LIST OF FIGURES

1. INTRODUCTION

This ANNEX F presents the hydrological study results concerned with flood disaster prevention plan.

Climatic conditions and tides are discussed first in order to clarify the present situation of objective area. Subsequently, available rainfall and streamflow data are investigated for the objective hydrological study on flood prevention countermeasures. Based on the available data and findings made by the team, rainfall and runoff analysis are carried out to estimate design discharges for alternative flood prevention plans. Finally, flooding analysis is conducted to estimation of flood damage due to probable floods.

The study was made over 6.5 months in total stretching two years of 1989 and 1990.

The study work flow is presented in Fig.F.1.

2. CLIMATIC CONDITIONS AND TIDES

2.1 Climatic Conditions

The study area is located in a subtropical zone bordering on the Atlantic ocean. The area is topographically divided into the three categories of plateau(EL.700 m), mountain(EL.800 m) and valley, and plain area.

The climate of the study area is characterized as subtropical and divided largely into the two seasons of summer(rainy) from October to March and of winter(dry) from April to September. In other words, this area is situated at northern edge of mild and moist climatic zone (cfa) which covers the southern part of Brazil and a part of Argentina from 23 to 40 degrees in south latitude, according to W.P.Koppen classification. Further, coastal zone of this area has been exposed to the warm current throughout the year. Japan also belongs to this climatic zone in this connection.

The average annual rainfall is around 3,400 mm on the mountain slopes of Serra do Cubatão(EL.500 m). About 75 % of the annual rainfall is concentrated in the summer (wet season) from September or October to March. The average rainfall in Santos, which faces directly to the Atlantic ocean is around 2,100 mm. An isohyetal map and the average monthly rainfalls in the study area are presented in Figs.F.2 and F.3 and Tables F.1 and F.2.

The mean temperature in Cubatão city is around 25 degree C in the summer and 20 degree C, in the winter(dry season), and the fluctuation in each season is quite small, as seen in Fig.F.4.

The mean relative humidity observed at the industrial estate of the Ultrafertil in Cubatão city is around 74 % varying from 78 % in the summer to 71 % in the winter. The mean relative humidity is presented in Fig.F.4.

The predominant wind direction observed in Santos city is SE with an average wind velocity of 3.2 m/s and is followed by E with 3.1 m/s. In the study area, a NE wind predominates in the daytime along the mountain slopes of Serra do Cubatão and SW, in the night time, as shown in Fig.F.5.

2.2 Tides

There are the three tidal observatory stations in the canals in the Santos estuary, as presented in Fig.F.6. In this area, one high and low tides appear twice a day.

The DAEE made an analysis of tide levels in the said areas in relation to a reclamation project in 1979(Project de Recuperacao das Areas Alodiais de Cubatão). This showed that the correlation of observed data be quite high between the three stations, as given in Fig.F.7.

The following tidal parameters have been established based on the records obtained from Ilha Barnabe station under the term of m in IGGSP (Instituto Geografico e Geologico de São Paulo), and these tide levels are presented in Fig.F.8.

MHHL(Mean high water of spring tide)	:	0.491 m IGGSP
MHL (Mean high water level)	:	0.386
MSL (Mean sea level)	:	-0.016
MLL (Mean low water level)	:	-0.541
MLLL(Mean low water of spring tide)	:	-0.908

3. AVAILABILITY OF RAINFALL AND STREAMFLOW DATA

3.1 Rainfall

There are the ten rainfall observation stations in and around the study area as shown in Table F.3 and Fig.F.8.

The observation stations were established by the Centro Tecnologico de Hidraulica(CTH) of Departamento de Agua e Energia Eletrica(DAEE). The observed rainfall data is of two kinds, daily and hourly (recording). The availability of rainfall data is presented in Fig.F.8. The daily rainfall data is defined as one-day rainfall recorded from AM 7:00 to AM 7:00.

The daily and hourly rainfall data are available since 1936 and 1952, respectively. The data are kept in the form of floppy diskette for the daily records and on recording paper for the hourly ones. The hydrological year is defined as 1 year from October 1 to September 30.

In addition to the above 10 observation stations, there are the six stations in a telemetering system and two stations by the telephone system as shown in Table F.3 and Fig.F.9. These stations were installed by DAEE as a part of a telemetering system for the Cubatão river basin. The stations came into operation in 1986 except for Baixo Pereque which is not yet in operation. Accordingly, availability of the records is only 3 years.

3.2 Streamflow

There are the three gauging stations for water levels in the rivers Cubatão(Posto Rio Cubatão), Pereque(Posto Baixo Pereque) and Moji(Posto Ultrafertil), respectively. The locations and main dimensions of the above three gauging stations are given in Table F.3 and Fig.F.9. These stations were installed by DAEE as part of the telemetering system for the Cubatão river basin.

Of the three stations, only Ultrafertil station is in operation. However, this station is at present out of use due to damage from the flood in the Dec.1988. Therefore, the availability of the water level records at this station is only 14 months from Sept. 1987 to Dec. 1988. The observed water levels are converted by using the formula for perfect flow over the weir.

4. RAINFALL ANALYSIS

4.1 Methodology

In this section, rainfall analysis is made 1) to grasp the characteristics of rainfall in the Cubatão region,2)to estimate the probable basin mean rainfalls of 1 day and 2 day durations and finally,3) to prepare design hyetographs for estimation of probable design floods.

The main items and work flow in this analysis are presented in Fig.F.1 and described below.

(1) Selection of Rainfall Observation Stations

Rainfall observation stations to be taken up in this analysis are selected from existing ones located in and around the study area. The selection of the stations are made with due regard to the observation period of data, topographical conditions of site,etc.

(2) Analysis of Characteristics of Rainfall

Several existing hyetographs which have caused floods in the basin since 1971 have been picked out from past records. Based on the selected hyetographs, the following rainfall characteristics are clarified.

- Cause of rainfall
- Regional or aerial distribution of rainfall
- Rainfall pattern and duration

(3) Analysis of Correlation Coefficient for Rainfall Amount of 1 Day and 2 Day Durations and Supplement of Missing Data

In order to grasp the relationship of rainfalls observed in the basin and to supplement the no data or missing data, correlation analysis is made. Finally, coefficients and correlation formulae are estimated. By using these formulae, data missing or data not measured are supplemented.

(4) Estimation of Probable Basin Mean Rainfalls of 1 Day and 2 Day Duration

The estimation is made as follows.

- The objective basin is divided into the two basins of Cubatão(A=182.7 km2) and Moji(A=64.3 km2). The probable basin mean rainfalls are estimated for the above basins and for the whole basin.
- The area to be controlled by one rainfall station is divided by combining topographic conditions and the Thiessen method.
- For the selected stations, the annual maximum basin rainfalls are selected for 1 day and 2 day durations. In this selection, the hydrological year is defined as one year from October 1 to September 30.
- Missing data is supplemented from adjacent station by using estimated correlation factor.
- By using the selected annual maximum basin mean rainfall, probable basin mean rainfalls are estimated by Gumbel method for 1 day and 2 day durations.

4.2 Characteristics of Rainfall

In order to grasp the rainfall characteristics in the flood time, eight hyetographs are selected among those which have occurred since 1971. These 4 days of rainfall observed at E3-153R and E3-038R stations are presented in Table F.4. The hourly rainfalls observed at both the typical stations of E3-153R (Cubatão river basin) and E3-038R(Moji river basin) are presented in Fig.F.10. The rainfall characteristics obtained from these eight hyetographs are summarized below.

(1) Cause of Rainfall

Typical weather charts which have brought about heavy rainfall in the Cubatão region are shown in Fig.F.11.

In generally, heavy rainfalls are caused by cold fronts(or polar fronts). If a front is accumulated by Serra do Mar, it brings about heavy rainfall with a long duration.

(2) Regional Distribution of Rainfall

Based on the isohyetal map in the period of January to March in which big floods mostly concentrate, the following can be said (Fig.F.12).

- Rainfall is higher on the mountain slopes of Serra do Cubatão than the plain area.
- Rainfall in the upper reach of the Rio das Pedras is the highest.
- Average monthly rainfalls are estimated at 400 to 460 mm in the mountain slopes and 320 to 340 mm in the plain areas.
- Those at Cubatão urban area is the lowest one at 320mm.

(3) Rainfall Pattern and Duration

The rainfall patterns for the major hyetographs are presented in Table F.4 and Fig.F.10. According to these, it is not possible to recognize that any special pattern exists.

In general, it can be said that rainfall is most concentrated at night although no particular time can be specified because the rainfall is mostly the result of fronts.

According to the major hyetographs, it can be concluded that the average rainfall duration is 50 hours varying from 34 to 63 hours, as seen in Table F.4. Further, it shows that 1 day rainfall occupies 59 % in average varying from 46 to 67 % of the total continuous rainfall amount and 2 day rainfall, 89 % on average varying from 78 to 100 % as seen in Table F.5. Approximately 90 % of the total rainfall is concentrated in 2 days.

4.3 Probable Rainfall

For the estimation of design hydrographs and for the other studies, the following three probable rainfalls are analyzed in this section.

- Probable basin mean rainfalls of 1 day and 2 day duration
- Probable point rainfalls of 1 day duration at E3-153R(Cubatão river basin) and E3-038R(Moji river basin)
- Probable rainfall intensity at Rio das Pedras station near E3-153R

(1) Probable Basin Mean Rainfalls of 1 Day and 2 Day Duration

Firstly, correlation coefficients among the 10 stations are estimated (see Data Book). Subsequently, the basin is largely divided into the two of the Cubatão basin and Moji basin.

Considering the topographic and meteorologic conditions and estimated correlation coefficients with high reliability, the 4 stations of E3-153R, E3-038R, E3-109 and E3-037 are selected. The data period since 1945 is taken up for estimation of annual maximum 1 day and 2 day rainfalls. No data at E3-153R station is supplemented as follows.

No Data Period	Objective Station
1945 - 1950	E3-109
1951 - 1952	E3-143

The areas covered by the above respective 4 stations are as follows.

Cubatão River Basin

- Mountain slope, valley area and fluvial plain : E3-153R
- Plateau : E3-109

Moji River Basin

- Mountain slope in the lower Moji and fluvial plain : E3-038R
- Mountain slope in the upper Moji : E3-037
- Plateau : E3-109

In the Moji river basin, the boundary between E3-038R and E3-037 is divided by the Thiessen method. Each basin area is summarized as follows.

Basin Area for Respective Objective Rainfall Stations

River	Drainage Area (km2)	Basin Area for Rainfall Station (km2)			
		E3-153R	E3-038R	E3-109	E3-037
Cubatão river	182.7	86.0	-	96.7	-
Moji river	64.3	-	42.5	8.2	13.6

From the above, the annual maximum basin mean rainfalls of 1 day and 2 day duration are summarized in Table F.6. Based on the estimated values in Table F.6, probable basin mean rainfalls of 1 day and 2 day durations are estimated by Gumbel method as shown in Fig.F.13, and are summarized below.

Probable Basin Mean Rainfall

Return Period (yr)	Probable Basin Mean Rainfall (mm)					
	Whole Basin		Cubatão River Basin		Moji River Basin	
	1 day	2 day	1 day	2 day	1 day	2 day
2	140.4	193.6	150.6	205.7	134.2	182.3
5	190.3	265.7	205.4	281.2	174.9	249.9
10	223.4	313.4	241.6	331.2	201.8	294.6
25	265.2	373.7	287.4	394.4	235.8	351.1
50	296.2	418.5	321.4	441.3	261.0	393.0
100	327.0	462.9	355.1	487.8	286.1	434.7

Estimated values by other formulae are presented in Data Book.

(2) Probable Point Rainfalls of 1 Day and 2 Day Duration

Probable point rainfalls are estimated at the two selected observatory stations of E3-153R station in the Cubatão river basin and E3-038R in the Moji river basin. The annual maximum 1 day and 2 day rainfalls are shown in Table F.7. By using Gumbel method, probable point rainfalls of 1 day and 2 day at both the stations are estimated as shown below.

Probable Point Rainfalls of 1 Day and 2 Day
Durations at E3-153R and E3-038R Stations

Return Period (year)	Probable Point Rainfall			
	E3-153R(mm)		E3-038R(mm)	
	1 day	2 day	1 day	2 day
2	171.7	233.1	140.1	191.5
5	229.3	311.4	187.6	262.7
10	267.4	363.3	219.0	309.9
25	315.6	428.9	258.7	369.4
50	351.3	477.5	288.1	413.6
100	386.8	525.7	317.3	457.5

(3) Probable Rainfall Intensity at Rio das Pedras Station near E3-153R

Data on rainfall with short duration observed at Rio das Pedras station has been collected and analyzed in Programa Serra do Mar (Relatorio No.23.394, Volume 5) by IPT. These are shown in Data Book.

In this part, probable rainfalls with short durations up to 24 hours are estimated as follows.

Probable Rainfalls at Rio das Pedras Station

Unit: mm

Return Period (year)	Duration								
	60	120	180	240	360	540	720	1440	1080
2	51.5	71.7	88.1	103.5	123.3	145.7	165.1	191.3	223.1
5	63.2	89.9	110.1	131.1	157.2	186.5	209.1	240.5	279.2
10	70.9	102.0	124.6	149.3	179.7	213.5	238.2	273.1	316.3
25	80.7	117.3	143.0	172.4	208.1	247.6	275.0	314.2	363.2
50	87.9	128.7	156.6	189.5	229.2	272.9	302.3	344.7	398.0
100	95.1	139.9	170.1	206.5	250.1	298.0	329.4	375.0	432.6

Source: IPT (Relatorio No.23,394 Vol.5)
Note : Gumbel Method is used for the analysis

By using the estimated probable rainfall, probable rainfall intensities and intensity formulae are estimated. The results are presented in Fig.F.14.

(4) Relationship Between Basin Mean Rainfall and Point Rainfall

The relationship between basin mean rainfall and point rainfall is checked at E3-153R station in Cubatão river basin and E3-038R station in Moji river basin. The objective data is obtained from the 8 past floods in the Cubatão basin and 5 main floods in the Moji basin.

Correlation of the basin mean rainfall with the 1 day and 2 day at the E3-153R station and the E3-038R station is presented in Fig.F.15.

5. RUNOFF ANALYSIS

5.1 Methodology

(1) General

A runoff simulation model was established to estimate runoff hydrographs from hyetographs, basin and channel conditions. The appropriate runoff calculation method must be selected according to the purpose of the calculations and the conditions of hydrological data required.

The following methods are commonly used for the calculation of flood runoff.

1. Rational formula method
2. Unit hydrograph method
3. Storage function method
4. Tank model method
5. Equivalent roughness method
6. Runoff function method

Among the above, the storage function method was selected for the present study for the following reasons:

1) Rational, unit hydrograph, runoff function methods are not suitable for the present study since the rational method gives only the peak runoff and other two methods cannot simulate the non-linearity of runoff.

2) Storage function, tank model and equivalent roughness methods will give the runoff hydrograph in consideration of non-linearity of runoff. Above all, the storage function method is the most suitable for the Cubatão river basin, since the rainfall and runoff records are limited and the method is simple and standardized, to some extent, based on the experience of rivers in Japan.

Method of storage function will be outlined in the following subsection.

(2) Runoff from Subbasin

A runoff equation from a subbasin is estimated as follows:

$S1 = Kq1^P$ (equation of storage)....................(1.1)

$r-q1 = dS1/dt$ (equation of continuity).............(1.2)

Where, S1 : storage in a subbasin (mm)
r : effective rainfall (mm/hr)
q1 : runoff from a subbasin (mm/hr)
k,p : storage coefficients

Factors such as primary runoff percentage f1 and saturation rainfall, Rsa are used for estimates of effective rainfall. The following assumptions are used in the calculation.

1) The drainage area of a subbasin may be divided into infiltration and primary runoff areas.

2) In the infiltration area, the rainfall is infiltrated up to a saturation point, after that all rainfall becomes direct runoff. The rainfall from the beginning to saturation point is called the saturation rainfall (Rsa).

3) In the primary runoff area, all rainfall changes to direct runoff, and a ratio of the primary runoff area to a drainage area is called the primary runoff percentage (f1).

The runoff from the primary runoff area, q1 is calculated by the following equation which is derived from Eqs. 1.1 and 1.2.

$q1(t) = 2[r(t)-k/dt\{q1^P(t)-q1^P(t-dt)\}]-q1(t-dt)$.......(1.3)

Where t is time and dt is time interval in calculation. In the calculation, the trial and error procedure is used. The runoff from the infiltration area, qsa1, is calculated by the following equation.

$$qsa1 = 0, \quad (total\ r < Rsa) \quad \ldots (1.4)$$
$$qsa1 = q1, \quad (total\ r > Rsa) \quad \ldots (1.5)$$

Where total r is a cumulative rainfall from the beginning.

The total discharge from a subbasin is calculated by use of the following equation.

$$Q' = f1*A*q1/3.6+(1-f1)*A*qsa1/3.6+Qb \quad \ldots (1.6)$$
$$Q(t) = Q'(t-T1) \quad \ldots (1.7)$$

Where, Q : runoff from a subbasin (m3/s)
Q': hypothetical runoff (m3/s)
q1 : runoff from a primary area (mm/hr)
qsa1 : runoff from an infiltration area (mm/hr)
f1 : primary runoff percentage
A : drainage area of subbasin (Km2)
Qb : base flow (m3/s)
T1 : lag-time (hr)

(3) Channel Flow

The storage function of channel flow is estimated as follows:

Equation for the channel flow:

$$S1 = K*Q1P - T1*Q1P \quad (equation\ of\ storage) \quad \ldots (1.8)$$
$$I-Q1 = ds1/dt \quad (equation\ of\ continuity) \quad \ldots (1.9)$$
$$Q(t) = Q1(t-T1) \quad (equation\ of\ retarded\ runoff) \quad \ldots (1.10)$$

Where, S1 : storage in channel (m3/s)
Q1 : discharge at the middle point in the channel (m3/s)
I : inflow at the channel entrance (m3/s)
K,p : storage coefficients
T1 : lag-time
Q : outflow at the channel exit (m3/s)

The procedure of calculation is the same as that of runoff from a subbasin.

(4) Base Flow

Base flow is the runoff which is not directly affected by the rainfall under consideration. The base flow is taken into account uniformly during the period of runoff.

5.2 Effect of Vegetation

It is generally recognized that the vegetation and forest in a watershed area affects the flood and low water runoff favorably and unfavorably. However, there is no generalized formula to quantify the effect of vegetation on runoff since it depends on various factors such as the kind and density of vegetation/ forest, soil and geological conditions of ground, as well as rainfall amount and pattern. In order to evaluate the effect, it is practical to observe the rainfall and runoff and to analyze the records in relation to the vegetation conditions.

In the study area, CETESB has studied the changes in vegetation of the watershed areas, especially in the Moji river basin based on the aerial photos taken during the period from 1962 to 1985. Rainfall records during the period are also available. However, no runoff records applicable to the study are available. Quantitative evaluation on the runoff effect of the vegetation in the study area is difficult.

In general, the vegetation of a watershed area affects the runoff as follows:

1) To increase rainfall: Leaves of trees trap some mist forming rain drops on them.

2) To shelter rainfalls: Trees shelter the rainfall by their leaves. Some of the rainfall evaporates from the leaves and the rest falls down along the trunk which retards the rain water in reaching at ground.

3) To retard runoff: Leaves and other organic materials fall on the ground and porous soil due to roots of vegetation function as natural retarding space of rain water.

4) To reduce moisture in the ground: Vegetation reduces the moisture in the ground consuming it for its growth.

5) To interfere with evaporation of water from the ground surface: Vegetation reduces the sunshine reaching the ground and keeps the air relatively humid, which can reduce the evaporation of water from the ground surface.

Among the above, items 2) through 4) make flood peaks smaller by retarding runoff, which items 1) and 5) affect adversely. In short, the effect of vegetation in a watershed area is to retard the runoff.

The effect of vegetation in a watershed area is therefore to retard rainfall runoff by holding it in its natural retarding space. The capacity of this space is limited by the type of vegetation and geological conditions.

According to observation on the mountain slopes, the thickness of soil covering the subsurface rock is thin in the study area. The retarding capacity of the surface soil seems to be small. The capacity would be filled by rainfalls at the beginning of the rainy season.

Considering the difficulty in quantification of the retarding effect due to watershed vegetation and its smaller retarding capacity, the effect of vegetation is not taken into the runoff analysis. However, the watershed area should be kept in good vegetation to maintain the existing retarding functions for sediment and flood runoff prevention.

5.3 Flood Runoff Simulation Model

5.3.1 Runoff system model

The drainage areas of the Cubatão and Moji rivers are divided into subbasins for runoff analysis as shown in Fig.F.16. The runoff system is explained by the runoff simulation model which is developed to estimate flood discharge as shown in Fig.F.17. The system consists of subbasins and channels.

5.3.2 Floods subject to calibration

For simulation of the runoff model, the following 4 floods subject to calibration are selected from the past floods in view of available data of rainfall and discharge.

Floods Subject to Calibration

Rivers	Flood	Point to be Calibrated	Peak Discharge (m3/s)
Cubatão	Feb.24-27 '71	20	1,250
		19-20	1.070
		15	890
Moji	Feb. 7 '88	30(Ultrafertil)	66
	Feb.20 '88	30(Ultrafertil)	92
Pereque	Dec.14 '89	24(Intake Weir)	140

Note: Point to be calibrated is shown in Fig.F.17.

The peak discharges of the Feb.24-27, 1971 flood in Cubatão and the Dec.14, 1989 flood in Pereque are obtained from the flood marks through discharge rating curves which were prepared by nonuniform flow method. These flood marks are given in Figs.F.18 and F.19, while the peak discharges in Moji river are converted from the stage hydrographs observed at Ultrafertil weir through discharge rating curve as shown in Fig.F.19.

5.3.3 Calibration of storage functions of basin

(1) Initial Values for Calibration

Initial Storage Function of Basin

The initial values of storage functions of basin are estimated from the empirical formula developed in the rivers of Japan. The estimated values are shown in Table F.8.

Storage Functions of Channel

The storage functions of channels are estimated in terms of storage volume - discharge relationship as shown in Data Book based on the water level calculation by nonuniform flow.

In this calculation, the flood plain is limited to from 100 to 500 m in width. The Manning's roughness coefficient is assumed to be 0.03 for the channel and 0.07 for the flood plain. Water levels at the lowest section of the river mouth is estimated based on the sea water level of 0.49 m IGGSP. The calculated water levels are shown in Figs.F.18 and F.19.

Primary Runoff Percentage (f1) and Saturation Rainfall (Rsa)

Primary runoff percentage (f1) and saturation rainfall (Rsa) are assumed from the relationship between the total rainfall and total height of direct runoff obtained from the the 2 past floods in Moji river, as shown in Fig.F.19. From the above, f1 and Rsa are assumed to be 0.8 and 100 mm, respectively.

Base Flow

In the Moji river, base flow is assumed at 6 m3/s for the Feb.7, 1988 flood and 8 m3/s for the Feb.19, 1988 flood, respectively based on the observed discharge hydrographs.

While, base flow in Cubatão and Pereque is assumed by using a specific discharge of 0.14 m3/s/km2 which was obtained from the average monthly discharges observed at the Ultrafertil weir of the Moji river during the rainy season, Mar. 1988 to Oct. 1989. In addition, an outlet discharge of 100 m3/s from Henry Borden is added.

(2) Calibration

Case 1: Calibration of Initial Values

The calibration is made for the initial values. The results are given in Figs.F.20 and F.21. According to the figure, the estimated result for the Feb.24'71 flood almost agrees with the observed one, but the others do not.

Case 2: Calibration for Varied K Values in Moji River

The calibration is made for varied k values in the 3 cases for the Moji river. The results are shown in Fig.F.21. In this result, the value of 1.1 k agrees with the observed one with a lag time of 1 hour in the basin for the Feb.7'88 flood. In case of the Feb.20'88 flood, the value of 0.6 k almost agrees with a lag time of 1 hour in the basin.

Case 3: Calibration for Varied k Value in Pereque River

The calibration is made for varied k values from which 1.5 was chosen for the Pereque river. The result agrees with the observed one as shown in Fig.F.21.

(3) Determination of Storage Function of Basin (k value)

Storage functions which agreed with observed values are outlined below.

Calibrated Functions/Coefficient

Flood	Storage Function of Basin (k)	Primary Runoff Percentage (f1)	Saturated Rainfall (Rsa,mm)	Lag Time in Basin (Tl,hr)
Cubatão				
Feb.24'71	Initial value (k)	0.8	100	-
Moji				
Feb. 7'88	1.1 x k	0.8	100	1.0
Feb.20'88	0.6 x k	0.8	100	1.0
Pereque				
Dec.14'89	1.5 x k	0.8	100	-

The discrepancy among the calibrated k values ranges from 0.6 to 1.5 times of the initial value, as seen in the above table.

Since, the catchment area of the objective basin is small and there is no significant difference in the geological conditions between the subbasins, it is reasonable to apply the functions obtained to the whole basin.

Thus, the initial values estimated for the respective sub-basins are applied to runoff estimation for the whole basin since the initial values in Cubatão river agree well with the observed ones for the biggest flood in the past.

The final values thus obtained are summarized in Table F.9. The storage discharge curves are presented in the Data Book. The primary run off percentage(f1) and saturated rainfall(Rsa) are determined at 0.8 and 100 mm, respectively.

6. DISCHARGE ANALYSIS

6.1 Methodology

Probable design hydrographs are estimated through the simulated runoff model by the storage function method. The estimation is made for 6 cases of return period of 1/2, 1/5, 1/10, 1/25, 1/50 and 1/100 under the two channel conditions of the present and improved. The procedure was as follows.

1) Determination of rainfall duration for design hyetograph

2) Selection of objective flood for probable design hydrographs

3) Determination of design hyetographs

4) Estimation of probable design hydrographs under present channel conditions

5) Estimation of probable design hydrographs under improved channel conditions

6.2 Determination of Rainfall Duration

The average rainfall duration of 8 major floods was 50 hrs ranging from 34 to 63 hrs as seen in Table F.4. Approximately 90 % of the total rainfall was thus concentrated in 2 days. Accordingly, the rainfall duration of 2 days is taken.

6.3 Selection of Objective Flood

In order to select an objective flood for the estimation of the probable design flood hydrographs, the characteristics of the 8 major past floods are clarified as shown in Table F.10.

Of the above 8 floods, the Feb.24'71 flood is selected as the objective flood in Cubatão river and the Jan.22'85 flood, in Moji river, respectively with due consideration of availability of the rainfall records, and the scales of peak discharge and flood damage brought into the basin.

6.4 Determination of Probable Design Hyetographs

Design hyetographs for the respective scales of return period were prepared by enlarging the existing hyetograph up to the probable 2 day rainfall amount.

If the existing hyetograph is simply enlarged, 1 hour rainfall of the 1/100 flood of the Jan.22'85 in the Moji river becomes far bigger and abnormal. Accordingly, 1 hour rainfall is limited to the amount of the probable 1 hour rainfall at 1/1000 yrs which was estimated from the Rio das Pedras station.

6.5 Estimation of Probable Flood

Under the present and the improved channel conditions, the probable floods are estimated for the respective design hyetographs. The estimated peak discharges are summarized in Table F.11. The S-Q curves of both the channel conditions and the estimated peak discharges are presented in Data Book.

7. FLOODING ANALYSIS

A flooding analysis is made by constructing a hydraulic model to estimate inundation depths. The model was constructed simply because the available data on flooding is limited.

7.1 Methodology

(1) Hydraulic Model

The objective flood prone area was simplified as an hydraulic model. The area was divided into the two categories of river and land area. The objective rivers are the Cubatão, Pereque, Moji, Piaçaguera and Indio.

(2) Objective Flood in Calculation

Probable floods under the present channel conditions which were estimated in the Discharge Analysis of this ANNEX, were applied. The 6 probable floods of 2, 5, 10, 25, 50 and 100 yrs were used in the calculations.

(3) Assumption of Overland Flow

The flood runoff exceeding the channel capacity is assumed to overflow onto the land area from a specific point of the low bank elevation. The flood water runs over the land area and finally returns to the rivers or debouches into the sea directly.

(4) Estimation of Inundation Depth on Land Area

The water depths of the overland flow were calculated by using an unsteady flow method. From this purpose, the land area is divided by mesh with 500 x 500 m wide. The applied unsteady flow formula is as follows.

$$1/g.ev/et + a.v/g.ev/ex + eh/ex - ib + (n^2/v/v)/h^{4/3} = 0$$

$$dv/dt = (int)\ q.ds$$

Where: e : Mollecule of differential equation

(int): integral

v : Velocity (m/s)

n : Water depth (m)

ib : River bed slop

n : Manning's roughness coefficient

g : Acceleration of gravity (m/sec2)

a : Energy coefficient

x : Distance (m)

t : Time (sec)

V : Volume of pond (m3)

q : Unit discharge (m3/s/m)

S : Boundary of pond (mesh)

7.2 Basic Condition of Calculation

The flooding analysis in this part is made on the following assumptions.

1) If river water exceeds the channel capacity, it overflows onto the land. The overflow points are assumed to be the following ones based on the existing channel and bank elevation conditions (see Fig. F.22).

Cubatão river	-	Upstream of Petrobras weir: A point (channel capacity = 1250 m3/s)
	-	Around road bridge of 9th of April street: B point (channel capacity = 900 m3/s)
Pereque river	-	Around railway bridge : C point (channel capacity = 150 m3/s)
Moji river	-	Downstream of railway bridge near Ultrafertil: D point (channel capacity = 150 m3/s)
Piaçaguera river	-	Upstream basin of railway bridge in Copebras: E point (channel capacity = 20 m3/s)
Indio river	-	Railway bridge in front of Ultrafertil : F point (channel capacity = 15 m3/s)

2) Time interval of the unsteady flow calculation is adopted every 2 seconds.

3) Discharge rating curves obtained at the estuaries of the Cubatão and Moji rivers as shown in Fig.I.7 in ANNEX-I are applied to the initial water levels.

4) Land areas divided by mesh with 500 m times 500 m wide are presented in Fig.F.22.

5) River waters to be questioned are presented in Data Book.

7.3 Estimation Results

Probable inundation depths were estimated in accordance with the above methodology and basic conditions. The estimated maximum inundation depths are presented in Table F.12 and Fig.F.23.

From the above results, it may be said that (1) in the Cubatão system, the overflow onto the land areas occurs with more than 5 yr. probability, while those in Moji river, with flood which probably occurs almost every year.

The estimated inundation depths on the land areas vary in places. The maximum depths of the respective probable floods are summarized below.

Estimated Maximum Inundation Depth

River	Maximum Inundation Depth					
	1/2	1/5	1/10	1/25	1/50	1/100
Cubatão	--	1.4	1.8	1.9	2.4	2.5
Moji	0.9	1.5	1.4	1.7	1.9	2.2

Duration of the inundation is from several hours to 1 day in both the river basins.

8. EVALUATION OF RAINFALL PROBABILITY AND RUNOFF ESTIMATION MODEL FOR SABO AREA

(1) Rainfall Probability for Past Sediment Disaster

Hourly rainfalls for 4 sediment disasters in the recent years are summarized in Table F.13. The hourly rainfalls were observed at E3-038R station which is located in the damaged area. The data of hourly rainfall have been adjusted in volume by the basin mean rainfall.

Probability of the hourly rainfall was estimated on the basis of the following assumptions.

- Ratio of probable hourly rainfall distribution at Rio das Pedras station is almost equal for every return period patterns, therefore the average one is adopted.

- Rainfall depths between R24 observed at Rio das Pedras station and R2 day at E3-153R are almost equal (see Fig.F.14). Accordingly, it is considered that R24 is equal to R2 day.

- Probability of hourly rainfalls was estimated by combining the average distribution curve of rainfall at Rio das Pedras station and the probable 2 day rainfall (R24) calculated at E3-038R station.

The probability of hourly rainfall was estimated through the above procedure. The result is presented in Table F.15. According to the table, probability of hourly rainfall in the Jan.1985 flood is about 1/26 for 1 hour duration and 1/17 - 1/18 for 3 to 4 hours.

(2) Runoff estimation Model

In this section, basic conditions for runoff estimation of small basins in the sabo area described.

Runoff estimation of small basins in the sabo area is done by using the storage function method. The storage functions are estimated as shown in Table F.14 as in Chapter 5 of this ANNEX. The respective small basins are further divided into subbasins.

Firstly, the runoff is estimated for each small basins. Then, the runoff of each subbasin is estimated by basin area ratio between subbasin and small basin.

The observed hyetograph of the Jan,1985 flood is adopted as design hyetograph for the above calculation.

LIST OF REFERENCE AND DATA COLLECTED

No.	Title	Issued on	Issued by
F01	Carta Sinofica	1988	EME
F02	Programa Serra do Mar (Relatòrio No.23,394 Volume 5)	Mar. 1986	IPT
F03	Projeto de Recuperação das Àreas Alodiais de Cubatão	1979	DAEE
F04	Rede Hidrogràfica (DAEE) (1 : 500,000)	Oct. 1989	DAEE
F05	Rede Hidrogràfica em Operação	Dec. 1985	DAEE
F06	Rede Telemètrica de Monitoramento Hidrològico da Serra do Mar em Cubatão	1989	DAEE
F07	Rede Telemètrica de Monitoramento Hidrològico da Serra do Mar em Cubatão (Mapa)	1989	DAEE
F08	Diàrias - Dados Pluviomètricos	1989	DAEE
F09	Horàrios - Dados Pluviomètricos	1989	DAEE
F10	Horàrios - Dados Pluviomètricos (no dia 14 Dez.'89)	1989	DAEE
F11	Redes Telemètricas de Hidrologia do Alto Tietê e Baixada Santista	1988	DAEE
F12	Hidrograma de Cheia / Rio Moji (Feb.7~20'88)	1988	DAEE
F13	Fluviometria - Rio Moji Posto Ultrafèrtil Mèdia Mensal (Sep.'87 - Dec.'88)	1988	DAEE

TABLES

TABLE F.1 MONTHLY RAINFALL AT E3-153R STATION

(Unit: mm)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1952-53	337.1	337.5	232.8	249.7	415.6	238.7	311.0	275.1	52.9	181.2	---	---	---
1953-54	---	---	437.5	142.1	145.9	213.6	302.5	427.4	100.7	92.8	108.5	298.7	---
1954-55	545.2	135.1	179.8	558.8	109.7	381.6	409.4	---	202.0	95.6	150.8	---	---
1955-56	277.7	204.5	277.9	203.5	371.5	981.8	95.7	76.0	283.0	---	143.8	149.2	---
1956-57	492.9	---	---	338.8	449.3	323.8	288.9	80.6	84.8	130.1	179.8	315.3	---
1957-58	293.0	168.4	294.6	179.4	88.9	475.1	349.3	221.6	68.5	20.9	72.7	230.5	2462.9
1958-59	531.4	420.6	701.0	362.3	825.9	494.7	91.6	270.1	29.8	83.6	179.6	217.3	4207.9
1959-60	289.7	354.0	533.0	377.8	690.0	141.7	263.9	141.5	406.4	161.3	207.0	188.2	3754.5
1960-61	392.0	229.5	510.1	862.4	570.5	583.4	212.2	196.0	94.7	152.6	18.1	195.5	4017.0
1961-62	214.1	303.5	451.8	431.4	290.7	287.9	227.1	204.5	70.6	107.5	83.0	306.1	2978.2
1962-63	570.2	361.8	704.2	436.1	387.4	267.1	61.3	188.3	125.5	53.6	96.3	36.2	3288.0
1963-64	485.9	385.5	155.9	164.5	259.3	262.0	289.1	129.3	173.2	62.2	190.2	159.7	2716.8
1964-65	179.7	279.9	455.1	449.9	345.9	328.2	644.0	468.2	188.5	380.6	46.7	305.6	4072.3
1965-66	253.5	264.6	562.5	701.4	324.9	499.5	269.4	183.2	83.4	98.8	205.4	287.0	3733.6
1966-67	591.3	544.4	635.5	425.8	570.4	542.3	228.5	81.8	92.8	130.0	59.0	294.9	4196.7
1967-68	367.0	549.4	333.0	226.3	250.0	459.3	325.5	166.9	85.2	106.3	103.2	116.7	3088.8
1968-69	333.3	191.0	468.8	258.1	366.9	328.9	303.7	119.6	116.4	141.7	206.3	144.5	2979.2
1969-70	410.6	593.3	423.7	412.9	512.6	565.8	410.3	79.1	115.1	79.1	147.3	186.2	3936.0
1970-71	281.9	229.9	249.9	329.9	540.3	380.8	183.0	134.2	187.4	115.6	217.8	145.7	2996.4
1971-72	226.2	234.7	286.9	289.9	234.7	201.6	305.0	194.1	16.0	79.3	203.2	483.7	2755.3
1972-73	576.0	298.4	218.0	694.7	505.0	347.6	338.1	267.2	199.7	280.8	151.6	353.1	4230.2
1973-74	378.6	329.0	475.5	354.4	109.8	281.7	161.2	75.1	166.2	84.5	97.5	197.0	2710.4
1974-75	223.5	181.9	522.4	772.7	617.9	270.0	129.5	137.0	97.7	181.1	78.4	154.4	3366.5
1975-76	482.4	750.9	697.0	969.8	484.5	442.0	409.3	272.1	74.7	214.8	232.2	414.1	5443.8
1976-77	324.8	218.0	351.0	508.0	69.3	182.0	660.6	299.8	109.4	45.0	192.6	383.4	3344.8
1977-78	472.3	344.5	414.0	502.8	441.2	439.9	148.4	135.5	63.7	91.2	27.6	58.5	3139.6
1978-79	52.3	477.5	241.0	288.0	---	---	158.5	133.3	70.6	77.7	104.9	359.8	---
1979-80	242.3	703.0	467.2	413.4	575.9	250.9	170.2	41.6	168.4	121.5	---	227.7	---
1980-81	504.6	280.5	283.5	473.6	245.7	455.4	335.4	165.2	124.2	130.7	124.1	174.9	3297.8
1981-82	273.2	---	293.1	442.8	332.2	---	---	141.9	191.3	117.2	100.8	153.1	---
1982-93	223.1	405.4	526.1	---	687.9	---	262.5	---	245.1	71.1	70.9	312.1	---
1983-84	307.3	131.7	283.7	355.8	110.3	327.1	266.6	53.9	16.4	160.2	246.1	140.2	2399.3
1984-85	187.6	445.6	355.3	631.6	427.0	397.5	499.0	176.3	66.1	17.9	48.5	---	---
1985-86	64.1	---	---	---	---	---	298.6	---	68.0	---	---	---	---
1986-87	---	---	---	---	---	---	---	---	---	---	---	---	---
1987-88	---	---	---	---	---	---	---	---	---	---	---	---	---
1988-89	---	---	---	---	---	---	---	---	---	---	---	---	---
AVE.	345.0	345.1	407.0	431.5	386.2	378.4	285.1	178.6	124.7	120.8	132.1	233.7	3439.8
MIN.	52.3	131.7	155.9	142.1	69.3	141.7	61.3	41.6	16.0	17.9	18.1	36.2	2399.3
MAX.	591.3	750.9	704.2	969.8	825.9	981.8	644.0	468.2	406.4	380.6	246.1	483.7	5443.8

Source; CENTRO TECNOLOGICO E HIDRAULICO/ DEPARTAMENTO DE AGUAS E ENERGIA ELETRICA

TABLE F.2 MONTHLY RAINFALL AT E3-038R STATION

(Unit: mm)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1935-36	---	---	---	584.2	185.4	497.8	48.2	88.9	96.5	28.0	121.9	243.8	---
1936-37	266.7	248.9	218.4	536.0	180.3	188.0	464.9	391.2	50.8	88.9	208.3	33.0	2875.4
1937-38	264.4	363.3	198.2	274.3	771.2	419.1	363.2	207.6	251.4	106.7	331.2	101.7	3651.3
1938-39	228.4	254.1	226.2	271.7	220.9	243.9	327.2	86.4	53.2	119.4	30.4	91.4	2153.2
1939-40	40.6	231.1	218.5	338.0	410.2	370.9	76.3	101.6	0.0	30.5	81.3	---	---
1940-41	279.6	215.9	376.1	233.7	414.1	467.5	279.4	182.9	94.0	124.6	83.8	213.4	2965.0
1941-42	177.9	355.7	568.2	216.0	708.6	431.8	261.7	58.4	124.5	116.9	104.2	81.3	2995.2
1942-43	117.8	276.9	360.8	373.4	241.3	94.0	35.5	58.4	170.2	15.3	198.0	163.8	2105.4
1943-44	330.3	132.1	175.4	177.9	701.2	337.8	322.7	73.7	104.1	93.9	20.3	40.7	2510.1
1944-45	111.7	279.4	391.2	287.0	21.5	335.3	215.9	167.6	383.6	119.4	35.5	183.1	2531.2
1945-46	73.7	160.6	269.3	337.9	---	411.7	81.3	73.7	139.7	35.5	43.2	114.3	---
1946-47	241.3	132.1	165.1	706.1	383.6	289.7	309.9	215.9	518.2	228.6	292.2	243.9	3726.6
1947-48	167.8	213.5	569.2	343.0	386.3	508.0	215.9	289.8	43.2	226.2	175.3	129.6	3267.8
1948-49	111.8	165.0	154.9	383.4	238.7	160.1	137.2	91.2	264.2	134.7	180.4	116.2	2137.8
1949-50	182.8	146.7	381.0	467.6	279.3	411.6	655.3	99.1	63.6	28.0	83.8	151.0	2949.8
1950-51	255.0	251.5	425.1	350.5	195.4	200.8	218.5	96.4	0.0	78.8	106.8	56.0	2234.8
1951-52	206.2	284.6	332.7	436.9	533.3	487.6	43.2	317.5	386.0	53.3	76.3	439.4	3598.0
1952-53	210.8	482.6	309.9	403.9	518.2	213.4	454.7	325.1	25.4	274.3	330.2	142.1	3590.6
1953-54	256.3	248.9	309.6	132.6	152.4	167.5	337.8	276.8	129.7	116.7	101.4	205.5	2435.2
1954-55	215.7	81.2	210.7	413.6	254.0	266.7	202.3	246.5	96.5	127.0	149.8	81.2	2345.2
1955-56	175.1	236.2	358.1	106.6	398.8	919.4	208.1	223.3	246.1	98.9	157.4	96.5	3229.5
1956-57	251.2	228.4	233.7	309.9	419.1	261.5	185.2	55.7	66.0	127.0	187.7	350.6	2676.0
1957-58	391.0	256.4	162.6	218.2	175.4	406.3	302.2	254.0	106.6	48.3	81.3	160.0	2562.3
1958-59	396.2	152.2	398.8	243.8	561.3	332.6	81.3	176.0	7.6	43.1	134.4	121.9	2649.2
1959-60	111.7	312.3	309.7	238.4	373.2	167.7	243.7	180.3	96.6	81.3	124.3	99.0	2338.2
1960-61	266.8	146.9	390.6	523.0	561.3	299.8	208.1	118.9	144.6	167.6	15.3	137.8	2980.6
1961-62	198.0	182.8	201.2	388.7	330.2	299.7	137.1	117.0	61.0	76.2	76.2	208.1	2276.2
1962-63	516.1	279.2	485.7	385.9	345.5	195.5	55.9	132.1	48.3	33.1	66.0	50.7	2594.0
1963-64	154.7	178.0	109.1	111.7	175.2	261.6	205.7	83.7	162.4	63.5	114.4	243.9	1863.9
1964-65	144.8	358.1	535.5	360.7	203.2	32.6	589.4	228.7	1.4	251.5	22.8	195.6	3212.3
1965-66	---	---	444.4	627.5	319.9	586.6	329.8	208.3	73.6	61.1	216.2	187.8	---
1966-67	368.3	259.0	487.5	457.4	632.6	536.0	208.2	48.3	149.8	101.6	55.9	190.4	3495.0
1967-68	208.4	667.9	220.9	190.6	88.8	431.8	238.8	165.2	66.0	81.2	86.3	83.8	2529.7
1968-69	159.9	104.2	215.8	144.8	261.5	228.6	192.9	55.9	132.1	58.4	76.1	66.1	1696.3
1969-70	365.6	414.1	307.4	393.7	317.5	261.6	172.7	78.7	101.5	35.6	139.8	221.1	2809.3
1970-71	226.0	129.5	119.5	271.3	230.6	425.5	186.0	186.5	218.9	57.0	137.9	74.7	2263.4
1971-72	325.1	261.6	279.2	325.8	243.8	226.5	232.9	109.6	13.1	73.1	191.6	168.6	2450.9
1972-73	337.1	174.0	129.8	279.0	348.8	372.2	202.4	252.4	97.9	169.4	66.4	204.2	2633.6
1973-74	184.4	259.2	320.8	409.0	90.3	324.3	155.6	43.7	146.2	69.9	34.1	155.0	2192.5
1974-75	165.3	183.9	311.6	464.0	600.2	209.6	117.6	143.7	71.0	121.3	74.1	98.0	2560.3
1975-76	171.2	375.3	643.2	704.6	297.4	282.1	412.6	249.6	73.6	178.4	234.3	205.6	3827.9
1976-77	142.8	230.8	269.1	419.5	90.2	103.5	417.9	157.1	127.8	16.0	124.2	230.6	2329.5
1977-78	227.8	184.6	246.6	344.1	295.9	462.3	170.6	144.0	54.5	56.2	23.8	82.8	2293.2
1978-79	50.5	342.4	252.4	272.4	104.9	431.5	183.5	118.1	80.8	121.2	79.7	261.9	2299.3
1979-80	182.1	446.0	293.6	311.5	434.4	214.3	162.3	22.0	140.7	99.3	112.5	97.0	2515.7
1980-81	322.8	234.6	371.4	342.3	129.2	---	540.7	197.8	53.1	144.1	114.7	111.1	---
1981-82	221.2	130.6	265.2	291.6	292.8	---	179.9	---	164.2	108.0	109.4	131.8	---
1982-83	190.8	105.3	329.2	195.2	164.5	426.8	342.9	223.7	186.8	69.5	59.9	243.8	2548.4
1983-84	---	120.0	268.2	303.3	15.7	117.0	125.4	45.8	5.7	103.1	153.7	124.9	---
1984-85	85.0	167.1	242.2	438.6	323.3	134.7	231.2	65.8	84.7	13.5	54.6	138.1	1978.8
1985-86	55.5	147.0	225.2	282.5	750.6	729.2	282.2	132.7	77.0	330.1	94.0	192.4	3298.5
1986-87	126.9	281.6	685.1	360.6	147.5	135.2	232.3	308.5	171.2	44.5	40.8	134.1	2668.3
1987-88	229.8	85.2	166.2	---	---	246.3	---	---	---	---	---	---	---
1988-89	235.7	125.2	395.1	225.4	527.7	436.3	307.6	199.0	---	---	---	---	---
AVE.	214.2	235.2	302.1	343.5	327.8	332.5	243.7	191.7	119.9	101.0	115.6	154.9	2688.1
MIN.	40.6	81.2	109.1	106.6	15.7	94.0	35.5	22.0	0.0	13.5	15.3	33.0	1696.3
MAX.	516.1	667.9	685.1	706.1	771.2	919.4	655.3	391.2	518.2	330.1	330.2	439.4	3827.9

Source: CENTRO TECNOLOGICO E HIDRAULICO/ DEPARTAMENTO DE AGUAS E ENERGIA ELETRICA

TABLE F.3 LOCATIONS OF RAINFALL STATION

RECORDING RAIN GAUGE

Number	Station	Recording Rain Gauge	Location		Altitude (m, IGGSP)
			Latitude	Longitudinal	
1	E3-236R	Apr. 1972	23'54'S	46'30'W	100
2	E3-143				
3	E3-153R	Sept. 1952	23'53'S	46'29'W	500
4	E3-144				
5	E3-101				
6	E3-038R	Nov. 1971	23'51'S	46'23'W	5
7	E3-241				
8	E3-109				
9	E3-149R	Sept. 1971	23'46'S	46'21'W	760
10	E3-037				

ORDINARY RAIN GAUGE

Number	Station	Ordinary Rain Gauge	Location		Altitude (m, IGGSP)
			Latitude	Longitudinal	
1	E3-236R	Mar. 1972	23'54'S	46'30'W	100
2	E3-143	Jan. 1950	23'53'S	46'29'W	400
3	E3-153R	Sept. 1952	23'53'S	46'29'W	500
4	E3-144	Nov. 1949	23'53'S	46'27'W	90
5	E3-101	July 1944	23'53'S	46'25'W	6
6	E3-038R	Jan. 1936	23'51'S	46'23'W	5
7	E3-241	June 1972-Aug. 1986	23'56'S	46'35'W	760
8	E3-109	June 1944	23'51'S	46'31'W	760
9	E3-149R	July 1965	23'46'S	46'21'W	760
10	E3-037	Jan.1936	23'47'S	46'18'W	800

Source; CTH/DAEE

Note:

1	E3-236R	Piloes
2	E3-143	Via Anchieta Cota 400
3	E3-153R	Curva da Onca
4	E3-144	Morro do Piche
5	E3-101	Cubatao
6	E3-038R	Piacagueraq
7	E3-241	Imigrantes
8	E3-109	Sao Bernardo do Campo
9	E3-149R	Campo Grande
10	E3-037	Paranapiacaba

TELEMETERING SYSTEM

Rainfall Station	Location	
	Latitude	Longitudinal
Paranapiacaba	23'47'S	46'18'W
Ultrafertil	23'50'S	46'23'W
Cota 400	23'53'S	46'29'W
Alto Pereque	23'49'S	46'27'W
Baixo Pereque *	23'51'S	46'25'W
COMDEC Central (Cubatao City)	23'53'S	46'25'W

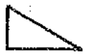
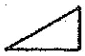
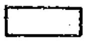
Water Level Station	Location	
	Latitude	Longitudinal
Ultrafertil (Mogi River)	23'50'S	46'23'W
Baixo Pereque * (Pereque River)	23'51'S	46'25'W
Rio Cubatao * (Cubatao River)	23'53'S	46'26'W

Sea Level Station	Location	
	Latitude	Longitudinal
Cosipa *	23'52'S	46'22'W

Source; CTH/DAEE

Note; * These stations are not operational yet.

TABLE F.4 RAINFALLS OF MAJOR FLOODS IN THE PAST

Flood	Station	Rainfall (mm/day)				Rainfall Pattern	Duration
Feb.24,'71	Date	24	25	26	27		
	E3-153R	58.3	292.3	17.8	21.1		34
	E3-038R	—	—	4.2	5.0		
Jan.15,'73	Date	14	15	16	17		
	E3-153R	4.2	172.3	157.7	16.5		—
	E3-038R	0.9	—	—	4.0		
Jan.20,'76	Date	20	21	22	23		
	E3-153R	104.6	304.1	50.5	1.2		58
	E3-038R	39.9	203.9	38.9	0.0		
Jan.27,'76	Date	27	28	29	30		
	E3-153R	76.7	351.7	18.5	33.1		44
	E3-038R	28.1	251.1	47.1	15.2		
Nov. 8,'79	Date	8	9	10	11		
	E3-153R	41.3	144.7	164.5	10.5		63
	E3-038R	27.0	102.3	106.5	4.7		
Jan.31,'83	Date	31	Feb.1	2	3		
	E3-153R	—	227.5	41.2	15.1		—
	E3-038R	—	—	—	—		
Jan.22,'85	Date	22	23	24	25		
	E3-153R	159.5	117.6	6.1	9.3		46
	E3-038R	150.0	110.0	9.0	0		
Dec.20,'88	Date	20	21	22	23		
	E3-153R	165.9	172.7	—	0.0		51
	E3-038R	152.3	106.0	0.2	0.0		

Source; CTH/DAEE
Note; Rainfall pattern and duration are based on records at E3-153R station

TABLE F.5 PERCENTAGE OF 1 DAY AND 2 DAY RAINFALL IN TOTAL DEPTH AT E3-153R STATION

Flood	Total Rainfall (mm)	1-Day Rainfall (mm)	%	2-Day Rainfall (mm)	%
Feb.24,'71	433.1	292.3	67	350.6	81
Jan.15,'73	354.3	172.3	49	330.0	93
Jan.20,'76	461.4	304.1	66	408.7	89
Jan.27,'76	552.2	351.7	64	428.4	78
Nov. 8,'79	361.0	164.5	46	309.2	86
Jan.31,'83	306.4	227.5	74	250.1	85
Jan.22,'85	295.4	159.5	54	277.1	94
Dec.20,'88	338.6	172.7	51	338.6	100
		Average	59		89

Source: DAEE/CTH

TABLE F.6 ANNUAL MAXIMUM BASIN MEAN RAINFALL OF 1 DAY AND 2 DAY DURATIONS

1 - DAY

	CUBATAO R.	X (mm)		MOJI R.	X (mm)		WHOLE	X (mm)
1	1976 1.28	324.340	1	1976 1.28	263.280	1	1976 1.28	308.440
2	1961 2.28	306.890	2	1947 6.21	259.700	2	1961 2.28	274.730
3	1970 11.20	255.470	3	1967 12.23	202.510	3	1983 2. 1	236.290
4	1971 2.25	254.400	4	1953 1.24	194.540	4	1971 2.25	230.830
5	1983 2. 1	251.950	5	1983 2. 1	191.780	5	1970 11.20	220.930
6	1980 2.19	210.030	6	1956 3. 1	186.250	6	1947 1.23	204.530
7	1956 3. 1	207.080	7	1961 2.28	183.360	7	1956 3. 1	201.660
8	1947 1.23	205.190	8	1966 3. 7	179.800	8	1980 2.19	194.910
9	1959 12.15	201.280	9	1958 3.23	174.190	9	1973 1.16	184.520
10	1973 1.16	193.430	10	1985 1.22	166.810	10	1959 12.15	173.790
11	1967 12.22	190.870	11	1971 2.25	163.860	11	1952 2.20	172.980
12	1968 3.16	187.260	12	1973 1.16	159.210	12	1985 1.22	170.330
13	1972 9.22	183.630	13	1970 2.23	154.650	13	1966 1.10	168.100
14	1952 2.20	182.420	14	1989 2. 5	153.010	14	1968 3.16	166.780
15	1966 1.10	181.570	15	1980 2.19	151.930	15	1958 3.23	164.440
16	1989 12.21	176.560	16	1986 3. 1	146.930	16	1967 12.22	164.000
17	1985 1.22	171.570	17	1952 2.20	146.160	17	1989 12.21	161.500
18	1958 3.23	161.010	18	1959 2.15	143.900	18	1972 9.22	150.170
19	1945 3. 3	153.700	19	1977 1. 6	143.780	19	1945 3. 3	142.370
20	1960 12. 5	152.420	20	1974 1.15	142.440	20	1953 1.24	142.040
21	1984 3.30	147.720	21	1965 4.19	142.400	21	1954 4.30	140.370
22	1954 4.30	145.830	22	1981 5.20	140.030	22	1984 3.30	140.150
23	1974 12.20	144.760	23	1957 11.26	138.640	23	1974 12.20	135.860
24	1955 1.15	140.120	24	1954 12. 4	138.380	24	1986 3. 1	134.910
25	1975 1.19	138.200	25	1978 1.15	130.860	25	1960 12. 5	134.740
26	1978 1.15	135.320	26	1962 1.26	129.580	26	1978 1.15	134.160
27	1963 12.27	134.830	27	1972 11.19	129.450	27	1951 12 30	129.670
28	1986 2. 2	133.740	28	1951 12. 4	127.690	28	1963 12.27	129.210
29	1953 10.12	132.950	29	1968 3.27	123.830	29	1962 1.26	127.090
30	1951 12 30	131.980	30	1950 4. 2	119.760	30	1975 1.19	126.630
31	1946 3.14	127.150	31	1984 3.30	118.640	31	1981 5.20	123.770
32	1962 1.26	126.210	32	1946 1.19	117.170	32	1955 1.15	119.770
33	1977 4.18	125.390	33	1975 2.25	115.100	33	1946 3.14	119.510
34	1981 10.12	123.540	34	1963 12.27	113.250	34	1977 1. 6	119.330
35	1965 4.18	122.840	35	1945 3. 3	110.180	35	1965 4.18	113.010
36	1950 5. 5	121.340	36	1948 3.11	109.090	36	1987 2. 7	110.030
37	1987 2. 7	120.090	37	1949 2. 8	107.560	37	1950 9.22	105.310
38	1964 10.23	119.790	38	1979 1. 4	104.200	38	1969 12. 1	104.340
39	1983 3. 8	110.870	39	1955 5. 5	102.710	39	1964 10.23	96.980
40	1969 12. 1	108.980	40	1982 1. 4	100.500	40	1948 3.11	96.610
41	1957 2.21	100.410	41	1960 11.25	93.690	41	1988 3. 8	96.170
42	1949 11.22	97.040	42	1969 12. 1	91.120	42	1957 2.21	87.120
43	1982 2.26	94.540	43	1987 2. 7	81.440	43	1982 2.26	86.770
44	1948 3.11	92.220	44	1988 2.20	69.830	44	1949 11.22	74.760
45	1979 11.15	42.840	45	1964 3. 7	68.190	45	1979 1. 4	54.670

Source; CTH/DAEE

2 - DAY

	CUBATAO R.	X (mm)		MOJI R.	X (mm)		WHOLE	X (mm)
1	1961 2.27	396.300	1	1947 6.20	420.020	1	1961 2.27	370.870
2	1976 1.27	390.870	2	1966 3. 6	313.850	2	1976 1.27	366.390
3	1973 1.15	346.990	3	1958 3.23	300.830	3	1947 6.20	340.740
4	1967 12.21	338.250	4	1961 2.27	298.590	4	1973 1.15	310.540
5	1966 1.10	313.460	5	1976 1.27	296.840	5	1966 3. 6	300.760
6	1947 6.20	312.840	6	1967 12.22	290.150	6	1967 12.21	295.790
7	1970 11.19	305.260	7	1985 1.22	286.530	7	1989 12.20	290.190
8	1989 12.20	301.230	8	1959 2.15	277.550	8	1959 2.15	289.470
9	1959 2.15	293.660	9	1989 12.20	258.820	9	1985 1.22	276.780
10	1971 2.24	291.060	10	1980 11. 9	241.610	10	1958 3.23	276.510
11	1980 11. 9	286.180	11	1965 4.18	227.480	11	1980 11. 9	274.570
12	1972 9.21	280.860	12	1983 1.31	218.370	12	1971 2.24	267.180
13	1983 1.31	275.850	13	1956 3. 1	214.480	13	1970 11.19	265.780
14	1985 1.22	273.340	14	1950 4. 1	213.100	14	1983 1.31	260.880
15	1958 3.23	267.960	15	1962 1.26	208.550	15	1954 12. 4	236.050
16	1954 12. 4	249.520	16	1973 1.15	206.960	16	1972 9.21	232.420
17	1956 3. 1	225.890	17	1952 2.20	205.200	17	1956 3. 1	222.920
18	1950 9.21	208.070	18	1986 2. 2	203.630	18	1965 4.18	211.040
19	1955 1.14	207.480	19	1971 2.24	199.330	19	1952 2.20	194.540
20	1965 4.18	205.260	20	1954 12. 4	197.770	20	1945 3. 3	188.770
21	1968 3.16	204.440	21	1953 1.24	194.540	21	1955 1.14	187.070
22	1945 3. 3	202.900	22	1968 3.27	189.270	22	1968 3.16	186.250
23	1969 2.19	200.150	23	1977 1. 5	175.870	23	1950 9.21	185.010
24	1977 4.18	190.830	24	1970 3.13	172.650	24	1969 2.19	182.160
25	1952 2.20	190.790	25	1978 1.15	170.170	25	1984 3.29	180.370
26	1960 12. 4	190.580	26	1984 3.29	169.490	26	1977 4.18	175.030
27	1984 3.29	184.200	27	1957 11.25	163.020	27	1978 1.15	171.770
28	1986 11. 3	183.200	28	1972 1.21	162.580	28	1951 12 30	170.280
29	1963 5.15	174.810	29	1951 12 30	159.790	29	1960 12. 4	164.620
30	1951 12 30	173.970	30	1974 1.15	157.480	30	1962 1.26	162.650
31	1978 1.15	172.330	31	1945 3. 3	148.620	31	1948 3.10	157.110
32	1975 1.18	163.260	32	1948 3.24	148.430	32	1963 12.27	156.090
33	1987 12.18	163.110	33	1946 1.19	143.420	33	1975 1.18	154.910
34	1948 3.10	162.090	34	1981 5.20	140.670	34	1987 12.18	154.150
35	1946 3.14	159.750	35	1963 12.27	135.260	35	1986 11. 2	153.660
36	1964 10.23	159.110	36	1975 1.18	131.210	36	1946 3.14	153.020
37	1974 12.20	154.470	37	1969 2.19	131.060	37	1953 1.24	148.210
38	1962 3.13	151.000	38	1955 1.14	129.050	38	1974 12.20	144.050
39	1981 10.12	147.130	39	1987 12.18	128.710	39	1981 10.12	137.580
40	1949 3.10	145.740	40	1949 2. 8	127.030	40	1964 10.23	127.710
41	1953 2. 1	138.260	41	1979 1. 4	111.090	41	1988 3. 8	118.730
42	1988 3. 8	138.240	42	1960 11.25	111.050	42	1957 2.20	115.740
43	1957 2.20	128.760	43	1982 1. 4	108.190	43	1949 3.10	111.850
44	1982 2.25	97.770	44	1964 3. 7	100.320	44	1982 2.25	89.460
45	1979 1. 4	48.860	45	1988 2.20	97.730	45	1979 1. 4	65.060

Source; CTH/DAEE

TABLE F.7 ANNUAL MAXIMUM 1 DAY AND 2 DAY RAINFALLS

1-DAY

(E3-153R STATION)

K		X (mm)
1	1976 1.28	351.700
2	1971 2.25	292.300
3	1961 2.28	277.300
4	1956 3. 1	275.200
5	197011.20	263.200
6	196712.21	230.000
7	1983 2. 1	227.500
8	195912.15	224.200
9	1978 1.15	221.700
10	1980 2.19	220.300
11	1989 2. 4	220.200
12	197412.20	203.300
13	196012. 5	193.700
14	1954 4.30	186.000
15	1975 1.19	184.300
16	1973 2. 6	180.300
17	1986 3. 1	170.400
18	1958 3.23	168.900
19	1966 1.10	165.000
20	1955 1.15	162.400
21	1965 4.19	157.200
22	1985 1.22	151.500
23	1968 3.16	151.000
24	1972 9.22	148.700
25	1977 1.18	146.500
26	1987 3.15	146.200
27	196912. 1	142.700
28	1981 5.20	140.600
29	196312.27	132.500
30	195710.30	130.600
31	1988 2. 7	129.000
32	1984 3.30	124.700
33	195310.12	122.000
34	196212.14	121.900
35	1982 2.26	119.200
36	196410.23	105.500
37	197912.26	94.500

Source; CTH / DAEE

(E3-038R STATION)

K		X (mm)
1	1947 6.21	299.700
2	1976 1.29	251.100
3	1944 2.27	246.400
4	1953 1.24	228.600
5	1942 2.18	223.500
6	1956 3. 1	221.000
7	1941 4.18	210.800
8	1936 1.17	203.200
9	1938 2. 9	198.100
10	196712.23	198.100
11	1989 2. 5	188.300
12	197211.19	188.000
13	1966 3. 7	177.800
14	1958 3.23	175.300
15	1981 4. 2	174.100
16	1965 4.19	170.100
17	1950 4. 3	167.600
18	195412. 4	165.100
19	1986 3. 2	158.400
20	1975 2.26	157.000
21	1970 2.23	152.400
22	1985 1.23	150.000
23	1961 2.28	147.300
24	1977 1. 7	146.200
25	1959 2.16	144.600
26	1974 1.16	144.300
27	195711.26	142.300
28	1940 3.14	137.200
29	1948 3.24	132.100
30	198412.11	130.000
31	1978 1.16	129.900
32	1963 1.11	129.500
33	1952 1.12	127.000
34	1951 4.14	121.900
35	1979 1. 4	119.300
36	198312. 3	116.900
37	1982 1. 4	115.300
38	1955 5. 5	114.300
39	1937 1.24	114.300
40	1946 1.19	114.300
41	1945 6.20	111.800
42	1971 3.24	111.000
43	196011.25	109.200
44	1980 3.31	109.100
45	1949 2. 8	106.600
46	1939 2.22	106.600
47	1973 1.25	104.600
48	1962 3.14	101.600
49	1968 3.27	96.500
50	1969 3.12	88.900
51	194311.17	83.800
52	198712.20	83.500
53	1988 4. 4	71.500
54	1964 3. 7	66.000

2-DAY

(E3-153R STATION)

K		X (mm)
1	1976 1.27	428.400
2	1961 2.27	389.000
3	1959 2.15	370.300
4	196712.21	359.000
5	1971 2.24	350.600
6	197011.19	336.700
7	1973 1.15	330.000
8	1965 4.18	313.600
9	198011. 9	309.200
10	1989 2. 5	303.700
11	1956 3. 1	290.300
12	1958 3.23	281.400
13	1985 1.22	272.000
14	195412. 4	264.600
15	1978 1.15	249.500
16	198611. 2	246.000
17	1966 1.10	240.000
18	198312. 2	239.000
19	1955 1.14	237.600
20	198712.18	235.500
21	1972 9.21	231.800
22	1975 1.18	223.700
23	196012. 4	223.500
24	1977 4.18	222.000
25	197412.20	217.300
26	196912. 1	217.200
27	1988 2. 7	191.100
28	1984 1.21	175.200
29	1982 1. 3	168.700
30	1968 3.16	163.900
31	1963 5.15	160.200
32	1981 5.20	159.400
33	196410.23	152.600
34	195710.30	146.800
35	1962 1.26	142.100
36	195310.12	127.600
37	197911.27	103.400

Source; CTH / DAEE

(E3-038R STATION)

K		X (mm)
1	1947 6.20	500.400
2	1942 2.18	358.100
3	1958 3.23	327.700
4	1950 4. 1	307.300
5	1966 3. 6	304.800
6	1976 1.30	298.200
7	1959 2.15	287.000
8	1961 2.27	269.200
9	1985 1.22	260.000
10	198912.20	258.300
11	1944 2.27	256.600
12	1965 4.18	256.500
13	196712.22	254.000
14	1956 3. 1	248.900
15	1938 2. 9	241.200
16	1953 1.24	238.800
17	1940 1. 7	231.200
18	1986 2. 2	228.900
19	1941 4.17	221.000
20	198011. 9	208.800
21	195412. 4	205.700
22	1937 5. 3	203.200
23	1936 1.17	203.200
24	198412.10	193.200
25	197211.19	193.100
26	1963 2. 6	193.000
27	1971 3.24	191.000
28	1952 1.11	190.500
29	194812.19	177.800
30	194512.25	177.800
31	196811.27	177.700
32	1977 1. 5	176.600
33	1978 3. 6	174.900
34	1981 5.20	174.600
35	195711.25	172.800
36	198712.21	167.200
37	198312. 2	165.700
38	194311.17	165.100
39	195112. 4	162.600
40	1975 2.25	159.700
41	1974 1.15	158.000
42	1970 3.13	157.500
43	1962 1.26	152.400
44	1946 1.19	139.700
45	1979 3.13	133.200
46	1949 2. 8	132.000
47	1955 1.14	129.500
48	1982 2.24	126.000
49	196011.11	124.500
50	1973 3. 9	121.200
51	1988 4. 3	108.600
52	1939 2.22	106.600
53	1969 3.11	101.600
54	1964 3. 7	91.400

TABLE F.8 INITIAL VALUES OF STORAGE FUNCTIONS

BASIN

Cubatao River Basin

Sub-basin No.	Drainage Area A(Km2) 182.7	Height of Sub-basin H max (m)	H min (m)	H (m)	Length of Sub-basin L (Km)	Grade I	$I^{-1/3}$	$L^{1/3}$ (Km1/3)	Storage Coefficient K	Lag-time Tl(hr)
101	40.4	760	700	60	13.5	1/225	6.08	2.38	75.4	0.07
102	42.9	760	40	720	3.5	1/4.9	1.70	1.52	13.5	0.00
103	12.6	740	680	60	6.6	1/110	4.79	1.88	46.9	0.00
104	13.4	760	700	60	6.6	1/110	4.79	1.88	46.9	0.00
105	15.3	740	160	580	4.2	1/7.2	1.93	1.61	16.2	0.00
106	5.8	720	20	700	2.4	1/3.4	1.50	1.34	10.5	0.00
107	6.1	740	10	730	2.6	1/3.6	1.53	1.38	11.0	0.00
108	10.5	740	10	730	3.2	1/4.4	1.64	1.47	12.6	0.00
109	12.9	760	700	60	5.5	1/92	4.51	1.77	41.6	0.00
110	13.7	840	40	800	2.5	1/3.1	1.46	1.36	10.3	0.00
111	9.1	740	5	735	4.5	1/6.1	1.83	1.65	15.7	0.00

Moji River Basin

Sub-basin No.	Drainage Area A(Km2) 64.3	Height of Sub-basin H max (m)	H min (m)	H (m)	Length of Sub-basin L (Km)	Grade I	$I^{-1/3}$	$L^{1/3}$ (Km1/3)	Storage Coefficient K	Lag-time Tl(hr)
201	39.1	800	5	795	9.5	1/12	2.29	2.12	25.3	0.0
202	2.6	600	5	595	2.0	1/3.4	1.50	1.26	9.8	0.0
203	3.3	950	5	945	4.4	1/4.7	1.68	1.64	14.3	0.0
204	0.4	3	2	1	0.5	1/500	7.94	0.79	32.7	0.0
205	4.0	119	2	117	1.8	1/15	2.47	1.22	15.7	0.0
206	7.3	960	5	955	5.3	1/5.5	1.77	1.74	16.0	0.0
207	2.4	419	5	414	2.0	1/4.8	1.69	1.26	11.1	0.0
208	1.7	106	6	100	1.0	1/10	2.15	1.00	11.2	0.0
209	3.5	127	1	126	2.0	1/16	2.52	1.26	16.5	0.0

Note: $K = 43.4 * C * I^{-1/3} * L^{1/3}$ Tl = 0.047L-0.56 (L>11.9)
$C = 0.120$ Tl = 0 (L<11.9)

CHANNEL

Sub-basin	Channel No.	Channel Length L(Km)	Height of Channel Hmax (m)	Hmin (m)	AH (m)	Gradient I	Lag Time Tl(hr)	Coefficient K	P
Cubatao River	A	12.50	340.0	15.0	325.0	1/ 38	0.06	12.8	0.600
	B	4.50	700.0	15.0	685.0	1/ 6.6	0.01	1.9	0.600
	C	2.37	14.6	3.2	11.4	1/ 210	0.03	*	*
	D	3.05	3.2	0.2	3.0	1/1020	0.07	*	*
	E	3.90	0.2	-3.8	4.0	1/ 980	0.09	*	*
	F	5.00	700.0	0.0	700.0	1/ 7.1	0.01	2.2	0.600
	G	1.90	0.2	-1.4	1.6	1/1190	0.05	*	*
	H	1.71	-3.8	-4.8	1.0	1/1710	0.05	*	*
Moji River	I	2.12	-0.4	-1.6	1.2	1/1770	0.07	*	*
	J	1.10	7.0	2.0	5.0	1/ 220	0.01	2.7	0.600
	K	2.39	-1.6	-3.0	1.4	1/1710	0.07	*	*
	L	1.70	1.0	-3.0	4.0	1/ 430	0.03	5.8	0.600
	M	3.42	-3.0	-3.8	0.8	1/4280	0.16	*	*

Note: (1) Lag time Tl is estimated by empirical formula of Tl=7.36*L*I-1/2*10-4.
(2) Storage functions of K in channels of A,B,F,J and L are estimated by empirical formula of K=0.1658*L*I-1/2*10-4 and P is fixed at 0.6.
(3) Storage functions of K in other channels of the above(2) are given as discharge-storage volume relationship.

TABLE F.9 FINAL VALUES OF STORAGE FUNCTIONS AND OTHER CONSTANTS

CONSTANTS OF BASIN

Sub-basin No.	K	P	f1	Lag-time (hr)	Area (km2)	Rsa (mm)	Baseflow (m3/s)
Cubatao River Basin							
101	75.4	0.333	0.8	0.07	40.4	100	5.5
102	13.5	0.333	0.8	0.00	42.9	100	5.8
103	46.9	0.333	0.8	0.00	12.6	100	1.7
104	46.9	0.333	0.8	0.00	13.4	100	1.8
105	16.2	0.333	0.8	0.00	15.3	100	2.1
106	10.5	0.333	0.8	0.00	5.8	100	0.8
107	11.0	0.333	0.8	0.00	6.1	100	0.8
108	12.6	0.333	0.8	0.00	10.5	100	1.4
109	41.6	0.333	0.8	0.00	12.9	100	1.8
110	10.3	0.333	0.8	0.00	13.7	100	1.9
111	15.7	0.333	0.8	0.00	9.1	100	1.3
Moji River Basin							
201	25.3	0.333	0.8	1.00	39.1	100	5.3
202	9.8	0.333	0.8	0.00	2.6	100	0.4
203	14.3	0.333	0.8	0.00	3.3	100	0.5
204	32.7	0.333	0.8	0.00	0.4	100	0.1
205	15.7	0.333	0.8	0.00	4.0	100	0.6
206	16.0	0.333	0.8	0.00	7.3	100	1.0
207	11.1	0.333	0.8	0.00	2.4	100	0.3
208	11.2	0.333	0.8	0.00	1.7	100	0.2
209	16.5	0.333	0.8	0.00	3.5	100	0.5

CONSTANTS OF IMPROVED RIVER CHANNEL

Sub-basin	Channel No.	K	P	Lag-time (hr)
Cubatao River	A	12.8	0.600	0.06
	B	1.9	0.600	0.01
	C	1.3	0.850	0.03
	D	2.2	0.731	0.07
	E	9.6	0.565	0.09
	F	2.2	0.600	0.01
	G	0.7	0.904	0.05
	H	7.4	0.458	0.05
Moji River	I	1.3	0.796	0.07
	J	2.7	0.600	0.01
	K	2.5	0.714	0.07
	L	5.8	0.600	0.03
	M	13.1	0.701	0.16

TABLE F.10 CHARACTERISTICS OF MAJOR FLOODS

Flood	Basin Mean 2day Rainfall (mm) Cubatao R.Basin	Moji R.Basin	Availability of Hourly Rainfall Data E3-153R Station	E3-038R Station	Rainfall Pattern	Evaluation Cubatao River	Moji River
Feb.24 1971	291.1	199.3	P	N		O	X
Jan.15 1973	347.0	207.0	I	N		X	X
Jan.20 1976	309.0	237.6	P	P		*	*
Jan.27 1976	390.9	296.8	P	I		*	*
Nov. 8 1979	286.2	241.6	P	P		X	X
Jan.31 1983	275.9	218.4	I	N		X	X
Jan.22 1985	273.3	286.5	P	P		*	O
Dec.20 1988	301.2	258.8	P	I		*	X

* P;perfect
I;imperfect
N;missing observed

* O;adopted
*;considered
X;abondoned

note; Data of "E3-153R station" is used for analysis of Cubatao River.
Data of "E3-038R station" is used for analysis of Moji River.

TABLE F.11 ESTIMATED PROBABLE DISCHARGES

PRESENT CHANNEL CONDITION

Return Period (Year)		2	5	10	25	50	100
CUBATAO RIVER SYSTEM (Feb.24.1971 Flood Type, 2DAY-Rainfall=301.8mm)							
Probable Rainfall (mm)		206	282	331	394	441	488
Scale factor of total rainfall		0.683	0.934	1.100	1.309	1.465	1.617
Probable Discharges at Major Points (m3/s)							
-River Mouth	(29)	916	1301	1555	1876	2121	2366
-After Pereque	(28)	915	1302	1552	1877	2128	2376
-Pereque River	(27)	212	321	382	460	519	581
-Before Pereque	(20)	724	1033	1231	1489	1690	1890
- "	(19)	748	1056	1258	1530	1743	1956
-Anchieta Bridge	(17)	586	878	1070	1330	1534	1739
-Imigrantes Brg.	(14)	537	828	1022	1289	1498	1708
-After Piloes	(10)	570	868	1062	1320	1521	1725
-Piloes River	(9)	173	282	356	455	532	609
-Before Piroes	(4)	397	586	706	865	1018	1172
MOJI RIVER (Jan.22.1985 Flood Type, 2DAY-Rainfall=286.5mm)							
Probable Rainfall (mm)		182	250	295	351	393	435
Scale factor of total Rainfall		0.639	0.873	1.030	1.229	1.375	1.568
Probable Discharges at Major Points (m3/s)							
-River Mouth	(49)	234	355	439	547	626	688
-After Piacag.	(48)	270	417	519	647	739	816
-Piacaguera R.	(44)	79	128	168	227	274	292
-Before Piacag.	(41)	225	349	438	552	648	703
-After Indio R.	(38)	224	350	452	589	694	750
-Indio River	(34)	28	44	58	79	95	101
-Before Indio	(33)	211	332	431	566	670	723
-Intake Weir	(30)	240	421	570	788	965	1040

IMPROVED CONDITION OF EXISTING CHANNEL

Return Period (Year)		2	5	10	25	50	100
CUBATAO RIVER SYSTEM (Feb.24.1971 Flood Type, 2DAY-Rainfall=301.8mm)							
Probable Rainfall (mm)		206	282	331	394	441	488
Scale factor of total rainfall		0.683	0.934	1.100	1.309	1.465	1.617
Probable Discharges at Major Points (m3/s)							
-River Mouth	(29)	920	1346	1617	1970	2242	2515
-After Pereque	(28)	915	1326	1589	1933	2199	2467
-Pereque River	(27)	209	324	395	488	558	627
-Before Pereque	(20)	724	1058	1270	1549	1767	1988
- "	(19)	751	1069	1278	1556	1774	1993
-Anchieta Bridge	(17)	589	891	1090	1356	1565	1776
-Imigrantes Brg.	(14)	537	827	1022	1279	1482	1687
-After Piloes	(10)	570	868	1062	1320	1521	1725
-Piloes River	(9)	173	282	356	455	532	609
-Before Piroes	(4)	397	586	706	865	1018	1172
MOJI RIVER (Jan.22.1985 Flood Type, 2DAY-Rainfall=286.5mm)							
Probable Rainfall (mm)		182	250	295	351	393	435
Scale factor of total Rainfall		0.639	0.873	1.030	1.229	1.375	1.568
Probable Discharges at Major Points (m3/s)							
-River Mouth	(49)	213	345	438	551	658	706
-After Piacag.	(48)	273	443	578	759	897	949
-Piacaguera R.	(44)	79	128	168	227	274	292
-Before Piacag.	(41)	228	378	503	676	810	864
-After Indio R.	(38)	231	377	487	632	740	778
-Indio River	(34)	28	44	58	79	95	101
-Before Indio	(33)	218	359	466	609	716	755
-Intake Weir	(30)	240	421	570	788	965	1040

TABLE F.12 MAXIMUM INUNDATION DEPTH BY PROBABLE FLOOD

CUBATAO

Unit : m

MESH No.	Return Period					
	2	5	10	25	50	100
1	-	-	-	-	0.8	1.4
2	-	-	-	-	0.3	0.9
3	-	-	-	0.3	0.8	1.1
4	-	-	-	0.3	0.7	0.9
5	-	-	-	-	0.4	0.8
6	-	-	-	-	-	0.2
7	-	-	0.3	1.4	1.9	2.2
8	-	-	0.5	0.9	1.3	1.6
9	-	-	-	-	-	0.4
10	-	-	-	-	-	0.7
11	-	-	-	-	-	-
12	-	-	-	-	-	-
13	-	-	-	0.3	0.6	0.9
14	-	-	0.4	1.1	1.4	1.7
15	-	-	-	0.1	-	0.1
16	-	-	-	-	-	0.3
17	-	-	-	0.5	0.9	1.1
18	-	-	-	-	-	-
19	-	-	-	-	-	-
20	-	-	0.3	0.3	0.3	0.3
21	-	-	0.3	0.3	0.3	0.4
22	-	0.1	0.4	0.9	1.2	1.4
23	-	0.2	0.6	1.2	1.5	1.7
24	-	0.8	1.3	1.9	2.3	2.5
25	-	0.9	1.3	1.9	2.2	2.5
26	-	0.4	0.5	0.8	1.0	1.2
27	-	0.3	0.5	0.6	0.6	0.7
28	-	0.2	0.1	0.1	0.1	-
29	-	0.3	0.7	1.0	1.3	1.5
30	-	0.3	0.4	0.5	0.7	0.9
31	-	0.8	1.1	1.6	1.9	2.1
32	-	0.7	1.0	1.5	1.8	2.1
33	-	0.8	1.2	1.8	2.2	2.4
34	-	0.7	1.1	1.7	2.0	2.3
35	-	-	0.3	0.8	1.0	1.2
36	0.8	1.2	1.4	1.4	1.5	1.5
37	-	-	0.4	0.7	0.9	1.1
38	0.3	0.9	1.3	1.6	1.9	2.1
39	0.5	1.4	1.8	2.1	2.4	2.5
40	0.1	0.9	1.3	1.6	1.9	2.1
41	-	0.3	0.6	1.1	1.4	1.6
42	-	-	-	-	-	-
43	-	-	-	-	-	-
44	0.5	1.1	1.5	1.8	2.0	2.2
45	0.1	1.0	1.4	1.7	1.9	2.1
46	-	1.0	1.3	1.7	1.9	2.1
47	0.1	0.8	1.1	1.4	1.6	1.8
48	-	-	-	-	0.1	0.4

MOJI

Unit : m

MESH No.	Return Period					
	2	5	10	25	50	100
1	-	-	-	-	-	-
2	-	-	-	-	-	-
3	0.4	0.8	0.9	1.0	1.1	1.4
4	0.4	0.7	0.9	1.2	1.4	1.7
5	0.3	1.1	1.4	1.7	1.9	2.2
6	-	-	-	-	-	-
7	-	-	-	-	-	-
8	0.5	0.6	0.7	0.6	0.6	0.6
9	0.5	0.7	0.7	0.9	1.1	1.3
10	0.6	1.0	1.2	1.4	1.5	1.7
11	0.5	0.9	1.1	1.3	1.4	1.6
12	-	-	-	-	0.1	0.3
13	0.1	0.5	0.5	0.6	0.6	0.6
14	-	0.3	0.3	0.1	0.3	0.3
15	-	0.5	0.7	0.8	0.8	0.8
16	-	-	-	0.2	0.4	0.6
17	0.5	0.8	1.0	1.2	1.4	1.6
18	0.3	0.7	0.9	1.1	1.2	1.4
19	-	1.0	1.3	1.5	1.6	1.8
20	-	0.3	0.3	0.4	0.4	0.5
21	0.2	0.4	0.6	0.7	0.8	0.8
22	0.1	0.4	0.4	0.5	0.6	0.7
23	0.3	0.6	0.6	0.7	0.7	0.8
24	0.7	1.5	1.8	1.9	1.9	2.0
25	-	-	-	-	-	-
26	-	-	-	-	-	-
27	0.6	0.9	1.0	1.2	1.3	1.4
28	0.8	1.2	1.2	1.3	1.5	1.6
29	0.9	1.3	1.4	1.5	1.6	1.7
30	-	-	-	-	-	-
31	-	-	-	-	-	-
32	-	-	-	-	-	-

TABLE F.13 OBSERVED HOURLY RAINFALL AND PROBABLE RAINFALL AT E3-038R STATION

Year	Month	Date	Actual N-hour Maximum Rainfall (mm) 1-hour	2-hour	3-hour	4-hour	6-hour	12-hour	24-hour
1976	Jan	27-29	38.8	57.6	72.4	99.3	134.3	182.4	275.5
			(1/1.7)	(1/1.8)	(1/1.9)	(1/2.6)	(1/3.5)	(1/3.8)	(1/6.2)
1980	Feb	18-19	32.7	52.3	80.0	92.3	117.0	211.2	233.7
			(1/1.3)	(1/1.5)	(1/2.3)	(1/2.1)	(1/2.4)	(1/6.6)	(1/3.4)
1985	Jan	22-23	84.3	101.0	137.5	162.7	175.6	224.2	265.0
			(1/ 26)	(1/ 11)	(1/ 18)	(1/ 17)	(1/9.9)	(1/8.4)	(1/5.2)
1988	Dec	20-22	25.3	48.8	62.6	68.8	82.1	107.3	134.7
			(1/1.1)	(1/1.4)	(1/1.5)	(1/1.3)	(1/1.3)	(1/1.3)	(1/1.2)

note; The data above was adjusted by using basin mean rainfall
( ) means return period (year)

ESTIMATED PROBABLE HOURLY RAINFALLS

Return Period	1-hour (0.2240)	2-hour (0.3226)	3-hour (0.3939)	4-hour (0.4723)	6-hour (0.5685)	12-hour (0.7534)	24-hour (1.0000)
100	102.5	147.6	180.2	216.1	260.1	344.7	457.5
50	92.7	133.4	162.9	195.4	235.2	311.6	413.6
25	82.8	119.2	145.5	174.5	210.0	278.3	369.4
10	69.4	100.0	122.1	146.3	176.2	233.5	309.9
5	58.8	84.8	103.5	124.1	149.4	197.9	262.7
2	42.9	61.8	75.4	90.5	108.9	144.3	191.5

note; ( ) means ratio

TABLE F.14 STORAGE COEFFICIENTS OF SUB-BASIN FOR SABO

Sabo Sub-basin Number	Area(km2)	Division Number of Hydrology	Ratio of Hydrology and Sabo
1	2.39	203	2.39/ 2.39
2	3.79	206	3.79/ 5.08
3	1.29	206	1.29/ 5.08
4	8.42	110(+109)	21.32/26.60
5	0.90	110	0.90/13.70
6	1.73	110	1.73/13.70
7	2.64	111	2.64/ 2.64
8	0.41	108	0.41/ 3.02
9	0.73	108	0.73/ 3.02
10	1.26	108	1.26/ 3.02
11	0.62	108	0.62/ 3.02
12	1.11	107	1.11/ 1.11

note; Number of sabo sub-basin is presented in ANNEX H.

Sub-basin Number	K	P	F	Time-Lag (hr)	Area (km2)	Rsa (mm)	Baseflow (m3/s)
107	9.3	0.333	0.8	0.0	1.11	100	0.1
108	9.6	0.333	0.8	0.0	3.02	100	0.3
109	41.6	0.333	0.8	0.0	12.90	100	1.8
110	10.3	0.333	0.8	0.0	13.70	100	1.9
111	9.9	0.333	0.8	0.0	2.64	100	0.3
203	11.4	0.333	0.8	0.0	2.39	100	0.4
206	11.8	0.333	0.8	0.0	5.08	100	0.7

FIGURES

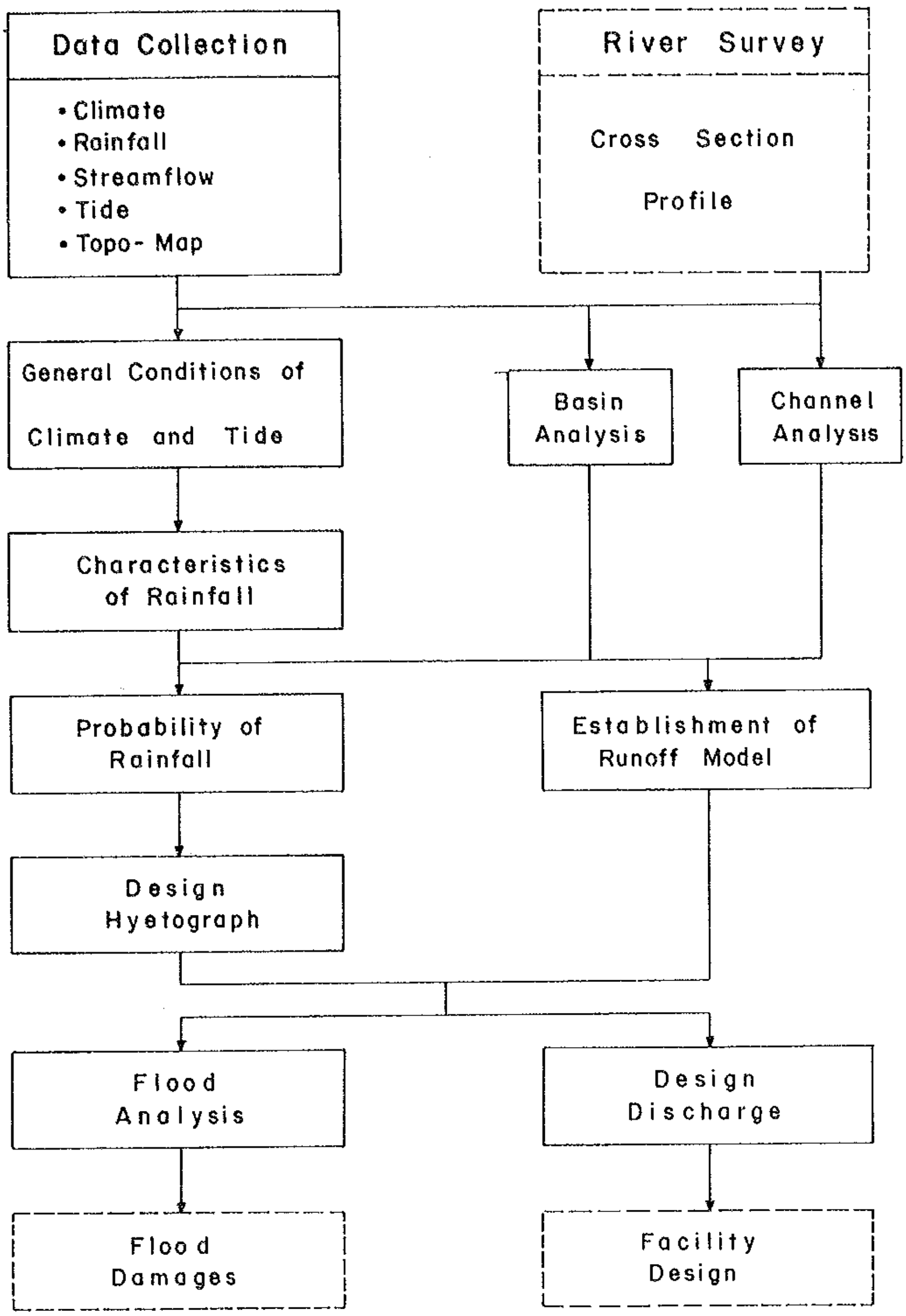


FIG F.1
STUDY FLOW CHART

GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL
THE STUDY ON THE DISASTER PREVENTION AND RESTORATION PROJECT IN SERRA DO MAR, CUBATÃO REGION, STATE OF SÃO PAULO
JAPAN INTERNATIONAL COOPERATION AGENCY

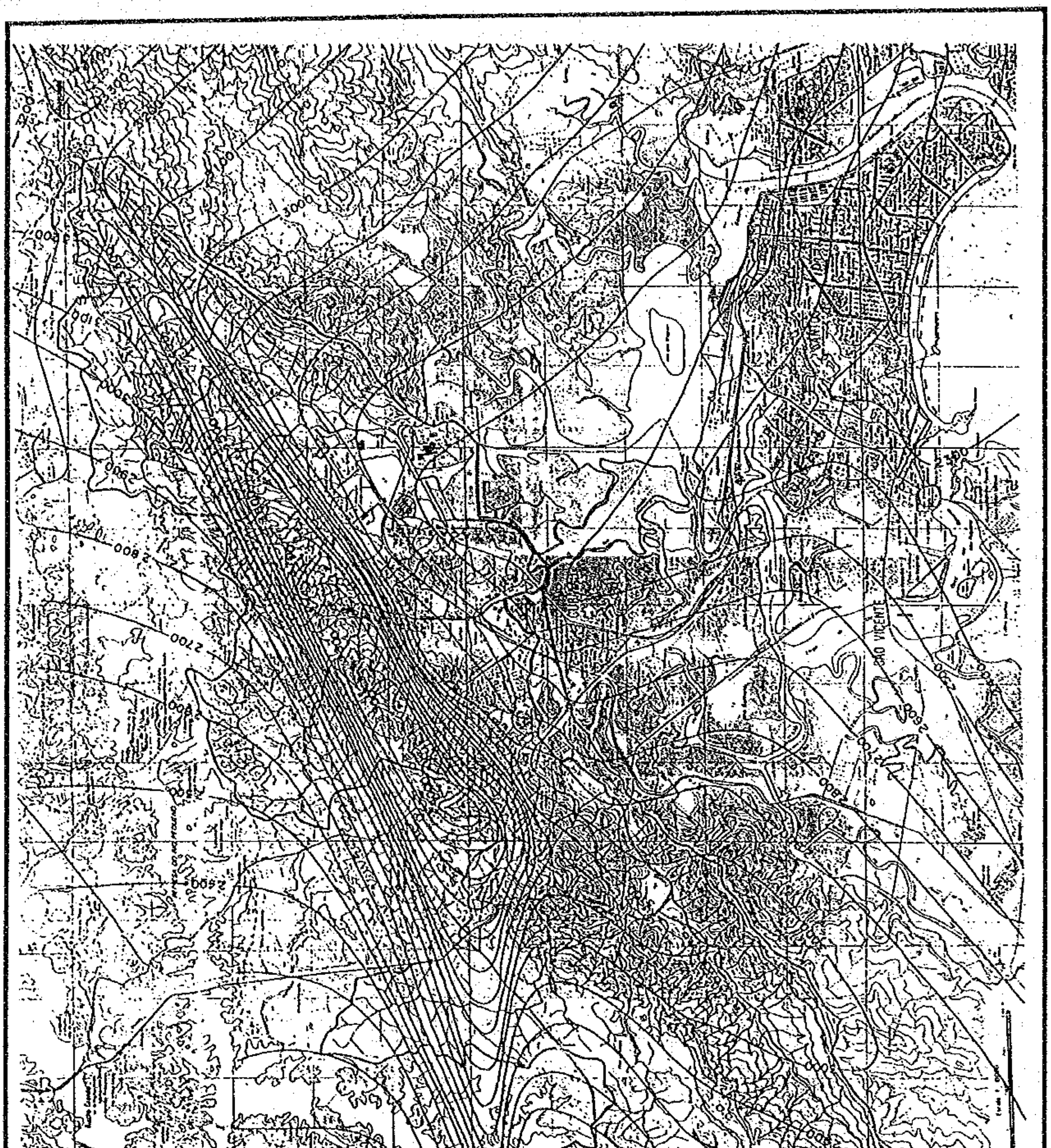


FIG.F.2
ISOHYETAL MAP IN AND AROUND
STUDY AREA

GOVERNMENT OF FEDERATIVE
REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND
RESTORATION PROJECT IN SERRA DO MAR,
CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

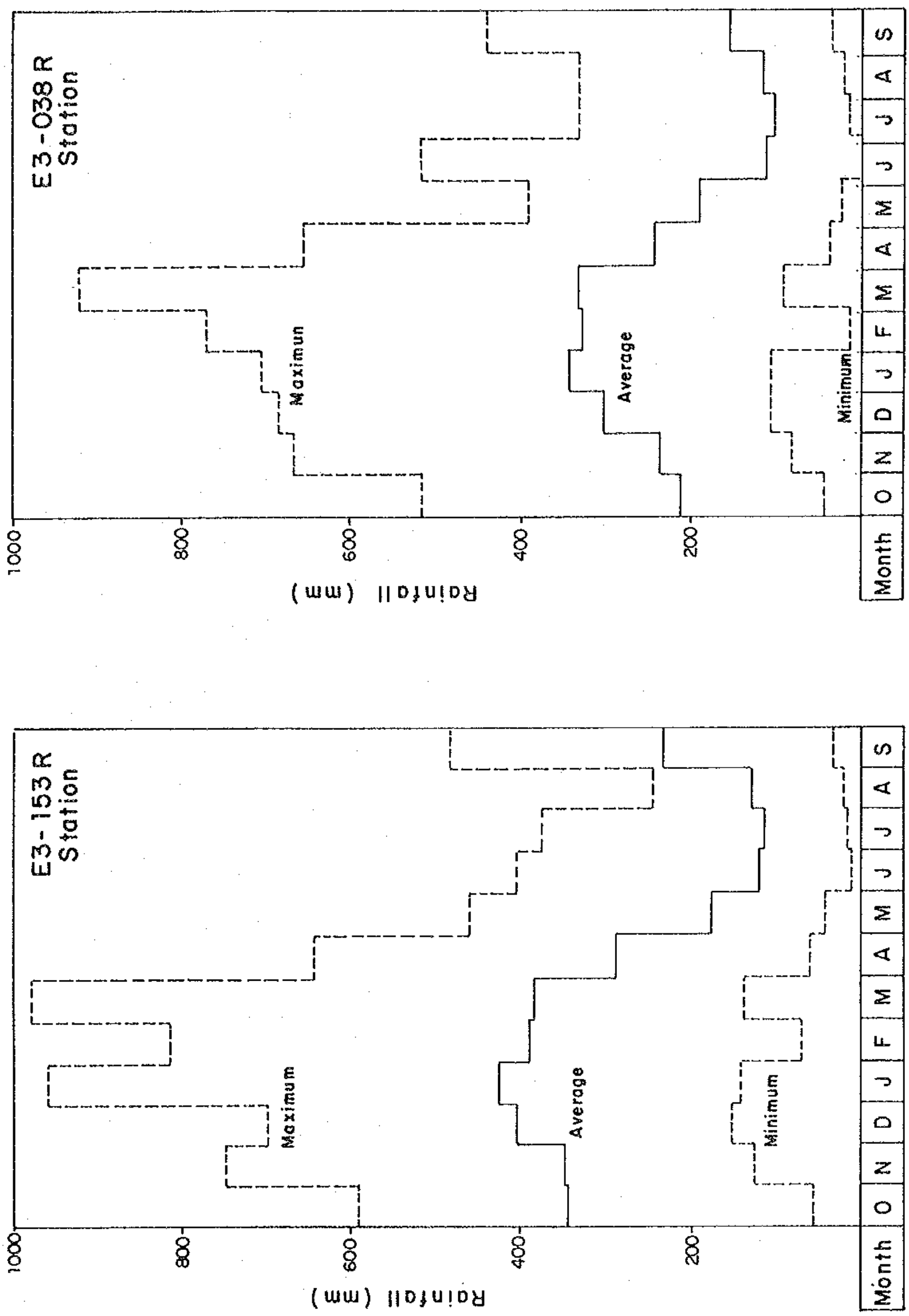
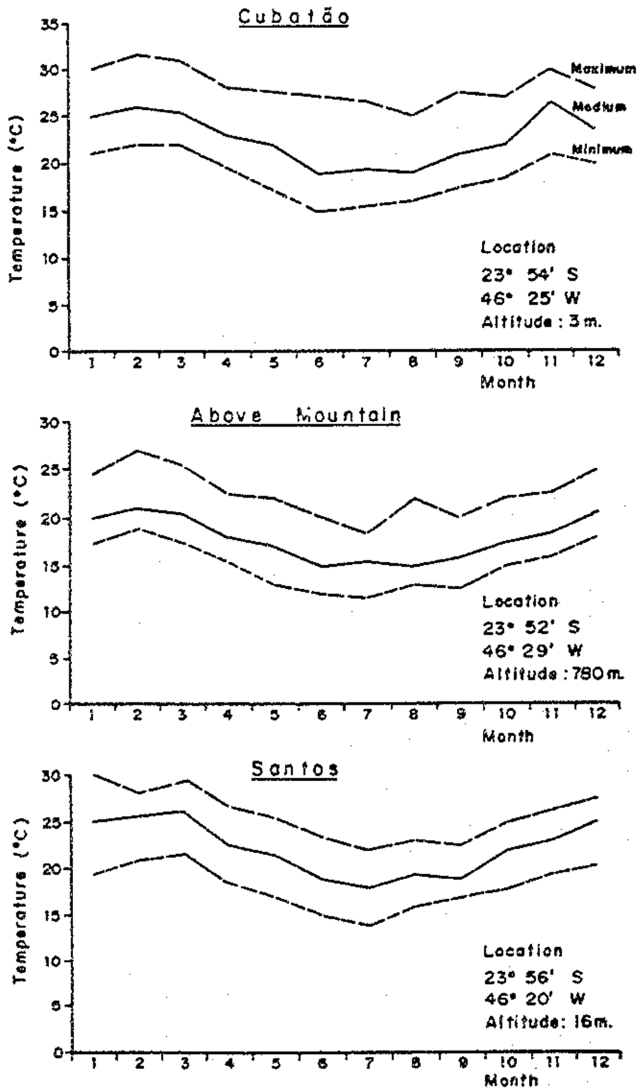


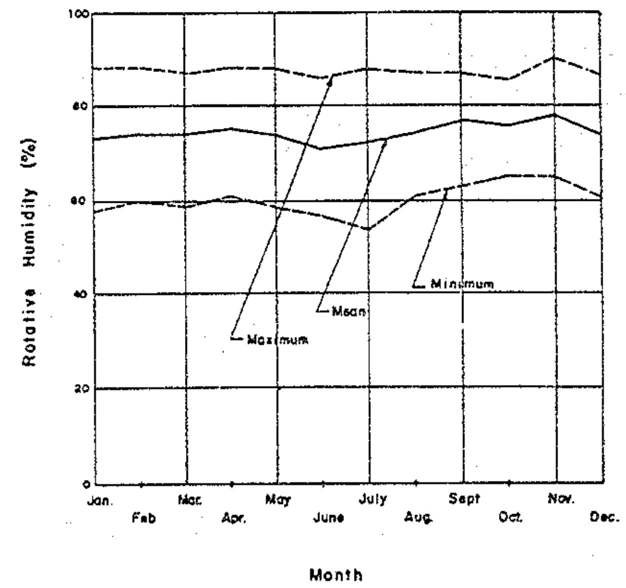
FIG.F.3
MONTHLY DISTRIBUTION OF RAINFALL

GOVERNMENT OF FEDERATIVE
REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND
RESTORATION PROJECT IN SERRA DO MAR,
CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY





Monthly Relative Humidity Observed at Ultrafertil (1969 - 1985)

Month	Jan.	Feb.	Mar	Apr	May	June	July	Aug	Sept	Oct.	Nov.	Dec	Annual
Max.	88	88	87	88	88	86	88	87	87	86	90	87	88
Mean.	73	74	74	75	74	71	72	74	77	76	78	74	74
Min.	58	60	59	61	59	57	54	61	63	65	65	61	60

Source : Programa Serra do Mar, 1985, IPT.

FIG.F.4
GENERAL CLIMATIC CONDITION
IN STUDY AREA

GOVERNMENT OF FEDERATIVE
REPUBLIC OF BRAZIL
THE STUDY ON THE DISASTER PREVENTION AND
RESTORATION PROJECT IN SERRA DO MAR,
CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

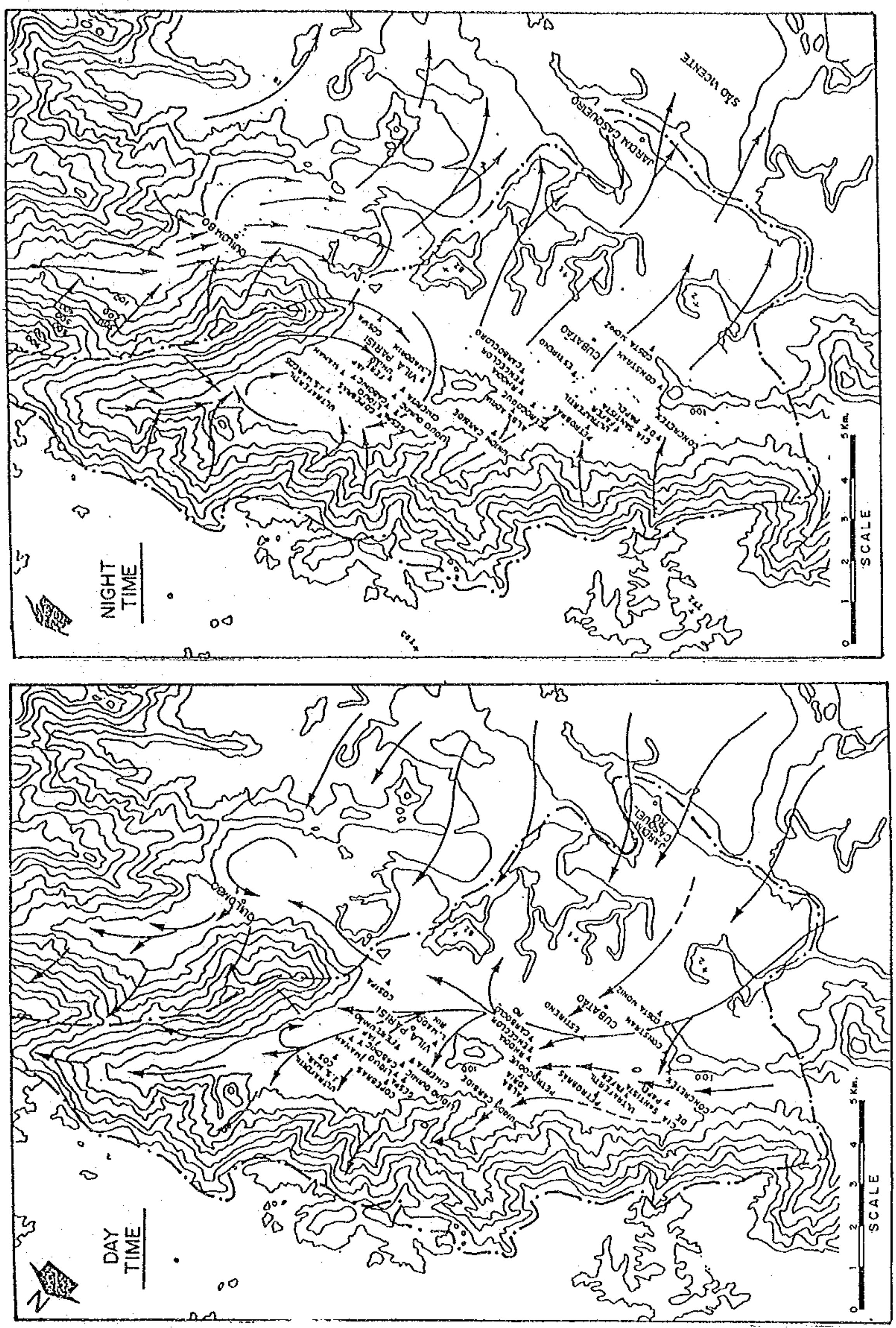


FIG.F.5
WIND DIRECTION IN AND
AROUND STUDY AREA

GOVERNMENT OF FEDERATIVE
REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND
RESTORATION PROJECT IN SERRA DO MAR,
CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

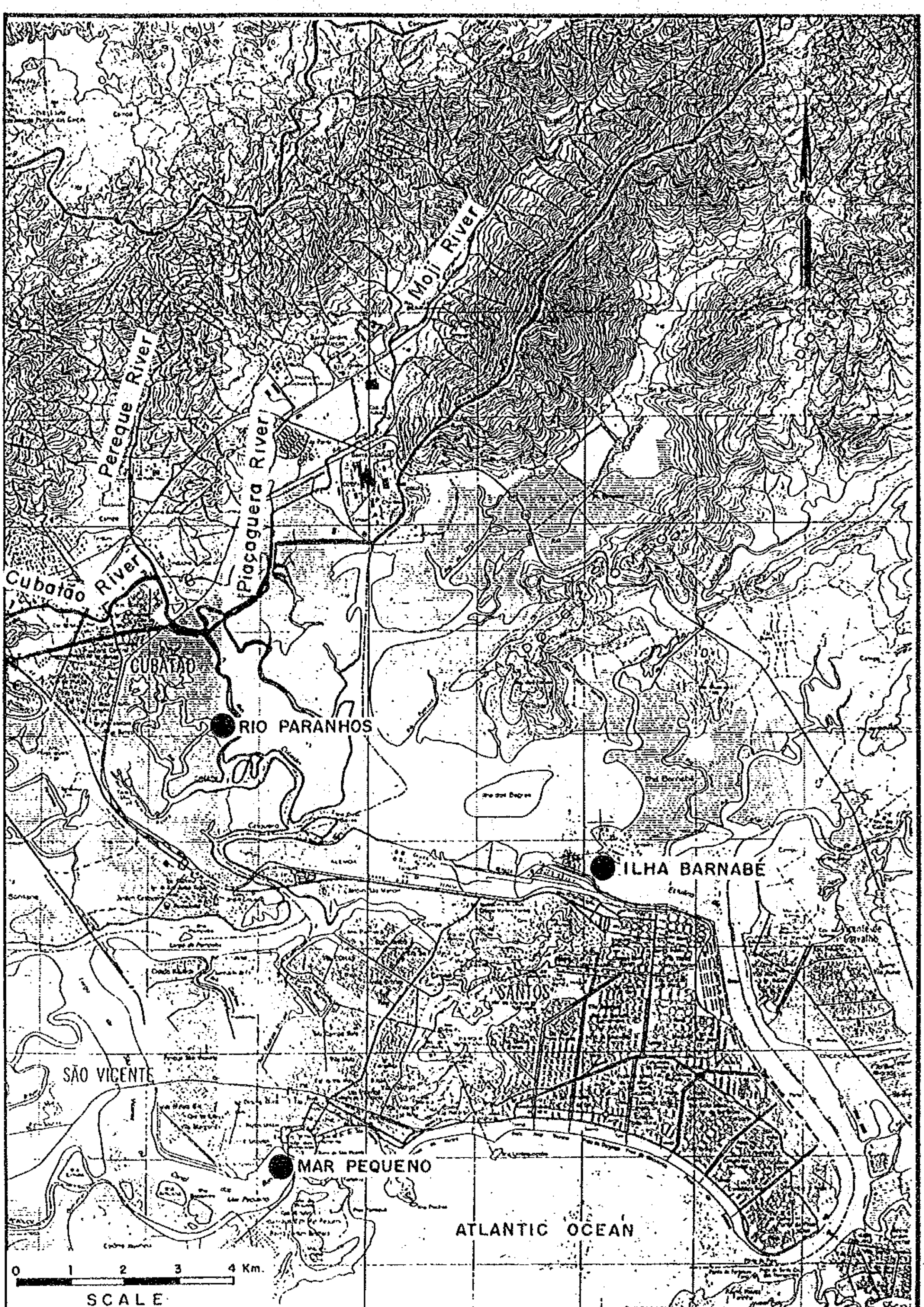
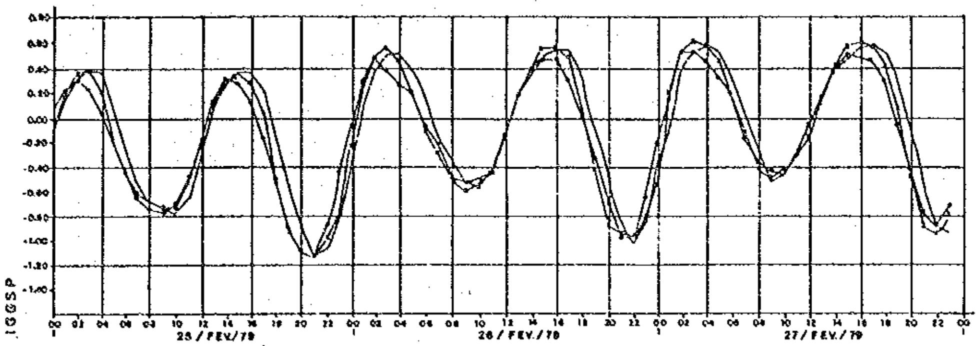


FIG.F.6
LOCATION MAP OF TIDE LEVEL STATION

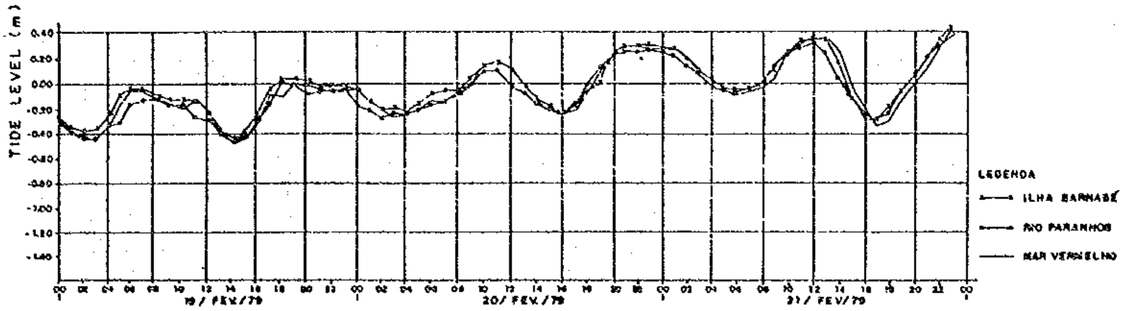
GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND RESTORATION PROJECT IN SERRA DO MAR, CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

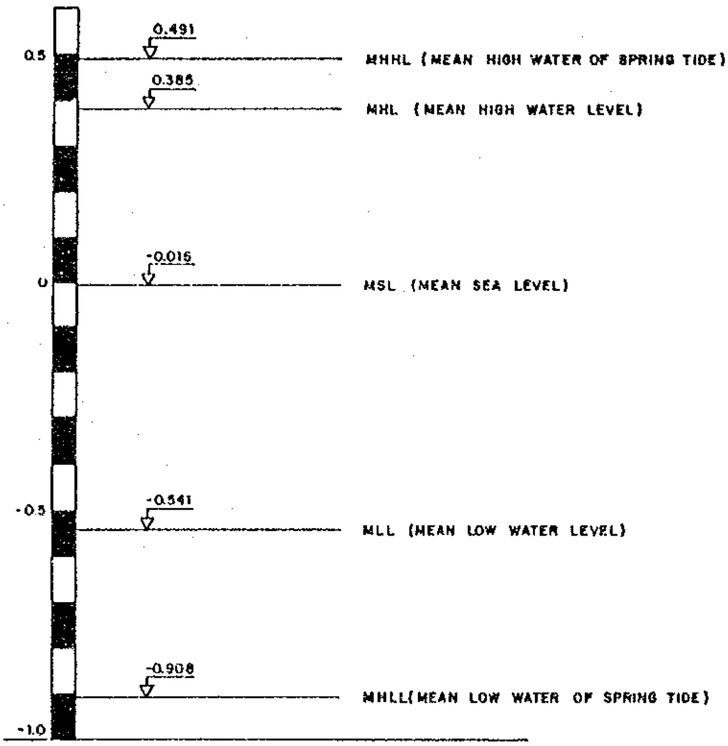


SPRING TIDE



NEAP TIDE

ELEVATION (m) in IGGSP

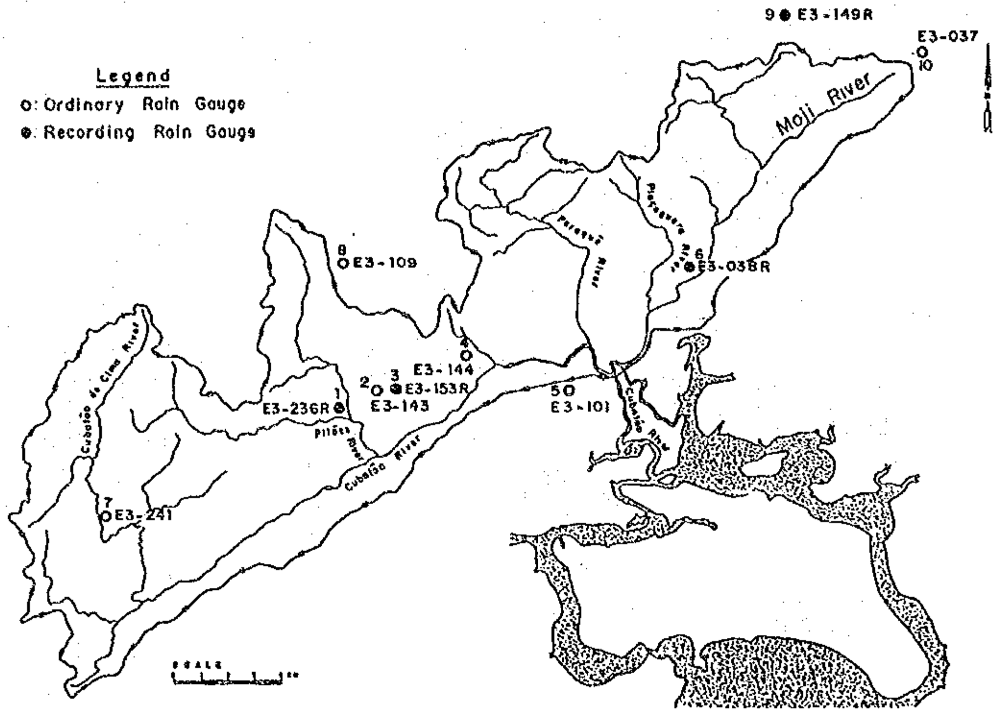


Source : Projeto de Recuperação das Áreas Alodiais de Cubatão 1979 DAEE

Note : IGGSP means Instituto Geografico e Geologico de São Paulo (data period 1956-1978)

FIG.F.7
OBSERVED TIDE LEVELS AND TIDAL PARAMETERS

GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL
THE STUDY ON THE DISASTER PREVENTION AND RESTORATION PROJECT IN SERRA DO MAR, CUBATÃO REGION, STATE OF SÃO PAULO
JAPAN INTERNATIONAL COOPERATION AGENCY



AVAILABILITY OF RAINFALL RECORDS

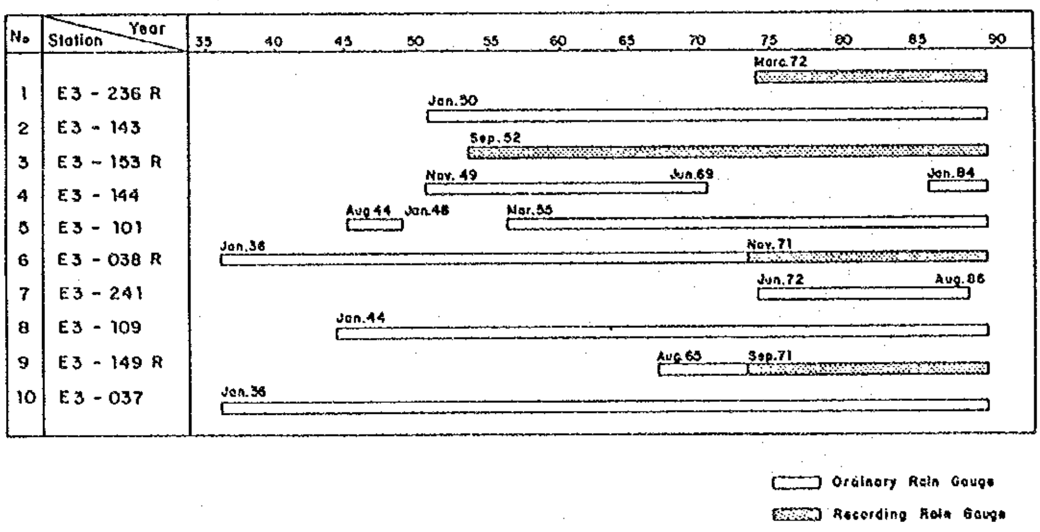


FIG.F.8
LOCATION MAP OF RAINFALL STATIONS
AND THEIR RECORD AVAILABILITY

GOVERNMENT OF FEDERATIVE
REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND
RESTORATION PROJECT IN SERRA DO MAR,
CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

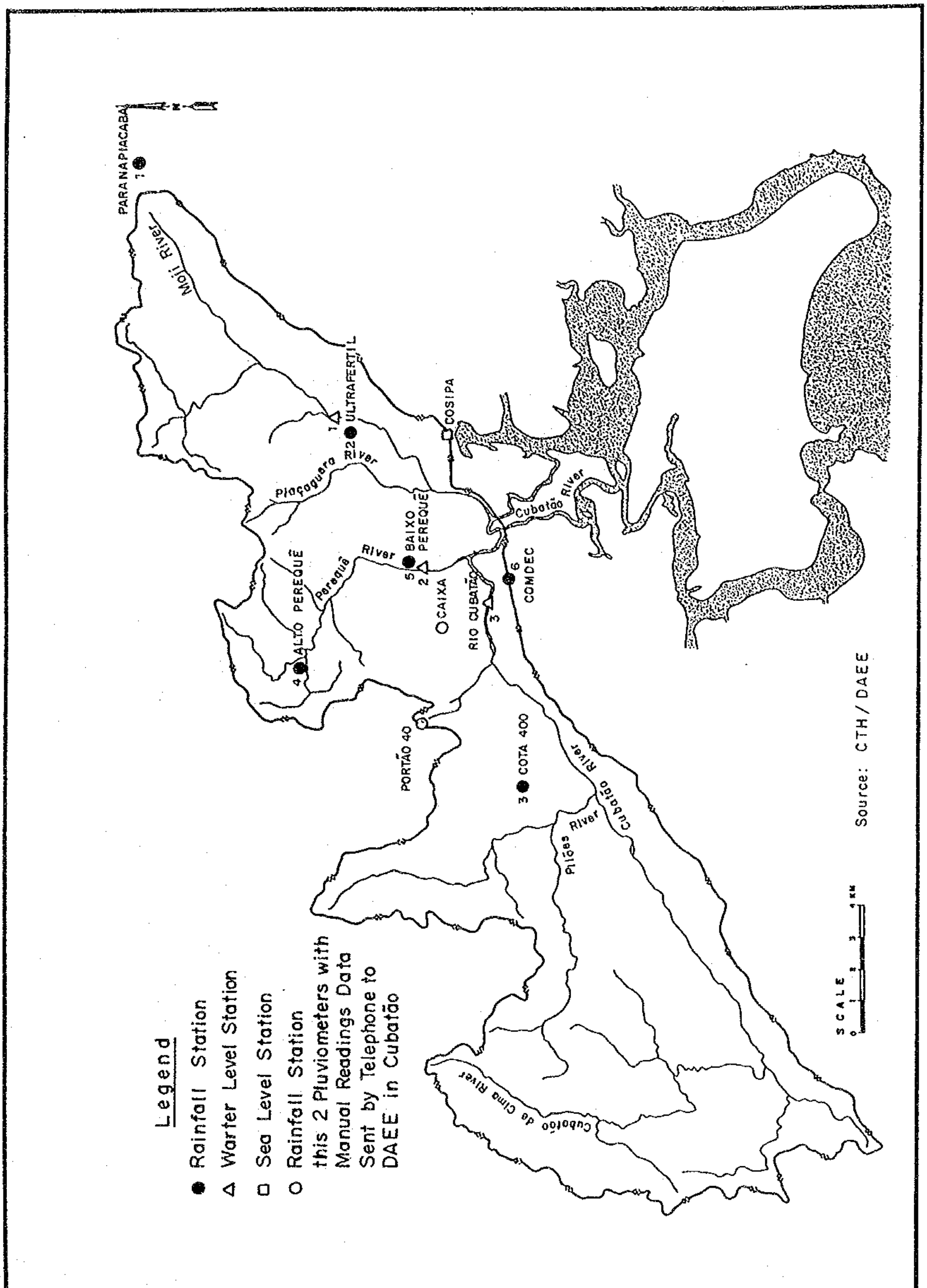


FIG.F.9
LOCATION MAP OF RAINFALL AND WATER LEVEL STATIONS BY TELEMETERING SYSTEM

GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL
THE STUDY ON THE DISASTER PREVENTION AND RESTORATION PROJECT IN SERRA DO MAR, CUBATÃO REGION, STATE OF SÃO PAULO
JAPAN INTERNATIONAL COOPERATION AGENCY

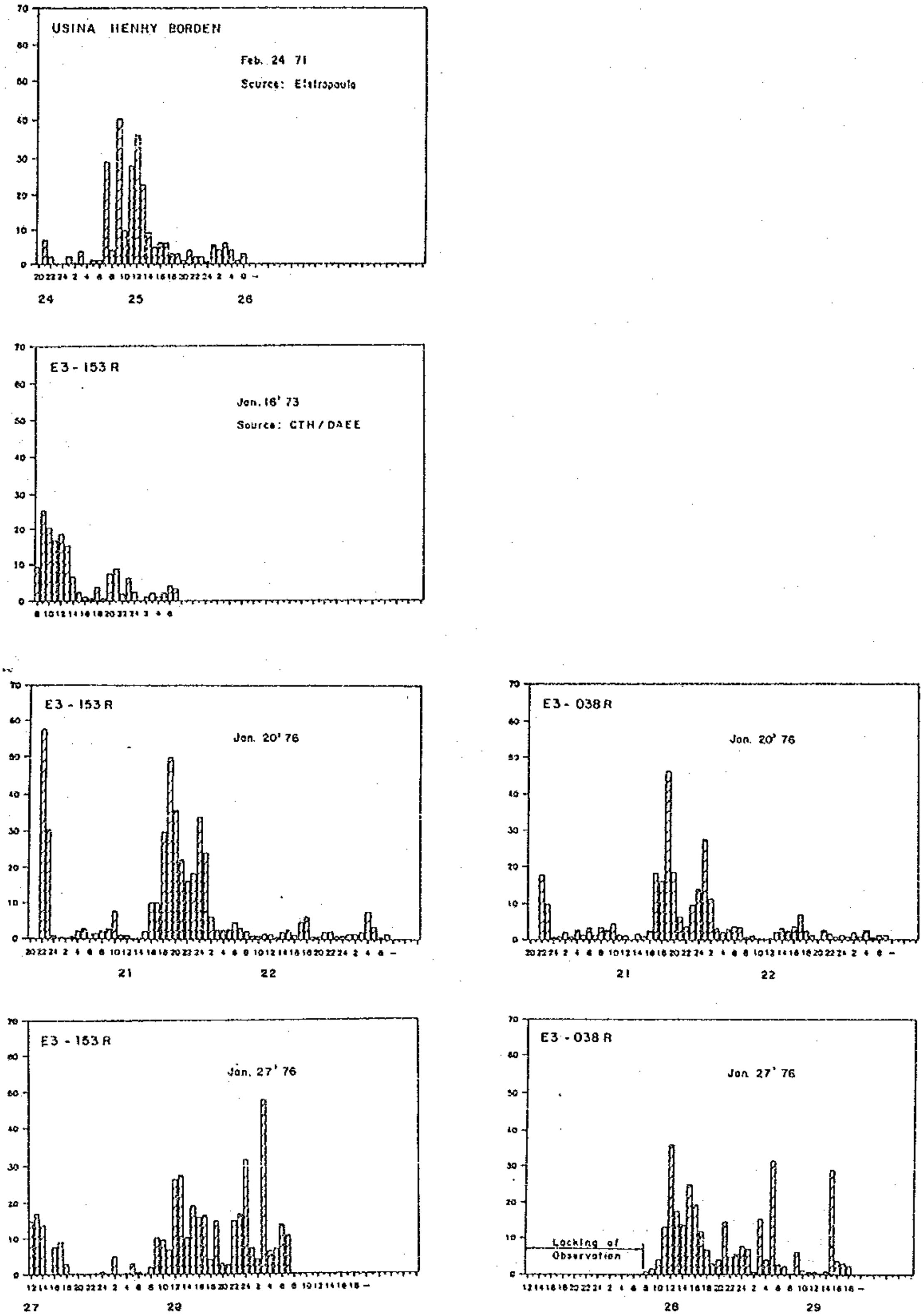


FIG. F. 10 (1/2)
HYETOGRAPH OF MAJOR PAST FLOODS

GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND RESTORATION PROJECT IN SERRA DO MAR, CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

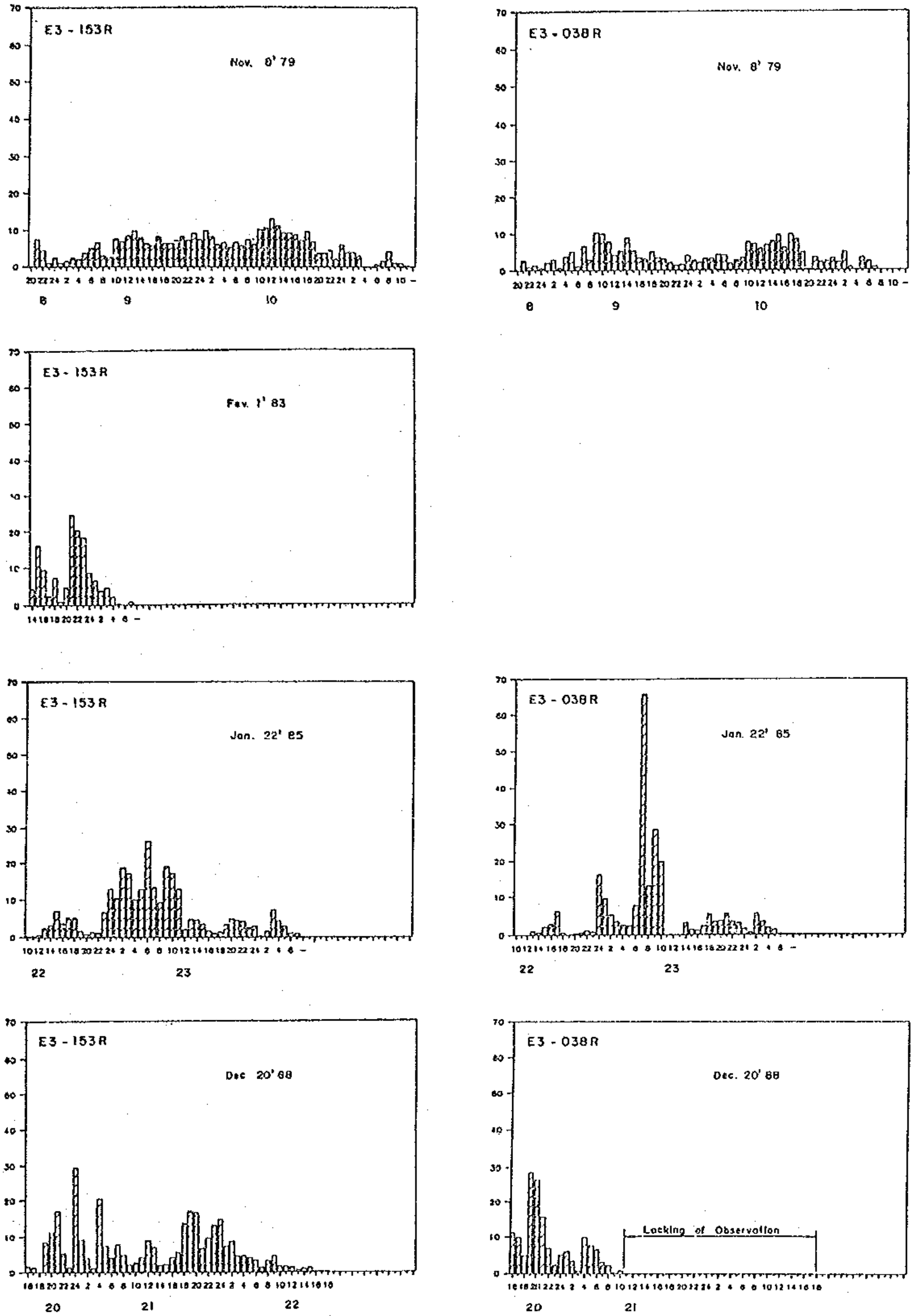
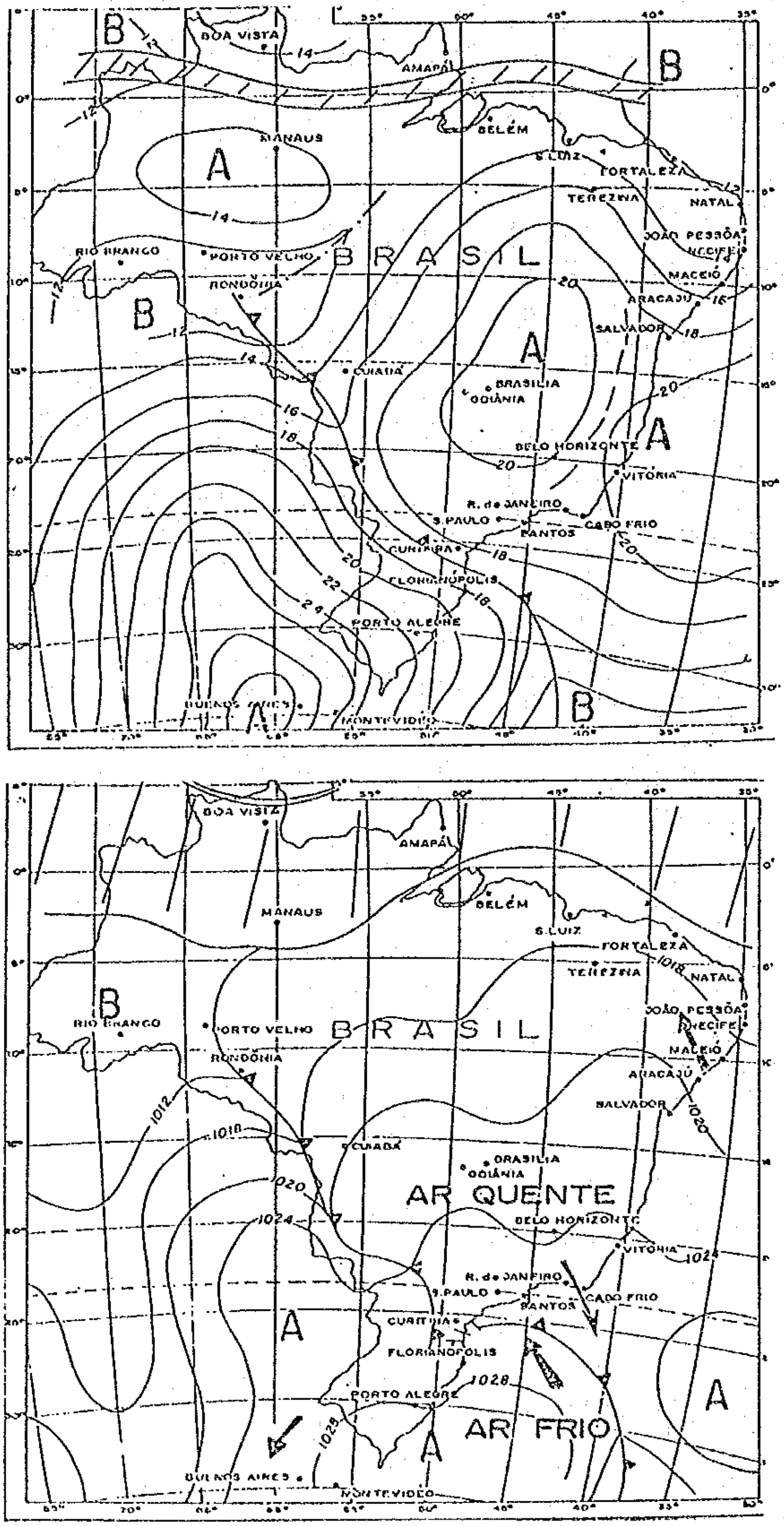


FIG.F.10 (2/2)
HYETOGRAPH OF MAJOR PAST FLOODS

GOVERNMENT OF FEDERATIVE
REPUBLIC OF BRAZIL
THE STUDY ON THE DISASTER PREVENTION AND
RESTORATION PROJECT IN SERRA DO MAR,
CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY



A : High Atmospheric Pressure

B : Low Atmospheric Pressure

Source: IPT (Report No. 23,394 Vol 5)

FIG.F.11
GENERAL CLIMATIC CONDITION
CAUSING RAINFALLS

GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND RESTORATION PROJECT IN SERRA DO MAR, CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

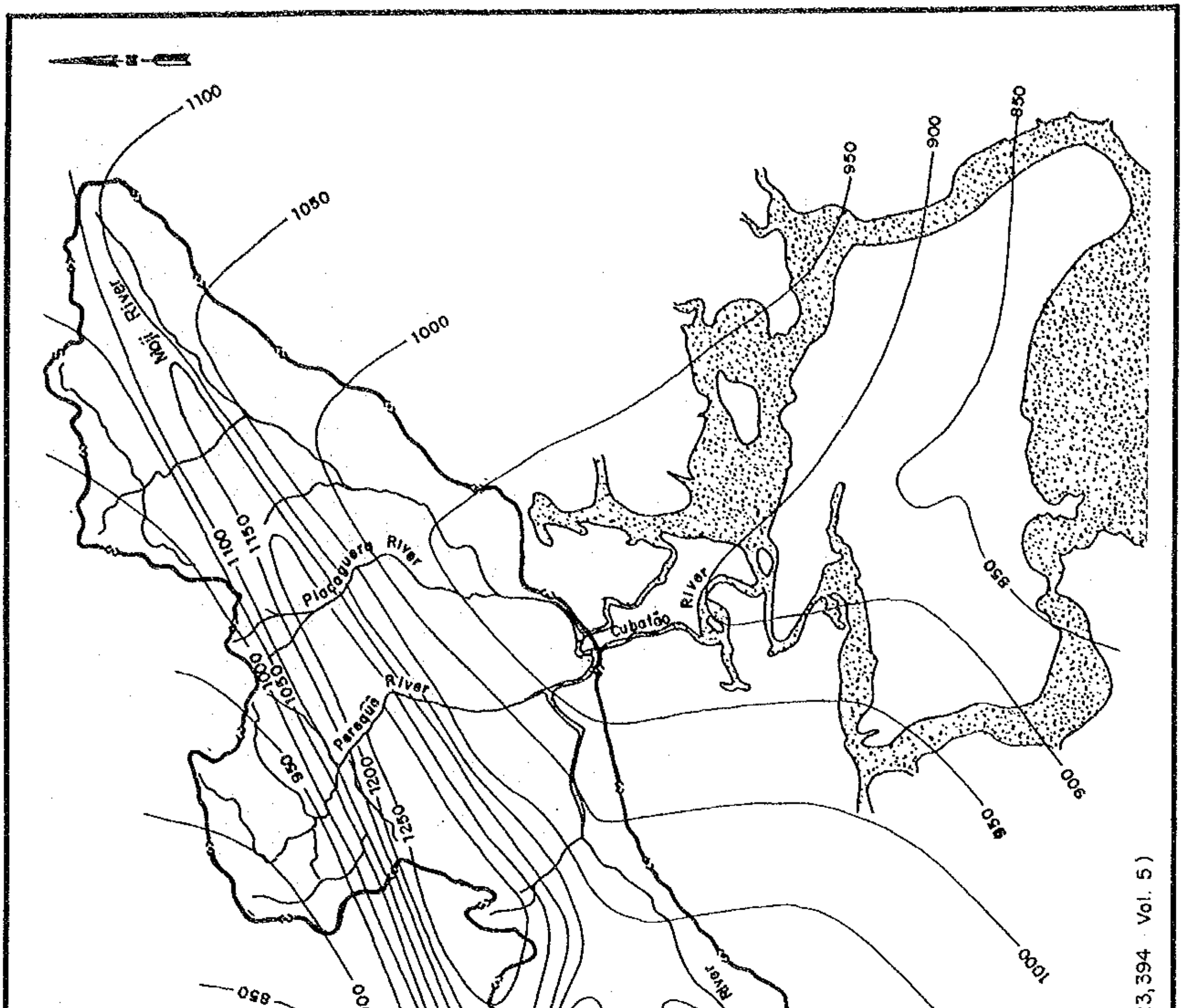


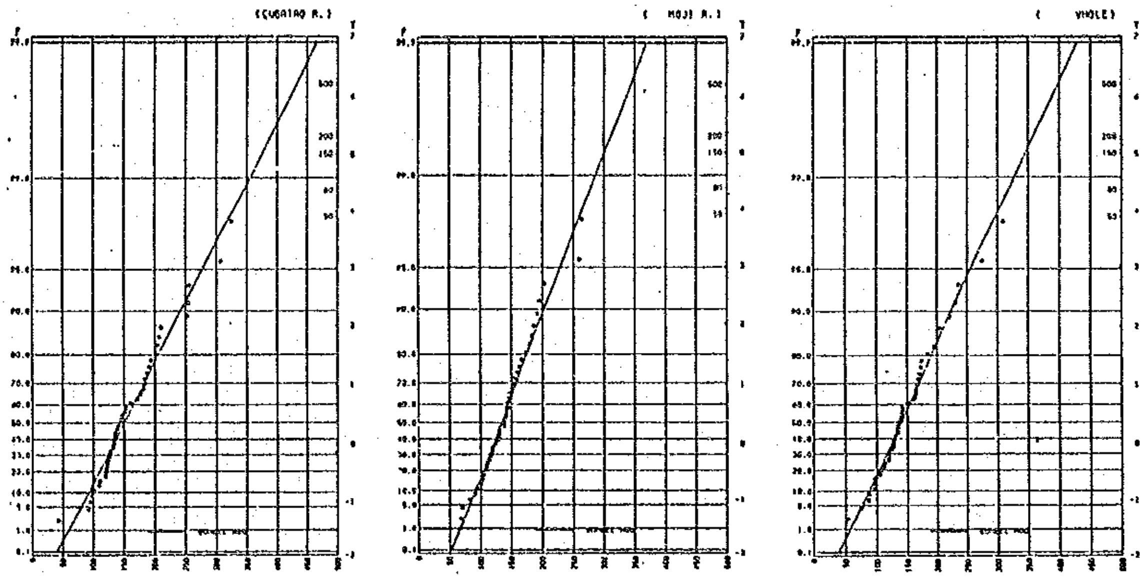
FIG.F.12
ISOHYETAL MAP FOR 3 MONTHS FROM JAN. TO MARCH(1953-1983)

GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL

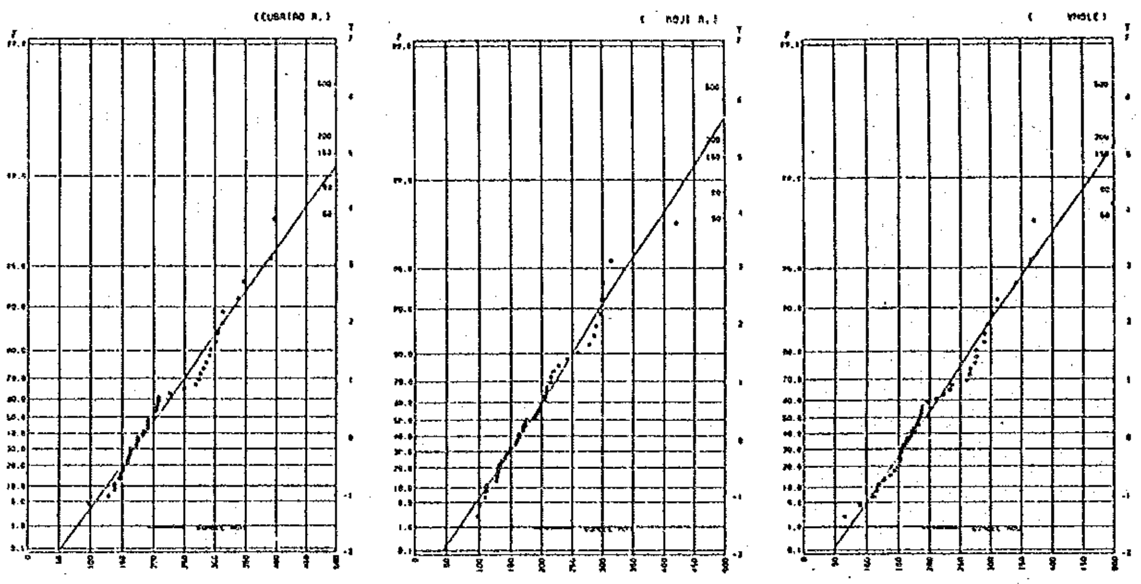
THE STUDY ON THE DISASTER PREVENTION AND RESTORATION PROJECT IN SERRA DO MAR, CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

1-DAY



2-DAY

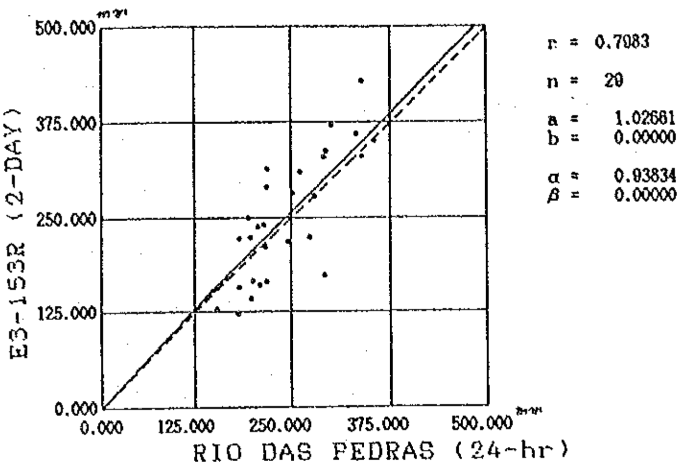


Source; CTH/DAEE

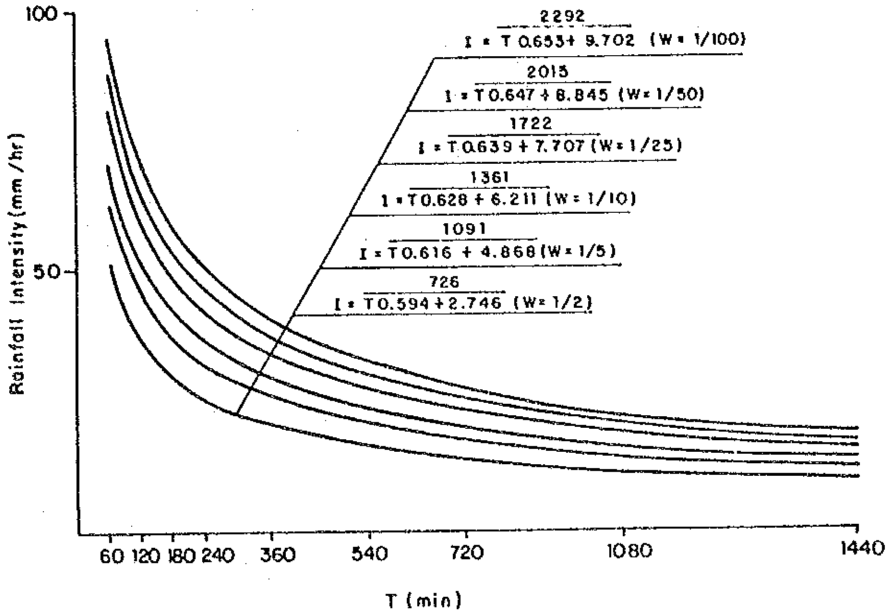
FIG.F.13
PROBABLE BASIN MEAN RAINFALL
OF 1 DAY AND 2 DAY DURATION
BY GUMBEL METHOD

GOVERNMENT OF FEDERATIVE
REPUBLIC OF BRAZIL
THE STUDY ON THE DISASTER PREVENTION AND
RESTORATION PROJECT IN SERRA DO MAR,
CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY



RELATIONSHIP BETWEEN
24-hr AND 2-DAY RAINFALL



T (MIN)	W=1/2	W=1/5	W=1/10	W=1/25	W=1/50	W=1/100
60.00	51.50	63.20	70.90	80.70	87.90	95.10
120.00	35.85	44.95	51.00	58.65	64.35	69.95
180.00	29.37	36.70	41.53	47.67	52.20	56.70
240.00	25.88	32.77	37.32	43.10	47.38	51.63
360.00	20.55	26.20	29.95	34.68	38.20	41.68
540.00	16.19	20.72	23.72	27.51	30.32	33.11
720.00	13.76	17.42	19.85	22.92	25.19	27.45
1080.00	10.63	13.36	15.17	17.46	19.15	20.85
1440.00	9.30	11.63	13.18	15.53	16.58	18.02

Note; Gumbel Method is used for the analysis

Source: IPT (Report No 23, 394; Vol 5)

FIG.F.14
RAINFALL INTENSITY CURVES

GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND RESTORATION PROJECT IN SERRA DO MAR, CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

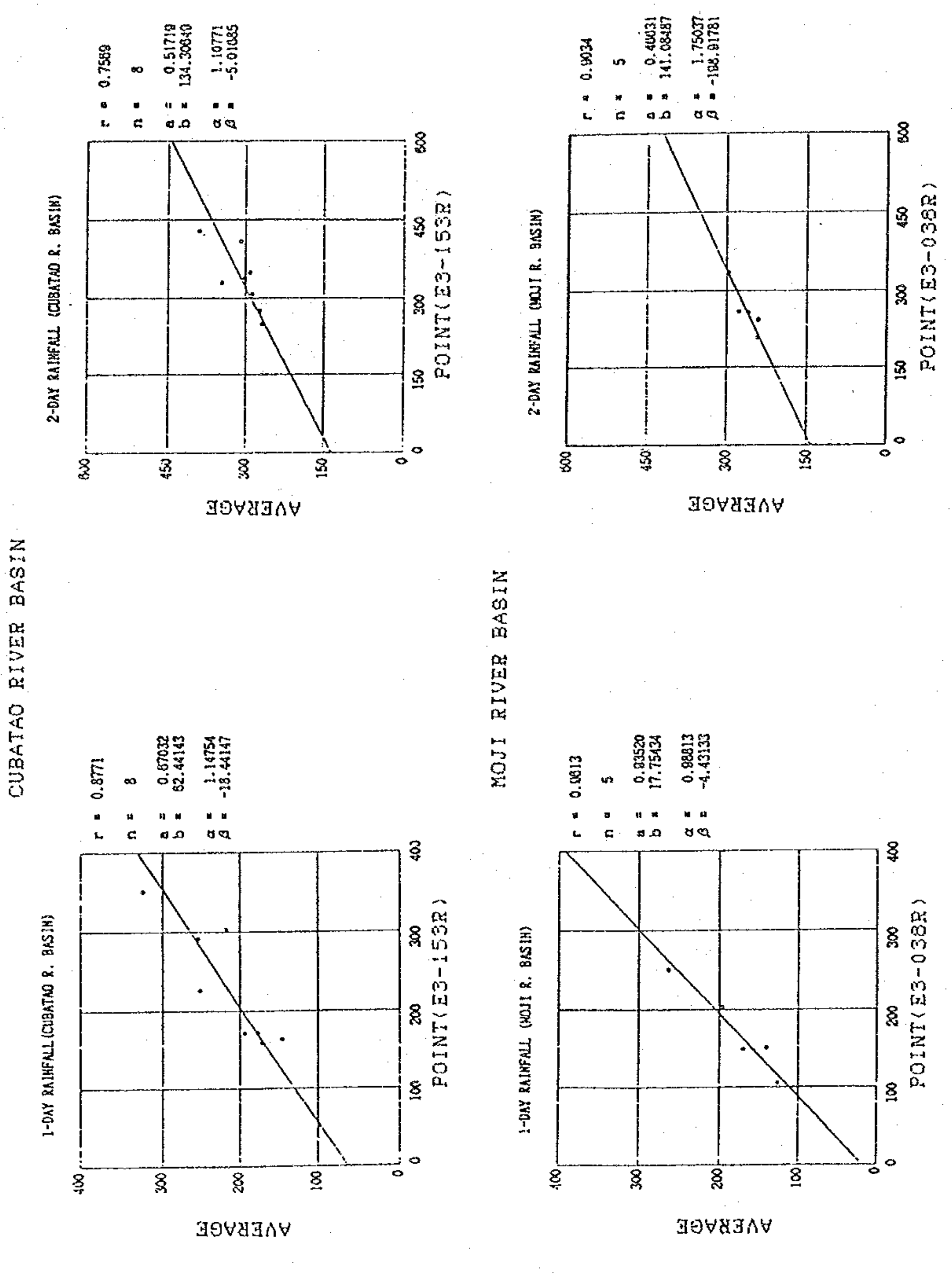


FIG. F. 15
RELATIONSHIP BETWEEN BASIN MEAN RAINFALL AND POINT RAINFALL

GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND RESTORATION PROJECT IN SERRA DO MAR, CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

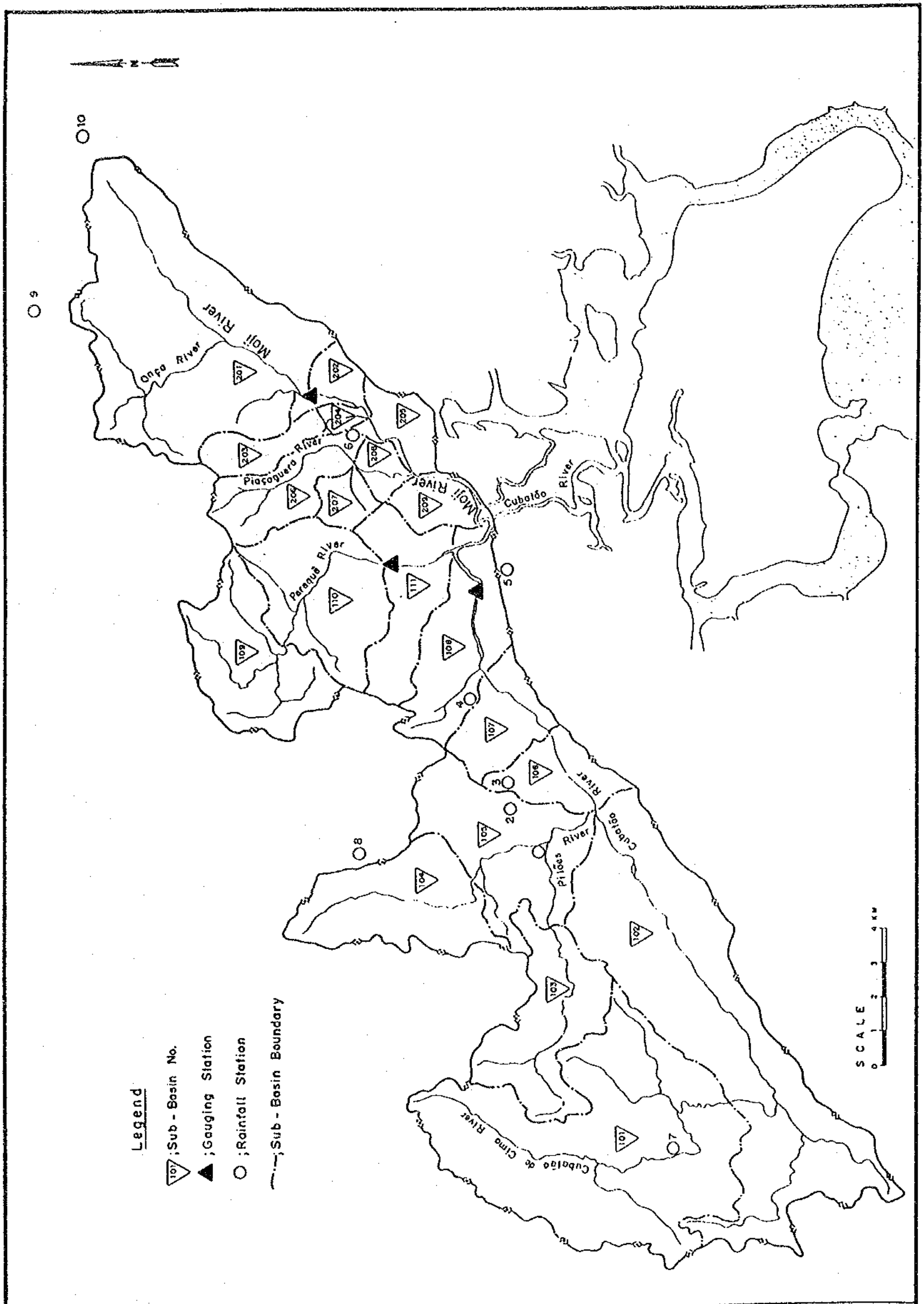


FIG.F.16
DIVISION OF RIVER BASIN FOR
ESTIMATION OF FLOOD RUNOFF

GOVERNMENT OF FEDERATIVE
REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND
RESTORATION PROJECT IN SERRA DO MAR,
CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

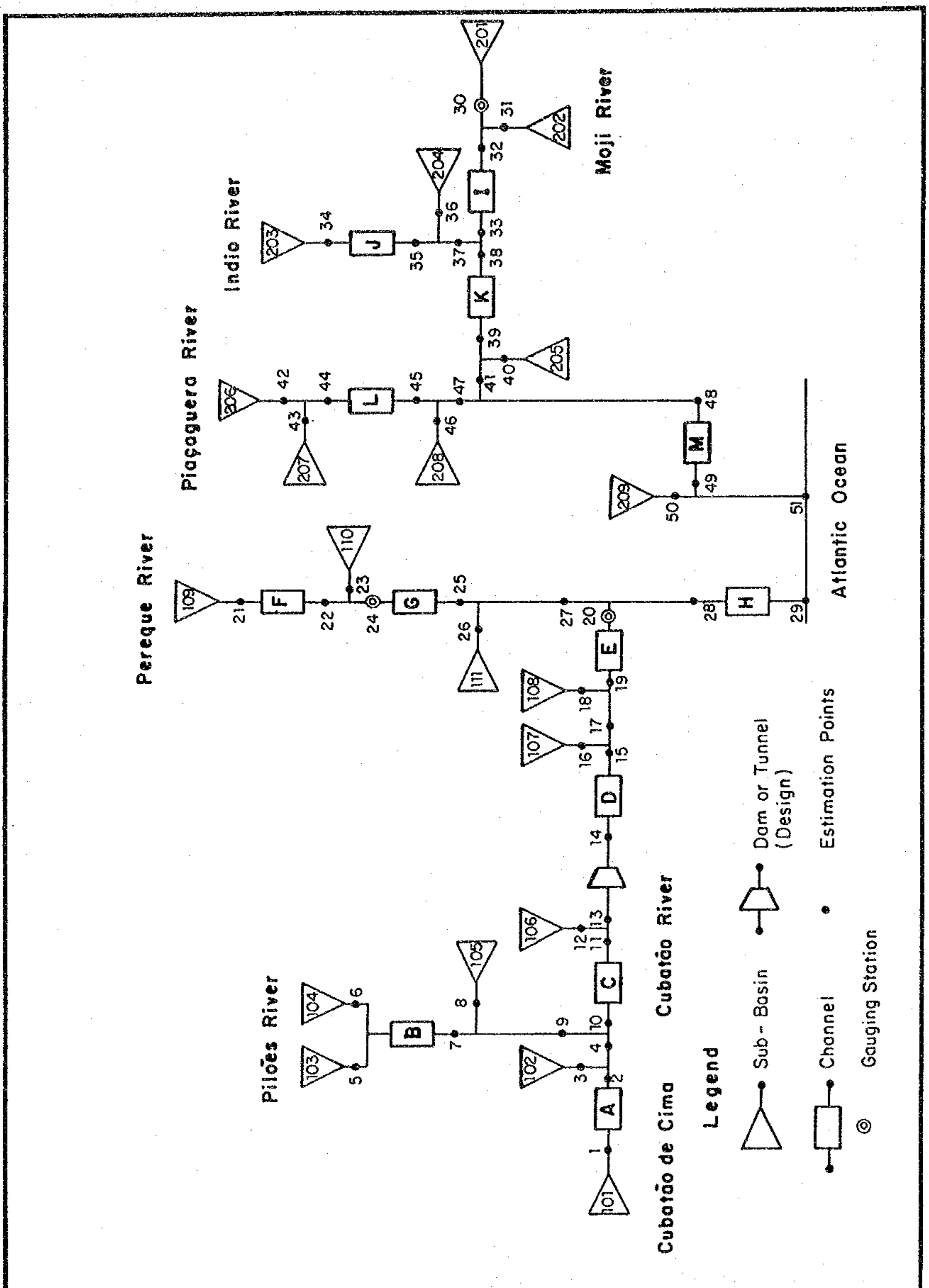


FIG.F.17
FLOOD RUNOFF ESTIMATION
MODEL DIAGRAM

GOVERNMENT OF FEDERATIVE
REPUBLIC OF BRAZIL
THE STUDY ON THE DISASTER PREVENTION AND
RESTORATION PROJECT IN SERRA DO MAR,
CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

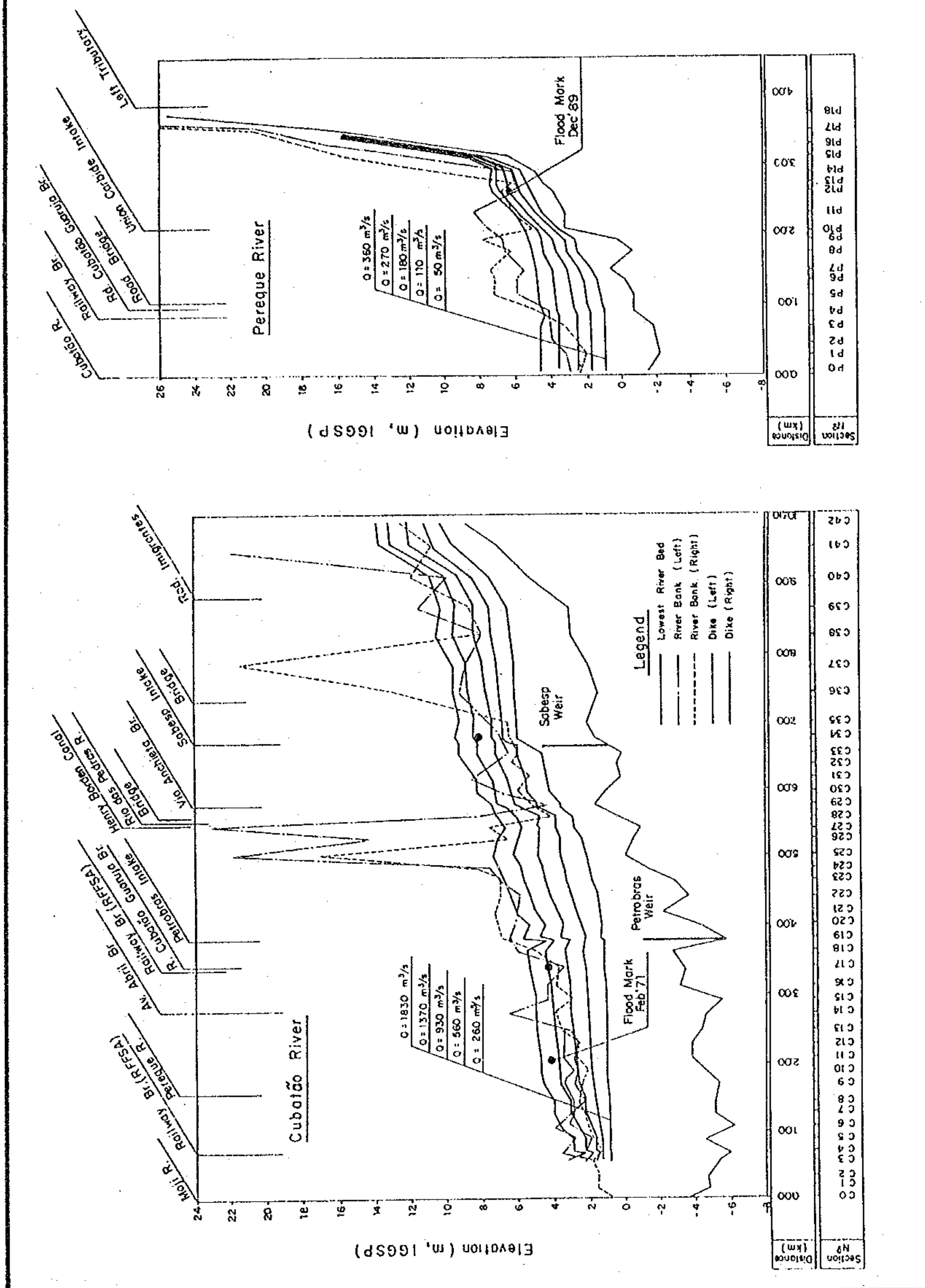


FIG. F. 18
CALCULATED WATER LEVELS IN CUBATÃO AND PEREQUE RIVERS

GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND RESTORATION PROJECT IN SERRA DO MAR, CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

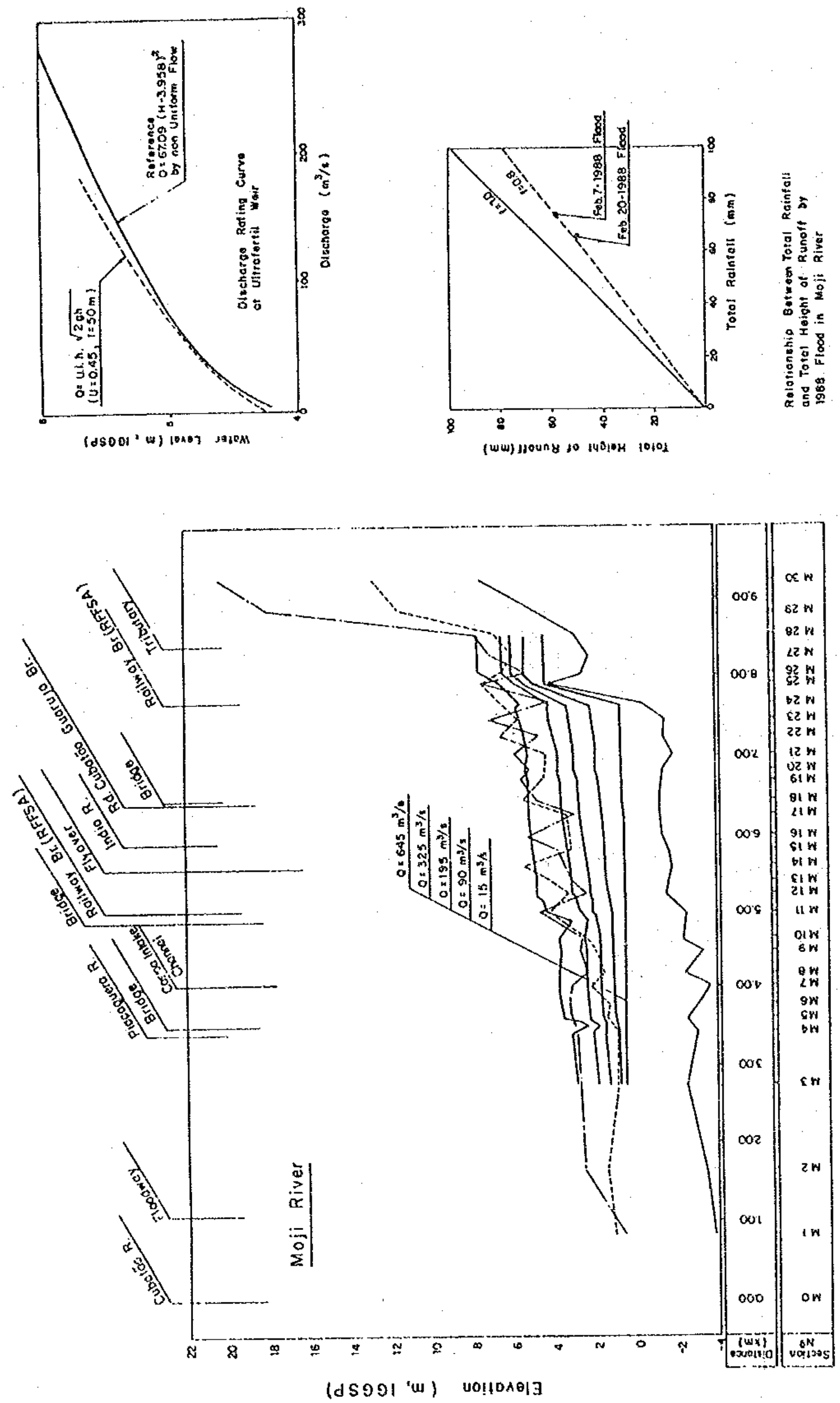


FIG.F.19
CALCULATED WATER LEVELS
IN MOJI RIVER

GOVERNMENT OF FEDERATIVE
REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND RESTORATION PROJECT IN SERRA DO MAR, CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

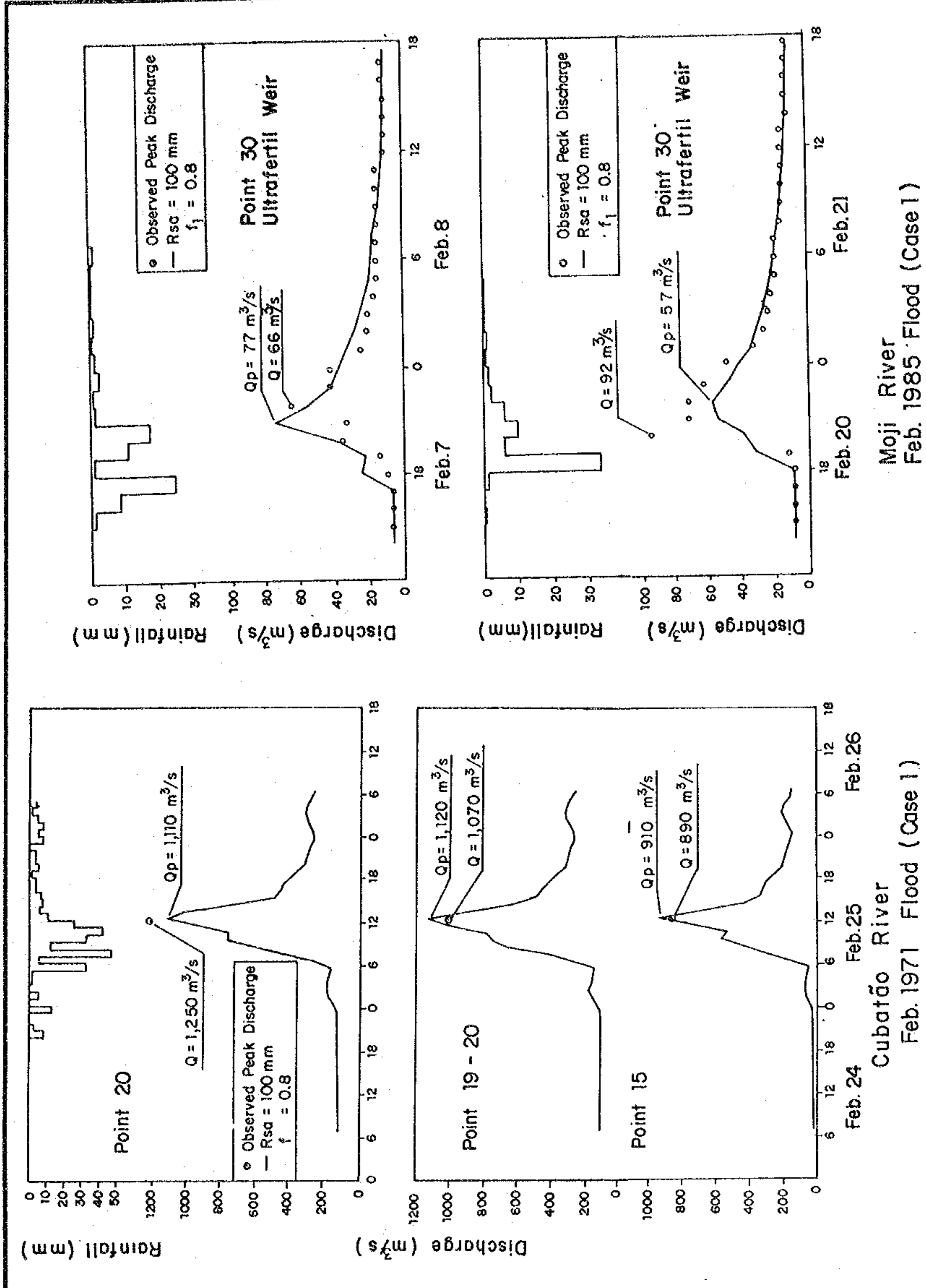


FIG.F.20
SIMULATION RESULT OF FEB.1971 FLOOD AND FEB.1985 FLOOD (CASE-1)

GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND RESTORATION PROJECT IN SERRA DO MAR, CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

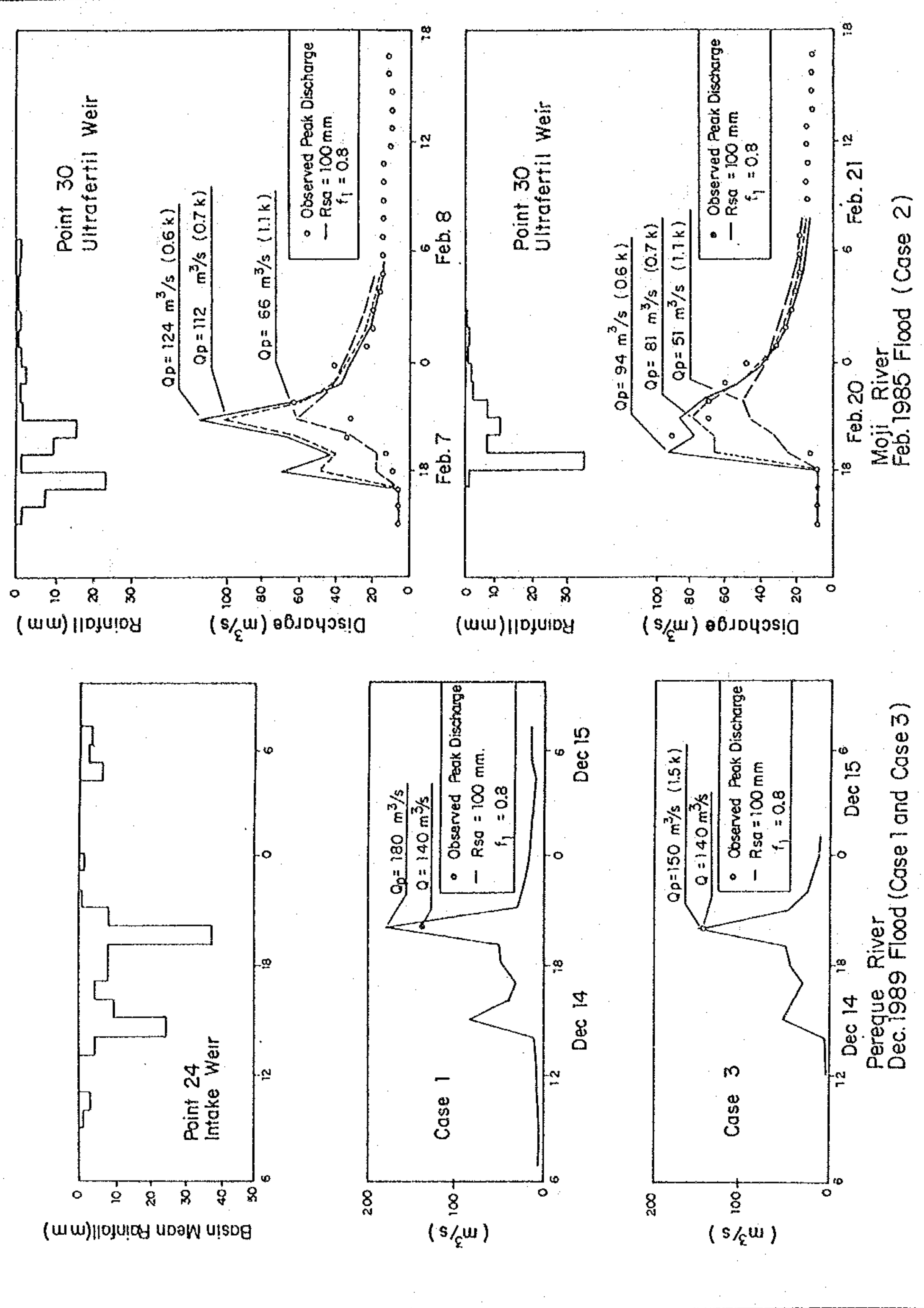


FIG. F. 21
SIMULATION RESULT OF FEB. 1985 FLOOD (CASE-2) AND DEC. 1989 FLOOD (CASE-1 AND CASE-3)

GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND RESTORATION PROJECT IN SERRA DO MAR, CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

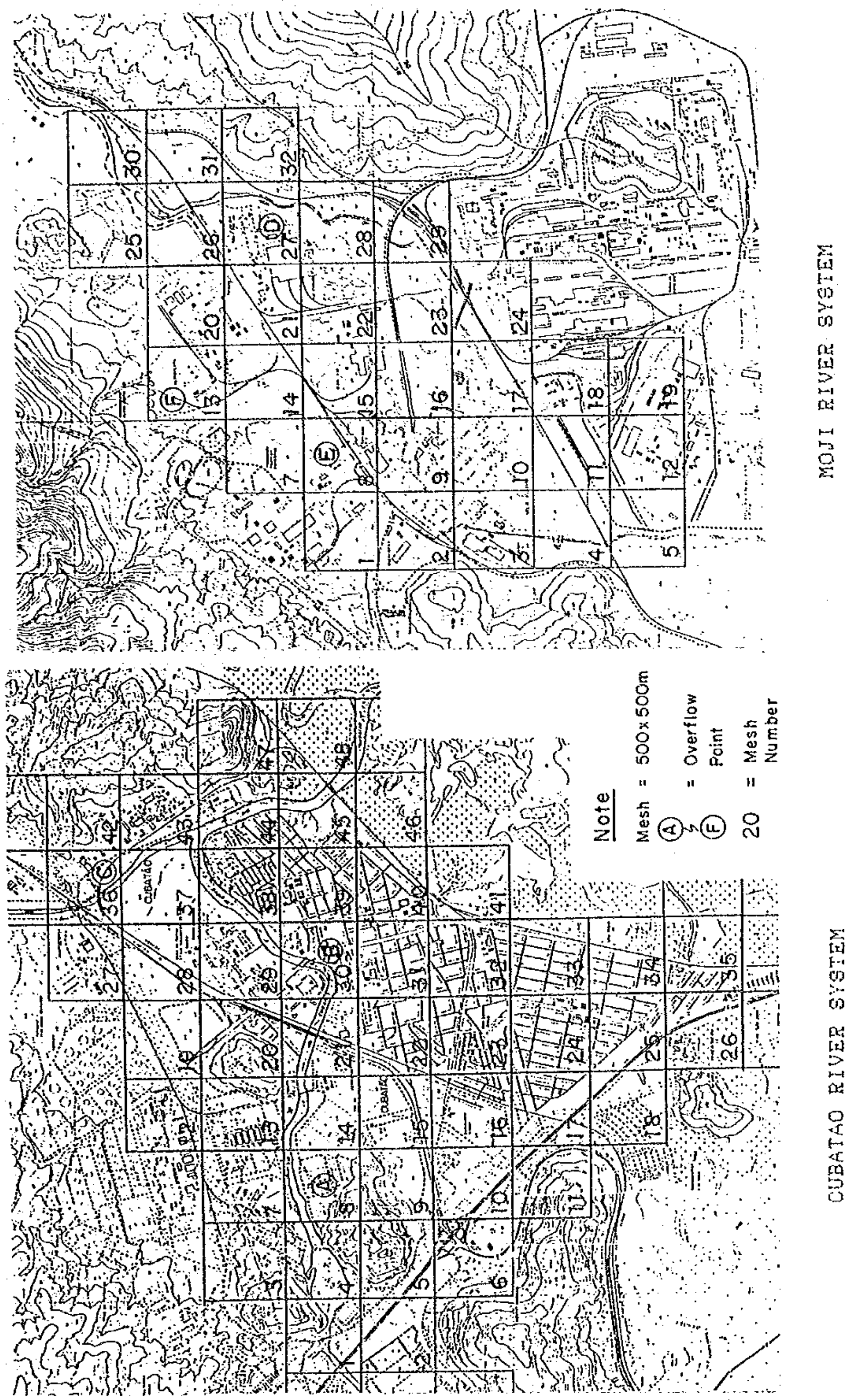


FIG.F.22
DIVISION OF LAND AREA BY MESH

GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND RESTORATION PROJECT IN SERRA DO MAR, CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

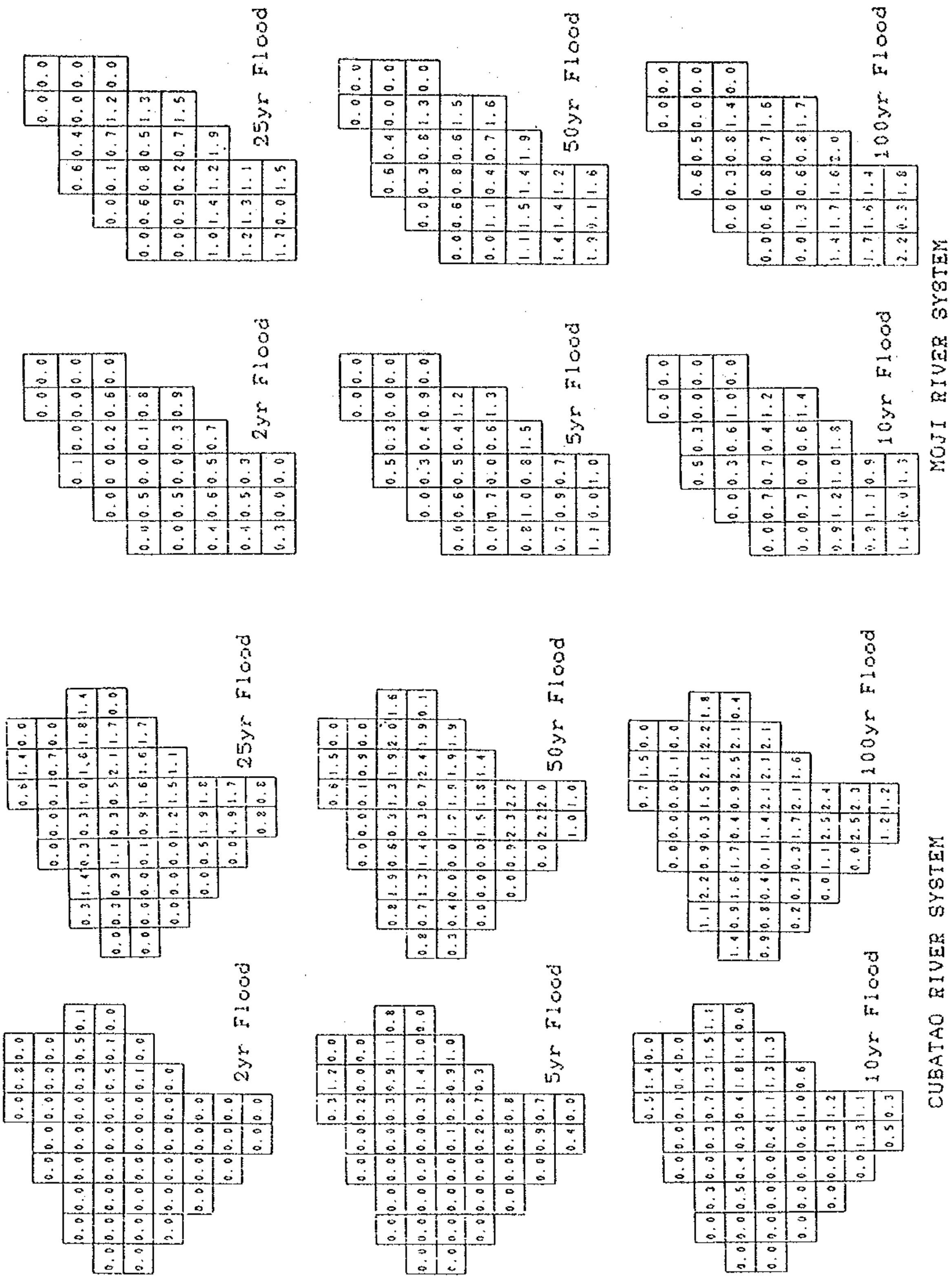


FIG. F. 23
MAXIMUM INUNDATION DEPTH BY PROBABLE FLOOD

GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY ON THE DISASTER PREVENTION AND RESTORATION PROJECT IN SERRA DO MAR, CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

ANNEX G

SEDIMENT STUDY

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

This ANNEX-G presents the sediment study results. Sediment features of channels in the study area are discussed here to provide basic data for studies on sediment runoff and flood disaster prevention works.

Historical changes in river channels are discussed first based on data prepared by the Brazilian authorities concerned in order to clarify the present and historical situation of the subject rivers. The sediment material investigations are then described covering those of river channels, mountain slopes and plateau. Based on the above data, sediment transport capacity is estimated. Firstly, sediment transport capacity is estimated for the existing lower channels. Finally, sediment study for lower reaches is made for the design of stable channel from the viewpoint of sediment transport.

Work flow of the sediment study is shown in Fig.G.1.

2. HISTORICAL CHANGES IN RIVER CHANNELS

2.1 River Morphology

A river morphologic map of the study area (scale: 1/25,000) was prepared by Eletropaulo (Eletricidade de São Paulo S.A.) in 1986. Although the map does not cover the upper portion of the Cubatão river basin, almost all the areas of interest are included. Based on this map, a simplified river morphologic map was produced as shown in Fig.G.2.

The following river morphological features of the study area are observed from the map:

1) The Cubatão and Moji rivers flow in valleys in Serra do Cubatão which runs from southwest to northeast forming a part of Serra do Mar.

2) On the mountain slopes, isolated talus exists in places along the river course. Small scale alluvial deposits are found at the outlets from the mountainous area. These are formed as the result of collapse of mountain slopes and transportation by flow.

3) A fluvial plain extends in the bottom of the valley. The fluvial plain of the Cubatão river is narrowed by the mountain ranges in the upstream reaches from Via Anchieta bridge. The plain of the upper Moji river is also narrowed by the talus from left side slope upto around Raiz da Serra. In the downstream reaches of these rivers, a wider fluvial plain develops. Most of the industrial factories and the town of Cubatão are located on the wider plain. The railway route follows the lower (southeastern) boundary of the fluvial plain.

4) There is a swampy area on the seaward side of the fluvial plain. The swampy area has fine sand zones and clay zones. The fine sand zones are located along the Cubatão river and the Canal of Cosipa which are deemed to have been previous main floodways of the Cubatão and Moji rivers.

From the above observations, it is obvious that the alluvial plain from the Via Anchieta bridge of the Cubatão river to Raiz da Serra of the Moji river is the area to be protected from sediment runoff and flood disasters. Facilities for disaster prevention should be planned in consideration of the river morphologic features of the sites.

2.2 Past Land Collapses

CETESB (Companhia Tecnologico de Saneamento Ambiental) has prepared historical vegetation cover, land use and land collapse maps of the study area excluding the upper Cubatão river basin based on aerial photos taken in 1962, 1972, 1977, 1980, and 1985. Based on the maps, sites of land collapse were superposed and a map of past land collapse was prepared. The map is shown in Fig.G.3.

Sites shaded in the map shows the area where land collapse took place during the last 30 years. Isolated and/or small scale land collapses are not always shown on the map. Some other collapse sites which may have been overlooked during the interpretation of photos may be found in the aerial photos. However, the map is useful in providing an overall view of the location of collapse sites.

There are few land collapse sites in the upper Cubatão river upstream from Rodovia dos Imigrantes bridge according to the aerial photos. Except the upper Cubatão river, sites of the land collapse are found in places. In the map, river channels which might be affected by the sediment runoff are shown emphasized with thick solid line. River channels more or less affected by the land collapse are the lower Cubatão, Rio das Pedras, Pedras, Pereque, Piaçaguera, Engenho, and Moji rivers and other tributaries of the upper Moji river.

On the fluvial plains of these rivers, heavy industrial areas are located. Except the Rio das Pedras river and a tributary of the Lower Moji (non-named), sediment control dams (cross dikes) are constructed at the outlets of these rivers from the mountainous area to protect the industrial areas, although most of them are simple and small scale.

Sediment runoff control works need to be planned for the sediment affected rivers mentioned above, by constructing new facilities and reinforcing the existing facilities.

2.3 Historical River Course Shifting

For the study of the historical shifting of river courses in the study area, the following data were used:

1) 1970-topographic map: Topographic map of IGGSP (Instituto Geografico e Geologico de São Paulo), originally prepared in 1962 and revised using aerial photos and hydrographic survey results conducted up to 1970.

2) 1984-topographic map: Topographic map of IBGE (Instituto Brasileiro de Geografia e Estatistica) published in 1984.

3) Aerial photos: Aerial Photos taken in 1960, 1972, 1980, 1985, 1987 and 1989 are available. Among these, aerial photos taken in 1960 and 1989 are used for the study.

The river courses of 1960 and 1989 are superposed on the above and are shown in Fig.G.4. From this figure, the shiftings of river course during past 29 years can be identified as follows:

1) River courses are stable in the mountainous area. Shiftings of river courses are seen in the fluvial plain and swampy areas. Most of the

channel shiftings are artificial channel realignments due to channel improvement and land reclamation for industrial factories. Natural shiftings are seen in the upper Moji river and rivers in the swampy area.

2) Cubatão river upstream from Moji junction: Sites of major river course shiftings are found at the following places:
   - At just upstream of Sabesp intake weir: Cut-off channel of meandering channel
   - At bridge of Av. 9 de Abril in Cubatão: Cut-off channel of meandering channel
   - At Pereque junction: Realignment of the Pereque river at its junction with the Cubatão
   - Just upstream of the railway bridge in the eastern part of Cubatão town: Cut-off channel of meandering channel
   - At Petrobras: Realignment of left tributary of the Cubatão and right tributary of the Pereque in the yard of Petrobras.

3) Moji river: Sites of major shiftings of river course are found at the following places:
   - Upper Moji river upstream from junction with the Engenho river (right tributary): River course shifting on fluvial plain
   - Moji river from the Engenho junction to junction with the India river (right tributary): Realignment or natural shifting of meandering channel
   - At Ultrafertil: Realignment of the India river, shifting the junction with the Moji river toward downstream
   - Piaçaguera river (right tributary): Realignment of channels in the highway and railway, and cut-off channel at just downstream of Vila Parisi

4) Rivers in swampy area: According to the aerial photos taken in 1960, there were three major floodways for the drainage of the Cubatão and Moji rivers passing through the swampy area. They are tentatively called here as the 1st, 2nd and 3rd floodways from the Moji river side. The 1st and 2nd floodways no longer function as floodways now. The 1st floodway was closed due to the extension of Cosipa and a part of the floodway is used as sedimentation basin for water intake. The 2nd floodway was clogged probably due to the maintenance and improvement of the navigation canal for Cosipa. One additional

floodway exists now to the west of the 3rd floodway which is now called the main Cubatão river. Therefore, two floodways now serve for the drainage of the Cubatão and Moji rivers.

In view of the above, the following matters should be taken into consideration in planning the sediment runoff and flood disaster prevention works:

1) Since the river courses are not yet stable in the upper Moji river, consideration should be given on the location of facilities for disaster prevention so that the proposed facilities may not cause further shifting of river course.

2) River channels seems to have been realigned and/or improved for the sake of various factories. It is recommended that the degree of safety and the capacity of these channels be checked from an overall view point as part of the river system.

3) The channel system in and around Ultrafertil and Copebras is complicated. The channels should be realigned and the system should be simplified for smooth flood flow and economical channel improvement.

4) River channels in the swampy area are meandering and changeable. The improvement of the river channels in this area should be planned carefully considering the water levels in the upstream reaches, silting-up of the floodway itself, and sedimentation problems in the Cosipa navigation canal. If the water levels are acceptable for upper reaches of the river, channels in the swampy area could be left as they are as a natural sedimentation basin for the lower navigation canals and the port.

2.4 Historical River Bed Fluctuation

(1) Available Data

Historical survey results of river sections were used for the study. Historical channel sections at flow observation stations are not available, since the stations in the study area are located at the intake weirs. The following survey results are available:

1) Survey and study by Cosipa

- Cosipa Canal Survey: A series of surveys of the Cosipa navigation canal carried out from June, 1966 to March, 1967. Longitudinal profiles are available.
- Cosipa Study on Moji R.: Survey and study of the Moji river with sedimentation basin of Cosipa carried out from August, 1981 to September, 1984. Longitudinal profiles are available.

2) DAEE Survey:

- Survey of DAEE carried out from August to October in 1986 for the following river reaches:
- Lower reaches of the Cubatão river
- Lower reaches of the Pereque river
- Middle reaches of the Moji river
- Middle reaches of the Piaçaguera river

3) JICA Survey:

- Survey by JICA Study Team carried out January, 1990 for the middle and lower reaches of the following rivers:
- Cubatão river
- Pereque river
- Moji river
- Piaçaguera river

The location of the available channel survey results is shown in Fig.G.5. Survey results by Cosipa were not used for the study on river bed fluctuation, since the longitudinal profiles are available only along the navigation canal or the center of the river channel.

(2) Cubatão and Pereque Rivers

The longitudinal profile surveyed in 1986 (by DAEE) and that surveyed in 1990 (by JICA) are superposed and shown in Figs.G.6 and G.7 for the Cubatão and Pereque rives. Significant river bed fluctuation is not observed for either river, although the stretches of available data are short.

River bed slopes of the Cubatão and Pereque are outlined as follows:

No.	Stretch	Bed slope
Cubatão R.		
C1.	U/s of Rd. Imigrantes br.	1/210
C2.	From Rd. Imigrantes br. to sta.C25	1/1,000
C3.	From sta.C25 to C23	Discontinuity in bed slope
C4.	From sta.C23 to railway bridge (sta.C4)	1/1,350
C5.	D/s of railway br.	Adverse slope
Pereque R.		
P1.	U/s of park (sta.P15)	1/30
P2.	From park to U. Carbide intake weir	1/300
P3.	From U. Carbide weir to Cubatão jct.	1/770

Sedimentation with wider channel width are seen at the downstream of stretch-C1, upstream of stretch-C3 and in stretch-C5 of the Cubatão river and at the downstream of stretch-P1 of the Pereque river.

There is a discontinuity in the river bed slope in stretch-C3. This stretch is located between hills on both banks. The intake facility of Petrobras is located on left bank of this stretch. There may be hard soil or rocks on the river bed.

(3) Moji River

River bed fluctuation of the Moji river during the period from 1986 to 1990 is shown in Fig.G.8. Although the fluctuation of this period is small, the river bed elevation has had a tendency to fall upstream of the railway bridge near Cosipa and to rise downstream.

There seems to be a discontinuity in the river bed elevation near the railway bridge (sta.M11 to M12). River bed slope is as gentle as around 1/6,250 in the upstream and downstream reaches of the discontinuity. The river bed slope gets steeper in the upstream reaches of Ultrafertil intake weir.

3. SEDIMENT MATERIAL INVESTIGATION

Sediment and soil materials were investigated by taking samples from river bed of major river channels in the study area and from mountain slope and plateau which are the source of the channel sediment.

The investigation consisted of sampling work in the field and physical tests in the laboratory. The main work items were as follows:

1) Material Sampling
   a) River bed materials
   b) Slope materials
   c) Plateau materials

2) Physical Tests
   a) Grain size analysis
      - Sieve analysis for materials coarser than 0.075mm
      - Sedimentation analysis for materials finer than 0.075mm
   b) Specific gravity

The sampling was carried out on January 3 to 11, 1990 and the sampled materials were tested in the laboratory of DAEE from January 10 to 24, 1990.

Suspended load samples were also taken on January 3, 1990 at intake weirs of Sabesp in the Cubatão river, Union Carbide in the Pereque river, and Ultrafertil in the Moji river. However, tests were not made on these, since the concentration of suspended solids (SS) was visually very low because the water samples were taken under ordinary flow conditions.

3.1 Material Sampling

The location of sampling sites is shown in Fig.G.9. A total of 26 samples were collected from 19 sites as presented below.

1) Bed Materials	:	15 sites, 21 samples
- Cubatão R.	:	6 sites, 9 samples
- Pedras R.	:	3 sites, 3 samples
- Pereque R.	:	3 sites, 5 samples

- Moji R. : 3 sites, 4 samples

2) Slope Materials : 1 site , 1 sample

3) Plateau Materials : 3 sites, 4 samples

Total 19 sites, 26 samples

Descriptions on the sampling sites are given in Table G.1. Materials were sampled with consideration to the following:

1) Sampling site shall be selected at the site which represents the typical features of the surrounding river reaches and areas.

2) Bed materials shall be sampled at the waters edge after removing surface material of about 30cm thickness.

3) Slope and plateau materials shall be sampled after removing surface organic and soil materials of about 30cm thickness.

4) About one liter of soil material shall be sampled and kept in a durable plastic bag with sample number.

3.2 Physical Tests

(1) Grading Analysis

1) Sieve analysis was conducted for all the samples based on ABNT (Associacao Brasileira de Normas Tecnicas)

2) If the material finer than 0.075mm was more than 20% of the total, sedimentation analysis was conducted for the material finer than 0.075mm based on ABNT.

3) Based on the results of sieve and sedimentation analyses, a grading curve was prepared for each sample.

(2) Specific Gravity Test

Specific gravity of the sampled material was tested based on ABNT.

3.3 Results of Investigation

Results of the physical tests are shown in Tables G.2 and Fig.G.9 for the bed, slope, and plateau materials. In the table, sorting coefficient (So) and standard deviation (SD) are also presented to show the distribution of grain size of the sample materials. For the uniform material, So = SD = 1.0. The bigger values of So and SD indicate wider distribution of grain sizes.

(1) Specific Gravity

The specific gravities of bed, slope and plateau materials have no have particular characteristics. The average specific gravity is 2.75 g/cm3 ranging from 2.68 to 2.81 g/cm3.

(2) Size and Distribution

Samples from site RC1 are coarse since it is located on a steep river reach while those from sites SN1 and P4 are very uniform probably due to some peculiarity of the sampling sites. Except for the samples from sites RC1, SN1 and P4 and those from river banks, the average grain sizes and distribution of river bed, cross dike and plateau materials are summarized below.

Site	Grain size (d50:mm)		Distribution (So)	
	Average	Range	Average	Range
Cubatão R.	0.25	0.10 to 0.51	1.57	1.27 to 1.73
Pereque R.	0.19	0.085 to 0.27	1.68	1.18 to 2.24
Moji R.	0.46	0.17 to 0.85	2.87	1.72 to 3.49
Cross dikes	1.15	1.00 to 1.30	4.82	3.22 to 6.42
Plateau	0.20	0.19 to 0.20	6.71	6.32 to 6.87

Grain sizes (d50) of the Cubatão and Pereque rivers are almost same as that of the plateau, while they get coarser in the Moji river and cross dikes. The sorting coefficients of the Cubatão and Pereque rivers are small with similar values. The coefficient becomes larger of the Moji river, cross dikes and plateau materials.

The bed materials of the Moji river discussed above are limited to reaches above the railway bridge near Ultrafertil intake. Regarding the bed materials of the lower reaches, Cosipa conducted a study in 1984. The result of the Cosipa study is shown in Fig.G.10. According to the figure, coarse to fine sands predominates in the upper reaches from Cosipa, while fine sand and clay predominates in the downstream reaches.

(3) Comparison of Sediment Materials

Averaged values and gradation curves of the river bed, cross dike and plateau materials are shown in Fig.G.11. From the gradation curves the following could be seen, although the curves are prepared based on limited samples:

1) The plateau material includes a wide range of grain sizes from clay to gravel

2) Grain sizes of the Cubatão and Pereque rivers are rather uniform subject to sorting action due to water flows. In the reaches of sampling, river channels seem to be stable. According to the grading curves, around 50 % of the plateau material is deemed to be transported to do the swampy area downstream.

3) Regarding the Moji river, from the bed material sampling, river bed slope is steep and grain size is distributed over wide range from sand to gravel. From these reaches around 65 % of the plateau material is transported to the lower reaches and to the swampy areas.

4) Sediment materials of the cross dikes of the Pedras river are coarse with wide grain size range from sand to gravel. Passing through these cross dikes, around 75 % of the plateau material is transported to the downstream reaches.

4. CHANNEL SEDIMENT TRANSPORT

The channel sediment transport study aims to clarify the channel transport capacity of the lower channels of the main rivers. Sediment transport capacity is estimated first for existing channels. Subsequently, those in designed channel of the subject rivers are checked from the viewpoint of stable channel for sedimentation.

4.1 Objective River and Applied Formula

(1) Objective River Stretches

The river is divided into the two reaches, i.e., lower reaches subject to channel improvement for flood control and upper reaches subject to sabo works. In this chapter, sediment study in the lower reaches is described. Objective rivers and those stretches are as follows.

- Cubatão river: river mouth (railway bridge) - Imigrantes road bridge
- Pereque river: confluence with Cubatão - 1.5 km upstream of weir

- Moji river : river mouth (road bridge) - 1 km upstream of weir

(2) Applied Formula

Sediment transport formula developed in alluvial rivers are applied to the study. It is difficult to identify the type of sediment transport in the rivers subject to study, since channel length is short and changes in slope is abrupt. Therefore, the following bed load and suspended load formulae are applied in parallel, selecting simple and widely used formulae:

<u>Sato - Kikkawa - Ashida formula for bed load</u>

$$qB = [U*^3/(dm/dw - 1)g].P.F(to/tc)$$

where,

qB : Bed load per width per unit time
U* : Friction velocity = $(g.H.Ie)^{1/2}$
H : Water depth (m)
Ie : Energy gradient
g : Acceleration due to gravity
dm : Density of riverbed material
dw : Density of water
P : n>=0.025 : P=0.623
n< 0.025 : $P=0.623(40.n)^{-3.5}$
n : Manning's roughness coefficient
to : Tractive force
tc : Critical tractive force = g.H.Ie
U*c : Critical friction velocity
F : Function of (to/tc) by Sato-Kikkawa-Ashida formula

U*c is given by Iwagaki's formula

$R* >= 671$: $U*c^2 = 0.05(dm/dw - 1).g.d$

$162.7 <= R* <= 671$: $U*c^2 = \{0.01505(dm/dw - 1).g\}^{25/22}.dc^{-3/11}.d^{31/22}$

$54.2 <= R* <= 162.7$: $U*c^2 = 0.034(dm/dw - 1).g.d$

$2.14 <= R* <= 54.2$: $U*c^2 = \{0.1235(dm/dw - 1).g\}^{25/32}.dc^{7/16}.d^{11/32}$

$R* <= 2.14$: $U*c^2 = 0.14(dm/dw - 1).g.d$

where,

R* : $\{(dm/dw - 1).g\}^{1/2}.d^{3/2}/dc$

d : Diameter of riverbed material

dc : Dynamic viscosity of water

Brown formula for bed load and suspended loads

$$qB/U*d = 10\{U*^2/(dm/dw - 1).g.d\}^2$$

where,

qB : Bed load and suspended load per width per unit time

U*, d, dm, dw and g : same as in the above

Engelund - Hansen formula for bed load and suspended loads

$$fe.Pe = 0.1\ t*^{5/2}$$

$$fe = 2.to/(dw.V^2) = 2.g.d.S/V2$$

$$Pe = gs/\{sg[(sg/sw - 1).g.d50^3]^{1/2}\}$$

$$t* = to/\{(sg - sw).d50\}$$

where,

fe : Friction factor

d50 : Median diameter of bed material

Pe : Dimensionless sediment discharge

t* : Dimensionless shear stress

gs : Discharge of bed sediment in weight per unit width

to : sw.rb.S : Bed shear stress

d : Depth of flow

S : Slope of stream

g : Acceleration of gravity

sw : Specific weight of water

sg : Specific weight of sediment grains

V : Mean flow velocity of stream

dw : Mass density of water

rb : Bed hydraulic radius

(3) Estimation of Sediment Transport

Sediment transport capacities are estimated for the existing channel and the designed channel under 6 probable floods of 2, 5, 10, 25, 50 and 100 years which estimated in the flood analysis in ANNEX-F.

Estimation is made by the three formulae in parallel mentioned in the above.

4.2 Basic Condition of Calculation

In calculation, grain sizes of bed material are needed. The grain sizes are assumed based on the grain analysis result made for rivers by the team.

Generally, d65 (65% diameter) is used in the formulae of Sato-Kikkawa-Ashida and Brown, while, d50 in Engelund-Hansen formula. In this study, d65 is applied to all formulae for comparison.

Longitudinal grain size distribution thus obtained is presented in Fig.G.12.

4.3 Result of Calculation

In order to check each sediment capacity by the three formulae, the sediment capacity which are transported by 2 yr probable flood is presented in Fig.G.13 (1/2) for the existing channels.

According to the above figure, the estimated capacities are dispersedly in places with wider ranges. However, it may be said that the estimated capacity by Brown formula shows the averaged amount of the three cases. Accordingly, the estimated result for the probable floods by Brown formula is summarized in Fig.G.13 (2/2)

As is understood in Fig.G.13 (2/2), it can be recognized that some reaches be relatively subject to aggradation due to decreasing of sediment transport capacity of the channel thereat. Such reaches are found at places of Sections from C.10 to C.20 and C.30 to C.38 in the Cubatão river and downstream reaches of Section M.10 in the Moji river.

Further, sediment transport capacities of the designed channels are checked in view of stable channel design. The results by Brown formula for several discharges are presented in Fig.G.14.

According to the figure, sediment transport capacities of the channels are uniform with a mild increasing tendency towards upstream when the channel improvement work is realized. The balance of capacities will be more uniform compared with these of the existing. However, it is inevitable that riverbed elevations near rivermouth are more or less raised due to abrupt decreasing of flow velocity.

TABLES

TABLE G.1 DESCRIPTION OF SAMPLING SITES

SITE	SAMPLE	LOCATION
BED MATERIALS OF CUBATAO R.		
RC1	RC11	River bed at sand pit site
	RC12	Right river bank at sand pit site
RC2	RC21	River bed at sand pit site
	RC22	Right river bank at sand pit site
RC3	RC31	River bed at sand pit site
	RC32	Right river bank at sand pit site
RC4	RC4	Right water edge at opposit side of PETROBRAS intake
RC5	RC5	Right water edge
RC6	RC6	Left water edge d/s of railway bridge
BED MATERIALS OF PEREQUE R.		
RP1	RP11	Left water edge inside park (lower layer)
	RP12	- do - (surface layer)
RP2	RP21	River bed at sand pit site
	RP22	Left river bank at sand pit site
RP3	RP3	Left water edge (lower layer)
BED MATERIALS OF MOJI R.		
RM1	RM1	Right water edge (lower layer)
RM2	RM2	Right water edge at the confluence of tributary
RM3	RM31	Right water edge d/s of railway bridge
	RM32	Right bank near water edge d/s of railway bridge
CROSS DIKE SEDIMENT OF PEDRAS R.		
NO.3	NO.3	3rd cross dike from downstream
NO.4	NO.4	4th cross dike from downstream
NO.5	NO.5	5th cross dike from downstream
SLOPE MATERIAL		
SN1	SN11	Slope along Via Anchieta
PLATEAU MATERIALS		
P1	P11	Plateau near cliff along Rd. Imigrantes
P3	P31	Plateau near cliff along Caminho do Mar
P4	P41	Plateau near cliff along Route 122

Remarks: Sampling site is shown in Fig.G.9.
d/s: downstream

TABLE G.2 RESULT OF SEDIMENT MATERIAL TEST

SAMPLE	SG G/CM3	GRADATION(MM) 16%	25%	50%	65%	75%	84%	So	S.D.
RC11	2.79	0.53	0.78	4.9	11	16	30	4.53	7.52
RC12	2.73	0.066	0.08	0.13	0.17	0.19	0.23	1.54	1.87
RC21	2.71	0.25	0.31	0.51	0.69	0.93	1.5	1.73	2.45
RC22	2.81	0.068	0.08	0.18	0.31	0.85	7	3.13	10.15
RC31	2.71	0.16	0.18	0.24	0.26	0.29	0.32	1.27	1.41
RC32	2.78	0.048	0.07	0.11	0.14	0.17	0.2	1.56	2.04
RC4	2.68	0.065	0.08	0.13	0.17	0.19	0.25	1.54	1.96
RC5	2.73	0.038	0.06	0.1	0.16	0.18	0.26	1.68	2.62
RC6	2.70	0.14	0.17	0.27	0.33	0.39	0.45	1.51	1.79
RP11	2.73	0.087	0.13	0.27	0.44	0.65	1.4	2.24	4.01
RP12	2.77	0.1	0.14	0.31	0.65	1.6	6	3.38	7.75
RP21	2.70	0.16	0.18	0.22	0.23	0.25	0.27	1.18	1.30
RP22	2.74	0.091	0.13	0.2	0.26	0.34	0.47	1.62	2.27
RP3	2.74	0.04	0.05	0.085	0.1	0.13	0.17	1.54	2.06
RM1	2.73	0.069	0.09	0.17	0.24	0.29	0.35	1.80	2.25
RM2	2.73	0.3	0.37	0.85	2.2	4.5	8	3.49	5.16
RM31	2.75	0.52	0.8	3.1	10	18	24	4.74	6.79
RM32	2.72	0.15	0.19	0.35	0.46	0.56	0.69	1.72	2.14
SN11	2.77	0.0056	0.00	0.018	0.026	0.033	0.04	1.97	2.67
P11	2.78	0.0053	0.01	0.19	0.42	0.64	1	6.32	13.74
P31	2.80	0.007	0.03	0.2	0.6	1.7	3.5	6.87	22.36
P41	2.73	0.051	0.06	0.12	0.17	0.22	0.29	1.83	2.38
P42	2.77	0.049	0.06	0.11	0.16	0.21	0.28	1.87	2.39
NO.3	2.76	0.24	0.34	1	3	14	100	6.42	20.41
NO.4	2.78	0.35	0.51	1.3	2.4	5.3	19	3.22	7.37
NO.5	2.81	1.50	4.00						

REMARKS

SG: SPECIFIC GRAVITY (g/cm3)
So: SQRT(d75/d25)
SD: SQRT(d84/d16)