Chapter 6

Hydrological Conditions of Patos Lake

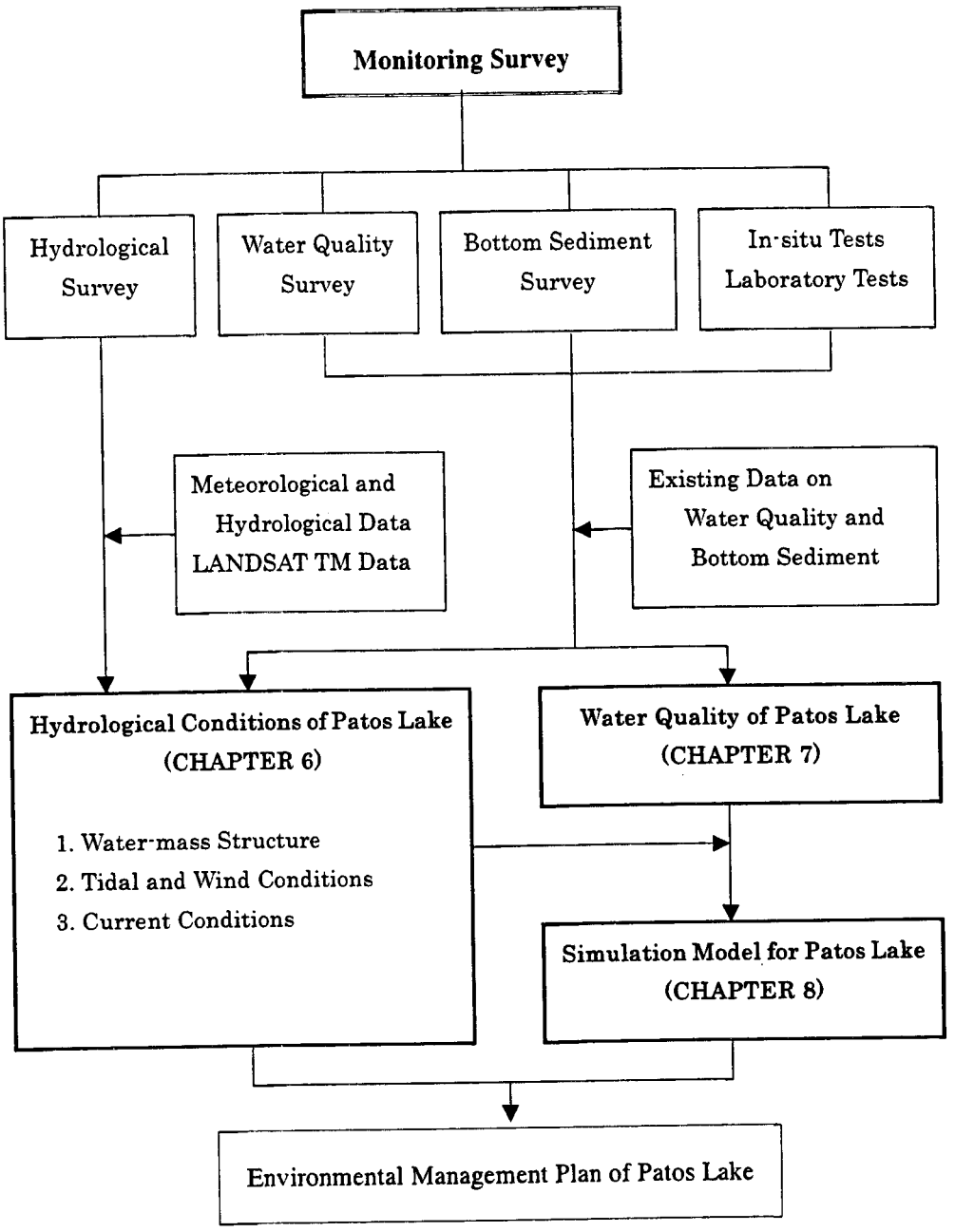
CHAPTER 6 HYDROLOGICAL CONDITIONS OF PATOS LAKE

6.1 Introduction

Present hydrological conditions and water quality were monitored to determine flow conditions and water quality to prepare a water quality and environmental management plan in the Patos and Mirim Lakes.

The monitoring survey was largely divided into the hydrological (river discharge and lake flow surveys) and water and bottom sediment quality surveys. In consideration of seasonal changes, the survey was carried out for a period of 12 months: twice (once each in the dry and rainy season) for hydrological and bottom sediment quality surveys and 11 times for water quality survey.

As shown in **Fig. 6.1-1**, this chapter deals with the Patos Lake flow characteristics determined based on the results of the monthly monitoring surveys and collected wind conditions and tidal data etc.. Distribution characteristics of water quality in Patos Lake are described in the next chapter (Chapter 7) and simulation models for hydrological condition and water quality in Patos Lake are discussed in Chapter 8.



THE STUDY ON THE ENVIRONMENTAL MANAGEMENT
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Fig. 6.1-1

Work Flow on Hydrological Conditions and Water Quality of Patos Lake

6.2 Monitoring Survey

6.2.1 Hydrological Survey

The details of the hydrological survey are as shown below. **Fig. 6.2-1** and **Table 6.2-1** show the survey stations.

(1) Current Observation at Fixed Points

(a) Observation points and layers : 3 points (C-1, C-3, C-4)
one layer for point C-1 & C-3 : middle layer (3.0m above sea bottom)
two layers for points C-4 : upper layer (9.2m above sea bottom)
lower layer (3.7m above sea bottom)

(b) Number of observation :
once each in the dry (summer) and rainy (winter) season

(c) Observation period :
point C-1 : 41 days in the dry season (28/2 to 10/4/1999)
20 days in the rainy season (5/8 to 25/8/1999)
point C-3 : 4 days in the rainy season (3/8 to 7/8/1999)
point C-4 : 18 days in the rainy season (2/8 to 20/8/1999)

(d) Observation method : installation of current meters
Sensordata SD-2000 at point C-1
Aanderaa RCM-7 at points C-3 and C-4

(2) Current Profiling

(a) Number of profiles : 4 lines (Line-1 to Line-4)

(b) Number of observation :
Line-1 : twice in the dry season (28/2/1999)
four times in the rainy season (5/8 and 25/8/1999)
Line-2 : once in the dry season (27/2/1999)
twice in the rainy season (4/8 and 26/8/1999)
Line-3 : once in the dry season (27/2/1999)

twice in the rainy season (3/8 and 27/8/1999)

Line-4 : four times in the dry season (26/2 and 3/3/1999)
six times in the rainy season (2/8 and 27/8/1999)

(c) Observation method : using an Acoustic Doppler Current Profiler (ADCP)
RD Instrument 1200 KHz

(3) Flow Measurement in Sao Goncalo Canal

(a) Measurement point and layer : one layer at one point (R-3)

(b) Number of measurements :
twice in the dry season (10/2 and 2/3/1999)
thrice in the rainy season (30/6, 19/7 and 23/8/1999)

(c) Measurement method : using a portable flow meter

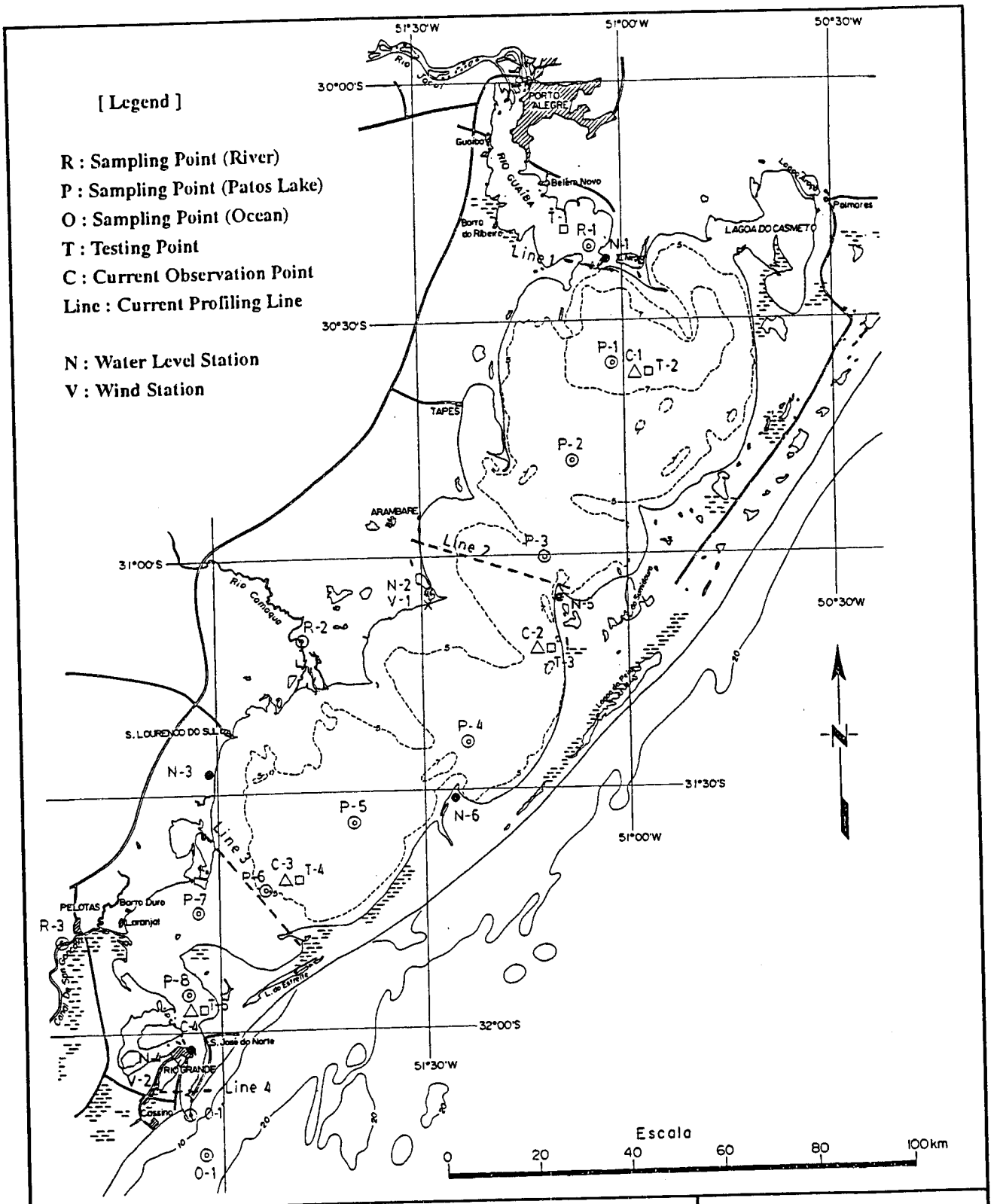

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Fig. 6.2-1

Location Map of Monitoring Survey

Table 6.2-1 Coordinates of Monitoring Points

1. Sampling Stations/Points (Water and Bottom Sediments)				
St. No.	Latitude	Longitude	Water Depth	Remarks
R-1	30 ° 21 ′ 42 ″ S	51 ° 03 ′ 36 ″ W	10.0 m	Rio Guiaba
R-2	31 ° 10 ′ 00 ″ S	51 ° 48 ′ 00 ″ W	—	Rio Camaqua
R-3	31 ° 48 ′ 30 ″ S	52 ° 22 ′ 30 ″ W	—	Canal Sao Goncalo
P-1	30 ° 36 ′ 00 ″ S	51 ° 00 ′ 00 ″ W	7.4 m	same as T-2, C-1
P-2	30 ° 47 ′ 00 ″ S	51 ° 07 ′ 30 ″ W	6.5 m	
P-3	31 ° 00 ′ 00 ″ S	51 ° 11 ′ 30 ″ W	6.8 m	
P-4	31 ° 24 ′ 00 ″ S	51 ° 23 ′ 00 ″ W	6.1 m	
P-5	30 ° 34 ′ 00 ″ S	51 ° 40 ′ 00 ″ W	6.7 m	
P-6	31 ° 41 ′ 00 ″ S	51 ° 53 ′ 30 ″ W	7.0 m	same as T-4, C-3
P-7	31 ° 43 ′ 00 ″ S	52 ° 03 ′ 00 ″ W	—	
P-8	31 ° 56 ′ 30 ″ S	52 ° 05 ′ 00 ″ W	7.2 m	same as T-5
O-1 (O-1’)	32 ° 15 ′ 00 ″ S (32 ° 10 ′ 33 ″ S)	52 ° 03 ′ 00 ″ W (52 ° 05 ′ 01 ″ W)	15.0 m (15.0m)	
2. In-situ and Laboratory Tests on Water Quality and Bottom Sediments				
St. No.	Latitude	Longitude	Water Depth	Remarks
T-1	30 ° 19 ′ 06 ″ S	51 ° 07 ′ 00 ″ W	—	
T-2	30 ° 36 ′ 00 ″ S	51 ° 00 ′ 00 ″ W	7.4 m	same as P-1, C-1
T-3	31 ° 12 ′ 30 ″ S	51 ° 13 ′ 00 ″ W	6.6 m	
T-4	31 ° 41 ′ 00 ″ S	51 ° 53 ′ 30 ″ W	7.0 m	same as P-6, C-3
T-5	31 ° 56 ′ 30 ″ S	52 ° 05 ′ 00 ″ W	7.2 m	same as P-8
3. Current Observation at Fixed Points				
St. No.	Latitude	Longitude	Water Depth	Remarks
C-1	30 ° 36 ′ 00 ″ S	51 ° 00 ′ 00 ″ W	7.4 m	same as P-1, T-2
C-3	31 ° 41 ′ 00 ″ S	51 ° 53 ′ 30 ″ W	7.0 m	same as P-6, T-4
C-4	32 ° 08 ′ 00 ″ S	52 ° 06 ′ 00 ″ W	13.0 m	
4. Current Profiling				
Line No.	Location		Line Length	Remarks
Line-1	Entrance part of Rio Guaiba		3.5 km	
Line-2	Central part of Patos Lake		32.0 km	
Line-3	Ponta da Feitoria – Ponta dos Lencois		30.0 km	
Line-4	Entrance part of Patos Lake		0.87km	

[Note] Water Depth : water depth in the existing chart (meters)

6.2.2 In-situ Observation and Sampling for Water Quality and Bottom Sediment Survey

The details of the water quality and bottom sediment survey are as shown below. The outline of the survey at each survey station and the survey frequency are as shown in **Table 6.2-2**. See **Fig. 6.2-1** and **Table 6.2-1** for the survey stations.

(1) Water Quality Survey

(a) Number of survey stations : 12 points
River mouth : 3 (R-1, R-2, R-3)
Patos lake : 8 (P-1, P-2, P-3, P-4, P-5, P-6, P-7, P-8)
Offshore area (Ocean) : 1 (O-1)

(b) Observation/Sampling layers :
2 layers for lake & offshore area : upper layer (0.5m below sea surface)
lower layer (1.0m above sea bottom)
1 layer for river mouth : 0.5m below sea surface

(c) Observation/Sampling frequency : 11 times (once a month)
(Date of observation/sampling)

① 09 to 11 Feb. 1999
② 02 to 03 Mar. 1999
③ 11 to 12 Apr. 1999
④ 17 to 18 May 1999
⑤ 23 to 24 June 1999
⑥ 20 to 21 July 1999
⑦ 23 to 24 Aug. 1999
⑧ 22 to 23 Sep. 1999
⑨ 04 to 05 Nov. 1999
⑩ 07 to 08 Dec. 1999
⑪ 18 to 19 Jan. 2000

(d) Survey items :
In-situ observation : salinity, water temperature, pH, DO, transparency, turbidity
Chemical analysis : see Chapter 7

(e) Sampling method : using a Van Dorn water sampler

(2) Bottom Sediment Survey

(a) Number of survey stations : 12 (same as water quality survey stations)

(b) Observation/Sampling layers : 1 layer (sea bottom, surface)

(c) Observation/Sampling frequency : twice (once each in the dry and rainy season)

(Date of observation/sampling)

① Dry season : Mar. 2 to 3, 1999

② Rainy season : Aug. 23 to 24, 1999

(d) Survey items :

In-situ observation : pH, ORP, characteristics of bottom materials

Chemical analysis : see Chapter 7

(e) Sampling method : using an Eckmann-berge mud sampler

(3) In-situ Tests and Laboratory Tests on Water Quality and Bottom Sediment

(a) Settling Test

Number of testing points : 5 points (T-1, T-2, T-3, T-4, T-5)

Testing layers : 2 layers (upper and lower layer)

Testing frequency : twice (once each in the dry and rainy season)

(Testing period)

① Dry season : T-1 : 41 days (28/2 to 10/4/1999)
T-2 : 41 days (28/2 to 10/4/1999)

② Rainy season : T-1 : 20 days (5/8 to 25/8/1999)
T-2 : 20 days (5/8 to 25/8/1999)
T-3 : 22 days (4/8 to 26/8/1999)
T-4 : 24 days (3/8 to 27/8/1999)
T-5 : 25 days (2/8 to 27/8/1999)

Testing items : see Chapter 7

(b) Primary Production Test

Number of testing points : 5 points (T-1, T-2, T-3, T-4, T-5)

Testing layers : 3 layers (upper, middle and lower layers)

Testing frequency : twice (once each in the dry and rainy season)

(Testing date)

① Dry season : T-1 : May 19, 1999 T-2 : Apr. 10, 1999
T-3 : Apr. 9, 1999 T-4 : Apr. 8, 1999
T-5 : Apr. 7, 1999

② Rainy season : T-1 : Aug. 5, 1999 T-2 : Aug. 5, 1999
T-3 : Aug. 4, 1999 T-4 : Aug. 3, 1999
T-5 : Aug. 2, 1999

Testing items : see Chapter 7

(c) Mud Elution Test

Number of testing points : 5 points (T-1, T-2, T-3, T-4, T-5)

Testing layers : 1 layer (sea bottom surface)

Testing frequency : twice (once each in the dry and rainy season)

Testing period : 20 days (test samples : every two days)

(Sampling date)

① Dry season : T-1 : Feb 28, 1999 T-2 : Feb. 28, 1999
T-3 : Feb. 27, 1999 T-4 : Feb. 26, 1999
T-5 : Feb. 26, 1999

② Rainy season : T-1 : Aug. 5, 1999 T-2 : Aug. 5, 1999
T-3 : Aug. 4, 1999 T-4 : Aug. 3, 1999
T-5 : Aug. 2, 1999

Testing items : see Chapter 7

Table 6.2-2 Water Quality and Bottom Sediment Monitoring Survey Outline

St. No.	Water Quality (Sampling/Analysis)		Bottom Sediments (Sampling/Analysis)	In-situ and Laboratory Tests		
	Layers	Frequency	Frequency	Settling Test	Mud Elution Test	Primary Production Test
R-1	1	11	2			
R-2	1	11	2			
R-3	1	11	2			
P-1	2	11	2			
P-2	2	11	2			
P-3	2	11	2			
P-4	2	11	2			
P-5	2	11	2			
P-6	2	11	2			
P-7	2	11	2			
P-8	2	11	2			
O-1	2	11	2			
T-1				2	2	2
T-2				2	2	2
T-3				2	2	2
T-4				2	2	2
T-5				2	2	2

[Note] Frequency : 11-refers to once a month sampling/observation.

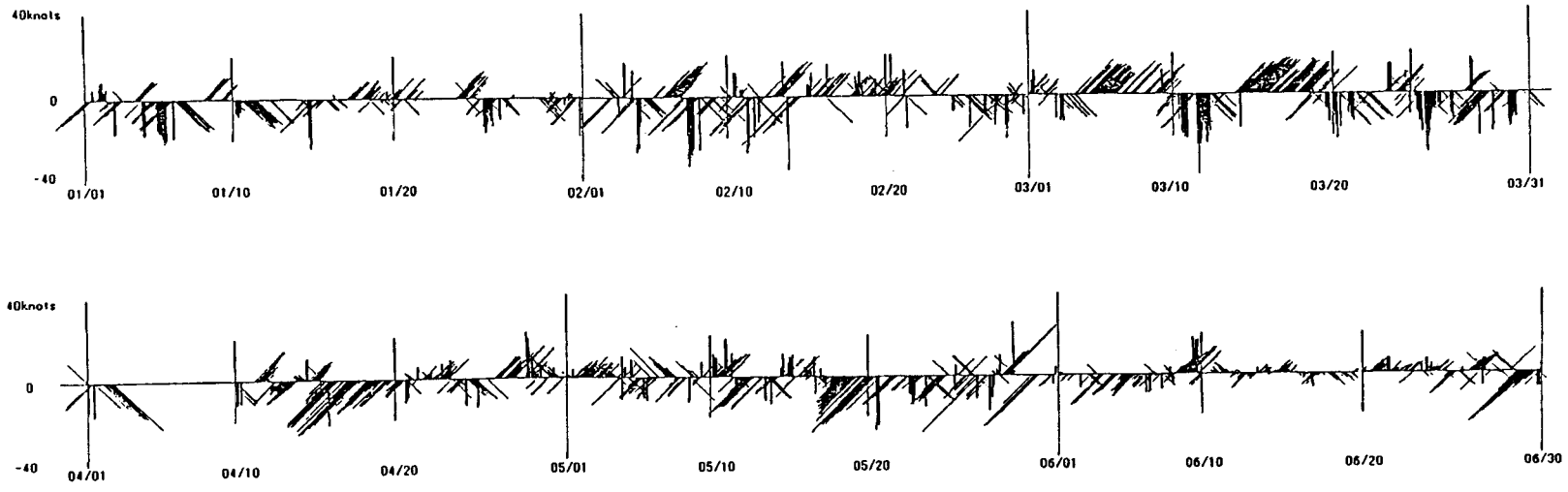
2-refers to sampling/observation carried out once each in the dry and rainy season.

6.2.3 Meteorological and Hydrological Conditions during the Survey

The monitoring survey is scheduled to be carried out every months for a period of one year from February 1999. The bottom sediment survey, various tests (settling test, primary production test, mud elution test), and the current survey were carried out in the dry (from late February to early April) and wet (August) season.

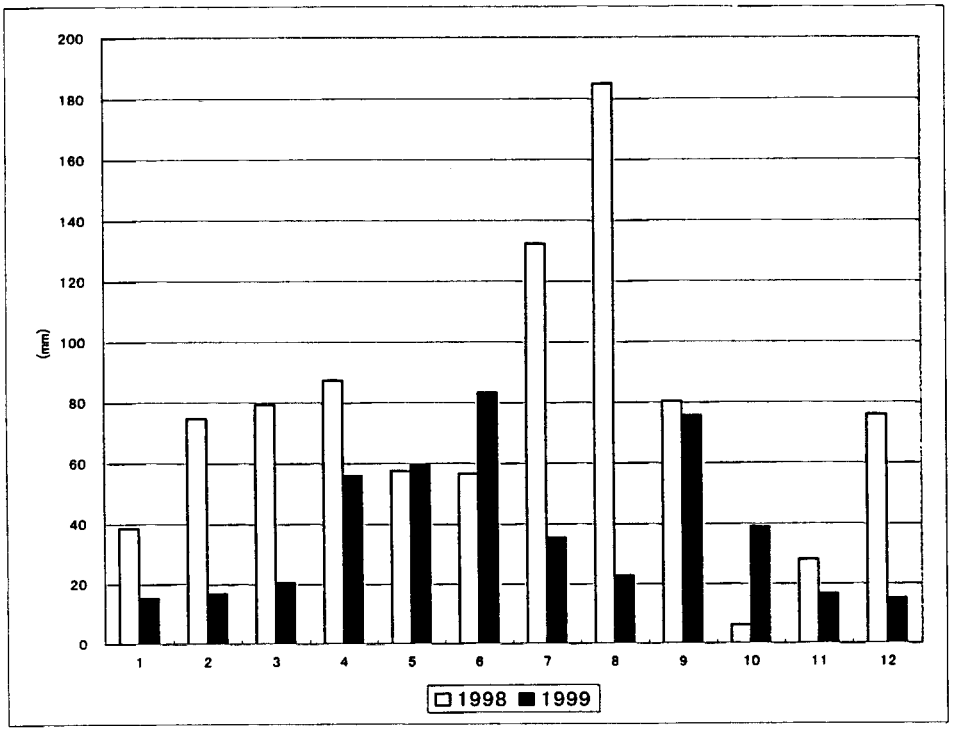
The meteorological and hydrological data in and around Patos Lake were obtained from the pilot station in Rio Grande (meteorological and water level data) and Itapua, Santa Rita, Sao Laurenco do Sul, Bojuru and Cristovao Pereira (water level data). Data on wind conditions were also obtained from Santa Rita.

These meteorological and hydrological data are summarized in **MON-F-1** of the annex. Using Santa Rita as a representative station, **Figs 6.2-2** and **6.2-3** were made to illustrate changes in wind conditions and tidal fluctuation. Rainfall data from the Rio Grande station were used to prepare **Fig. 6.2-3**, which illustrates precipitation in 1998 and 1999.

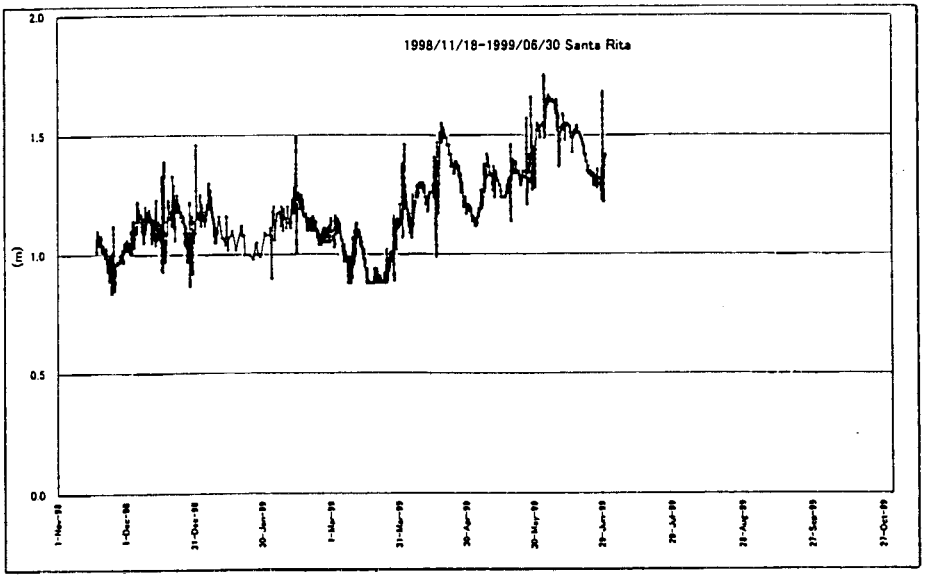


THE STUDY ON THE ENVIRONMENTAL MANAGEMENT OF THE HYDROGRAPHIC BASIN OF PATOS AND MIRIM LAKES IN THE FEDERATIVE REPUBLIC OF BRAZIL	Fig. 6.2-2
JAPAN INTERNATIONAL COOPERATION AGENCY KOKUSAI KOGYO CO., LTD. / PACIFIC CONSULTANTS INTERNATIONAL	**Wind Condition in Santa Rita during the Survey Period**

Precipitation (Rio Grande)



Tidal Fluctuation (Santa Rita)



THE STUDY ON THE ENVIRONMENTAL MANAGEMENT OF THE HYDROGRAPHIC BASIN OF PATOS AND MIRIM LAKES IN THE FEDERATIVE REPUBLIC OF BRAZIL	**Fig. 6.2-3**
JAPAN INTERNATIONAL COOPERATION AGENCY KOKUSAI KOGYO CO., LTD. / PACIFIC CONSULTANTS INTERNATIONAL	**Precipitation and Tidal Fluctuation during the Survey Period**

6.3 Water-mass Structure

The in-situ water quality observation results were summarized and arranged as shown in **MON-T-1** of the annex, and used to summarize data on water temperature, salinity, pH, DO, turbidity and transparency in **MON-T-2**.

6.3.1 Water Temperature

From the water temperature observation results, **Fig. 6.3-1** was made to illustrate water temperature distribution patterns in the dry season (March 1999) and the wet season (August 1999).

Observations carried out in March and August show a decrease in temperature in the southward flow from the mouth of Rio Guaiba and a slight increase in temperature at the estuary of Patos Lake. In the same month, however, a discrepancy of less than 1ºC was observed in the surface water temperature. Observations carried out at the mouth of Rio Guaiba and the open sea section in March and August showed a discrepancy in surface water temperature of 2.7ºC (March) and 1.8ºC (August).

Vertically, water temperature was observed to fall with depth.

6.3.2 Salinity

From the salinity observation results, **Fig. 6.3-2** was made to illustrate salinity distribution patterns in February 1999 (dry season) and August 1999 (rainy season).

In February, salinity was 11.7‰ at the surface in the offshore area of Ponta da Feitoria, and 20.4‰ at the bottom layer. Concentration, however, was observed to diminish rapidly to the utmost north toward the main body of the lake.

On the other hand, concentration even in the central lake area (P-6 to P-4 stations) was observed at 3.0 to 4.4‰, and from 0.2 to 0.3‰ in the north area (P-2 station).

The overall tendency observed in August was similar to observations made in February, although the concentration tends to decrease overall. In particular, salinity is low at the surface of the lake estuary (P-8 station) and the open sea section (0-1 station), at 2.3‰ and 10.9‰ respectively.

Vertically, concentration tends to intensify with depth.

6.3.3 Dissolved Oxygen

From the dissolved oxygen (DO) observation results, **Fig. 6.3-3** was made to illustrate DO distribution patterns in March 1999 (dry season) and August 1999 (rainy season).

In March, the observation shows a DO distribution of over 6.0mg/l overall, with stations P-5 and P-7 in the central and southern areas showing lower values.

In August, a value of over 8.0mg/l was observed, and the concentration tends to decrease in the bottom layer from the mouth of Rio Guaiba all the way downstream.

As for vertical distribution, DO levels in Patos Lake declined with depth.

6.3.4 Turbidity

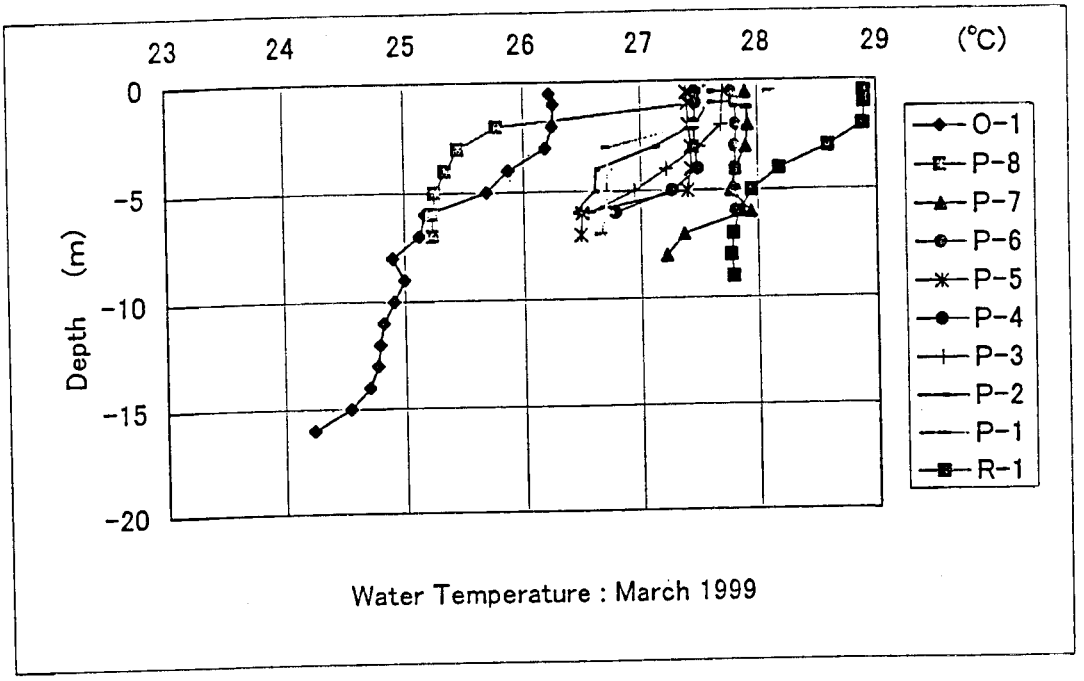
From the turbidity observation results, **Fig. 6.3-4** was made to illustrate turbidity distribution patterns in February 1999 (dry season) and August 1999 (rainy season).

In February, the northern section of the lake, from stations P-1 to P-3, was distinctively found to be highly turbid.

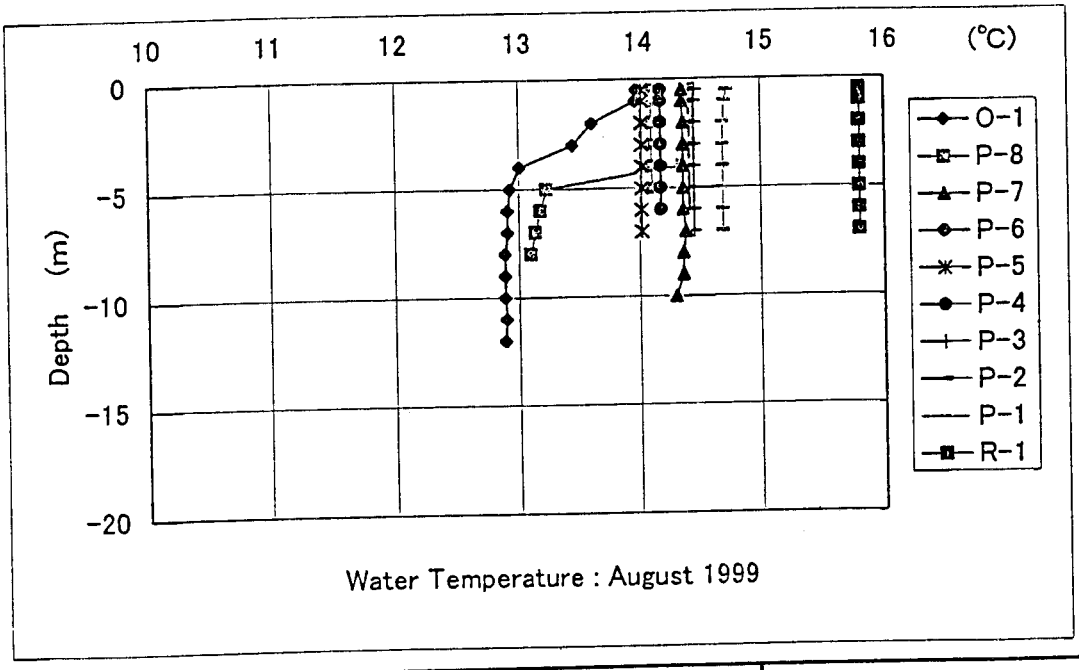
In contrast, turbidity in stations P-5 to P-7 in the central and southern lake areas was low in August.

Concentration varied between the surface and bottom layers, with concentration in the latter exceeding the former.

Summer

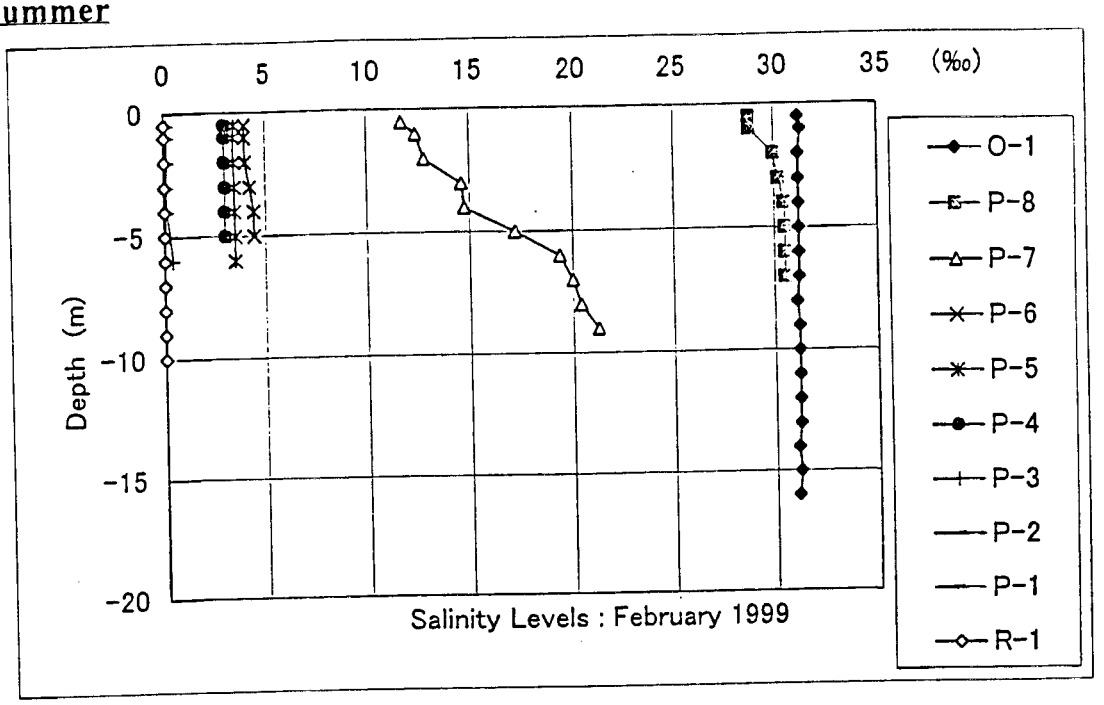


Winter



THE STUDY ON THE ENVIRONMENTAL MANAGEMENT OF THE HYDROGRAPHIC BASIN OF PATOS AND MIRIM LAKES IN THE FEDERATIVE REPUBLIC OF BRAZIL	**Fig. 6.3-1**
JAPAN INTERNATIONAL COOPERATION AGENCY KOKUSAI KOGYO CO., LTD. / PACIFIC CONSULTANTS INTERNATIONAL	**Water Temperature by Profiling**

Summer



Winter

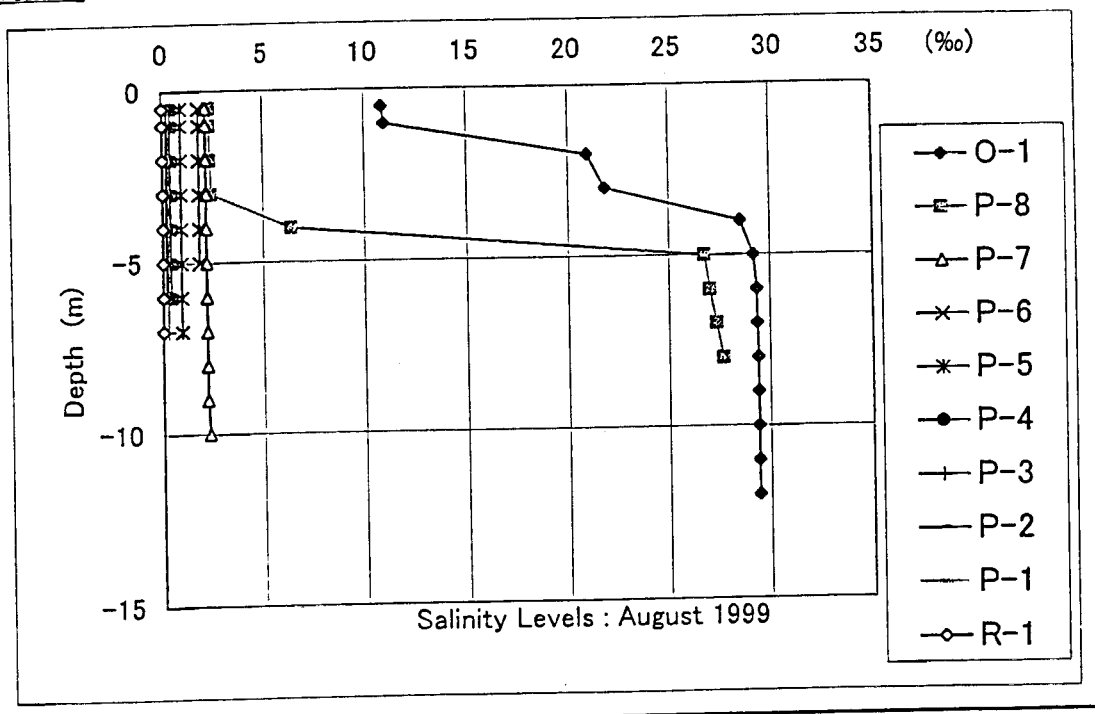


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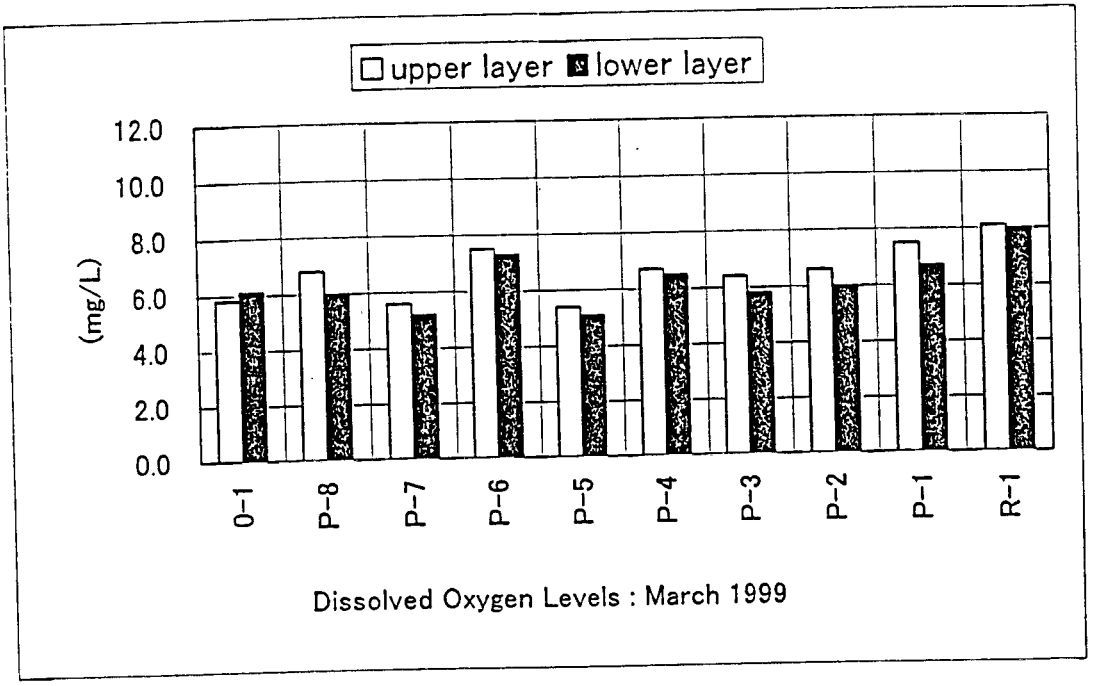
Fig. 6.3-2

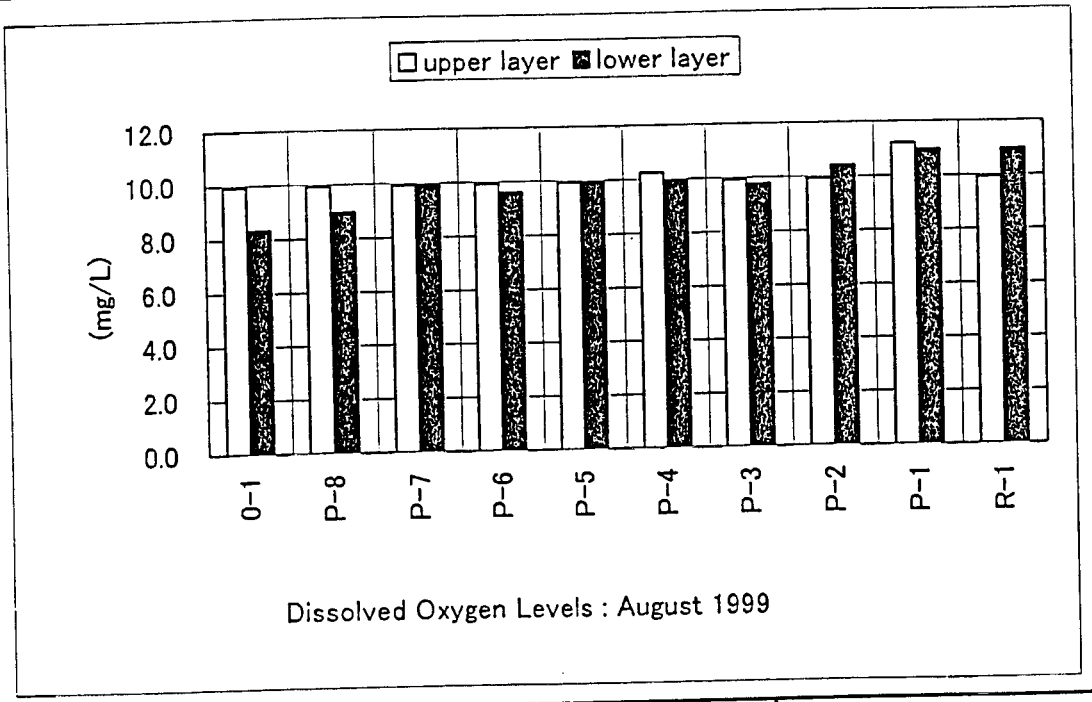
Salinity Levels by Profiling

Summer



Dissolved Oxygen Levels : March 1999

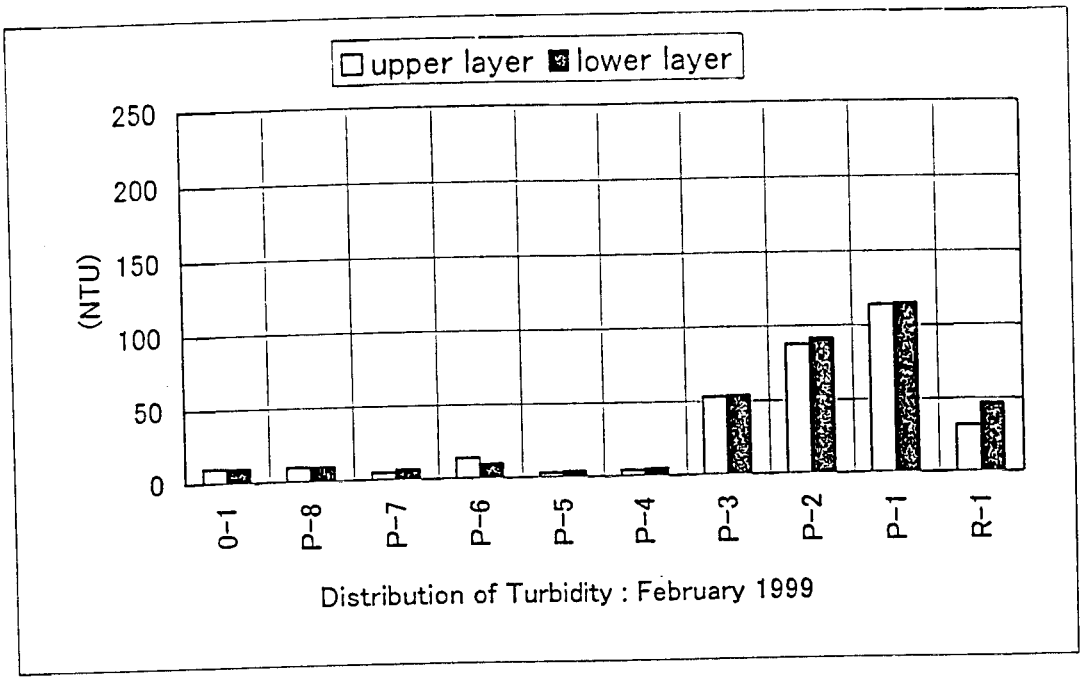
Winter



Dissolved Oxygen Levels : August 1999

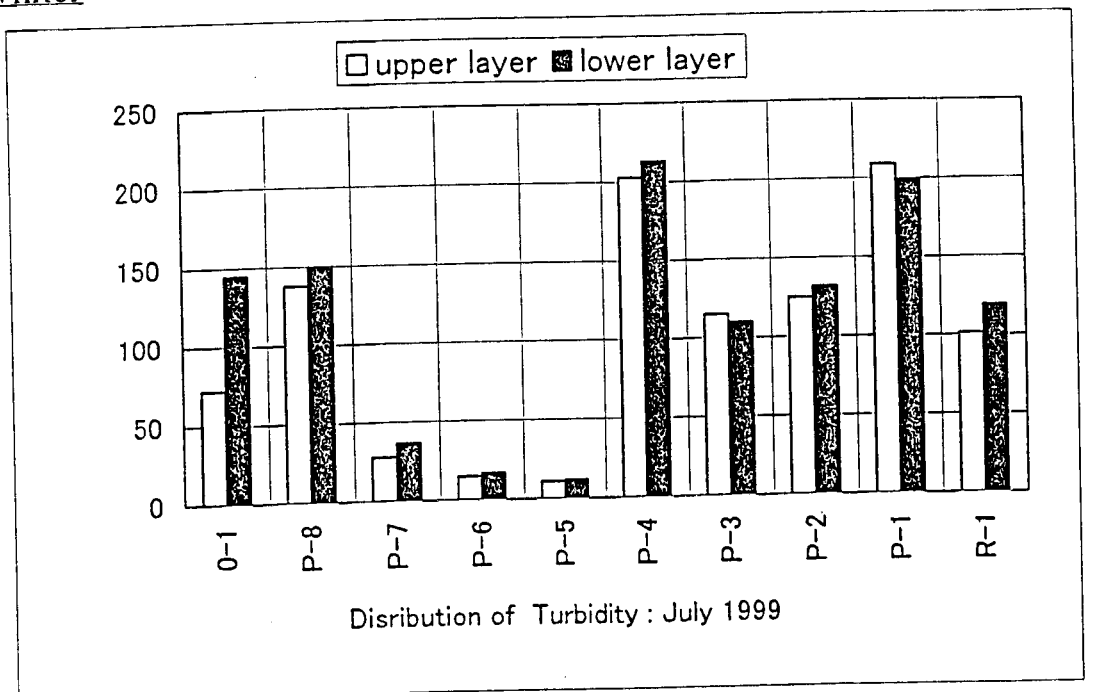
THE STUDY ON THE ENVIRONMENTAL MANAGEMENT OF THE HYDROGRAPHIC BASIN OF PATOS AND MIRIM LAKES IN THE FEDERATIVE REPUBLIC OF BRAZIL	**Fig. 6.3-3**
JAPAN INTERNATIONAL COOPERATION AGENCY KOKUSAI KOGYO CO., LTD. / PACIFIC CONSULTANTS INTERNATIONAL	**Dissolved Oxygen (DO) Levels**

Summer



Distribution of Turbidity : February 1999

Winter



Disribution of Turbidity : July 1999

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JAPAN INTERNATIONAL COOPERATION AGENCY KOKUSAI KOGYO CO., LTD. / PACIFIC CONSULTANTS INTERNATIONAL	**Turbidity Levels**

6.3.5 Water-mass Structure in Patos Lake

In addition to monitoring at the site, LANDSAT TM data (12/6/1996) covering the study area were also analyzed. The analysis of the Patos Lake LANDSAT image was carried out to determine water temperature, turbidity, and Chlorophyl-a levels. The results of the analysis are shown in **Figs. 6.3-5**, **6.3-6** and **6.3-7**, respectively.

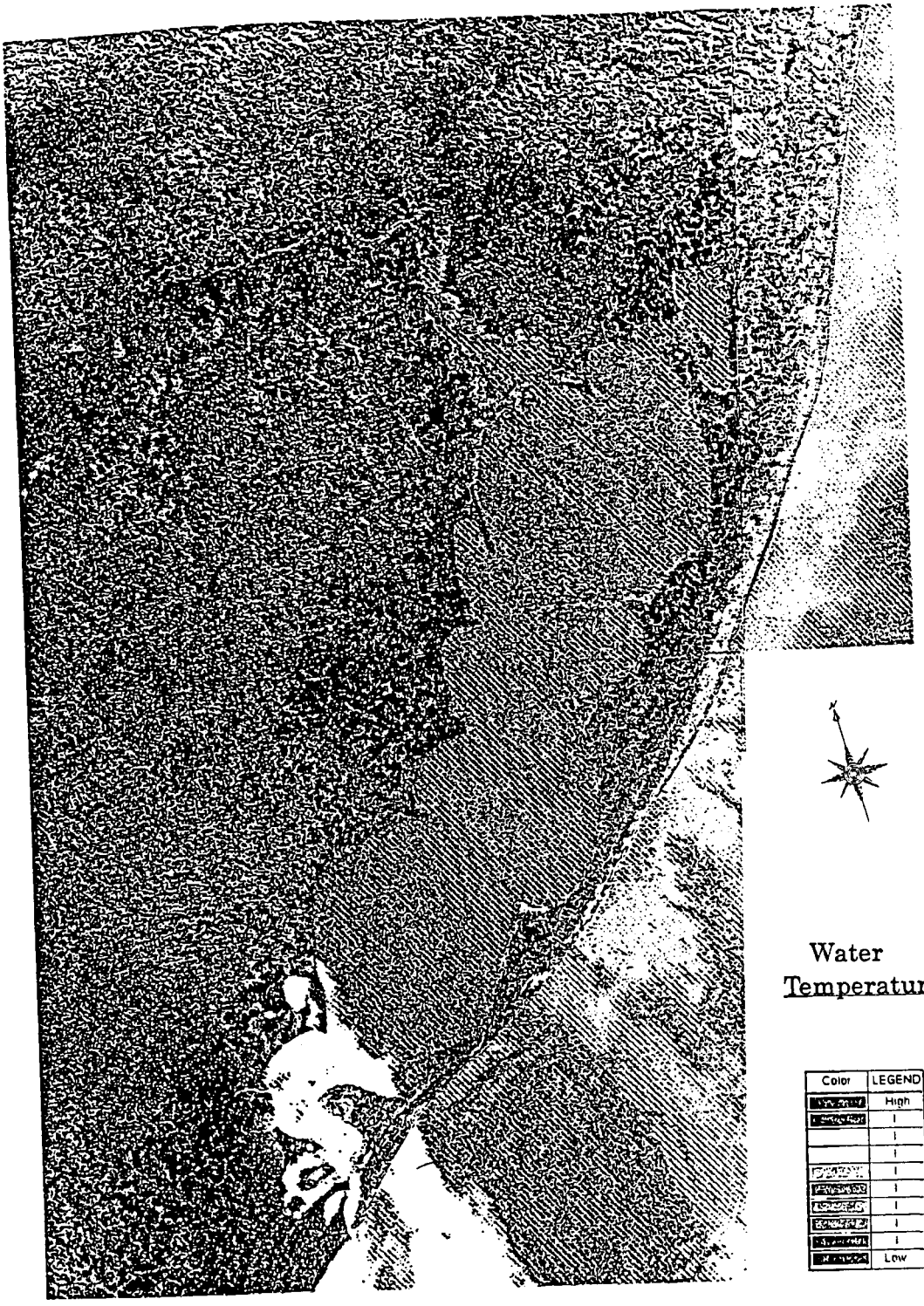
The results of the monitoring survey and image analysis were used to divide Patos Lake into three areas, i.e. northern, central, southern (lake estuary) areas, to illustrate the horizontal structure of the water mass in the lake, as shown in **Fig. 6.3-8**. The central lake area was further divided into the upper (north) and lower (south) sections.

The northern lake area at the northernmost end of Ponta do Cristovao Pereira is characterized by high water temperature and turbidity, and freshwater qualities. No monitoring survey stations were established along the shore in this area of the lake. Nonetheless, the results of the Landsat image analysis show extremely turbid and high Chlorophyl-a levels in Saco de Tapes and the eastern section along the lake shore (see **Figs. 6.3-6** and **6.3-7**).

The central lake area extends from Ponta do Cristovao Pereira all the way to Ponta da Feitoria. Water quality in this area is a cross between that of the northern area aforementioned and the southern area to be discussed hereafter. This lake area was observed to be slightly salty (brackish). In comparison with the lower section (Ponta do Bojuru – Ponta da Feitoria), the upper central section (Ponta do Cristovao Pereira – Ponta do Bojuru) of the central lake area was found to be low in salinity but with increasing turbidity levels.

The southern lake area, the estuary, refers to the southernmost region of Ponta da Feitoria. This lake area is comparatively deep and high in salinity. The water temperature is also comparatively high due to freshwater inflow.

Vertically, there is nothing significant about the water mass structure in the main lake body as the overall depth is shallow. However, sudden changes are observed (2 to 5m) at the estuary due to its deep water and closeness to the open sea.



(June 12, 1996)

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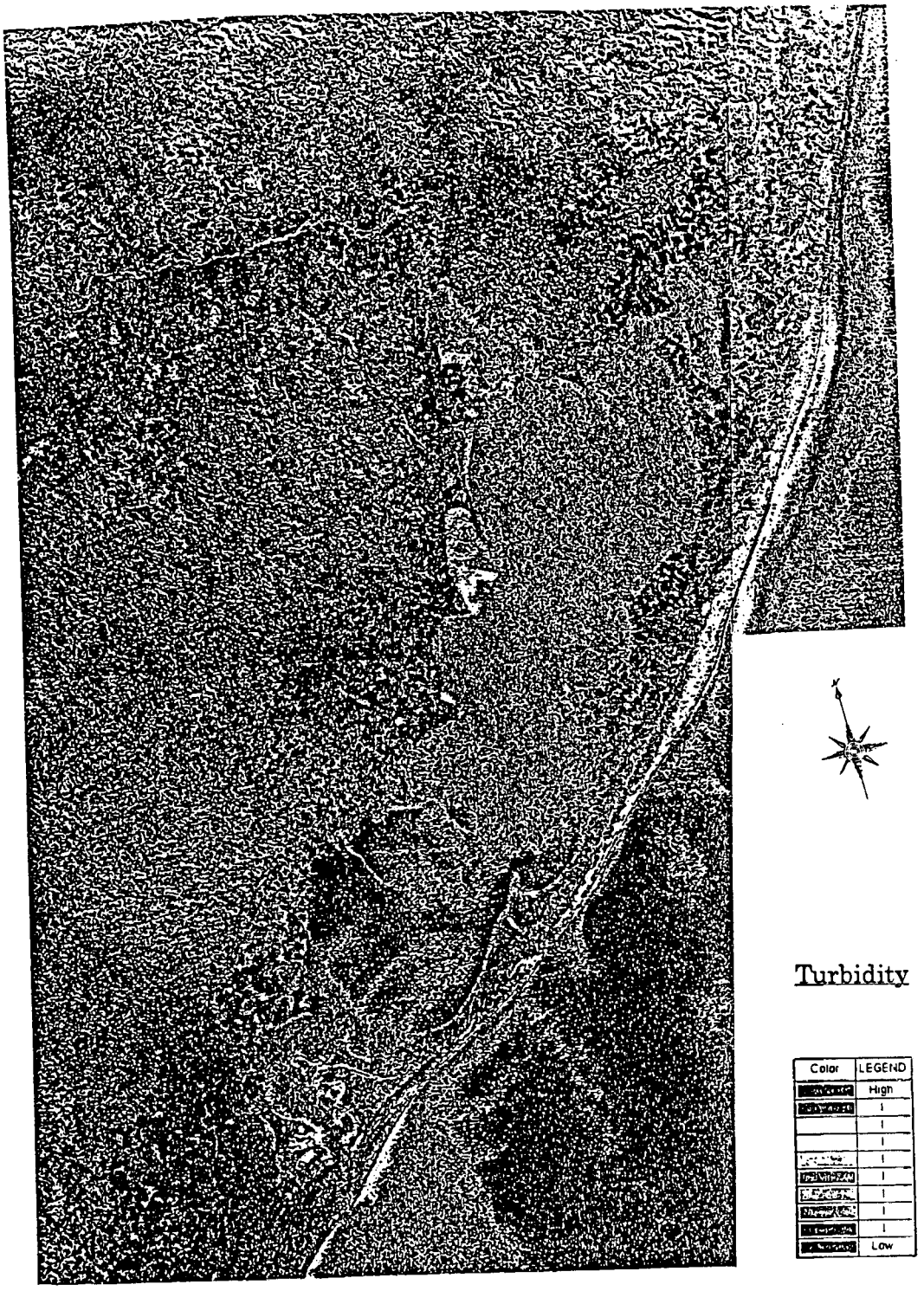
Fig. 6.3-5

LANDSAT Data Analysis for Water Temperature



Turbidity

Color	LEGEND
	High
	I
	I
	I
	I
	I
	I
	I
	Low

(June 12, 1996)

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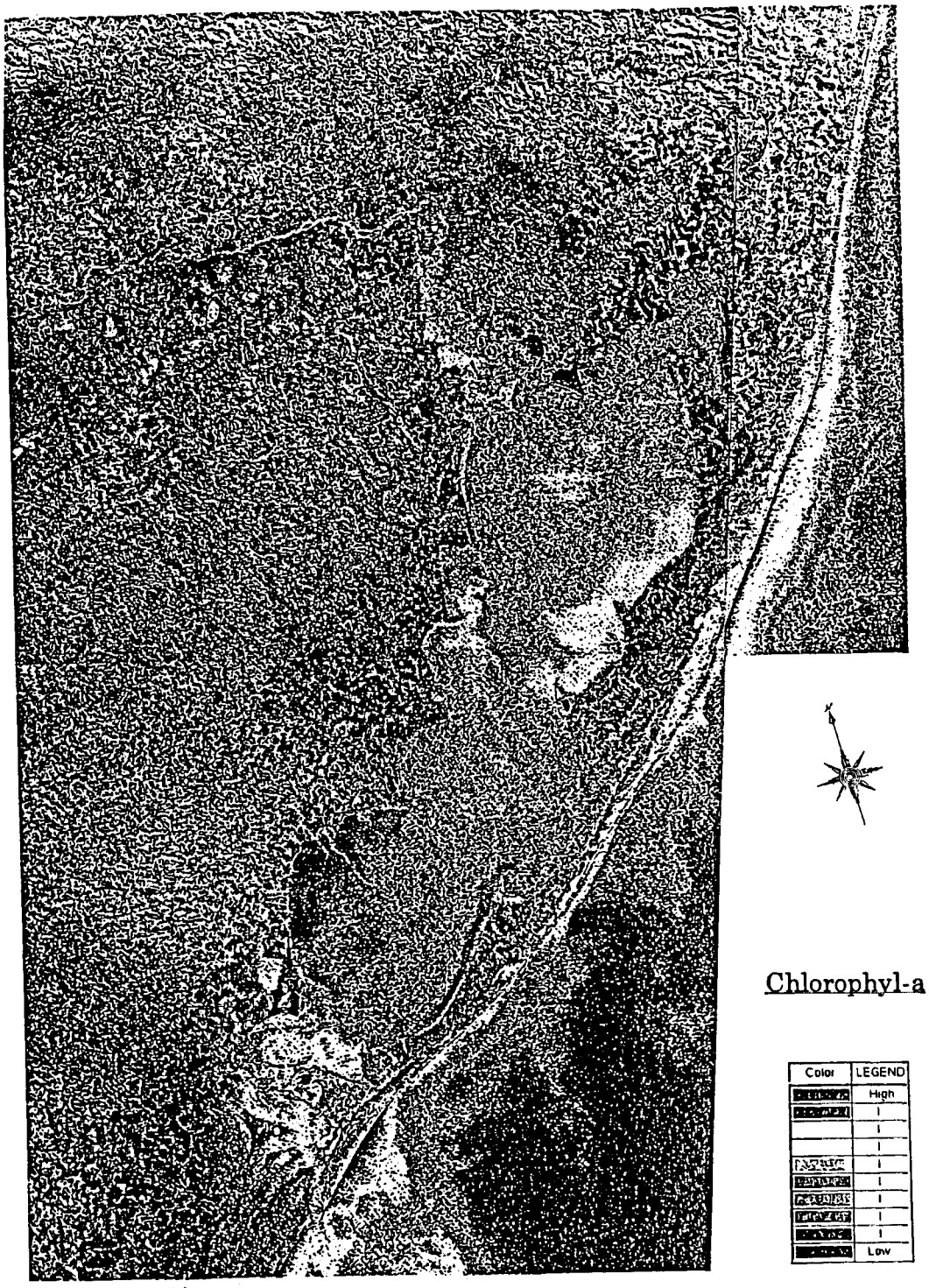
Fig. 6.3-6

LANDSAT Data Analysis for Turbidity



Chlorophyl-a

Color	LEGEND
	High
	I
	I
	I
	I
	I
	I
	I
	Low

(June 12, 1996)

THE STUDY ON THE ENVIRONMENTAL MANAGEMENT
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Fig. 6.3-7

LANDSAT Data Analysis for Chlorophyl-a

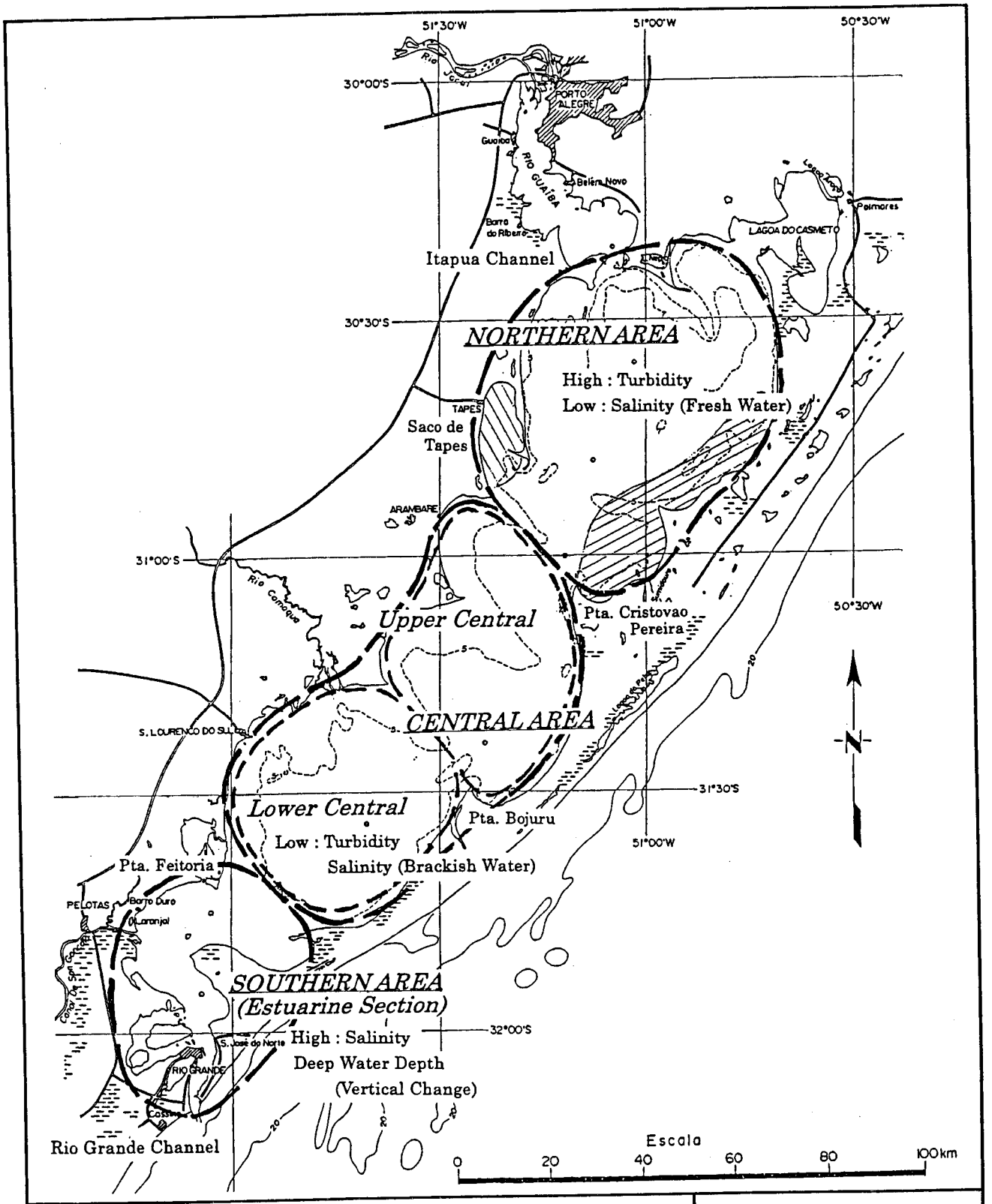

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Fig. 6.3-8

General View of Water-mass Distribution