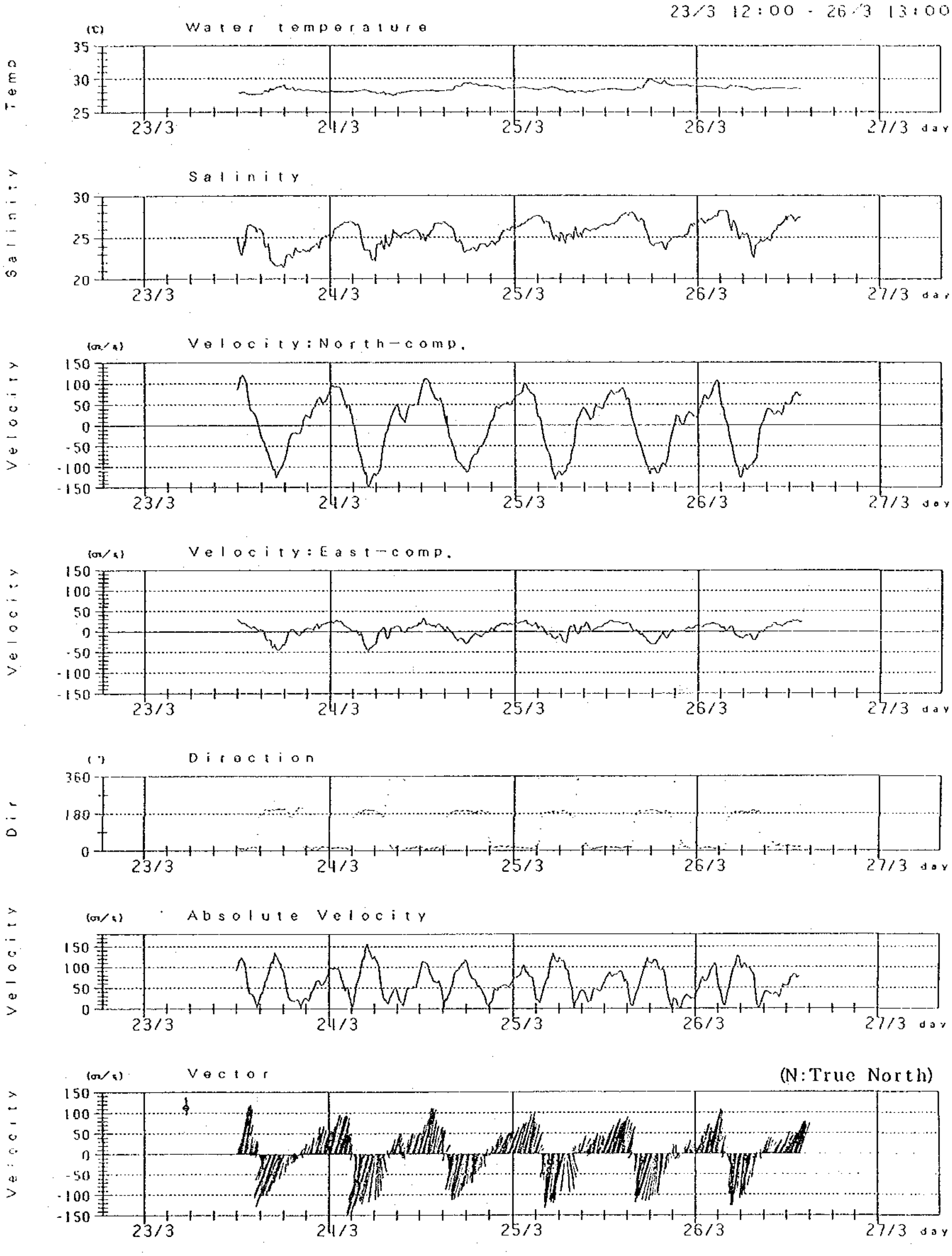
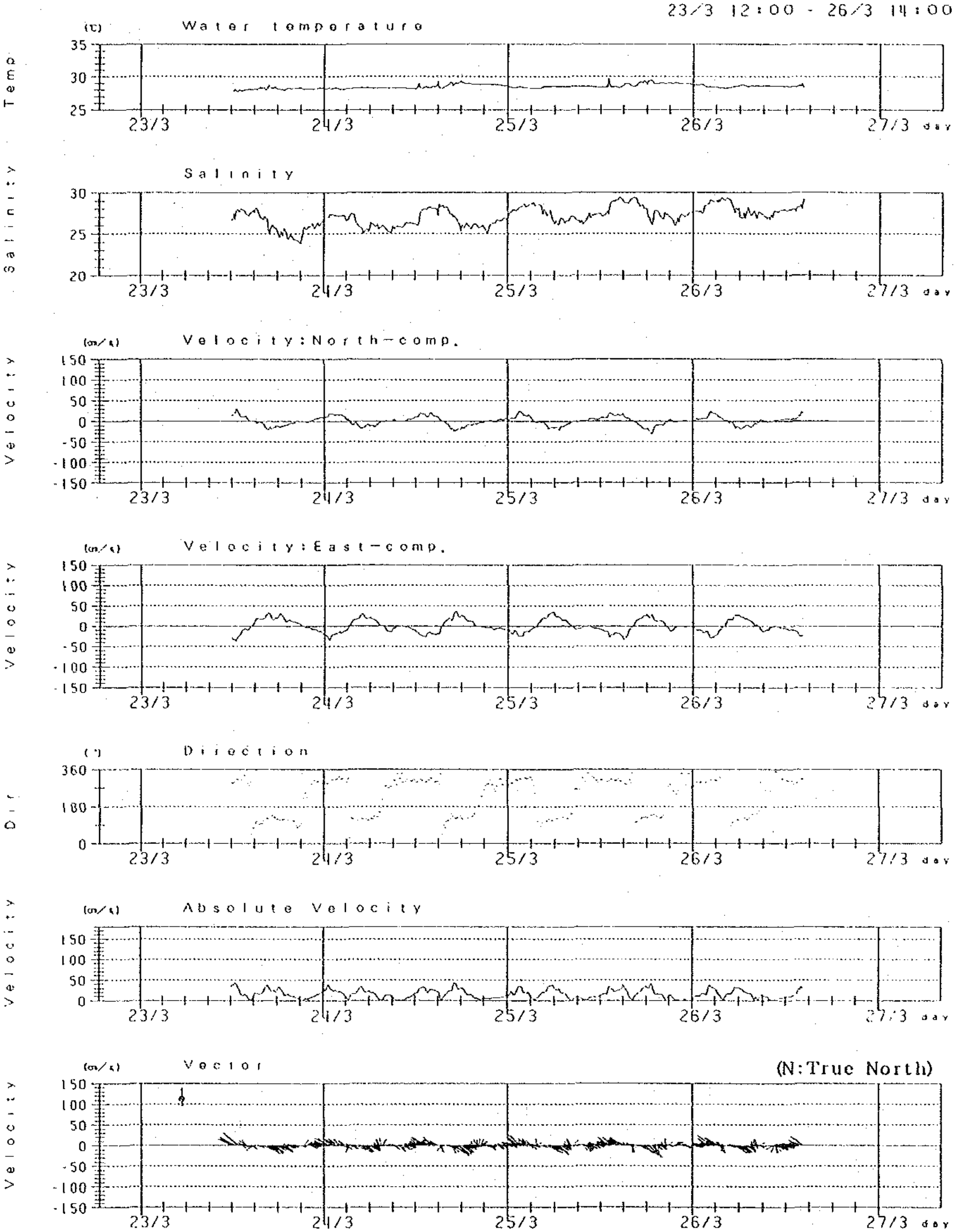


Fig. 2.3-2 Tidal Current Curves (St. II)



Tidal Current Curves (St. J)

3.2.3 Maximum Speed of Tidal Currents

The maximum speed observed at each station is summarized in Table 3.2-1, together with the observed direction of their flood and ebb currents.

High speeds were observed at the mouth of the bay (especially at St.B) and at the channel behind Ilha do Governador. The highest speed was 156 cm/sec at the upper layer of St.B and 157 cm/sec at St.H of the channel.

The speed of tidal currents in the bay tends to weaken as it goes farther from the mouth of the bay except the channel, that is, 50 - 70 cm/sec in the center of the bay, 30 - 50 cm/sec around Ilha de Paqueta and 20 - 30 cm/sec in the northern part of Ilha do Governador with maximum speed. Outside of the bay, the maximum speed was 31 cm/sec.

On the other hand, the salinity at the channel shown that the value at St.H was about 2 to 4% lower than that at St.J. This means that the area around St. H has a strong influence of river waters, comparing with the area around St. J (Table 3.2-2).

Above that, it was observed that salinity values on ebb currents were lower than those on flood currents because of fresh waters from rivers.

Table 3.2-1 Maximum Speed of Tidal Currents

St.	Layer	Flood / Ebb	June (Phase 1)		Oct.-Nov. (Phase 2)		March (Phase 3)	
			Max.Speed	Dir.	Max.Speed	Dir.	Max.Speed	Dir.
A	upper	Flood	49 cm/sec	350°	85 cm/sec	19°		
		Ebb		148	65	169		
	lower	Flood		356	96	2		
		Ebb		158	57	188		
B	upper	Flood	67 cm/sec	346°	156 cm/sec	358°		
		Ebb	68	171	137	203		
	lower	Flood	52	338	105	3		
		Ebb	54	167	53	197		
C	upper	Flood	52 cm/sec	359°	54 cm/sec	342°		
		Ebb	48	194	44	158		
D	upper	Flood	46 cm/sec	23°	62 cm/sec	42°		
		Ebb	45	200	57	201		
E	upper	Flood	-	-	42 cm/sec	5°		
		Ebb	-	-	21	132		
F	uper	Flood	31 cm/sec	2°	48 cm/sec	356°		
		Ebb	16	231	19	199		
G	upper	Flood	-	-	24 cm/sec	110°		
		Ebb	-	-	32	262		
H	upper	Flood	-	-	100 cm/sec	20°	123 cm/sec	10°
		Ebb	-	-	57	183	157	207
I	upper	Flood	-	-	10 cm/sec	44°		
		Ebb	-	-	31	213		
J	upper	Flood	-	-	-	-	43 cm/sec	309°
		Ebb	-	-	-	-	43	134

[Note] Dir.: Current direction of Max. Speed
(Clockwise from True North)

Table 3.2-2 Maximum Speed of Tidal Currents at the Channel

[St.H]

Date	Time	Tidal Current		Water Temperature	Salinity
		Speed	Direction		
Mar. 23	12:40	122.6 cm/s	30.0 deg.	28.0 ℃	22.91 ‰
	16:50	135.4	218.4	28.5	21.58
24	00:20	98.7	32.2	28.2	24.90
	05:00	156.6	217.3	28.1	23.42
	12:30	113.0	31.5	28.3	24.64
	17:50	116.8	214.9	29.3	23.35
25	01:20	105.4	35.7	28.7	26.66
	05:10	133.3	207.9	28.7	24.68
	14:10	90.6	31.5	28.3	27.69
	17:40	122.3	213.5	29.6	24.78
26	02:30	110.1	29.0	28.8	27.48
	05:30	128.1	206.8	28.8	24.71
	13:00	83.6	38.8	28.6	27.20

[Note] Direction of Tidal Current : clockwise from Magnetic North

(to be continued)

[St. J]

Date	Time	Tidal Current		Water Temperature	Salinity
		Speed	Direction		
Mar. 23	12:30	43.2 cm/s	318.8 deg.	28.1 ℃	26.68 ‰
	16:50	38.3	138.9	28.7	25.36
24	00:40	40.3	317.8	28.3	26.98
	05:00	34.2	136.8	28.4	25.61
	13:00	32.5	324.8	28.2	27.93
	17:10	42.7	144.2	29.7	27.19
25	01:30	35.1	336.0	28.5	28.25
	05:50	37.7	134.4	28.6	26.55
	15:00	38.6	317.1	28.7	28.90
	18:40	41.8	157.8	29.4	25.98
26	02:20	38.9	330.0	28.4	29.10
	05:50	32.2	135.4	28.6	28.13
	14:00	34.5	332.1	29.0	27.97

[Note] Direction of Tidal Current : clockwise from Magnetic North

3.3 Harmonic Analysis of Tidal Currents

Results of the tidal current observation were analysed using the harmonic analysis method. As the method of harmonic analysis for tidal currents is generally the same with that for tides, refer to Appendix 1 of Chapter 2 for the harmonic analysis of tidal currents.

3.3.1 Harmonic Constants of Tidal Currents

The harmonic constants of each station obtained by the harmonic analysis of tidal currents are shown in Table 3.3-1.

The principal harmonic constants, the velocity of the major axis if tidal ellipses, at each station obtained by harmonic analysis oaf tidal current are summarized in Table 3.3-20.

The result shows that the semi-diurnal currents (M_2 and S_2) are predominant in the area form the month to the center of the bay (Sts.A, B, C and D). In the northern part of the bay(Sts. E, F and G), the diurnal currents (K_1 and O_1) also grew larger showing a mixed tidal current.

However, the currents at St.H in the channel behind Ilha do Governador and St.I located outside of the bay take on a different appearance. Shallow-water tidal currents (M_1 and MS1) having a six-hour period grew larger at St.H, while diurnal and constant currents are predominant at St.I.

3.3.2 Tidal Current Ellipses

The tidal current ellipses, which are obtained using the results of the harmonic analysis, are shown in Appendix 2 for diurnal, semi-diurnal, quarter-diurnal and compound currents.

These results show that the semi-diurnal current is predominant at every station.

Table 3.3-2 Harmonic Constants of Tidal Currents

(unit : cm/sec)

St.	Layer	Velocity on Major Axis							Remarks
		V_0	K_1	O_1	M_2	S_2	M_4	MS_4	
(Phase 1)									
A	upper	15.4	2.2	3.8	24.9	14.9	7.6	9.2	
	lower	8.6	2.2	3.7	31.2	18.7	5.5	6.7	
B	upper	8.9	1.8	2.9	34.1	20.4	9.0	1.0	
	lower	3.1	1.2	2.0	28.7	17.2	5.8	7.1	
C		2.2	2.9	5.0	23.0	13.8	5.3	6.5	
D		5.4	3.2	5.3	26.1	15.7	6.5	8.0	
F		5.4	1.4	2.2	11.6	7.0	2.5	3.0	
(Phase 2)									
A	upper	5.0	1.4	5.5	27.8	15.5	12.2	3.0	+ 159°, - 339°
	lower	3.2	1.3	1.8	19.7	14.0	10.2	6.5	+ 166°, - 346°
B	upper	12.6	2.9	10.1	56.4	33.4	24.9	8.7	+ 167°, - 347°
	lower	2.7	3.8	4.6	23.6	11.9	13.2	9.4	+ 163°, - 343°
C		3.4	6.3	10.6	19.3	11.6	4.5	5.4	
D		3.8	2.5	5.4	24.0	14.0	9.8	4.0	+ 18°, - 198°
E		6.7	5.6	9.4	12.9	7.7	2.8	3.4	
F		3.9	8.3	14.1	10.5	6.3	3.0	3.6	
G		1.1	4.5	7.6	9.7	5.8	1.8	2.2	
H		6.7	9.2	15.6	27.1	16.2	11.7	14.3	
I		10.3	11.0	18.6	6.0	3.6	1.9	2.4	
(Pase 3)									
H		3.1	5.0	8.5	59.1	35.4	15.4	18.8	
J		0.6	6.7	11.3	15.1	9.0	5.0	6.1	

[Note] V_0 : Constant Current (Residual Current)

Table 3.3-1

Harmonic Constants of Tidal Currents

Phase 1

Table 10-1 Harmonic Constants of Tidal Currents

HARMONIC ANALYZED RESULTS OF THE TIDAL CURRENT

AREA ** RIO DE JANEIRO STATION ** NO. STAU
DEPTH ** 3.0 M BELOW SEA SURFACE
DURATION ** 25 HOURS FROM HEISEI 4- 6-15 TO 6-16

ELEMENTS OF CURRENT

		GEODETIC AXES		TIDAL CURRENT ELLIPSE		
		NORTH	EAST	MAJOR	MINOR	RATIO
1) CONSTANT CURRENT						
	DIR.	0	90	147	- -	
	VEL.	-0.131	0.082	0.154	- -	- -
2) DIURNAL CURRENT						
	DIR.	0	90	5	95	
	VEL.	0.065	0.006	0.065	0.001	0.018
	KAPPA	211	199	210	120	
	ROTATION . . COUNTER CLOCKWISE					
3) SEMI-DIURNAL CURRENT						
	DIR.	0	90	150	240	
	VEL.	0.288	0.171	0.328	0.066	0.200
	KAPPA	353	147	166	256	
	ROTATION . . CLOCKWISE					
4) QUARTER-DIURNAL CURRENT						
	DIR.	0	90	154	244	
	VEL.	0.150	0.074	0.167	0.007	0.042
	KAPPA	51	225	230	320	
	ROTATION . . CLOCKWISE					
5) RESIDUAL CURRENT (PROBABLE ERROR)						
	DIR.	0	90	173	263	
	VEL.	0.050	0.027	0.050	0.027	0.527

LIST OF HARMONIC CONSTANT

AXIS	CONST.	K1	O1	M2	S2	M4	MS4
NORTH							
VEL.	-0.131	0.022	0.038	0.214	0.128	0.068	0.083
KAPPA	--	245	183	358	6	78	86
EAST							
VEL.	0.082	0.002	0.003	0.127	0.076	0.033	0.040
KAPPA	--	234	172	153	160	252	260

Table 10-2 Harmonic Constants of Tidal Currents

HARMONIC ANALYZED RESULTS OF THE TIDAL CURRENT

AREA ** RIO DE JANEIRO STATION ** NO. STAU
DEPTH ** 5.0 M ABOVE SEA BOTTOM
DURATION ** 25 HOURS FROM HEISEI 4- 6-15 TO 6-16

ELEMENTS OF CURRENT

	GEODETIC AXES		TIDAL CURRENT ELLIPSE		
	NORTH	EAST	MAJOR	MINOR	RATIO
1) CONSTANT CURRENT					
DIR.	0	90	337	- -	
VEL.	0.080	-0.033	0.086	- -	- -
2) DIURNAL CURRENT					
DIR.	0	90	160	250	
VEL.	0.061	0.022	0.065	0.004	0.056
KAPPA	193	23	14	284	
ROTATION . . COUNTER CLOCKWISE					
3) SEMI-DIURNAL CURRENT					
DIR.	0	90	171	261	
VEL.	0.412	0.082	0.416	0.054	0.131
KAPPA	342	204	163	73	
ROTATION . . COUNTER CLOCKWISE					
4) QUARTER-DIURNAL CURRENT					
DIR.	0	90	173	263	
VEL.	0.113	0.048	0.114	0.046	0.404
KAPPA	8	265	191	101	
ROTATION . . COUNTER CLOCKWISE					
5) RESIDUAL CURRENT (PROBABLE ERROR)					
DIR.	0	90	155	245	
VEL.	0.042	0.032	0.045	0.028	0.630

LIST OF HARMONIC CONSTANT

AXIS	CONST.	K1	O1	M2	S2	M4	MS4
NORTH							
VEL.	0.080	0.021	0.035	0.306	0.183	0.051	0.062
KAPPA	--	228	166	348	355	35	42
EAST							
VEL.	-0.033	0.008	0.013	0.061	0.036	0.021	0.026
KAPPA	--	58	357	210	217	292	299

Table 10-3 Harmonic Constants of Tidal Currents

HARMONIC ANALYZED RESULTS OF THE TIDAL CURRENT

AREA ** RIO DE JANEIRO STATION ** NO. STBU
DEPTH ** 3.0 M BELOW SEA SURFACE
DURATION ** 25 HOURS FROM HEISEI 4- 6-15 TO 6-16

ELEMENTS OF CURRENT

	GEODETIC AXES		TIDAL CURRENT ELLIPSE		
	NORTH	EAST	MAJOR	MINOR	RATIO
1) CONSTANT CURRENT					
DIR.	0	90	194	- -	
VEL.	-0.086	-0.022	0.089	- -	- -
2) DIURNAL CURRENT					
DIR.	0	90	163	253	
VEL.	0.049	0.016	0.050	0.009	0.172
KAPPA	207	60	29	299	
ROTATION . . COUNTER CLOCKWISE					
3) SEMI-DIURNAL CURRENT					
DIR.	0	90	167	257	
VEL.	0.443	0.120	0.453	0.073	0.162
KAPPA	355	214	177	87	
ROTATION . . COUNTER CLOCKWISE					
4) QUARTER-DIURNAL CURRENT					
DIR.	0	90	162	252	
VEL.	0.191	0.062	0.200	0.011	0.053
KAPPA	61	231	240	330	
ROTATION . . CLOCKWISE					
5) RESIDUAL CURRENT (PROBABLE ERROR)					
DIR.	0	90	1	91	
VEL.	0.042	0.029	0.042	0.029	0.697

LIST OF HARMONIC CONSTANT

AXIS	CONST.	K1	O1	M2	S2	M4	MS4
NORTH							
VEL.	-0.086	0.017	0.028	0.329	0.197	0.086	0.105
KAPPA	--	241	179	2	9	89	96
EAST							
VEL.	-0.022	0.006	0.009	0.089	0.053	0.028	0.034
KAPPA	--	95	33	220	228	259	266

Table 10-4 Harmonic Constants of Tidal Currents

HARMONIC ANALYZED RESULTS OF THE TIDAL CURRENT

AREA ** RIO DE JANEIRO STATION ** NO. STBU
DEPTH ** 5.0 M ABOVE SEA BOTTOM
DURATION ** 25 HOURS FROM HEISEI 4- 6-15 TO 6-16

ELEMENTS OF CURRENT

	GEODETIC AXES		TIDAL CURRENT ELLIPSE		
	NORTH	EAST	MAJOR	MINOR	RATIO
1) CONSTANT CURRENT					
DIR.	0	90	235	- -	
VEL.	-0.018	-0.025	0.031	- -	- -
2) DIURNAL CURRENT					
DIR.	0	90	148	238	
VEL.	0.029	0.020	0.033	0.011	0.339
KAPPA	255	34	63	153	
ROTATION . . CLOCKWISE					
3) SEMI-DIURNAL CURRENT					
DIR.	0	90	155	245	
VEL.	0.350	0.161	0.385	0.004	0.010
KAPPA	29	208	209	299	
ROTATION . . CLOCKWISE					
4) QUARTER-DIURNAL CURRENT					
DIR.	0	90	154	244	
VEL.	0.116	0.057	0.129	0.010	0.078
KAPPA	134	303	312	42	
ROTATION . . CLOCKWISE					
5) RESIDUAL CURRENT (PROBABLE ERROR)					
DIR.	0	90	170	260	
VEL.	0.056	0.028	0.056	0.027	0.474

LIST OF HARMONIC CONSTANT

AXIS	CONST.	K1	O1	M2	S2	M4	MS4
NORTH							
VEL.	-0.018	0.010	0.017	0.261	0.156	0.052	0.064
KAPPA	--	289	227	36	43	162	169
EAST							
VEL.	-0.025	0.007	0.011	0.120	0.072	0.025	0.031
KAPPA	--	69	7	214	221	331	338

Table 10-5 Harmonic Constants of Tidal Currents

HARMONIC ANALYZED RESULTS OF THE TIDAL CURRENT

AREA ** RIO DE JANEIRO STATION ** NO. STC
DEPTH ** 3.0 M BELOW SEA SURFACE
DURATION ** 25 HOURS FROM HEISEI 4- 6-16 TO 6-17

ELEMENTS OF CURRENT

		GEODETIC AXES		TIDAL CURRENT ELLIPSE		
		NORTH	EAST	MAJOR	MINOR	RATIO
1) CONSTANT CURRENT						
	DIR.	0	90	221	- -	
	VEL.	-0.017	-0.015	0.022	- -	- -
2) DIURNAL CURRENT						
	DIR.	0	90	173	263	
	VEL.	0.089	0.013	0.090	0.008	0.085
	KAPPA	214	72	34	304	
	ROTATION . . COUNTER CLOCKWISE					
3) SEMI-DIURNAL CURRENT						
	DIR.	0	90	0	90	
	VEL.	0.295	0.006	0.295	0.004	0.015
	KAPPA	0	312	0	270	
	ROTATION . . COUNTER CLOCKWISE					
4) QUARTER-DIURNAL CURRENT						
	DIR.	0	90	178	268	
	VEL.	0.116	0.009	0.116	0.008	0.068
	KAPPA	76	191	255	345	
	ROTATION . . CLOCKWISE					
5) RESIDUAL CURRENT (PROBABLE ERROR)						
	DIR.	0	90	11	101	
	VEL.	0.028	0.020	0.029	0.019	0.675

LIST OF HARMONIC CONSTANT

AXIS	CONST.	K1	O1	M2	S2	M4	MS4
NORTH							
VEL.	-0.017	0.029	0.050	0.230	0.138	0.053	0.065
KAPPA	--	246	185	15	22	117	124
EAST							
VEL.	-0.015	0.004	0.007	0.005	0.003	0.004	0.005
KAPPA	--	104	42	327	335	232	239

Table 10-6 Harmonic Constants of Tidal Currents

HARMONIC ANALYZED RESULTS OF THE TIDAL CURRENT

AREA ** RIO DE JANEIRO STATION ** NO. STD
DEPTH ** 3.0 M BELOW SEA SURFACE
DURATION ** 25 HOURS FROM HEISEI 4- 6-16 TO 6-17

ELEMENTS OF CURRENT

		GEODETIC AXES		TIDAL CURRENT ELLIPSE		
		NORTH	EAST	MAJOR	MINOR	RATIO
1) CONSTANT CURRENT						
	DIR.	0	90	190	- -	
	VEL.	-0.053	-0.010	0.054	- -	- -
2) DIURNAL CURRENT						
	DIR.	0	90	33	123	
	VEL.	0.079	0.054	0.095	0.014	0.150
	KAPPA	203	184	197	107	
	ROTATION . . COUNTER CLOCKWISE					
3) SEMI-DIURNAL CURRENT						
	DIR.	0	90	20	110	
	VEL.	0.313	0.117	0.334	0.016	0.047
	KAPPA	0	9	1	91	
	ROTATION . . CLOCKWISE					
4) QUARTER-DIURNAL CURRENT						
	DIR.	0	90	17	107	
	VEL.	0.136	0.046	0.143	0.012	0.086
	KAPPA	71	87	72	162	
	ROTATION . . CLOCKWISE					
5) RESIDUAL CURRENT (PROBABLE ERROR)						
	DIR.	0	90	12	102	
	VEL.	0.029	0.014	0.030	0.013	0.421

LIST OF HARMONIC CONSTANT

AXIS	CONST.	K1	O1	M2	S2	M4	MS4
NORTH							
VEL.	-0.053	0.026	0.044	0.245	0.147	0.062	0.076
KAPPA	--	235	173	16	23	112	119
EAST							
VEL.	-0.010	0.018	0.030	0.091	0.055	0.021	0.025
KAPPA	--	217	155	24	31	129	136

Table 10-7 Harmonic Constants of Tidal Currents

HARMONIC ANALYZED RESULTS OF THE TIDAL CURRENT

AREA ** RIO DE JANEIRO STATION ** NO. STF
DEPTH ** 3.0 M BELOW SEA SURFACE
DURATION ** 25 HOURS FROM HEISEI 4- 6-17 TO 6-18

ELEMENTS OF CURRENT

	GEODETIC AXES		TIDAL CURRENT ELLIPSE		
	NORTH	EAST	MAJOR	MINOR	RATIO
1) CONSTANT CURRENT					
DIR.	0	90	328	- -	
VEL.	0.046	-0.028	0.054	- -	- -
2) DIURNAL CURRENT					
DIR.	0	90	20	110	
VEL.	0.037	0.017	0.040	0.009	0.237
KAPPA	211	174	206	116	
ROTATION . . COUNTER CLOCKWISE					
3) SEMI-DIURNAL CURRENT					
DIR.	0	90	18	108	
VEL.	0.129	0.045	0.136	0.013	0.097
KAPPA	4	345	2	272	
ROTATION . . COUNTER CLOCKWISE					
4) QUARTER-DIURNAL CURRENT					
DIR.	0	90	15	105	
VEL.	0.048	0.014	0.050	0.003	0.058
KAPPA	60	73	61	151	
ROTATION . . CLOCKWISE					
5) RESIDUAL CURRENT (PROBABLE ERROR)					
DIR.	0	90	172	262	
VEL.	0.023	0.012	0.023	0.012	0.529

LIST OF HARMONIC CONSTANT

AXIS	CONST.	K1	O1	M2	S2	M4	MS4
NORTH							
VEL.	0.046	0.013	0.021	0.110	0.066	0.024	0.029
KAPPA	--	241	179	25	32	107	115
EAST							
VEL.	-0.028	0.006	0.009	0.038	0.023	0.007	0.008
KAPPA	--	203	141	7	14	120	127

Phase 2

Table 10-8(1) Harmonic Constants of Tidal Currents(ST. A(Upper))

LIST OF HARMONIC CONSTANT

AREA ** RIO DE JANEIRO STATION ** NO. STAU
POSITION ** 0 DEGREE. 0.00KM FROM RIO
GEODETIC CO-ORDINATE ** LAT. ** - 54.33 N. LONG. -43 - 9.32 E
DEPTH ** 3.0 M BELOW SEA SURFACE

DURATION ** 15 TIMES.
EACH 25 HRS. FROM FOLLOWING EPOCKS

	EPOCH		CONSTANT CURRENT NORTH	CONSTANT CURRENT EAST
1)	1992-10-28. 13H 0M	1)	-0.054	-0.019
2)	1992-10-29. 13H 0M	2)	-0.012	-0.007
3)	1992-10-30. 13H 0M	3)	-0.001	0.004
4)	1992-10-31. 13H 0M	4)	-0.027	0.016
5)	1992-11- 1. 13H 0M	5)	-0.002	0.005
6)	1992-11- 2. 13H 0M	6)	0.011	-0.003
7)	1992-11- 3. 13H 0M	7)	0.003	-0.025
8)	1992-11- 4. 13H 0M	8)	-0.002	-0.039
9)	1992-11- 5. 13H 0M	9)	-0.063	0.015
10)	1992-11- 6. 13H 0M	10)	-0.126	0.008
11)	1992-11- 7. 13H 0M	11)	-0.055	0.019
12)	1992-11- 8. 13H 0M	12)	-0.101	0.045
13)	1992-11- 9. 13H 0M	13)	-0.120	0.058
14)	1992-11-10. 13H 0M	14)	-0.083	0.056
15)	1992-11-11. 13H 0M	15)	-0.096	0.063
		MEAN	-0.049	0.013

	NORTH		EAST		MAJOR			MINOR			GENERAL	
	VEL.	KAPPA	VEL.	KAPPA	DIR.	VEL.	KAPPA	DIR.	VEL.	KAPPA	VEL.	KAPPA
V0	-0.049	***	0.013	***	164	0.050	***	**	***	***	0.050	***
K1	0.013	231.2	0.006	83.3	338	0.014	235.7	68	0.003	145.7	0.014	55.7
P1	0.004	230.0	0.002	73.8	337	0.005	233.6	67	0.001	143.5	0.005	53.3
O1	0.055	214.7	0.022	316.8	354	0.055	212.6	84	0.021	302.6	0.053	26.5
Q1	0.011	206.5	0.004	254.0	16	0.011	210.9	106	0.003	300.9	0.009	19.4
M2	0.260	41.7	0.096	220.8	159	0.278	221.6	249	0.001	311.6	0.278	221.6
N2	0.050	44.4	0.019	220.5	159	0.054	224.0	249	0.001	314.0	0.054	224.0
S2	0.146	36.5	0.052	221.4	160	0.155	217.0	250	0.004	127.0	0.155	217.1
K2	0.040	36.0	0.014	221.4	160	0.042	216.6	250	0.001	126.6	0.042	216.7
M4	0.114	95.9	0.045	292.1	159	0.122	278.0	249	0.012	188.0	0.122	278.0
MS4	0.021	212.9	0.022	3.4	314	0.030	197.7	44	0.008	287.7	0.027	24.6

GENERAL DIRECTION ** 159 (POSITIVE) 339 (NEGATIVE)

Table 10-8(2) Harmonic Constants of Tidal Currents(ST. A(Lower))

LIST OF HARMONIC CONSTANT

AREA ** RIO DE JANEIRO STATION ** NO. STAL
POSITION ** 0 DEGREE, 0.00KM FROM RIO
GEODETIC CO-ORDINATE ** LAT. ** - 54.33 N, LONG. -43 - 9.32 E
DEPTH ** 5.0 M ABOVE SEA BOTTOM

DURATION ** 15 TIMES,
EACH 25 HRS. FROM FOLLOWING EPOCKS

			CONSTANT CURRENT	
			NORTH	EAST
1) 1992-10-28,	13H 0M	1)	0.082	-0.030
2) 1992-10-29,	13H 0M	2)	0.025	0.001
3) 1992-10-30,	13H 0M	3)	-0.022	0.000
4) 1992-10-31,	13H 0M	4)	0.003	-0.004
5) 1992-11- 1,	13H 0M	5)	-0.012	0.014
6) 1992-11- 2,	13H 0M	6)	0.014	0.002
7) 1992-11- 3,	13H 0M	7)	0.017	-0.003
8) 1992-11- 4,	13H 0M	8)	-0.007	0.005
9) 1992-11- 5,	13H 0M	9)	0.038	-0.009
10) 1992-11- 6,	13H 0M	10)	0.055	-0.033
11) 1992-11- 7,	13H 0M	11)	0.041	-0.027
12) 1992-11- 8,	13H 0M	12)	0.048	-0.026
13) 1992-11- 9,	13H 0M	13)	0.026	-0.011
14) 1992-11-10,	13H 0M	14)	0.054	-0.038
15) 1992-11-11,	13H 0M	15)	0.070	-0.038
		MEAN	0.029	-0.013

	NORTH		EAST		MAJOR			MINOR			GENERAL	
	VEL.	KAPPA	VEL.	KAPPA	DIR.	VEL.	KAPPA	DIR.	VEL.	KAPPA	VEL.	KAPPA
V0	0.029	***	-0.013	***	335	0.032	***	**	***	***	-0.031	***
K1	0.013	287.6	0.004	118.3	342	0.013	288.5	72	0.001	198.5	0.013	108.4
P1	0.004	279.4	0.001	105.1	342	0.004	279.9	72	0.000	189.9	0.004	99.8
O1	0.017	178.3	0.005	302.3	350	0.018	176.0	80	0.004	266.0	0.018	355.0
Q1	0.003	124.2	0.001	215.1	359	0.003	124.1	89	0.001	214.1	0.003	300.0
M2	0.193	32.3	0.043	222.2	167	0.197	212.8	257	0.007	122.8	0.197	212.9
N2	0.037	28.3	0.008	221.4	167	0.038	208.9	257	0.002	118.9	0.038	209.0
S2	0.136	40.0	0.034	223.7	166	0.140	220.2	256	0.002	130.2	0.140	220.2
K2	0.037	40.6	0.009	223.8	166	0.038	220.8	256	0.001	130.8	0.038	220.8
M4	0.097	109.1	0.030	286.6	162	0.102	288.9	252	0.001	18.9	0.102	289.0
MS4	0.060	129.2	0.025	282.4	339	0.065	125.6	69	0.011	215.6	0.064	306.8

GENERAL DIRECTION ** 166 (POSITIVE) 346 (NEGATIVE)

Table 10-9(1) Harmonic Constants of Tidal Currents(ST.B(Upper))

LIST OF HARMONIC CONSTANT

AREA ** RIO DE JANEIRO STATION ** NO. STBU
POSITION ** 0 DEGREE, 0.00KM FROM RIO
GEODETIC CO-ORDINATE ** LAT. ** - 54.32 N, LONG. -43 - 8.45 E
DEPTH ** 3.0 M BELOW SEA SURFACE

DURATION ** 15 TIMES,
EACH 25 HRS. FROM FOLLOWING EPOCKS

	EPOCH		CONSTANT CURRENT NORTH	CONSTANT CURRENT EAST
1)	1992-10-28, 13H 0M	1)	-0.264	0.011
2)	1992-10-29, 13H 0M	2)	-0.112	-0.050
3)	1992-10-30, 13H 0M	3)	-0.111	-0.048
4)	1992-10-31, 13H 0M	4)	-0.129	-0.014
5)	1992-11- 1, 13H 0M	5)	-0.150	-0.018
6)	1992-11- 2, 13H 0M	6)	-0.129	0.010
7)	1992-11- 3, 13H 0M	7)	-0.160	-0.029
8)	1992-11- 4, 13H 0M	8)	0.181	-0.026
9)	1992-11- 5, 13H 0M	9)	0.071	-0.053
10)	1992-11- 6, 13H 0M	10)	-0.145	-0.081
11)	1992-11- 7, 13H 0M	11)	-0.111	-0.082
12)	1992-11- 8, 13H 0M	12)	-0.077	-0.116
13)	1992-11- 9, 13H 0M	13)	-0.162	-0.091
14)	1992-11-10, 13H 0M	14)	-0.189	-0.068
15)	1992-11-11, 13H 0M	15)	-0.268	-0.036
		MEAN	*-0.117*	*-0.046*

	NORTH		EAST		MAJOR			MINOR			GENERAL	
	VEL.	KAPPA	VEL.	KAPPA	DIR.	VEL.	KAPPA	DIR.	VEL.	KAPPA	VEL.	KAPPA
V0	-0.117	***	-0.046	***	201	0.126	***	**	***	***	0.104	***
K1	0.028	358.4	0.018	65.0	201	0.029	191.0	291	0.016	281.0	0.026	169.8
P1	0.009	346.1	0.006	63.5	193	0.009	174.9	283	0.006	264.9	0.009	157.2
O1	0.097	193.4	0.032	44.9	343	0.101	196.0	73	0.016	106.0	0.101	15.5
Q1	0.019	111.5	0.006	34.9	184	0.019	290.0	274	0.006	200.0	0.018	295.9
M2	0.551	36.7	0.119	222.8	167	0.564	217.0	257	0.012	127.0	0.564	217.0
N2	0.107	40.4	0.023	211.3	168	0.109	220.0	258	0.004	310.0	0.109	220.0
S2	0.327	29.8	0.082	244.3	168	0.334	211.4	258	0.045	121.4	0.334	211.6
K2	0.089	29.2	0.022	246.0	168	0.091	210.9	258	0.013	120.9	0.091	211.1
M4	0.239	111.0	0.070	288.6	163	0.249	290.8	253	0.003	20.8	0.248	290.8
MS4	0.085	201.6	0.016	4.2	349	0.087	201.0	79	0.005	291.0	0.087	20.9

GENERAL DIRECTION ** 167 (POSITIVE) 347 (NEGATIVE)

Table10-9(2) Harmonic Constants of Tidal Currents(ST.B(Lower))

LIST OF HARMONIC CONSTANT

AREA ** RIO DE JANEIRO STATION ** NO. STBL
POSITION ** 0 DEGREE, 0.00KM FROM RIO
GEODETIC CO-ORDINATE ** LAT. ** - 54.32 N, LONG. -43 - 8.45 E
DEPTH ** 5.0 M ABOVE SEA BOTTOM

DURATION ** 15 TIMES,
EACH 25 HRS. FROM FOLLOWING EPOCKS

			CONSTANT CURRENT NORTH	EAST
1) 1992-10-28,	13H 0M	1)	0.071	-0.029
2) 1992-10-29,	13H 0M	2)	0.050	-0.017
3) 1992-10-30,	13H 0M	3)	0.001	0.008
4) 1992-10-31,	13H 0M	4)	0.022	-0.002
5) 1992-11- 1,	13H 0M	5)	0.023	-0.007
6) 1992-11- 2,	13H 0M	6)	0.009	0.010
7) 1992-11- 3,	13H 0M	7)	-0.023	0.009
8) 1992-11- 4,	13H 0M	8)	-0.046	0.022
9) 1992-11- 5,	13H 0M	9)	-0.007	0.019
10) 1992-11- 6,	13H 0M	10)	-0.010	0.029
11) 1992-11- 7,	13H 0M	11)	0.042	0.003
12) 1992-11- 8,	13H 0M	12)	0.067	-0.005
13) 1992-11- 9,	13H 0M	13)	0.078	-0.019
14) 1992-11-10,	13H 0M	14)	0.057	-0.016
15) 1992-11-11,	13H 0M	15)	0.064	0.000
		MEAN	0.027	0.000

	NORTH		EAST		MAJOR			MINOR			GENERAL	
	VEL.	KAPPA	VEL.	KAPPA	DIR.	VEL.	KAPPA	DIR.	VEL.	KAPPA	VEL.	KAPPA
V0	0.027	***	0.000	***	0	0.027	***	**	***	***	-0.025	***
K1	0.036	225.7	0.013	54.9	339	0.038	226.8	69	0.002	136.8	0.038	46.6
P1	0.012	224.4	0.004	53.2	339	0.013	225.4	69	0.001	135.4	0.013	45.3
O1	0.044	208.6	0.014	32.3	342	0.046	208.9	72	0.001	118.9	0.046	28.9
Q1	0.008	200.1	0.003	21.0	342	0.009	200.2	72	0.000	110.2	0.009	20.2
M2	0.228	28.3	0.058	209.5	165	0.236	208.4	255	0.001	118.4	0.235	208.4
N2	0.044	19.3	0.011	196.1	165	0.046	199.1	255	0.001	289.1	0.046	199.0
S2	0.114	45.2	0.036	234.4	162	0.119	226.0	252	0.005	136.0	0.119	226.0
K2	0.031	46.6	0.010	236.4	162	0.032	227.4	252	0.002	137.4	0.032	227.4
M4	0.127	109.0	0.036	306.2	164	0.132	290.2	254	0.010	200.2	0.132	290.3
MS4	0.083	165.9	0.045	358.6	332	0.094	168.7	62	0.009	78.7	0.093	347.7

GENERAL DIRECTION ** 163 (POSITIVE) 343 (NEGATIVE)

Table10-10 Harmonic Constants of Tidal Currents(ST.D)

LIST OF HARMONIC CONSTANT

AREA ** RIO DE JANEIRO STATION ** NO. STD
POSITION ** 0 DEGREE, 0.00KM FROM RIO
GEODETIC CO-ORDINATE ** LAT. ** - 49.95 N, LONG. -43 - 9.25 E
DEPTH ** 3.0 M BELOW SEA SURFACE

DURATION ** 15 TIMES,
EACH 25 HRS. FROM FOLLOWING EPOCKS

EPOCH		CONSTANT CURRENT NORTH	EAST
1) 1992-10-28, 13H 0M	1)	-0.084	-0.017
2) 1992-10-29, 13H 0M	2)	-0.048	-0.021
3) 1992-10-30, 13H 0M	3)	-0.047	0.011
4) 1992-10-31, 13H 0M	4)	-0.017	-0.028
5) 1992-11- 1, 13H 0M	5)	-0.033	0.014
6) 1992-11- 2, 13H 0M	6)	0.000	-0.008
7) 1992-11- 3, 13H 0M	7)	-0.001	-0.009
8) 1992-11- 4, 13H 0M	8)	0.007	-0.017
9) 1992-11- 5, 13H 0M	9)	-0.009	-0.025
10) 1992-11- 6, 13H 0M	10)	-0.104	-0.012
11) 1992-11- 7, 13H 0M	11)	-0.035	-0.005
12) 1992-11- 8, 13H 0M	12)	-0.055	0.001
13) 1992-11- 9, 13H 0M	13)	-0.057	0.008
14) 1992-11-10, 13H 0M	14)	-0.053	0.012
15) 1992-11-11, 13H 0M	15)	-0.030	0.001
	MEAN	-0.038	-0.006

	NORTH VEL.	NORTH KAPPA	EAST VEL.	EAST KAPPA	MAJOR DIR.	MAJOR VEL.	MAJOR KAPPA	MINOR DIR.	MINOR VEL.	MINOR KAPPA	GENERAL VEL.	GENERAL KAPPA
V0	-0.038	***	-0.006	***	189	0.038	***	**	***	***	-0.038	***
K1	0.013	206.1	0.023	153.9	246	0.025	343.8	336	0.010	253.8	0.018	187.9
P1	0.004	207.3	0.008	158.2	245	0.008	347.9	335	0.003	257.9	0.006	190.2
O1	0.049	222.7	0.023	211.5	205	0.054	40.6	295	0.004	310.6	0.054	221.2
Q1	0.010	230.9	0.005	240.1	205	0.011	52.5	295	0.001	142.5	0.010	232.1
M2	0.230	45.4	0.070	50.4	16	0.240	45.8	106	0.006	135.8	0.240	45.8
N2	0.044	45.1	0.014	51.1	16	0.046	45.6	106	0.001	135.6	0.046	45.7
S2	0.135	45.8	0.037	49.1	15	0.140	46.0	105	0.002	136.0	0.140	46.1
K2	0.037	45.8	0.010	49.0	15	0.038	46.1	105	0.001	136.1	0.038	46.1
M4	0.095	109.8	0.022	110.1	13	0.098	109.9	103	0.000	199.9	0.097	109.9
MS4	0.037	203.9	0.015	203.9	202	0.040	23.9	292	0.000	113.9	0.040	203.9

GENERAL DIRECTION ** 18 (POSITIVE) 198 (NEGATIVE)

Table10-11 Harmonic Constants of Tidal Currents(ST.C)

HARMONIC ANALYZED RESULTS OF THE TIDAL CURRENT

AREA ** RIO DE JANEIRO STATION ** NO. STC
DEPTH ** 3.0 M BELOW SEA SURFACE
DURATION ** 25 HOURS FROM 1992-10-24 TO 10-25

ELEMENTS OF CURRENT

		GEODETIC AXES		TIDAL CURRENT ELLIPSE		
		NORTH	EAST	MAJOR	MINOR	RATIO
1) CONSTANT CURRENT						
	DIR.	0	90	275	--	
	VEL.	0.003	-0.034	0.034	--	--
2) DIURNAL CURRENT						
	DIR.	0	90	151	241	
	VEL.	0.057	0.032	0.065	0.006	0.091
	KAPPA	105	273	282	12	
	ROTATION . . CLOCKWISE					
3) SEMI-DIURNAL CURRENT						
	DIR.	0	90	170	260	
	VEL.	0.331	0.058	0.336	0.013	0.038
	KAPPA	23	190	203	293	
	ROTATION . . CLOCKWISE					
4) QUARTER-DIURNAL CURRENT						
	DIR.	0	90	7	97	
	VEL.	0.089	0.019	0.090	0.014	0.158
	KAPPA	69	19	68	338	
	ROTATION . . COUNTER CLOCKWISE					
5) RESIDUAL CURRENT (PROBABLE ERROR)						
	DIR.	0	90	165	255	
	VEL.	0.042	0.030	0.043	0.029	0.675

LIST OF HARMONIC CONSTANT

AXIS	CONST.	K1	O1	M2	S2	M4	MS4
NORTH							
VEL.	0.003	0.055	0.093	0.190	0.114	0.044	0.053
KAPPA	--	230	168	17	24	61	68
EAST							
VEL.	-0.034	0.030	0.051	0.033	0.020	0.009	0.011
KAPPA	--	38	336	184	191	10	17

COMBINED FACTOR 0.960 0.572 0.494
WHEN THIS IS GREATER THAN 4, CONSTANTS ARE DOUBTFUL.

STANDARD PORT ** I.FISCAL

	DIURNAL		SEMI-DIURNAL	
	K1	O1	M2	S2
VEL.	5.780	10.540	30.870	17.860
KAPPA	147.7	85.9	83.6	90.7

Table 10-12 Harmonic Constants of Tidal Currents(ST. E)

HARMONIC ANALYZED RESULTS OF THE TIDAL CURRENT

AREA ** RIO DE JANEIRO STATION ** NO. STE
DEPTH ** 3.0 M BELOW SEA SURFACE
DURATION ** 25 HOURS FROM 1992-10-24 TO 10-25

ELEMENTS OF CURRENT

	GEODETIC AXES		TIDAL CURRENT ELLIPSE		
	NORTH	EAST	MAJOR	MINOR	RATIO
1) CONSTANT CURRENT					
DIR.	0	90	38	- -	
VEL.	0.052	0.042	0.067	- -	- -
2) DIURNAL CURRENT					
DIR.	0	90	69	159	
VEL.	0.028	0.051	0.054	0.022	0.405
KAPPA	174	230	221	311	
ROTATION . . CLOCKWISE					
3) SEMI-DIURNAL CURRENT					
DIR.	0	90	172	262	
VEL.	0.223	0.031	0.225	0.001	0.005
KAPPA	45	223	225	315	
ROTATION . . CLOCKWISE					
4) QUARTER-DIURNAL CURRENT					
DIR.	0	90	1	91	
VEL.	0.051	0.025	0.051	0.025	0.482
KAPPA	95	182	96	186	
ROTATION . . CLOCKWISE					
5) RESIDUAL CURRENT (PROBABLE ERROR)					
DIR.	0	90	8	98	
VEL.	0.032	0.024	0.032	0.023	0.721

LIST OF HARMONIC CONSTANT

AXIS	CONST.	K1	O1	M2	S2	M4	MS4
NORTH							
VEL.	0.052	0.027	0.045	0.128	0.076	0.025	0.031
KAPPA	--	299	237	39	46	87	94
EAST							
VEL.	0.042	0.049	0.083	0.018	0.011	0.012	0.015
KAPPA	--	355	293	217	224	174	181

COMBINED FACTOR 0.960 0.572 0.494
WHEN THIS IS GREATER THAN 4. CONSTANTS ARE DOUBTFUL.

STANDARD PORT ** I.FISCAL

	DIURNAL		SEMI-DIURNAL	
	K1	O1	M2	S2
VEL.	5.780	10.540	30.870	17.860
KAPPA	147.7	85.9	83.6	90.7

Table10-13 Harmonic Constants of Tidal Currents(ST.F)

HARMONIC ANALYZED RESULTS OF THE TIDAL CURRENT

AREA ** RIO DE JANEIRO STATION ** NO. STF
DEPTH ** 3.0 M BELOW SEA SURFACE
DURATION ** 25 HOURS FROM 1992-10-24 TO 10-25

ELEMENTS OF CURRENT

		GEODETIC AXES		TIDAL CURRENT ELLIPSE		
		NORTH	EAST	MAJOR	MINOR	RATIO
1) CONSTANT CURRENT						
	DIR.	0	90	343	- -	
	VEL.	0.037	-0.011	0.039	- -	- -
2) DIURNAL CURRENT						
	DIR.	0	90	165	255	
	VEL.	0.082	0.028	0.085	0.019	0.230
	KAPPA	36	261	219	129	
	ROTATION . . COUNTER CLOCKWISE					
3) SEMI-DIURNAL CURRENT						
	DIR.	0	90	8	98	
	VEL.	0.180	0.035	0.182	0.023	0.125
	KAPPA	28	347	27	297	
	ROTATION . . COUNTER CLOCKWISE					
4) QUARTER-DIURNAL CURRENT						
	DIR.	0	90	12	102	
	VEL.	0.059	0.016	0.060	0.010	0.163
	KAPPA	53	14	51	321	
	ROTATION . . COUNTER CLOCKWISE					
5) RESIDUAL CURRENT (PROBABLE ERROR)						
	DIR.	0	90	162	252	
	VEL.	0.034	0.021	0.035	0.019	0.548

LIST OF HARMONIC CONSTANT

AXIS	CONST.	K1	O1	M2	S2	M4	MS4
NORTH							
VEL.	0.037	0.079	0.133	0.103	0.062	0.029	0.035
KAPPA	--	161	99	21	29	44	52
EAST							
VEL.	-0.011	0.027	0.046	0.020	0.012	0.008	0.010
KAPPA	--	26	324	341	348	6	13

COMBINED FACTOR 0.960 0.572 0.494
WHEN THIS IS GREATER THAN 4, CONSTANTS ARE DOUBTFUL.

STANDARD PORT ** I.FISCAL

	DIURNAL		SEMI-DIURNAL	
	K1	O1	M2	S2
VEL.	5.780	10.540	30.870	17.860
KAPPA	147.7	85.9	83.6	90.7

Table 10-14 Harmonic Constants of Tidal Currents(ST.G)

HARMONIC ANALYZED RESULTS OF THE TIDAL CURRENT

AREA ** RIO DE JANEIRO STATION ** NO. STG
DEPTH ** 3.0 M BELOW SEA SURFACE
DURATION ** 25 HOURS FROM 1992-10-24 TO 10-25

ELEMENTS OF CURRENT

	GEODETIC AXES		TIDAL CURRENT ELLIPSE		
	NORTH	EAST	MAJOR	MINOR	RATIO
1) CONSTANT CURRENT					
DIR.	0	90	296	- -	
VEL.	0.005	-0.010	0.011	- -	- -
2) DIURNAL CURRENT					
DIR.	0	90	84	174	
VEL.	0.024	0.040	0.040	0.024	0.603
KAPPA	291	206	210	120	
ROTATION . . COUNTER CLOCKWISE					
3) SEMI-DIURNAL CURRENT					
DIR.	0	90	76	166	
VEL.	0.053	0.160	0.165	0.037	0.224
KAPPA	259	214	217	127	
ROTATION . . COUNTER CLOCKWISE					
4) QUARTER-DIURNAL CURRENT					
DIR.	0	90	80	170	
VEL.	0.013	0.035	0.036	0.011	0.315
KAPPA	308	243	246	156	
ROTATION . . COUNTER CLOCKWISE					
5) RESIDUAL CURRENT (PROBABLE ERROR)					
DIR.	0	90	111	201	
VEL.	0.014	0.025	0.027	0.011	0.420

LIST OF HARMONIC CONSTANT

AXIS	CONST.	K1	O1	M2	S2	M4	MS4
NORTH							
VEL.	0.005	0.023	0.040	0.031	0.018	0.006	0.008
KAPPA	--	56	354	253	260	300	307
EAST							
VEL.	-0.010	0.039	0.065	0.092	0.055	0.017	0.021
KAPPA	--	331	269	208	215	235	242

COMBINED FACTOR 0.960 0.572 0.494
WHEN THIS IS GREATER THAN 4. CONSTANTS ARE DOUBTFUL.

STANDARD PORT ** I.FISCAL

	DIURNAL		SEMI-DIURNAL	
	K1	O1	M2	S2
VEL.	5.780	10.540	30.870	17.860
KAPPA	147.7	85.9	83.6	90.7

Table10-15 Harmonic Constants of Tidal Currents(ST.II)

HARMONIC ANALYZED RESULTS OF THE TIDAL CURRENT

AREA ** RIO DE JANEIRO STATION ** NO. STH
DEPTH ** 3.0 M BELOW SEA SURFACE
DURATION ** 25 HOURS FROM 1992-10-24 TO 10-25

ELEMENTS OF CURRENT

	GEODETIC AXES NORTH	EAST	TIDAL CURRENT ELLIPSE MAJOR	MINOR	RATIO
1) CONSTANT CURRENT					
DIR.	0	90	153	- -	
VEL.	-0.060	0.030	0.067	- -	- -
2) DIURNAL CURRENT					
DIR.	0	90	26	116	
VEL.	0.086	0.044	0.095	0.012	0.130
KAPPA	8	350	4	274	
ROTATION . . COUNTER CLOCKWISE					
3) SEMI-DIURNAL CURRENT					
DIR.	0	90	13	103	
VEL.	0.461	0.109	0.473	0.013	0.027
KAPPA	359	6	0	90	
ROTATION . . CLOCKWISE					
4) QUARTER-DIURNAL CURRENT					
DIR.	0	90	13	103	
VEL.	0.231	0.055	0.237	0.009	0.037
KAPPA	39	30	39	309	
ROTATION . . COUNTER CLOCKWISE					
5) RESIDUAL CURRENT (PROBABLE ERROR)					
DIR.	0	90	21	111	
VEL.	0.081	0.042	0.086	0.030	0.345

LIST OF HARMONIC CONSTANT

AXIS	CONST.	K1	O1	M2	S2	M4	MS4
NORTH							
VEL.	-0.060	0.082	0.139	0.264	0.158	0.114	0.139
KAPPA	--	133	71	353	0	31	38
EAST							
VEL.	0.030	0.042	0.071	0.062	0.037	0.027	0.033
KAPPA	--	114	53	0	7	22	29

COMBINED FACTOR 0.960 0.572 0.494
WHEN THIS IS GREATER THAN 4, CONSTANTS ARE DOUBTFUL.

STANDARD PORT ** I.FISCAL

	DIURNAL K1	O1	SEMI-DIURNAL M2	S2
VEL.	5.780	10.540	30.870	17.860
KAPPA	147.7	85.9	83.6	90.7

Table 10-16 Harmonic Constants of Tidal Currents(ST. 1)

HARMONIC ANALYZED RESULTS OF THE TIDAL CURRENT

AREA ** RIO DE JANEIRO STATION ** NO. ST1
DEPTH ** 3.0 M BELOW SEA SURFACE
DURATION ** 25 HOURS FROM 1992-10-24 TO 10-25

ELEMENTS OF CURRENT

	GEODETIC AXES		TIDAL CURRENT ELLIPSE		
	NORTH	EAST	MAJOR	MINOR	RATIO
1) CONSTANT CURRENT					
DIR.	0	90	222	- -	
VEL.	-0.076	-0.070	0.103	- -	- -
2) DIURNAL CURRENT					
DIR.	0	90	64	154	
VEL.	0.071	0.090	0.095	0.065	0.681
KAPPA	31	319	337	247	
ROTATION . . COUNTER CLOCKWISE					
3) SEMI-DIURNAL CURRENT					
DIR.	0	90	31	121	
VEL.	0.088	0.055	0.103	0.012	0.117
KAPPA	56	41	52	322	
ROTATION . . COUNTER CLOCKWISE					
4) QUARTER-DIURNAL CURRENT					
DIR.	0	90	26	116	
VEL.	0.035	0.019	0.039	0.009	0.223
KAPPA	12	341	6	276	
ROTATION . . COUNTER CLOCKWISE					
5) RESIDUAL CURRENT (PROBABLE ERROR)					
DIR.	0	90	168	258	
VEL.	0.017	0.012	0.017	0.011	0.659

LIST OF HARMONIC CONSTANT

AXIS	CONST.	K1	O1	M2	S2	M4	MS4
NORTH							
VEL.	-0.076	0.068	0.116	0.051	0.030	0.017	0.021
KAPPA	--	156	94	49	56	4	11
EAST							
VEL.	-0.070	0.086	0.146	0.031	0.019	0.009	0.011
KAPPA	--	83	22	34	41	333	340

COMBINED FACTOR 0.960 0.572 0.494
WHEN THIS IS GREATER THAN 4, CONSTANTS ARE DOUBTFUL.

STANDARD PORT ** I.FISCAL

	DIURNAL		SEMI-DIURNAL	
	K1	O1	M2	S2
VEL.	5.780	10.540	30.870	17.860
KAPPA	147.7	85.9	83.6	90.7

Phase 3

Table 2.3-2 Harmonic Constants of Tidal Currents (St. H)

```
       ***HARMONIC ANALYZED RESULTS OF THE TIDAL CURRENT***
 0AREA     **  RIO DE JANEIRO          STATION ** NO.  ST.H
  DEPTH    **  3.0 M BELOW SEA SURFACE
  DURATION ** 25 HOURS FROM  1993- 3-23  TO  3-24
 0      *ELEMENTS OF CURRENT*

                  GEODETIC AXES         TIDAL CURRENT ELLIPSE
                NORTH      EAST      MAJOR      MINOR      RATIO
 01) CONSTANT CURRENT
      DIR.          0         90         40        - -
      VEL.      0.024      0.021      0.031        - -        - -
 02) DIURNAL CURRENT
      DIR.          0         90          0         90
      VEL.      0.035      0.001      0.035      0.001      0.031
     KAPPA        213        280        213        303
     ROTATION . . CLOCKWISE
 03) SEMI-DIURNAL CURRENT
      DIR.          0         90         12        102
      VEL.      0.911      0.210      0.934      0.003      0.004
     KAPPA        354        355        354         84
     ROTATION . . CLOCKWISE
 04) QUARTER-DIURNAL CURRENT
      DIR.          0         90         13        103
      VEL.      0.337      0.083      0.347      0.005      0.013
     KAPPA        113        110        113         23
     ROTATION . . COUNTER CLOCKWISE
 05) RESIDUAL CURRENT (PROBABLE ERROR)
      DIR.          0         90         17        107
      VEL.      0.099      0.056      0.103      0.049      0.475
 0
     *LIST OF HARMONIC CONSTANT*

  AXIS   CONST.    K1      O1      M2      S2      M4     MS4
 0NORTH
    VEL.  0.024  0.050  0.085  0.576  0.345  0.150  0.183
   KAPPA   --      345    283    348    355     88     95
 0EAST
    VEL.  0.021  0.002  0.003  0.133  0.079  0.037  0.045
   KAPPA   --       51    350    349    356     85     92
```

Harmonic Constants of Tidal Currents (St. J)

HARMONIC ANALYZED RESULTS OF THE TIDAL CURRENT

0AREA ** RIO DE JANEIRO STATION ** NO. ST.J

DEPTH ** 3.0 M BELOW SEA SURFACE

DURATION ** 25 HOURS FROM 1993- 3-23 TO 3-24

0 *ELEMENTS OF CURRENT*

	GEODETIC AXES		TIDAL CURRENT ELLIPSE		
	NORTH	EAST	MAJOR	MINOR	RATIO
01) CONSTANT CURRENT					
DIR.	0	90	0	- -	
VEL.	0.006	0.000	0.006	- -	- -
02) DIURNAL CURRENT					
DIR.	0	90	119	209	
VEL.	0.023	0.040	0.046	0.004	0.082
KAPPA	93	283	281	191	
ROTATION . . COUNTER CLOCKWISE					
03) SEMI-DIURNAL CURRENT					
DIR.	0	90	123	213	
VEL.	0.133	0.199	0.239	0.012	0.048
KAPPA	12	186	188	278	
ROTATION . . CLOCKWISE					
04) QUARTER-DIURNAL CURRENT					
DIR.	0	90	125	215	
VEL.	0.065	0.092	0.113	0.003	0.024
KAPPA	114	291	292	22	
ROTATION . . CLOCKWISE					
05) RESIDUAL CURRENT (PROBABLE ERROR)					
DIR.	0	90	98	188	
VEL.	0.017	0.035	0.035	0.016	0.452

0

LIST OF HARMONIC CONSTANT

AXIS	CONST.	K1	O1	M2	S2	M4	MS4
0NORTH							
VEL.	0.006	0.034	0.057	0.084	0.050	0.029	0.035
KAPPA	--	224	162	6	13	89	96
0EAST							
VEL.	0.000	0.058	0.098	0.126	0.075	0.041	0.050
KAPPA	--	55	353	180	187	266	273

3.3.3 Tidal Current Map

Using the harmonic constants of tidal currents obtained by the harmonic analysis to observed data, we can know hourly tidal currents as well as a constant current at each station.

Fig. 3.3-1 shows the distribution of constant currents in the Guamabara Bay, which expresses the speed and direction as a vector at each observation point.

With regard to tidal currents, hourly tidal currents are predicted using the harmonic constants at each station for some seasons as shown in Appendix 3.

Fig. 3.3-2 shows the distribution of the predicted hourly tidal currents on the mean spring tides, which mean the annual average state of the spring tides (24 times of spring tides are in a year).

The time of the tidal current map is expressed with a lumar hour after the high water at the part of Rio de Janeiro (Ilha Fiscal).

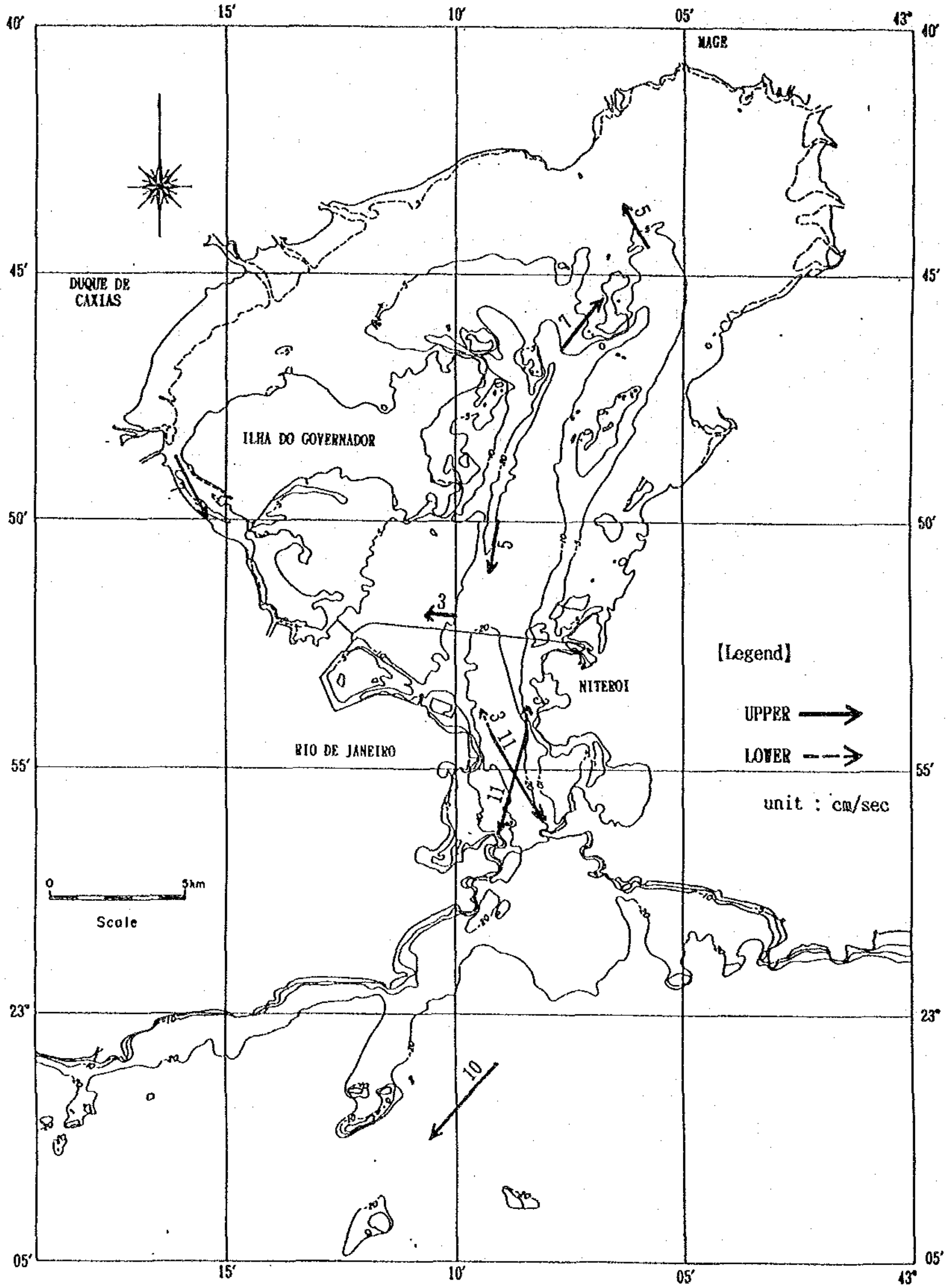


Fig. 3.3-1 Constant Current Map

Fig.3.3-2

Tidal Current Map on Mean Spring Tides

T = 0 (High Water)

T = 1 (1 hour after H.W.)

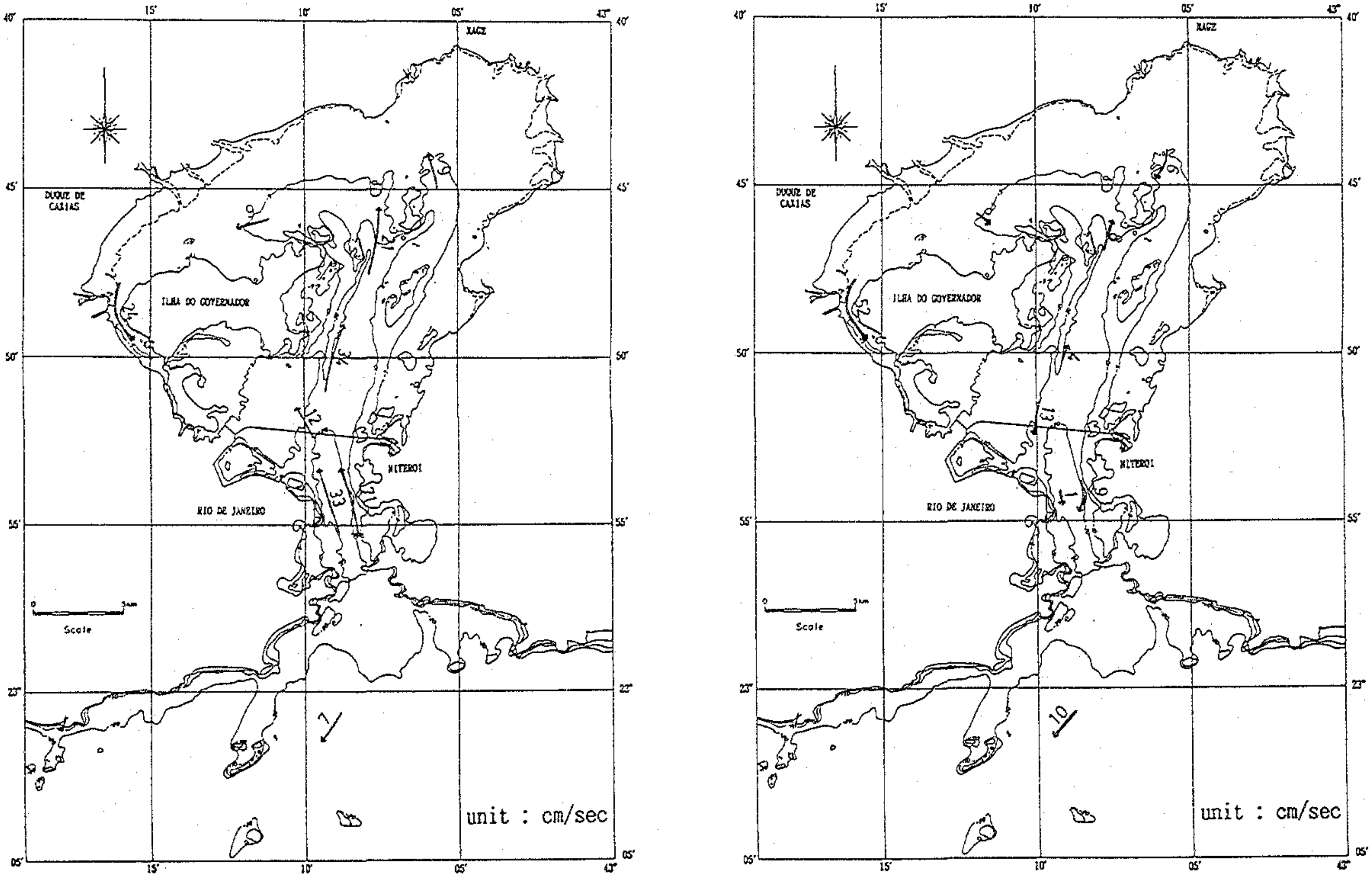
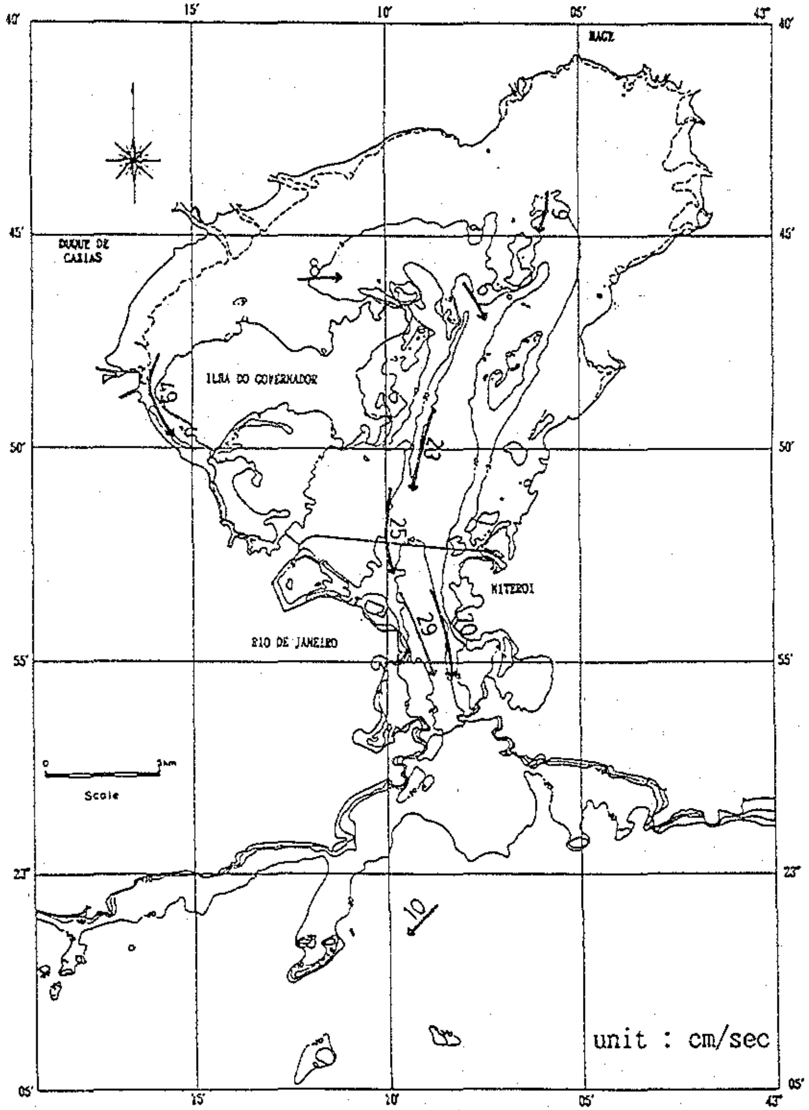


Fig. 3.3-2 (1) Tidal Current Map on Mean Spring Tides

T = 2 (2 hours after H.W.)



T = 3 (3 hours after H.W.)

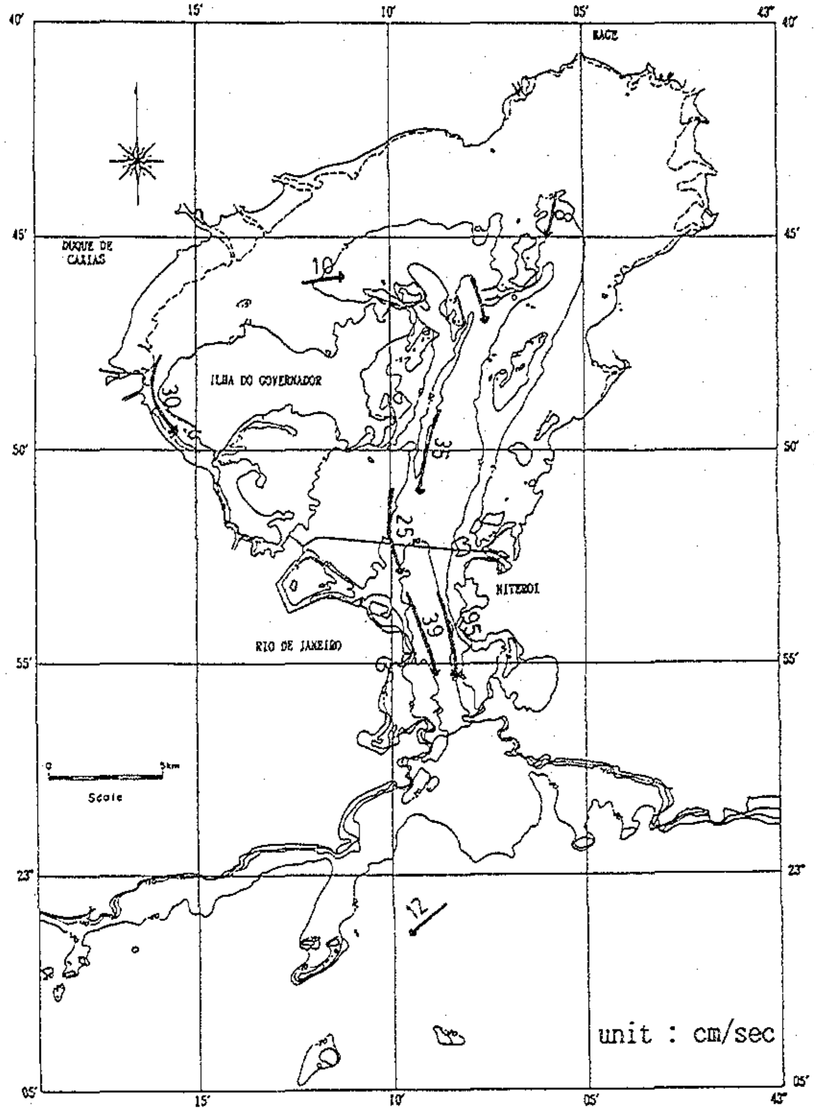
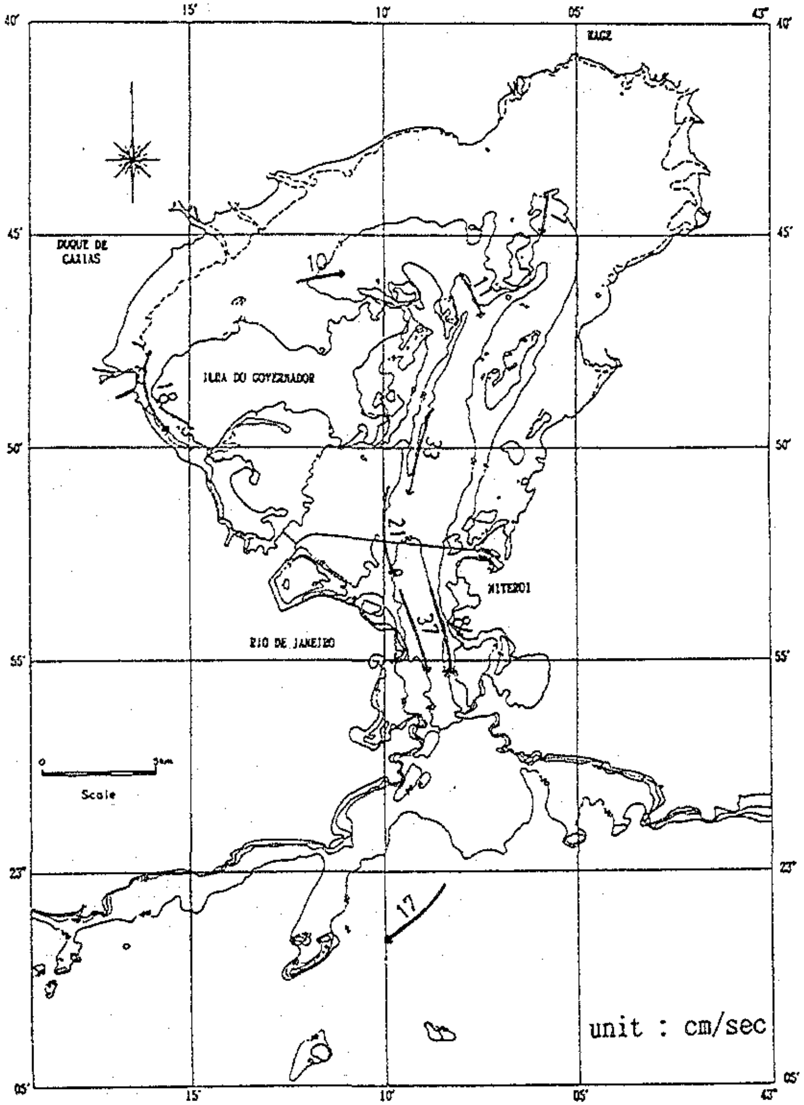


Fig. 3.3-2 (2) Tidal Current Map on Mean Spring Tides

T = 4 (2 hours before L.W.)



T = 5 (1 hour before L.W.)

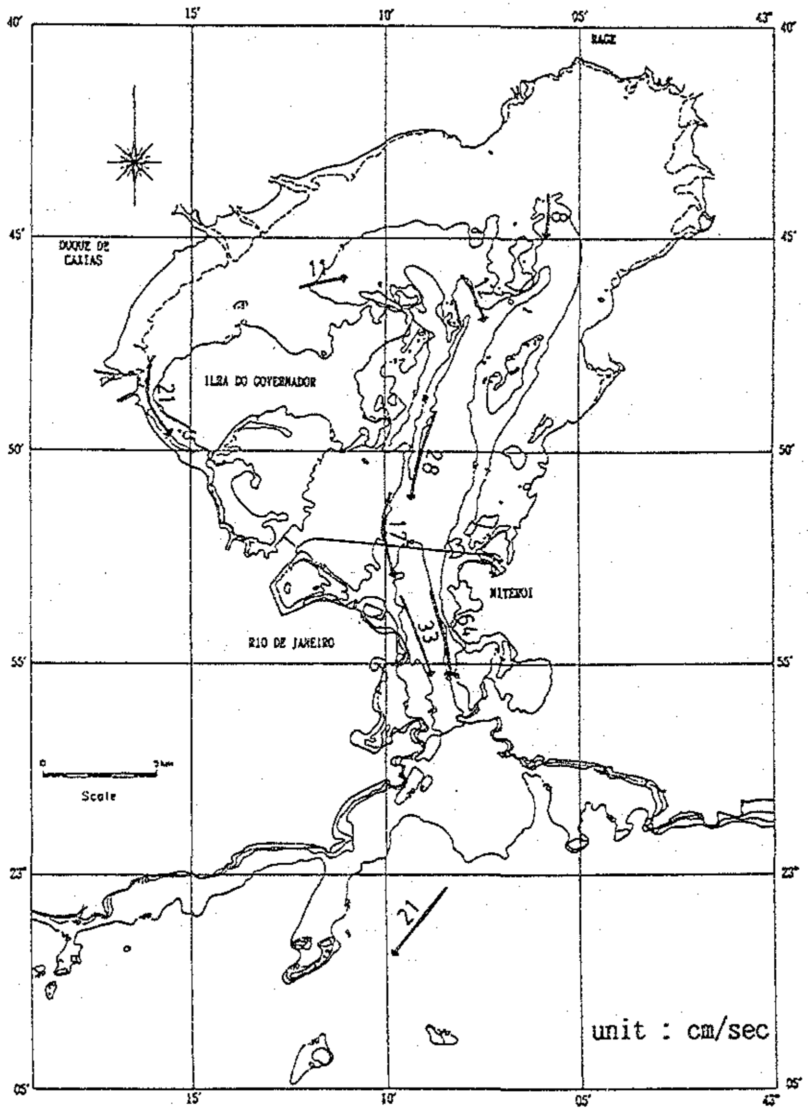
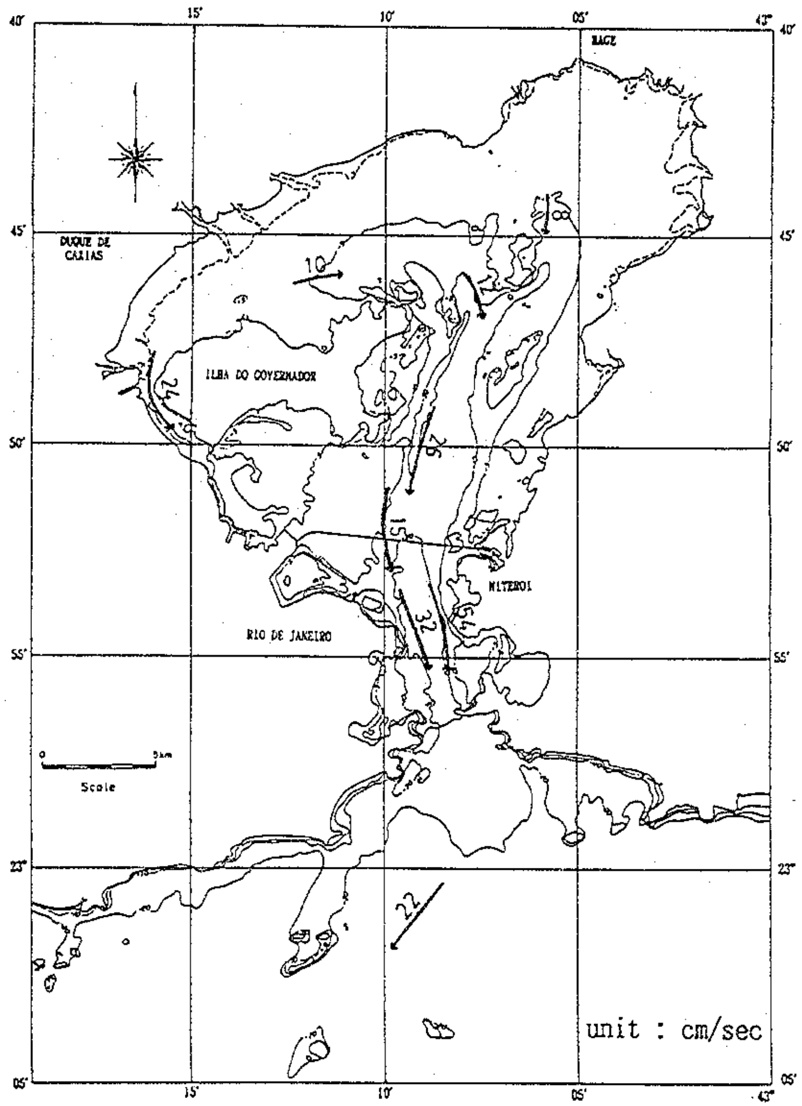


Fig. 3.3-2 (3) Tidal Current Map on Mean Spring Tides

T = 6 (Low Water)



T = 7 (1 hour after L.W.)

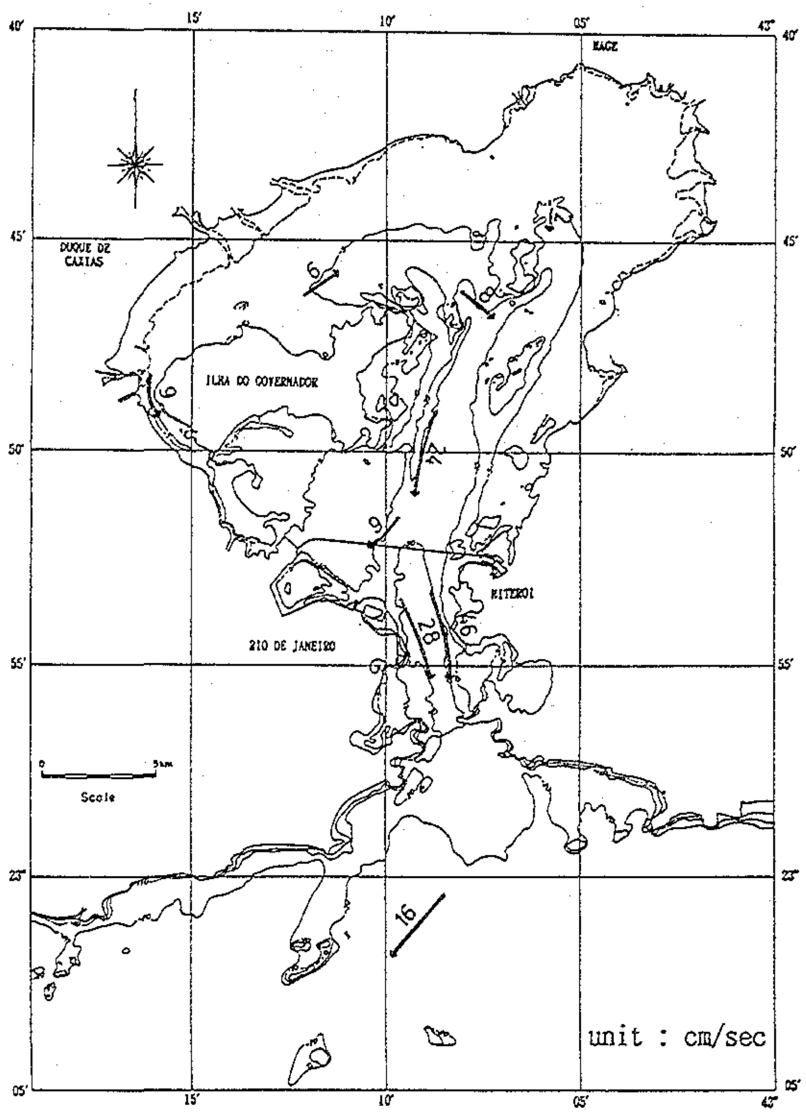


Fig. 3.3-2 (4) Tidal Current Map on Mean Spring Tides

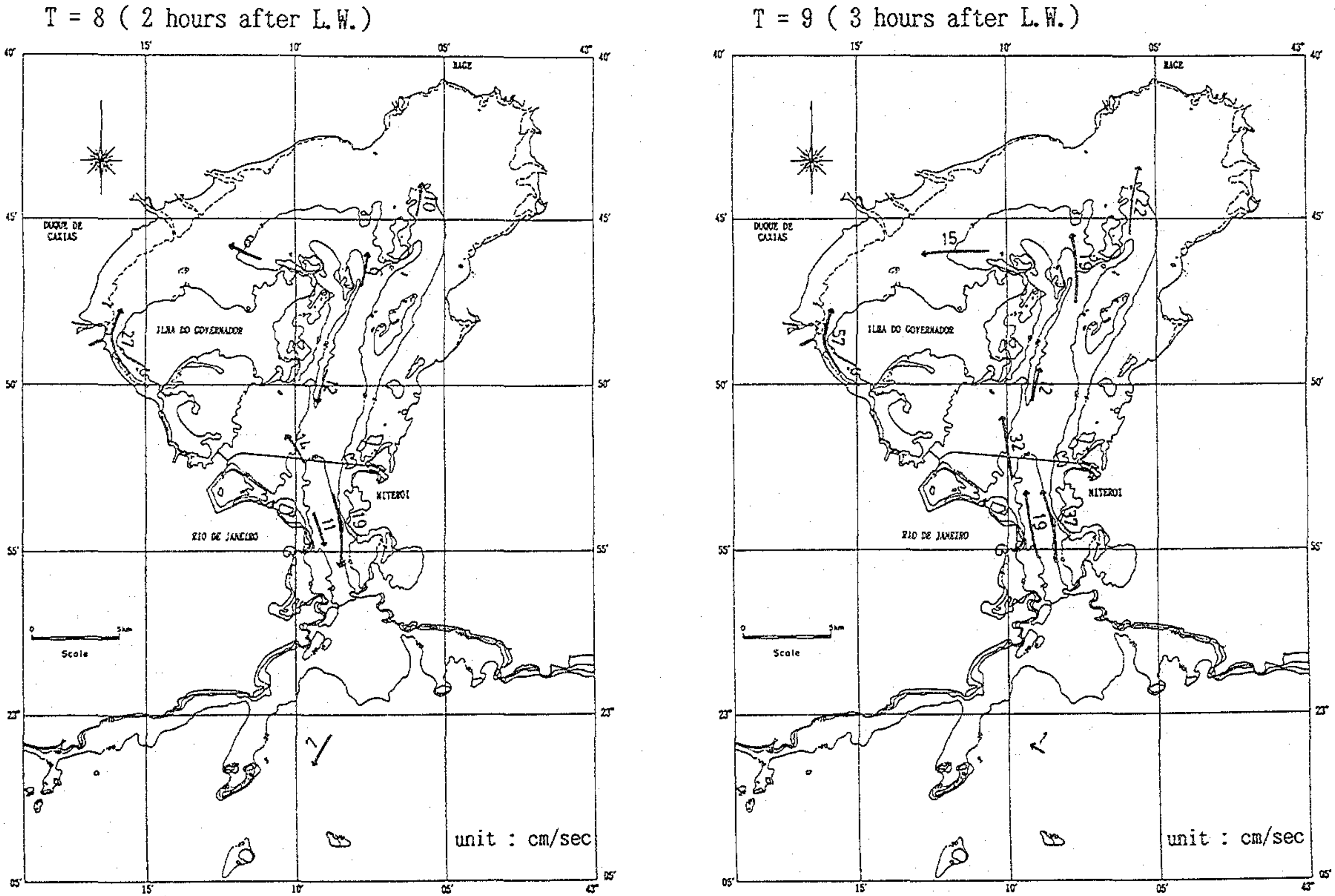


Fig. 3.3-2 (5) Tidal Current Map on Mean Spring Tides

T = 10 (2 hours before H.W.)

T = 11 (1 hour before H.W.)

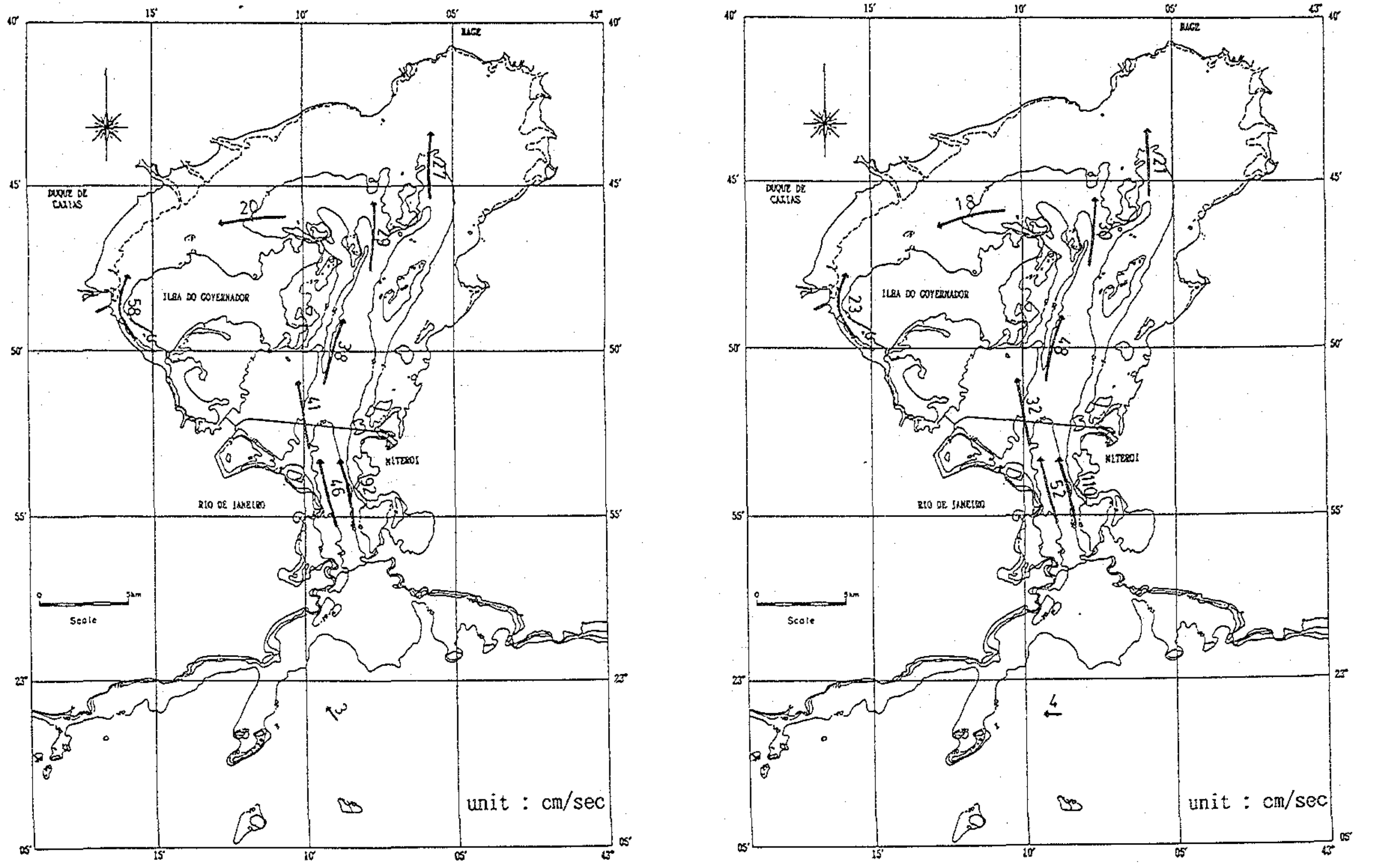


Fig. 3.3-2 (6) Tidal Current Map on Mean Spring Tides

3.4 Characteristics of Tidal Currents

3.4.1 Seasonal Change of Tidal Currents

In this study, the tidal current observation was performed twice on the same points in june and in October to November 1992 and a supplementary observation in March 1993. The frequency of the direction and speed in both seasons at representative stations are shown in Fig. 3.4-1 and Fig. 3.4-2.

Fig. 3.4-1 shows that the frequency of directions is almost the same at St.C situated in the central part of the bay and the principal direction was north-south in both seasons. Though the maximum speed observed was 52 to 54 cm/sec, with the same order at both stations, the speed in October was faster than in June.

At St.F, situated in the northeast of Ilha de Paqueta, the maximum speed in October was 1.5 times of June. Regarding the direction, the frequency distribution was nearly the same, with the flood current moving north and the ebb current south west.

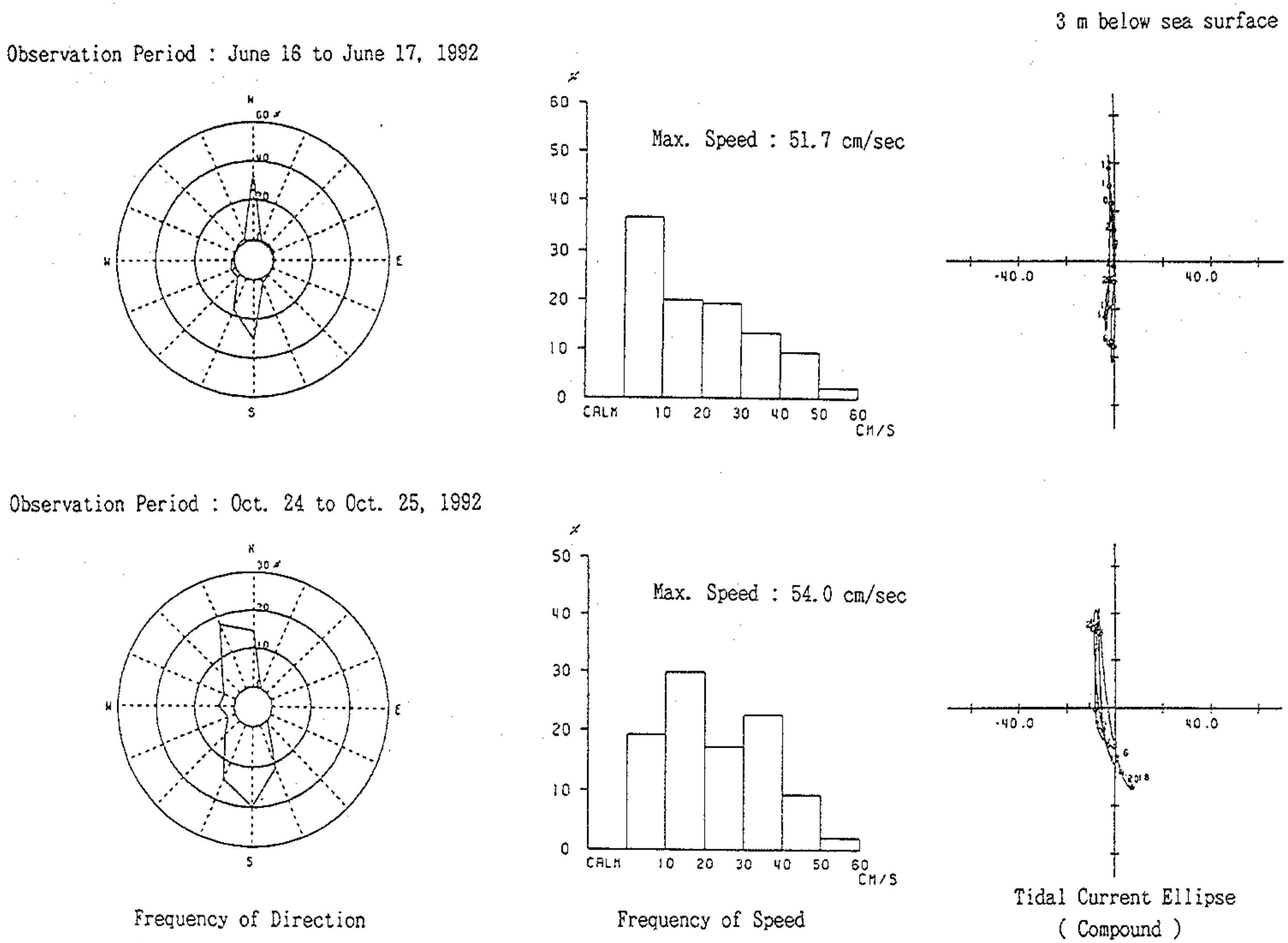


Fig. 3.4-1 Seasonal Change of Tidal Currents (St.C)

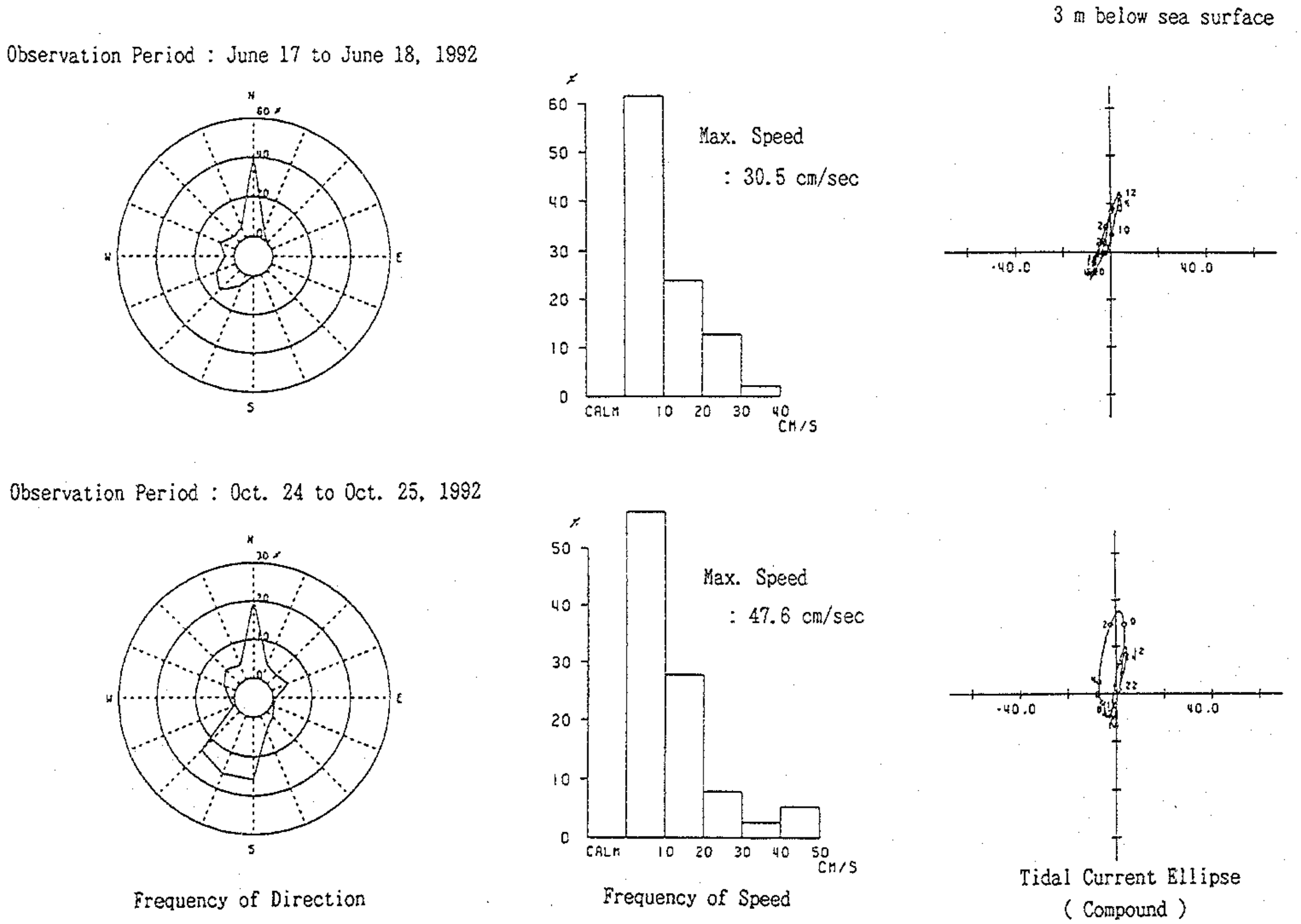


Fig. 3.4-2 Seasonal Change of Tidal Currents (St.F)

3.4.2 Vertical Change of Tidal Currents

Using the results of the two layer-observation performed at St.A and St.B at the mouth of the bay, the tidal current curves and current ellipses are shown in Fig. 3.4-3 and Fig. 3.4-4. We should like to emphasize that the observation period in June was conducted for twenty five hours to October's fifteen days and nights.

The characteristics of the difference between surface and bottom currents are seen in the duration of the flood and ebb currents. The duration of flood current is fairly shorter than that of the ebb current: wherein flood lasted for 4.5 hours and ebb for 8 hours, at the surface of both stations. On the other hand, the duration of flood and ebb currents is the same at about 6 hours at the bottom of both stations.

The maximum speed was observed to be faster in the bottom current in St.A in opposition to the surface current at St.B. The difference in speed of flood and the ebb currents was clearly observed in November, and the results show that the flood current is faster than the ebb current.

With regard to direction, bottom current's direction has a clockwise deviation of around 20 degrees at St.A in both seasons.

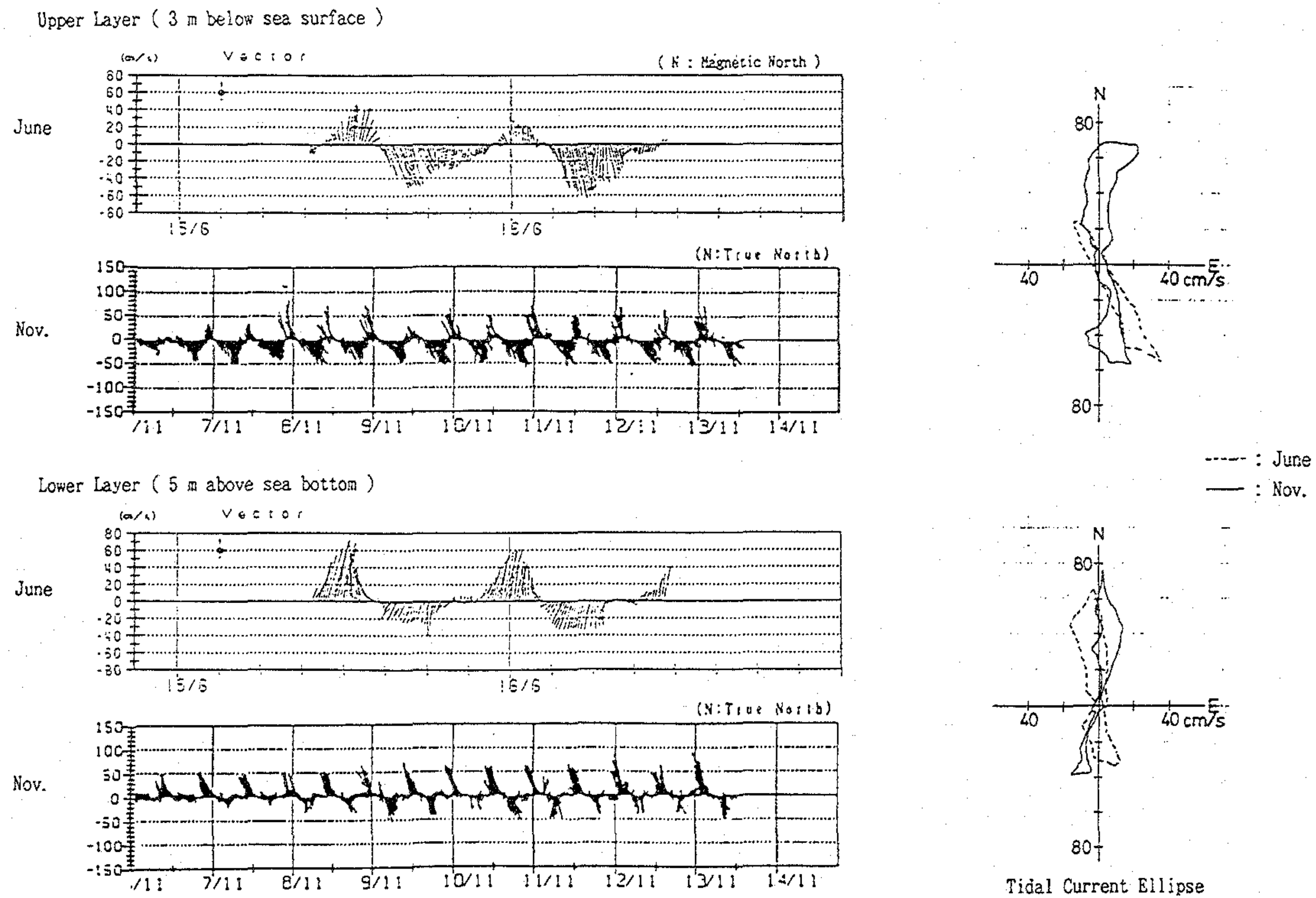


Fig. 3.4-3 Vertical Change of Tidal Currents (St.A)

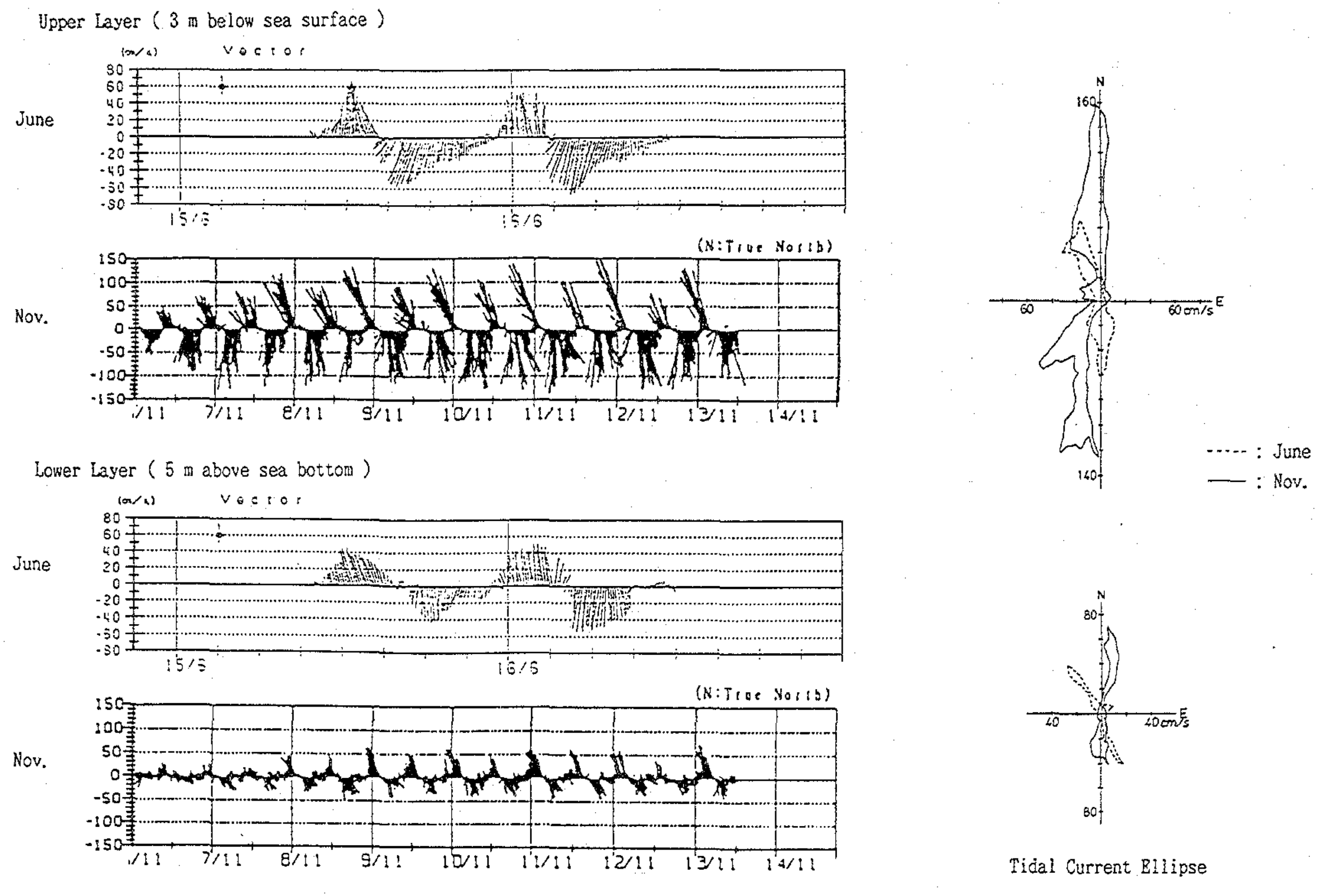


Fig. 3.4-4 Vertical Change of Tidal Currents (St.B)

3.4.3 Currents in the Bay

Fig. 3.4-5 with tidal ellipse visually gives an outline of the tidal current in the Guanabara Bay. The major axis of ellipses shows that the principal direction at each point.

The currents in the bay are controlled not only in topography of the coastal line but also of the submarine topography. Therefore, the principal directions of tidal currents follow an abyss in the center of the bay which is used as a navigational route.

The tidal current decreases its speed, which is expressed by the length of the major axis, in proportion to the distance form the mouth of the bay.

The flatness of the ellipse denotes a short slack period.

The strong ebb current arises in about three hours after high water at Ilha Fiscal at the mouth to the central part of the bay, and the strongest flood current can be observed in one to two hours before high water.

It should be noteworthy that the velocity in Fig.3.3-2 is the speed in the mean spring tides. The maximum speed in a year, speed in maximum spring tides, will be estimated by multiplying the speed by about 1.3 for the central part to about 1.7 for the mouth and the inner part of the bay

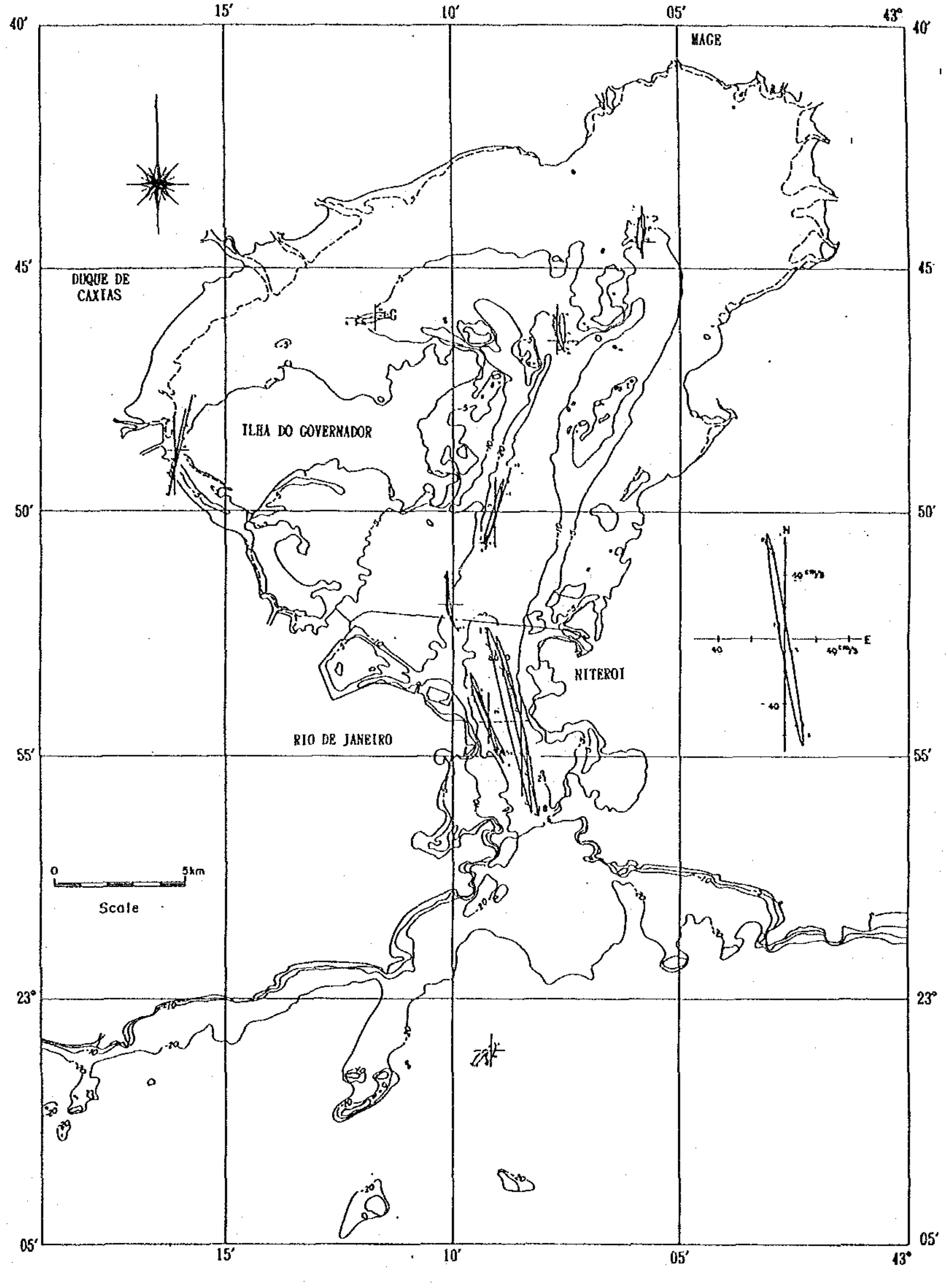


Fig. 3.4-5 Tidal Currents in the Bay

CHAPTER 4

BOTTOM SEDIMENTS

4.1 Bottom Sediments

4.1.1 Quality of Bottom Sediments

Bottom sediments were sampled at fifteen stations shown in Fig. 4.1-1 on June 4th to 6th, 1992 from the surface of the sea bottom using on Eckman-Birge sampler. The core samples were also collected at two stations, St. 9 and St. 13.

The collected samples were analysed on the following items;

COD, Volatile Solids, T-N, T-P, TOC, Total Sulfide
Cu, Zn, T-Hg, Cr, Cd, Pb, DDT, PCB
Particle Size

The results of chemical analyses are stated in Supporting Report IV.

The survey area is roughly divided into four areas, as shown in Figure 4.1-1, according to the field observation.

Area D (St. 3) does not seem to be seriously polluted yet. Odorless sands make up its bottom material.

In area C (St. 5 and St. 8), the bottom materials were made up of fine sands weakly smelling of decomposed organic materials.

In area B (St. 6, 9 and 11), the bottom materials were made up of sand-silts weakly smelling of decomposed organic materials.

In area A, the bottom materials was made up of silt-clay smelling of sulfide and sewage, black or dark grey in color with a shiny surface. The odor of sulfide, which indicates the progressive state of anaerobic conditions, is especially strongly observed near the surface of the bottom of St. 4, 7, 12 and 16.

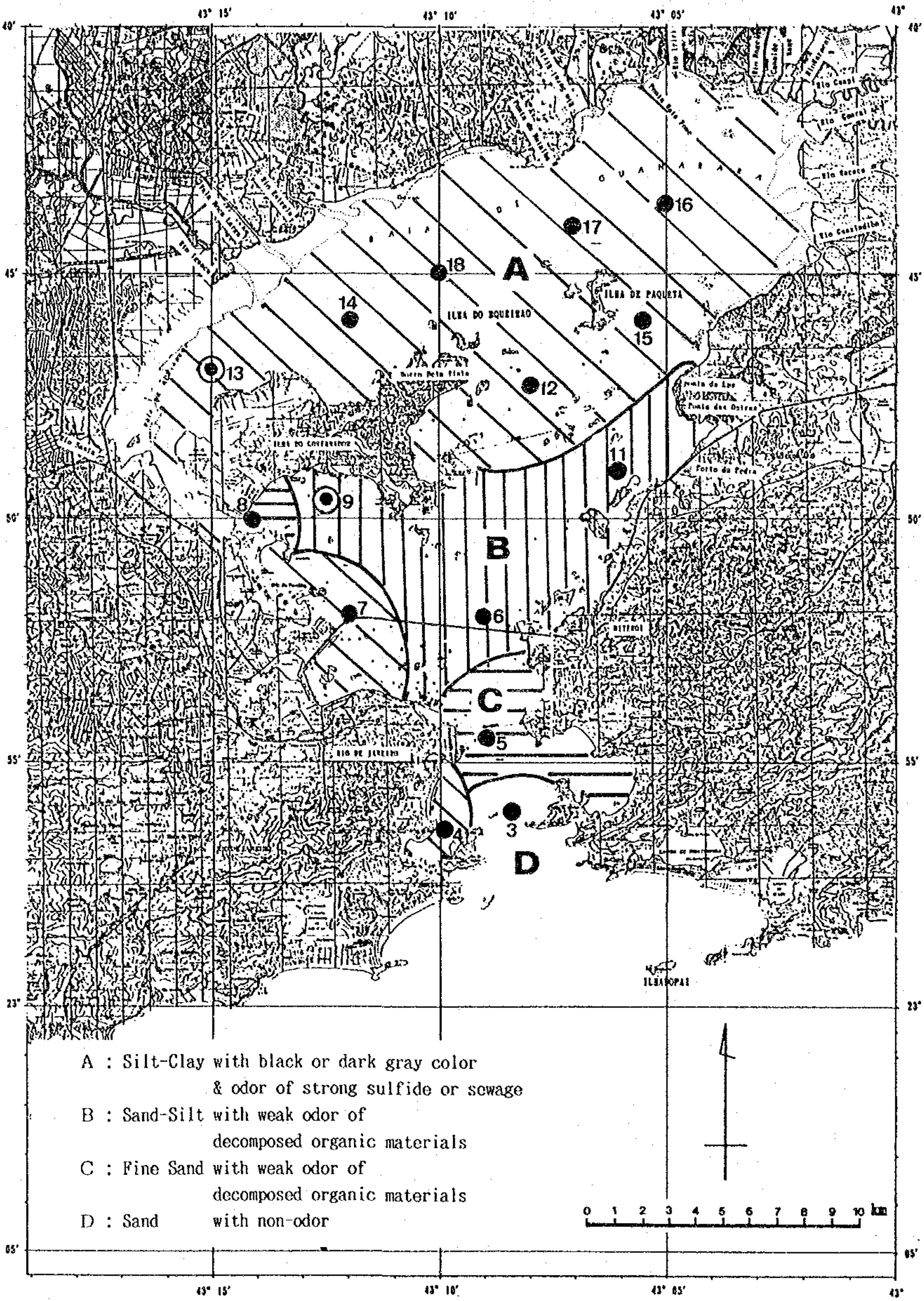


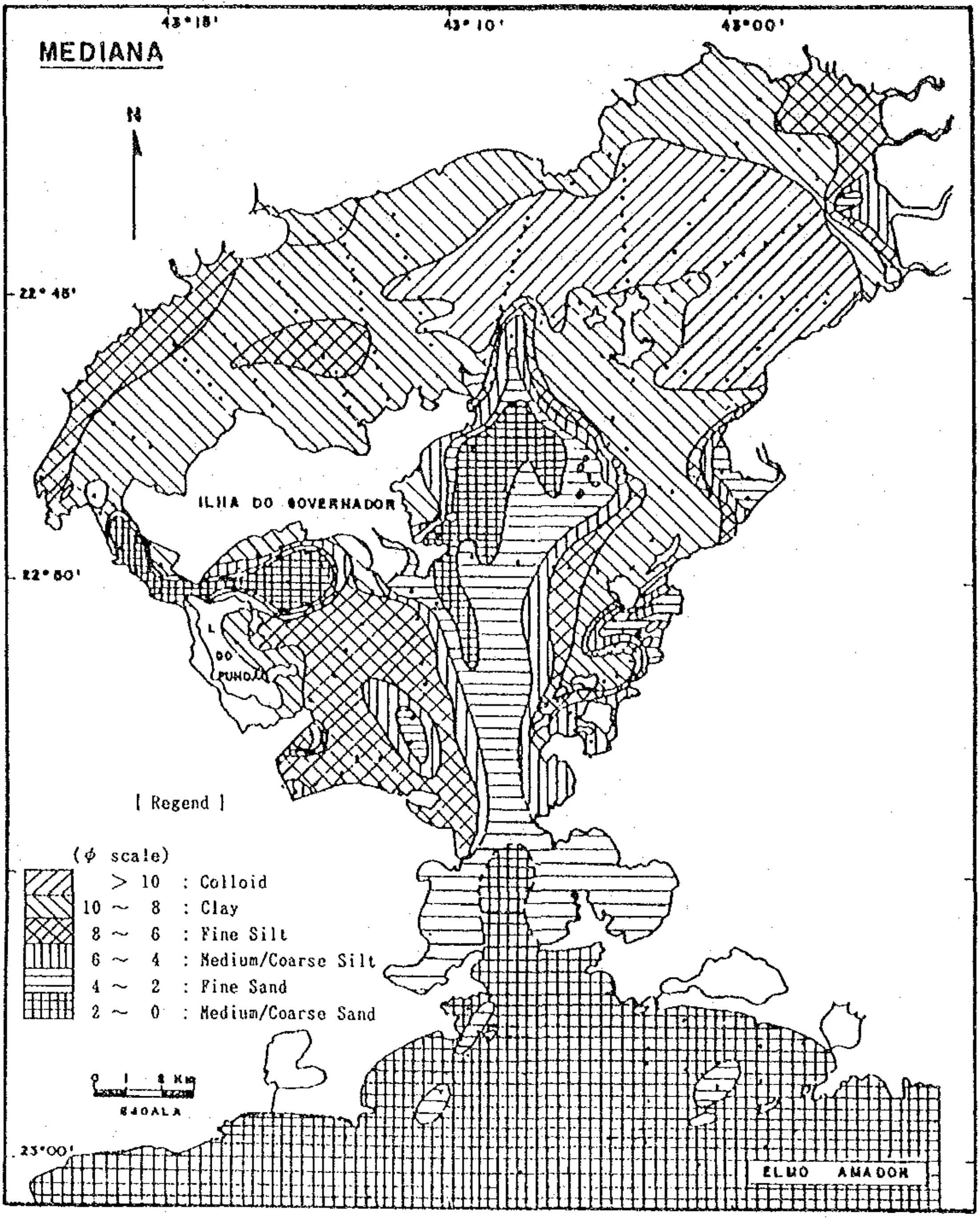
Fig. 4.1-1 Sampling Stations of Bottom Sediments

4.1.2 Grain Size Distribution

Sea bottom sediments in the bay has been studied in detail by Prof. Elmo Amador by dividing the distribution of the sea bottom materials into six categories using ϕ scale as shown in Fig. 4.1-2 ($\phi = -\log_2 d(mm)$).

This shows that fine silts to colloids are widely distributed in the inner part and in the coastal area of the middle part of the bay. On the other hand, fine to medium sand are distributed along the deeper part of the center of the bay and in the area between Ilha do Governador and Ilha do Fundao.

The study team collected fifteen (15) samples of surface sediment in the bay. Twelve (12) of them contains more than 90% of clay and silt. This result does not contradict with that of Prof. E. Amador.



(Elmo da Silva Amador : Sedimentos de Fundo da Baia de Guanabara)

Fig. 4.1-2 Grain Size Distribution of Sea Bottom Materials
(Median Diameter)

4.2 Thickness of Sediments

4.2.1 Acoustic Prospecting

The acoustic prospecting was carried out in the bay to grasp the distribution of the soft layer (silt - clay) using a depth meter with dual frequencies, that is a high frequency of 200 KHz for sea bed and a low frequency of 7, 10 or 12 KHz for materials under the seabed, successively in the inner parts of the bay of the Phase 1 Study.

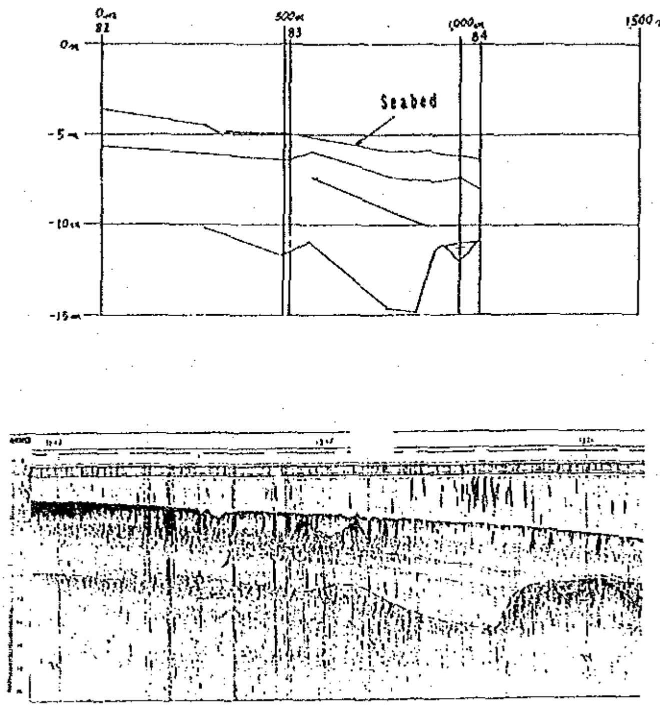
The typical profile are shown in Fig. 4.2-1 together with the location.

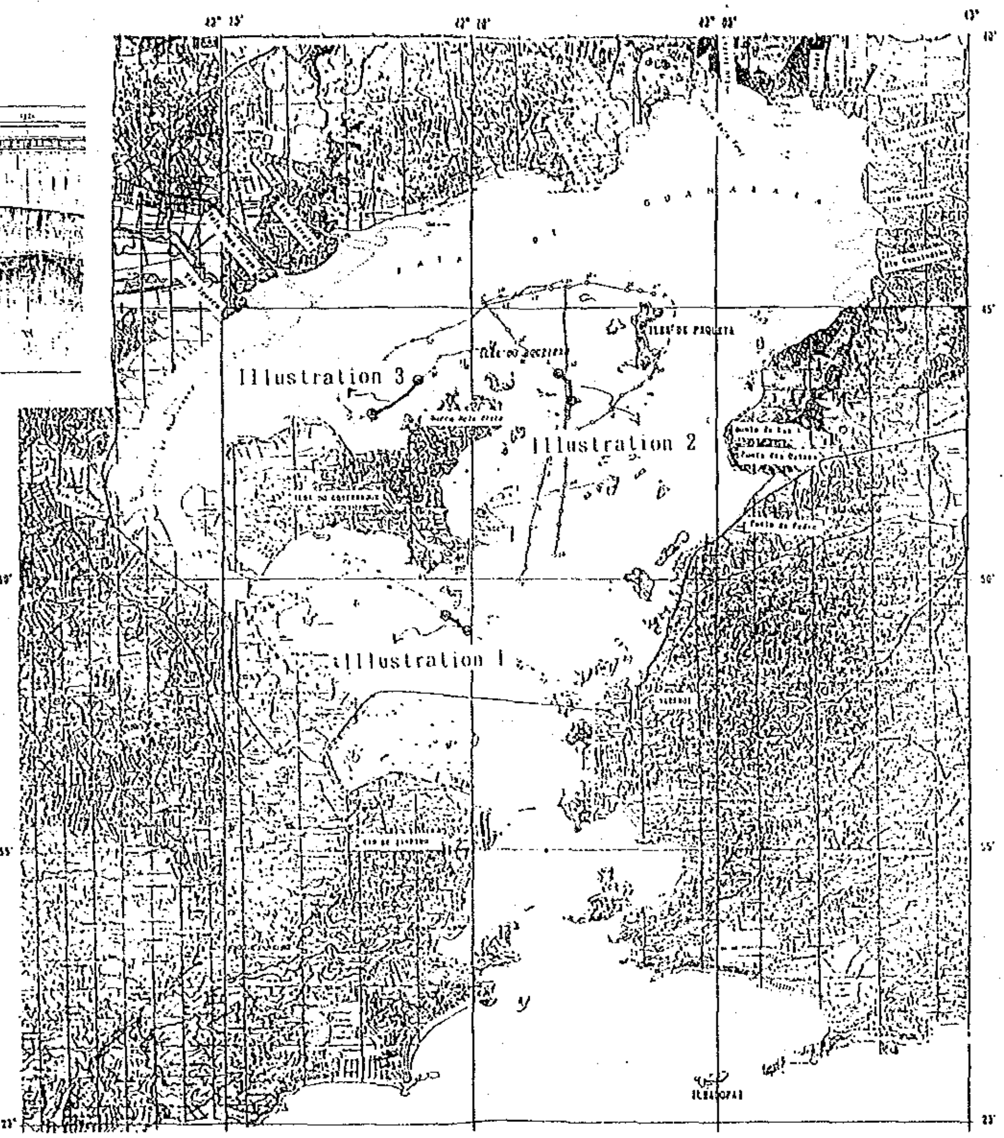
The tracking chart of the acoustic prospecting is shown in Fig. 4.2-2 and the preliminary iso-thickness maps for suspendid sediments and silts are shown in Fig.4.2-3 and Fig.4.2-4, respectively.

The results show that suspendid sediments are widely distributed on the inner part of the bay, especially with the thickness of one (1) to two (2) meters in the north part of the Ilha do Governador.

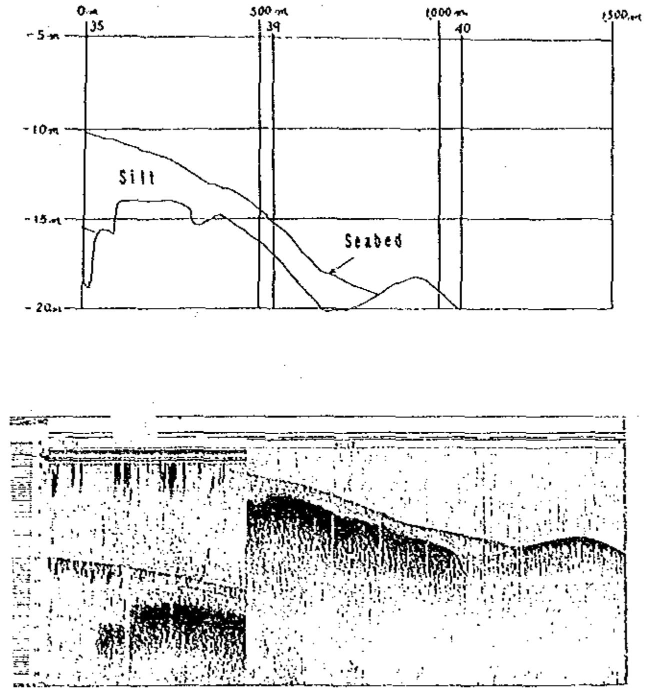
On the other hand, the thickness of silts is also distributed widely on the inner part of the bay with a maximum thickness around ten (10) meters. Thick silts are seen in the central part of the Jurujuba Bay, too.

【 Illustration-3 】





【 Illustration-2 】



【 Illustration-1 】

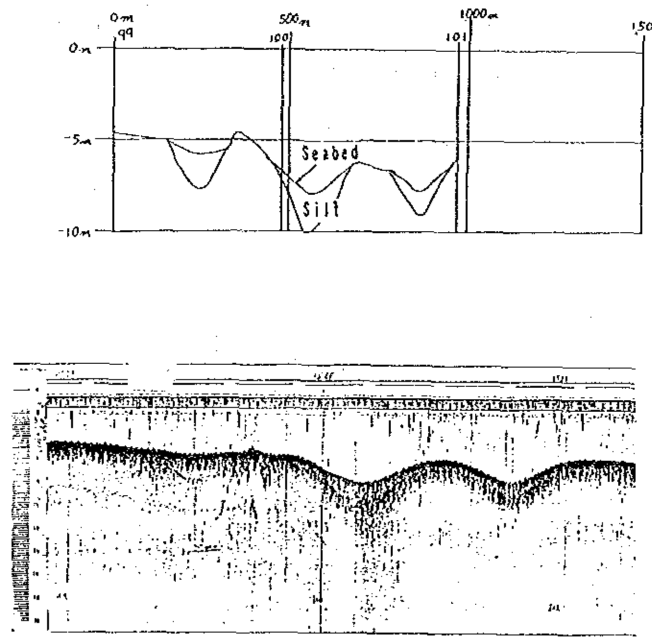


Fig. 4.2-1 Typical Profiles of Acoustic Prospecting

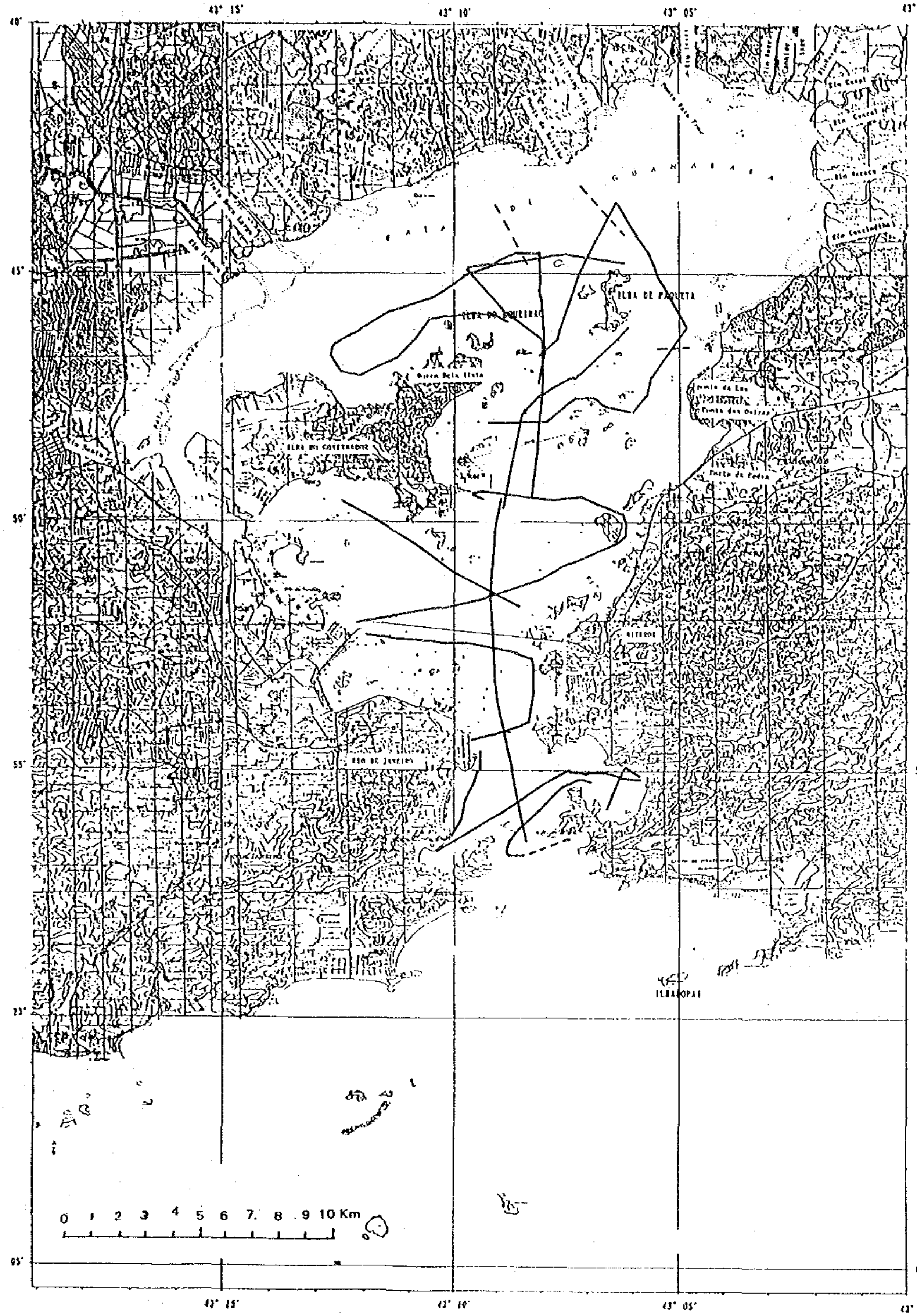


Fig. 4.2-2 Tracking Chart of Acoustic Prospecting

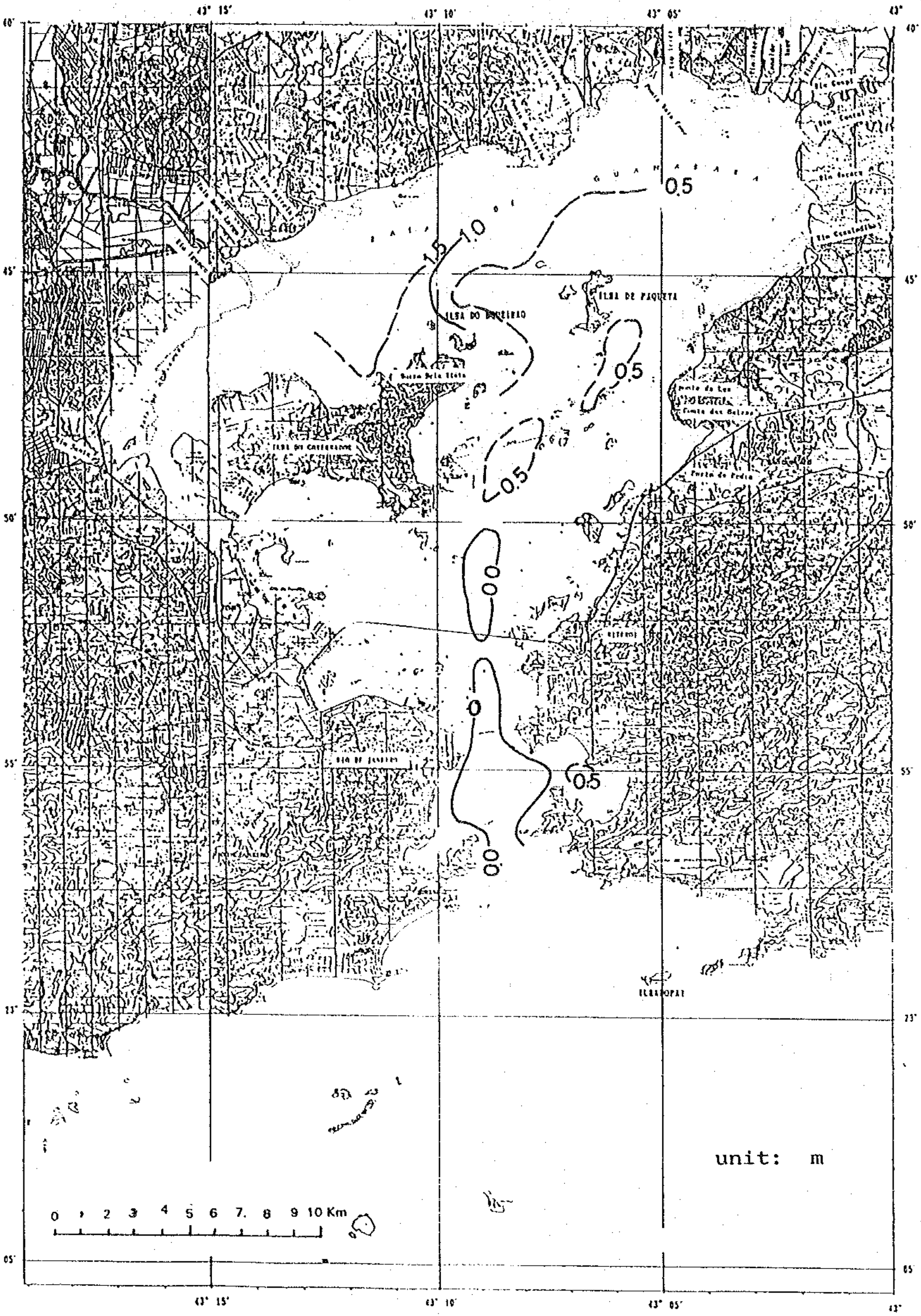


Fig. 4.2-3 Iso-Thickness Map of Suspendid Sediments

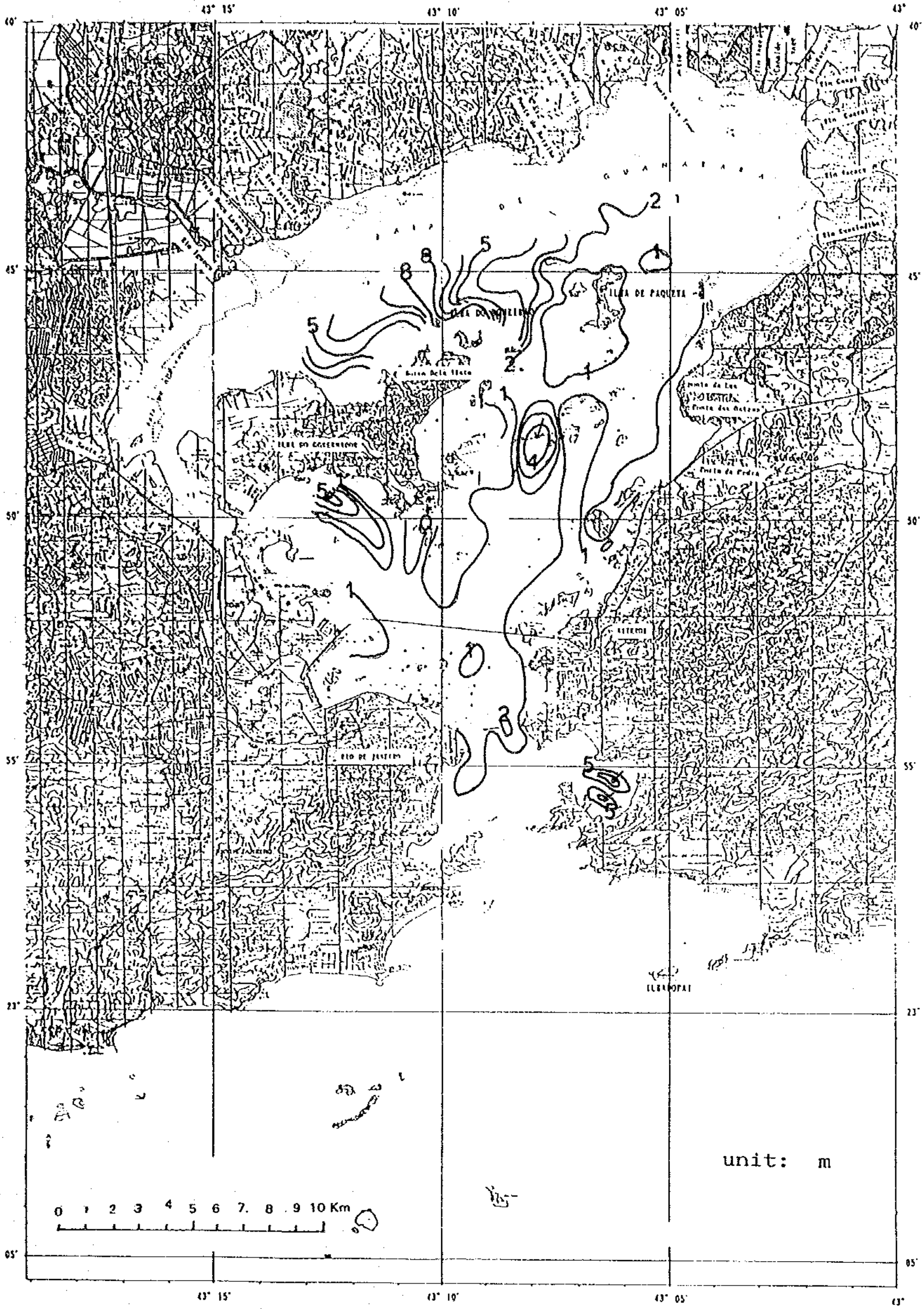


Fig. 4.2-4 Iso-Thickness Map of Silts

4.2.2 Core Sampling

The core samplings for the sea bottom materials were carried out on October 26 and 31, 1992 at four (4) stations shown in Fig.4.2-5 using a specially designed core sampler with a diameter of 3.8 cm.

The length obtained at each station by core sampling was as follows;

Station 23 : 97 cm
Station 24 : 126 cm
Station 25 : 160 cm
Station 26 : 140 cm

The relation between the core samples and acoustic profiles is shown in Fig.4.2-6 as a reference.

Above that, the following samples were prepared for the dating by the method of Pb^{210} in Japan.

Station 25 : Total 5 samples
0-6cm, 17-23 cm, 47-53 cm,
97 - 193 cm 148 - 155 cm

Station 26 : Total 5 samples
0-10cm, 17-23cm, 52-58cm,
87-93cm, 129.5-135.5cm

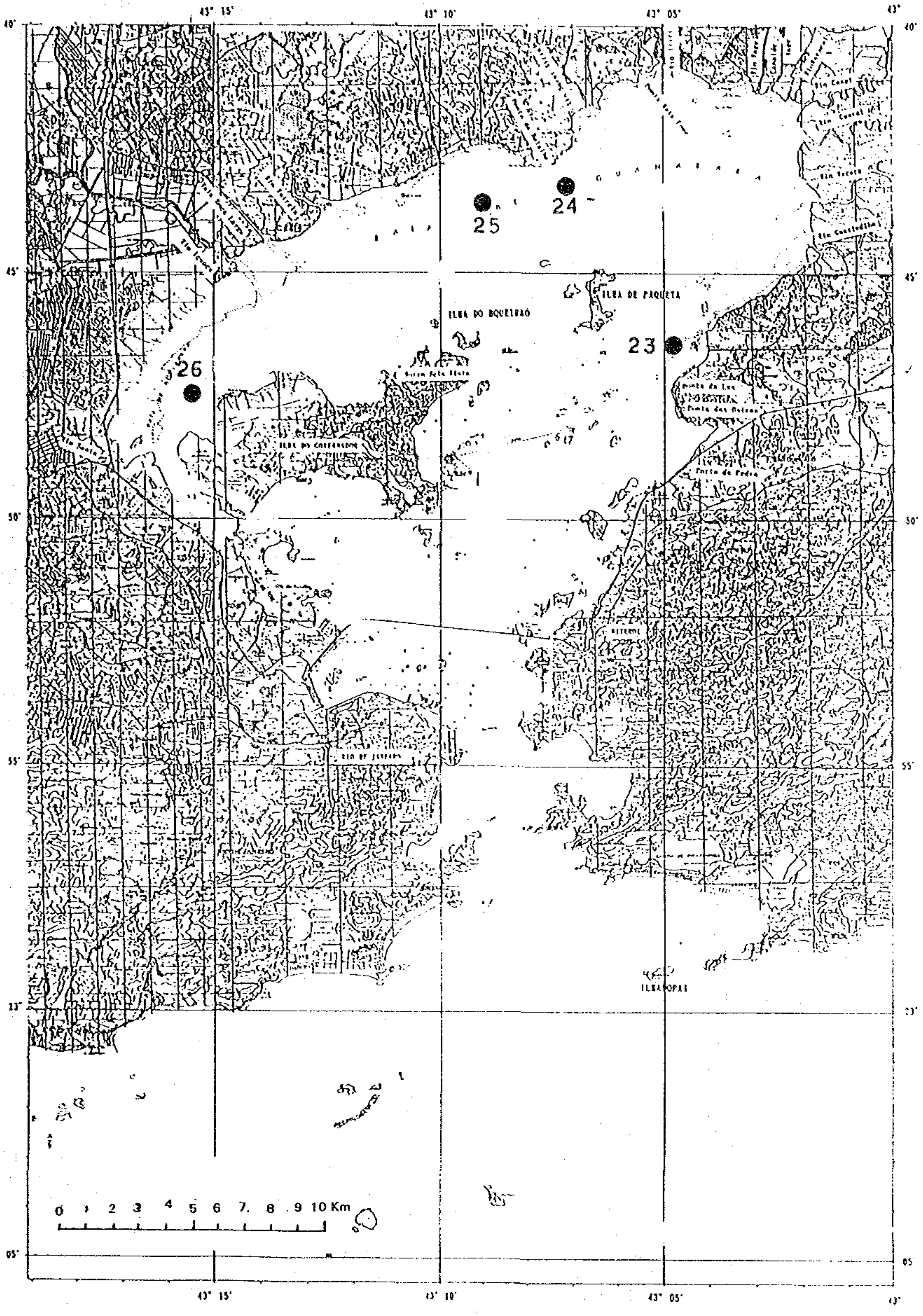


Fig. 4.2-5 Location Map of Core Sampling

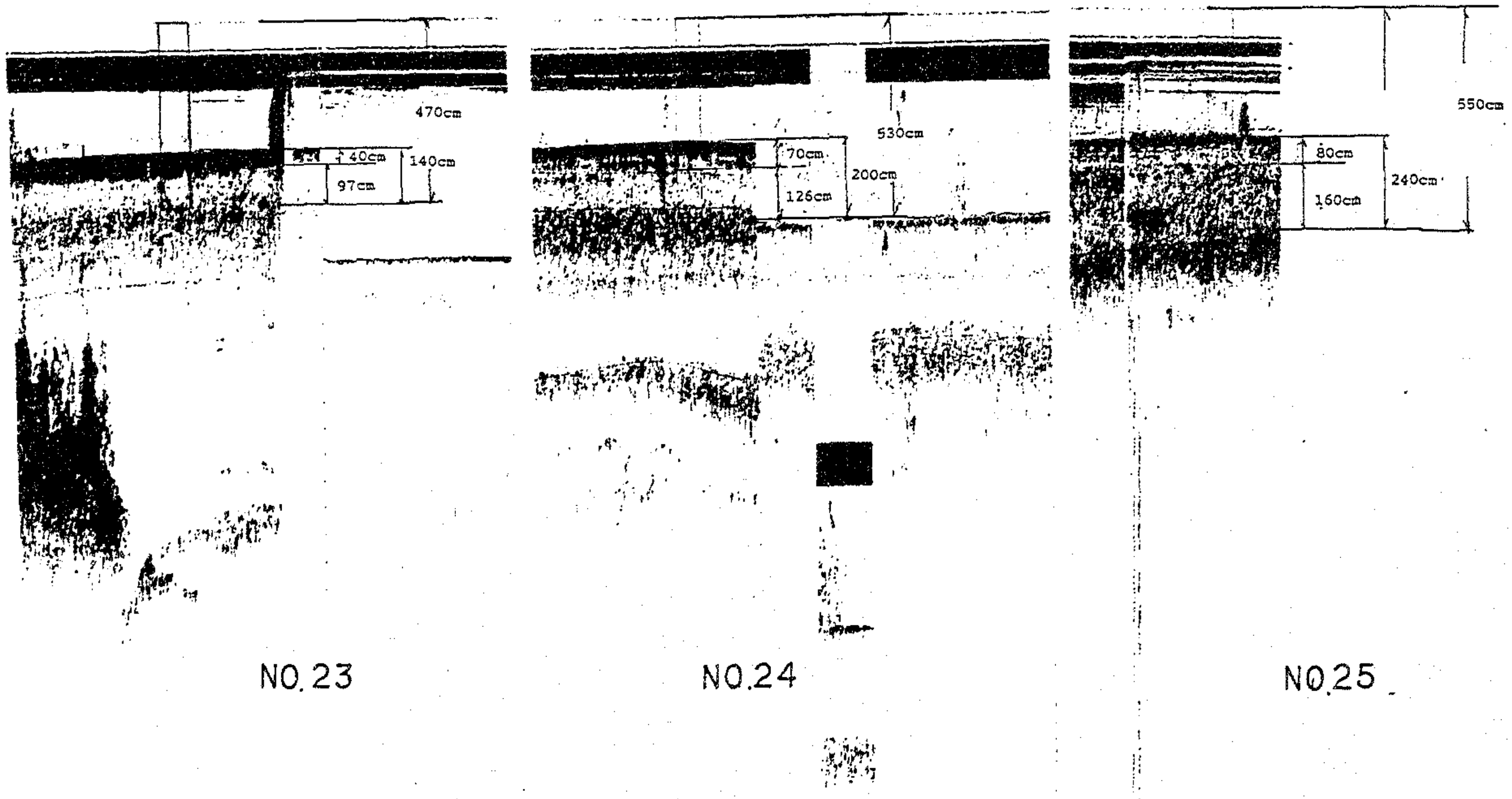


Fig. 4.2-6 Relation between Core samples and Acoustic Profiles

4.2.3 Thickness of Bottom Sediments

The thickness of soft sediments (clay to fine silt) varied irregularly in the bay depending on the topography and flow regime of the basement. It was confirmed, however, to be partially more than 10 meters in the northern part through acoustic prospecting.

Geological profiles of the bay by Prof. Elmo Amador shown in Fig. 4.2-7 also show that the sediments are around 10 meters thick in the inner part.

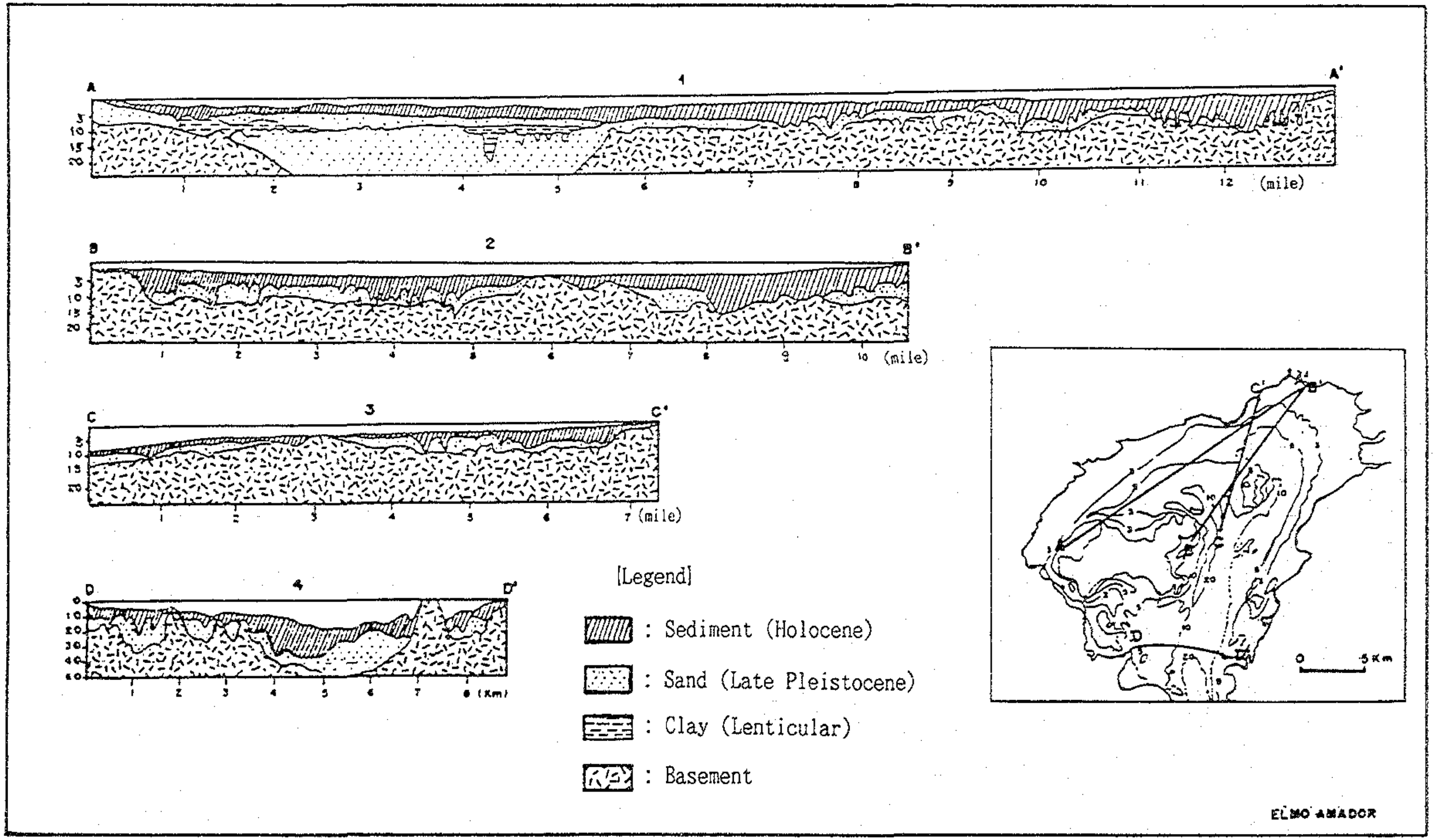


Fig. 4.2-7 Geological Profile of the Guanabara Bay

4.3 Annual Change of Seabed

To investigate the depth of the seabed in the inner part of the bay, the bathymetric survey was performed along the representative lines shown in Fig. 4.3-1.

The seabed profiles along the lines in Fig. 4.3-1 are shown in Fig. 4.3-2 and Fig. 4.3-3. These profiles show the seabed in this survey (1992) by the dotted line, in the Chart published at 1992 by the solid line and in that at 1962 by the dot-solid line.

these profiles show clearly that seabed on the Chart published in 1992 is shallow about 1 to 2 meters all over comparing with that in 1962. The seabed surveyed in this study have a tendency to be shallow comparing with the chart published in 1992 on the whole.

Further we should like to add that the actual survey period of the Chart published in 1992 was in April 1961 and August 1962 almost over the inner part of the bay as shown in Fig. 4.3-4. On the hand, the survey period of the chart published in 1962 was said to be between 1922 and 1938.

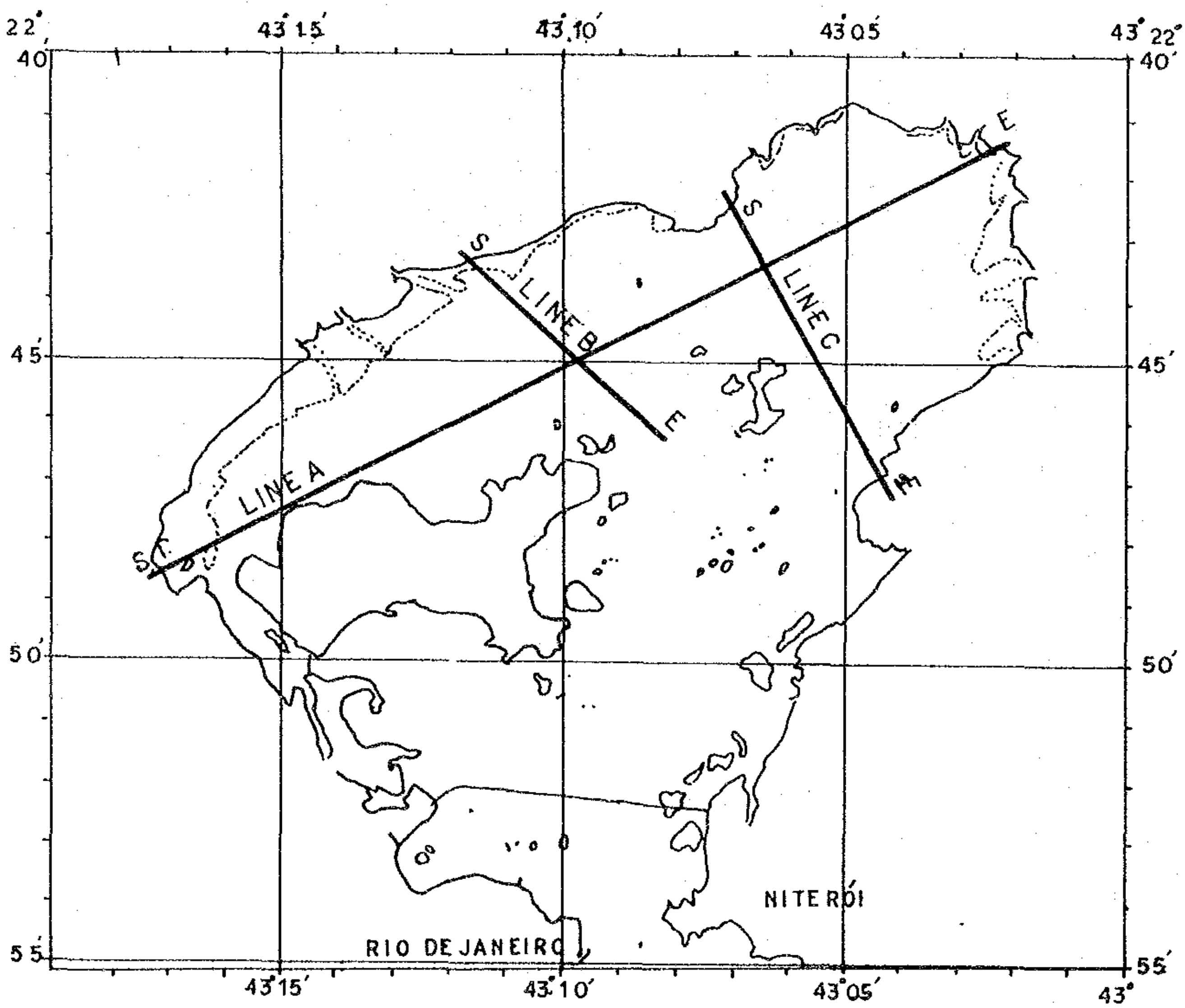


Fig. 4.3-1 Index Map for Profiles

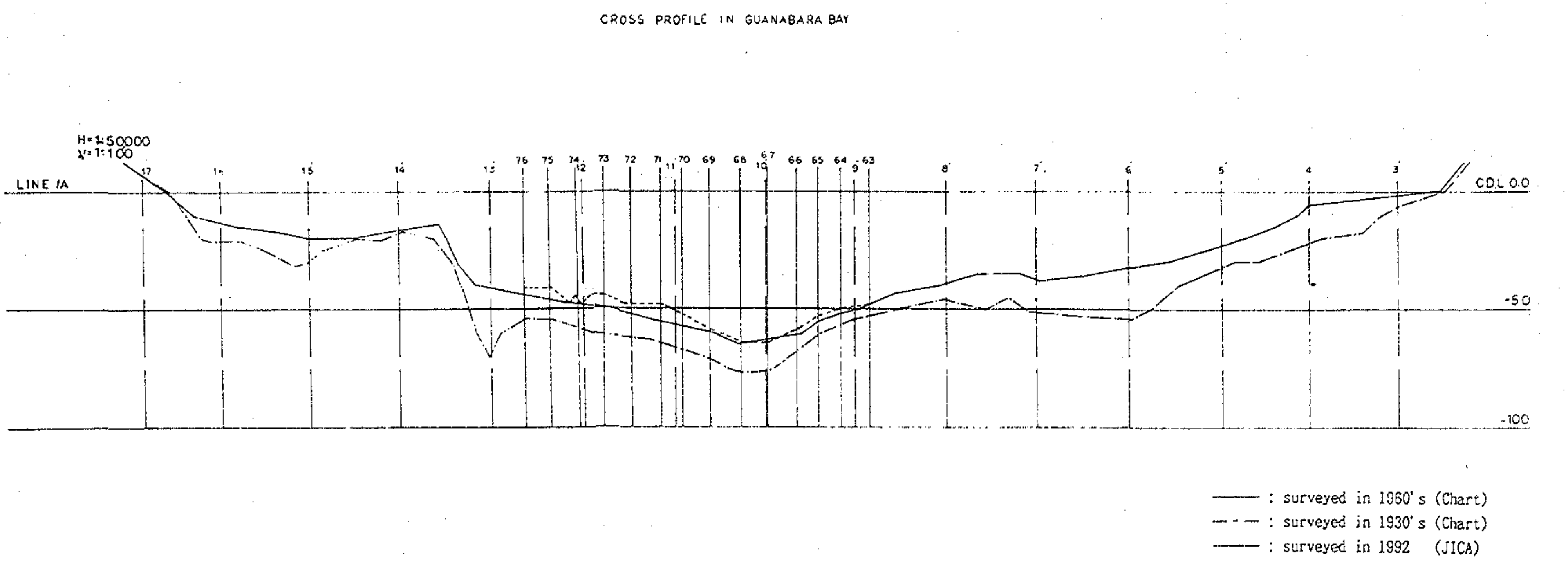


Fig. 4.3-2 Seabed Profile Along Line A

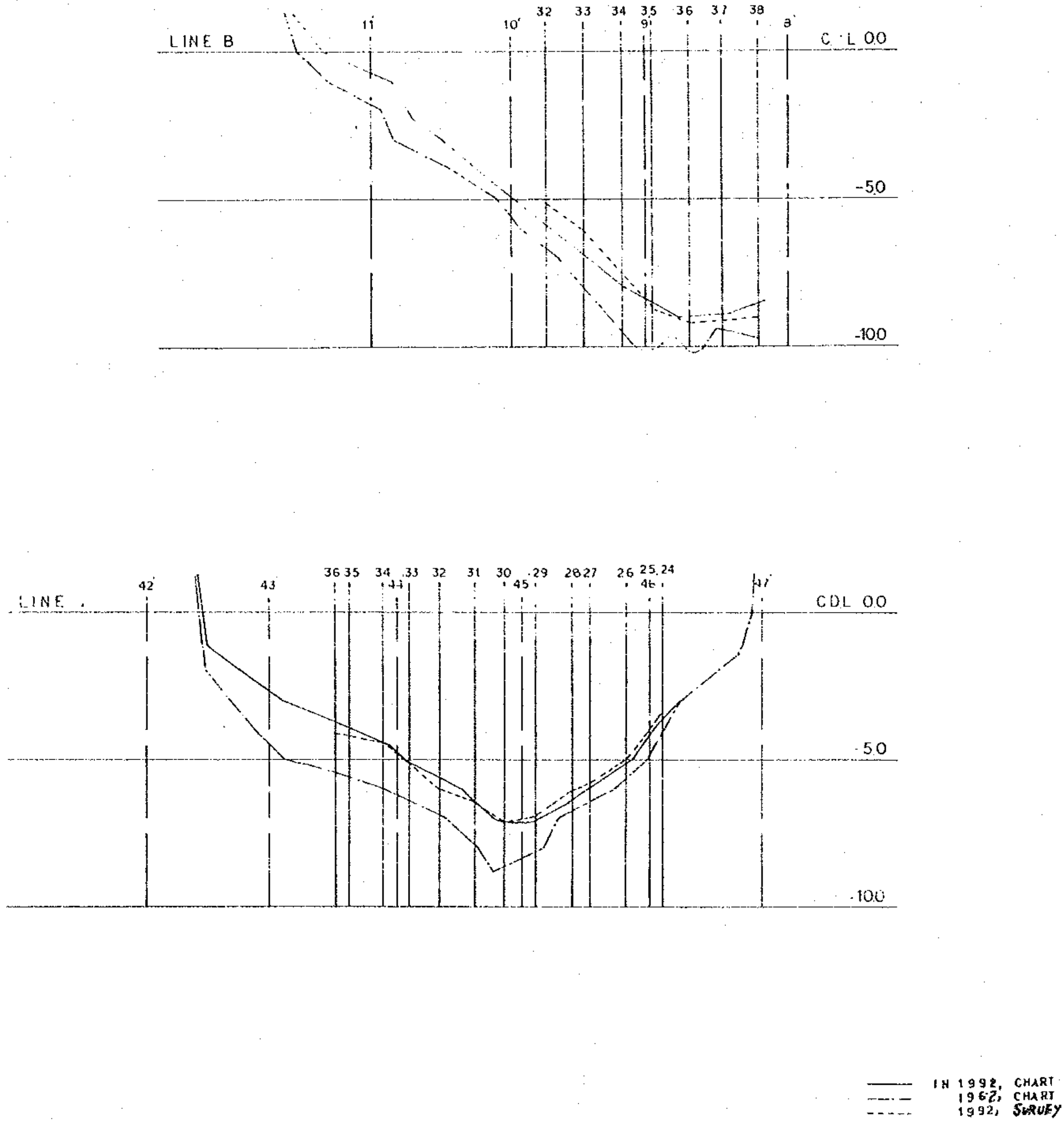


Fig. 4.3-3 Seabed Profile Along Line B and Line C

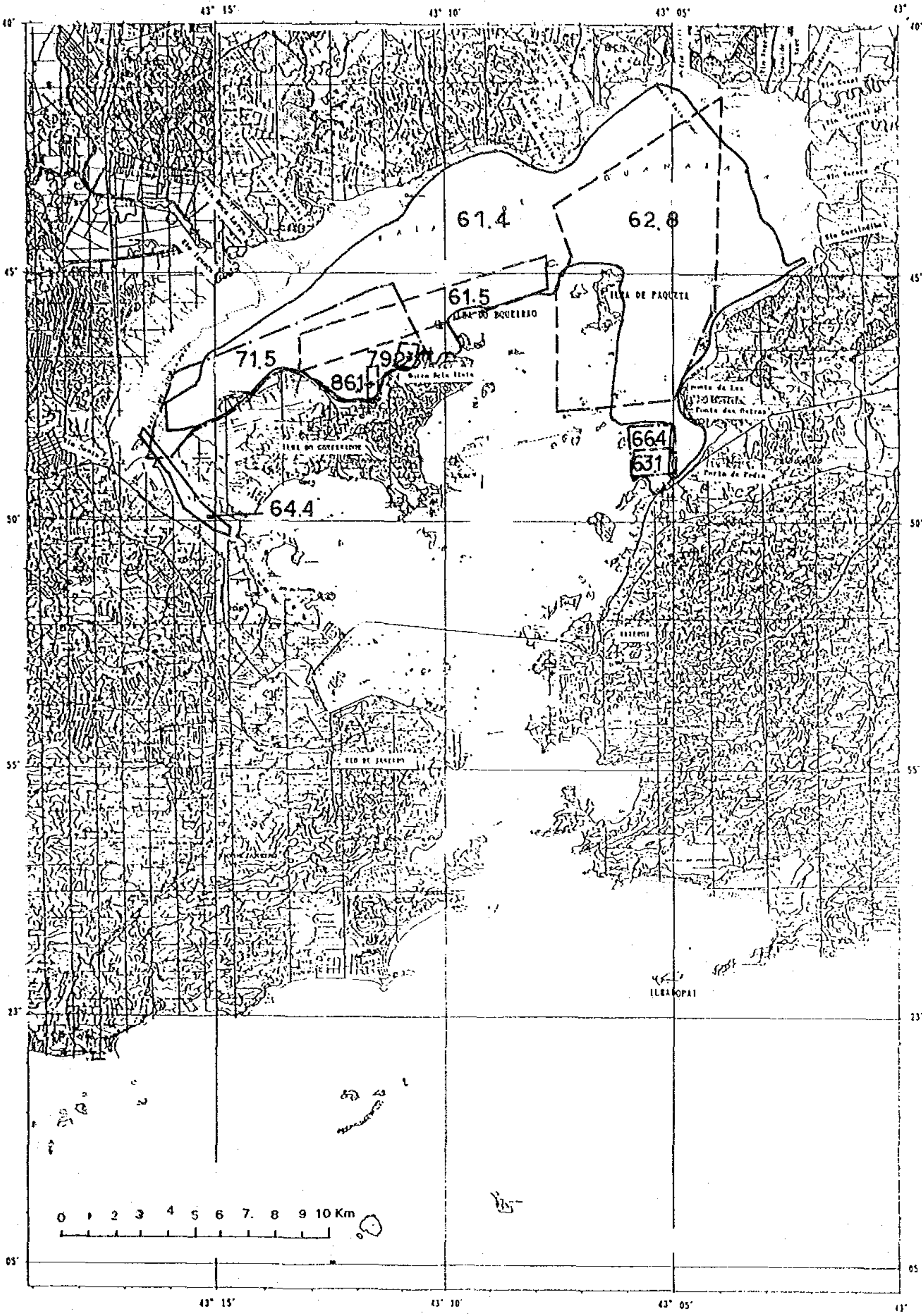


Fig. 4.3-4 Survey Period of the Chart Published in 1992

4.4 Sedimentation Rate

4.4.1 Existing Data for Sedimentation Rate

Seabed profiles in the northern part of the bay, which were compiled using the existing charts, clearly show considerable maximum situations of 1.5 m to 2 m in the period of 1920's / 1930's to 1960's, as shown in Fig. 4.3-2 and Fig. 4.3-3.

The sedimentation rate in the Guanabara Bay of ^{210}Pb method by Godoy J.M. et al is shown in Fig. 4.4-1. It is considered to have increased after 1950's reflecting the industrial development in the Guanabara bay basin. The sedimentation rate will be estimated at 2 to 3 cm/year at the inner part of the bay in recent years.

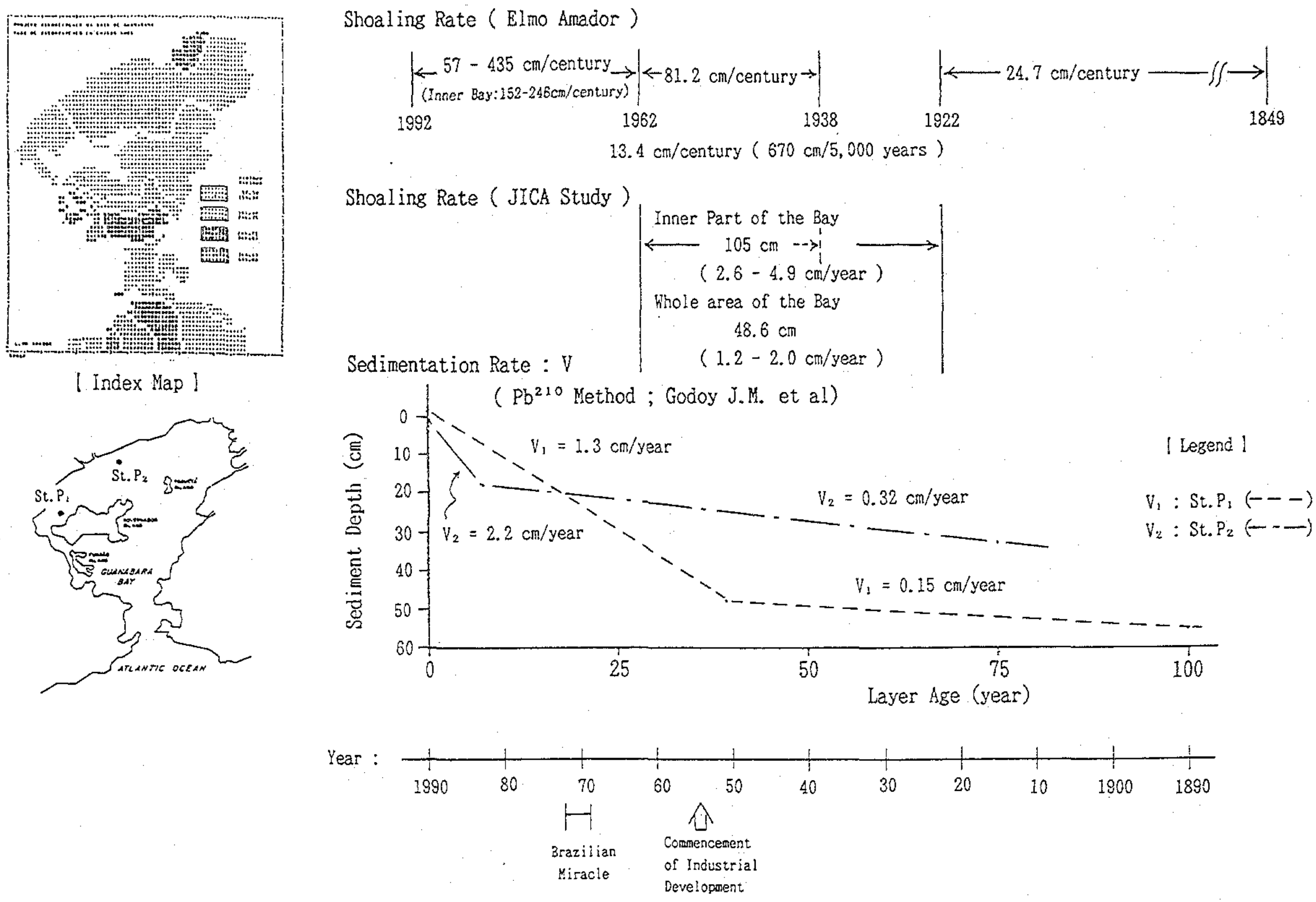


Fig. 4.4-1 Sedimentation Rate in the Guanabara Bay

4.4.2 Age Determination of Sediments

Using the undisturbed core samples collected in the Guanabara Bay, mean sedimentation speed (S) can be calculated by the following equation in the method of ^{210}Pb age determination;

$$\exp(-\lambda z - S) = {}^{210}PB_{excess}(Z) \ / \ {}^{210}Pb_{excess}(0)$$

$${}^{210}Pb_{excess}(Z) = {}^{210}Pb_{total}(Z) \ / \ {}^{210}Pb_{original}(Z)$$

Here, S : mean sedimentation speed (cm/year)

λ : disintegration constant

λ = ln 2 / half-life of ^{210}Pb

= 0.693 / 22.2 years = 0.0312 /year

z : depth (cm)

$^{210}Pb_{total}$: measured concentration of ^{210}Pb

$^{210}Pb_{original}$: ^{210}Pb concentration contained in mineral particles (background concentration)

$^{210}Pb_{excess}$: excess concentration of ^{210}Pb (mainly atmospheric origin)

The results of the measurement for ^{210}Pb concentration of core samples at the location shown in Fig. 4.4-2 using a low-background gas-flow counter are summarized in Table 4.4-1. Here, we assumed the $^{210}Pb_{original}$ concentration as 0.85 dpm/g, which was the lowest value in $^{210}Pb_{total}$ concentration.

The $^{210}Pb_{excess}$ concentrations obtained in Table 4.4-1 were plotted on Fig. 4.4-3 for both St.25 and St.26. The values have deviations from regularity, which is thought to be caused by disturbances due to various reasons. The sedimentation speed, however, seems around 2.0 cm-year. Referring to the existing data, 4 case in Fig. 4.4-3 is thought suitable. In this case, the sedimentation speed is 2.0 cm/year in recent years and 0.5 cm/year in former years.

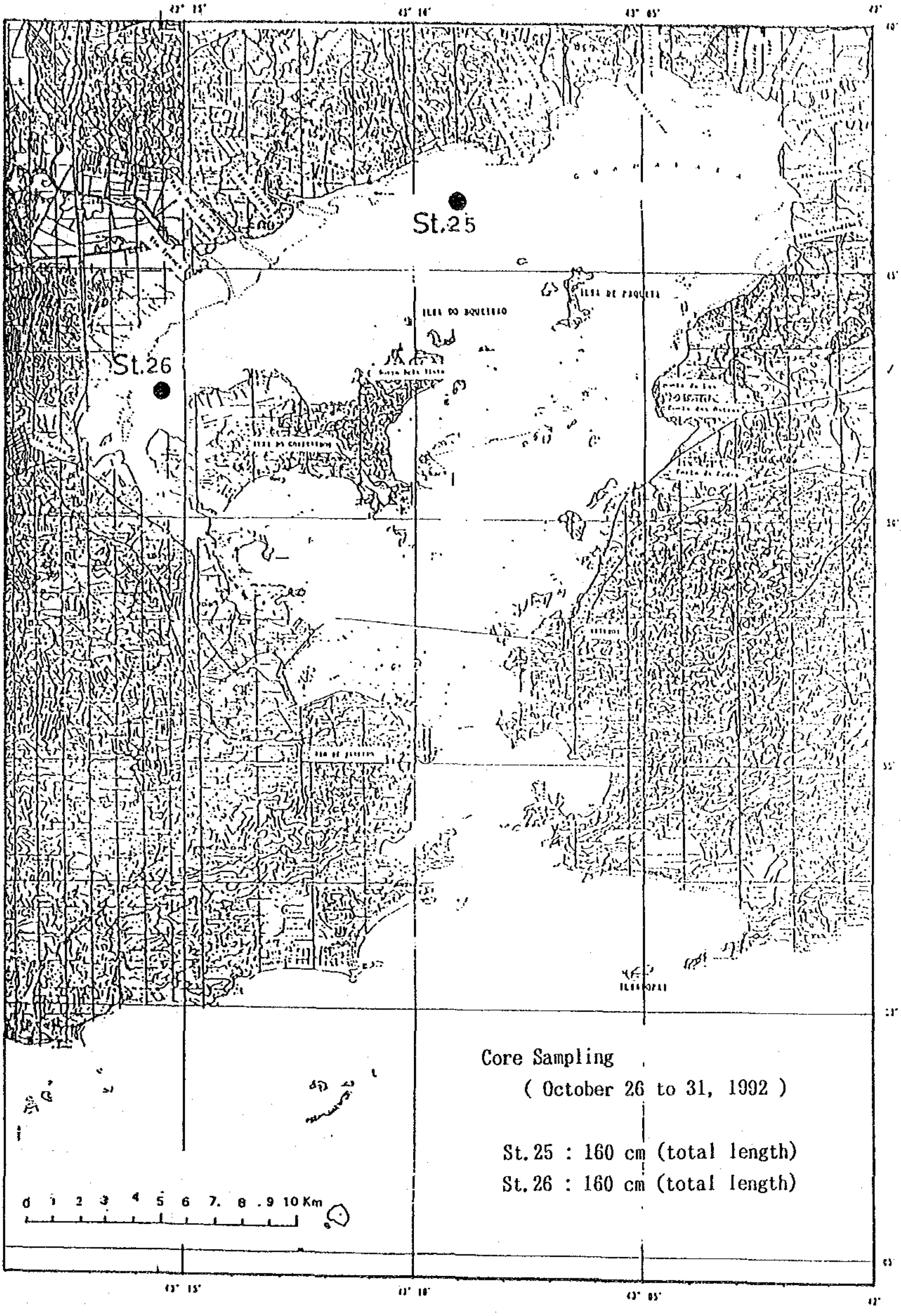


Fig. 4.4-2 Location Map of Core Sampling for Age Determinaton

Table 4.4-1 Results of ^{210}Pb Concentration Measurement

St. No. Sampling Depth	St. 25				
	0m-6m	17m-23m	47m-53m	97m-103m	149m-155m
Dry weight (g)	23.5244	25.8842	23.0440	40.2412	42.1856
PbSO (mg)	4.42	8.89	13.75	9.09	6.06
Yeild (%)	24.24	48.75	75.40	49.84	33.23
Counts	900	643	960	1442	1280
Time (min.)	120	120	120	120	120
Counting rate (cpm)	7.500	5.358	8.000	12.017	10.667
Counting rate - Background (cpm)	6.111	3.969	6.611	10.628	9.278
Efficiency (%)	37.76	37.02	36.20	36.98	37.49
$^{210}Pb_{total}$ (dpm/g)	2.84	0.85	1.05	1.43	1.77
$^{210}Pb_{excess}$ (dpm/g)	1.99	-	0.20	0.58	0.92

St. No. Sampling Depth	St. 26				
	0m-10m	17m-23m	52m-58m	87m-93m	130m-136m
Dry weight (g)	15.9046	17.0844	20.7326	24.3880	31.8650
PbSO (mg)	9.55	17.47	8.21	912.37	9.45
Yeild (%)	52.37	95.79	45.02	68.83	51.82
Counts	1266	2560	1145	1068	1536
Time (min.)	120	120	120	120	120
Counting rate (cpm)	10.550	21.333	9.542	8.900	12.800
Counting rate - Background (cpm)	9.161	19.944	8.153	7.511	11.411
Efficiency (%)	36.91	35.58	37.13	36.43	36.92
$^{210}Pb_{total}$ (dpm/g)	2.98	3.42	12.35	1.25	1.87
$^{210}Pb_{excess}$ (dpm/g)	2.13	2.57	1.50	0.40	1.02

Note 1) Background : 1.389 cpm

2) We assumed 0.85 dpm/g as a $^{210}Pb_{original}$ concentration.

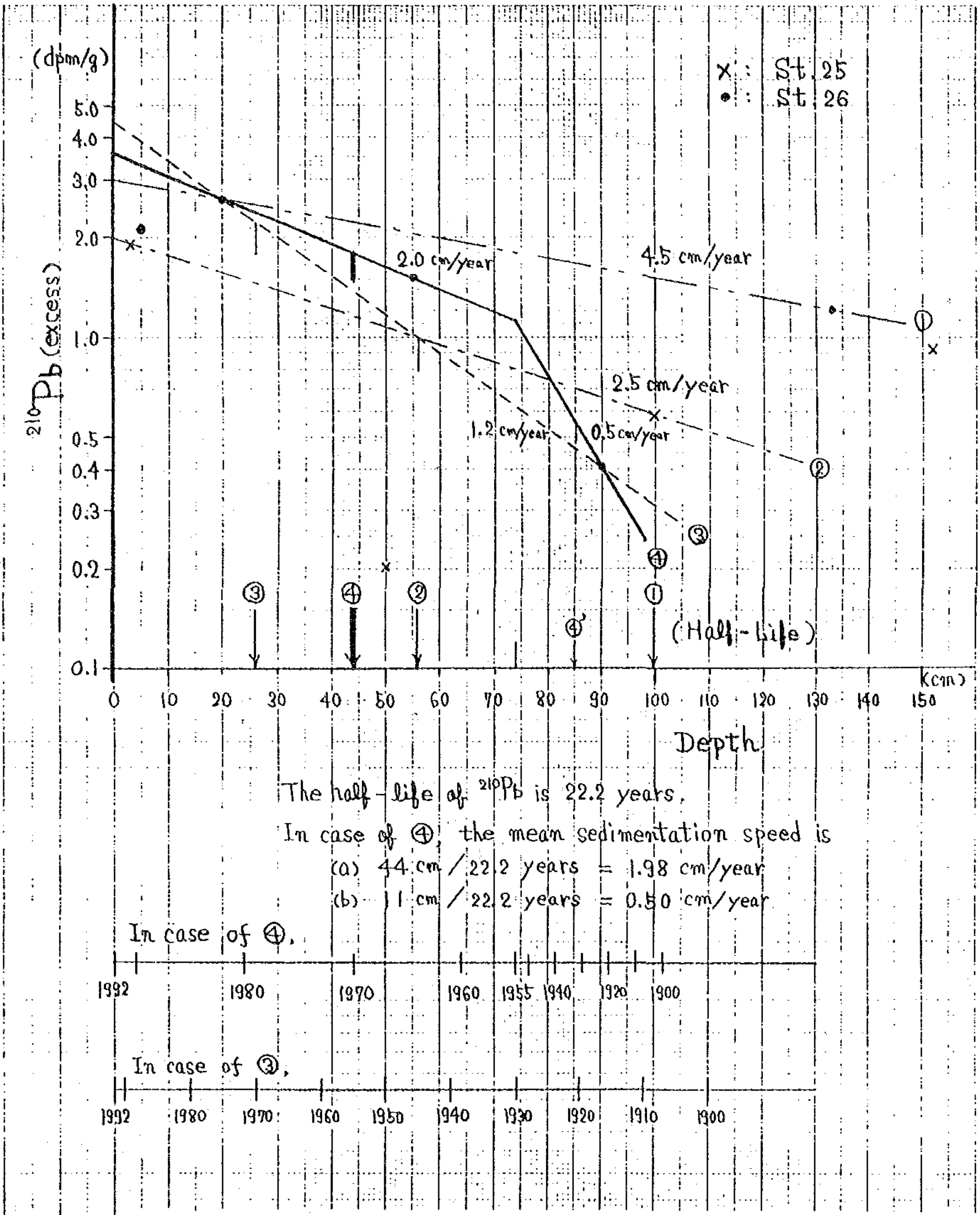


Fig. 4. 4-3 Sedimentation Speed in the Guanabara Bay by the Method of Age Determination Using ^{210}Pb

APPENDIX

APPENDIX 1

METHOD OF TIDAL HARMONIC ANALYSIS

PRINCIPLES OF HARMONIC ANALYSIS

1. The data for harmonic analysis

It is desirable when discussing the principles of harmonic analysis to consider the data available for analysis. *In many physical problems the analyst is only* concerned with relatively simple harmonic motions, in which the only oscillatory motion is made up of a primary oscillation of known period together with secondary oscillations which have periods related to the primary period in the exact ratios 1/2, 1/3, 1/4, 1/5 . . . . If the tide, for instance, were composed of only the solar constituents S_1, S_2, S_3, S_4, . . . we should have to cope with a relatively simple problem.

The principal difficulty in the analysis of actual tidal observations is due to the variety of periodic terms, the greater number of which have periods which are not numerically related to one another in a simple way. As a result of this complexity, very elaborate methods have had to be devised and reduced to simple rules for the guidance of computers.

Another important feature of the observations is that they are subject to errors of a casual nature due to meteorological causes, and these errors may be rather large at times. Methods of analysis have to take such errors into account, and in practice it is necessary to utilise many observations in order to minimise the casual errors.

2. Designation of a harmonic constituent

A harmonic constituent can be expressed as either a sine or cosine of the angular variable, but there are many conveniences attached to tidal usages in which harmonic constituents are expressed as cosines in the form

$$R \cos (nt - k) \quad . \quad . \quad . \quad . \quad . \quad (13.2a)$$

where R is the " amplitude " ;
$nt - k$ is the " argument " or " the phase " ;
t is the time, generally expressed in units of a mean solar hour from some arbitrary origin ;
n is the " speed " *or the increment in angle per unit of time ;*
k is the non-variable part of the argument, and is called the phase-lag, or alternatively, $-k$ is the phase at the origin of time.

The angle k in the analysis is regarded as a constant angle within the period covered *by the observations treated, though it may physically have a slowly varying part.* The arguments of the tidal constituents described in Chapters VI and VII contain a small angle denoted by u, which varies in a period of 19 years, but for the purpose of analysing a year's observations this part of the argument is regarded as equal to its mean value in the interval covering the observations.

The angle k may also be defined as follows :—

k is the lag of the phase behind nt, the variable part of the phase.

This definition is important when considering special origins of time, for, clearly, if time is measured from an arbitrary origin then k itself will not have physical significance, which is only acquired when the phase of the tidal constituent is related to the phase of the constituent of forces giving rise to the tidal constituent.

Proper rules, of course, have to be provided to relate the phase to the standard

Admiralty Manual of Tides (A.T. Doodson and H.D. Warburg ;
Her Majesty's Stationery Office in London)

of reference. If the time origin is changed so that time is measured from the moment when $t = t'$, then we have

$$nt - k = n(t - t') - (k - nt')$$

so that the apparent lag of phase is dependent upon the time origin. When t' is chosen so as to make $n(t - t')$ equal to the phase of the standard of reference then the new lag of phase is often referred to as "*the* phase-lag."

3. Analysis of a simple oscillation, free from casual error

Clearly, for any given oscillation which is free from casual error, it suffices to determine R, n and k. The value of R is determinable from a curve, being equal to the maximum excursion from the mean value, or half the range between the extreme values of high and low water. If the times of two high waters are determined then the interval between them gives the period in hours, and the value of n is equal to 360° divided by this value for the period. Then k is the value of the first high water time, in hours, multiplied by the value of n, since

$$nt - k = n(t - k/n)$$

and high water occurs when $t = k/n$.

It has been supposed in the above discussion that the curve is wholly free from casual error and has been carefully drawn, but in practice graphical methods are not used very much, as they leave far too much scope for individual errors of draughtmanship. Numerical data are preferable because the work can be submitted to adequate checks. The standard form (13.2a), however, is not well suited to numerical work and it is usual to replace it by the expression.

$$A \cos nt + B \sin nt \qquad (13.3a)$$

where

$$\left.\begin{array}{ll} A = R \cos k, & B = R \sin k \\ R^2 = A^2 + B^2, & \tan k = B/A \end{array}\right\} \qquad (13.3b)$$

Obviously any two values of the "curve" will theoretically suffice to give the two quantities A and B so long as n and t are known. For instance, suppose that the motion takes the values 10 and 5 for values of nt equal to 10° and 50°, then we have

$$A \cos 10° + B \sin 10° = 10$$
$$A \cos 50° + B \sin 50° = 5$$

To solve simultaneous equations of this type is a well-known type of scholastic exercise, but it is not often necessary in practice to resort to such methods. The matter is mentioned to bring out the principle that in theory two observations are sufficient, and to point out that this simple method, even with observations entirely free from errors, requires some care in choosing the observations to be utilised. If the values of phase differ by 180°, then we cannot solve the equations, since the second one is only a repetition of the first. We must therefore avoid taking observations at intervals of half a period.

The easiest method of solving the equations is to take the observations for $nt = 0°$ and 90°, for the elevations are then simply equal to A and B respectively. More generally, the most accurate numerical results will follow from choosing the two points a quarter-period apart.

4. Simple oscillations with casual errors

If the recorded oscillation is not perfect then the two-point methods described above are not suitable. By "errors" we describe any perturbations of the oscillation which is under discussion, whether these are caused by defects in instruments, human failure, or external physical causes not related to the true oscillation, such as wave action, etc. As a general principle, influences of casual errors can only be minimised by increasing the number of observations to be analysed. As an elementary principle we may apply the two-point method many times over and take the average of the results, which means that we perform many calculations accurately and retain the errors with their full values until the last process, that of averaging, in which the errors, being supposed to be distributed positively and negatively at random, tend to cancel out one another.

Obviously, a better way is to perform the simple averaging first, if possible, and thus to minimise the amount of calculation required to determine A and B. It is one of the cardinal principles of methods of harmonic analysis to endeavour to combine the observations by elementary grouping and averaging prior to attempting to analyse.

When we have done all that is possible in grouping the observations, then we have to assume, with a degree of truth depending upon the number of the observations, that the results are entirely due to the oscillation in which we are interested. The question then arises, What has been the consequence of these processes as concerning the harmonic constituent? If we have been careless in grouping the observations we may actually have been cancelling the positive part of the oscillation by the negative part, and so get a zero result.

A simple way of treating the observations is as follows: Suppose, for simplicity, that we are dealing with 24 observations of a diurnal oscillation of period exactly equal to 24 mean solar hours. Let these observations be regarded as at hours $t = 0, 1, \ldots 23$. What would be the effect of averaging the observations in two separate groups for $t = 0$ to 11 and $t = 12$ to 23? The process of averaging would undoubtedly reduce the casual errors but what about the oscillation itself?

Since the errors are all supposed to be casual then clearly the average value of any one group of observations has no claims over the average value of any other group of observations, so far as the probable diminution of error is concerned, provided that the groups have equal numbers of observations in them. But it is a different matter when we consider the effects of the grouping on the true oscillation, which we have seen can be expressed by

$$y = A \cos nt + B \sin nt$$

If one group can be found which will make the average value of $\cos nt$ in the group equal to zero then we can determine B very simply, and similarly for A.

The values of $\cos nt$ and $\sin nt$ are given in the following table for $n = 15°$, 30°, 45°, 60°, 90° with n, of course, equal to 15° per mean solar hour for the diurnal constituent, since $n = 360°/\text{period}$.

TABLE 13.1

Tables of cos *nt* and sin *nt*

	$n = 15°$		$n = 45°$	
t	$\cos nt$	$\sin nt$	$\cos nt$	$\sin nt$
0	1·000	0·000	1·000	0·000
1	0·966	0·259	0·707	0·707
2	0·866	0·500	0·000	1·000
3	0·707	0·707	– 0·707	0·707
4	0·500	0·866	– 1·000	0·000
5	0·259	0·966	– 0·707	– 0·707
6	0·000	1·000	0·000	– 1·000
7	– 0·259	0·966	0·707	– 0·707
8	– 0·500	0·866	1·000	0·000
9	– 0·707	0·707	0·707	0·707
10	– 0·866	0·500	0·000	1·000
11	– 0·966	0·259	– 0·707	0·707
12 to 23	Repeat with opposite sign			

TABLE 13.1—*continued.*

t	$n = 30°$ cos nt	sin nt	$n = 60°$ cos nt	sin nt	$n = 90°$ cos nt	sin nt
0	1·000	0·000	1·000	0·000	1·000	0·000
1	0·866	0·500	0·500	0·866	0·000	1·000
2	0·500	0·866	– 0·500	0·866	– 1·000	0·000
3	0·000	1·000	– 1·000	0·000	0·000	– 1,000
4	– 0·500	0·866	– 0·500	– 0·866	1·000	0·000
5	– 0·866	0·500	0·500	– 0·866	0·000	1·000
6	– 1·000	0·000	1·000	0·000	– 1·000	0·000
7	– 0·866	– 0·500	0·500	0·866	0·000	– 1·000
8	– 0·500	– 0·866	– 0·500	0·866	1·000	0·000
9	0·000	– 1·000	– 1·000	0·000	0·000	1·000
10	0·500	– 0·866	– 0·500	– 0·866	– 1·000	0·000
11	0·866	– 0·500	0·500	– 0·866	0·000	– 1·000
12 to 23	Repeat with same sign.					

Considering the diurnal oscillation, clearly the sum of the observations from $t = 1$ to 11 will yield a zero result when applied to cos nt (see Table 13.1), while the sum of the values of sin nt is 7·596. A similar process with the observations from 13 to 23 will yield a contribution of – 7·596 B from the oscillation. We can combine the two results, by saying that we have multiplied the values of y by + 1, – 1, 0 according to whether sin nt is positive, negative or zero, and the sum of the results, divided by 2 × 7·596 will give B.

A similar process will give A for the diurnal constituent ($n = 15°$) and exactly similar processes will give multipliers 1, – 1, 0 (Table 13.2) for the analyses of

TABLE 13.2

Multipliers for Analyses of Simple Oscillations

t	$n = 15°$ A_1	B_1	$n = 45°$ A_3	B_3	$n = 30°$ A_2	B_2	$n = 60°$ A_4	B_4	$n = 90°$ A_6	B_6
0	1	0	1	0	1	0	1	0	1	0
1	1	1	1	1	1	1	1	1	0	1
2	1	1	0	1	1	1	– 1	1	– 1	0
3	1	1	– 1	1	0	1	– 1	0	0	– 1
4	1	1	– 1	0	– 1	1	– 1	– 1	1	0
5	1	1	– 1	– 1	– 1	1	1	– 1	0	1
6	0	1	0	– 1	– 1	0	1	0	– 1	0
7	– 1	1	1	– 1	– 1	– 1	1	1	0	– 1
8	– 1	1	1	0	– 1	– 1	– 1	1	1	0
9	– 1	1	1	1	0	– 1	– 1	0	0	1
10	– 1	1	0	1	1	– 1	– 1	– 1	– 1	0
11	– 1	1	– 1	1	1	– 1	1	– 1	0	– 1
12 to 23	Repeat with opposite sign.				Repeat with same sign.					
Divisor	15·19	15·19	14·48	14·48	14·93	14·93	16·00	13·86	12	12