6.4 Tidal and Wind Conditions

6.4.1 Fluctuation in Tidal Level

(1) Seasonal fluctuations in Patos Lake water level

The water level data obtained from long term surveys on several stations in Patos Lake were used to determine seasonal fluctuations in water level. Using the nautical chart (No. 2140), the data were copied to prepare **Fig. 6.4-1**.

The figure shows minimum level from December to March and maximum level from July to October. In terms of average water level, yearly fluctuation in the water level in Sao Lourenco varies at approximately 0.6m.

(2) Water level around Patos Lake

Using the most recent data of the water level observation stations on the area surrounding Patos Lake, comparisons were made between data obtained from 6 survey stations, i.e. Itapua, Santa Rita, Sao Laurenco, Cristovan Pereira, Bojuru, and Rio Grande. The results are shown in **Fig, 6.4-2**.

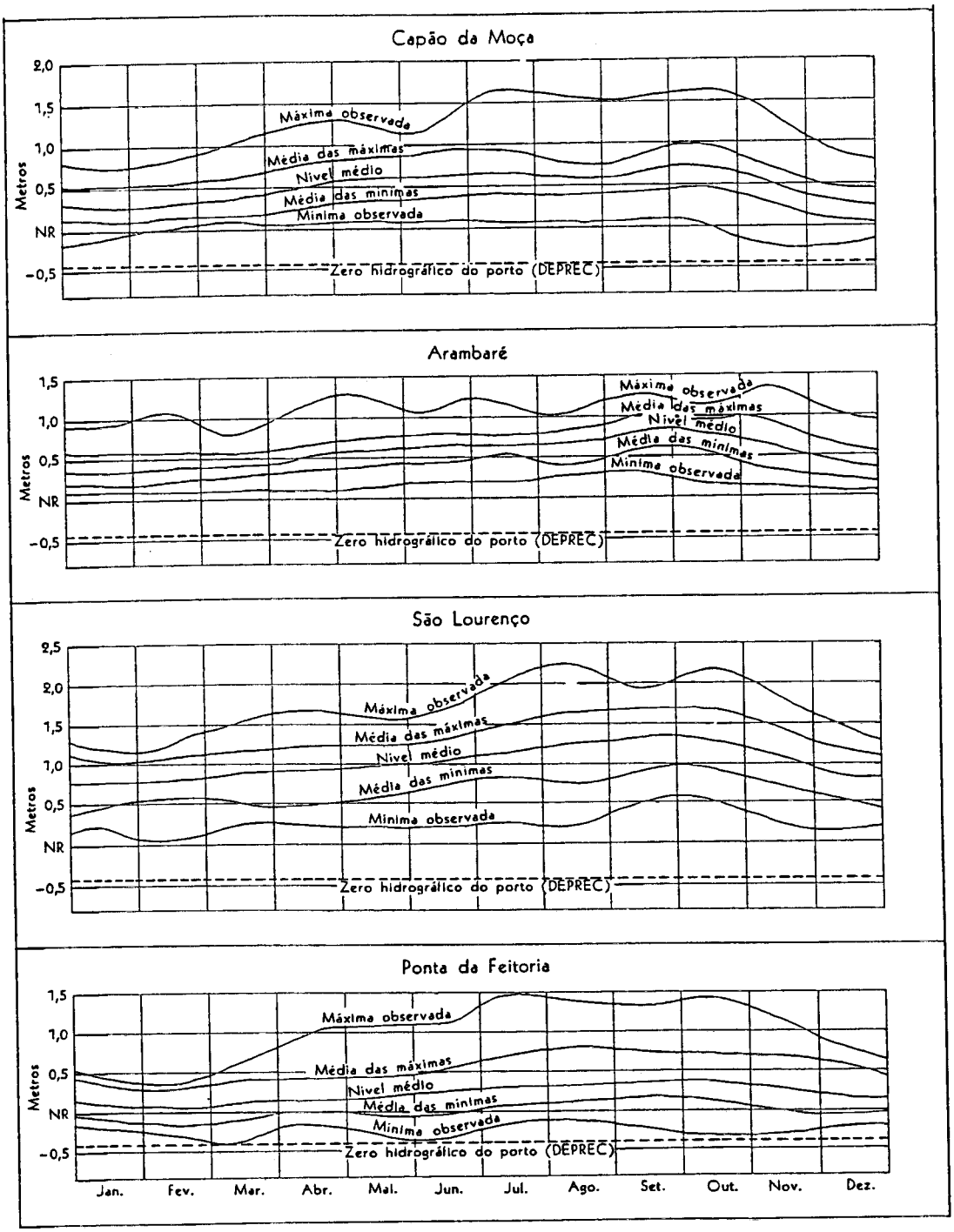
Data used for comparison only covered a short time span, e.g. 5 months. Except for Rio Grande, however, water level at each station was observed to have similar fluctuation patterns. Being situated at the estuary, Rio Grande is strongly influenced by changes in tidal conditions and hence showed a fluctuation pattern different from the rest.

As the relationship between observation stations in terms of datum levels employed was not determined, the water level height shown in **Fig. 6.4-2** is relative.

(3) Daily water level fluctuations in Patos Lake

Table 6.4-1 shows the harmonic constants of tides at Rio Grande which are used to forecast tides in Brasil. **Fig. 6.4-3** shows the daily water level in Rio Grande observed in January 1999.

As can be seen from the water level records, water level fluctuations were not periodic as tidal variation in the study area is small. On the contrary, any changes that take place are more likely caused by meteorological factors. This was also estimated from the tidal harmonic constants, which show a considerable diminution in the amplitude of diurnal and semi-diurnal tides.



Source : Nautical Chart (No.2140)

THE STUDY ON THE ENVIRONMENTAL MANAGEMENT
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Fig. 6.4-1

Annual Tidal Level Fluctuation in Patos Lake

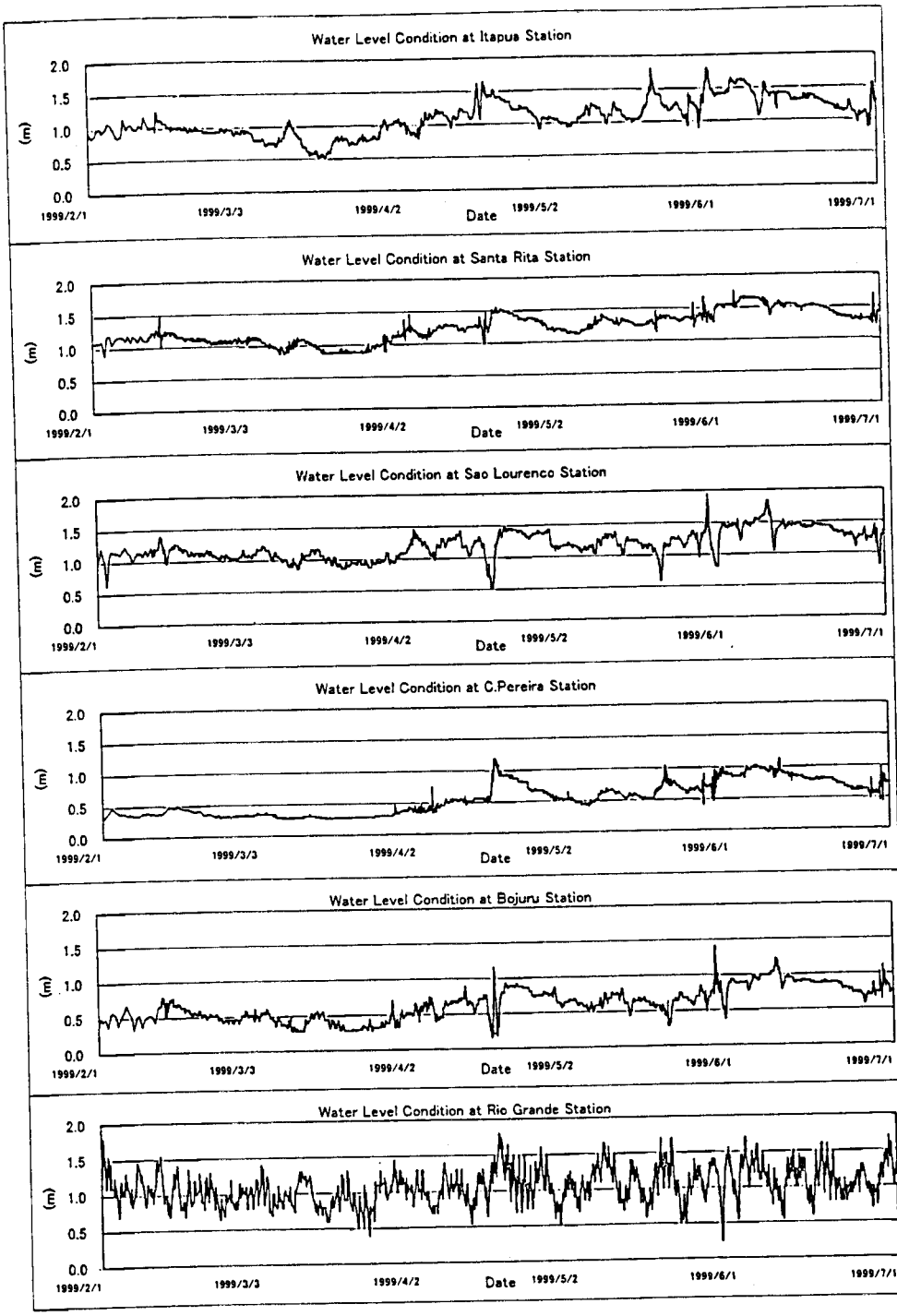

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Fig. 6.4-2

Tidal Level Fluctuation along the Shore of Patos Lake

Table 6.4-1 Harmonic Constants of Tides at Rio Grande

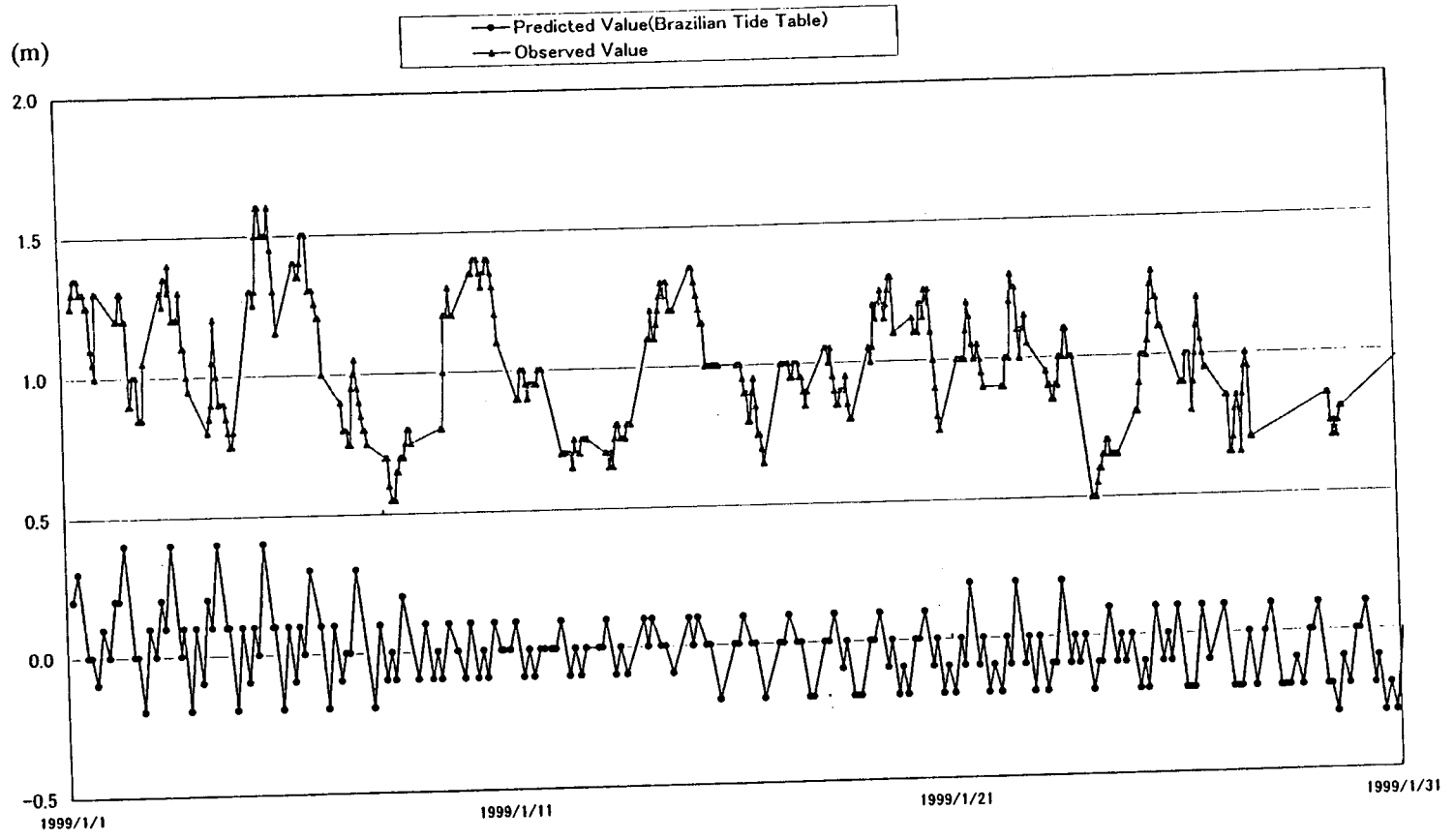
Station : Porto de Rio Grande

No.	Type of Tide	Name of Constituent	Angular Velocity (degree)	Amplitude H (cm)	Phase Lag G (degree)
1	Long Period Tide	SA	0.0410686	5.30	177.30
2		SSA	0.0821373	27.40	83.80
3		MF	1.0980331	5.60	118.50
4		MSF	1.0158958	4.60	243.20
5	Diurnal Tide	K1	15.0410686	4.70	134.10
6		O1	13.9430356	10.80	71.70
7		P1	14.9589314	1.40	136.40
8		Q1	13.3986609	3.00	30.90
9		RO1	13.4715145	0.70	74.90
10		SIGMA1	12.9271398	0.90	154.40
11		S1	15.0000000	0.80	168.30
12	Semi-Diurnal Tide	M2	28.9841042	3.40	229.70
13		S2	30.0000000	3.50	26.80
14		N2	28.4397295	4.10	193.32
15		K2	30.0821373	1.30	14.20
16		NU2	28.5125831	1.00	227.30
17		MU2	27.9682084	0.60	146.70
18		T2	29.9589333	0.30	223.30
19		2N2	27.8953549	1.00	160.40
20		KJ2	30.6265119	0.50	202.30
21	Short Period Tide	M3	43.4761563	1.00	161.30
22		MK3	44.0251728	0.60	330.40
23		MO3	42.9271398	0.40	307.60
24		SK3	45.0410686	0.40	44.40
25		M4	57.9682084	4.60	110.60
26		MS4	58.9841042	1.40	182.00
27		MN4	57.4238337	2.30	65.00
28		SN4	58.4397295	0.60	105.10
29		M6	86.9523127	0.40	206.90-
30		2MS6	87.9682084	0.70	258.30
31		2MN6	86.4079380	0.40	150.70
32		2SM6	88.9841042	0.20	346.30
33		MSN6	87.4238337	0.20	261.20
34		2MK6	88.0503457	0.30	220.00
35		MSK6	89.0662415	0.20	340.00

[Note] 1. Porto de Rio Grande : Latitude: 32 ° 07.6 ′ S, Longitude : 52 ° 06.0 ′ W

2. Data for Analysis : Oct. 2, 1959 to Sep. 21, 1960

3. Source : Diretoria de Hidrografica de Navegacao



THE STUDY ON THE ENVIRONMENTAL MANAGEMENT OF THE HYDROGRAPHIC BASIN OF PATOS AND MIRIM LAKES IN THE FEDERATIVE REPUBLIC OF BRAZIL	**Fig. 6.4-3**
JAPAN INTERNATIONAL COOPERATION AGENCY KOKUSAI KOGYO CO., LTD. / PACIFIC CONSULTANTS INTERNATIONAL	**Tidal Level Fluctuation at Rio Grande (January 1999)**

6.4.2 Wind Conditions

(1) Seasonal Impact on Wind Conditions Around Patos Lake

Data from recent surveys on Rio Grande were used to prepare **Fig. 6.4-4** (Seasonal Wind Rose in Rio Grande).

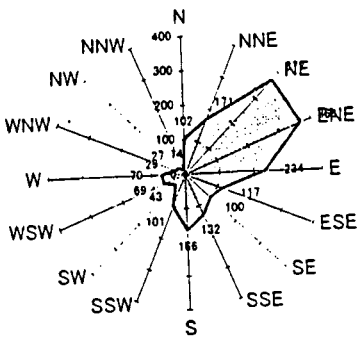
These data indicate that northeasterly winds generally prevail around the lake area. In summer, northeasterly to north-east-north winds prevail, while north to north-northeast and southwest to west winds prevail in winter.

(2) Wind Conditions in Santa Rita and Rio Grande

Recent data of the wind observation stations were used to compare wind conditions in Santa Rita and Rio Grande (see **Fig. 6.4-5**).

Although the comparative analysis was carried out in March 1999 and the observation stations were quite far, these stations may be concluded to have similar wind patterns.

1998/09/01-1998/11/31



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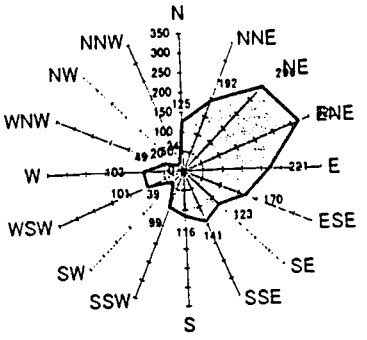
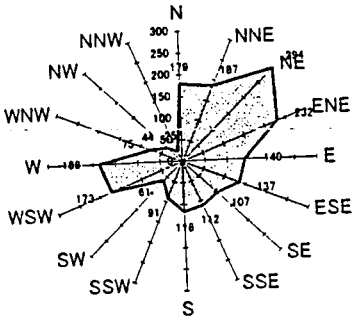
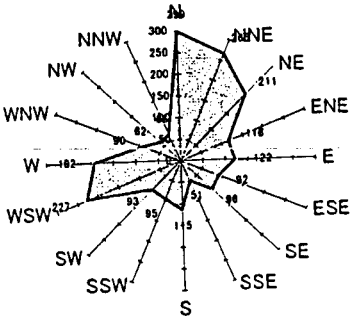


1999/03/1-1999/05/31



1999/06/01-1999/08/31



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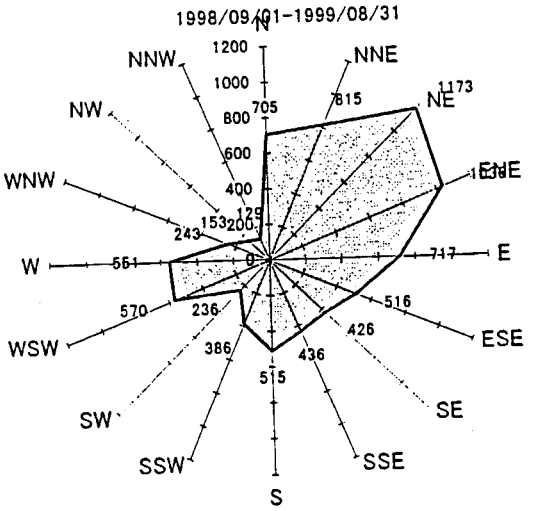
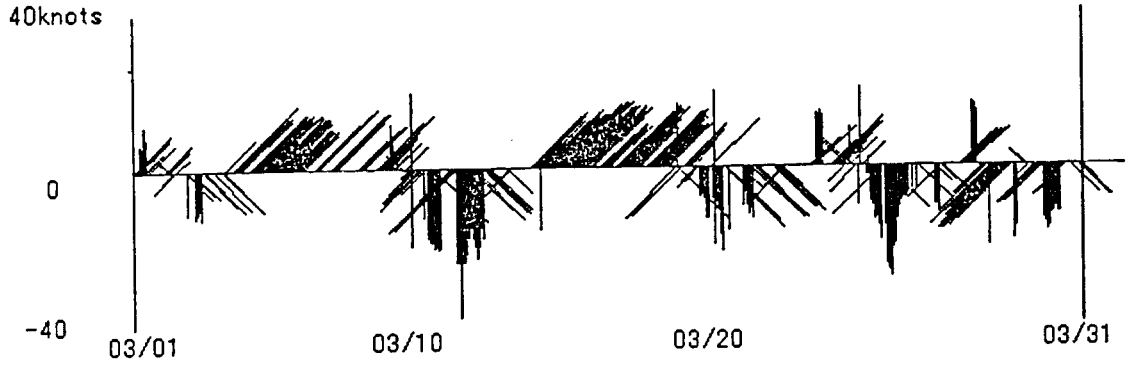
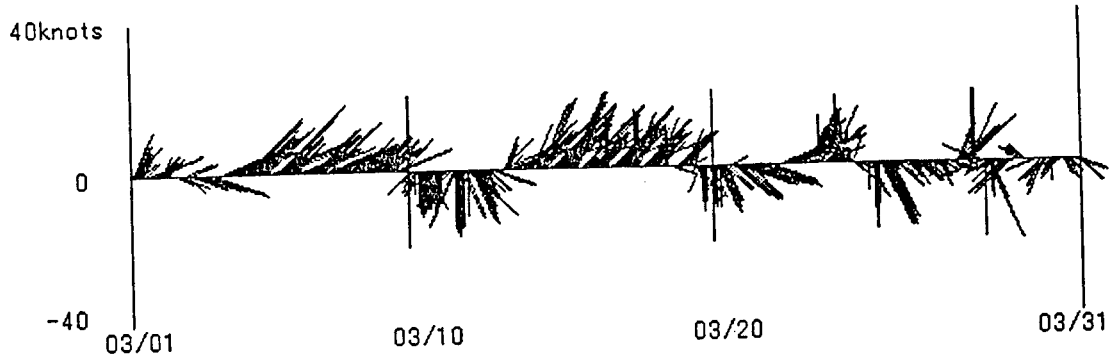


THE STUDY ON THE ENVIRONMENTAL MANAGEMENT OF THE HYDROGRAPHIC BASIN OF PATOS AND MIRIM LAKES IN THE FEDERATIVE REPUBLIC OF BRAZIL	**Fig. 6.4-4**
JAPAN INTERNATIONAL COOPERATION AGENCY KOKUSAI KOGYO CO., LTD. / PACIFIC CONSULTANTS INTERNATIONAL	**Seasonal Wind Rose at Rio Grande (Pilot Station)**



Wind Condition Mar.1999
at Santa Rita Station



Wind Condition Mar.1999
at Rio Grande Station

THE STUDY ON THE ENVIRONMENTAL MANAGEMENT OF THE HYDROGRAPHIC BASIN OF PATOS AND MIRIM LAKES IN THE FEDERATIVE REPUBLIC OF BRAZIL	**Fig. 6.4-5**
JAPAN INTERNATIONAL COOPERATION AGENCY KOKUSAI KOGYO CO., LTD. / PACIFIC CONSULTANTS INTERNATIONAL	**Wind Conditions in Santa Rita and Rio Grande**

6.5 Current Conditions

6.5.1 Observation Results at Fixed Points

Patos Lake current observations at fixed points were carried out twice, one each in summer and winter, by installing current meters. The details of the observations are summarized in **Table 6.5-1**.

As indicated in the table, surveys were carried out in both seasons by installing 4 self-recording type current meters in 3 survey stations. Due to theft of instruments and missing data, only data from stations C-1 (41 days each in summer), and C-3 and C-4 (4 and 18 days in winter respectively) were obtained.

Table 6.5-1 Details of Current Observations (Current Meter)

Season	Station Number	Number of Layers	Date of Set up	Current Meter	Effective Date of Data
Summer (Dry) Season	C-1	1 (Middle)	28/2/1999	SD-2000	28/2/1999 to 10/4/1999
	C-3	1 (Middle)	26/2/1999	SD-2000	None
	C-4	2 (Upper & Lower)	26/2/1999	SD-2000	None
Winter (Rainy) Season	C-1	1 (Middle)	5/8/1999	SD-2000	None
	C-3	1 (Middle)	3/8/1999	RCM-7	3/8/1999 to 7/8/1999
	C-4	2 (Upper & Lower)	2/8/1999	RCM-7	2/8/1999 to 20/8/1999

[Note] Middle Layer : 3.0m above sea bottom
Upper Layer : 9.2m above sea bottom
Lower Layer : 3.7m above sea bottom

(1) Results of Survey at Station C-1

The survey result obtained from station C-1 in summer is arranged in **Fig. 6.5-1**, showing the changes that have occurred in time (vector representation). Wind conditions (Rio Grande) in the same period are annotated in the map for referential purposes.

Water temperature observation was done simultaneous with current observations, and the results are shown in **Fig. 6.5-2**.

(2) Results of Surveys at Station C-3

The results of current survey in winter carried out at station C-3 are illustrated in **Fig. 6.5-3**. The results of water temperature observation simultaneously carried out at this time are annotated on the map.

(3) Results of Surveys at Station C-4

The results of current survey in winter carried out at station C-4 are illustrated in **Fig. 6.5-4** for the surface (upper) layer and **Fig. 6.5-5** for the bottom (lower) layer. The results of water temperature observation simultaneously carried out at this time are annotated on the map.

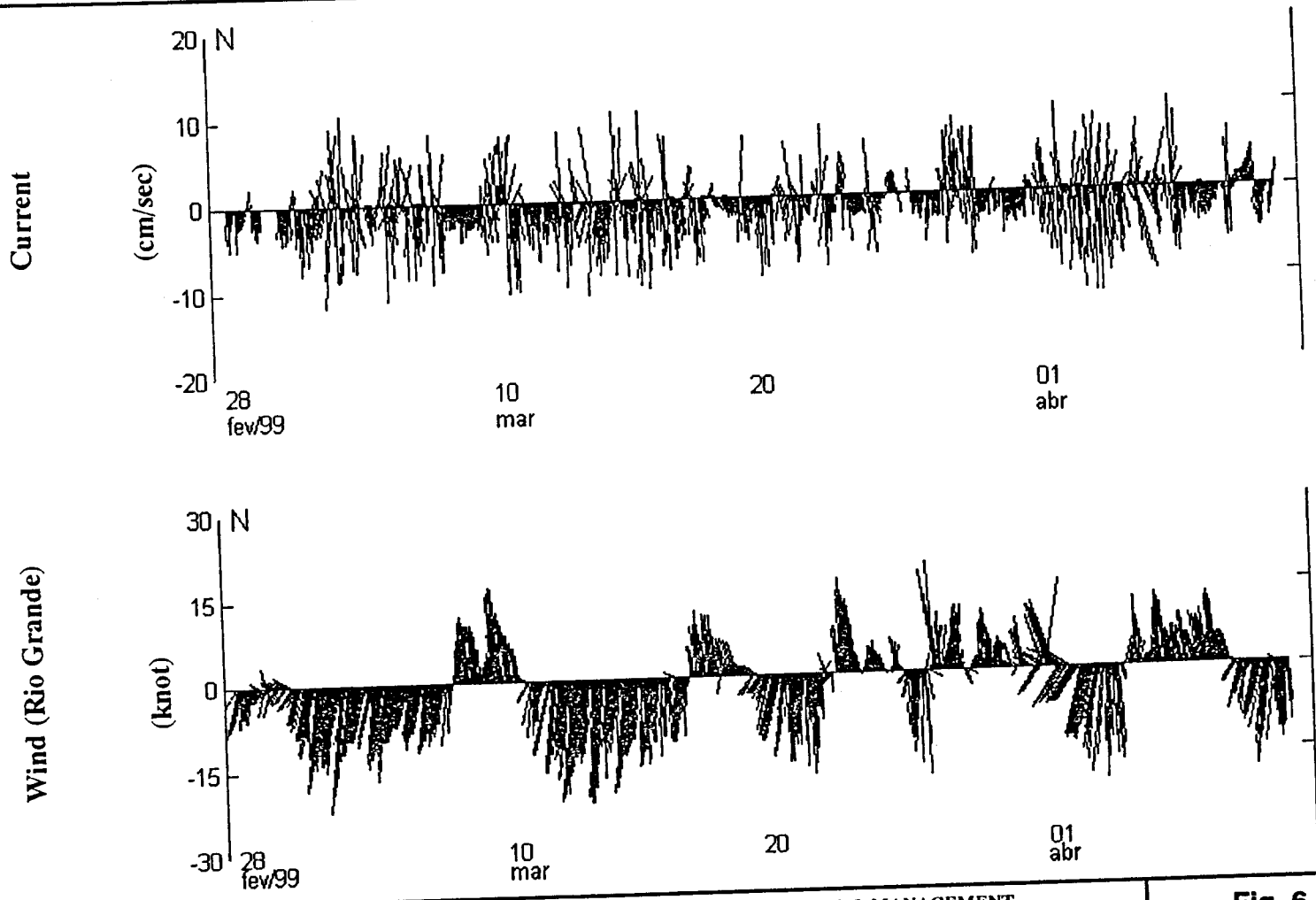


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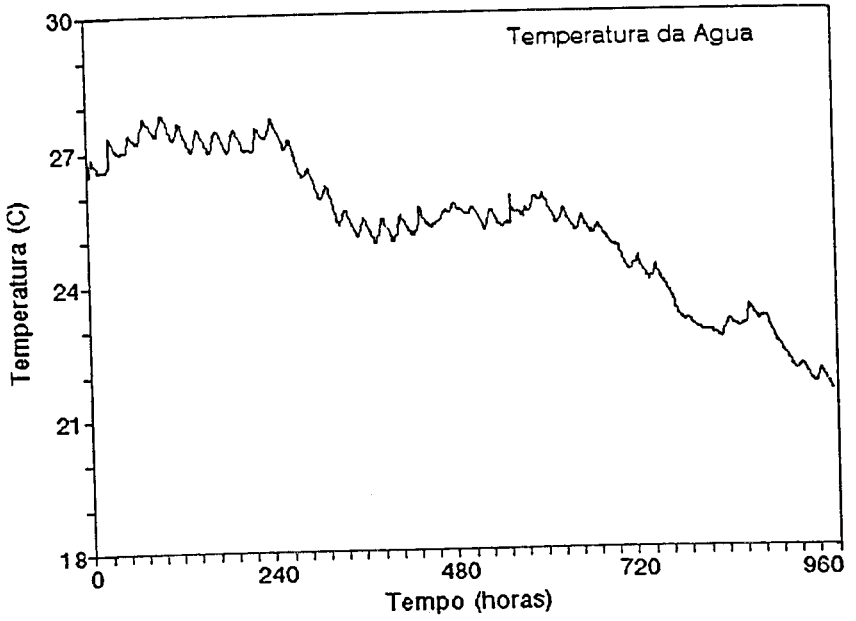
Fig. 6.5-1

Current Curves at Station C-1 (Summer)

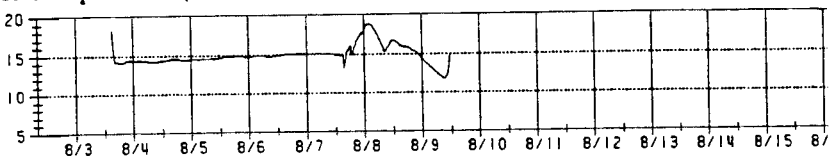
Summer



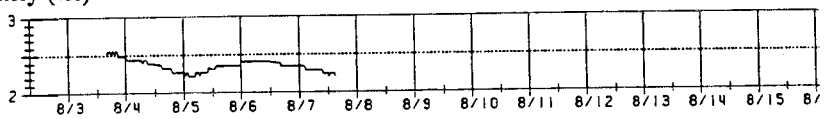
Winter

THE STUDY ON THE ENVIRONMENTAL MANAGEMENT OF THE HYDROGRAPHIC BASIN OF PATOS AND MIRIM LAKES IN THE FEDERATIVE REPUBLIC OF BRAZIL	Fig. 6.5-2
JAPAN INTERNATIONAL COOPERATION AGENCY KOKUSAI KOGYO CO., LTD. / PACIFIC CONSULTANTS INTERNATIONAL	**Fluctuation in Water Temperature at Station C-1**

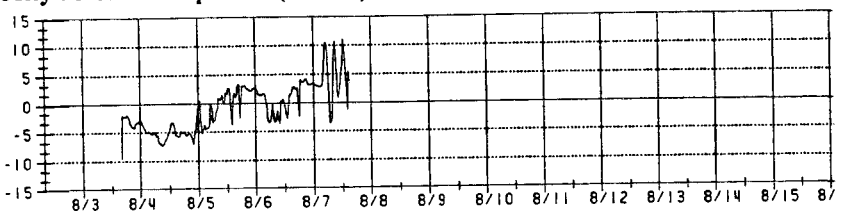
Water Temperature (℃)



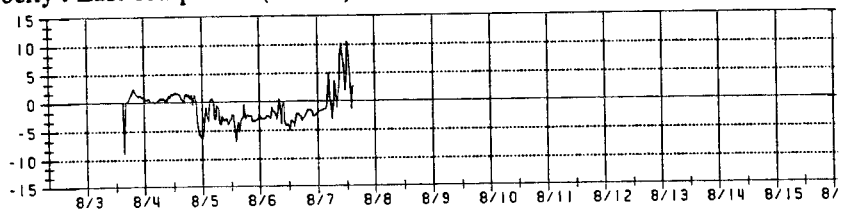
Salinity (‰)



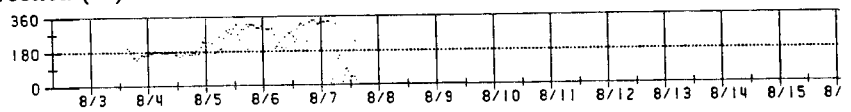
Velocity : North-component (cm/sec)



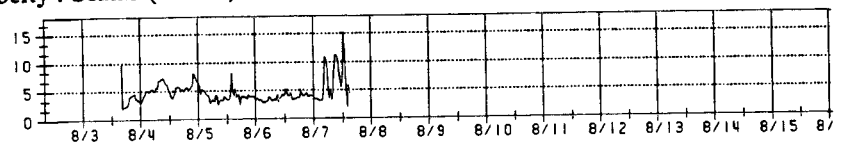
Velocity : East-component (cm/sec)



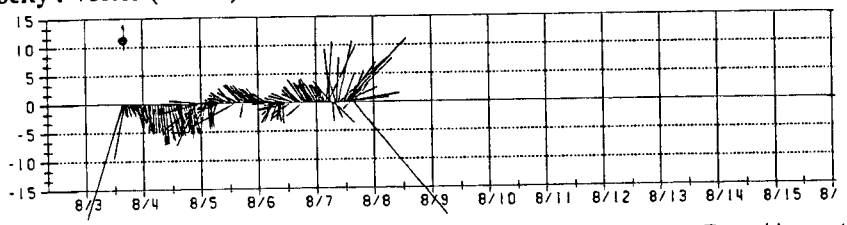
Direction (°)



Velocity : Scalar (cm/sec)



Velocity : Vector (cm/sec)



Date (August 1999)

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JAPAN INTERNATIONAL COOPERATION AGENCY KOKUSAI KOGYO CO., LTD. / PACIFIC CONSULTANTS INTERNATIONAL	**Current Curves at Station C-3 (Middle Layer, Winter)**

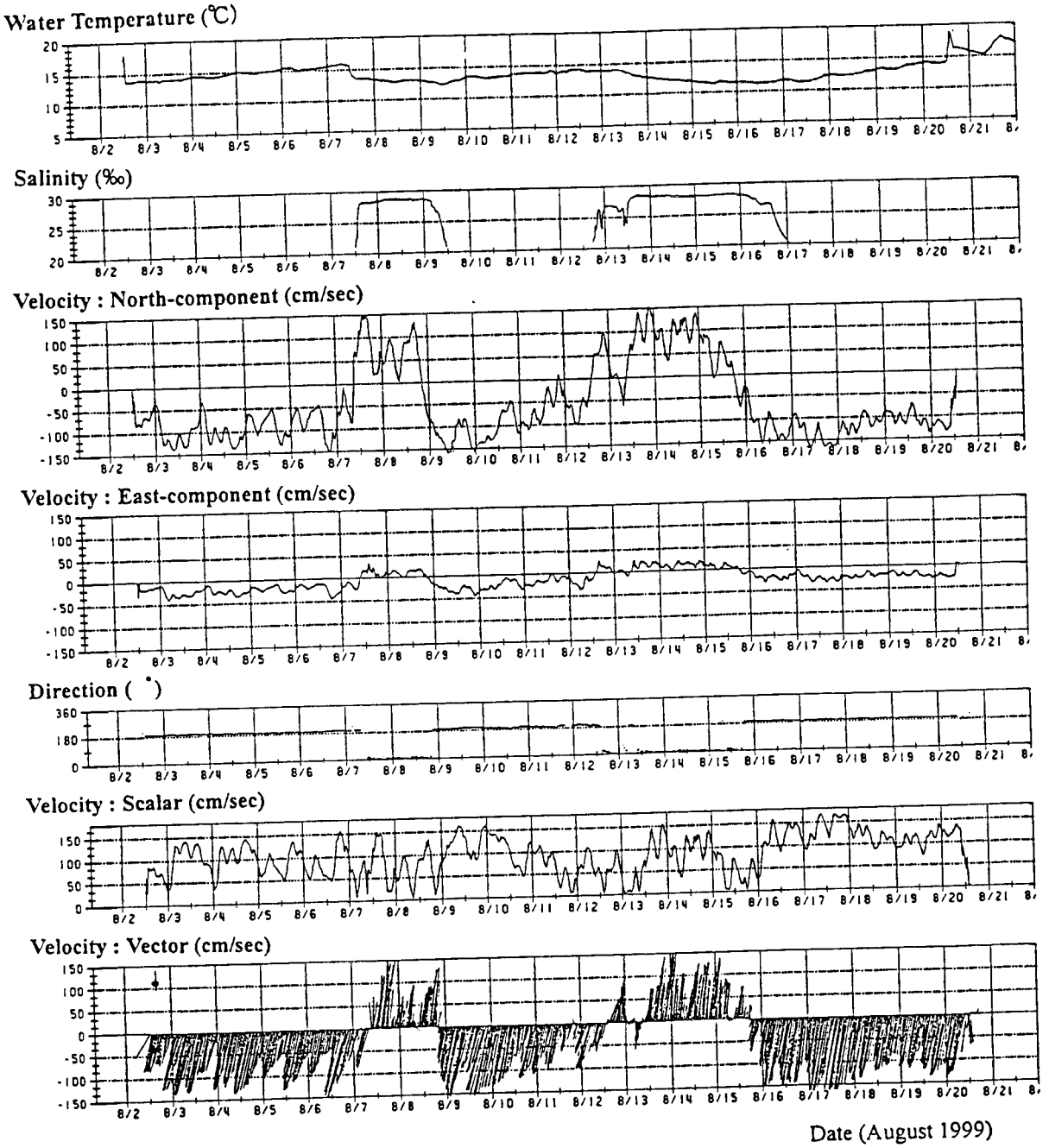

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Fig. 6.5-4

Current Curves at Station C-4 (Surface Layer, Winter)

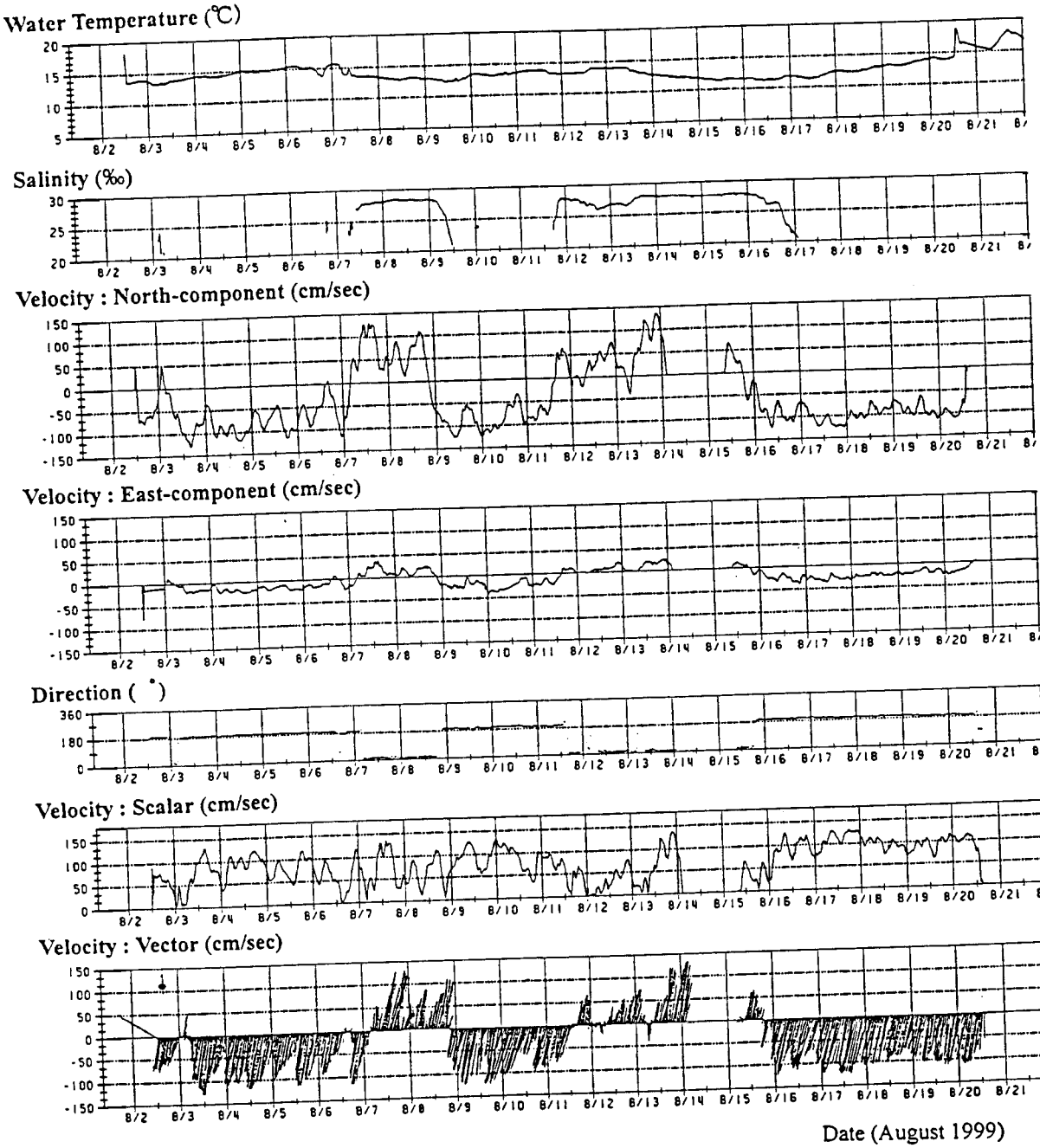

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Fig. 6.5-5

Current Curves at Station C-4 (Bottom Layer, Winter)

6.5.2 Observation Results by ADCP

The Acoustic Doppler Current Profiler (ADCP) was used for the cross section current survey carried out in summer and winter. **Table 6.5-2** shows the results of the survey along with the date and time of survey.

The tracks of the survey lines are arranged in **MON-F-2** of the annex, and the current profiles along the survey lines, prepared based on the survey results, is in **MON-F-3**.

Table 6.5-2 Current Observation Dates (ADCP)

Season	Line Number	Start of Line	End of Line
Summer (Dry Season)	Line – 1	16:13 28/2/99	16:30 28/2/99
		16:32 28/2/99	16:52 28/2/99
	Line – 2	20:40 27/2/99	23:51 27/2/99
	Line – 3	06:12 27/2/99	09:14 27/2/99
	Line – 4	10:17 26/2/99	10:22 26/2/99
		10:27 26/2/99	10:32 26/2/99
		13:16 03/3/99	13:20 03/3/99
		13:23 03/3/99	13:27 03/3/99
Winter (Rainy Season)	Line – 1	13:27 05/8/99	13:43 05/8/99
		13:45 05/8/99	14:05 05/8/99
		14:14 25/8/99	14:33 25/8/99
		14:36 25/8/99	14:52 25/8/99
	Line – 2	11:26 04/8/99	14:40 04/8/99
		13:03 26/8/99	16:12 26/8/99
	Line – 3	17:13 03/8/99	20:20 03/8/99
		06:06 27/8/99	09:08 27/8/99
	Line – 4	13:53 02/8/99	13:59 02/8/99
		14:00 02/8/99	14:04 02/8/99
		14:07 02/8/99	14:12 02/8/99
		15:07 27/8/99	15:12 27/8/99
		15:13 27/8/99	15:17 27/8/99
		15:18 27/8/99	15:23 27/8/99

(1) Survey Results at Line-1

Line-1 is located at the estuary of Rio Guaiba and is the offshore survey line of Itapua. The results of the current profile along the survey line are shown in **Fig. 6.5-6** (summer) and **Fig.6.5-7** (winter).

As shown in **Fig. 6.5-6**, overall flow moves northwards in summer at a maximum speed of about 20cm/sec for surface flow and around 10cm/sec for bottom flow.

On the other hand, the opposite was observed in winter. Flow was observed to move southwards at a maximum speed of 35cm/sec for surface flow and around 10cm/sec for bottom flow.

(2) Survey Results at Line-2

Line-2 is at the central area of Patos Lake and is the survey line linking Arambare and Pta. Cristovao Pereira. **Fig. 6.5-8** and **Fig. 6.5-9** show the flow profile carried out along this survey line.

As shown in **Fig. 6.5-8**, the distinctive aspect of the flow conditions along this cross section observed in summer is that while southward flow is comparatively strong (a little over 15cm/sec) in the eastern section (Pta. Cristovao Pereira area), in the western section the flow moves northwards.

Conditions shown in **Fig. 6.5-9**, on the other hand, contrast with **Fig. 6.5-8**, with flow in the eastern section moving northeastward and southwards in the western section.

Wind direction, which is also indicated in both figures, at the time of survey is considered to have a direct influence on the difference in flow direction observed in both surveys.

(3) Survey Results at Line-3

Line-3 connects Feitoria and Pta. Lencois at the southernmost section of Patos Lake. **Fig. 6.5-10** and **Fig. 6.5-11** show the current profile carried out along this survey line.

As shown in **Fig. 6.5-10**, flow patterns along this cross section are similar to that of survey Line-2: southward flow in the eastern section（Pta. Lencois）as opposed to the northward flow in the western section (Feitoria).

Fig. 6.5-11, on the other hand, shows that overall the flow moves southwards.

(4) Survey Results at Line-4

Line-4 is located in the estuary of Patos Lake and is the survey line near the Rio Grande jetty. The current profile done along this survey line is shown in **Fig. 6.5-12** (summer) and **Fig. 6.5-13** (winter).

Fig. 6.5-12 (summer) indicates an overall southward flow at a high speed of over 80cm/sec in the surface layer and around 50cm/sec in the bottom layer.

Fig. 6.5-13 (winter) indicates an extremely interesting condition whereby surface and bottom layer flows move in opposite directions: overall southward flow in the surface layer as opposed to the northward flow in the bottom layer.

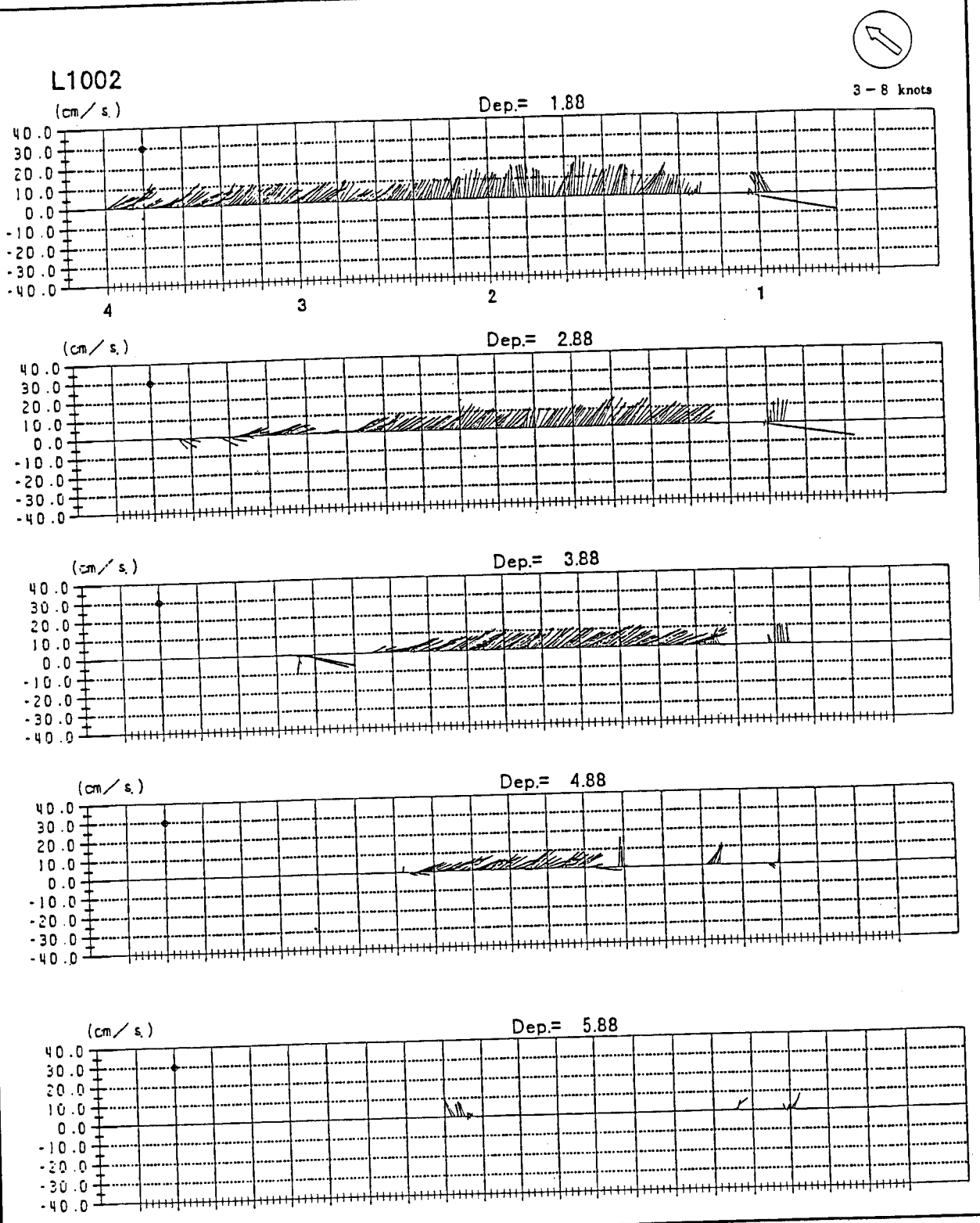

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Fig. 6.5-6

Current Profile of Line-1 (28 February 1999)

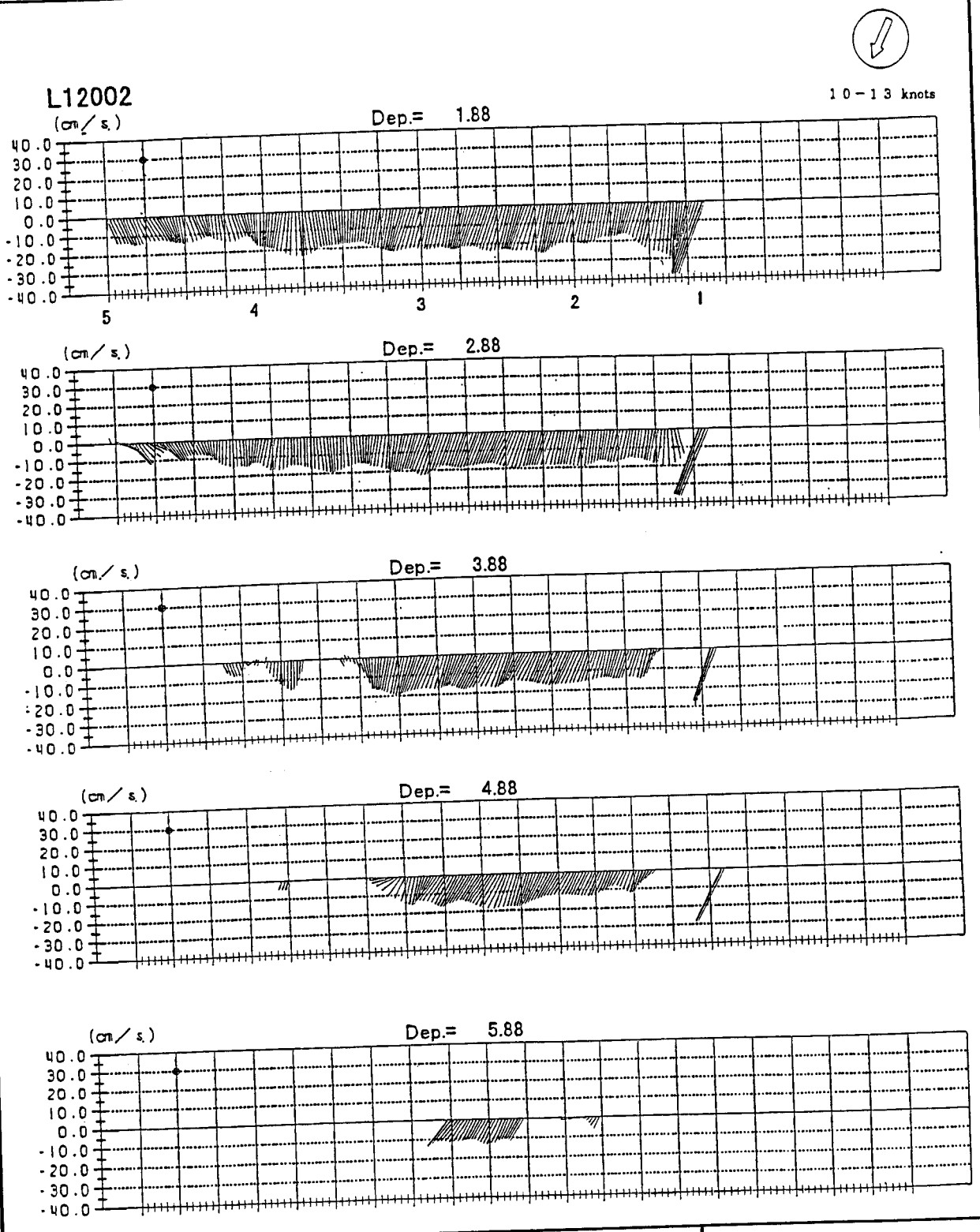

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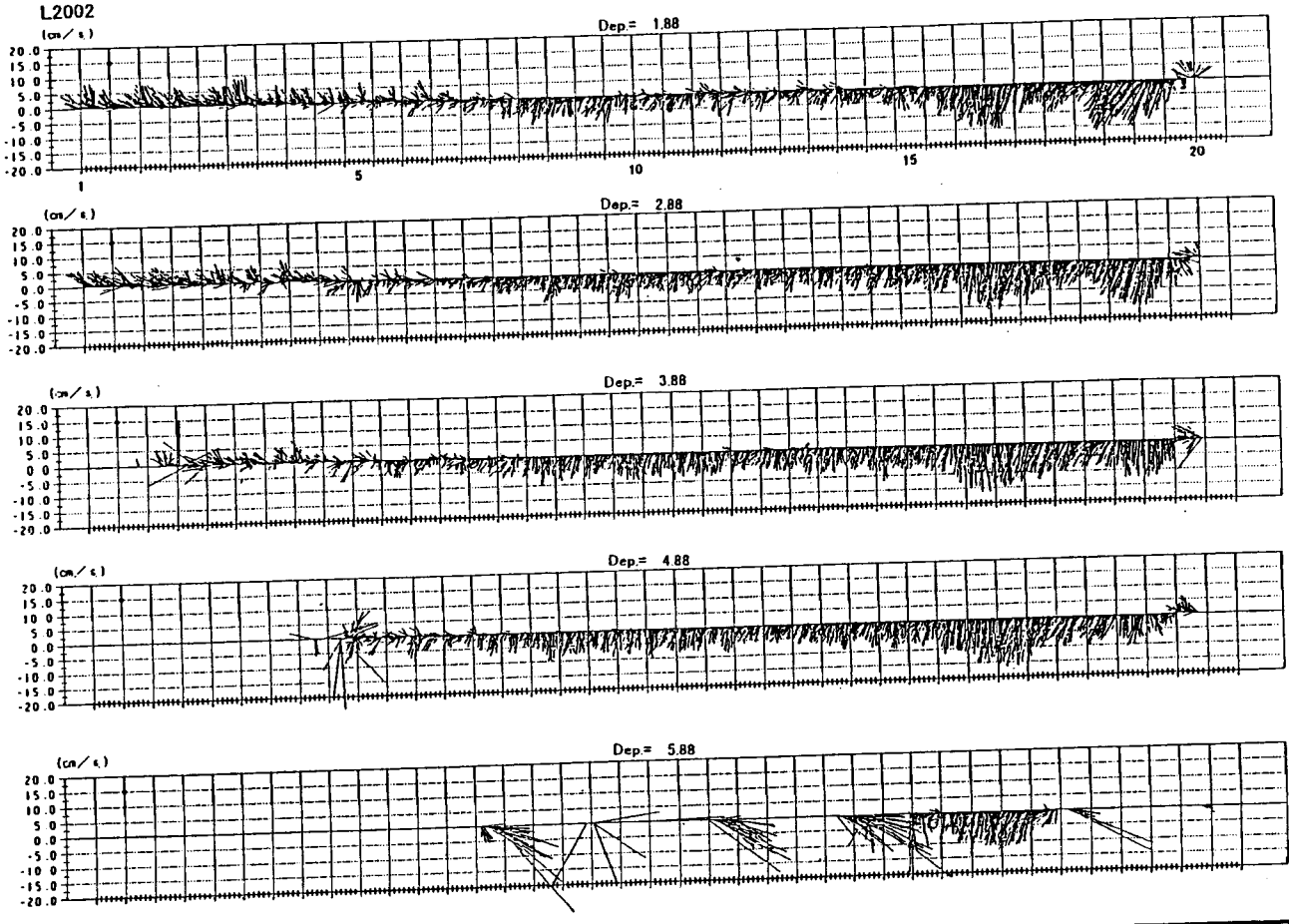
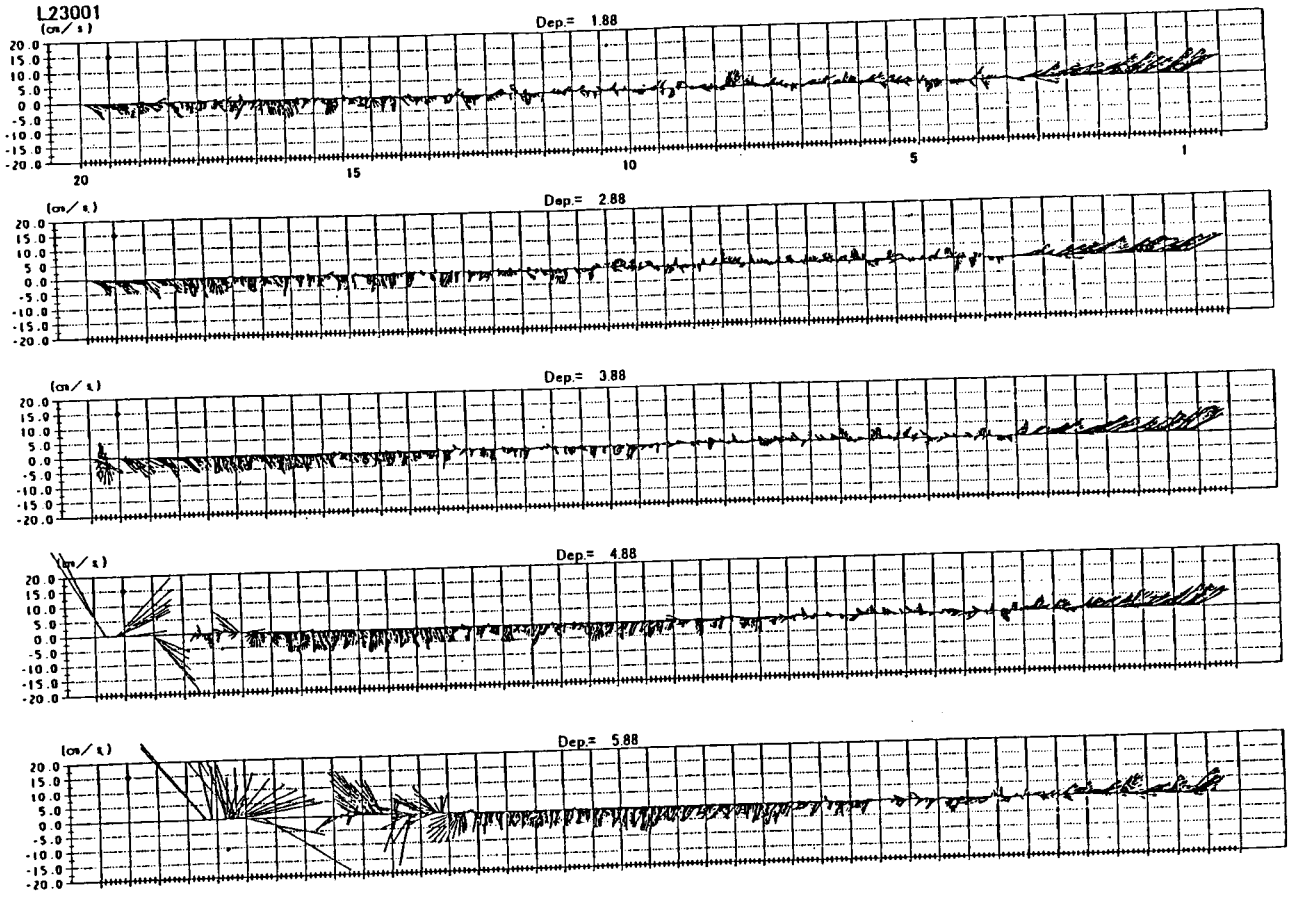
Fig. 6.5-7

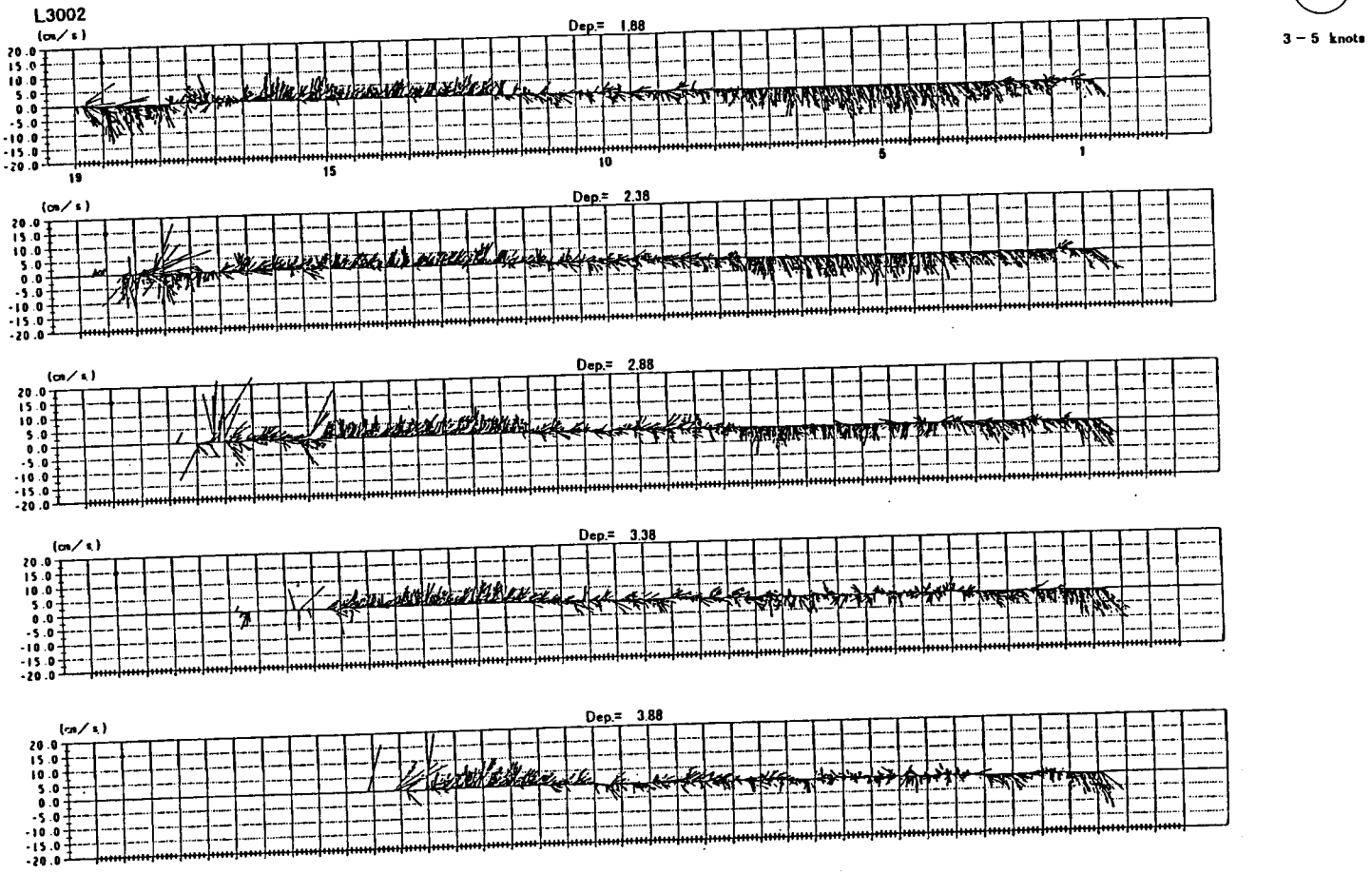
Current Profile of Line-1 (5 August 1999)



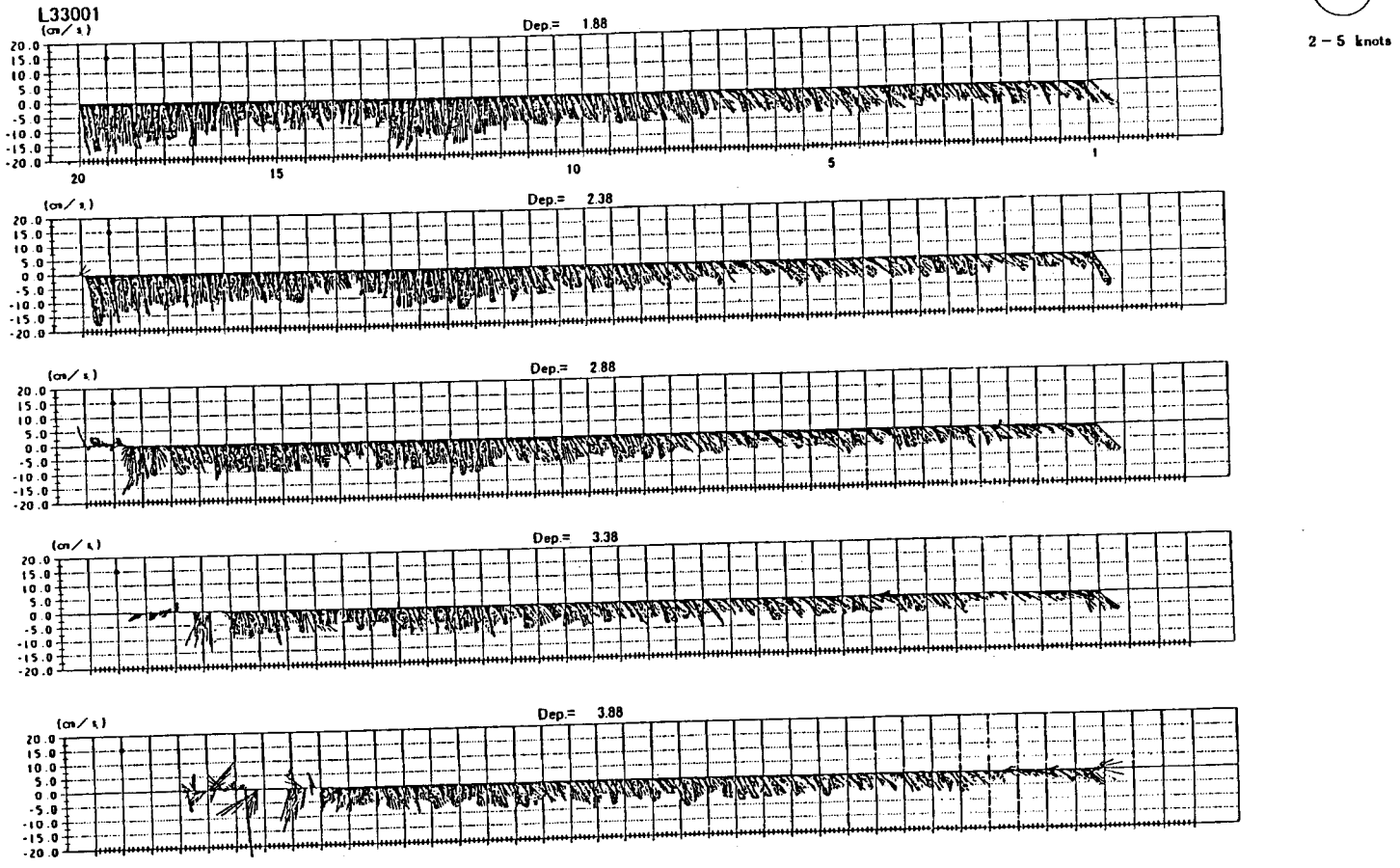
THE STUDY ON THE ENVIRONMENTAL MANAGEMENT OF THE HYDROGRAPHIC BASIN OF PATOS AND MIRIM LAKES IN THE FEDERATIVE REPUBLIC OF BRAZIL	**Fig. 6.5-8**
JAPAN INTERNATIONAL COOPERATION AGENCY KOKUSAI KOGYO CO., LTD. / PACIFIC CONSULTANTS INTERNATIONAL	**Current Profile of Line-2 (27 February 1999)**



THE STUDY ON THE ENVIRONMENTAL MANAGEMENT OF THE HYDROGRAPHIC BASIN OF PATOS AND MIRIM LAKES IN THE FEDERATIVE REPUBLIC OF BRAZIL	Fig. 6.5-9
JAPAN INTERNATIONAL COOPERATION AGENCY KOKUSAI KOGYO CO., LTD. / PACIFIC CONSULTANTS INTERNATIONAL	Current Profile of Line-2 (26 August 1999)



THE STUDY ON THE ENVIRONMENTAL MANAGEMENT OF THE HYDROGRAPHIC BASIN OF PATOS AND MIRIM LAKES IN THE FEDERATIVE REPUBLIC OF BRAZIL	**Fig. 6.5-10**
JAPAN INTERNATIONAL COOPERATION AGENCY KOKUSAI KOGYO CO., LTD. / PACIFIC CONSULTANTS INTERNATIONAL	**Current Profile of Line-3 (27 February 1999)**



THE STUDY ON THE ENVIRONMENTAL MANAGEMENT OF THE HYDROGRAPHIC BASIN OF PATOS AND MIRIM LAKES IN THE FEDERATIVE REPUBLIC OF BRAZIL	**Fig. 6.5-11**
JAPAN INTERNATIONAL COOPERATION AGENCY KOKUSAI KOGYO CO., LTD. / PACIFIC CONSULTANTS INTERNATIONAL	**Current Profile of Line-3 (27 August 1999)**

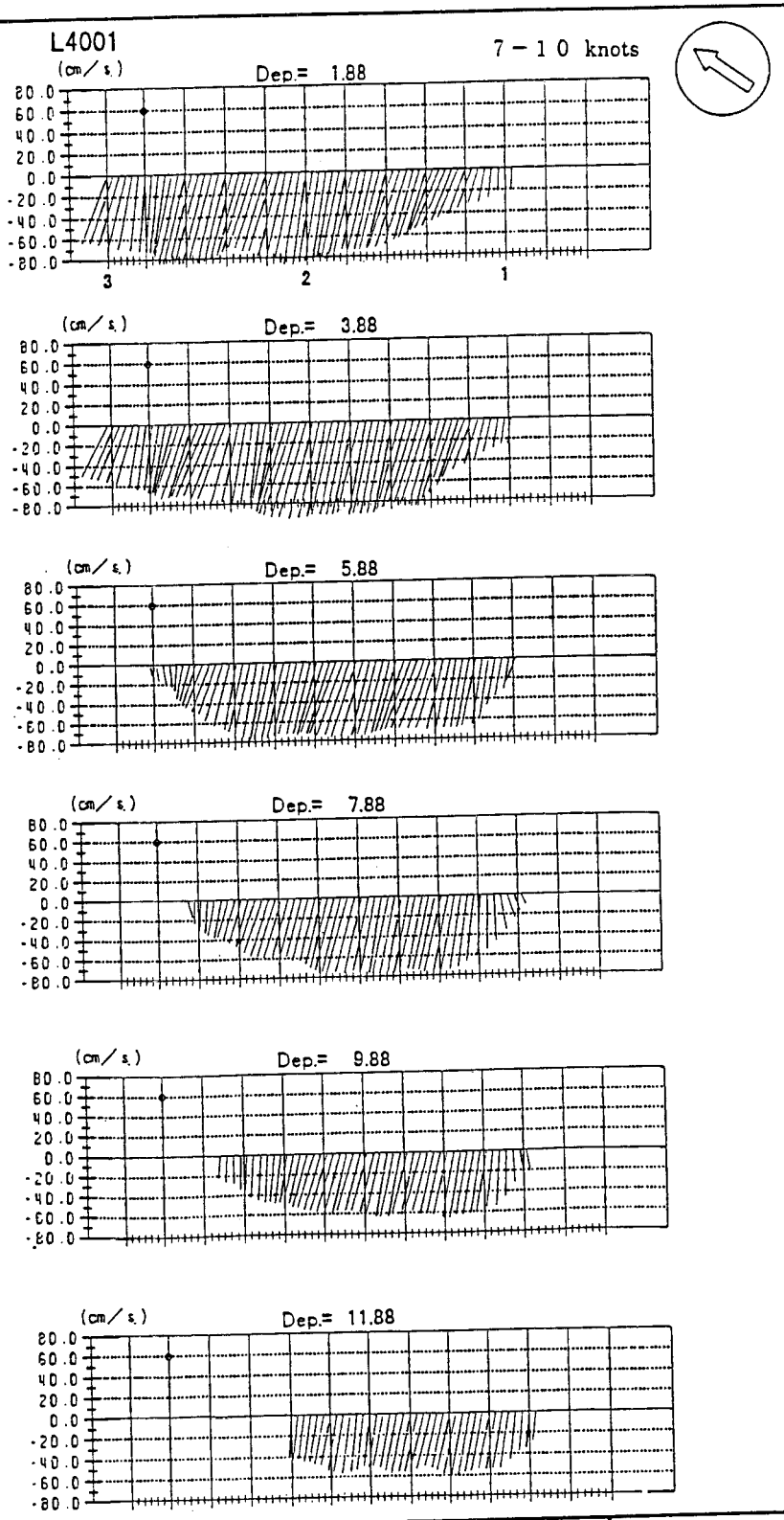


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Fig. 6.5-12

Current Profile of Line-4 (26 February 1999)

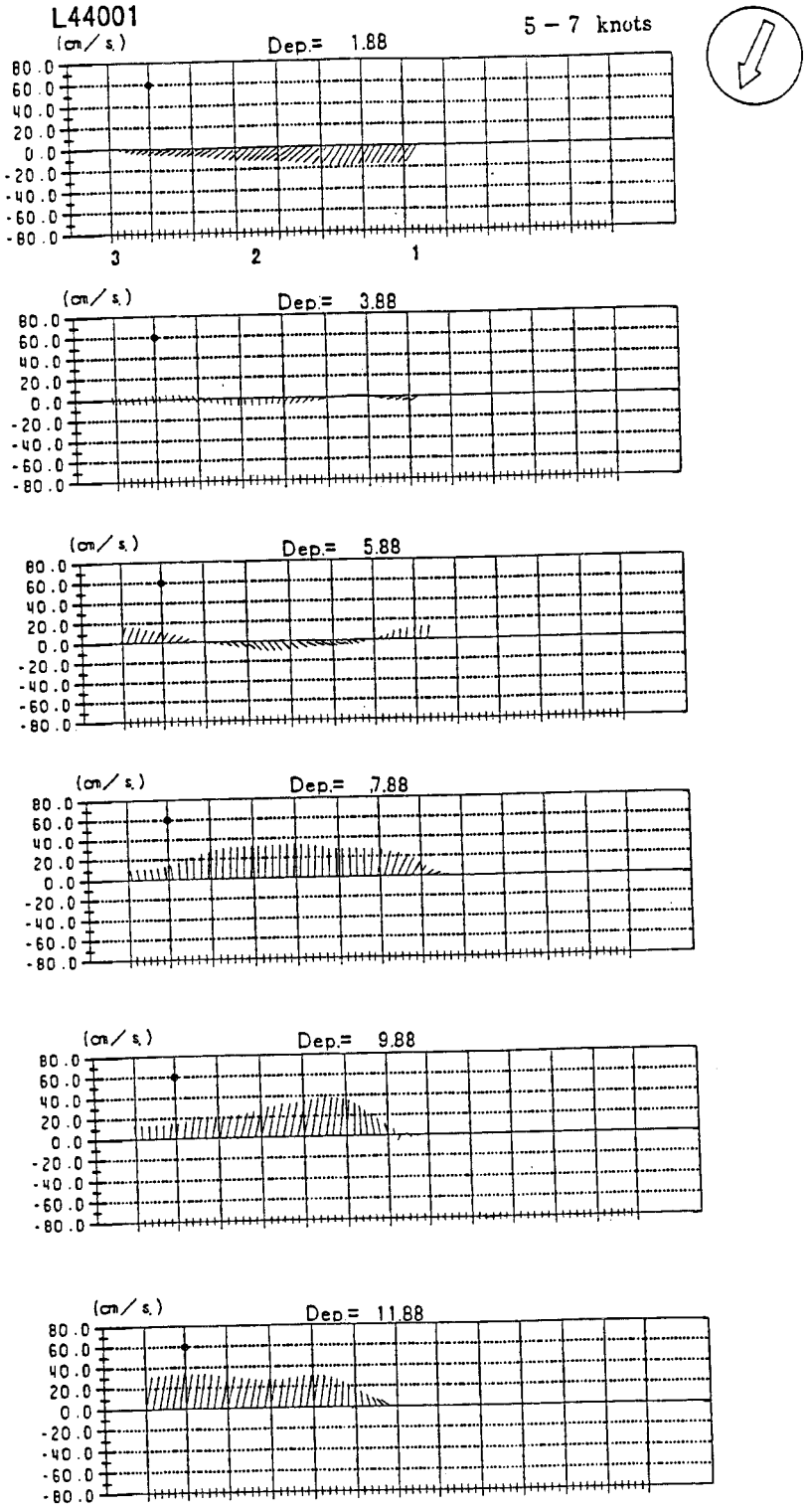

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Fig. 6.5-13

Current Profile of Line-4 (27 August 1999)

(5) Cross Section Flow

Based on the results of the current profile carried out using ADCP, **Table 6.5-3** was prepared to indicate the rough cross section flow at the time of the observation along the target cross sections.

In addition to the fact that measurements could not be carried out on the surface and bottom layers, the survey line does not extend all the way to the shore because the water is shallow, hence the cross section flow is not exactly accurate. The values indicated in **Table 6.5-3** are, therefore, roughly calculated according to the flow sequence.

Table 6.5-3 Amount of Flowing Water through the Cross Section along the Survey Lines

Season	Survey Line	Observation Date	Flow Volume
Summer (Dry Season)	Line – 1 (1)	28/ 2/99	+1.1 x 10^3 m^3/sec
	(2)	28/ 2/99	1.2
	Line – 2	27/ 2/99	+7.0
	Line – 3	27/ 2/99	+1.4
	Line – 4 (1)	26/ 2/99	5.3
	(2)	26/ 2/99	+5.3
	(3)	03/ 3/99	-3.8
	(4)	03/ 3/99	+4.7
Winter (Rainy Season)	Line – 1 (1)	05/8/99	2.4 x 10^3 m^3/sec
	(2)	05/8/99	+2.9
	(3)	25/8/99	+1.8
	(4)	25/8/99	2.2
	Line – 2 (1)	04/8/99	–
	(2)	26/8/99	0.1
	Line – 3 (1)	03/8/99	7.2
	(2)	27/8/99	1.8
	Line – 4 (1)	02/8/99	6.7
	(2)	02/8/99	+6.5
	(3)	02/8/99	6.7
	(4)	27/8/99	+1.0
	(5)	27/8/99	0.9
	(6)	27/8/99	+0.8

[Note] Inflow: positive figures refer to northward flow, while negative figures refer to southward flow.

6.5.3 Current Conditions in Patos Lake

Although the current survey in summer and winter only covered a limited number of stations and survey lines, several new information were obtained. Along with existing data, the current characteristics in Patos Lake were summarized as shown below.

(1) Outline of Current Conditions

With inflow from Lake Guaiba, Patos Lake flows southward through the Rio Grande channel to the open sea along with the inflow from Rio Camaqua and Canal de Sao Goncalo.

Observations show that meteorological conditions and the amount of inflowing water from rivers significantly affect current conditions in Patos Lake.

(2) Current Conditions in the Mouth of Lake Guaiba (Offshore of Itapua)

The flow at the mouth of Lake Guaiba (offshore of Itapua) normally moves southward. The ADCP survey, however, confirmed that certain meteorological and hydrological conditions cause the flow to move northwards. Existing data also report the same tendencies.

(3) Current Conditions in the Northern Area

Surveys to determine current conditions in the northern area were only carried out in station C-1. Although southward flow was observed for an extensive period of time, certain meteorological conditions were found to result in a northward flow.

LANDSAT images of Saco de Tapes indicate very weak flow in this area.

(4) Current Conditions in the Central Area

Profiling carried out to determine current conditions in the central area covered two survey lines: Line-2 (line linking Arambare and Pta. Cristovao Pereira) and Line-3 (line linking Feitoria and Pta. Lencois). The survey results show that although the flow mainly moves southward, flow from some sections moves northwards, partly generating circulatory area (see **Figs. 6.5-8** to **6.5-11**).

(5) Current Conditions in the Southern Area (Lake Estuary)

Current conditions in this area are quite complex because some parts are deep (over 15m) and proximity to the open sea results in susceptibility to tidal influences.

The results of observations on fixed points (station C-4) and the ADCP profiling on Line-4 indicate that although the lake water mainly flows into the sea, the opposite also takes place due to meteorological and hydrological influences.

Due to tidal influences, salt water intrusion is observed in this area. A typical example would be the results of the profiling in the Rio Grande Channel (see **Fig. 6.5-13**), which state that while surface water flows southwards to the open sea, water from below flows in the opposite direction due to the inflow from the sea.

(6) Seasonal Impacts on Current Conditions

Surveys on current conditions were carried out in summer (dry season) and in winter (rainy season). As precipitation in winter this year was extremely lower than usual, significant seasonal impacts on current conditions based on variations in river inflow were not determined.

On the other hand, all data confirm the significant relationship between wind and flow.

(7) Vertical Current Pattern

Vertical current patterns in the northern and central areas of Patos Lake were not observed to significantly vary presumably because overall these areas are shallow.

However, vertical current was observed to significantly vary in the southern area, due to its depth and susceptibility to tidal influences, the latter because of its proximity to the sea.

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