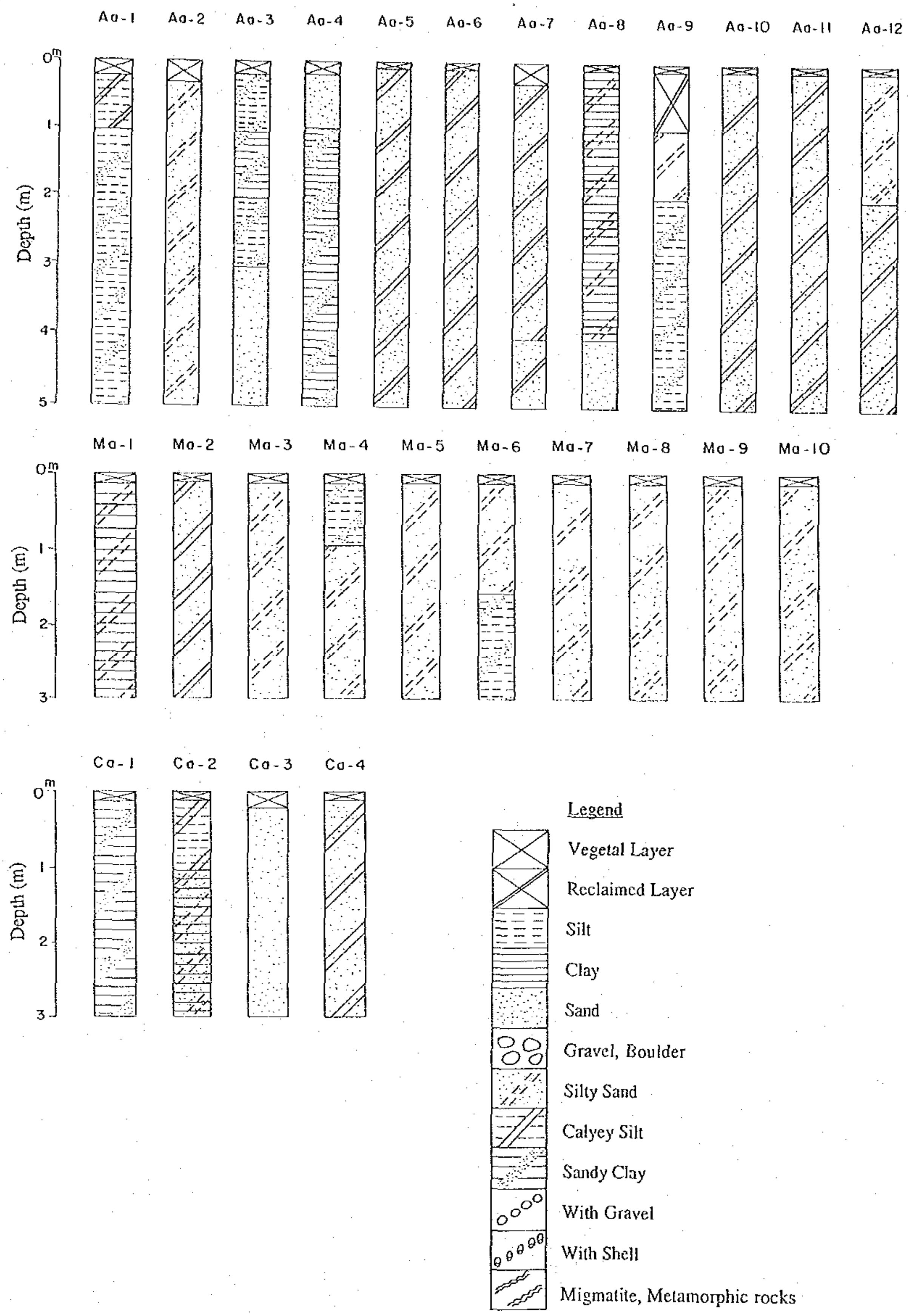


Fig.III.3.6 RESULT OF AUGER BORING

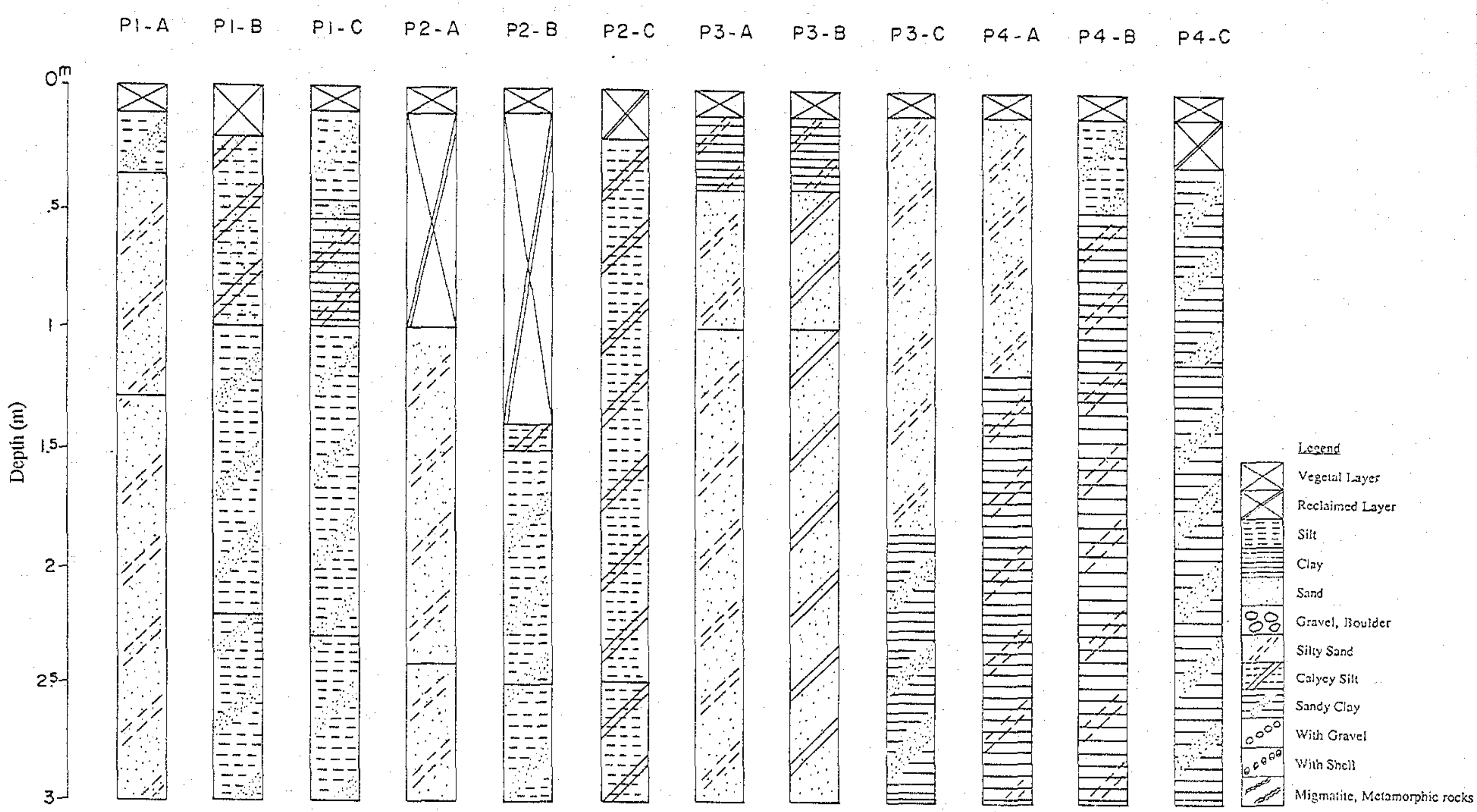
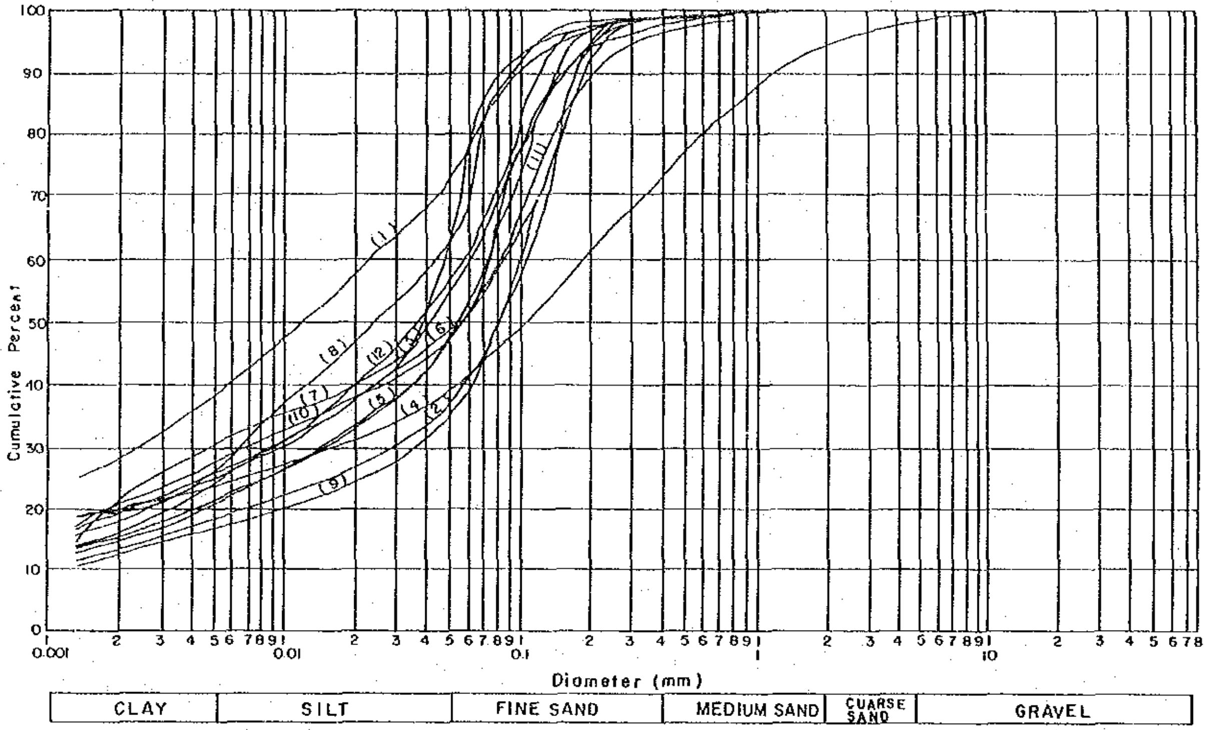


Fig.III.3.7 RESULT OF TEST PITTING

Aal-Aal2 (Area along the Itajai river)



Cal-Ca4 (Itajai Mirim short-cut channel)

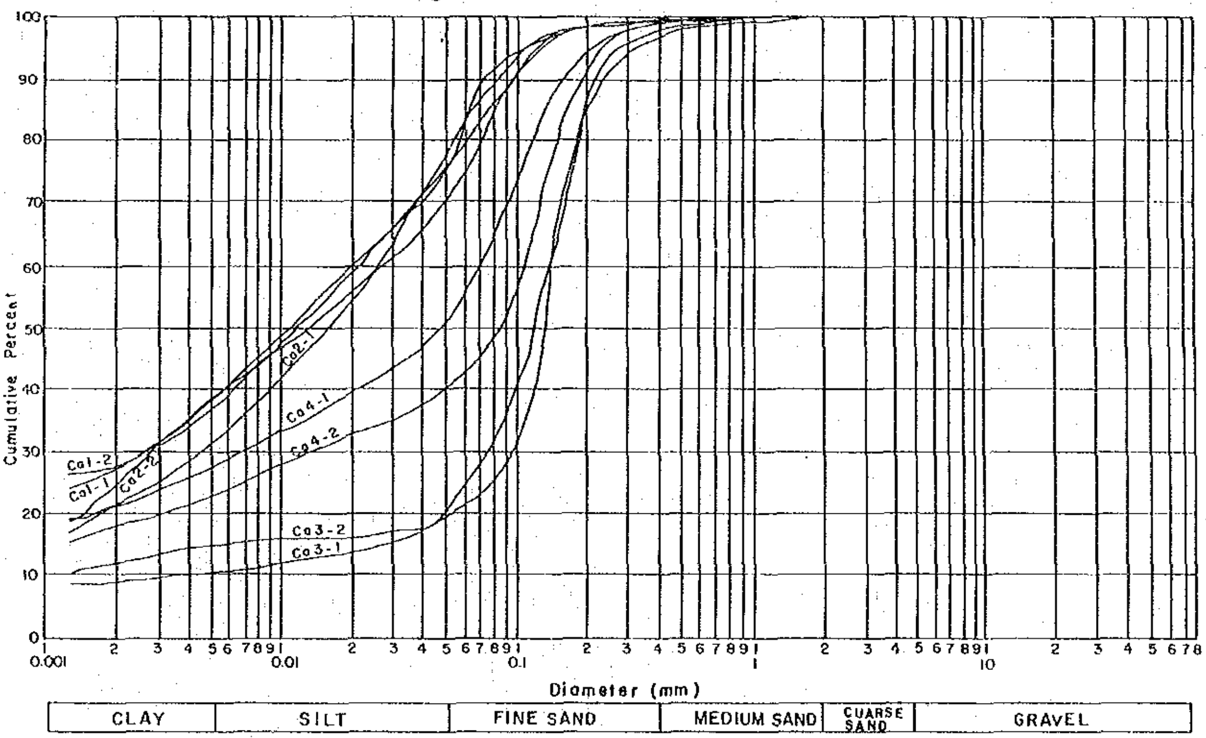
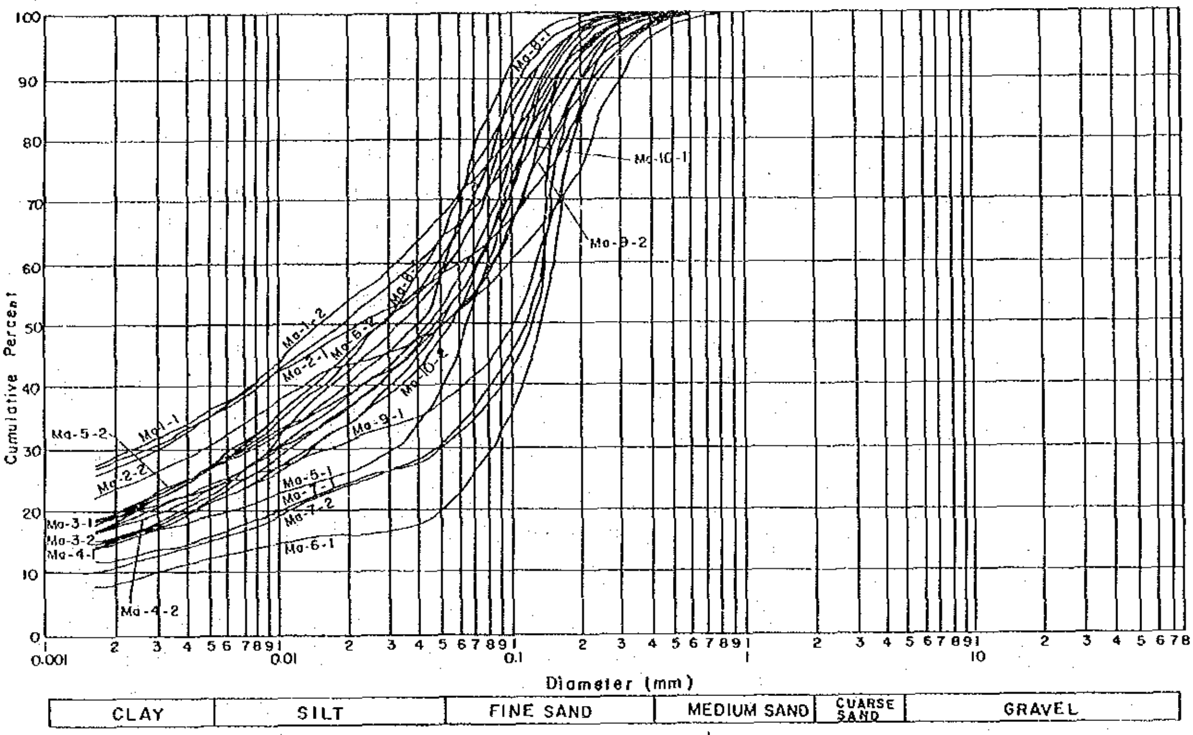


Fig.III.3.8 PARTICLE SIZE DISTRIBUTION (1/3)

Ma1-Ma10 (Itajai Mirim river)



P1A-P1C, P2A-P2C, P3A-P3C, P4A-P4C

(Borrow areas along the Itajai and ltajai Mirim rivers)

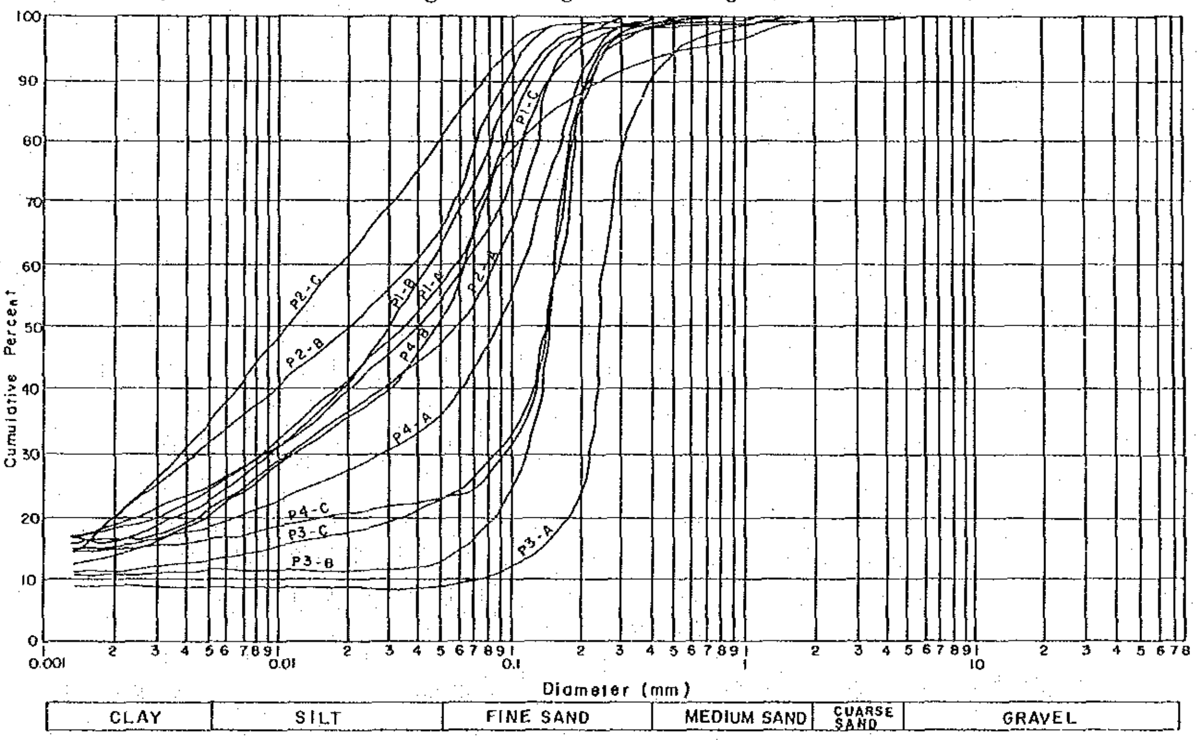
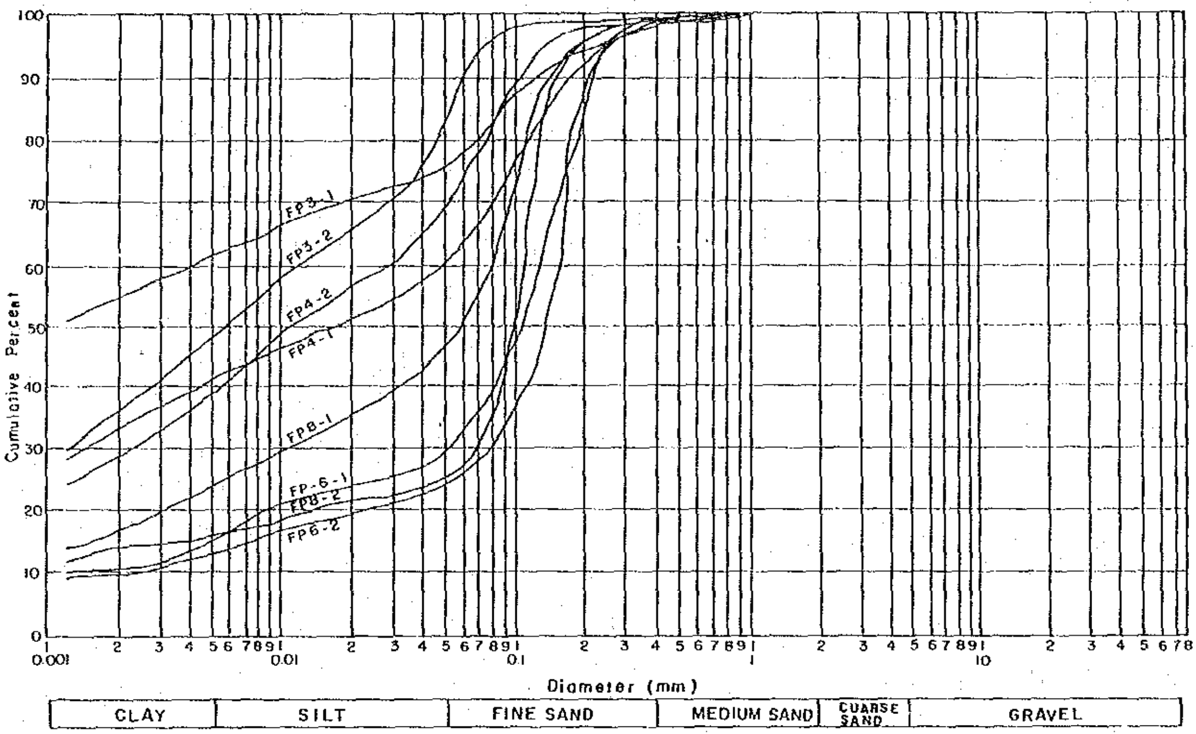


Fig.III.3.8 PARTICLE SIZE DISTRIBUTION (2/3)

FP3-FP8 (Originally proposed floodway to Picarras)



Fa1-Fa3 (Alternative floodway to Navegantes)

M1-M2 (Itajai Mirim river)

C1-C2 (Short-cut channel of Itajai Mirim river)

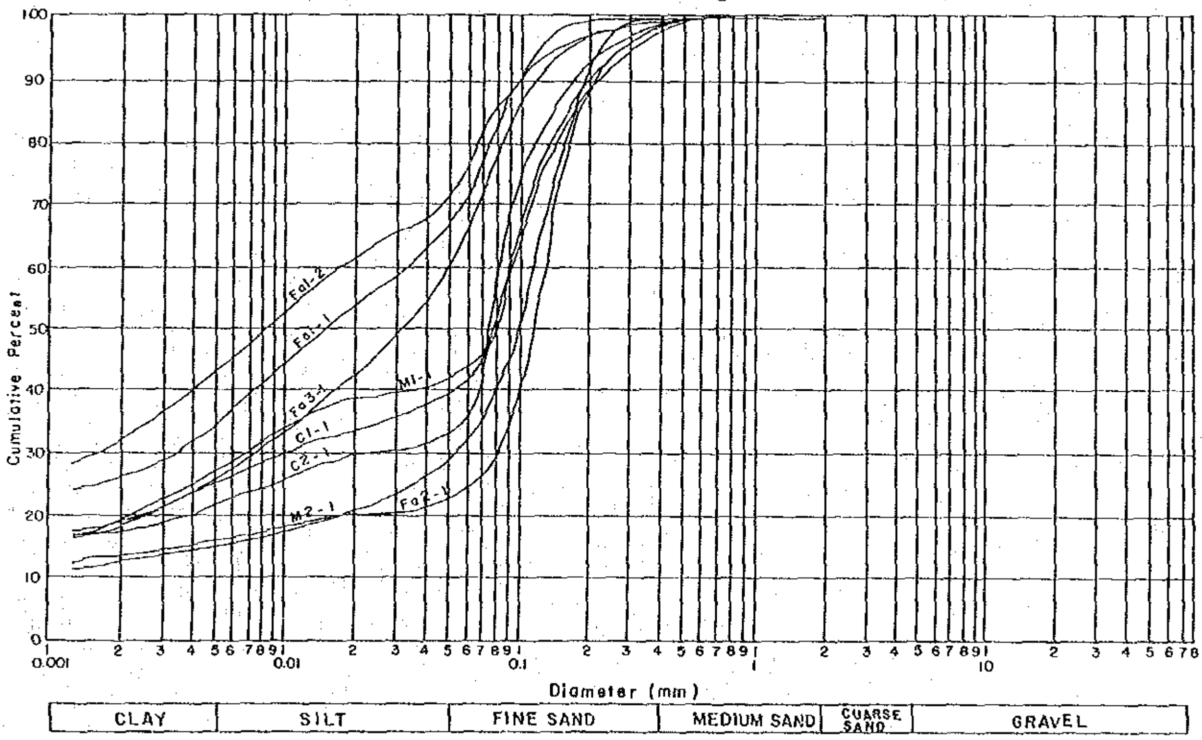


Fig.III.3.8 PARTICLE SIZE DISTRIBUTION (3/3)

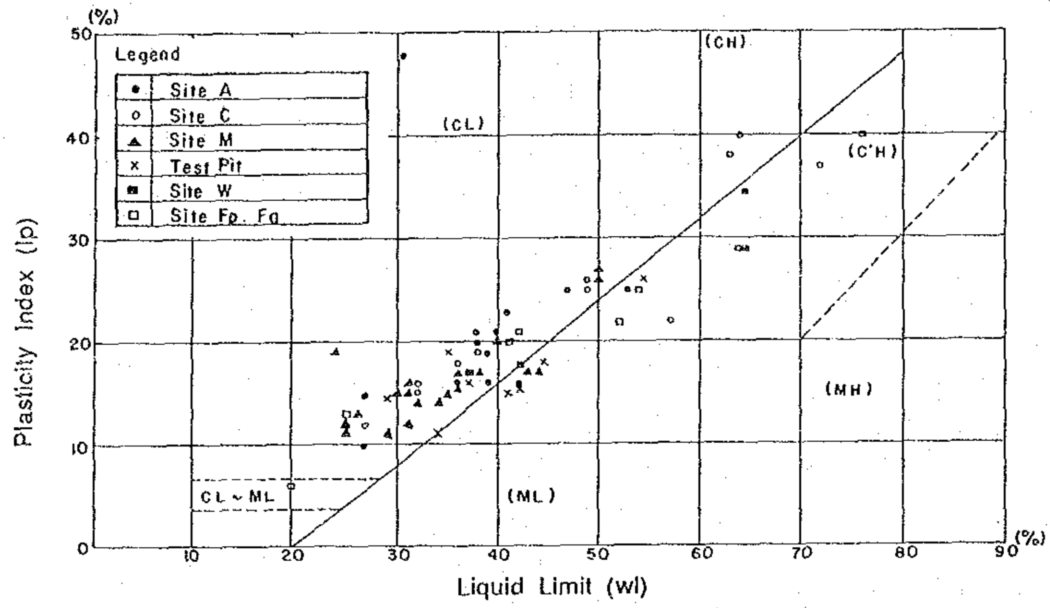


Fig.III.3.9 PLASTICITY OF FILL MATERIAL

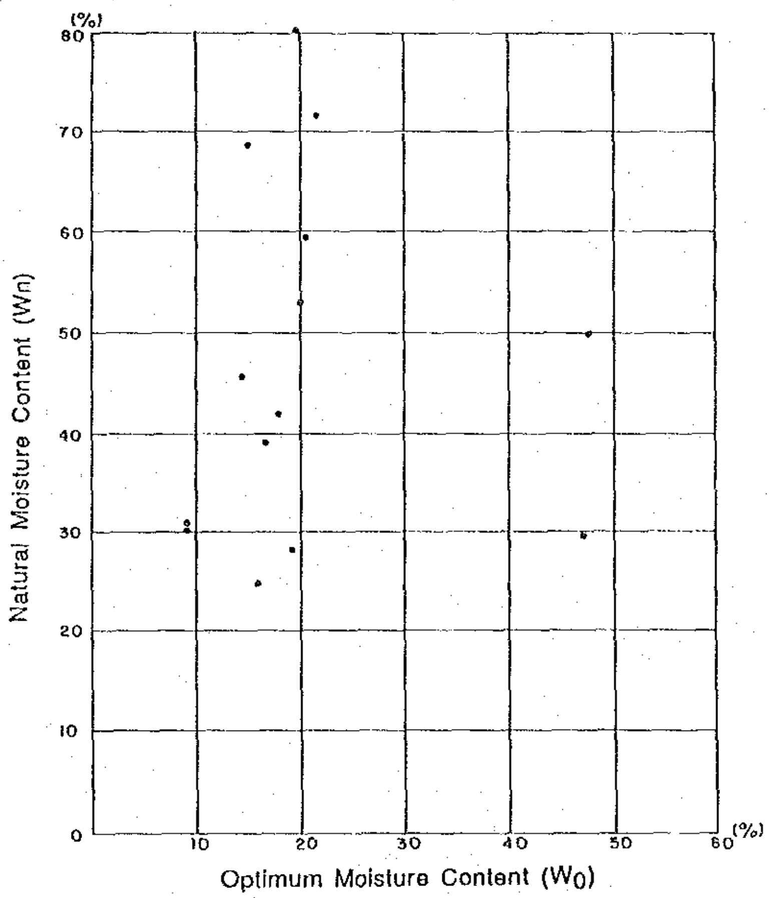


Fig.III.3.10 RELATION BETWEEN NATURAL MOISTURE CONTENT
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ANNEX IV.

COASTAL INVESTIGATION

ANNEX IV. COASTAL INVESTIGATION

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ANNEX IV. COASTAL INVESTIGATION

1. INTRODUCTION

In order to treat the flood discharge exceeding the flow capacity of the Itajai main stream, it has been planned to provide a floodway which extends from the Itajai river to the Atlantic Ocean near Picarras coast or Navegantes coast as shown in Fig. VI.1.1 in ANNEX VI. FLOOD CONTROL PLAN. Since there are no data on tide, wind, wave, tidal current and seabed materials along the Picarras coast and Navegantes coast which are required to examine the influence on Picarras coast and Navegantes coast by the proposed floodway and the possibility of closure of its outlet as well as to carry out design work for the jetty based on analyses shown in Fig. IV.1.1, coastal investigation on these items was carried out from November 1988 to October 1989 as shown in Fig. IV.1.2 using observation equipment supplied by JICA in cooperation with DNOS's staff under direction of staff of JICA Study Team.

Main items of the coastal investigation are as follows:

- Tide water level
- Wind direction and velocity
- Wave height
- Velocity of tidal current
- Sampling of coast and seabed material and suspended sand and laboratory tests of the samples
- Sampling of sea water and its quality analysis

In addition to the above, collection of the existing coastal data and their review were carried out as described in Section 2.1.

2. COASTAL FIELD INVESTIGATION CARRIED OUT

2.1 Data Collection and Review

The following data were collected during the Phase I field survey period:

- Sounding map of the Itajai river mouth on 15th July 1983 and 26th September 1984
- Sedimentation data of the Itajai river mouth on 26th August 1984 and 1st September 1984.
- Flow velocity data of the Itajai river mouth on 26th August 1984 and 1st September 1984.
- Salinity data of the Itajai river mouth on 26th August 1984 and 1st September 1984.
- Sounding map of the Itajai river mouth in March and August 1983.
- Change of riverbed elevation of the Itajai river mouth after flood on 10th July 1983.
- Navigation map around Picarras coast.
- Navigation map around Itajai port.
- Wave height in Paranagua and Imbituba ports.
- Report on erosion of Picarras coast.
- Sounding map of Picarras coast in September 1985.

These data were carefully checked and reviewed.

2.2 Coastal Observation at Picarras Coast

The following coastal observation has been carried out to obtain data on Picarras coast.

2.2.1 Tide water level

Tide water level gauge with an automatic recording system was installed at the Picarras coast and its observation has been carried out by the counterpart personnel of DNOS under supervision of the JICA Study Team. Location of the observation point is shown in Figs. IV.2.1. This observation was continued for about one year.

Arranging and processing of the data recorded for the period from December 1988 to October 1989 were carried out by the JICA Study Team in Japan. The recorded tidal data were compiled on hourly, daily and monthly basis.

2.2.2 Wind

An anemometer for wind observation was installed by the JICA Study Team at the location shown in Fig. IV.2.1 and its observation was carried out by DNOS. The anemometer is an automatic recording type which simultaneously records wind velocities and directions and indicates their average and peak values. The wind observation was also continued for about one year.

The data arrangement and processing as well as their analysis were carried out by the JICA Study Team in Japan for the records from December 1988 to October 1989. Recorded data were digitized at 10 minute intervals and were compiled into daily, monthly and annual tables.

2.2.3 Tidal current

Tidal current observation was carried out using current meter provided by JICA at the observation points shown in Fig. IV.2.1. Duration of observation was about 15 days for each observation. Observation was carried out three times a year during the field survey period.

Processing and analysis of the observed tidal current data were carried out by the JICA Study Team in Japan. Recorded tidal data were compiled for the full installation periods.

2.2.4 Wave

A wave gauge supplied by JICA was installed at the location shown in Fig. IV.2.1 and its observation was carried out by DNOS. The wave observation was continued for about one year.

The recorded wave data were analyzed to obtain a significant wave height and its period. The data in two hour recording sessions are compiled on daily, monthly and annual basis. Cumulative frequency curves of the height and period of significant wave are measured by the above-mentioned wave gauge for the period from December 1988 to October 1989.

2.3 Grain Size Analysis

2.3.1 Picarras coast

To obtain basic data for analyzing the mechanism of coastal sediment movement due to wave and currents, sampling of coastal and seabed material was conducted at the location shown in Fig. IV.2.2. Sampling of coastal material was carried out at intervals of 300 to 500 m along the shore and sampling of seabed material at every 1 m water depth. The laboratory test of the collected samples was carried out by Instituto de Pesquisas Hidraulicas (I.P.H.) in Porto Alegre.

2.3.2 Navegantes Coast

In the same manner as Picarras coast, sampling of coastal material at Navegantes coast was conducted at the location shown in Fig. IV.2.2.

3. PRESENT COASTAL CONDITION AT OUTLET SITE OF FLOODWAY

3.1 Picarras Coast

3.1.1 Topography of seabed for floodway-I.

The longitudinal profile of the seabed for floodway-I is shown in Fig. IV.3.1. The seabed slope of Picarras coast is about 1/160.

3.1.2 Tide water level

The tide water level curves are shown in Fig. IV.3.2. Based on the result of tide water level observation the harmonic analysis was carried out. The estimated nearly highest high water level, high water level of ordinary spring tide and mean sea level are +0.66 m, +0.51 m, +0.05 m respectively, and these water levels are shown in Fig. IV.3.3.

3.1.3 Wind

Wind roses in Picarras coast are shown in Fig. IV.3.4. Regarding the prevailing wind direction, SSE wind is strong. The maximum wind velocity was recorded at 15 m/sec during the observation period.

3.1.4 Tidal current

Tidal current curves are shown in Fig. IV.3.5. As seen in this Figure, the tidal current velocity was derived to be less than 30 cm/sec at nearly 2 m above the seabed. Primary direction of tidal currents is S-SE. According to the results of the harmonic analysis based on the observed tidal current data, coefficients of diffusion are as shown in Fig. IV.3.6 and the velocity vector diagram is shown in Fig. IV.3.7.

3.1.5 Wave

The maximum significant wave caused by south direction wind since start of observation was 3 m in height and 8 sec in period. The predominant wave direction is SW. Diagrams of frequency of wave height and period are shown in Table IV.3.1. The waves at Picarras coast are not so strong, because the headland of Penha and Armacao is judged to act as a shelter for predominant SE waves from the topographical point of view.

3.1.6 Coastal material

The median diameter of coastal material is shown in Fig. IV.2.2. This Figure shows that the coastal sand deposited along Picarras coast from the Iriri river to 2 km northward of the Picarras river is fine. Therefore, the coastal sand would be moved easily by wave action. The median diameter of seabed material is shown in Fig. IV.3.8. As seen in this Figure, the median diameter of the seabed materials from 0 m to 4 m in depth becomes finer gradually as the depth increases. Considering the variation of particle size of the seabed material, it is predicted that the seabed material from 0 m to 4 m in depth is apt to move by wave. The seabed material from 4 m to 10 m in depth is very fine and its median diameter is almost constant. Hence it seems that seabed material from 4 m to 10 m in depth is not moved so much.

3.1.7 Erosion at Picarras coast.

The Picarras coast is under erosion. 15 years ago, the foreshore was 30 m wide, but it has become less than 10 m at present. Especially, coastal erosion near the Imperador Hotel is severe. In front of the restaurant which is located adjacent to the Imperador Hotel, there is a seawall and the foreshore is being eroded more and more by reflection waves due to this seawall. No predominant long shore current direction of littoral drift was found and therefore littoral drift in the offshore direction is estimated to be predominant. The Picarras river is the only a source of littoral drift.

PORTOBRAS carried out sounding of the seabed at the Picarras coast in September 1985. In Fig. IV.3.9, the sounding map obtained in January 1989 is compared with that of September 1985. As seen in this Figure, the seabed from the Iriri river to the Imperador Hotel is eroded, but the seabed from the Imperador Hotel to northwards becomes shallow due to deposition of seabed material.

3.2 Navegantes Cost

3.2.1 Topography of seabed for floodways-II and III

The longitudinal profile of the seabed for floodways-II and III is shown in Fig. IV.3.1. The seabed slope of Navegantes coast is about 1/90.

3.2.2 Tide water level

DHN (Diretoria de Hidrografia e Navegacao) carried out the harmonic analysis of Itajai port in 1976. The estimated nearly highest high water level, high water level of ordinary spring tide and sea level water are + 0.62 m, + 0.46 m and 0 m, respectively, and these water levels are shown in Fig. IV.3.10. The tide water level at Navegantes coast is almost the same as that at the Itajai port.

3.2.3 Wind

The wind at Navegantes coast is almost the same as that at the Picarras coast.

3.2.4 Wave

There are no data on wave in Navegantes coast. It appears that the wave of Navegantes coast is stronger than that of Picarras coast. But, it is considered that the waves of Navegantes coast are almost the same as the waves of Paranagua and Imbituba coasts which faced open sea and located about 150 km north and south of Navegantes coast, respectively. From observation data of Paranagua and Imbituba port, the predominant direction of wave is judged to be E-SE as shown in Fig. IV.3.11. Maximum significant wave height in deep water is about 6 m for 50-year return period.

3.2.5 Coastal material

The median diameter of coastal sand is shown in Fig. IV.2.2. This Figure shows that the coastal sand deposited along Navegantes coast is very fine. The median diameter of coastal material is 0.1 to 0.2 mm. The median diameter of seabed material is shown in Fig. IV.3.12. This Figure shows that the median diameter of the seabed material from 0 m to 5 m in depth gradually becomes finer as the depth increases. It seems that the seabed material from 0 m to 5 m in depth is apt to move by wave. It is considered that the seabed material from 6 m to 10 m in depth is not moved so much.

3.3 Comparison of Present Condition at Floodway Outlet Site at Picarras and Navegantes Coasts

(1) Tide water level

Tide water levels at the floodway outlet sites at Picarras and Navegantes coasts are almost the same.

(2) Wave

Predominant direction of waves is the same at both sites. Maximum significant wave height at the Picarras and Navegantes coasts is about 3.6 m and 5.7 m, respectively for the 1 and 50 year return period.

(3) Coastal material and littoral drift

The coastal sand at Navegantes coast is finer than that at Picarras coast. Therefore, coastal sand at Navegantes coast is moved more easily by wave action as compared with the Picarras coast. The amount of littoral drift at Navegantes coast is more than that at Picarras.

(4) Seabed slope

Seabed slope at the Navegantes site is steeper than that at the Picarras site.

(5) Tidal current

Tidal current at Picarras coast is more complex than that at Navegantes coast.

4. COASTAL ANALYSIS

4.1 Objective

Coastal analysis was carried out to; 1) clarify the degree of change of the coast after construction of the proposed floodway; 2) understand change of tidal current caused by the construction of the proposed floodway and 3)understand diffusion of discharged turbid water from the proposed floodway.

4.2 Study on Coastal Change

In the optimization study on the proposed floodway, the outlet route of the floodway was selected at Navegantes coast and a long jetty is planned to be constructed not only to prevent the shoaling of the outlet of the proposed floodway by littoral material but also to protect it from the predominant wave and weaken littoral drift in the parts which are partially sheltered by the jetty. But, waves reflected by the jetty and waves along the jetty will be generated. These waves will strengthen the littoral drift. Coastal change caused by the construction of the proposed floodway was studied through numerical simulation applying the one-line theory. This numerical simulation is composed of two steps. First step is a calculation of the deformation of wave and estimation of distribution of the energy flux along shore. Based on the results of the first step, the shore line change is calculated in second step.

The study on coastal change was made based on the navigation map on a scale of 1:10,000. In order to proceed with the study in the first step, the right-angled lines with the shore line are set in the range of about 5 km from the shore line and 11 km in width from the river mouth of Itajai. An interval of the lines is 250 m. For each of these lines, the deformation of wave and distribution of its energy flux are calculated from offshore toward the shore line. Based on the result of these calculations, sand moving volume to estimate the shore line change is estimated in the second step. In this calculation, it is assumed that the calculation period is 10 years and its time step is one day, and wave phenomena throughout 10 years are set as follows;

(1)	Predominant direction of wave	:	E-SE
(2)	Wave height (cm)	:	100
(3)	Wave period (sec)	:	8

Fig. VI.4.1 shows the result of simulation study on coastal change. It is predicted in this Figure that after the construction of the jetty, erosion will take place in the north of the jetty while deposit occurs in the south of the jetty. The extent of this coastal change during 10 years is predicted to be about 30 m for deposit and 20 m for erosion. The extent of the deposit and erosion is the largest in the initial first and second years such as about ±3 to 4 m/year. It will gradually decrease with a long lapse of time and in 10th year, the extent is predicted to decrease up to about ±0.5 to 0.8 m/year. The sediment efflux discharged through the Itajai river is not considered in this study. Since the outlet portion of the jetty is curved to the northern direction, degree of erosion seems to be weakened due to the discharged sediment load. However, it may be necessary to protect the exist coastal road from the erosion by protection works such as riprap wall in future stage.

4.3 Study on Change of Tidal Current

It is anticipated that change of tidal current in Navegantes coast takes place due to construction of the floodway. In order to investigate velocity and direction of tidal current, the offshore area employed in the aforesaid study on coastal change is divided into mesh with 250 m in width and length. It is assumed in this study that the discharge in the Itajai river is about 2,000 m^3/sec which may occur once a year, time step for calculation is 6 seconds, and tidal height is M2+S2 in 12 hour cycle.

The study is initiated for the case of without the floodway to calibrate sea bottom function and others. Using the calibrated factors, the change of tidal current in the case with the floodway is assessed.

Figs. IV.4.2 and IV.4.3 show the result of the simulation study on change of tidal current without and with the floodway. The Figure in the case with the floodway shows that the tidal current tends to slow down around area sheltered by the jetty and velocity of tide changes only within the range of 2 km from the jetty. Besides, the direction of flow changes only at the area around the jetty.

4.4 Study on Diffusion of Discharged Turbid Water

The diffusion of the turbid water to be discharged from the Itajai river was studied through numerical simulation using the tidal current model.

The turbid water is discharged from the Itajai main stream even after the construction of the proposed floodway. Then, in order to compare the extents of diffusion of turbid water at the Navegantes coast before and after the construction of the floodway, the study on the diffusion of turbid water was made for the case without and with the floodway assuming the following conditions;

(1) The direction and velocity of the tidal current are the same as those studied in the change of tidal current.

(2) The flood peak of about 2,000 m^3/sec is adopted as the discharge from the Itajai river. The flood hydrograph of this peak discharge is given in Fig. IV.4.4.

(3) The suspended solid (S.S.) concentration for this selected flood discharge is estimated based on the sediment concentration data at Indaial. The result of the estimation is shown in Fig. IV.4.4. The average grain size of S.S. is 0.01 mm.

(4) The flood discharge flows down through the floodway and Itajai river at the rate of 0.3 and 0.7 under the condition that tide water level is at the mean sea level of 0.067 m.

(5) The time step for calculation is 5 minutes.

Figs. IV.4.5 and IV.4.6 show the result of the simulation study on diffusion of turbid water in case without and with the floodway, respectively.

It is said that the diffusion of turbid water having S.S. of more than 100 ppm can be visually judged. The Figure in case without the floodway shows that the turbid water having S.S. of 100 ppm extends up to the northern part of the proposed floodway site. The diffusion of this turbid water is further extended up to about 3 km toward the northern area due to the construction of the floodway as shown in Fig. IV.4.6.

Figs. IV.4.5 and IV.4.6 show the maximum extent of the diffusion of the turbid water. The result of the simulation study clarifies that the turbid water having S.S. of more than 100 ppm disappears in about 10 days after the flood discharge flows down. This phenomenon is almost same for the cases without and with the floodway.

5. DESIGN OF OUTLET FACILITY FOR FLOODWAY

5.1 Design Condition

In order to establish design criteria for the jetty, an analytical study was made to determine the design wave height and tide level at Navegantes coast. The results are as follows;

- Design tide level ; +0.46 m (High water level of ordinary spring tide)

- Design wave height ;

  Design wave height is estimated based on a significant wave height in deep water, which is defined as the height that does not exert any influence on wave phenomena. The significant wave height in deep water in this study is estimated as follows;

Wave height in deep water		:	6.02 m
note)	significant wave height	:	50 years return periods.
	Wave direction	:	110 degrees
	Wave period	:	8, 10, 12 sec.

  The design wave height and period at the project site are estimated at 5.7 m, 12 sec, respectively.

note)	wave height in deep water		reflection coefficient		shoaling coefficient		
	6.02 m	x	0.87	x	1.08	=	5.7 m

5.2 Design of Jetty

The jetty structure at Navegantes coast was designed considering the following points;

a) The jetty structure is constructed almost at right angle with the coastal line. Since the predominant direction of wave with height larger than 0.5 m is SE as shown in Fig. IV.3.11, the head of the jetty is curved to northern direction to avoid intrusion of the predominant waves. A radius of the curved portion will be 5 times channel width.

b) The jetty is extended seaward to the place where its depth is equal to the channel depth to avoid movement of sediment by wave action and also to minimize the dredging cost.

c) Workable day in which significant wave height is less than 0.5 m is limited to about one month throughout the year at the project sea site. Then, construction work of the jetty structure is required to be commenced from land side toward offshore.

d) An armor stone and concrete block with large scale and sufficient weight is required to be placed on the surface of the jetty structure to prevent the materials from flowing out by wave action. The required weight of the stone and concrete block for its stabilization is calculated by Hadson's formula.

e) The head portion of the jetty is affected by wave of various directions and falling down of coating material is anticipated to occur. Hence, a deformed concrete block is adopted to be placed in the head portion.

The jetty structure designed based on the foregoing conditions is illustrated in Fig. IV.5.1 and its feature is summarized as follows;

- Structure of jetty	: Rock rubble mound
- Depth of floodway	: -8.6 m
- Bottom width of channel	: 135 m
- Crest level of jetty	
Head	: +6.2 m
-9 m ~ -6 m	: +6.2 m
-6 m ~ -4 m	: +5.1 m
-4 m ~ -0 m	: +3.6 m
- Crest width of jetty	
Head ~ 0 m	: +10 m
- Side slope	
Head ~ 0 m	: 1:2
- Armor stone	
Head	: 16 ton deformed concrete block
Head ~ 0 m	: 16 ton ~ 3 ton stone
- Filter stone	: 1.6 ton ~ 300 kg stone
- Core stone	: 80 kg ~ 1 kg
- Length of jetty	
Right side	: 1,158 m
Left side	: 898 m
- Work volume	
Filter and armor stone	: 795,000 m^3
Core stone	: 510,000 m^3
Deformed concrete block (16 t)	: 3,675 Nos
Dredging	: 544,000 m^3

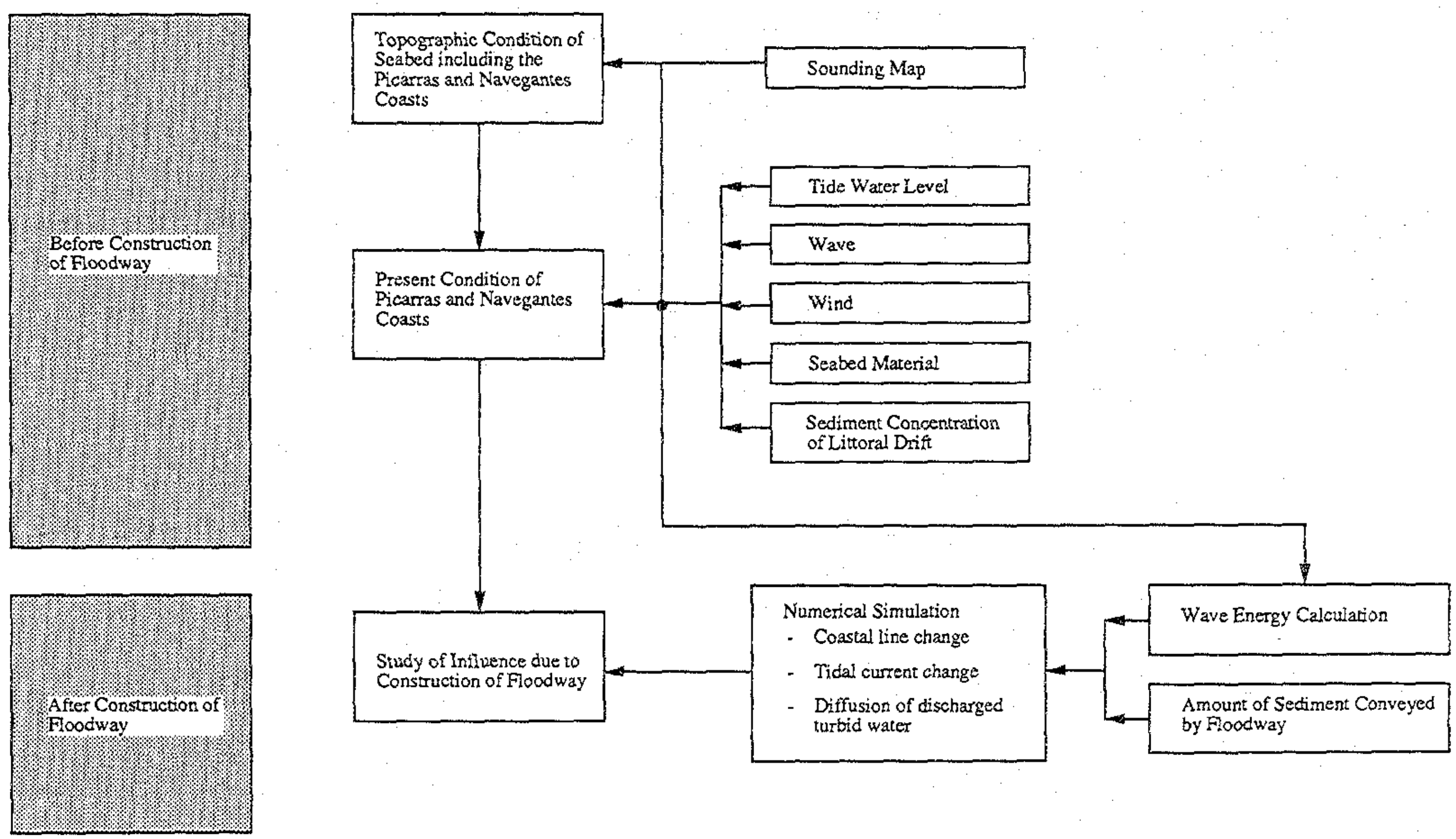
Tables

Table IV.3.1 DIAGRAM OF FREQUENCY OF WAVE HEIGHT AND PERIOD AT PICARRAS

Data Period : December 1988 to October 1989

Period	Wave Height (m)														Total	
	0.0-0.5		0.5-1.0		1.0-1.5		1.5-2.0		2.0-2.5		2.5-3.0		3.0-			
(sec)		(%)		(%)		(%)		(%)		(%)		(%)		(%)		(%)
0 - 1																
1 - 2																
2 - 3																
3 - 4																
4 - 5																
5 - 6			39	(1.5)	23	(0.9)									62	(2.4)
6 - 7	21	(0.8)	332	(12.7)	104	(4.0)	17	(0.7)	7	(0.3)	2	(0.1)			483	(18.5)
7 - 8	46	(1.8)	463	(17.8)	181	(6.9)	28	(1.1)	6	(0.2)					724	(27.8)
8 - 9	63	(2.4)	345	(13.2)	96	(3.7)	8	(0.3)	1	(0.0)					513	(19.7)
9 - 10	88	(3.4)	265	(10.2)	75	(2.9)	8	(0.3)							436	(16.7)
10 - 11	28	(1.1)	124	(4.8)	22	(0.8)	5	(0.2)							179	(6.9)
11 - 12	18	(0.7)	61	(2.3)	31	(1.2)	17	(0.7)							127	(4.9)
12 -	3	(0.1)	55	(2.1)	15	(0.6)	7	(0.3)	4	(0.2)					84	(3.2)
Total	267	(10.2)	1684	(64.6)	547	(21.0)	90	(3.5)	18	(0.7)	2	(0.1)			2608	(100.0)
Accumlated	267	(10.2)	1951	(74.8)	2498	(95.8)	2588	(99.2)	2606	(99.9)	2608	(100.0)				

Figures



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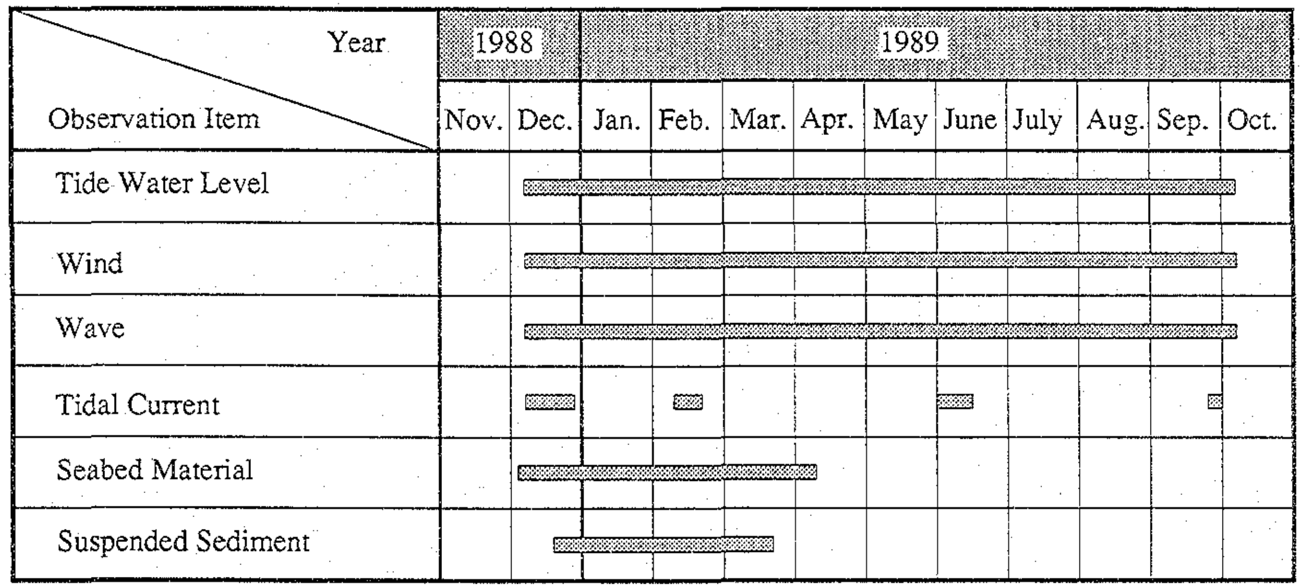

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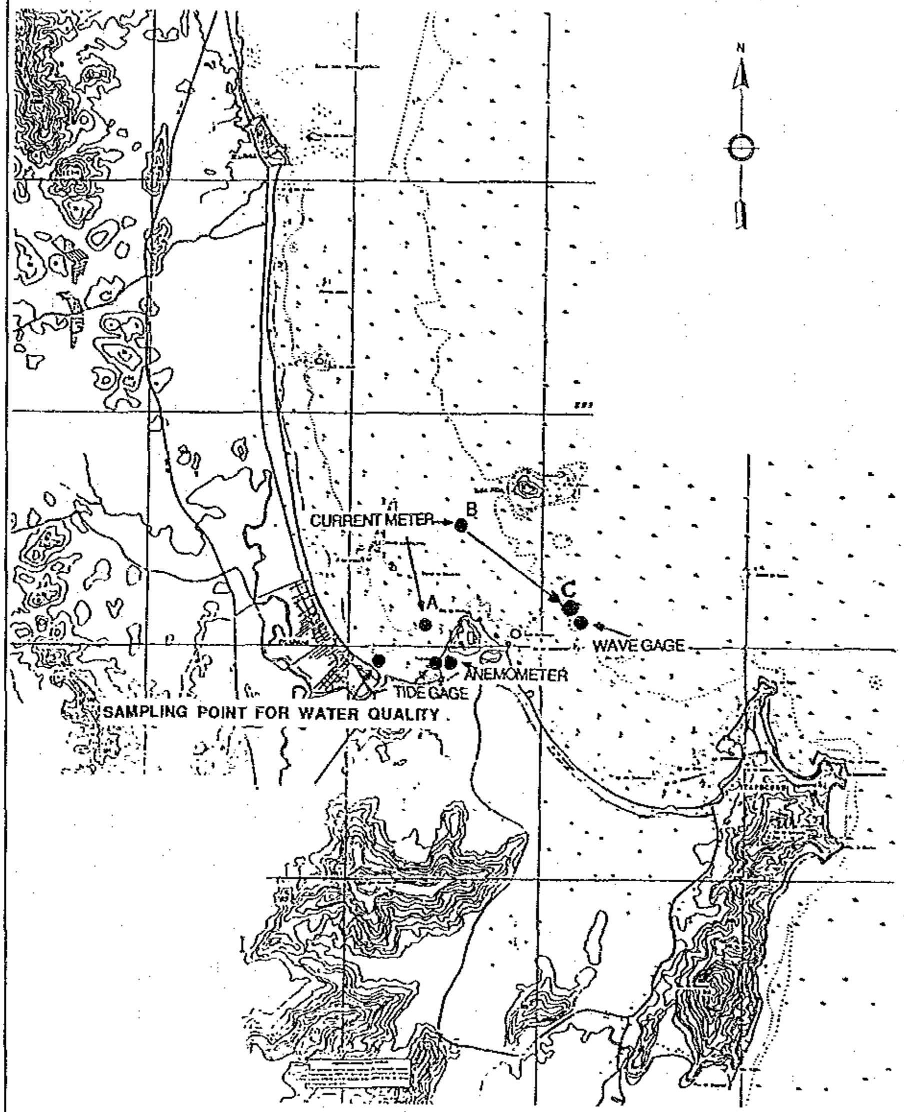

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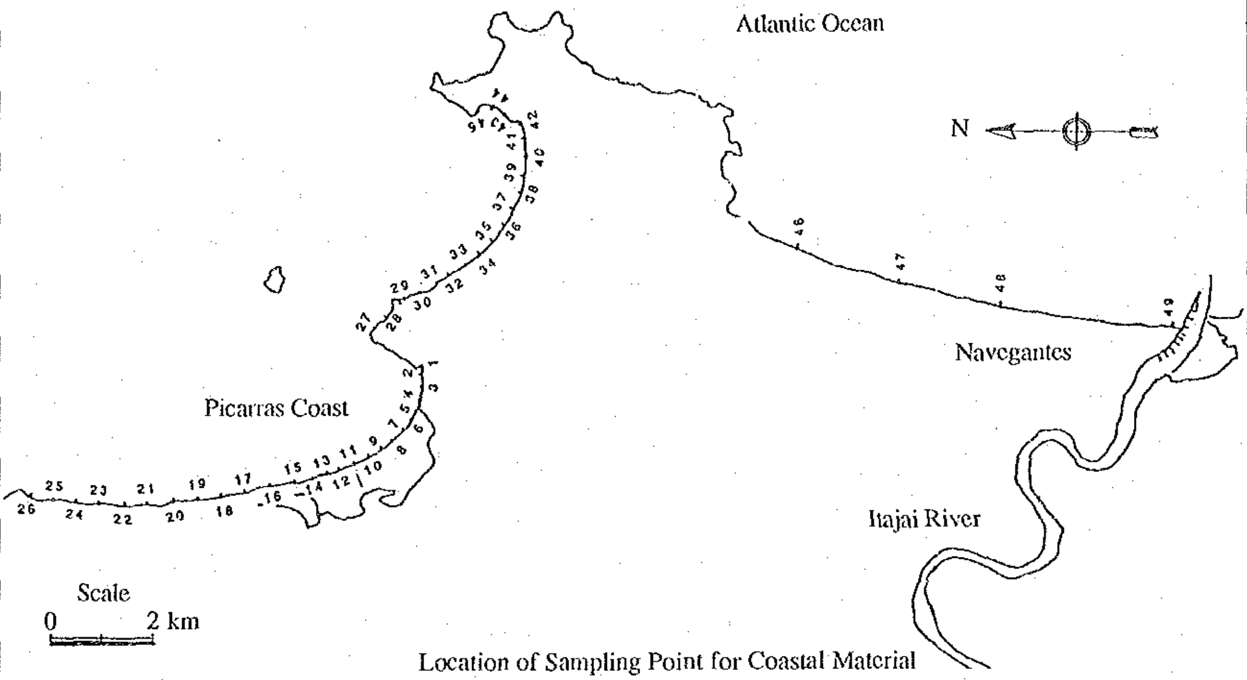
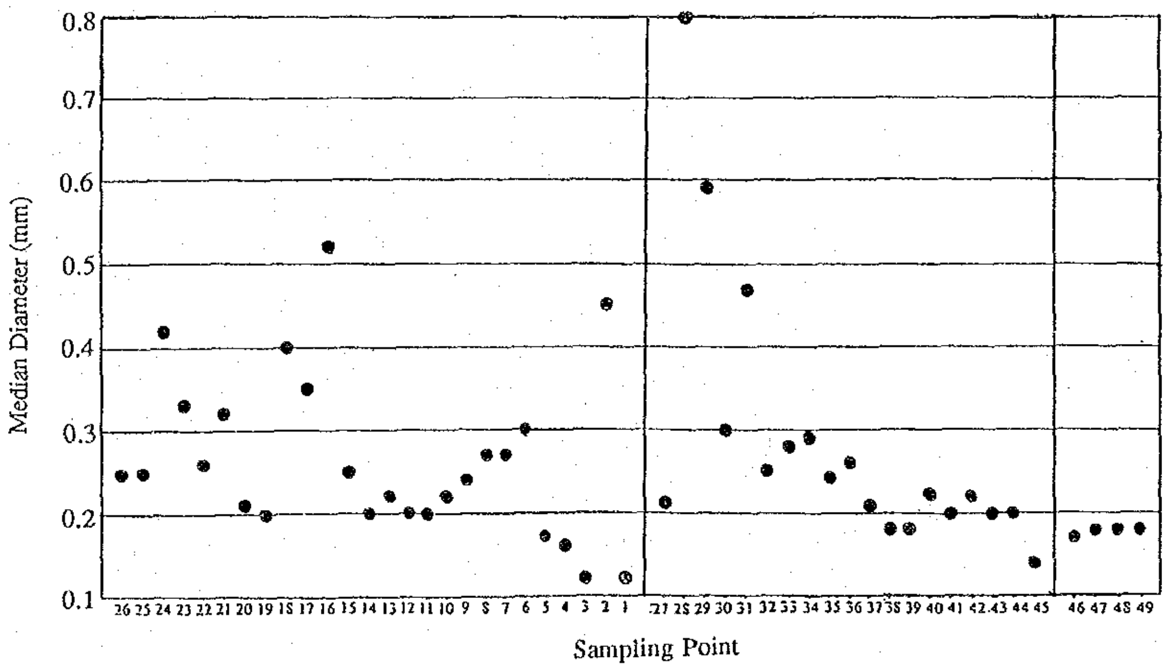


Location of Sampling Point for Coastal Material



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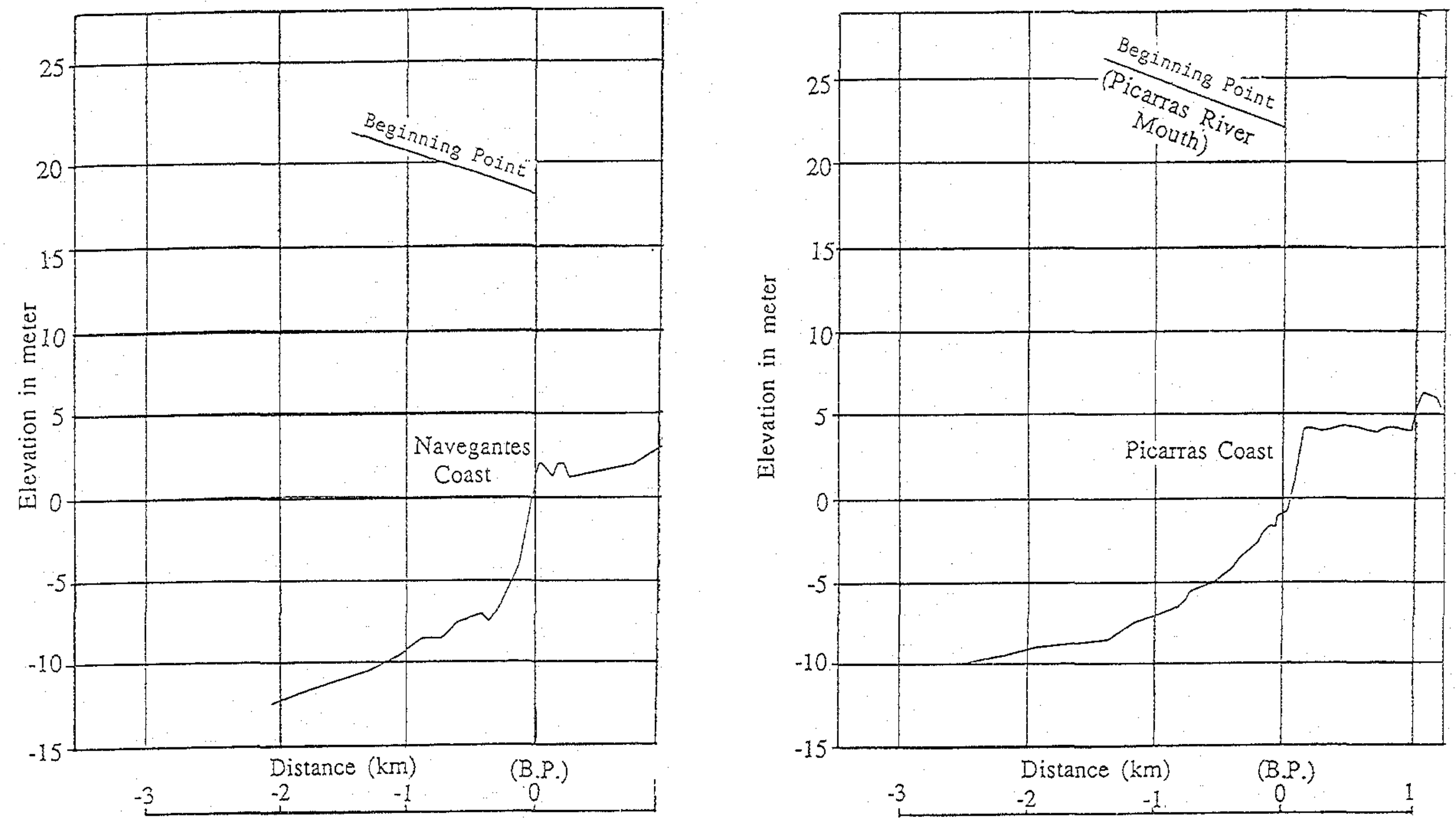

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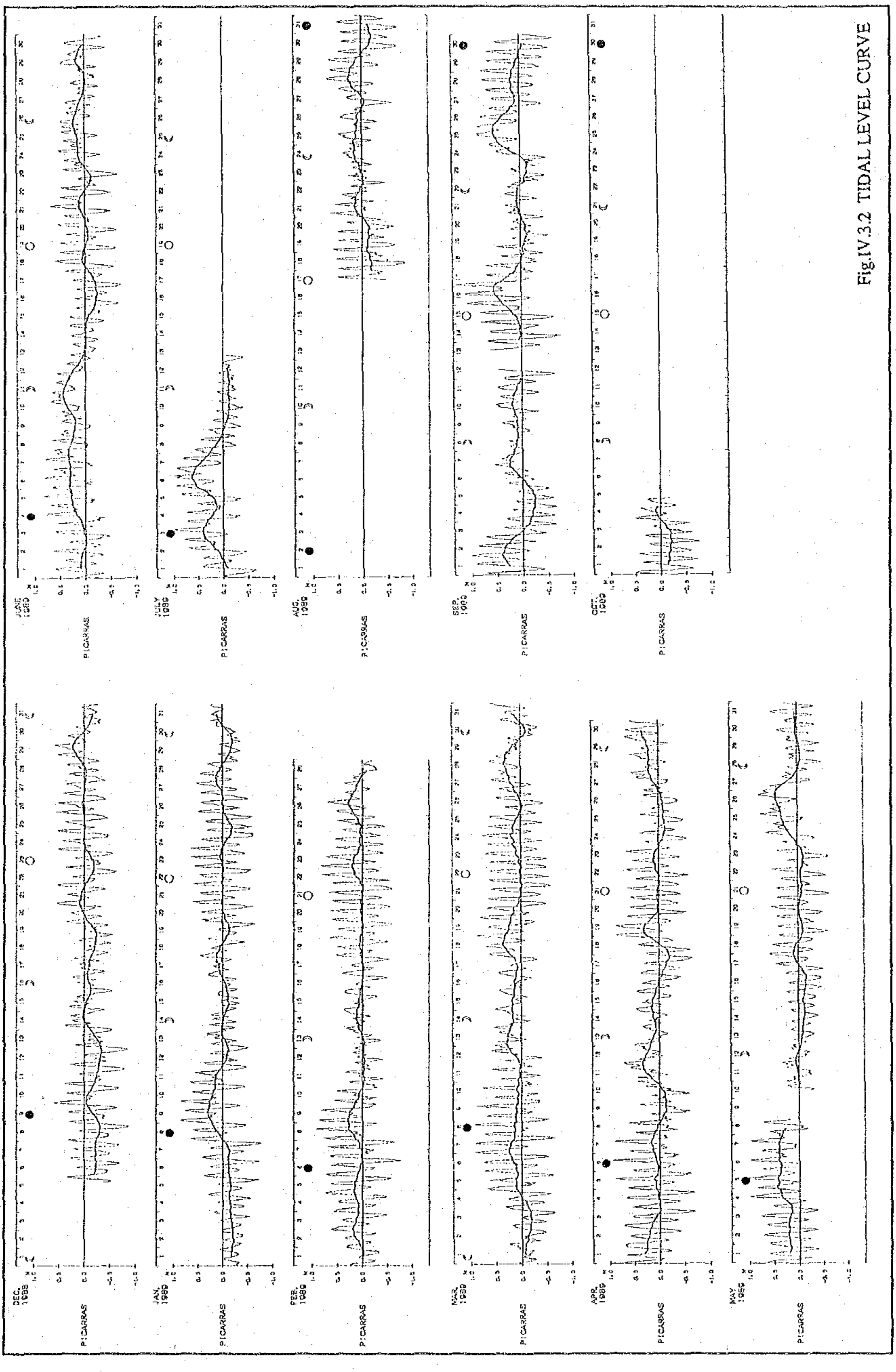

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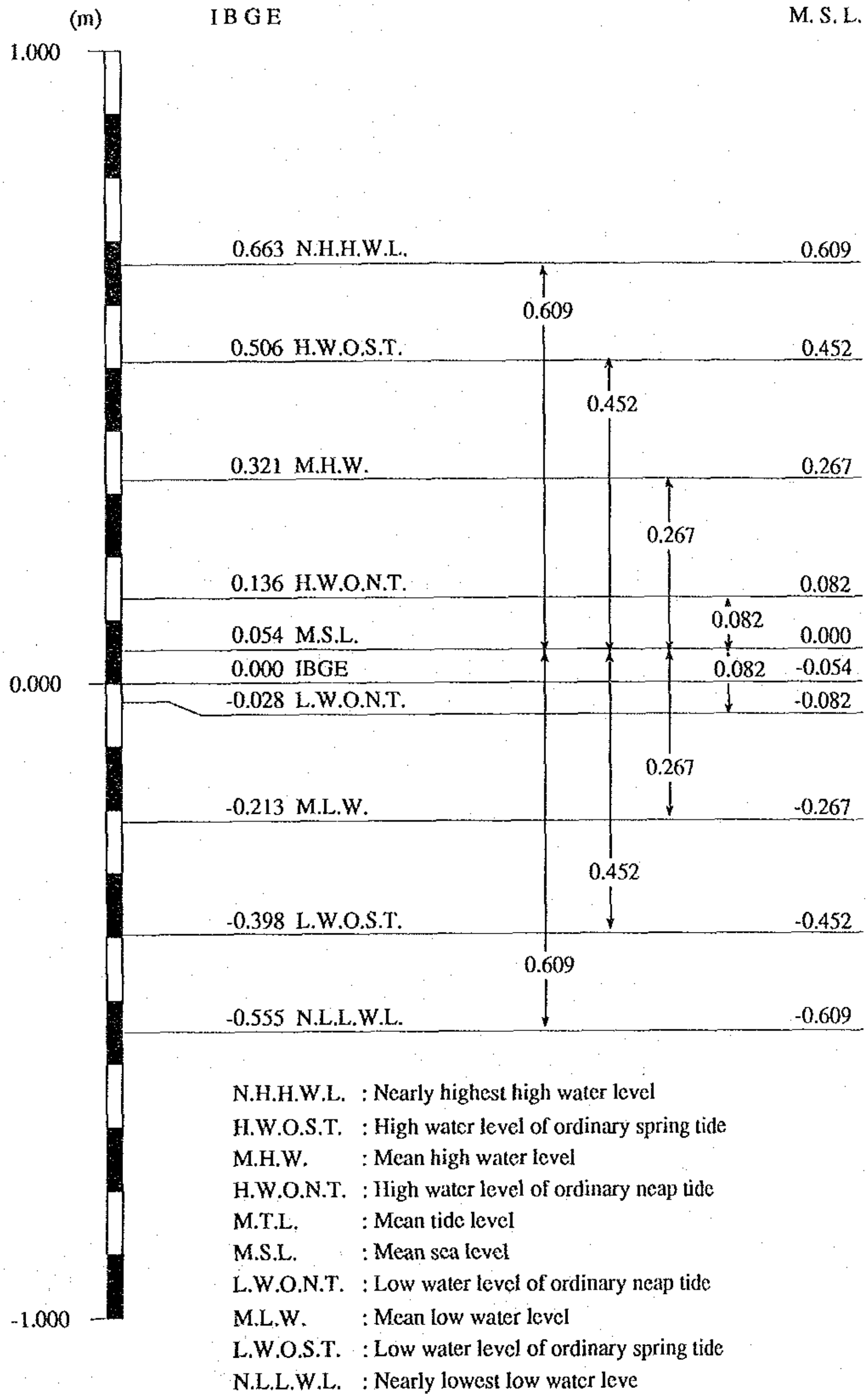

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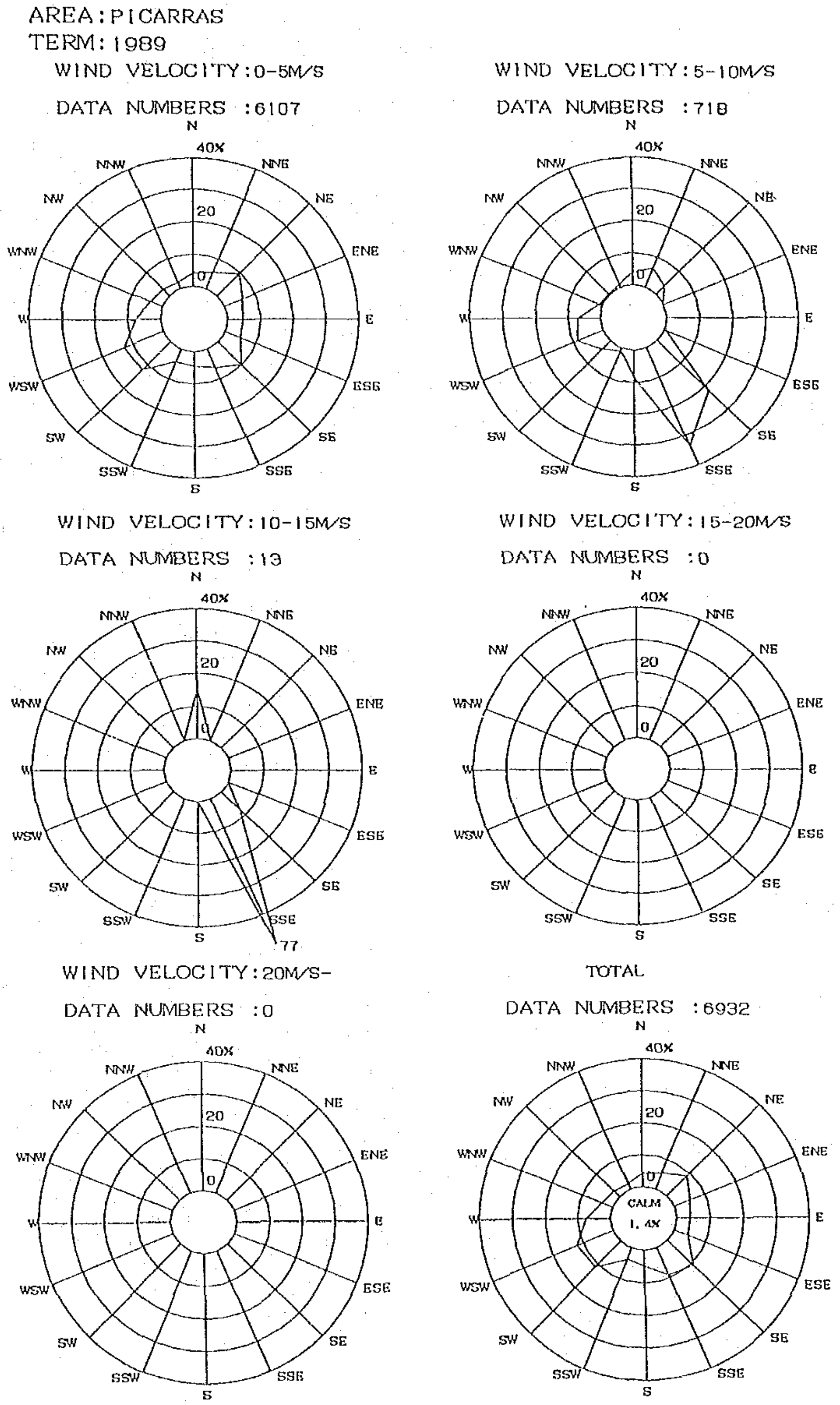
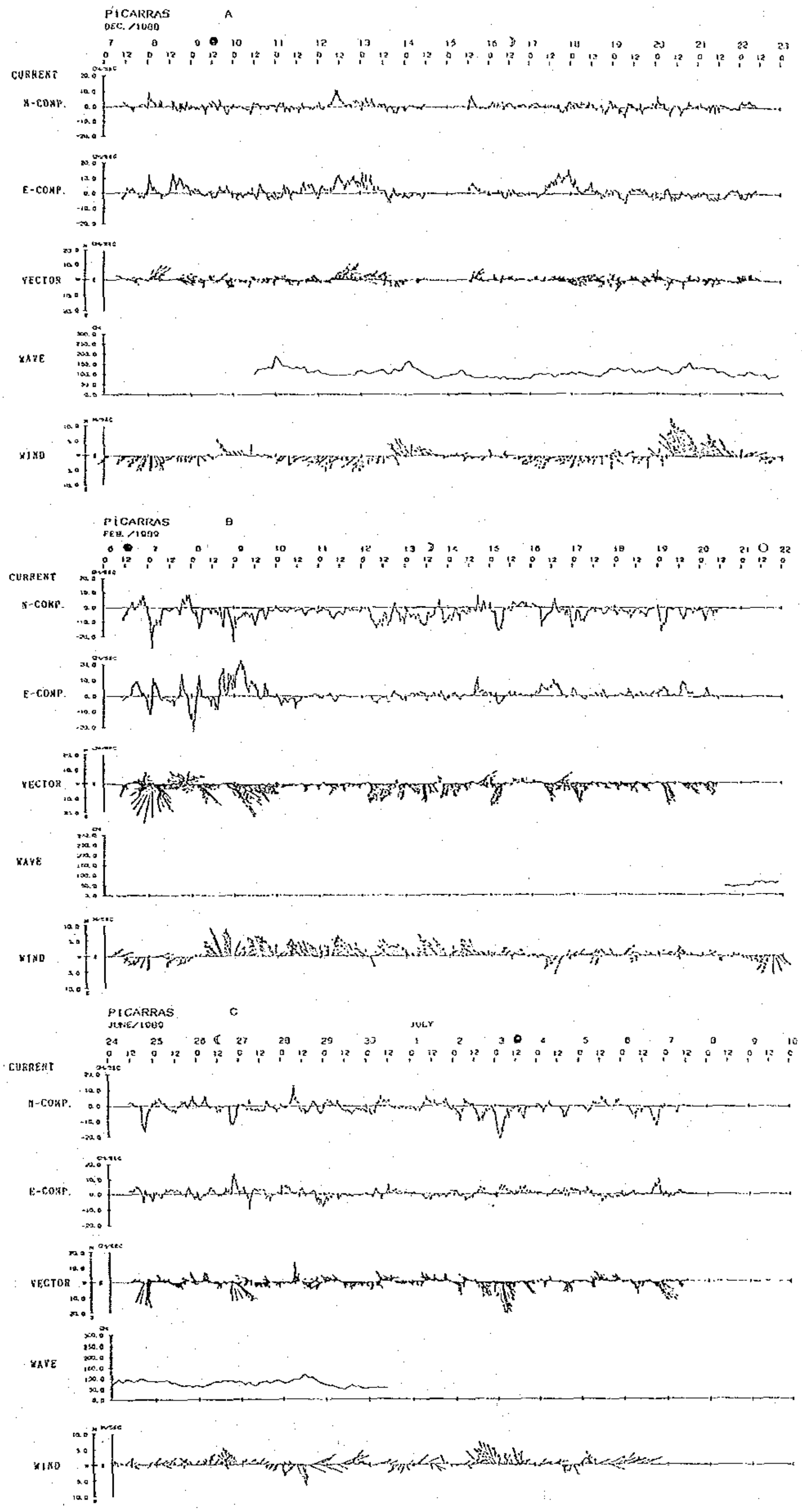


Fig.IV.3.4 WIND ROSE



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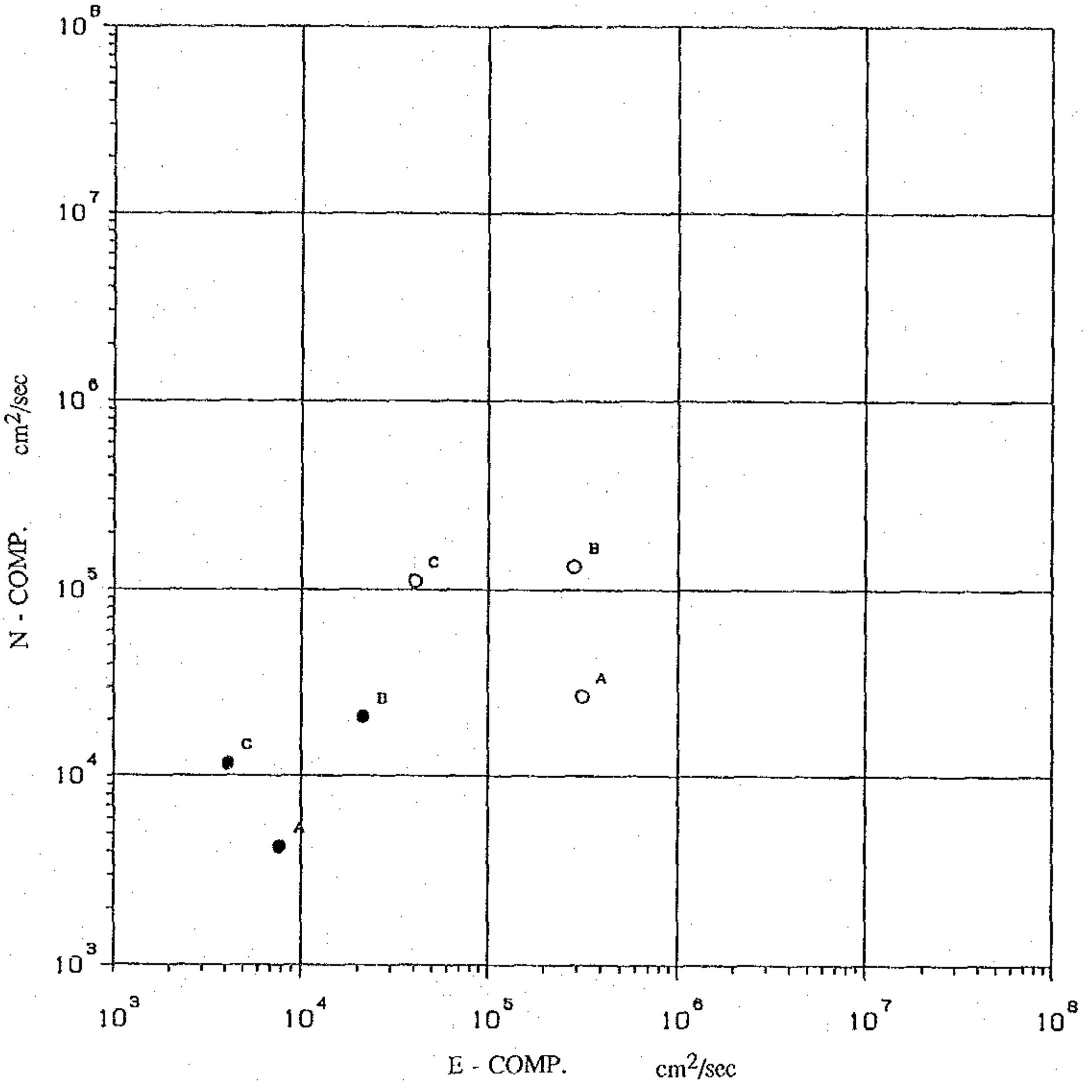
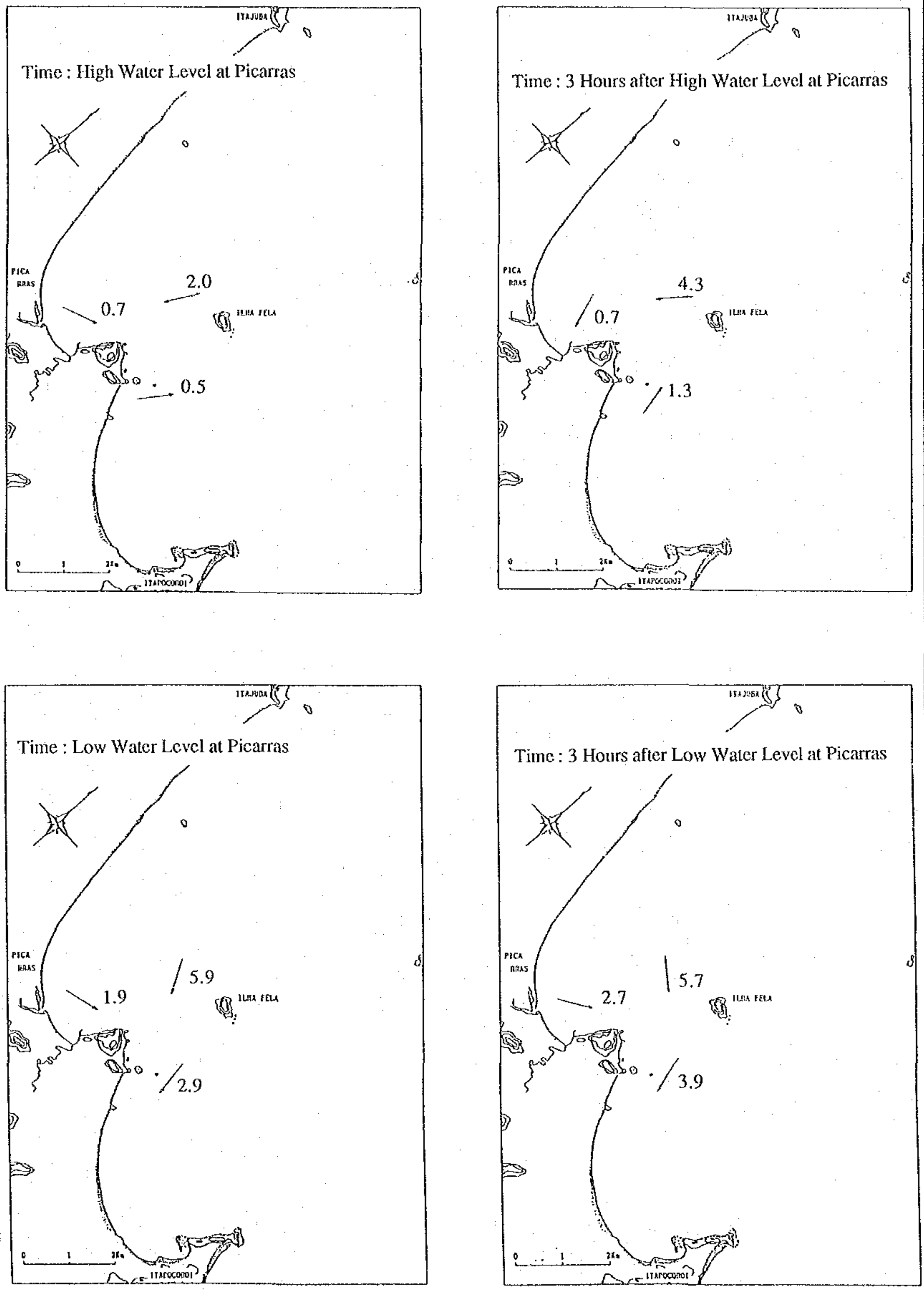


Note ;

○ : in case of with permanent current

● : in case of without permanent current

Fig.IV.3.6 COEFFICIENT OF DIFFUSION



Unit : cm/sec.

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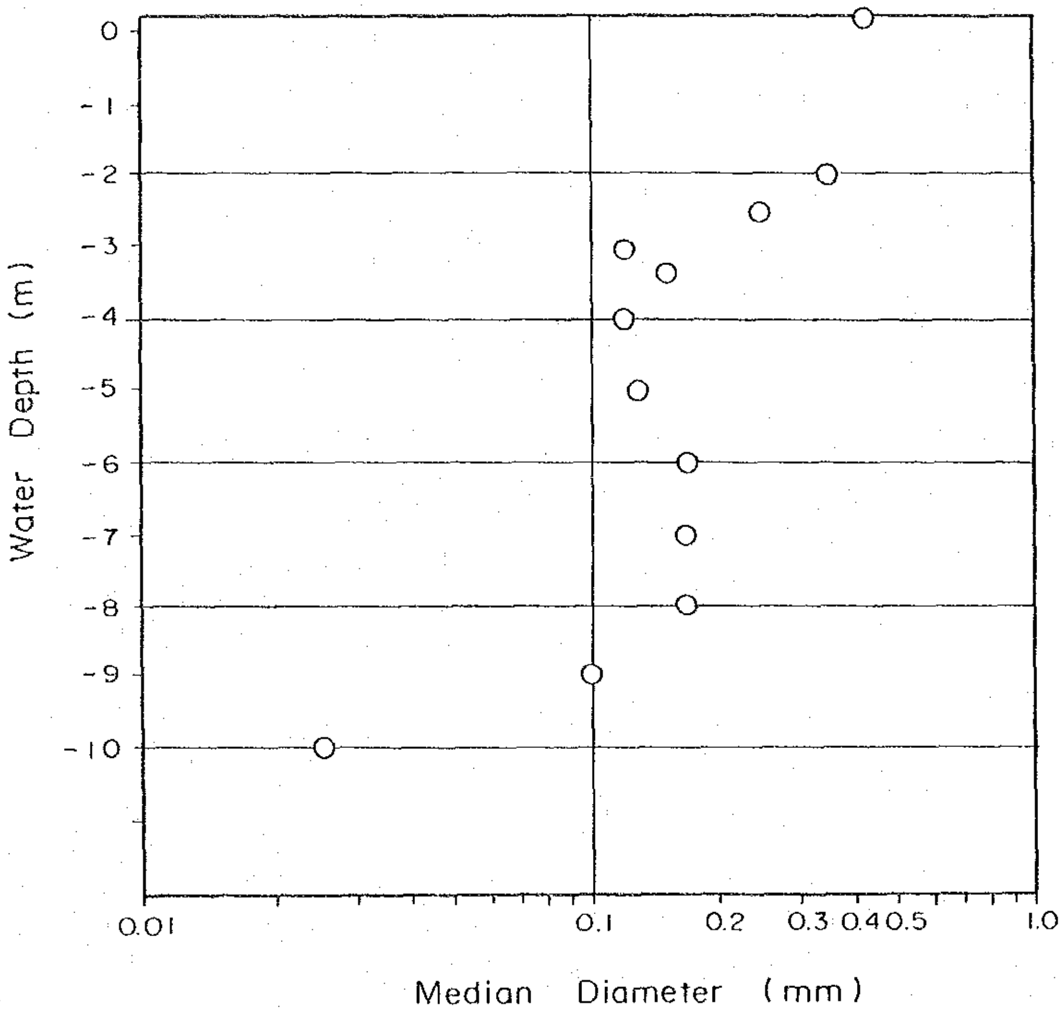

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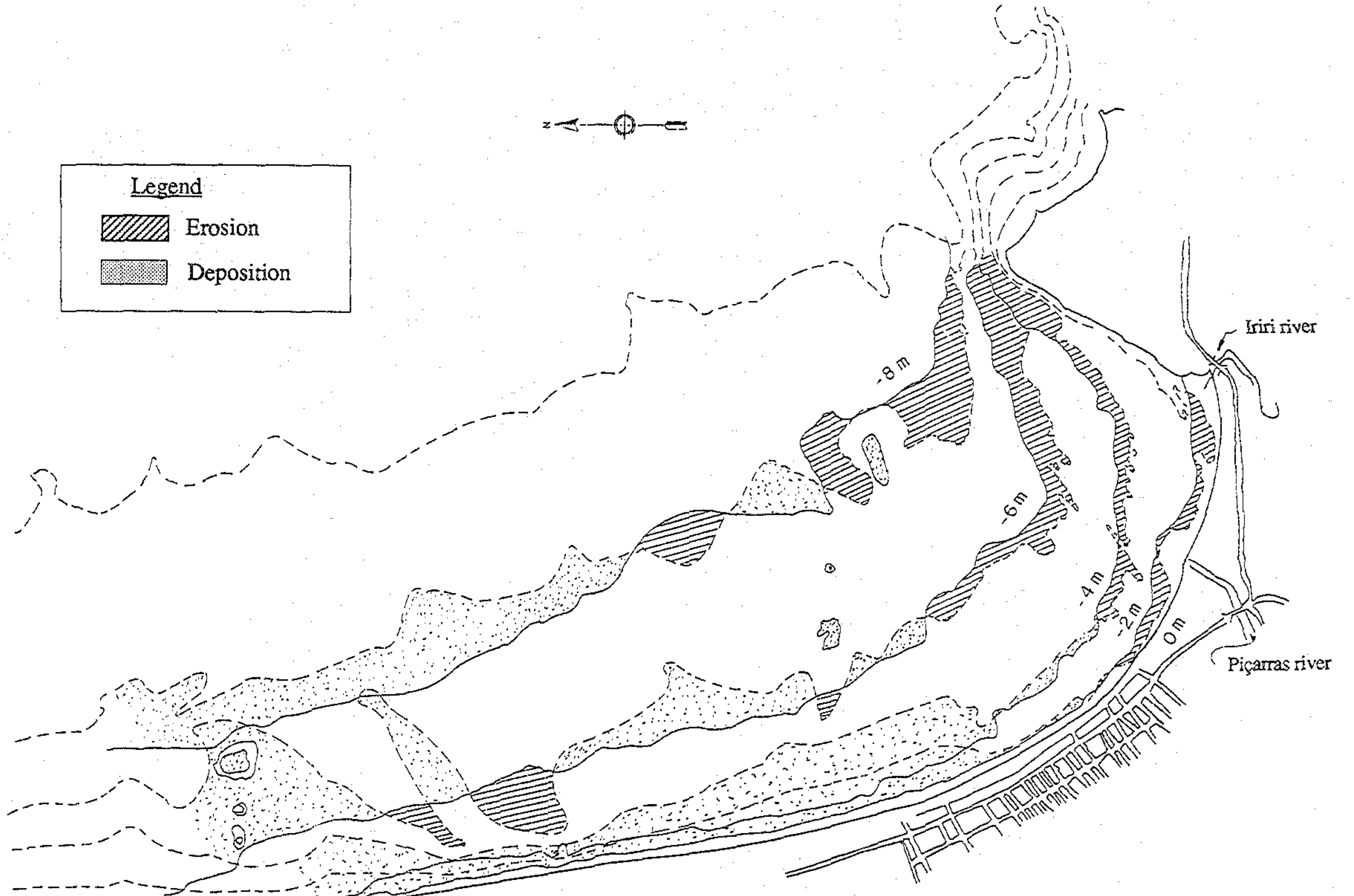

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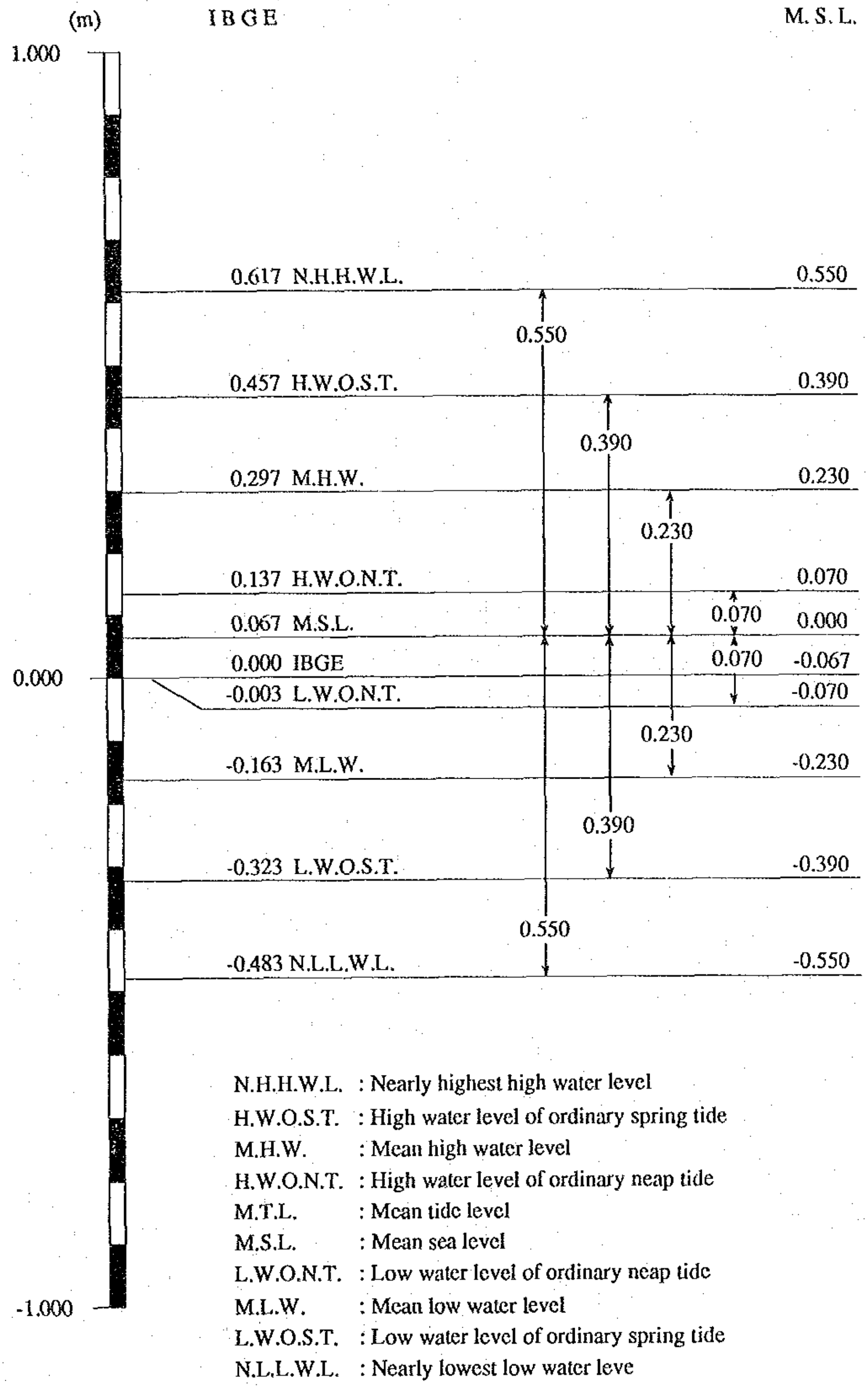

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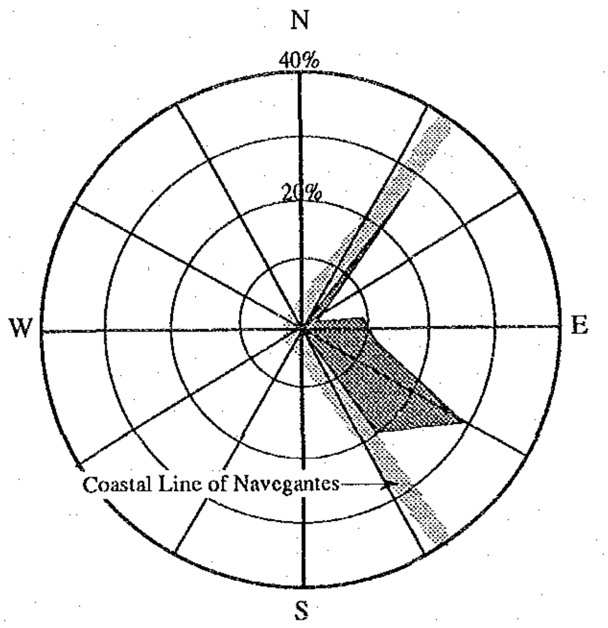

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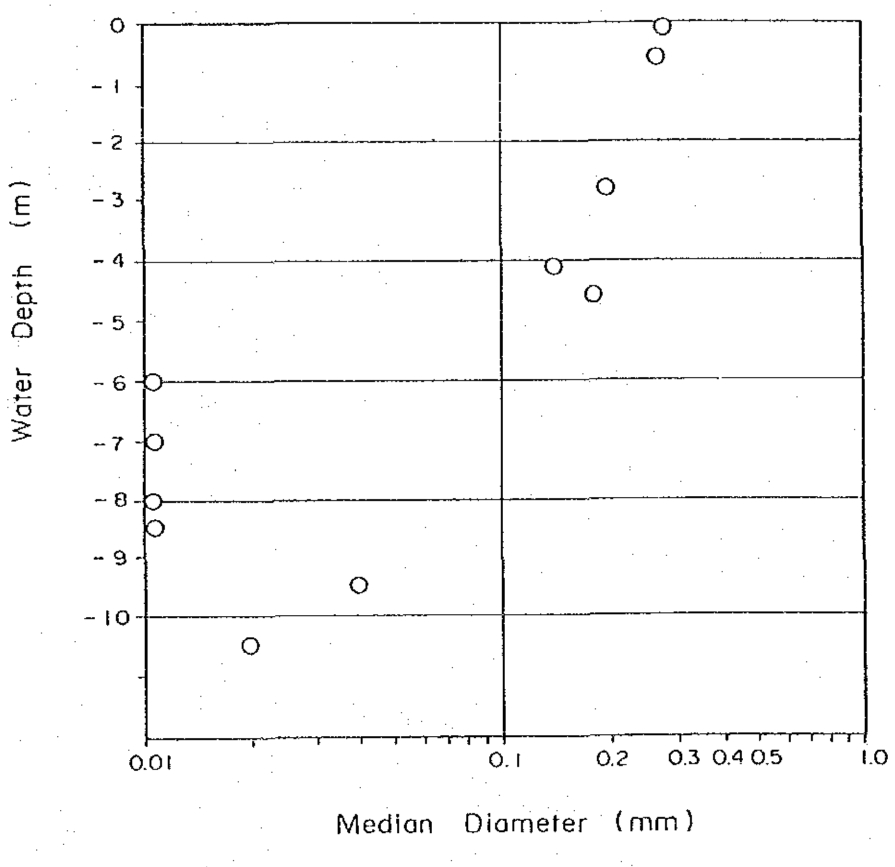

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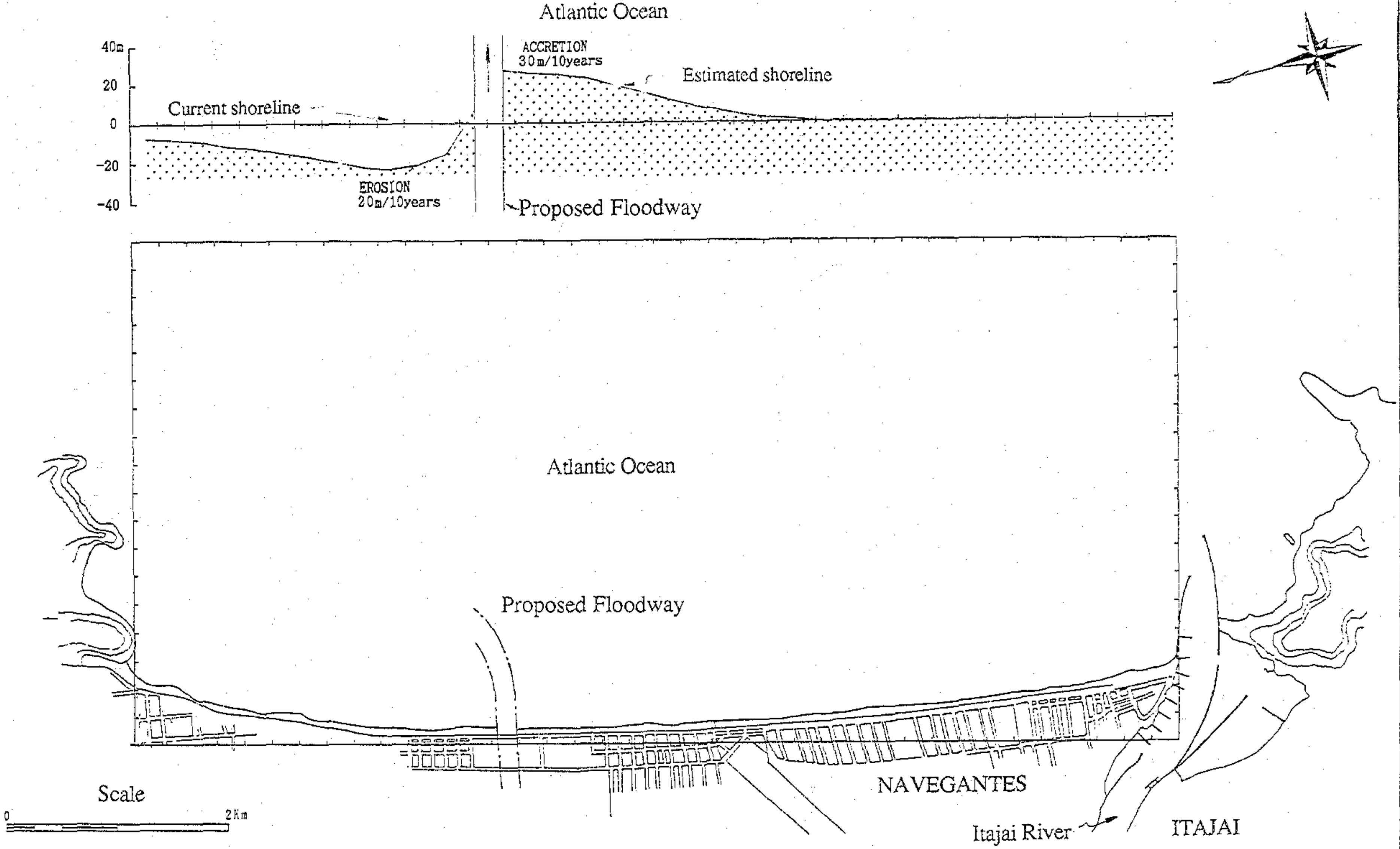

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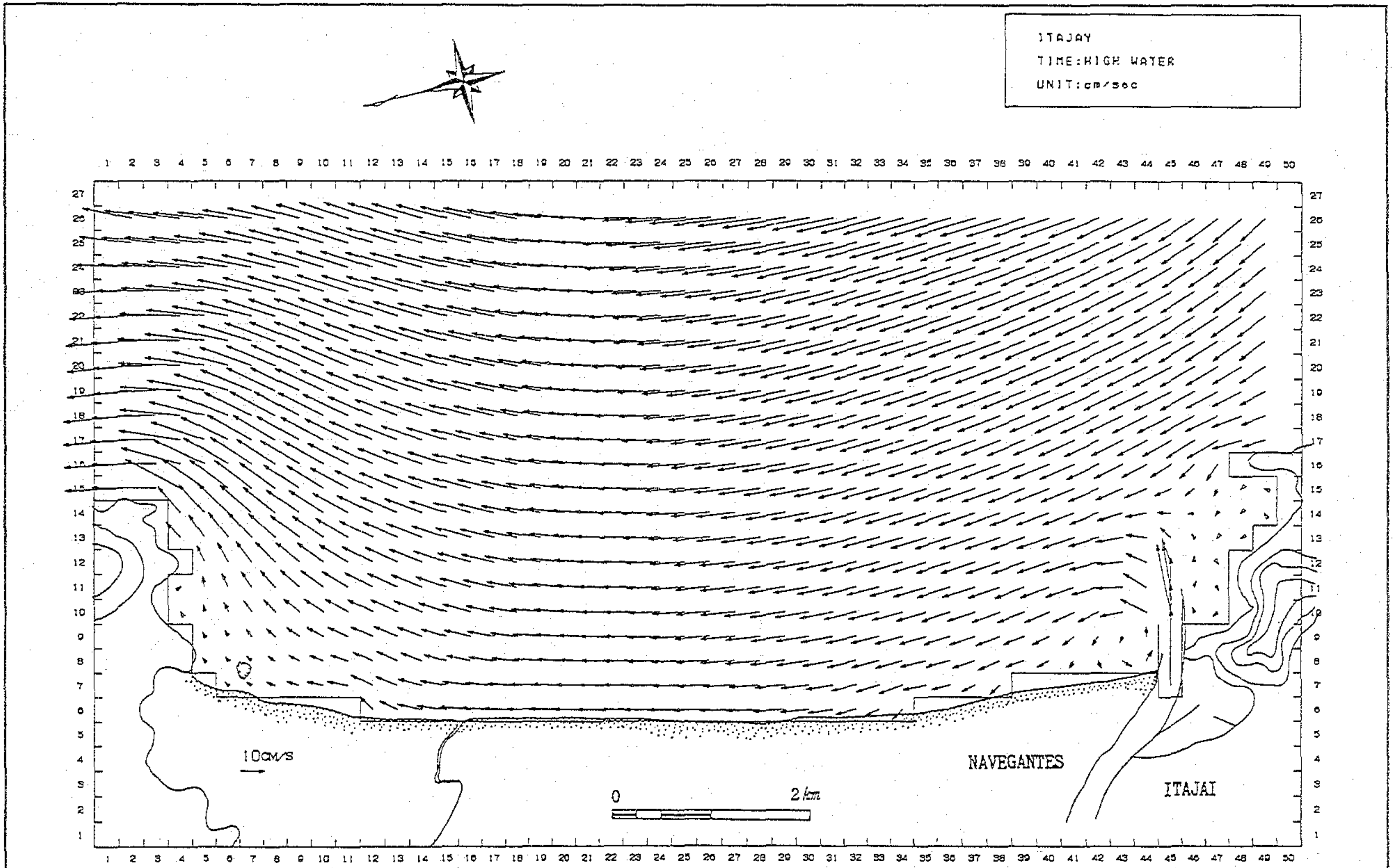


Fig.IV.4.2 TIDAL CURRENT DISTRIBUTION (WITHOUT FLOODWAY)

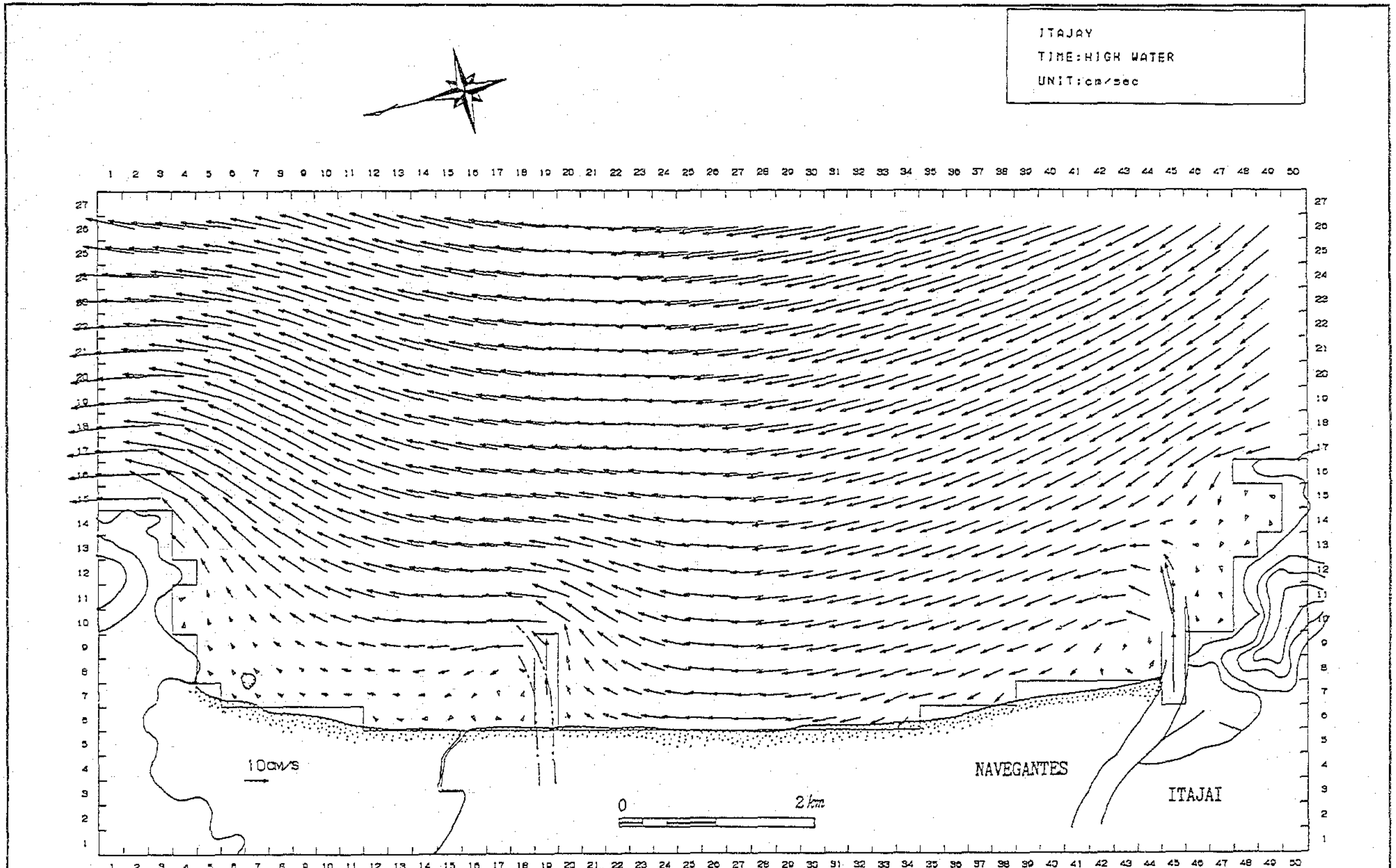
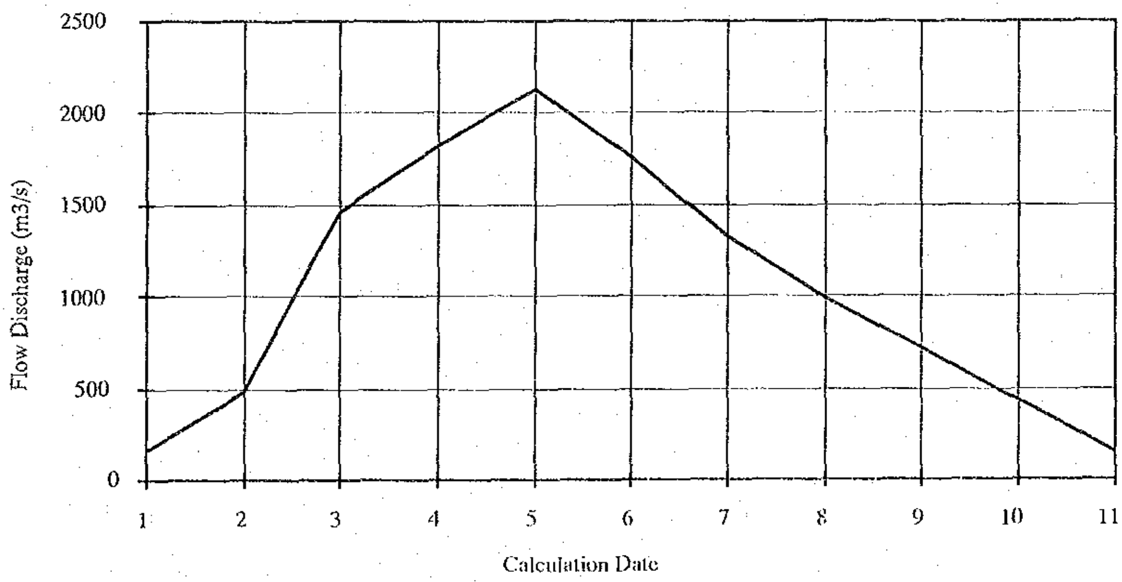
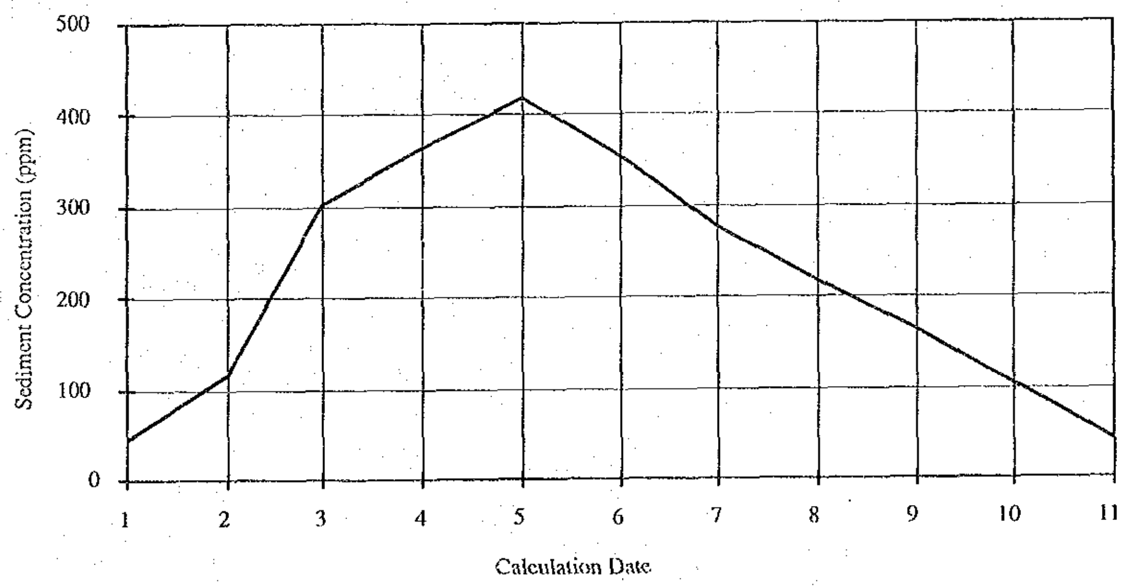


Fig.IV.4.3 TIDAL CURRENT DISTRIBUTION (WITH FLOODWAY)

Calculation Date	Observed Date	Sediment Concentration (ppm)	Flow Discharge (m3/s)
1	Nov. 15 in 1939	45	162
2	16	117	483
3	17	302	1457
4	18	365	1819
5	19	418	2126
6	20	355	1756
7	21	277	1319
8	22	217	996
9	23	163	713
10	24	105	429
11	25	41	146





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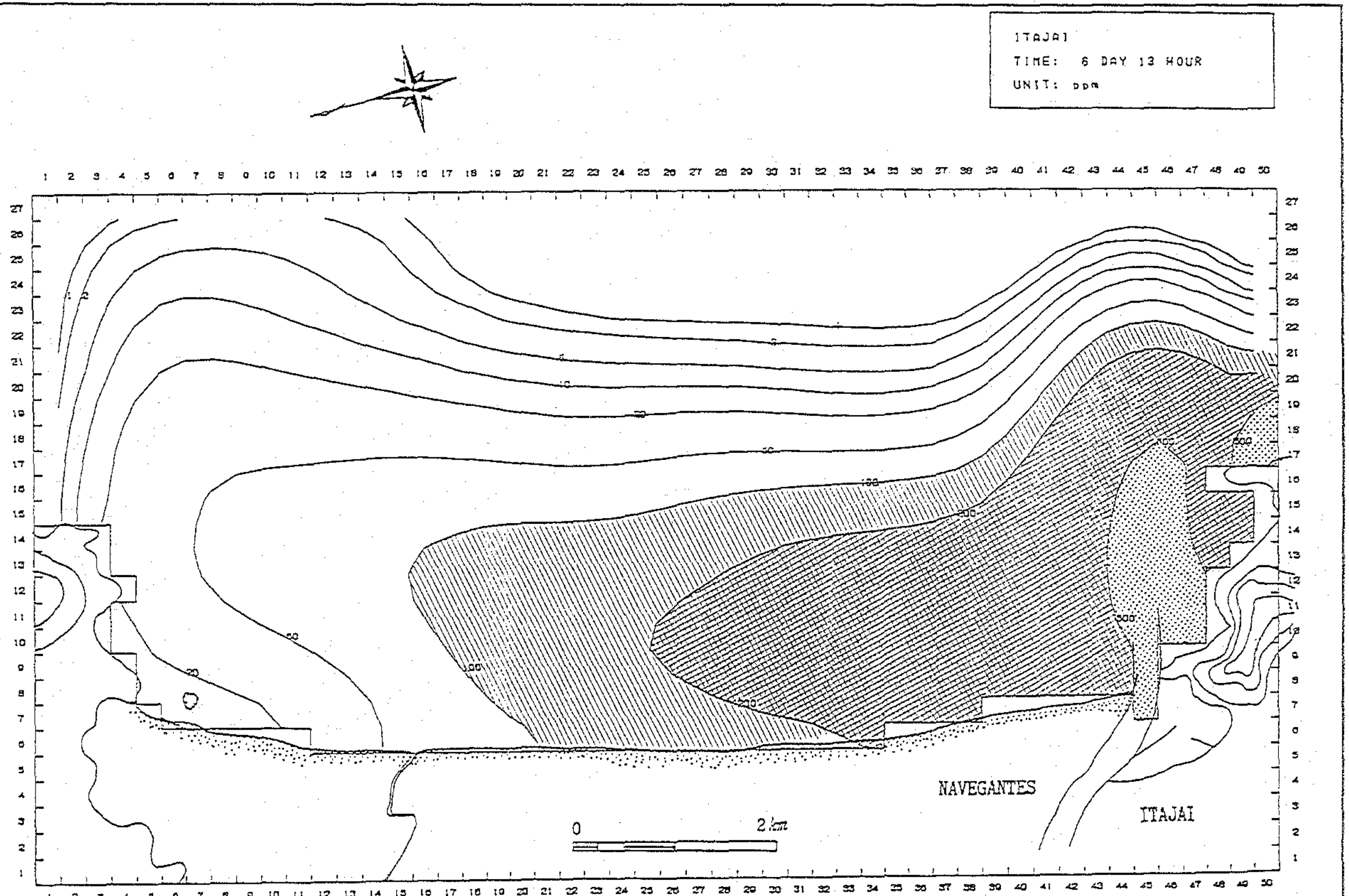

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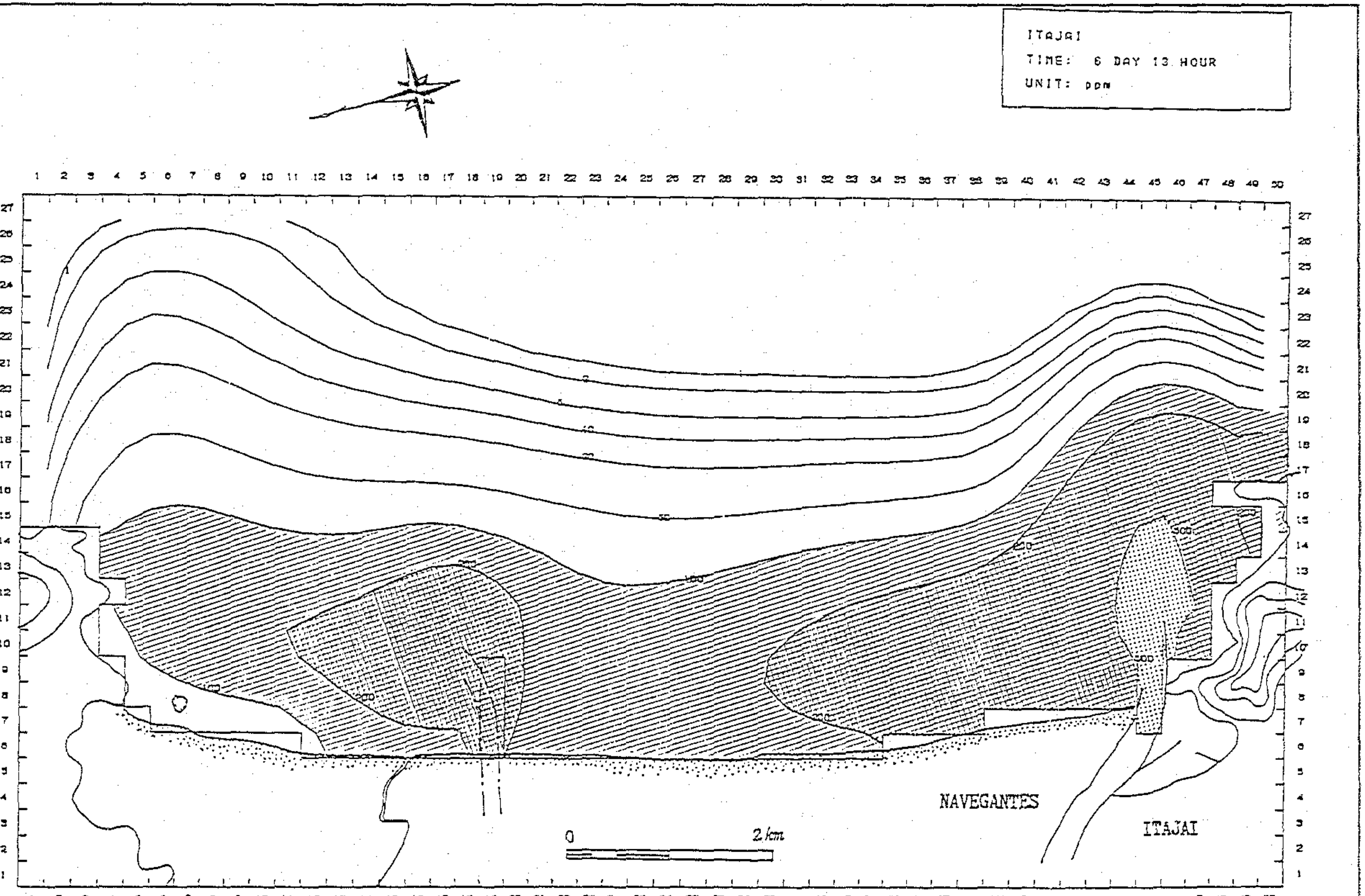
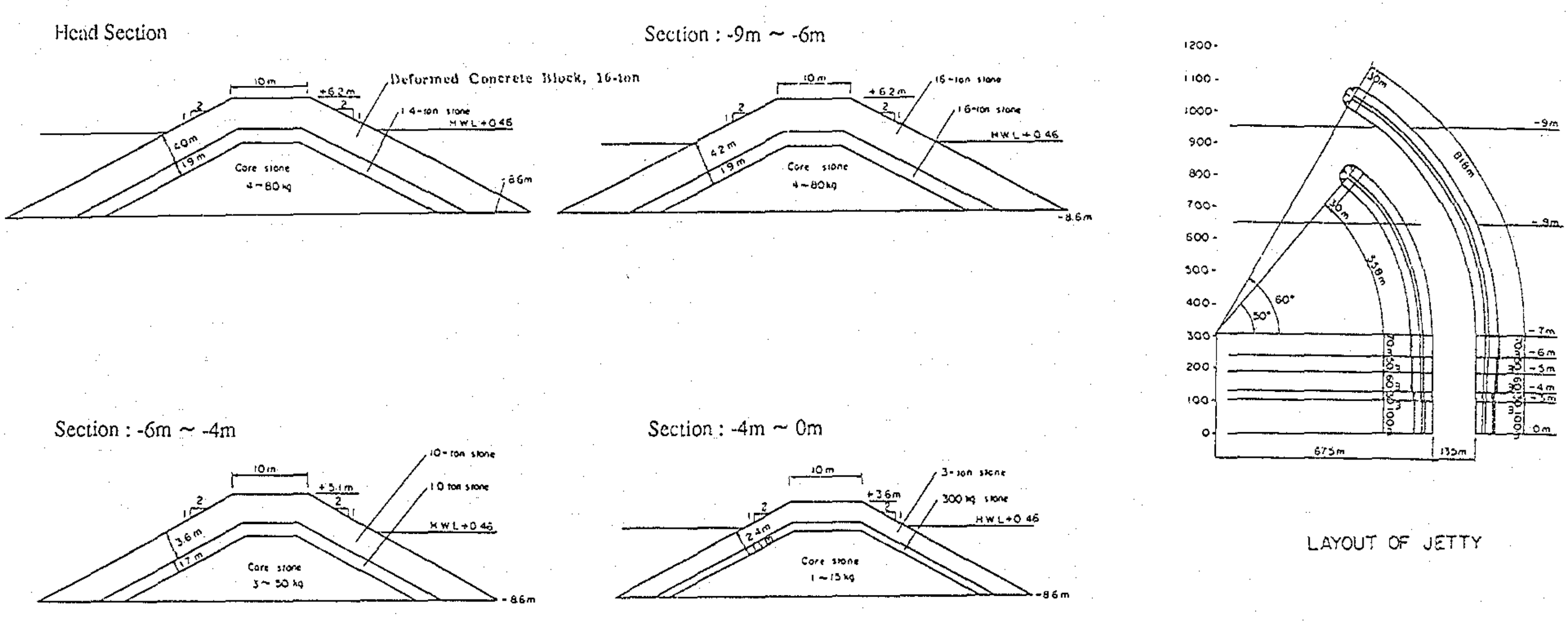


Fig.IV.4.6 DIFFUSION OF DISCHARDED TURBID WATER (WITH FLOODWAY)



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ANNEX V.

SOCIO-ECONOMY AND FLOOD DAMAGE STUDY

ANNEX V SOCIO-ECONOMY AND FLOOD DAMAGE STUDY

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ANNEX V. SOCIO-ECONOMY AND FLOOD DAMAGE STUDY

1. INTRODUCTION

This "Socio-economy and flood damage study" aims at presenting the following four major objectives: (1) the socio-economic structure in the project area not only under the present conditions but also under the future conditions in order to identify the project planning conditions and to contribute basic information for project evaluation; (2) the actual flood damages experienced in 1983 and 1984 to understand inundation conditions and damage structure in the flood protection area; (3) the probable flood damage under the both present and future conditions based on hydrological simulation and estimated damageable unit value in the flood protection area; and (4) the assessment of socio-economic impacts which would be influenced by the introduction of the proposed project in the project area.

The socio-economic study was carried out on the basis of socio-economic data presented by the agencies concerned, such as municipal and state governments, and through census reports. The flood damage study was carried out by means of an interview survey of local people about flooding and by collection of damage records through the organizations concerned. In cases of appropriate data not being available, a field survey was conducted in cooperation with the agencies concerned.

This ANNEX V is made up of six chapters. Chapter 2 mentions the present social and economic conditions in both the study area and the flood protection area. Hence, the study area here comprises four municipalities: Itajai, Navegantes, Penha and Picarras. The flood protection area comprises the inundated area in Itajai and Navegantes, where it is demarcated by the national highways of BR-101 and BR-470. Chapter 3 describes the actual flood damage in the flood protection area in 1983 and 1984. Chapter 4 explains the methodology and procedure of flood damage estimation, an inventory of the various properties existing in the flood protection area and the estimated probable flood damage under the present conditions. Chapter 5 discusses the socio-economic conditions in the future, which are projected on the basis of the several assumptions presented by the agencies concerned. Finally, Chapter 6 shows the estimated probable flood damage under the future conditions which are depicted in Chapter 5 by means of the same procedure presented in Chapter 4.

2. SOCIO-ECONOMIC CONDITION

2.1 Social Conditions

2.1.1 Administration

The study area, comprising four municipalities in the basin of lower Itajai river, covers 601 km^2, distributing as follows: 304 km^2 in Itajai Municipality; 97 km^2 in Navegantes; 46 km^2 in Penha; and 154 km^2 in Picarras. Each municipality is divided into urban and rural areas, as shown in Fig. V.2.1 and Table V.2.1. An urban area is demarcated by municipal ordinance. Even within the urban area, rural activities are still carried on in circumference of the urban area. The respective municipalities have the following urban areas: 45 km^2 in Itajai; 27 km^2 in Navegantes; 28 km^2 in Penha; and 14 km^2 in Picarras.

The flood protection area lies across the two municipalities of Itajai and Navegantes. Its location is illustrated in Fig. V.2.1. Its area is estimated at approximately 55 km^2, comprising 39 km^2 in Itajai and 16 km^2 in Navegantes. These areas account for 13% of the municipal area of Itajai and 16% of Navegantes. The Itajai portion is located completely within the urban area. It occupies about 86% of the urban area, including the most urbanized central zone. Navegantes portion is divided into two areas as follows: 6.4 km^2 in the urban area; and 9.6 km^2 in the rural area. The urban area within the Navegantes portion also includes the central zone of the municipality. This relation between the flood protection area and the administrative areas of the two municipalities is explained in Table V.2.2.

The flood protection area is not delineated by administrative boundary, so it is difficult to ascertain its socio-economic conditions by means of data presuming different boundaries, such as a census. As mentioned in the above paragraph, it occupies the important areas of both municipalities in socio-economic aspect. So, socio-economic conditions of the flood protection area are taken as those for the whole municipality for Itajai and Navegantes in case that data are not available.

2.1.2 Population and labor force

The study area had a population of 116,000 in the latest census year of 1980. In 1989 it is estimated to have a population of 147,000. The population has increased by 31,000 over nine years. The average growth rate of the population is 2.7% per annum, which is larger than both the growth rates of the state of Santa Catarina (2.1%) and the country (2.2%) during the same period. In particular, the population in urban areas increased at higher rate of 3.2%. On the other hand, the population in rural areas decreased at the rate of 0.7% per annum. The population density in the study area is 245 persons per km^2. The density of urban area is

1,139 persons per km^2 and the rural one, 34 persons per km^2. The urban area in Itajai recorded the highest density of 2,333 persons per km^2 in the study area.

The flood protection area is estimated to have a population of 115,800 in 1989 as shown in Table V.2.2. The population is divided into two municipal divisions as follows: 100,960 in Itajai and 14,840 in Navegantes. All the people in Itajai portion live in the urban area, corresponding to 97% of the total urban population in the municipality of Itajai. The population in Navegantes is further divided into two parts: 10,560 in urban area and 4,280 in rural area. The urban population of the Navegantes portion accounts for 95% of the total urban population in the Municipality of Navegantes. The rural population comprises 72% of the total rural population of Navegantes.

The population density is estimated at about 2,116 persons per km^2 on average. The density in the urban area is 2,470 persons per km^2, but the density in the rural area is 447 persons per km^2. In the Itajai portion, the urban density reaches to 2,600 persons per km^2, since the central zone which is the most densely inhabited zone in the study area is included in this portion.

The population of the two municipalities has grown at the average rate of 2.9% for the decade of the 1960's and 3.2% for the next decade as shown in Table V.2.3. During the 60's, the growth rate was lower than that of the state (3.2%), but during the next decade, the growth rate became much bigger than that of the state (2.3%). This means that the two municipalities have grown more quickly during the 70's than during the 60's. In earlier times, the two municipalities developed slower than the other, more developed municipalities in the state, such as Joinville and Blumenau. Since the 70's, however, the two municipalities developed at higher rate than the average of the state. This rapid increase of population might be caused by immigration into the two municipalities from outside areas, in addition to the natural increase in the municipalities. In fact, the population in the municipalities grew at a higher rate than that of the state, even in the 80's as shown in Table V.2.1.

The number of families in the two municipalities was about 23,500 in 1980 as shown in Table V.2.3. During the 70's, it grew at the average rate of 5.0% per annum which was higher than the growth rate of population during the same period. As a result, an average family size decreased from 5.1 persons per family in 1970 to 4.3 persons per family in 1980.

The number of housing units in the municipalities was 22,384 in 1980 as shown in the table. It is slightly smaller than the number of families, demonstrating the housing shortage problem seen in the municipalities. The supply of homes could not keep up with the increase of population because of its rapidity. The problem has become serious from year to year, since the number of residences per family went down from 1.0 in 1960 to 0.95 in 1980 as shown in the table.

The number of earning workers was registered at 35,775 as shown in Table V.2.4. Of this total, 19,819 or 55.4% worked in the service sector (or tertiary sector). The hotel and catering sub-sector of services absorbed the largest number of 7,316 in the tertiary sector, accounting for 20.5% of the total. The number in the tertiary sector grew at the average rate of 6.1% annually during the 70's. 11,445 people worked in the industrial sector in 1980, which was the second biggest share among the main three economic sectors, accounting for 32.0% of the total. However, it grew at 8.9% per annum during the same period, which resulted in higher growth than the tertiary sector. On the other hand, the primary sector occupied only 2,881 or 8.1% of the total in 1980. It increased slightly at an annual rate of 0.3%. Accordingly, the major economic activities in the two municipalities are still in the field of trading and services, and the municipalities has industrialized at a high pace during the 70's.

Table V.2.5 shows income distribution in the two municipalities in 1980. The distribution is quite similar to that of the state of Santa Catarina. The average income in the municipalities was somewhat larger than that of the state. The former was about 1.5 times the minimum wage (Cr$4,150/month in 1980) including people with no income and the latter, 1.4 times the minimum wage. Thus, people in the two municipalities were getting a slightly higher average income than the average for the state.

2.1.3 Housing conditions

In 1980, there were 22,384 housing units in the two municipalities, as mentioned before and seen in Table V.2.6. Most of them (98.9% of the total) are of a durable type, whose main structure is of concrete and bricks. This condition is the same as for the rest of the state. This type of building is promoted by the banks concerned with housing loans, as national policy. Other types of building such as rustic or wooden houses are seen in the surrounding areas where people of low income and urban squatters live.

In the two municipalities, 15,801 families or 71.1% of the total families were getting potable water through the piped distribution network in 1980 as shown in Table V.2.7. This rate was quite high as compared with the whole state (41.3%). 4,624 families or 20.8% in the municipalities relied on wells for obtaining water. On the other hand, there was no sewerage system installed in the municipalities. The majority (87.5%) of the families treated their sewage with septic tank. This situation was similar to that of the whole state.

Almost all the families (96.3%) were covered by the electricity supply network in the municipalities in 1980. This coverage was higher than that of the state (79.0%). In addition, the modern electric appliances, such as television set and refrigerator, were introduced in the greater part (more than 80%) of the families in the municipalities. These rates were far higher than that of the state as shown in the Table. However, only 2,473 families or 11.1% of the total subscribed to a telephone in 1980. This rate was somewhat higher than the state, but it was still low as compared with other facilities.

2.2 Economic Conditions

2.2.1 Economic profile

The two municipalities function as the marketing center for external trade through Itajai port as well as the internal trade. Recently, their sphere of business covers not only the Itajai river basin but also the state of Santa Catarina and its surroundings. Corresponding to these trading activities, manufacturing industries have been established along the Itajai river and the national arterial roads. On the other hand, the primary sector has correspondingly declined in the municipalities, although it has experienced the exceptional development of sugarcane production in the last few years.

(1) Primary sector

The primary sector is generally divided into five sub-sectors: crop production, livestock production, fishery, forestry and rural industry. The total production of these five sub-sectors amounted to Cr$1,290 million in the two municipalities of Itajai and Navegantes in 1980 at current prices as shown in Table V.2.8. It accounted for only 1.3% of the state production (Cr$96.6 billion). Among the five sub-sectors, fishery is the leading sector in the municipalities, which accounted for 83.5% of the total production value.

The main crops cultivated in the municipalities are rice, sugarcane and cassava in order of production value in 1980 as shown in Table V.2.9. Rice (paddy) is cultivated with the area of 964 ha (net area) in the flat low land along both the Itajai river and the Itajai Mirim river courses. The production was 3,340 tons, so unit yield of paddy was 3.5 tons/ha. The paddy production amounted to Cr$32 million at current prices, accounting for 39.7% of the total production in the municipalities. The production of other main crops such as sugarcane and cassava totaled 28,100 tons and 3,500 tons, respectively. Their production reached values of Cr$18 million and Cr$11 million, accounting for 22.6% and 13.7% respectively. However, the crop production in 1987 changed drastically, as shown in the Table. The area harvested for sugarcane totaled 2,480 ha. It means that during seven years 2,000 ha of newly cultivated area was added to the area harvested (494 ha) in 1980. The area harvested for paddy production reached 1,930 ha, doubling the area harvested in 1980. Although the production of other crops increased slightly, its increment was small as compared with the production in 1980. Thus, the amount of sugarcane resulted in Cz$78 million in 1987, accounting for 60% of the total production in the municipalities. In the same manner, the paddy accounted for 18.6%. As a result, the share of crop production in the municipalities to that in the state increased from 0.18% in 1980 to 0.49% in 1987. In the flood protection area, however, only 125 ha of paddy field exists in the Navegantes side as agricultural crop land.

The important livestock and its products in the municipalities are chicken, beef and milk in order of production value as shown in Table V.2.10. The amount of chicken production reached Cr$61 million, accounting for 51% of the total production. The total production in the municipalities bears 0.3% of the state production.

The total production of fishery in the municipalities was 85,000 tons in 1980 and its value was Cr$1,077 million accounting for 50.3% of the total state production as shown in Table V.2.11. The sea food products are distributed not only to local fresh food markets all over the state, but also preserved by freezing and canning factories along the Itajai river. These products are also important as export products. Thus, fishery has kept a quite important position in the municipal economy. In 1987, however, its production decreased to 55,000 tons and its value Cz$954 million, although its share increased to 75.6% of the state total. The production in 1987 was exceptionally low, but the production did not increase in the last few years not only in the two municipalities, but also in the whole state. Fishery production has reached a mature level under present fishing techniques. They are now studying methods of improving of fishery industry.

Forestry production in the municipalities was poor. Also, the greater part (68.9%) of production was for firewood in 1980. This may be because there was no longer forest appropriate to supply timber in the municipalities. The total value (Cr$4.8 million) accounted for only 0.07% of the state production as shown in Table V.2.12.

The main rural industry products in the municipalities were cassava-related products and cheese in order of production value as shown in Table V.2.13. The total value of production was Cr$6.3 million in 1980, accounting for only 0.19% of the state production. The municipalities supply raw materials such as sugarcane, but do not have any remarkable rural industry.

(2) Secondary sector

The secondary sector is usually divided into four sub-sectors: (a) mining, (b) manufacturing, (c) construction and (d) public utilities such as water supply, electricity supply and telephone. The manufacturing sub-sector is the most representative and predominant industry among the four sub-sectors. According to the municipal information, there are 301 manufacturing establishments in the two municipalities in 1989, distributing as follows: 245 establishments in Itajai and 56 in Navegantes as shown in Table V.2.14. The major industrial products are (a) non-metal products and (b) food products in order of the number of establishments.

According to the economic census in 1980, the manufacturing and mining sub-sectors recorded 281 establishments, 5,480 workers and a production value of Cr$7,321 million at current prices. These figures are shown in Tables V.2.15 to V.2.17. They accounted for 2.5%, 2.0% and 1.9% of the state, respectively.

The main industrial product types in the municipalities were (a) food industry and (b) non-metallic industry in order of production value. They accounted for 36.5% and 20.5% of the total production of the mining and manufacturing sub-sectors in the municipalities, respectively. In terms of workers, they absorbed 27.7% and 11.8%, respectively. Regarding the number of establishments, the respective types occupied only 18.1% and 19.2%. Accordingly, the production value per establishment of these types achieved the sizable amounts of Cz$ 52.4 million and Cz$ 27.8 million, respectively as shown in Table V.2.18. Besides, their productivity per worker recorded good efficiency as compared with other industrial types. However, their average number of workers per establishment does not mean to have absorbed such a large number as other industrial types. On the whole, the scale of industry in the municipalities was much smaller than that in Blumenau located in the middle reach of Itajai river.

The third industrial type was the paper industry (9.1%) in order of production value, the transport producing industry (11.0%) such as shipbuilding in order of the number of workers, or the timber industry (11.4%) in order of the number of establishments. Figures in parentheses show the occupation rates of each category to the total in the municipalities.

Table V.2.19 shows the asset holdings of manufacturing industry in the state of Santa Catarina as of December 31, 1980. An average manufacturing entity had the following tangible fixed assets: Cr$2.4 million of site and building; Cr$3.4 million of machinery and production equipment; Cr$0.5 million of installation; Cr$0.1 million of office furniture; and Cr$0.5 million of transportation facilities such as vehicles. At the same time, it had the following stock inventory: Cr$1.9 million of raw material and semi-manufactured products; Cr$1.3 million of manufactured products; and a small proportion of other products for resale.

(3) Tertiary sector

The tertiary sector in the two municipalities is characterized as a mixed market of the large number of small-scale establishments and the small number of slightly larger wholesaling establishments. According to the municipal information, there are 815 commercial establishments and 695 service establishments in the two municipalities in 1986 as shown in Table V.2.14. These numbers are somewhat smaller than those in the census year 1980.

In 1980, there were 832 commercial establishments and 842 service establishments in the municipalities as shown in Table V.2.20. These numbers corresponded to 3.5% and 3.7% of the total number of establishments in the state, respectively. The annual sales of commercial sector was Cr$26,489 million and that of service sector was Cr$1,263 million at 1980 current prices as shown in Table V.2.22. Respective sales accounted for 11.8% and 4.2% of those of the state, respectively. Thus, sales per establishment was Cr$34 million for the commercial sector and Cr$1.5 million for service sector as shown in Table V.2.23. Of all the tertiary sub-sectors, the wholesale sector attained the largest sale per establishment, i.e., Cr$227.5 million. Its total sales bore the biggest share in the sector, accounting for 68.9% of the total.

In tertiary sector, 7,857 workers were involved in 1980, distributed as follows: 4,846 in the commercial sector, accounting for 4.8% of the state; and 3,011 in the other service sector, 3.6%. Table V.2.21 shows the details of this structure. Although the average number of workers per establishment in the tertiary sector was 4.6 persons, about 14 persons or 3 times of the average number of workers per establishment were absorbed in the wholesale sub-sector. The productivity of labor in the wholesale sub-sector was also at a high level as compared with other sub-sectors as shown in Table V.2.23. This means that the wholesale sub-sector is well developed in comparison with the other sub-sectors. In fact, the municipalities, especially Itajai, are playing an important role as a marketing channel in the state.

Table V.2.24 shows assets holdings of the tertiary sector in the state as of December 31, 1980. An average entity had the following tangible fixed assets: Cr$413,000 of its site and building; Cr$194,000 of equipment; Cr$71,000 of office furniture; and Cr$98,000 of transport facilities such as vehicles. At the same time, it had Cr$703,000 of inventory stock such as merchandise and raw materials.

2.2.2 Gross regional domestic product

The gross regional domestic product (GRDP) in the state of Santa Catarina was Cz$3,741 billion in 1988 as shown in Table V.2.25. Its sectoral distribution was as follows: Cz$640 billion or 17.1% of the total in primary sector; Cz$1,474 billion or 39.4% in secondary sector; and Cz$1,627 billion or 43.5% in tertiary sector. In real terms, GRDP declined by 1.1% in 1988, after it had steadily grown up to 1987 as shown in the Table. GRDP per capita in the state was Cz$873,000 (equivalent to US$2,970), which is 16% larger than that (US$2,560) in 1980 in real terms.

The GRDP data in the municipalities of Itajai and Navegantes are not available. Therefore, GRDP is estimated on the basis of both the production value of each economic sector mentioned in previous subsection based on the following assumptions:

(1) In the primary sector, since the total production value in the municipalities is available, value added (VA) is estimated by the coefficient of VA to the total production value, which is assumed to be equal to the coefficient of the state of about 67%;

(2) In the secondary sector, since VA of the manufacturing and mining sub-sectors is available in the economic census report, VA of the sector is estimated by the coefficient of VA of the sub-sectors to the total VA of the secondary sector, which is assumed to equal the state coefficient of 115% in 1980 and 129% in 1970;

(3) In the tertiary sector, since only the sales value of the commercial and other service sectors is available in the economic census reports, VA of the sector is estimated through the following three steps:

   (a) VA of the commercial sector is estimated based on the coefficient of VA of the commercial sector because of data availability;
   (b) VA of the service sub-sectors listed in Table V.2.23 is estimated based on the coefficient of VA in the Table, i.e., 79.5%; and

(c) VA of other service sub-sectors such as finance, transport and communication, and public services is estimated by the coefficient of the total of these sub-sectors to the total of all the other sectors. ; and

(4) GRDP in 1987 is estimated on the basis of available production data in the municipalities, applying the corresponding coefficients of 1980.

GRDP in the two municipalities is shown in Table V.2.26. The primary sector grew at a lower pace (8.6% per annum) than other sectors during the 70's but has grown at a higher rate (11.7% per annum) than the others since 1980. This is due to the rapid development of sugarcane production in last few years as mentioned in the previous subsection. Although it grew at a remarkable rate, the degree of contribution to the regional economy was not so large because its share of GRDP was comparatively small. The secondary sector grew at a rate of less than the state average during the 70's. Even afterwards, it did not attain a remarkable growth, as the number of manufacturing establishments has scarcely increased since 1980. The tertiary sector grew considerably during the 70's. It contributed to the regional economy, since it bore a large share (65%) of GRDP in 1987.

GRDP per capita in the municipalities was estimated at Cz$125,000 (equivalent to around US$3,330) in 1987 at current prices . It was equivalent to about 1.1 times of that of the state (about US$3,030). This ratio did not change remarkably since 1970, in spite of the fact that GRDP grew at higher pace than the state average. This might be because population in the municipalities has grown at such a high rate so that GRDP per capita did not grow at the expected rate.

2.2.3 Public investment for flood control

Table V.2.27 shows the public investment for flood control as a public capital formation for the latest five years. The percentage share of the annual expenditure by the federal government to the gross domestic product (GDP) increased from 9% in 1984 to 17% in 1988. Of the total expenditure in 1988, the government disbursed 0.04% to the 14th regional office of DNOS which is in charge of the management of river control in Santa Catarina. This share recovered to 0.04% in 1988 after it had gradually decreased to 0.01% up to 1987. The regional office invested about 84% of this allotted budget into flood control schemes. It has still continued to invest into the flood control project of the two major rivers, i.e., the Itajai river and Tubarao river. The revenue share to the state of Santa Catarina ranges between 0.31% and 0.46% of the total for five years.

2.2.4 Prices

The whole country has been suffering from high inflation rates over more than two decades. However, recent inflation is showing a serious aspect, as the annual inflation rate was more than 1,000% in 1988. Table V.2.28 shows the consumer price index, GDP implicit deflator and foreign exchange rate between new cruzado in Brazil and US dollar since 1980. The consumer price in Santa Catarina has risen almost 67,000 times up to September 1989 since 1980 as shown in the Table. Concurrently, the foreign exchange rate rose from Cr$65 (NCz$0.000065) in December 1980 to NCz$3.778 in September 1989. In the last few months, the government introduced dual exchange rates: one being the official rate and the other so called as tourist rate which is applicable only to tourists.

2.2.5 Standard conversion factor for economic price

All the costs involved in every project and its alternatives have to be measured as economic costs or "opportunity costs" incurred from the viewpoint of the nation's economy. The measurement of economic cost of a commodity, therefore, depends on how it is likely to be procured. Clearly it is impracticable to trace procurement sources for all the project inputs. Thus, the following principles were applied to those project inputs which constitute a major part of the project costs.

All equipment and materials to be newly imported for the project were estimated at their C.I.F. prices. Competitive rates applicable to services provided by the expatriate were used as economic costs of foreign labor. In fact the foreign currency portion of the project costs has been estimated in the ways described above. Thus it can be used as economic costs without any conversion. On the other hand, for tradable (exportable) goods to be procured in local markets, their F.O.B. prices represent the shadow prices to be used in economic analysis, rather than their purchase prices in local markets used in financial analysis. Moreover, for un-tradable goods in local markets, their prices should be presented in economic prices, as well. In general, a standard conversion factor (SCF) is used to convert them into international market prices, i.e., economic prices.

Internal transfer portions have to be excluded from local currency costs of other projects inputs. In general, the internal transfer portions in Brazil were estimated to be only 5 - 10% by inspection of data on government revenue from taxes and excise duty. In this study, the combined effects of eliminating internal transfer portions and the shadow pricing mentioned above have been deduced instead of adjusting financial costs by each cost element to calculate the economic costs. Table V.2.29 shows SCF in Brazil, which is estimated referring both the national statistical yearbooks and the UN study report. That expresses that the local currency portion of economic costs was estimated to be approximately 90% of the financial costs.

A wage of unskilled labor, which is used in financial analysis, reflecting severe working conditions at the project site does not apply for economic analysis. Since unskilled labor for the project would most likely come from farm households, the opportunity to be sacrificed by the project would be agricultural activities. Thus, the wages paid to seasonal farm workers are more indicative of the opportunity costs of unskilled labor. Also there exists some surplus labor in rural areas. It has been determined, therefore, that much lower wage than that applied to unskilled labor in financial analysis is used as its shadow price in economic analysis. In this study, the shadow rate of unskilled labor is assumed to be about 50% of the financial wage rate, taking into accounts the above mentioned conditions and the previous feasibility study in Blumenau and Gaspar stretch.

2.3 Infrastructure

2.3.1 Physical infrastructure

In the study area, there are two national arterial highways maintained by the federal government. The BR-101 interconnects the northern and southern regions of the country. It cuts the study area into two portions along the coast as shown in Fig. V.2.1. The BR-470 also cuts the study area into two portions along west bank of the Itajai river. Part of the road is still under construction between Gaspar and the intersection within the BR-101.

Besides the national roads, there are three important arterial highways maintained by the state government. The SC-470 runs through the center of the study area along the right bank course of the Itajai river, connecting Itajai city to upstream cities such as Blumenau and Rio do Sul. The SC-486 runs through the Itajai municipality along the course of the Itajai Mirim river, connecting the BR-101 to upstream cities such as Brusque. The SC-413 runs in the west portion of Navegantes municipality, connecting the BR-470 to Luiz Alves located in the northern part of the study area.

The major arterial highways, BR-101 and BR-470, dividing the flood protection area in the study area, are covered by asphalt paving. Major main streets in the area are paved with cobblestones or flagstones like old European cities. Most of other streets are macadam roads. New roads in developing areas or squatted areas still remain unpaved.

Other infrastructures are supplied by the following agencies: municipal water by Companhia Catarinense de Aguas e Saneamento (CASAN); electricity by Centrais Eletricas de

Santa Catarina (CELESC); and telephone by Telecomunicacoes de Santa Catarina (TELESC). Their covering rates in the study area are described in Subsection 2.1.3.

2.3.2 Social infrastructure

According to the municipal information, there are 146 educational facilities in the two municipalities, distributing as follows: 56 nursery schools/kindergartens, 76 first grade schools, 14 second grade schools. There are no tertiary sector establishments such as colleges and universities in the municipalities. Regarding medical facilities, the municipalities offers 17 facilities as follows: 2 hospitals, 5 clinics and 10 other medical care offices. Itajai municipality has 51 churches and 35 public buildings for public services. These inventories are listed up in Table V.2.30.

2.4 Present Land Use

2.4.1 Present land use in study area

The land use maps of the respective municipalities in the study area are not available, as they have not yet been formulated. IBGE/SC is preparing to draw up the land use map using the landsat information, but it will still take long time to cover the whole state area. In this study, the land use map is delineated on the basis of the following information: (a) development conditions such as urbanization and reclamation relying on a topographic map (1:5000) and aerial photograph taken by JICA in 1989; (b) development information for areas that the aerial photography does not cover, is based on topographic maps (1:50,000) made by IBGE in 1981; and (c) planting conditions of agricultural land, compiled from cropping information from the local staff of the Associacao de Credito e Assistencia Rural de Santa Catarina (ACARESC) which is in charge of agricultural extension services.

The land use map in the study area was delineated on the basis of the aforesaid information, which is shown in Fig. V.2.2. The land use was primarily classified into four categories: (1) built-up area of urban activities; (2) agricultural area; (3) grassland and pasture for cattle breeding; and (4)forest and bush. Secondarily, agricultural area was divided into three sub-categories: (a) paddy field; (b) sugarcane field; and (c) other crop land which produces vegetables and fruit.

The total land of 601 km^2 in the study area is currently used as follows: (1) 62 km^2 or 10% of the total land is built-up area; (2) 84 km^2 or 14% is agricultural production; (3) 193 km^2 or 32% is grassland and pasture; and 262 km^2 or 44% is forest and bush area. Agricultural land of 84 km^2 is further divided as follows: (a) 29 km^2 for paddy production;

(b) 40 km^2 for sugarcane; and (c) 15 km^2 for other crops. Table V.2.31 shows the details of land use in the respective municipalities.

The alternative floodways are mostly planned in grassland and sugarcane field areas. The Floodway-1 runs through an area of broad grassland and sugarcane fields in the Navegantes and the Picarras municipalities and goes into Picarras river which is a boundary between Picarras and Penha through bush land and some urbanized areas. The Floodway-II is planned to be aligned in grassland including some bush land and paddy fields. The Floodway-III cuts through a portion of some urbanized areas in Navegantes.

2.4.2 Urbanization

Itajai area seems to have been settled at a lower pace than the state average up to the 60's. In the 70's, population growth in the state decelerated to 2.3% per annum from 3.2% in the 60's, but population growth in the municipalities accelerated to 3.2% annually and keeps almost the same pace up to the present. Thus, this area has expanded rather rapidly since the 70's.

In the Itajai municipality, the increase of population has been absorbed in the urban area. As a result, the population in the rural areas decreased in spite of a population rise as a whole in the municipality. In Navegantes municipality as well, most of the population rise must have been absorbed in the urban area, because population growth rate in rural area (1.6% on average) is much lower than that in the urban area (3.2%) and that of the total (2.6%). In the last few years in particular, the active development of sugarcane and paddy production was promoted in the rural area. Despite these conditions, people have emigrated into the urban areas of the municipalities.

Owing to this centralization, the urban area has expanded into outside areas. Fig. V.2.3 shows the transition of urbanization in the municipalities since the year 1956. The urban settlement started around the port and afterwards expanded radially along the axis of the old roads on the right bank of the Itajai river. After construction of the BR-101 the urban expansion occurred towards the highway in a predominantly horizontal form. Besides the tendency towards horizontal growth along the river, the urban area expanded to the opposite bank, Navegantes. Thus, the urban area of Itajai expanded in all directions. However, it is contained by the natural physical limits: the ocean to the east, the hills to the south, the Itajai river to the north. Although it has expanded beyond the river, the river is still a barrier to expansion without a bridge. Thus, the urban area is still expanding to the west, towards the BR-101. In Navegantes, the urban area expanded along both the river and the seashore. The urbanization towards the north along the coast is limited by the airport, so the urban area is expanding to the west along both the river and the BR-470. Beyond the airport to the north, most of newly developed area is used for summer houses which are only used in the summer vacation.

2.4.3 Present land use in flood protection area

The flood protection area is about 54.7 km^2 in extent, as seen in Table V.2.2. Land use in this area is basically categorized in the same way as done in the study area. However, since the area is almost completely urbanized, particularly in Itajai side, and the categories between bush and grassland are ambiguous in urbanized areas, so grassland and bush are put into one item. Water area, such as the river, is distinguished to make an inundation area clear and to make it easier to estimate the flood damage. The total land in the area is used as follows at present: (1) 27.5 km^2 or 50% of the total land is built-up area; (2) 1.3 km^2 or 2% is agricultural production; (3) 20.6 km^2 or 38% is grassland, pasture and bush; and (4) 5.5 km^2 or 10% is river area. The built-up area of 27.5 km^2 is further divided into the following two categories: (a) 22.4 km^2 for residential use; (b) 5.1 km^2 for other industrial or commercial activities. The agricultural land in the flood protection area is used only for paddy production in Navegantes. In some grasslands, animal husbandry is carried out, but it is operated in a small scale and is a temporary activity. Table V.2.32 shows the details of land use in the respective municipalities.

3. LARGE SCALE FLOOD DAMAGE

3.1 Existing Records of Large Scale Floods in the Past

Among the past large scale floods, the largest and second largest ones recently occurred in 1983 and 1984. Overall flood damage data in the Itajai river basin was collected during the master plan study in 1986. For this study, the additional data collection of actual damage records in the municipalities of Itajai and Navegantes was carried out to make more detailed analysis of damage.

Damage records of the public sector, consisting of public buildings and infrastructure belonging to municipal governments in both 1983 and 1984 were collected from the both municipalities. Some damage records were collected from other non-public bodies. However, since these records were compiled more than five years ago, it was difficult to make a complete collection as parts of the records had disappeared.

Damage records of the 1984 flood on the private sector which were originally compiled by Secretaria da Industria, do Comercio e do Turismo (SICT), consisting of manufacturing industry and commercial sector in Itajai municipality, were collected from the municipal government. Damage records for the private sector in Navegantes were collected through the municipal government. There are no damage records of the 1983 flood for the private sector in either of the municipalities.

To identify the inundated areas of both floods, a flood mark survey and an interview survey were conducted for residents in probably inundated areas. Before these surveys, the flood mark survey records of DNOS (Ref. V043) were referred to raise the efficiency of the investigation. Although inundation area maps of major cities in the basin has been demarcated by Departamento Nacional de Agua e Energia Eletrica (DNAEE), the one for the Itajai area has not been completed yet.

3.2 Estimation of Inundated Area

3.2.1 Demarcation of inundated area

Inundated area due to 1983 and 1984 floods was identified in the study area along the lower Itajai river and the Itajai Mirim river as shown in Fig. V.3.1. This inundation map was demarcated on the basis of the results of the flood mark survey. The inundated areas were about 130 km^2 for the 1983 flood and 132 km^2 for the 1984 flood. They account for more than 20% of the total administrative territories. These areas were distributed administratively as follows.

(Unit : km^2)

Municipality	1983	1984
Itajai	91	95
Navegantes	22	20
Penha	4	4
Picarras	13	13
Total	130	132

The municipalities of Penha and Picarras are located outside the Itajai river basin. In both floods, however, flood water invaded these municipalities along a drainage canal of a sugarcane field which flows into the Picarras river. This water did not damage the residents in these inundated areas seriously, according to the interview survey.

The inundated area in the flood protection area, due to the both floods, is identified in the same manner as done in the study area. Inundated areas were about 31 km^2 in the 1983 flood and 34 km^2 in the 1984 flood. They covered 63% in 1983 and 68% in 1984 of the flood protection area (49.2 km^2 in net land area excluding river area). These areas were distributed administratively as follows.

(Unit : km^2)

Municipality	1983	1984
Itajai	26.9	29.9
Navegantes	9.2	8.8
Total (Gross Area)	36.1	38.7
River	5.1	5.2
Total (Net Area)	31.0	33.5

Regarding the flood in 1984, rainfall in the Itajai Mirim river basin is said to be a more serious cause of flooding than rainfall in the Itajai river basin. Overflowing water from the Itajai Mirim river invaded the Itajai urban area which is located at the downstream end of the Itajai Mirim river. Thus, the southern part of the Itajai urban area was damaged more seriously in 1984 than in 1983.

3.2.2 Inundated area-depth-duration

The water level of the Itajai river at the BR-101 bridge was around 4.8 m above average sea level in 1983 and around 4.6 m in 1984. Ground level at the same point is between 2.0 m and 2.5 m, so inundation depth in the river bank area along the river was between 2.3 m and 2.8 m in 1983, and between 2.1 m and 2.6 m in 1984. The difference between the maximum water levels of the two floods was around 0.2 m.

The water level of the Itajai Mirim river at the bridge of Avenida Governador Adolfo Konder, connecting the BR-101 to the center of Itajai city, was around 3.8 m above sea level in 1983 and 4.1 m in 1984. Ground level at the same point is around 3.4 m, so the water depth in the river bank area along the river was 0.4 m in 1983 and 0.7 m in 1984. The difference between the maximum water levels of the two floods was about 0.3 m.

The duration of the inundation in 1983 was around a half of month in the most seriously inundated area along both sides of Itajai river, although in 1984 it was less than a week even at seriously affected places. On the other hand, the duration of the inundation in 1984 was around a week in the most seriously affected area along the Itajai Mirim river. But in 1983, at the same place, it lasted only a few days. This information of duration was collected through the interview survey of local people in the study area.

3.3 Actual Flood Damage and Influence

Flood damage in the municipalities of Itajai and Navegantes by inundation in 1983 and 1984 is compiled in Table V.3.1, based on the information collected from the agencies concerned. In this Table, only direct flood losses are observable in all their aspects, as some data disappeared and are lacking. Most of monetary figures of flood damage in the Table show not lost values but amounts estimated for repair costs.

The number of people affected by the flood in 1984 was estimated at 60,000 in Itajai and 2,030 in Navegantes. Compared to the entire population of both municipalities, it turns out to be 60% and 15%, respectively. The number of people affected in 1983 was not available, but its magnitude would be of the same order considering the inundated area in 1983.

The number of houses affected by both floods are categorized by damage degree such as destroyed, damaged and inundated. During the 1984 flood, 90 units in Itajai and one unit in Navegantes were "destroyed". Most of them were wooden houses with brick type foundation, which are vulnerable to inundation water. Most of the houses categorized as "damaged" suffered from such serious structural damage in the portions, such as roof and walls that they had to be reconstructed. They were enumerated to be 2,500 units in Itajai. During the flood, many residents living in the affected areas took refuge as follows: 20,000 people in Itajai and 480 in Navegantes were evacuated; and 15,000 in Itajai and 27 in Navegantes moved from their own houses to other places for safety. 800 people in Itajai and 9 in Navegantes lost their houses that were destroyed and damaged. The vast number of "inundated" houses were spoiled with minor damage to walls, gates and electric wiring inside the houses.

Damage to the agricultural sector in 1984 was estimated at Cr$632 million, distributed into sub-sectors as follows: Cr$500 million in crop production; Cr$83 million in animal husbandry; and Cr$49 million in other production facilities and equipment. Among damages to crops, sugarcane and paddy production suffered the most serious damage, estimated at Cr$162 million and Cr$38 million respectively. Details of these damages are given in Table V.3.2.

Table V.3.3 shows the detailed damage in the municipality of Itajai in 1984 to both (1) industrial sector, manufacturing in particular, and (2) commercial sector. 110 manufacturing establishments or about 50% of the total number were affected by the flood, more than 40% of which had to suspend production activities for the inundation period. Most of damaged factories were small and medium sized establishments having less than 30 persons employed. The total number of affected industrial workers was reported to be 3,159, corresponding to about 60% of all workers engaged in manufacturing and mining sectors. The most seriously damaged type of industry in terms of employees and monetary terms of damage was the food industry, employing 1,258 people and damage to property estimated at Cr$1,191 million. In all types of manufacturing industry, the total amount of direct damage was estimated at Cr$2,174 million, corresponding to 2.7% of the estimated annual production value. The operation of factories was affected not only during the inundation period but also after the flood had abated. Such losses of operation reached 33 days on an average. This kind of losses, called business activity loss, has to be considered as indirect losses, although it is difficult to estimate them with accuracy.

90 commercial establishments or more than 10% of the total number were affected by the flood, nearly 50% of which had to suspend sales activities for the inundation period. Most of damaged establishments listed in the table are of a medium size, having an average number of employees of about 25 persons, since the total number of affected commercial workers was reported to be 2,218 people. The total amount of direct damage was estimated at Cr$2,951 million, corresponding to 7.8% of the estimated annual sales value. The loss of operation in the commercial sector was 30 days on average.

Flood damage to the public sector consists of (1) public facilities such as municipal offices, schools and utilities, and (2) transportation system such as roads and the port. The amount of damage to the public sector shown in Table V.3.1 indicates the cost of reconstruction of numerous damaged facilities in the 1983 and 1984 floods. For the public sector, the most seriously damaged facilities were the port and the road system as shown in the table. In the port, three of the five berths were completely destroyed by the flood in 1983. The Empresa de Portos de Brasil (PORTOBRAS) spent five years in restoring it to its previous condition. It is said that the federal government invested approximately US$100 million for reconstructing of these berths. Besides this, a number of workers in the port, estimated at 2,000 in 1983, lost their jobs during these five years. Therefore, this indirect damage is estimated to be an enormous amount.

Table V.3.4 shows direct damage to the road system in the municipalities due to the 1983 and 1984 floods. There is a marked contrast in damage conditions to the road system caused by the both floods. Damage in Navegantes was more serious in 1983 than in 1984, because in 1983 more overflow water came from the Itajai river than from the Itajai Mirim river. But, in 1984 overflow water from the Itajai Mirim river affected the road system in Itajai municipality, so the road system in Itajai was damaged more seriously in 1984 than in 1983.

Due to the serious damage to the entire road system, it took more than ten days for the road system to get back to normal conditions after the flood had abated. The disturbance of transportation indirectly affected economic activities of the secondary and tertiary sectors. A lot of establishments which were not directly damaged by inundation in the 1983 and 1984 floods, suffered from the opportunity loss of selling goods in the commercial sector and the opportunity loss of industrial production because intermediate materials required for producing final goods could not be transported.

The rest of damages to the public sector consists of utilities, social infrastructure such as schools, medical facilities and public facilities. These damage amounts are listed in Table V.3.1, as far as damage data are available. The total amounts over all sectors excluding damage to residential units were as follows: in 1983, Cr$69.6 billion (equivalent to approximately US$102 million) in Itajai including damage to the port and Cr$0.4 billion (US$0.6 million) in Navegantes; and in 1984, Cr$17.6 billion (US$7.7 million) in Itajai and Cr$0.4 billion (US$0.2 million) in Navegantes.

4. PROBABLE FLOOD DAMAGE

4.1 Procedure of Estimation of Probable Flood Damage

The purpose of this Chapter is to estimate a probable flood damage which is the basic figures to estimate the benefit accruing from the flood protection works under the present conditions. The benefit is defined as the difference between both flood damages with the project and without the project. First of all, the structure of flood damage and the procedure of estimation of probable flood damage are discussed in this Section. Succeedingly, the probable flood damage is estimated based on the procedure in the following sections.

The economic losses due to flooding are divided into two main sections: (1) Losses of damages to existing facilities and suspension of business activities because of inundation and (2) Expenses of emergency activities to flood victims during and after inundation. In the former section, the economic field, the losses comprise the following two parts: (a) damage losses to properties of economic entities which consist of (i) accumulated properties and structures such as buildings, equipment and irrigation facilities and (ii) inventory stock and products such as raw materials, manufactured products, merchandise and crops under cultivation; and (b) opportunity losses which also consist of two parts: (i) expected profits through damaged products and merchandise and (ii) suspension of business or production activities due to inundation and restoration of damaged facilities and infrastructure. In the social field also in the former section, the losses comprise the following two parts: (a) damage to housing units, which include household effects as well as the residence and (b) damage to infrastructure which consists of (i) social infrastructure such as schools, medical facilities, religious facilities and public halls and (ii) physical infrastructure such as transportation facilities, water supply, electricity supply, telephone and river structures. This structure of damage losses is illustrated in Fig. V.4.1.

Taking this structure into consideration, the flood damage is estimated by the following itemization because of data availability (refer to Fig. V.4.1).

(1) Direct damage, which is divided into the four categories.

(a) Housing unit: damageable property of the building itself and the household effects in it.

(b) Industrial establishment: damageable properties consisting of factory, installation, equipment for production, inventory of stock such as raw materials and manufactured products, and expected profit through damageable products.

(c) Commercial and service establishments: damageable property consisting of store, installation, office furniture, inventory of stock such as merchandise and raw materials for services, and expected profit through damageable inventory of stock.

(d) Paddy production: damageable value consisting of accumulated production cost and expected net income. Irrigation facilities are considered to be a kind of physical infrastructure.

(2) Infrastructure damage, to social and physical infrastructure, is assumed to be 30% of the above direct damage, referring to the master plan study in 1986.

(3) Indirect damage comprises (a) opportunity losses of business and/or production activities and (b)emergency activities. Indirect losses incurred in manufacturing and commercial sectors are estimated based on affected establishments. The costs for emergency activities and operation losses are explained in the government reports (Ref. V047 and V048). In spite of these assumptions and the information, the amount of these indirect losses was still ambiguous. The amount of indirect damage is assumed to be the same 10% of the direct damage as adopted in the previous feasibility study in 1987.

The number of damageable properties was basically counted from the information of the latest topographic map with a scale of 1:5,000 prepared by JICA in 1989. A grid of 250 m interval squares was super-imposed on the map of the flood protection area, each square representing 6.25 ha. The elevation of the ground surface is read from the topographic map. The flood damage is calculated square by square. In every square, the damage is estimated as a product of the number of property by type, unit value of the property and a damage rate corresponding to the inundation depth.

4.2 Area-Depth Analysis

Area-depth analysis is made using the following probable flood peak discharge flowing into the lower Itajai river under present river condition with the existing three flood control dams;

(Unit : m^3/s)

Return Period (Year)	Probable Flood Peak Discharge at River Mouth			
	1978	1980	1983	1984
2	2,390	2,300	2,020	2,500
5	2,960	2,820	2,770	3,090
10	3,020	2,990	3,100	3,400
25	3,830	3,600	3,900	3,920
50	4,410	4,120	5,090	4,580
100	4,980	4,610	6,050	5,090

For converting the flood peak discharge to water level, non-uniform flow calculation based on topographic information from 1:5,000 scaled map and river cross section at average interval of 300 m was made under the following roughness coefficient;

- Present river course: 0.035 and
- Flooding area: 0.05.

Inundation area and depth in the lower Itajai river are listed in Table V.4.1 in terms of the above probable floods, and inundation map of 10-year probable flood, which is equivalent to design scale of the provisional flood control plan, is illustrated in Fig. V.4.2. Comparing the inundation area simulated against 50-year probable flood with actual inundation area due to floods in 1983 and 1984 in Chapter 3, those areas are almost same as being about 40 km^2. The maximum inundation area for 10-year probable flood, which is flood protection level for the project, is caused by flooding pattern in 1984 and extends to about 26 km^2 corresponding to 50 % of the flood protection area.

4.3 Types of Damageable Properties

4.3.1 Identification of damageable properties

Having confirmed the number of damageable properties based on the topographic map, a reconnaissance survey was conducted for the purpose of clarifying the present conditions of some areas which could not be identified by the map. Newly developing areas along urban roads and sprawling squatter areas into grassland are also fully taken into account to reflect present conditions precisely.

Since multistory buildings in central zone of Itajai and furniture in floors higher than the second floor are not considered to be inundated, a rough estimation in terms of the number of multistory buildings was conducted during the field survey. Furthermore, the quality of buildings in both the central zone and its circumference was also identified through the field investigation, for the purpose of estimation of building value.

4.3.2 Inventory of damageable properties

Through the above procedure, the number of damageable properties in the flood protection area is estimated as follows in total and detailed in Table V.4.2: 29,600 housing units, 208 industrial establishments, 1,329 commercial and service establishments and 125 ha of paddy field. Among these properties, it is clear that the paddy production in the flood protection area is quite small as compared with other properties. Incidentally, the total damageable value of paddy in the flood protection area would be estimated at about NCz$125,000, even if the whole paddy production is assumed to be damaged completely. This figure is converted to the present economic value on the basis of the unit values which were estimated in the previous feasibility study. This amount is as large as only one-fifth of the damageable value (NCz$605,000: explained in Subsection 4.4.2) of an average industrial establishment. Accordingly, the damage to paddy production in the flood protection area is so small as compared with building damages, that it is hereinafter neglected in this study.

Table V.4.3 enumerates the aforesaid properties by elevation above sea level. About two-thirds of the total buildings are located between 2.0 m and 4.0 m. In particular, more than 40% of the total is in the level of 3.0 m to 4.0 m. The Table also shows the distribution of buildings by zone. As seen in the Table, 17,800 units of residence or 60% of the total number of residences are located in the central zone which is within 3 km from the center of Itajai city. In the same manner, 148 establishments of industry or about 70% of the total and 1,213 establishments or about 90% are located in the central zone, as well. Thus, most of damageable properties are concentrated in this central zone.

4.4 Estimation of Unit Value of Damageable Properties

4.4.1 Housing Unit

There are lots of old residences in the center area of Itajai, since Itajai city has a long history of more than 100 years. On the other hand, many new houses have still been constructed in the surrounding areas in Itajai and Navegantes. There are various types of houses in the flood protection area, which are not of a size. However, the statistical information in terms of size of housing units is not available. So, through the interview survey to agencies concerned, the following results regarding the average size were collected:

Agency	Site Area (m^2)	Flood Area (m^2)
Caixa Economica Federal	-	70
Tax Office in Itajai	350	120
Tax Office in Navegantes	300	80

The Caixa Economica Federal (Federal Economic Bank) is a public creditor for housing loans in the country. The bank has charge of giving a credit to low-income people based on the public loan policy. Accordingly, an average housing unit built by a debtor tends to be a smaller size, because of the budget in proportion to his income level. The average size of 70 m^2 seems to be somewhat smaller than the average of the whole houses. Tax offices in the two municipalities are collecting a fixed properties tax through residents in the municipalities. Although they do not have any statistical data, they have an experience of evaluation to fixed properties. So, their information might be capable of comprehending the situation by intuition. According to their information, an average size distributes between 80 and 120 m^2, as shown in the above table. Taking these conditions into accounts, the average size of floor area is assumed to be 80 m^2 conservatively.

An unit value of new residence made by brick and concrete as of the end of September 1989 distributes as follows, although it is difficult to identify the unit cost because of serious inflation:

Informant	Range of Construction Cost of New House (NCz\$/m^2)	Value of Middle Class (Mean Value) (NCz\$/m^2)
Caixa Economica Federal	20 VRF - 3 2 VRF	26 VRF
	(Equivalent to 738 - 1,181)	(960)
PINI Editora (in July)	485 - 680	610
DNOS (for Indemnity)	630 - 1,200	960

The Caixa Economica Federal has a standard of unit cost regarding construction of a new house for apprising an application of a loan debtor. Its unit cost ranges from 20 VRF to 32 VRF, being 26 VRF as a mean value. VRF is an index for rectifying inflation, which is announced by the Banco Central do Brasil (Central Bank of Brazil) once a month. At the end of September 1989, it was valued at NCz\$36.91. Therefore, the unit cost is equivalent to between NCz\$738 and NCz\$1,181, and its mean value is about NCz\$960. PINI publisher presents unit costs in its monthly magazine as a range of NCz\$485 and NCz\$680 and a medium class of NCz\$610 at current prices in July 1989. The 14th regional office of DNOS has a standard of unit cost for indemnity, as seen in the above table. Its value is NCz\$960 for a housing unit in a medium class. Referring to these values, an average value of a housing unit is assumed at NCz$960/$m^2$ conservatively. Therefore, as an average floor area is about 80 m^2, it costs NCz$76,800 in total to built an average new house in the flood protection area.

Although a statistical research regarding household effects is not available, a research of living conditions in Blumenau city was conducted by Fundacao Universidade da Regional de Blumenau (FURB) in 1988, which includes a research result with regard to inventory survey of household effects in a house located in Blumenau city. In the report, a researcher put some points for an individual article of furniture and electric appliances in order to classify inhabitant's living conditions by means of marks of the point. A list of furniture and electric appliances is shown in Table V.4.4, with a corresponding point. According to the results of the research, an average point in a house was 36. Since a point is estimated to be about NCz$670 referring to relation between points on furniture and market prices on corresponding furniture, an average family has household effects valued at NCz$24,120 in the case that it newly installed them in a house.

Taking the above results into consideration, it will cost NCz$100,920 to build an average new furnished house in the flood protection area. This value of NCz$100,920 is estimated in financial terms. In economic evaluation, the value has to be estimated in economic terms. Applying the standard conversion factor, the economic cost of a new furnished house amounts to NCz$90,800 as shown in Table V.4.4.

Yet, existing residences in the flood protection area are not always new houses. Most of them are considerably depreciated because they are built for rather a long time ago and in addition they are depreciable assets. Since no statistical data regarding year when they were built are available, it is difficult to assess the present value of the houses and their household effects. Then, in this study, a present average value of an existing house is assumed to be a half of costs for a newly built house. The economic present value is calculated at NCz$45,400 in total and comprises as follows: NCz$34,550 for a residence and NCz$10,850 for household effects.

4.4.2 Industrial establishment

Damageable properties of industrial establishment consist of (1) liquid assets such as cash and deposit, (2) site and building such as factory and office, (3) equipment such as manufacturing machine, (4) installation such as power transformer and water treatment, (5) furniture and utensil, (6) vehicle, (7) intangible assets such as stock and bonds, (8) inventory stock such as raw material, semi-manufactured products and manufactured products and (9) expected net profit through inventory stock. The properties of (2) to (6) are tangible fixed assets. Among these items, items of (1), (7) and site in (2) are not damaged by inundation, so other items are enumerated as damageable properties.

Items between (2) and (8) were estimated in the report of the economic census in 1980 (Ref. V019), which are shown in Table V.2.19 as average values in the whole state of Santa Catarina. The fixed tangible assets were estimated at Cr$6,982,000 as shown in Table V.4.5. So, damageable fixed assets were estimated at Cr$6,496 excluding site's value. The inventory stocks were estimated at Cr$3,275,000. Expected net profit through the inventory stock was estimated at Cr$261,000 as calculated in the Table. So, damageable value of inventory stock was Cr$3,536,000. Then, the total average damageable value of an industrial establishment was Cr$10,032,000 at 1980 current prices.

The damageable value of industrial establishment in 1989 is converted from that in 1980 by the price index, because of data availability. The price index in September 1989 is about 6.7 million in the case that price in 1980 was set as 100, as shown in Table V.2.28. As a result, the depreciable properties are calculated at NCz$672,200 and distributed as follows: NCz$435,200 for depreciable assets and NCz$236,900 for inventory stock.

The economic value of damageable properties is converted by SCF, as done in the previous Section. It is valued at NCz$605,000 in total in economic terms as of September 1989. It is distributed into NCz$392,000 for depreciable assets and NCz$213,000 for inventory stock as shown in the Table.

4.4.3 Service establishment

In the same manner as the industrial establishment, damageable properties of commercial and service establishment consist of (1) liquid assets such as cash and deposit, (2) site and building such as store and office, (3) equipment such as machines and utensils for showroom and appliances for catering, (4) furniture such as showcases (5) vehicle, (6) intangible assets such as stock and bonds, (7) inventory stock such as raw material and merchandise and (8) expected net profit through inventory stock. The properties of (2) to (5) are fixed tangible assets. Among these items, items of (1), (6) and site in (2) are not damaged by inundation, so other items are counted as damageable properties.

Items between (2) and (7) were estimated in the report of the economic census in 1980 (Ref. V020 and V021), which are shown in Table V.2.24 as average values in the whole state. The fixed tangible assets were estimated at Cr$776,000 as shown in Table V.4.6. Damageable fixed assets were estimated at Cr$693,000 excluding site's value. The inventory stocks were estimated at Cr$703,000. Expected net profit through the inventory stock was estimated at Cr$72,000 as calculated in the table. Damageable value of inventory stock was Cr$775,000. Thus, the total average damageable value of a commercial or service establishment was Cr$1,469,000 at 1980 current prices.

The damageable value of commercial and service establishment in 1989 is converted from that in 1980 by the price index, as done in the same way in the previous Section. As a result, the depreciable properties are calculated at NCz$98,400 and distributed as follows: NCz$46,500 for depreciable assets and NCz$51,900 for inventory stock.

The economic value of damageable properties is converted by SCF, as done in the previous Section. It is valued at NCz$89,000 in total in economic terms as of September 1989. It is distributed into NCz$42,000 for depreciable assets and NCz$47,000 as shown in the Table.

4.5 Flood Damage Rate

The damage rates for estimation of flood damages are assumed as follows:

(1) The standard flood damage rate of buildings and other properties is not available in Brazil. Then, the rate developed by the Ministry of Construction in Japan is taken as the approximate damage rate conceivable in Brazil. Table V.4.7 shows the standard flood damage rate by type of building and by inundation level.

(2) Damage rate of infrastructure to direct damages is assumed to be 30% which is also referred to in the Master Plan study in 1986.

(3) Damage rate of indirect damage to direct damage is assumed to be 10% in a conservative way as discussed in Section 4.1.

4.6 Probable Flood Damage

Flood damages by different scale and pattern of flood are simulated based on the result of area-depth analysis and economic analysis on damageable properties and damage rate. The result is shown in Table V.4.8 and summarized as follows;

Return Period (Year)	Probable Flood Damage (NCz$ million)			
	1978	1980	1983	1984
2	34.6	31.8	30.7	39.0
5	55.8	48.6	46.7	61.4
10	77.1	67.7	64.5	84.9
25	116.9	100.2	122.2	129.2
50	187.4	152.2	262.5	216.3
100	263.1	230.8	365.0	280.4

Based on the above probable flood damage, the annual flood damage is estimated as shown in Table V.4.8. The following table summarizes the flood damage to be mitigated by implementation of the provisional (10-year flood), mid-term (25-year flood) and long-term (50-year) flood control plans.

(Unit : NCz$ million)

Flood Pattern	Flood Damage to be Mitigated		
	10-year	25-year	50-year
1978	28.9	34.7	37.7
1980	25.8	30.9	33.4
1983	24.8	30.4	34.3
1984	32.1	38.5	42.0

5. PROJECTION OF REGIONAL FRAMEWORK

5.1 Target of Projection

The direct tangible benefits of the project are generally given as the economic effect of reduction in flood damage to assets in and around the flood protection area under present socio-economic conditions. The flood protection area has still been developed rapidly, and it would be more urbanized than before as discussed in Subsection 2.4.2. This economic enhancement of the urban area would facilitate an increase of various social and industrial assets which support the regional economy in the future and which at the same time become the damageable assets of flood. Therefore, considering this land enhancement in the future, the project benefits are estimated under the future socio-economic conditions as well as under the present conditions in this study. Taking the limited data availability into account, however, the future socio-economic conditions are projected up to the year 2020 in the same year as done in the previous feasibility study. Since the project evaluation is conducted for the economic project life of 50 years after completion of the proposed project, the socio-economic conditions are assumed to be constant for the period over the year 2020 .

5.2 Existing Regional Development Plans

The federal government published the national development plan as "I Plan Nacional de Desenvolvimento (I PND)" (Ref. V055) in 1986, just after the civil government had started. Succeedingly, the government implemented the several economic development plans such as "Cruzado Plan" to control and lead the economic development, but they resulted in failure so far. In the state level, however, the state government has not established a regional development plan in the territory of the state.

Both municipal governments of Itajai and Navegantes have established urban zoning plans which intend to lead to desirable utilization of urban areas in municipal territories. These plans are based on the present land use and show the direction of urban expansion in both municipalities. However, their implementation schedules are not proposed in the plans.

5.3 Socio-Economic Projection

5.3.1 Population

An official population projection is not available except national total population estimated by IBGE (Ref. V017). Therefore, the future population of both the study area and the flood protection area are projected on the basis of the following assumption:

(1) The methodology of projection is the same as the adopted in the master plan study, that is, (a) at first, the state population grows in proportion to national population increase and (b) the municipal population is estimated base on the AiBi methodology;

(2) The definition of urban area will be kept in the same as legislated by municipal laws in 1972. The urban population is principally absorbed in urban areas demarcated by the laws; and

(3) The distribution of land area in the flood protection area accounts for the same percentage (96% in Itajai, and 92% of urban and 70% of rural in Navegantes) in the future as it was in 1980. Accordingly, the urban population within the flood protection area accounts for 98% of the total population. The rural population accounts for 50%.

Table V.5.1 shows population projection in the flood protection area up to the year 2020. According to the Table, the population in the flood protection area grows to 183,500 in 2020, or 1.6 times of the population in 1989 (115,800). The population is divided into two municipalities as follows: 161,300 or 88% in Itajai and 22,200 or 12% in Navegantes. The urban population in 2020 accounts for 97% of the total population. The total population in the flood protection area grew at 2.5% per annum in the 1980's but in the 2010's its growth rate goes down to 1.1% per annum. The rural population in the year 2020 is 4,990, which is almost the same as the present population.

An average family size decreased from 5.2 in 1960 to 4.3 in 1980 continuously as shown in Table V.2.3. Provided that this decrease in family size continued up to date, the size would be about 4.0 through the regression analysis on the basis of the past transition. Since this size is significantly small as compared with that of the industrialized countries, it could be kept to be the same size even in the future. Then, based on this assumption, about 45,900 families will live in the flood protection area, though 29,000 families existed in 1989.

5.3.2 Economic growth

In the two municipalities of Itajai and Navegantes, any regional economic development plans are not available. Economic projection in the two municipalities is not available, as well. Therefore, GRDP projection is done on the basis of the following assumptions:

(1) Projection of GDP in the country for medium term is basically based on the aforesaid national development plan;

(2) Projection of GDP for long term refers to an UN project, that is, "Long term trends in economic development : Report of the Secretary-General, 26 May 1982" (Ref.V052). According to the medium growth scenario of the report, the petroleum importing economies in Latin America will grow at the annual rate of 5.9% up to 1990 and 6.0%

during a decade of the 1990's. Although there is no projection after the year 2000, the growth rate for that period is assumed to reduce to two-thirds (4.0%) of the projection in the previous decade;

(3) Percentage share of the product in the two municipalities to the state product would be steady at 3% because the percent shares in 1970, 1980 and 1987 were 2.7%, 3.1% and 3.1% respectively, as shown in Table V.2.26.;

(4) Agricultural production would keep constant after 1987, although it had increased drastically since 1980 as shown in Table V.2.9. Because, the productivity of agricultural production would be improved as time passes, in spite of increase of rural population year by year.;

(5) Industrial sector would grow at the same pace as the regional economic growth of the two municipalities, which VA occupied 25% of GRDP in 1980, as shown in Table V.2.26.; and

(6) To attain the expected growth in the flood protection area, the rest of the product by the service sector.

Based on these assumptions, GRDP and per capita GRDP in the two municipalities are estimated as shown in Table V.5.2. GRDP will reach NCz$29.6 million in the year 2000 and NCz$64.8 million in 2020 at 1987 constant prices. Hence, GRDP in 1980 is converted into 1987 prices by implicit deflator (857.57 times between 1980 and 1987) and denomination (Cr$1,000,000=NCz$1). Per capita GRDP in the municipalities, which is calculated by GRDP and the aforesaid population projection, will grow from NCz$106.8 in 1980 to NCz$206.2 in 2000 and to NCz$350.7 in 2020. These figures correspond to 1.9 times in 2000 as large as per capita GRDP in 1980 of Cz$106.8 at 1987 constant prices and 3.3 times in 2020. This growth of per capita seems to be somewhat moderate as compared with the growth of the entire state. This is because population grows faster than the economic production. As a result, the difference between the two values of per capita GRDP reduces from 1.11 times in 1980 which is the ratio of the per capita GRDP of the municipalities (NCz$106.8) to the one of the state (NCz$95.8), to 1.07 times (NCz$350.7 to NCz$327.5) in 2020.

5.4 Land Use Plan

5.4.1 Urbanization and zoning

The two municipalities of Itajai and Navegantes have been urbanized quickly, as explained in Subsection 2.4.2. To lead the town area to proper urbanization, the both municipal governments enacted a guideline as a counter-measure against urban sprawl. In the guideline, a zoning plan is established for sound utilization of urban area, which is demarcated