FIGURES

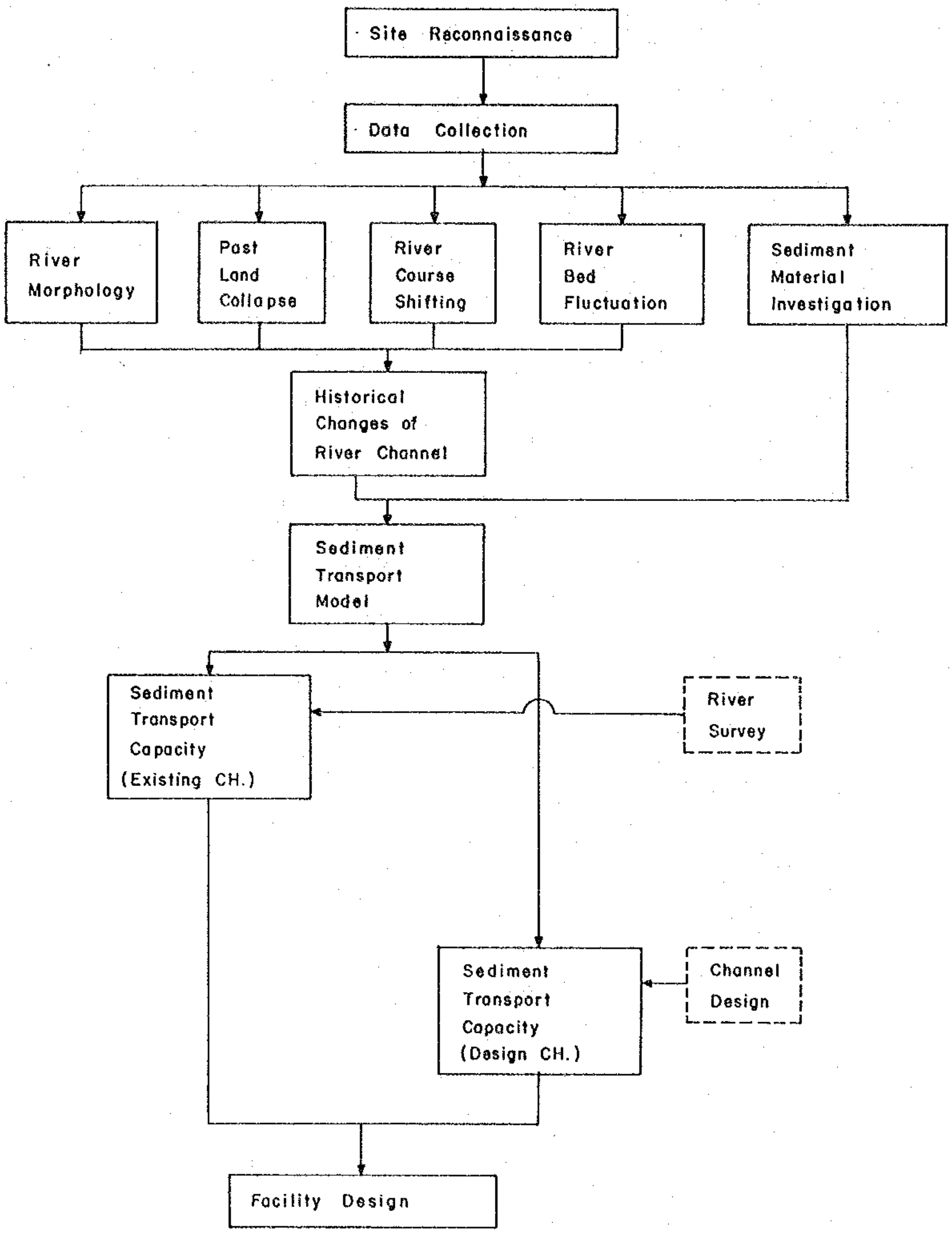

FIG.G.1
WORK FLOW OF SEDIMENT STUDY

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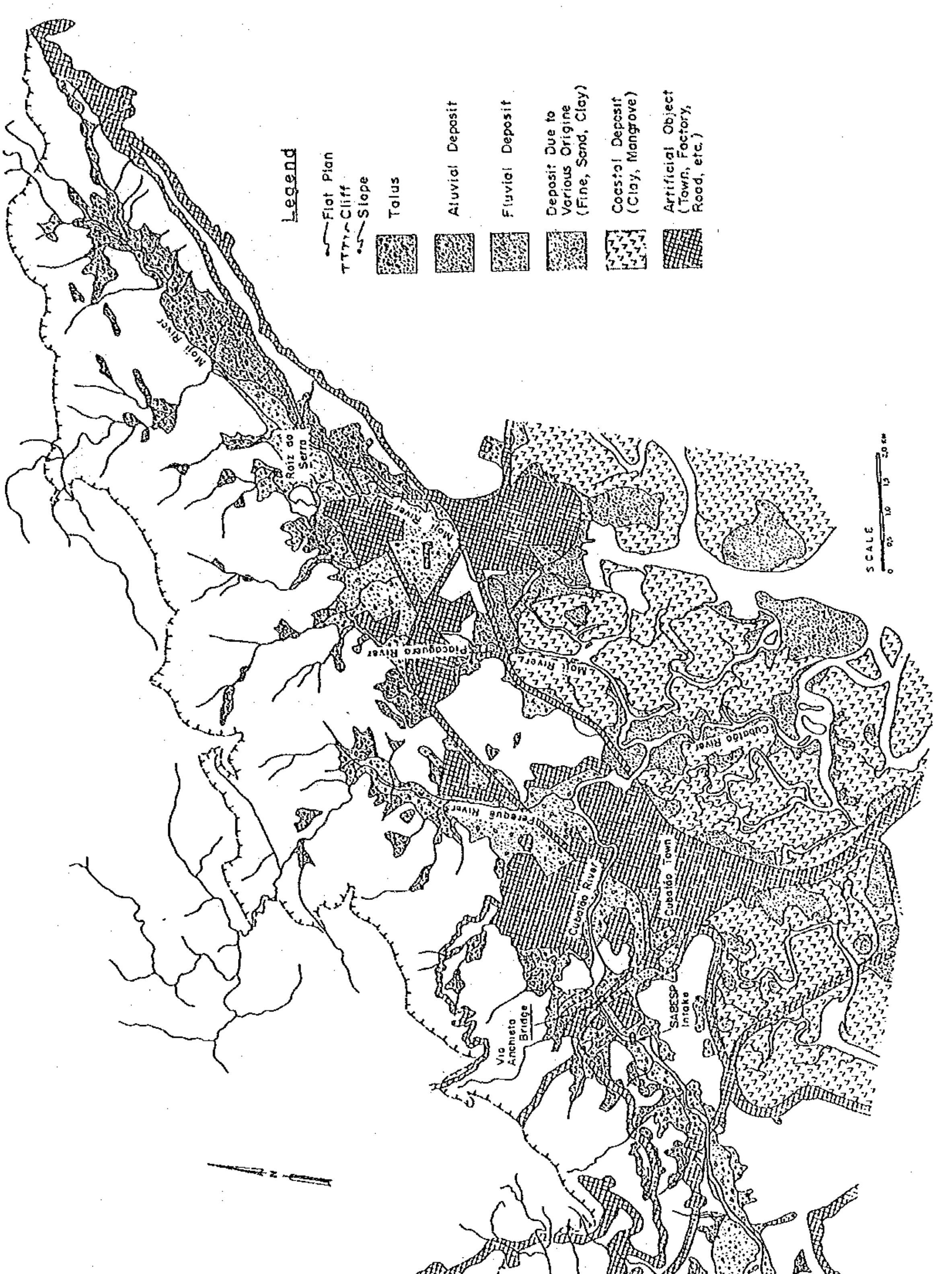

FIG.G.2
RIVER MORPHOLOGIC MAP
OF STUDY AREA

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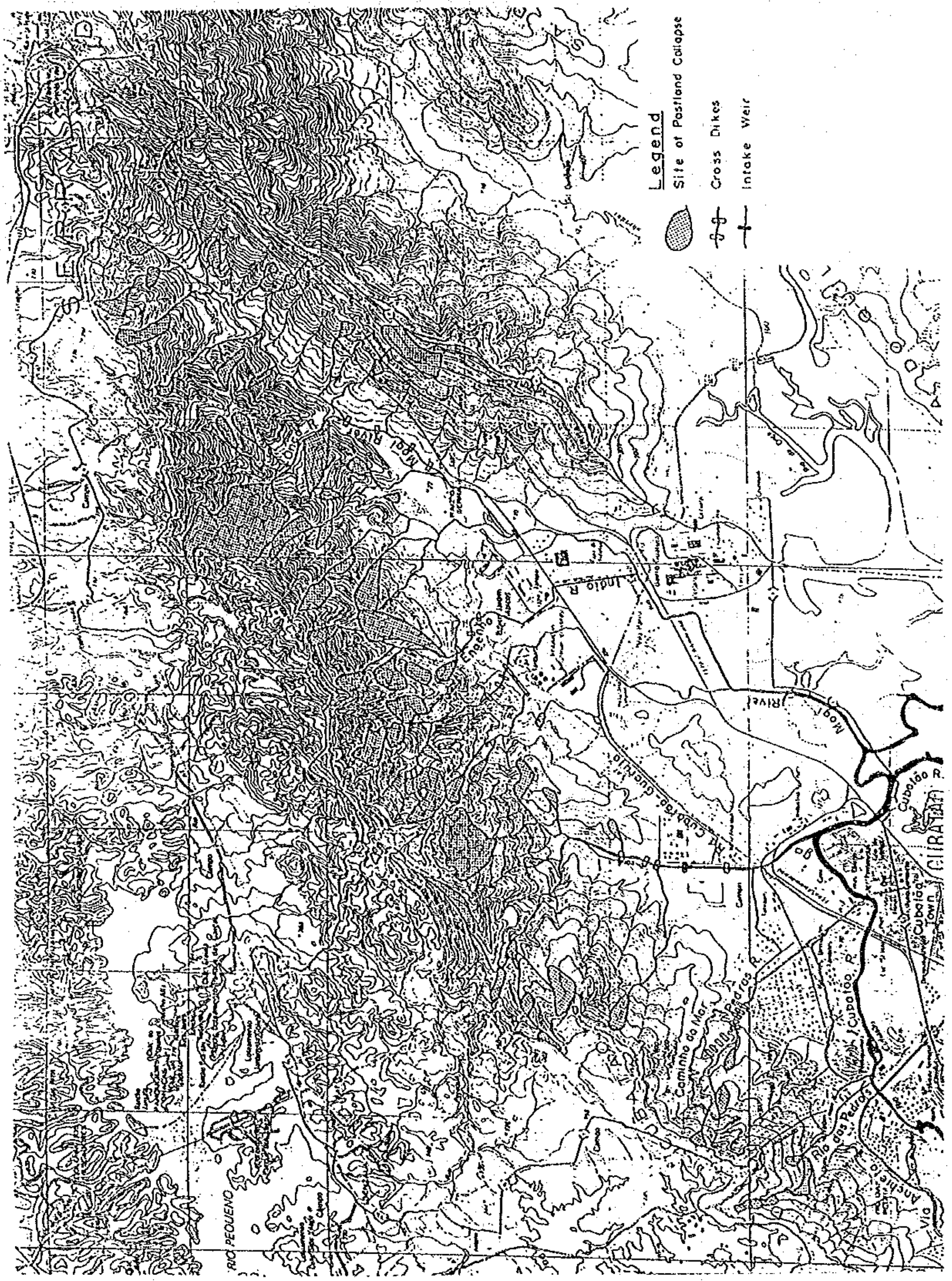

FIG. G. 3

RIVERS AFFECTED BY LAND SLIPS

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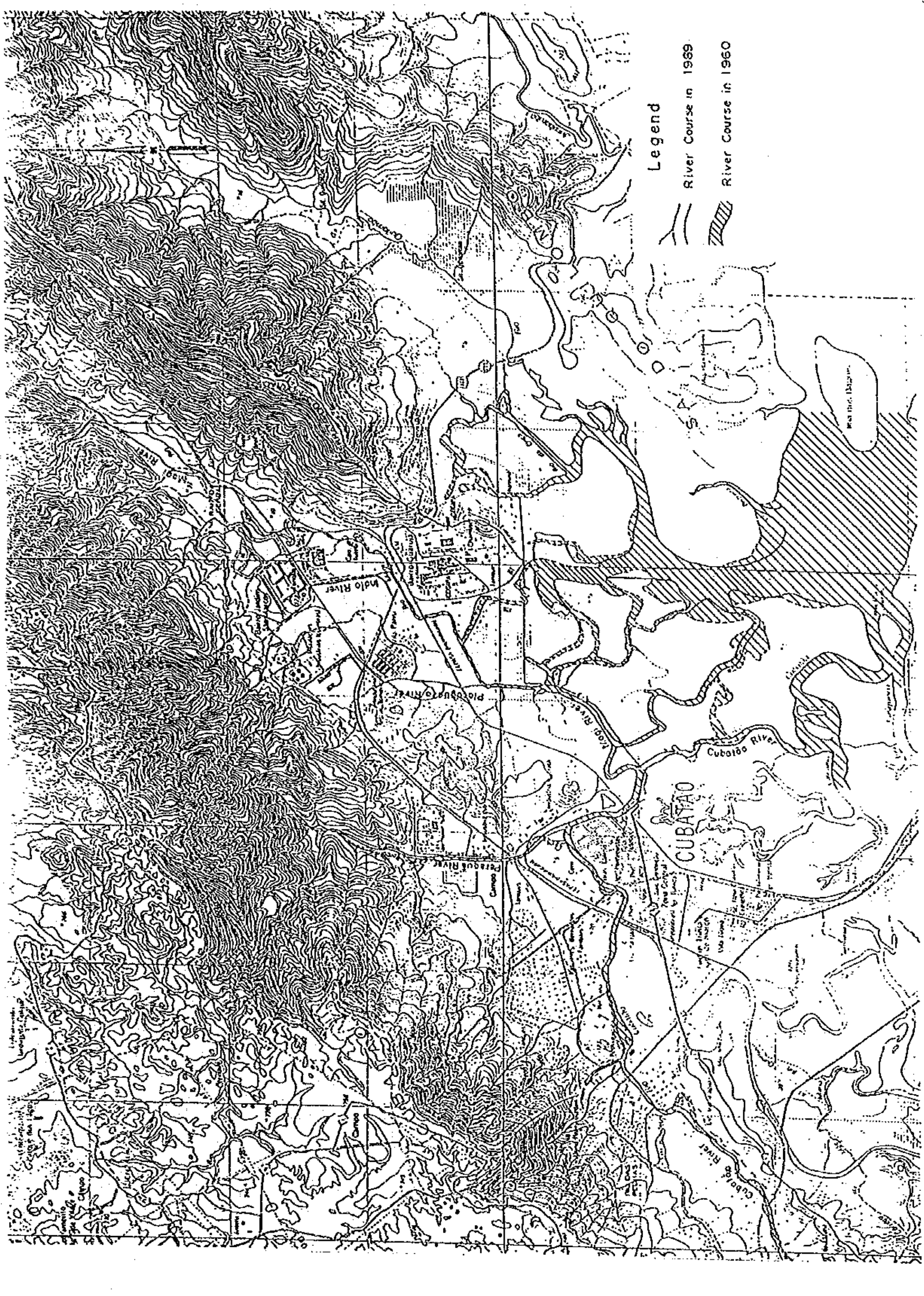

FIG.G.4

RIVER COURSE SHIFTING

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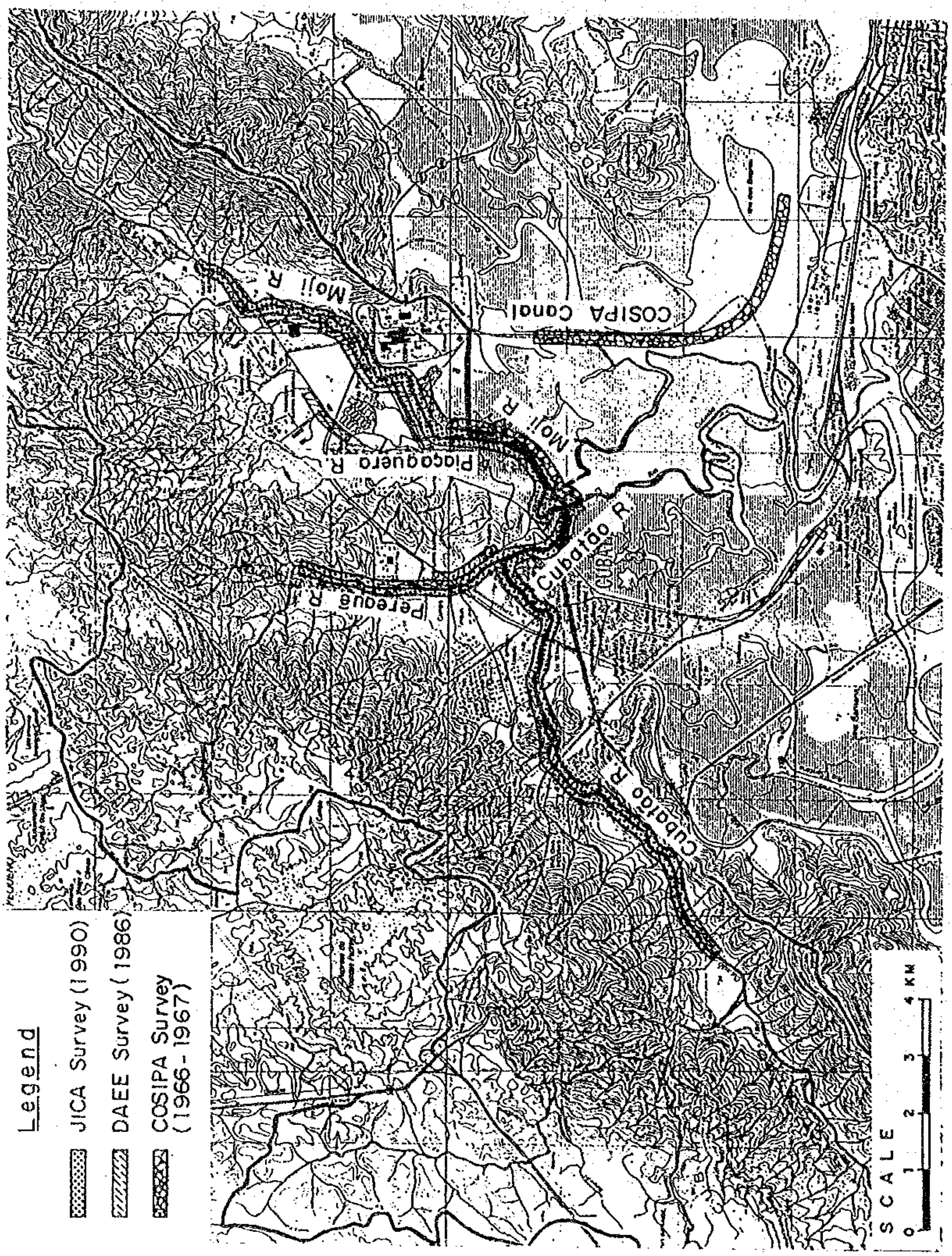

FIG.G.5
LOCATION MAP OF AVAILABLE
CHANNEL SURVEY RESULTS

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REPUBLIC OF BRAZIL

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RESTORATION PROJECT IN SERRA DO MAR,
CUBATÃO REGION, STATE OF SÃO PAULO

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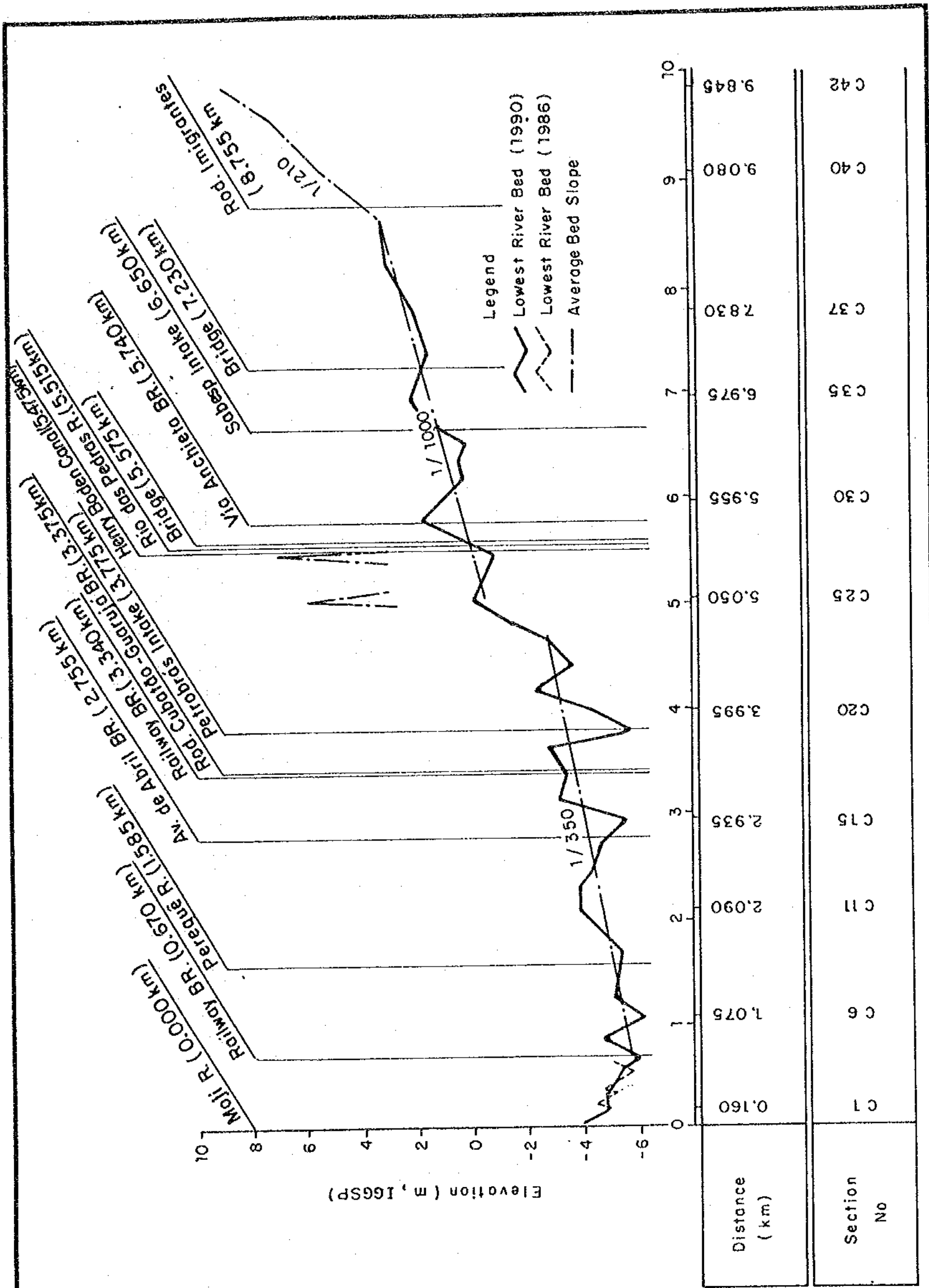

FIG.G.6
RIVER BED FLUCTUATION
(CUBATÃO RIVER)

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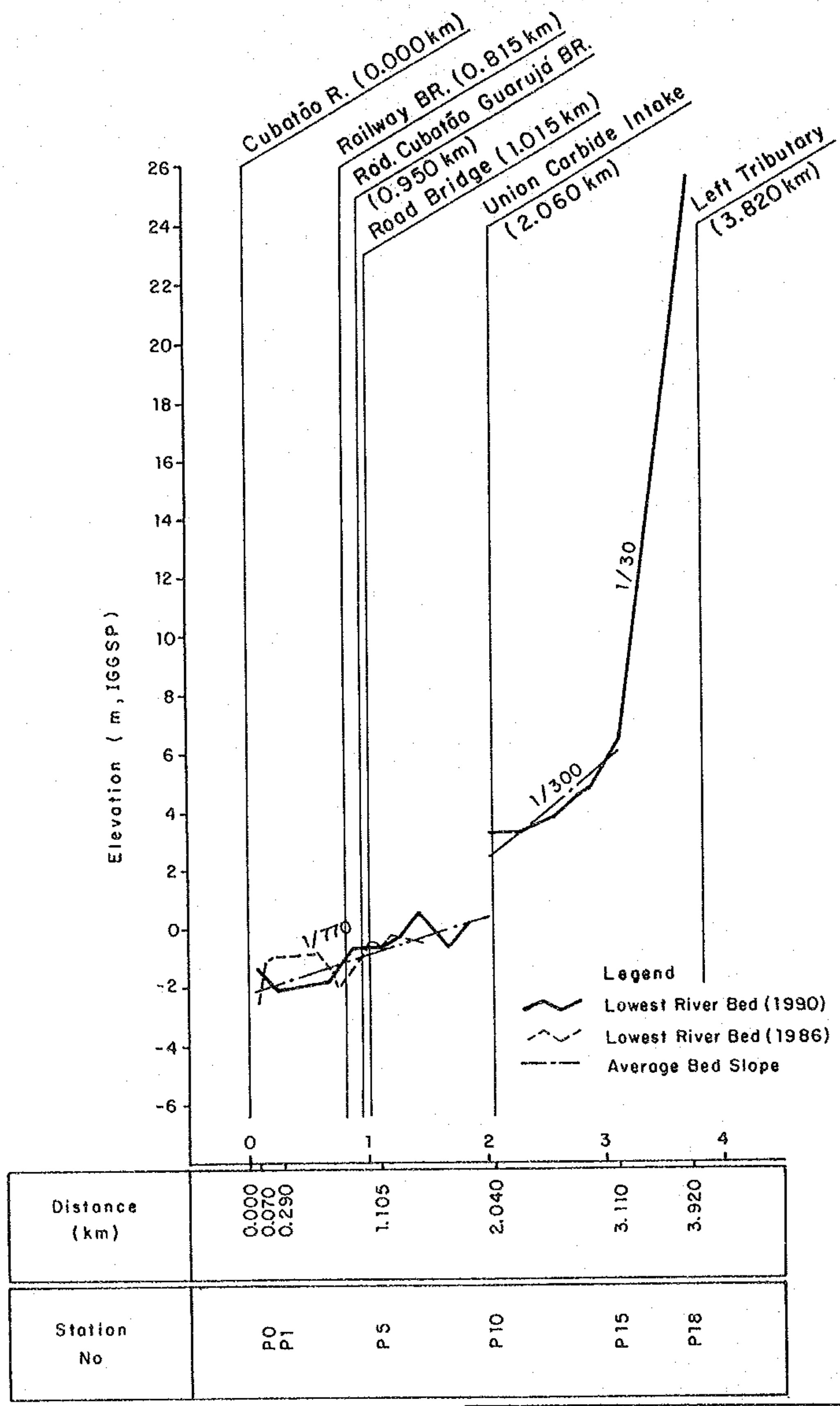

FIG.G.7
RIVER BED FLUCTUATION
(PEREQUE RIVER)

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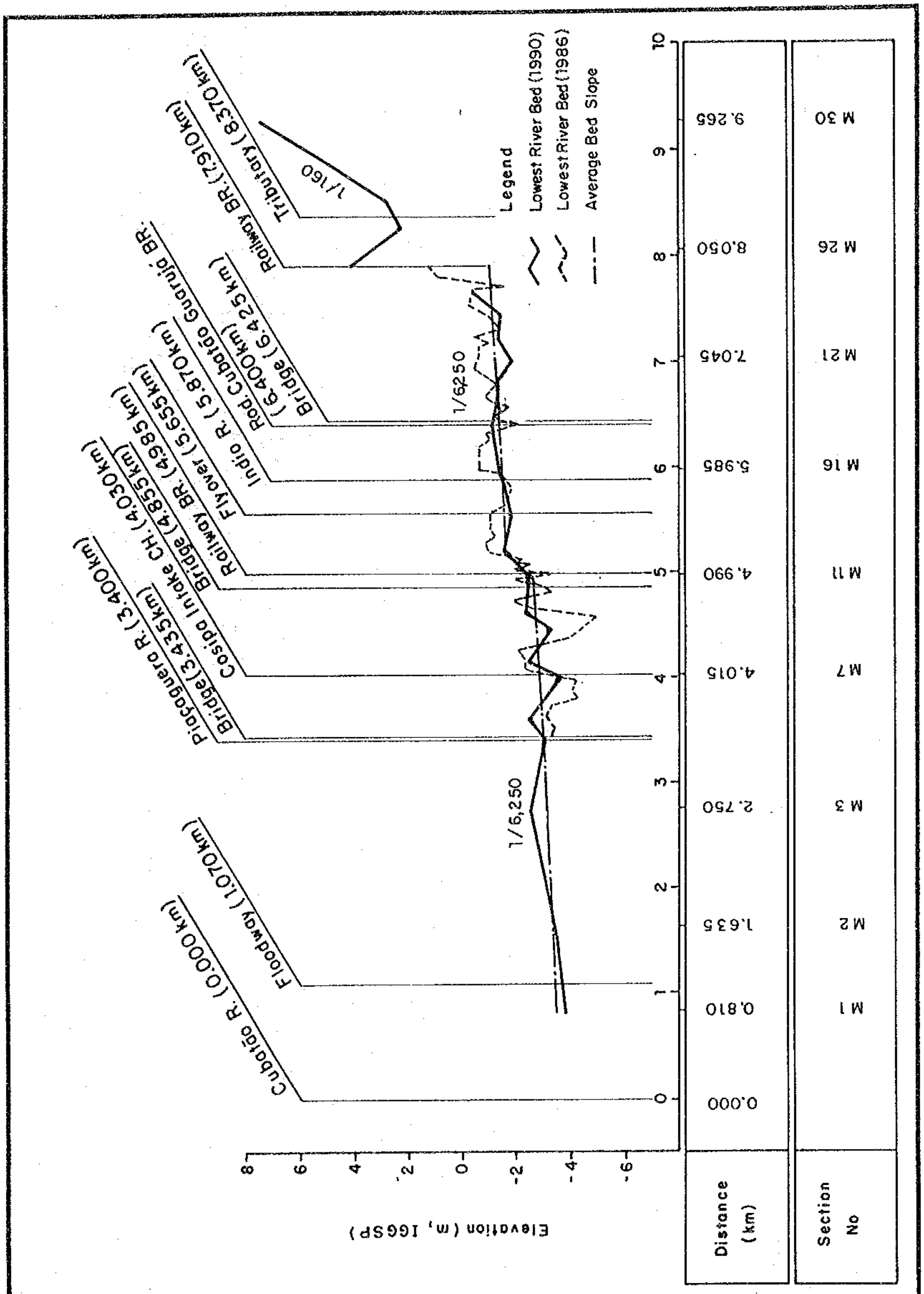

FIG.G.8
RIVER BED FLUCTUATION
(MOJI RIVER)

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REPUBLIC OF BRAZIL

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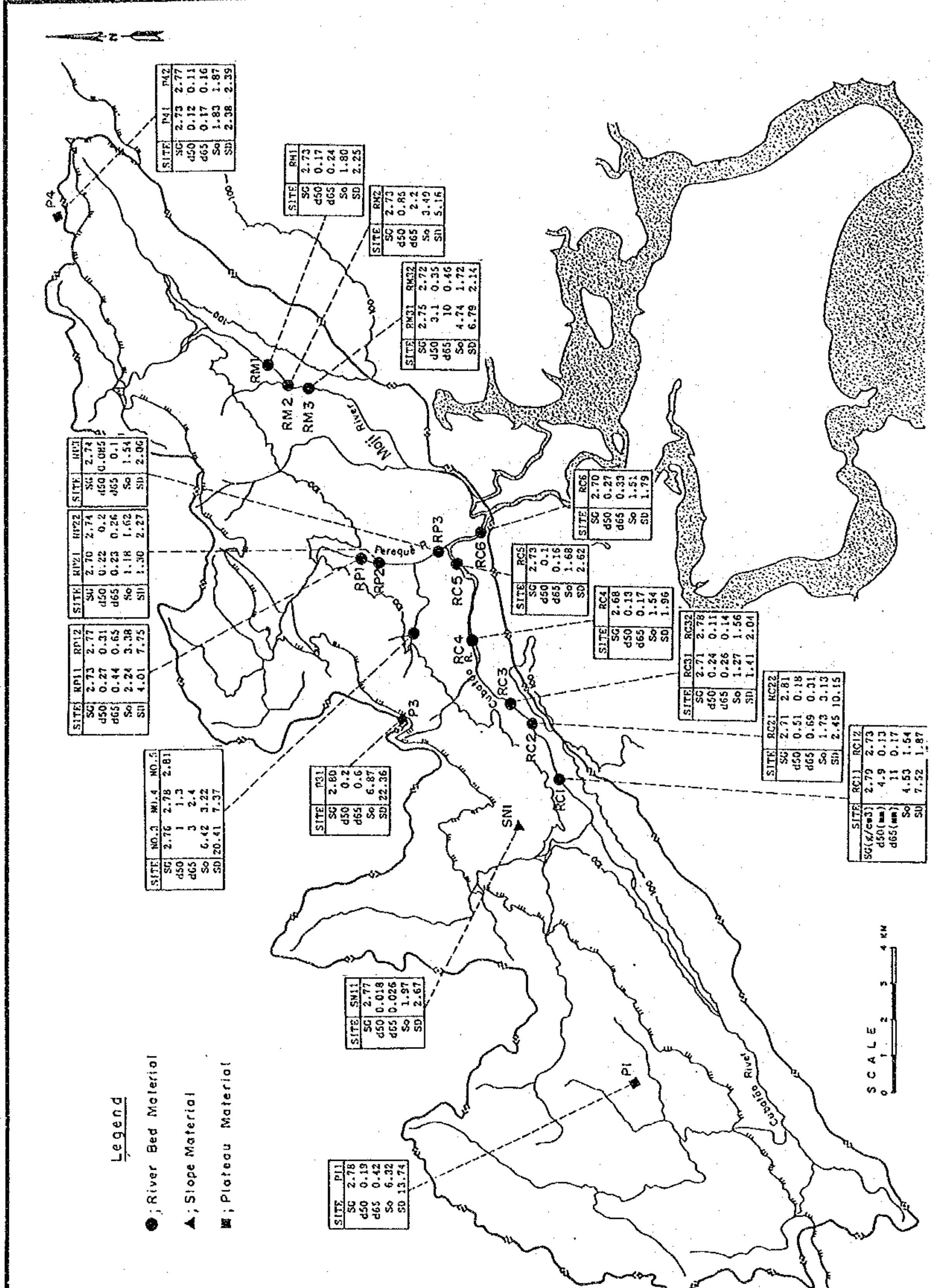

FIG.G.9
SEDIMENT MATERIAL SAMPLING SITES AND TEST RESULT

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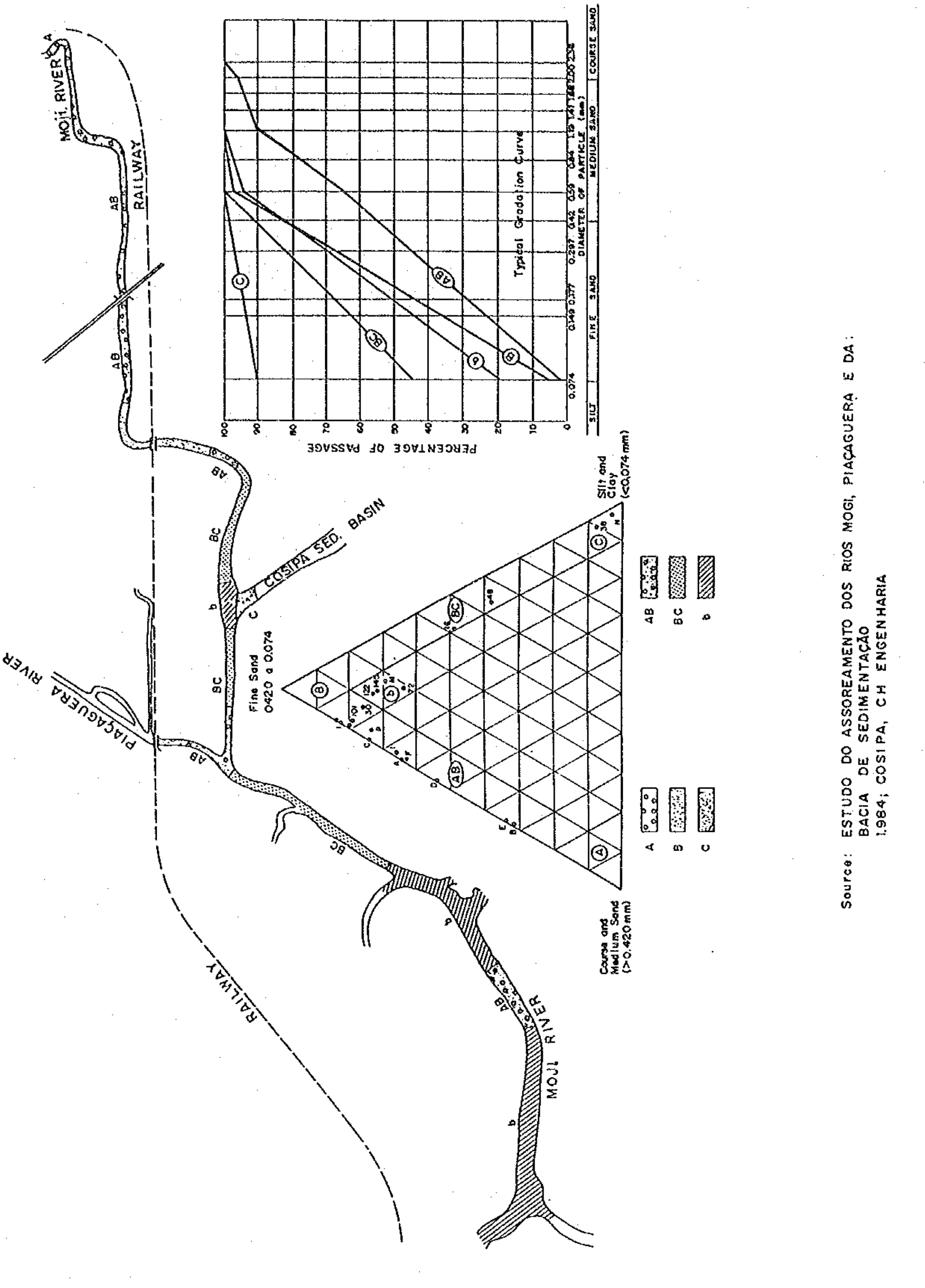

FIG.G.10
BED MATERIALS OF LOWER MOJI RIVER

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CUBATÃO REGION, STATE OF SÃO PAULO

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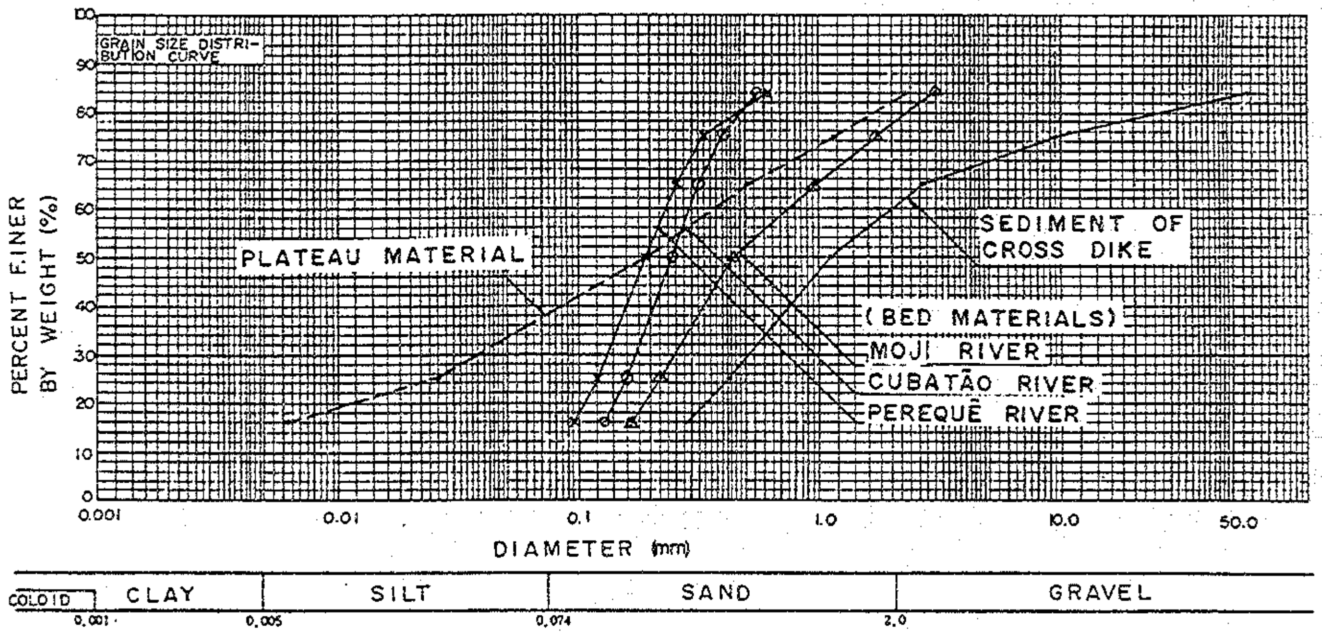

SITE(SAMPLE USED)	GRADATION(MM) 16%	25%	50%	65%	75%	84%	So	S.D.
CUBATAO R.(RC21,31,4,5,6)	0.1306	0.1608	0.25	0.322	0.396	0.556	1.569	2.063
PEREQUE R.(RP11,21,3)	0.0956	0.1216	0.1916	0.2566	0.3433	0.6133	1.679	2.532
MOJI R.(RM1,2,32)	0.173	0.2166	0.4566	0.9666	1.7833	3.0133	2.868	4.173
PLATEAU (P11,31)	0.0061	0.026	0.195	0.51	1.17	2.25	6.708	19.12
CROSS DIKE (NO.3,4)	0.295	0.425	1.15	2.7	9.65	59.5	4.820	13.89

FIG.G.11
AVERAGE GRADATION CURVES

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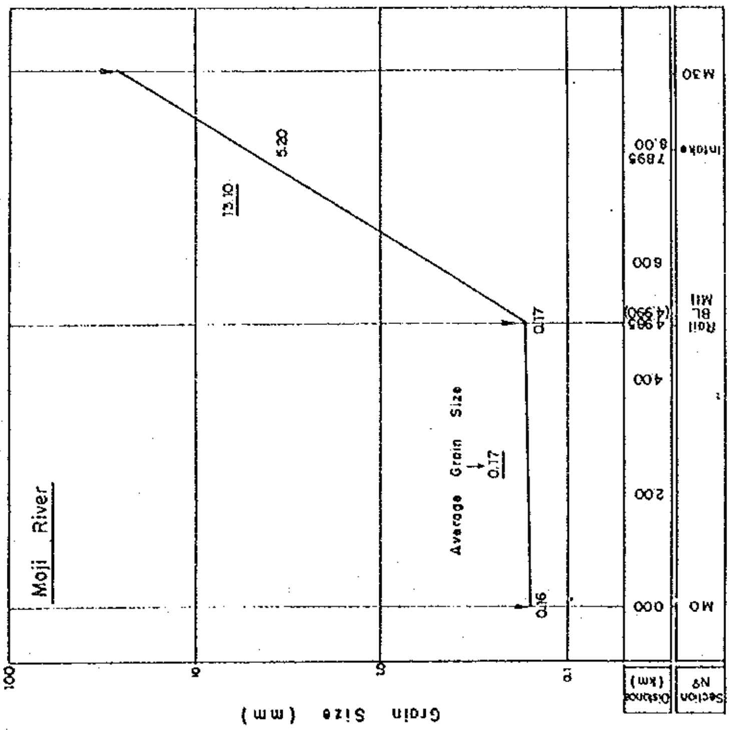

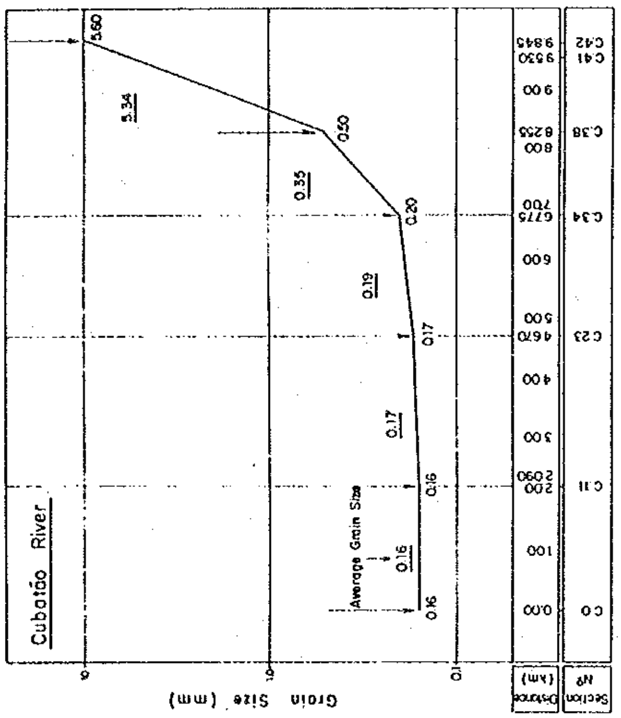

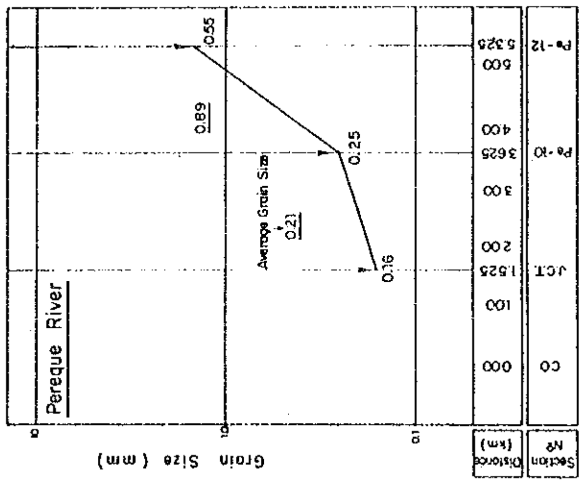

FIG.G.12
GRAIN SIZE DISTRIBUTION

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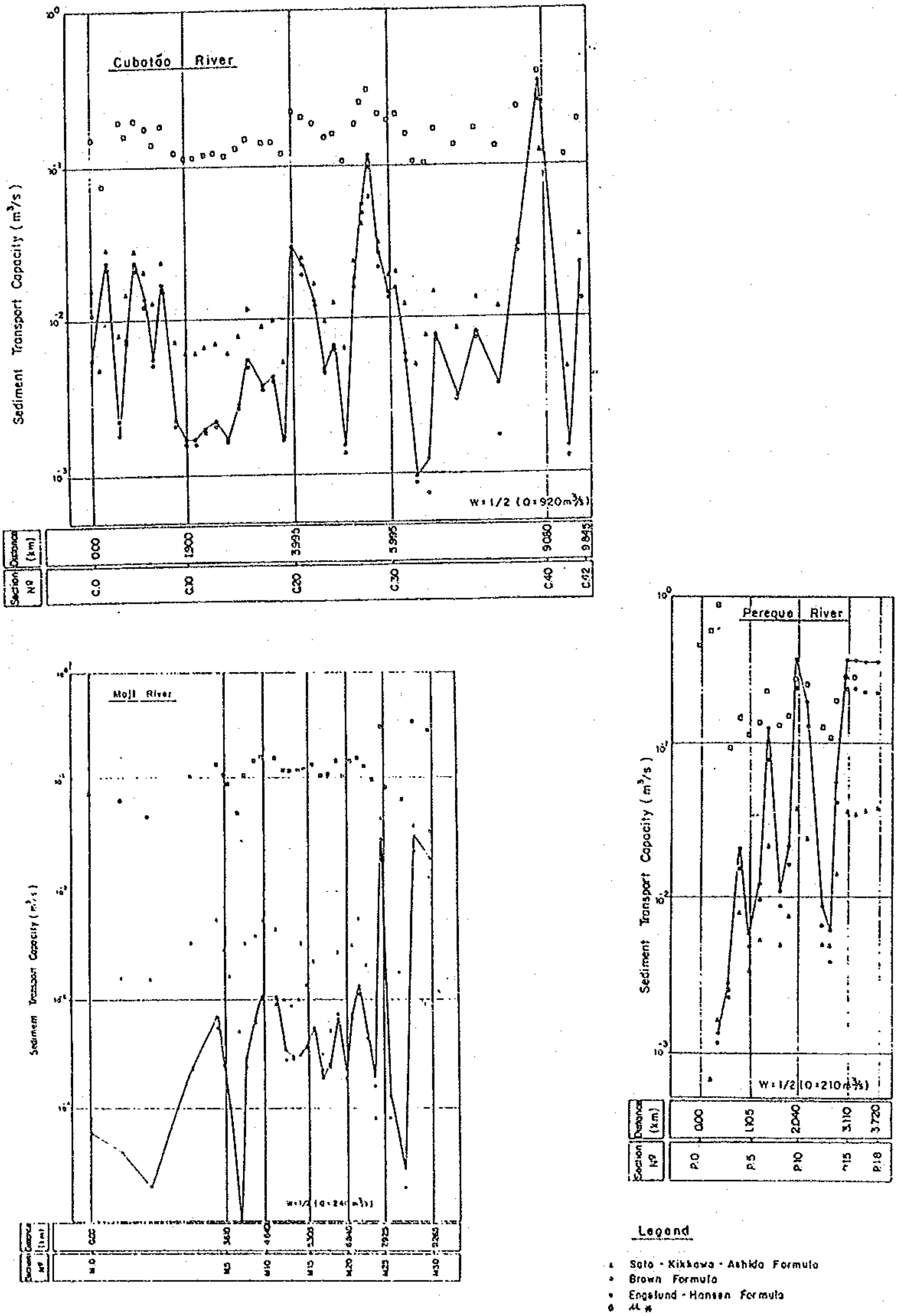

FIG.G.13 (1/2)
SEDIMENT TRANSPORT CAPACITY
IN EXISTING CHANNEL

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RESTORATION PROJECT IN SERRA DO MAR,
CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

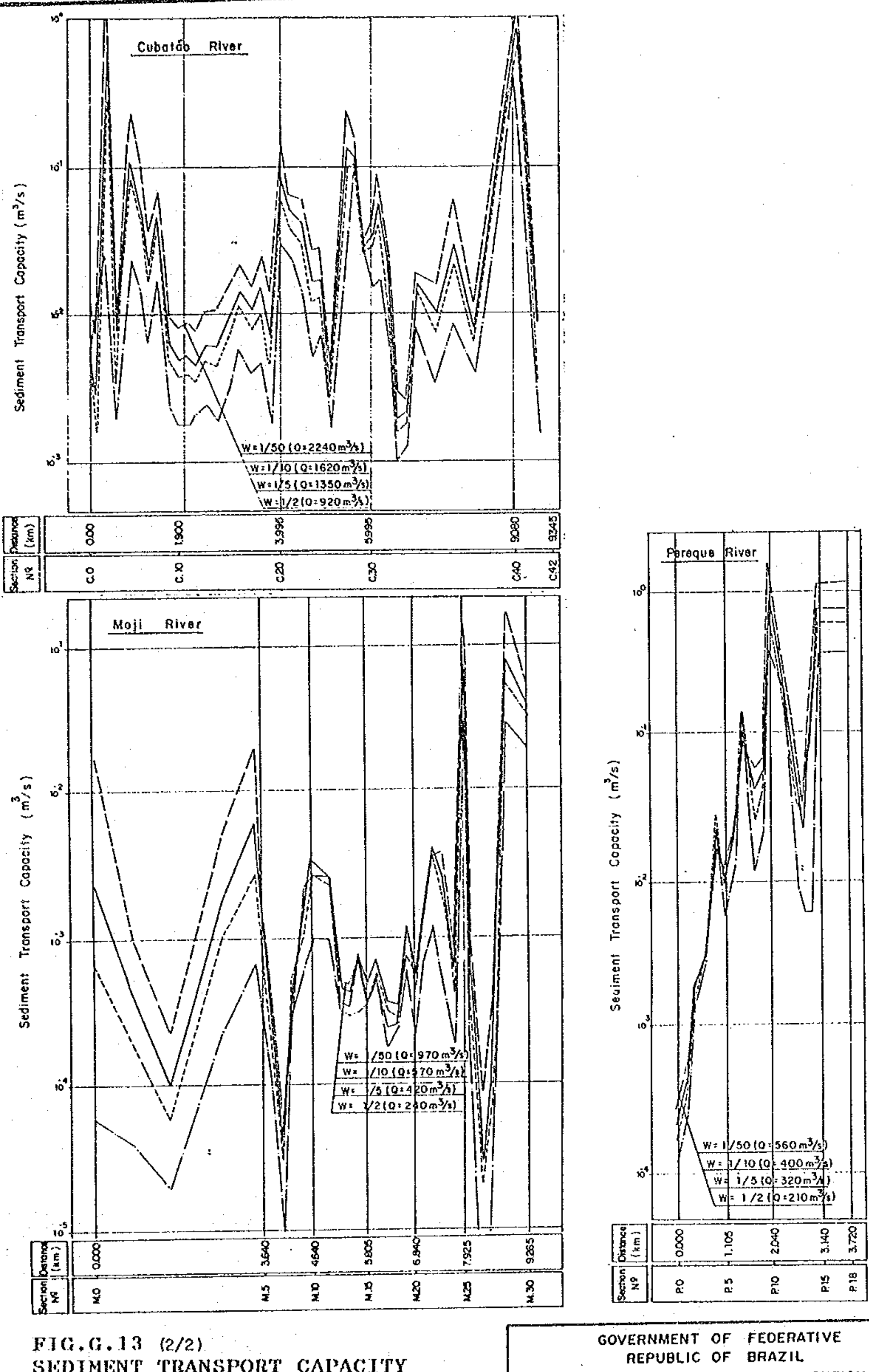

FIG.G.13 (2/2)
SEDIMENT TRANSPORT CAPACITY
IN EXISTING CHANNEL
(by Brown Formula)

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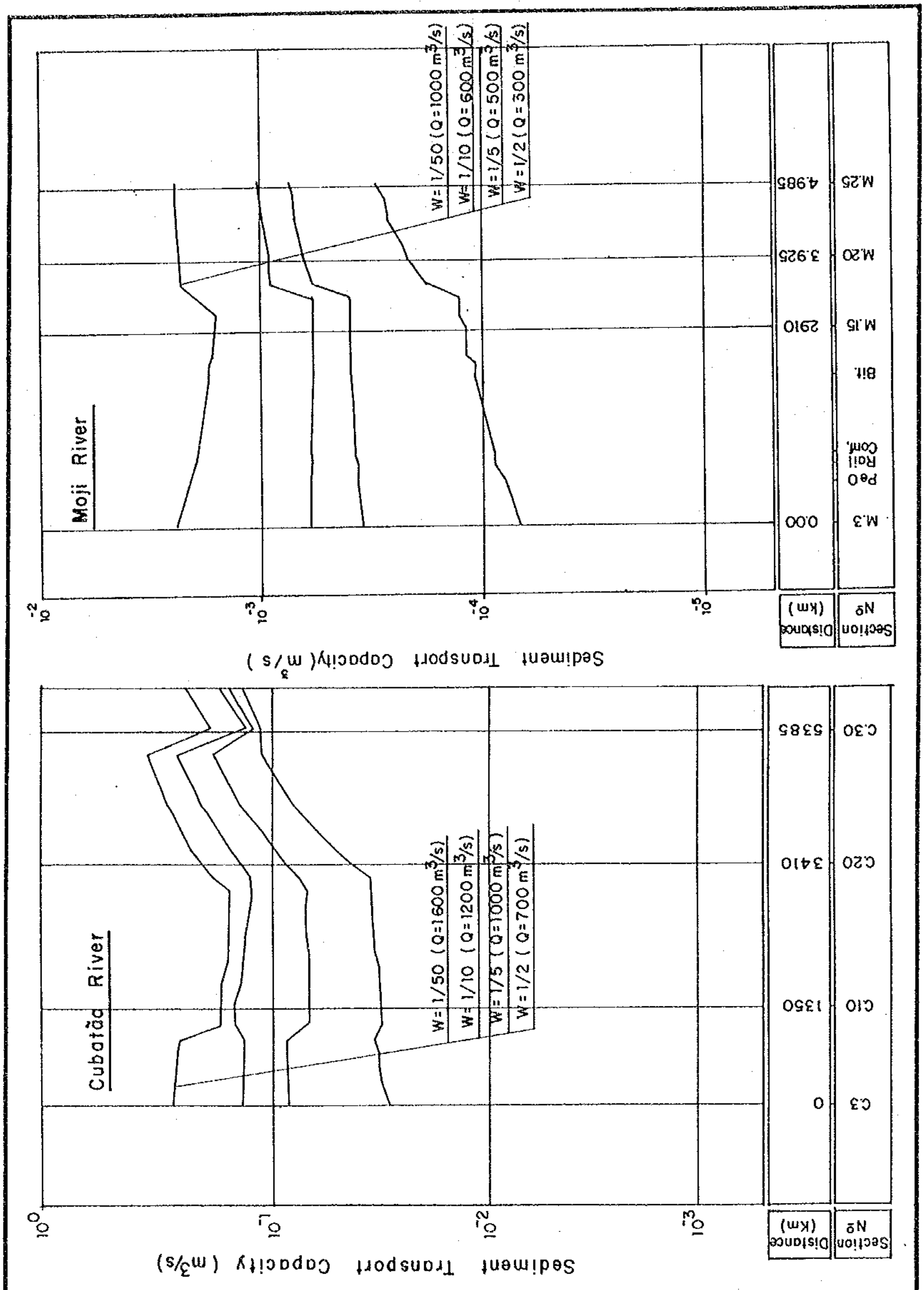

FIG.G.14
SEDIMENT TRANSPORT CAPACITY
IN DESIGNED CHANNEL
(by Brown Formula)

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RESTORATION PROJECT IN SERRA DO MAR,
CUBATÃO REGION, STATE OF SÃO PAULO

JAPAN INTERNATIONAL COOPERATION AGENCY

ANNEX H

SEDIMENT RUN-OFF DISASTER PREVENTION STUDY

TABLE OF CONTENTS

Page

LIST OF TABLE

LIST OF FIGURES

1. INTRODUCTION

This ANNEX-H describes the sediment run-off disaster prevention study of the master plan carried out from the beginning of December, 1989 to the end of March, 1990 and the middle of June, 1990 to the middle of August, 1990 in Brazil.

The purposes of the study are as follows:

(1) to clarify past major disaster conditions and characteristics of sediment run-off.

(2) to review the existing facilities protecting sediment run-off disasters.

(3) to formulate a master plan on the sediment run-off disaster prevention.

(4) to select a priority project among the master plan formulated.

The data available to the study were obtained from IPT, CETESB, DAEE, CTH and other related agencies. The basic concept, sediment run-off amount, structural layout and so on, were determined through the close discussion with IPT stuff.

2. PAST MAJOR SEDIMENT RUN-OFF DISASTERS

Slope failures and unstable torrent bed deposits in the tributaries of the Moji and the Cubatão Rivers are considered to be the main sources of sediment run-off in the study area.

Aiming at the detailed evaluation, the study area has been divided into 17 sectors, including 9 sectors selected by the Special Commission in 1985, as shown in Table H.1 and Fig. H.1.

A large number of small scale landslides on the steep slopes (hereinafter referred to as slope failures) have occurred every 5 to 10 years in times of heavy rain from November to April in the past 30 years, 1962-1989. Past major sediment run-off caused by slope failures are listed as follows:

Date of occurrence			Slope failures in the study area	
Year	Month	Day	Number	Total area (x10E4 m^2)
1962	---	---	40	7.6
1971	Feb	24-27	218	70.6
1976	Jan	27-30	303	94.4
1980	Feb	18-19	187	58.6
1985	Jan	22-25	905	194.3
1988	Dec	20-22	215	103.4

Note: Data of 1962 is not certain.
: Number and total area of slope failures in the study area are estimated by aerial photograph interpretation.

Concept of the sediment discharge in 1985 was reported to have caused great damage to a portion of the factory facilities as a result of a large number of slope failures which occurred on the mountain slopes.

According to information from various agencies and the field interviews conducted by the study team with local inhabitants in the study area, past major disasters from sediment run-off, shown in Table H.2 and Fig. H.2, may be summarized as follows:

(1) Railway bridge (1971)

The railway bridge on the left branch of the Moji River was destroyed by sediment run-off/debris flow. At present another railway crossing the branch is utilized without any slope failure disaster.

(2) Copebrás (1976)

Sediment run-off derived from the slope failures occurred upstream of the Canal Norte and the Cachoeira Rivers in the rain of Jan 27-30 1976. Sediment run-off flow into the factory amounted to about 1x10E5 m^3 on the basis of the deposit removal record.

After this disaster several structural measures such as rock and earth dams, concrete block dam, riprap cross dam and spilway were introduced to prevent sediment run-off. These structural measures were constructed between January and September in 1978 by Copebrâs.

(3) Petrobrâs (1985)

Sediment run-off/debris flow reached near the storage tanks located at the foot of the mountain area in the factory of Petrobrâs on January 22-25, 1985. Afterwards, a series of 9 gabion dams were built on the upstream of the factory.

(4) Rio Das Pedras (1988)

A flood with sand, gravel and timber, and other debris flow, occurred on January 20-22, 1988 about 1 km upstream of the confluence of the Rio das Pedras River and the Cubatão River. Nine(9) inhabitants were killed, three(3) bridges and several houses were destroyed.

3. CHARACTERISTICS OF SEDIMENT RUN-OFF

3.1 Slope Failures

3.1.1 Distribution

Interpretation of the aerial photographs as shown in Table H.3 taken in 1962, 1972, 1977, 1980/81, 1985, 1989 was performed to reveal the past slope failures distribution and their features.

The distribution maps of total slope failures in the last 30 years, 1962-1989, and individual past major slope failures were prepared as shown on Fig. H.3 and Fig. H.4, respectively. Number and area of the slope failures in every sector were also summarized in Table H.4.

As a result of the interpretation analysis, the followings were concluded:

It was clear that almost all the slope failures occurred on the mountain slopes of the Moji River, the Perequê River and the lower Cubatão River basins.

Each sector can be classified into 5 groups as indicated in the following table on the basis of the number of the past slope failures in 1962-1982 shown in Table H.5. Fig.H.5 shows the classified sectors and especially, group A, B and C were judged to be susceptible area to slope failures.

Group	Sector	Number of slope failures per km^2 in 1962-1989	Main factories of downstream
A	MR-2,MR-3	50-70	Ultrafêrtil, Copebrâs
B	MR-1,CL-6,CL-7	30-50	Union Carbide, Petrobrâs
C	MR-5,ML-1,CL-5	10-30	ELETROPAULO
D	CL-3,CL-4,CL-8	5-10	
E	CR-3,CL-1,CL-2	less than 5	

From Table H.6 and Fig.H.7, it was found that group A and B have a tendency to increase their number of slope failures rapidly since 1971 comparing with group C,D and E.

3.1.2 Dimension

As illustrated in Fig.H.6, slope failures in the study area may be defined as a typical landslide of colluvial soil and saprolitic soil with a thickness of 0.5-2.0m and 0.7m on an average. The dimensions of slope failures were discussed and determined between the study team and IPT staff based on the interpretation results of aerial photographs and the field investigation results provided by IPT as shown below.

Average slope failures in study area		
Area(m^2)	Depth to slip surface(m)	Volume(m^3)
2420	0.7	1700

As for the average scale of slope failures, the area was calculated by using aerial photographic interpretation and depth to slip surface was determined by the IPT's field investigation result. Volume was obtained by multiplication of area and depth to slip surface.

3.1.3 Cause and trigger

In considering the cause and trigger of slope failures, slope gradient, slope configuration and vegetation conditions can be pointed out as main cause coupled with intensive rainfall.

From the viewpoint of soil mechanics, the reduction of apparent cohesion at the slip surface by the vertical infiltration and the saturated zone enlargement with time are considered to be main cause of the slope failures in the mountain slopes underlain by migmatites and schists of Pre-Combrian age. The detailed mechanism of the slope failure was revealed by C. M. Wolle(1989) and C. S. Carvalho(1989) in IPT.

A similar type of slope failures with a thickness of approximately 1-2 m may be seen on decomposed granite slopes in Japan.

Thus the cause and trigger of the slope failures could be summarized as follows:

(1) Slope gradient

A map of the slope gradients in the study area made by IPT and the study team, as shown on Fig. E.7 (see ANNEX-E), which indicates that both the Moji and the Cubatão Rivers are similar in regard to slope gradient. Table H.7 shows the relationship between slope failures and the slope gradient. The number of slope failures at different gradients is shown in the following table.

Number: per km^2

Gradient	$i < 20^o$	$20^o \leqq i < 30^o$	$30^o \leqq i < 40^o$	$i \geqq 40^o$
Number of slope failures	1.2(1.6%)	14.7(18.2%)	25.1(31.9%)	47.1(48.3%)

Note: i means slope gradient

It is found that the slopes with gradients of less than 20^o are free from slope failures but those greater than or equal to 30^o are susceptible to slope failures.

(2) Slope configuration

The relationship between the slope failures and configuration is shown in Table H.8 and a map of the slope configuration was prepared by IPT on Fig. E.8 (refer to ANNEX-E). The relationship may be summarized as follows:

Number: per km^2

Configuration	Rectilinear	Convex	Others
Number of slope failures	30.9(59.0%)	17.8(34.0%)	3.7(7.0%)

Note: Others means mainly slope underlain by talus

It is found that the ratio of slope failures on a rectilinear slope is highest followed by a convex slope and few slope failures can be recognized on talus slopes.

(3) Vegetation

The relationship between changes in vegetation and slope failures was evaluated by using the vegetation maps of 1962, 1972, 1977, 1980 and 1985 obtained from CETESB and IPT. These vegetation maps cover the Moji, the Perequê and the lower Cubatão River basins where vegetation conditions have been degraded by air pollution but only the map of 1985 can cover the entire study area as shown in Fig. H.8.

From the vegetation point of view, the Moji, the Perequê and the lower Cubatão River basins have been divided into four(4) zones by CETESB and IPT as shown in the following table.

Zone	Degree of air pollution	Vegetation community
I	not affected	M, Cp
II	moderately affected	M-Fr, Cp-A, Cp-N
III	affected	M-Me, M-Fo, Cp-Fr
IV	strongly affected	Cp-Fo, Cp-N-Re

Note: For vegetation communities see ANNEX-J

Changes in the number of slope failures in the affected vegetation area are shown in Table H.9 and Table H.10. The evaluation results may be summarized as follows:

As a result of analysis of vegetation changes and slope failures shown in Fig. H.9, it can be concluded that the change in vegetation caused by air pollution is one of main cause of slope failures because both vegetation degradation and changes in vegetation community have been recognized at the same level since the mid-1970s in the pollution affected area. It is noteworthy that about 80 percent of the area had changed into polluted vegetation by 1977 and more than 95 percent by 1985.

From the following table, it will be seen that slope failures per km^2 in zone I, not-affected vegetation, varies from 0.1 to 2.6 in number. While, zones II, III and IV where the vegetation is being affected shows high values of 2.8 to 14.8. Therefore, the degradation of vegetation is judged to be able to induce slope failures in the study area.

Zone	Number of slope failures per km^2					
	1962	1971	1977	1980	1985	1989
I	0.4	2.6	0.2	0.5	0.1	2.2
II	-	9.1	4.1	3.5	14.8	3.9
III	-	-	7.5	2.8	13.8	5.0
IV	-	-	-	-	6.7	13.0

Note : - means no area occupied

In the affected vegetation area, water can easily penetrate into the colluvial soil and induce slope failures due to root decay.

(4) Rainfall

It is well known that heavy rainfall triggers slope failures and then sediment run-off occurs due to unstable torrent bed deposits. Past major rainfall, actual N-hour maximum rainfall, related to sediment run-off is listed below (refer to ANNEX F).

Actual N-hour Maximum Rainfall

unit:(mm)

Year	1-hour	2-hour	3-hour	4-hour	6-hour	12-hour	24-hour
1976	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	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	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	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)

Relationship between rainfall and slope failures was analyzed by using actual rainfall records obtained from E3-038R Station of DAEE, located in the middle reaches of the Moji River, and slope failures analysis results. The summarized results were as follows:

With regard to occurrence conditions of slope failures, the Special Commission has clarified the relationship of slope failures and rainfall, hourly rainfall intensity and accumulated rainfall until the occurrence of slope failures, as shown in Fig.H.10. Actual rainfall data corresponding to the major past failures of 1976, 1980, 1985 and 1988 are illustrated and compiled in Fig.H.11 and Table H.11, respectively.

Correlation analysis between actual N-hour maximum rainfall and total area of slope failures per Km^2 shown in Table H.12 was carried out for group A, B and C.

As a result of the analysis, six (6) hour rainfall was considered to be the best index for estimating the total area of slope failures because of the high correlation coefficient of more than 0.94 as shown in Fig.H.12. Therefore, the following equations can be proposed as estimate-equations of slope failures area and amount of six (6) hour rainfall.

Unit: $Y(m^2 x 10^3)$, X(mm)

Group	Equation	Correlation Coefficient
A	$Y = 0.46(X-63.3)$	0.940
B	$Y = 0.30(X-80.6)$	0.944
C	$Y = 0.21(X-80.3)$	0.971

Note: Y means total area of slope failures per km^2
X means six hour maximum rainfall

3.2 Torrent Bed Deposits

3.2.1 Distribution

The distribution of torrent bed deposits was revealed by interpretation of aerial photographs of 1987 at a scale of 1 to 10,000. A distribution map of torrent bed deposits is shown on Fig.

H.13.

3.2.2 Dimension

Sand and gravel with thin layers of silt/clay is typical of torrent bed deposits and one of the main sources of sediment run-off. However, particle size of the deposits depends on the river conditions such as gradients of river course, width, meandering conditions and geological conditions, etc.

Gradation curves of the torrent bed deposit at the gabion dams of Petrobrás, as shown in Fig. G.11, indicate that particle size of the deposits ranges from silt to pebble.

On the other hand, boulders with a diameter of approximately 50 cm or more are scattered in the river course of the Rio das Pedras and upstream of each tributary.

3.2.3 Erosion

Torrent bed deposit conditions were investigated by the study team for the purpose of estimation of erosion scale and thickness of deposit by the past floods in order to estimate sediment run-off amount.

The cross section shown in Fig. H.14 suggests that torrent bed deposits, which had been carried from upstream by sediment run-off in heavy rain, may range in thickness from 0.3m to 1.0m and around 0.5m on an average.

4. EXISTING FACILITIES PROTECTING SEDIMENT RUN-OFF DISASTER

The main structural measures to protect the factory areas and residential area, such as cross dams made of riprap stones, gabions and earth materials, dikes and channel works, are described in detail in ANNEX C. Main structural measures are summarized as follows :

(1) Sector 1 (Moji)

Four (4) riprap cross dams in the middle reaches of the Moji river, around 60 m long and 1.5 m high, will be sufficient for sediment control and river bed stabilization but they are judged to be temporary structures because of random arrangement of riprap materials. It is recommended they be re-constructed in concrete materials.

(2) Sector 2 (Ultrafertil)

A series of three (3) gabion dams have been constructed upstream of the factory. Three(3) gabion dams with storage capacity of 24,800 m^3, 138,200 m^3 and 44,200 m^3 in ascending order may be expected to be sufficient but rather fragile to direct attack of sediment run-off because of many destruction examples of this kind dams in Japan.

A dike built of industrial waste with a height of about 10m in the factory may be deemed to play an important role as a protection wall against sediment run-off.

(3) Sector 3 (Copebras)

Two(2) rock and earth dams and two(2) riprap cross dams have been built at the foot of the mountain slope, outlets of the Cachoeiro and the Canal Norte Rivers, and their detailed description such as location and dimension, is shown on Fig. C.5.

The rock and earth dam, around 4-5 m high and 250 m long, is considered to be sufficient with its maximum sediment run-off storage capacities of 70,000 m^3 for the Canal Norte and 82,000 m^2 for the Cachoeiro River. However, if sediment run-off exceeding storage capacity occurs, the dam will be destroyed by overflow of rushing sediment run-off because of its earth materials. Other facilities like riprap cross dams may be evaluated to be small scale facilities.

(4) Sectors (Refinaria)

A series of nine(9) gabion dams with small storage capacities are located on the Pedras River from 10 to 500m upstream of oil tanks but these dams are considered not to be enough to protect against large scale sediment run-off.

(5) Other Sectors

Other protection facilities such as a protection wall and channel works have been built to provide against sediment run-off and floods by factories and local Government.

5. FORMULATION OF MASTER PLAN

5.1 Basic Concepts

A master plan for sediment run-off disaster prevention was formulated on the assumption that the present vegetation conditions will not change in the future. Fig. H.15 shows work flow of the formulation and basic concepts on the master plan are summarized as follows:

5.1.1 Protection area

The protection area, having twelve(12) sabo sub-basins and corresponding to sectors MR-2, MR-3, CL-5, CL-6, CL-7 and CL-4, was decided in accordance with the following selection criteria Fig. H.16 shows the protection area.

(1) Possibility of slope failures

The susceptibility map shown in Fig.H.17 suggesting the possibility of slope failure in the study area was prepared by the study team. The criteria to classify the sub basins into 3 categories, namely high potential susceptibility slope, potential susceptibility slope and not susceptibility slope, are shown in Table H.13.

The susceptibility map indicates that almost all of the high potential susceptibility slopes are concentrated on the Moji, the Perequê and Cubatão downstream basins.

(2) Past major sediment run-off and slope failures.

Group A,B,C,D and E, classified based on the records of the past major sediment run-off, may be pointed out as a effective index for showing possibility of sediment run-off in the future.

Of these five(5) groups, group A, B and C can be identified as susceptible to slope failures.

(3) Objectives to be protected

Factory facilities, infrastructure and local residents may be considered main objectives to be protected.

5.1.2 Design scale

Probable return period of a 100 year was adopted to the master plan for the following reasons.

(1) Importance of protection area

In this case, since the protection area has factory facilities with toxic or explosive liquid and gases, generating station, highway, residential area facilities destruction will result in serious incredible disaster and damages not only to the factories but also inhabitants at around the Cubatão city and nearby.

(2) Uncertainty of natural disaster

As sediment run-off is a typical natural phenomenon it is difficult to predict future accidents accurately.

(3) Others

Japan is the most experienced country on sediment run-off disaster in the world. Usually a 100 return year is likely to be adopted in planning sabo prevention works except in particular cases.

5.1.3 Probable sediment run-off amount

The sediment yield from slope failures(Vs), sediment yield from torrent bed deposits(Vt) and potential sediment yields of each sub-basin(Vs + Vt=Vp) are basic criteria for Sediment run-off prevention planning. Above mentioned sediment run-off amount was calculated by the following methods. The calculated results are shown in Table H.14.

(1) Sediment yield from slope failures (Vs)

Sediment yields of slope failures with return periods of 5, 25, 50 and 100 years were calculated by using the proposed estimate equations shown below and six(6) hour maximum probable rainfall (see ANNEX F).

A slope group $Vs = Y \cdot D = 0.46\ (X-63.3)$

B slope group $Vs = Y \cdot D = 0.36\ (X-80.6)$

C slope group $Vs = Y \cdot D = 0.21\ (X-80.3)$

where:

Vs = Sediment yield from slope failures by probable rainfall ($m^3 \times 10^3$)

Y = Total area of slope failures per km^2 ($m^2 \times 10^3$)

D = Average thickness of slope failures (0.7m)

X = Six (6) hour maximum rainfall (mm)

(2) Sediment yield from torrent bed deposit (Vt)

The estimate equation of sediment yield from torrent bed deposits is as follows:

$Vt = B \cdot l \cdot d$

$B = \alpha Q^{1/2}_{max}$ ---------------- (Regime theory)

where:

Vt = Sediment yield from torrent bed deposit by probable rainfall

B = Average erosion width

l = Total length of torrent bed deposits

d = Average erosion thickness (0.50^m)

Q_{max} = Peak discharge of probable rainfall at control point of each sub-basin (refer to ANNEX-F)

α = Constant (4)

"l" and "d" were determined on the basis of the interpretation of aerial photographs of 1987 at a scale of 1 : 10,000 and the cross section of torrent bed deposits prepared by the field investigation respectively. The calculated results are shown in Fig.H.18.

(3) Potential sediment yield (Vp)

Vs plus Vt may be defined as potential sediment yield (Vp) similar to the present maximum sediment yield in sub-basins. Vp is a very significant amount in evaluating the design sediment discharge.

5.1.4 Design sediment run-off discharge

Design sediment run-off discharge may be defined as the sediment amount which passes the control points in probable rainfall and is the basic amount for determining structural layout. Three (3) representative formulas were applied to estimate design sediment run-off discharge as follows:

<u>Inductive method</u>

- Discharge ratio method

This is a experimental method used potential sediment yield (Vp) and discharge ratio (f).

$$D = Vp \cdot f$$

where:

D : Sediment run-off discharge

Vp : Potential sediment yield

f : Discharge ratio ($= I^{0.4}/A^{0.2 \sim 0.3}$)

I : Average gradient of catchment area.

A : Catchment area of sub-basin

- Stream Power Method

This method was proposed by Asida and Okumura in 1977 and can be adapted in the case of poor gradation of river bed deposits.

$$D = \alpha (A \cdot R \cdot I)^{\beta}$$

D : Sediment run-off discharge
A : Catchment area of sub-basin
R : Probable daily rainfall (refer to ANNEX F or Table H.16)
I : Average gradient of torrent bed between control point and 200 m upstream in elevation
α, β: Constant (α = 10, β = 2 in Japan)

Physical Method

- Takahashi's formula

This method can be applied in the case of river bed gradient of less than 1/4. Prior to the calculation of sediment run-off discharge, it should be necessary to decide sediment run-off transport type such as debris flow and sediment flow tabulated in Table H.15. According to Table H.15, almost all the sediment run-off through the control points of every sub basins can be belong to sediment flow because of their slope gradient of less than 1/4. Therefore, Takahashi's formula may be adopted to the study.

where:

qs : Sediment discharge
q_{s*} : Sediment discharge per unit width
C_{dc} : Density of sediment run-off(=0.42 C_*)
$*$: Non-dimensional bed-load transportation capacity
$*_c$: Non-dimensional critical bed-load transportation capacity (=0.05)
C_* : Density of river bed material (=0.6)
ϕ : Internal friction angle (=35^{o})

Table H.16 shows calculation results of sediment run-off discharge. It may be concluded that Takahashi's formula was applicable method to the study due to its apparent fit with the past record of the sediment run-off in Copebras of 1976.

Comparing Takahashi's formula result with the potential yield of sediment run-off, smaller one was recommended as design sediment run-off discharge in consideration of the existing structure storage capacities as shown in Table H.17.

On the other hand, average sediment run-off discharge at a return period of a 100 year in Japan ranges in volume from 30,000 - 150,000 m^3 per km^2 and 30.000 - 85.000 m^2 per km^2 in the study area. Accordingly, proposed design sediment run-off discharge can be judged adequate for the study.

5.1.5 Inundation area of design sediment run-off discharge

Using an experimental equation proposed by Ikeya in 1977, which was established on the basis of the sediment run-off disaster record of Shoudo Island, Takamatu prefecture, in Japan, the length of inundation areas of sediment run-off, which means the distance from the control point to the furthest point reached, was calculated as follows:

$$\log L' = 0.42 \log (Q \times Q_s) + 0.935$$
$$L = 2L'$$

L' : length of inundation area of sediment run-off (in the case of sediment flow)

L : length of inundation area of debris flow

Q : average gradient of sediment run-off inundation area

Q_s : design sediment run-off discharge

With regard to expansion of the inundation area, aerial photograph interpretation was available.

Finally, inundation areas by each design sediment run-off were predicted as shown in Table H.18 and Figs. H.19 to H.23.

5.2 Sediment Run-off Disaster Prevention Plan

5.2.1 Applicable structural measures

From the geological and topographic points of view, sabo dam, channel works including groundsills can be considered to be applicable structural measures in the study area. The following were basic concepts in planning each structural measure.

(1) Sabo Dam

- Effective dam height, between dam crest and ground surface of river bed, should be 10m maximum because of soft foundation of sand/gravel and scouring of dam front portion.

- In the case that waterfalls exists very close to the proposed damsite, damsite should be decided taking into account the relative location from waterfalls.

- Sabo dam should include sub-dam and front-apron except in particular cases.

- Two functions, namely storage function and control function, should be adopted to sabo-dams. Fig.H.24 illustrates the functions.

(2) Channel Works

- In the case of an unstable present river channel, channel works should be adopted between sabo dam and downstream stable river channel.

5.2.2 Structural layout

The structural layout was determined on the basis of design sediment run-off discharge and the above mentioned basic concepts.

The selection procedure of the structural layout were as follows:

1st : Possible dam sites were selected from geological and topographic considerations.

2nd : Only the most downstream dam will have a storage function; other dams will have a control function. If the structural layout is sufficient for a sediment run-off discharge of a 100 year return period the arrangement was satisfactory. If not, next step was required.

3rd : If the above layout is not satisfactory after changing the dam height or adding new damsites, a return to the 1st step was required.

Finally, thirty-two (32) sabo dams and eleven (11) channel works with a total length of 5,740 m were proposed for the master plan and their locations dimensions are shown in Fig.H.25, Table H.19.

Sabo Sub-Basins	Structural Measures	
	Sabo - dam	Channel works (m)
1	1	860
2	3	560
3	2	530
4	2	600
5	2	450
6	3	700
7	6	350
8	2	420
9	3	150
10	2	-
11	3	560
12	3	560
Total	31	5,740

5.2.3 Selection of priority project

Priority project with a target year to mid-1990s was selected among the master plan formulated. Selection criteria are as follows:

(1) Selection of sub-basins

Selection of sub-basin was done in accordance with the following procedure.

1st : Sub-basins having high serious disaster potential, such as contamination and/or explosion of toxic liquid and gases which would cause tremendous damages to the factories and residential area at and around the Cubatão city, were selected without any other consideration like economic evaluation.

2nd : Other sub-basins excluding high potential sub-basins of serious disaster were selected based on high economic effectiveness of EIRR.

The following table shows the selected priority projects:

Sub Basin No.	1	2	3	4	5	6	7	8	9	10	11	12
Possibility of serious disaster		++	++				++	+				
Economic Evaluation (EIRR)	-	12.7	14.7	2.4	1.8	2.1	17.0	9.1	3.9	11.8	11.9	12.9
Priority Project		+	+				+	+		+	+	+

Note: ++ means especially high evaluation
+ means high evaluation

(2) Selection of structural measures

As the optimum structural measures to be proposed in the priority project, nine(9) sabo dams in seven(7) sub-basins, six(6) channel works of 2,980m long were selected as shown in Fig. H.26.

These structural measures can cover more than the probable sediment run-off discharge of a 25 year return period, which is almost equal to or a little larger than the past maximum discharge of 1985.

The following table showns the structural measures for the priority project.

Sabo Sub-basins	Structural Measures		
	Sabo-dam		Channel works (m)
	Number	Effective Height(m)	
2	1	7	560
3	1	10	530
7	3	10,10,10	350
8	1	7	420
10	1	8	-
11	1	10	560
12	1	9	560
Total	9		2,980

LIST OF REFERENCES AND DATA COLLECTED

No.	TITLE	ISSUED ON	ISSUED BY
H01	MASS MOVEMENT RISK ZONING PRIORITY AREAS TO THE PRIORITY AREAS TO THE REFORESATION OF SERRA DO MAR, SLOPES OF THE CUBATÃO AREA SÃO PAULO STATE		IPT
H02	ENSAIO DE CORRELAÇÃO ENTRE PLUVIOSIDADE E ESCORREGAMENTO NO MEIO TROPICAL ÚMIDO		IPT
H03	RESULTADOS DAS ANALISES GRANNUMETRICAS DAS AMOSTRAS DE SOLO PROCEDENTES DA BACIA DO		IPT
H04	ESTUDO INFILTRACÃO EM ENCOSTAS DE SOLOS INSATURADOS NA SERRA DO MAR (CENSO 1989)		IPT
H05	CUBATÃO INDUSTRIAL COMPLEX-STUDY ON FLOOD PROTECTION(FINAL REPORT)Nov 1976 -COPEBRÀS		IPT
H06	CUBATÃO INDUSTRIAL COMPLEX - CONSTRUTION DESIGN FOR FLOOD PROTECTION WORK(FINAL REPORT) Sep 1979 -COPEBRÀS		IPT
H07	ANALISE DE CORRELACÃO ENTRE CHUVAS E ESCOR-REGAMENTOS -SERRA DO MAR, MUNICIPIO DE CUBATÃO		IPT
H08	MODELAMENTO NUMERICO DA ANALISE DE CORRELA-CÃO ENTRE CHUVAS E ESCORREGAMENTOS APLICA-DO AS ENCOSTAS DA SERRA DO MAR NO MUNICI-PIO DE CUBATÃO		IPT
H09	PROGRAMA DO SERRA DO MAR - CARTA GEOTÉCNICA DA SERRA DO MAR NAS FOLHAS DE SANTOS E RIACHO GRANDE (23394 Vol.5)		IPT
H10	ANALISE DE CORRELACÃO ENTRE CHUVAS E ESCOR REGAMENTOS. -SERRA DO MAR, MUNICIPIO DE CUBATÃO (25342)		IPT

(TO BE CONTINUED)

(CONTINUATION)

H11	MODELAMENTO NUMÊRICO DA ANALISE DE CORRELA CÃO ENTRE CHUVAS E ESCORREGAMENTOS APLICADO AS ENCOSTAS DA SERRA DO MAR.	IPT
H12	PROGRAMA SERA DO MAR - CARTA GEOTÊCNICA DA DA SERRA DO MAR NAS FOLHAS DE SANTOS E RIACHO GRANDE	IPT
H13	ENSAIO DE CORRELACO ENTRE PLUVIOSIDADE E ESCORREGAMENTO NO MEIO TROPICAL ÚMIDO	IPT
H14	ELABORACÃO DE SUBSÍDIOS TÊCNICOS PARA UM PLANO DE EMERGENCIA PARA A ÀREA DE CUBATÃO	IPT
H15	SUBSÍDIOS GEOLÓGICO-GEOTÊCNICOS PARA ESTABELECIMENTO DE CRITÊRIOS PARA A RESTAURACAO DA COBERTURA VEGETAL NAS ENCOSTAS DA SERRA DO MAR AFETADAS PELA POLUICÃO ATMOSFÊRICA 2o RELATÒRIO DE ANDAMENTO	IPT
H16	OS RESULTADOS DAS AÑLISES GRANULOMÊTRICA DAS AMOSTRAS DE SOLO PROCEDENTES DA BACIA DO SETOR ULTRAFÊRTIL EM CUBATÃO	IPT
H18	PROGRAMA SERRA DO MAR - LEVANTAMENTOS BÀSICOS NAS FOLHAS DE SANTOS E RIACHO GRANDE DE ESTADO DE SÃO PAULO, Vol.2	IPT
H18	PROGRAMA SERRA DO MAR - LEVANTAMENTOS BÀSICOS NAS FOLHAS DE SANTOS E RIACHO GRANDE DE ESTADO DE SÃO PAULO, Vol.3	IPT
H19	PROGRAMA SERRA DO MAR - LEVANTAMENTOS BÀSICOS NAS FOLHAS DE SANTOS E RIACHO GRANDE DE ESTADO DE SÃO PAULO, Vol.5	IPT
H20	ESTUDO DA INFILTRACÃO EM ENCOSTAS DE SOLOS INSATURADOS NA SERRA DO MAR.	IPT

(TO BE CONTINUED)

(CONTINUATION)

H21	BARRAGEM INFERIOR -TRATAMENTOS DE IMPERMEABILIZACÃO		IPT
H22	GEOTECHNICAL PARAMETERS FOR THE STUDY OF NATURAL SLOPES INSTABILIZATION AT SERRA DO MAR BRAZIL		IPT
H23	A SLIDE MECHANISM IN THE SLOPES OF THE SERRA DO MAR		IPT
H24	RAIN - INDUCED LANDSLIDS IN SOUTHEASTERN BRAZIL		IPT
H25	CUBATÃO INDUSTRIAL COMPLEX-CONSTRUCTION DESIGN FOR FLOOD PROTECTION WORK	1977	EBRA

TABLES

TABLE H.1 DIVISION OF STUDY AREA

Division	Sector Name	Area (Km2)	Remarks
MR-1	Sector1(Moji)	17.2	Right bank of the Moji River
MR-2	Sector2(Ultrafertil)	2.7	-do-
MR-3	Sector3(Copebras)	5.3	-do-
MR-4	Sector8(Dutos)	1.8	-do-
MR-5		1.7	-do-
ML-1	Sector9(Morrao)	13.4	Left bank of the Moji River
CR-1		10.1	Right bank of the Cubatao River
CR-2		6.8	-do-
CR-3		1.2	-do-
CL-1		10	Left bank of the Cubatao River
CL-2		7.4	-do-
CL-3		10.1	-do-
CL-4		5.8	-do-
CL-5	Sector6(Eletropaulo)	3.4	-do-
CL-6	Sector5(Refinaria)	3.3	-do-
CL-7	Sector4(Pereque)	11.4	-do-
CL-8	Sector7(Carbocloro)	1.5	-do-
Total		113.1	

Note: Each sector was decided on the basis of the sediment run-off records by COMISSAO ESPECIAL PARA RECUPERACAO DO MAR in 1985.

TABLE H.2 PAST MAJOR DISASTER

Year	Date: Month	Date: Day	Type of Disater	Damage
1971	Feb.	24-27	Sediment run-off/ Debris flow	Railway bridge was destroyed at the left bank of the Moji River
1976	Jan.	27-30	Sediment run-off	Inundation in factory lot of Copebras, 100,000 m2
1985	Jan.	22-25	Sediment run-off/ Debris flow	Inundation in factory lot of Petrobras
1988	Jan.	20-22	Sediment run-off/ Debris flow	9 inhabitants killed. 3 bridge and several houses destroyed at R. DAS PEDRAS

TABLE H.3 AERIAL PHOTOGRAPHS FOR INTERPRETATION

Date of shoot: Year	Date of shoot: Month	Scale	Kind of photos
1962	-----	1:25,000	Monocrome
1972	-----	1:40,000	- do -
1977	June, July	1:25,000	- do -
1980/81	March(80), May(81)	1:40,000	- do -
1985	June/August	1:25,000	False color
1989	April	1:25,000	- do -

TABLE H.4 PAST MAJOR SLOPE FAILURES

Area: Unit (10E-2 Km2)

Division Name	1962 Nos.	1962 Area	1971 Nos.	1971 Area	1976 Nos.	1976 Area	1980 Nos.	1980 Area	1985 Nos.	1985 Area	1988 Nos.	1988 Area	1962-1989 Nos.	1962-1989 Area
MOJI RIVER BASIN														
MR-1	3	0.98	100 (1)	34.07	77 (6)	21.25	45 (9)	12.21	302 (29)	61.05	26 (2)	5.13	664	161.7
MR-2	7	1.1	7 (1)	3.79	43 (3)	12.82	16 (4)	3.42	57 (9)	12.45	10 (2)	1.75	155	39.34
MR-3	2	0.49	13 (0)	2.67	88 (1)	19.9	31 (7)	10.5	136 (10)	27.23	40 (10)	5.86	342	73.06
MR-4	0	0	0	0	2 (0)	0.73	0	0	0	0	0	0	2	0.73
MR-5	0	0	0	0	0	0	0	0	8 (0)	1.22	0	0	18	1.22
ML-1	9	2.56	38 (0)	16.85	7 (1)	18.8	10 (8)	8.42	118 (16)	35.29	12 (8)	2.56	252	109.74
Sub-Total	21	5.13	158 (2)	57.38	217 (11)	73.5	102 (28)	34.55	621 (64)	137.24	88 (22)	15.30	1433	385.79
CUBATAO RIVER BASIN														
CR-1	4	0.2	20 (0)	3.33	16 (3)	2.92	0	0	1 (0)	0.73	0	0	43	5.86
CR-2	0	0	12 (0)	1.88	10 (0)	1.88	2 (0)	1.56	1 (0)	0.73	2 (0)	1.59	26	3.79
CR-3	0	0	0	0	0	0	0	0	4 (0)	2.13	0	0	4	2.56
CL-1	1	0.1	4 (0)	0.38	0	0	8 (0)	1.46	3 (0)	0.79	2 (0)	1.59	21	2.81
CL-2	3	0.2	1 (0)	0.1	1 (0)	0.16	5 (0)	1.04	6 (0)	2.13	11 (1)	3.79	32	8.18
CL-3	5	0.33	3 (0)	0.31	2 (0)	0.16	4 (0)	3.25	16 (1)	3.05	21 (1)	4.5	64	8.01
CL-4	0	0	0	0	0	0	0	0	3 (0)	1.59	24 (0)	3.3	45	8.15
CL-5	0	0	0	0	0	0	2 (0)	1.71	26 (0)	3.42	14 (1)	1.71	68	11.63
CL-6	0	0	4 (0)	1.47	1 (0)	0.73	1 (0)	1.22	44 (1)	7.2	14 (1)	2.32	114	23.05
CL-7	6	1.59	16 (0)	5.74	56 (1)	15.26	63 (10)	13.8	172 (15)	34.19	39 (4)	5.37	446	96.23
CL-8	0	0	0	0	0	0	0	0	6 (0)	1.10	0	0	8	1.47
Sub-Total	19	2.42	60 (0)	13.21	86 (4)	21.11	85 (10)	24.04	282 (17)	55.96	127 (8)	24.17	871	171.74
Total	40	7.55	218 (2)	70.59	303 (15)	94.61	187 (38)	58.59	903 (81)	193.2	215 (30)	39.47	2304	557.53

Note: ( ) Shows number of slope failures that occured again at the same places compared with previous aerial photographs interpretation results.

TABLE H.5 NUMBER OF PAST SLOPE FAILURES PER KM^2

Sector	1962	1971	1976	1980	1985	1988	1962-1989
MOJI RIVER BASIN							
MR-1	0.2	5.8	4.5	2.6	17.6	1.5	38.6
MR-2	2.6	2.6	15.9	5.9	21.1	3.7	57.4
MR-3	0.4	2.5	16.6	5.8	26.0	7.5	64.5
MR-4	0.0	0.0	1.1	0.0	0.0	0.0	1.1
MR-5	0.0	0.0	0.0	0.0	4.7	0.0	10.6
ML-1	0.7	2.8	0.5	0.7	8.8	0.9	18.8
Basin Mean	0.5	3.8	5.2	2.4	15.0	2.1	34.0
CUBATAO RIVER BASIN							
CR-1	0.4	2.0	1.6	0.0	0.1	0.0	2.8
CR-2	0.0	1.8	1.5	0.3	0.1	0.3	2.1
CR-3	0.0	0.0	0.0	0.0	3.3	0.0	4.2
CL-1	0.1	0.4	0.0	0.8	0.3	0.2	1.3
CL-2	0.4	0.1	0.1	0.7	0.8	1.5	3.8
CL-3	0.5	0.3	0.2	0.4	1.6	2.1	5.5
CL-4	0.0	0.0	0.0	0.0	0.5	4.1	7.8
CL-5	0.0	0.0	0.0	0.6	7.6	4.1	20.0
CL-6	0.0	1.2	0.3	0.3	13.3	4.2	34.5
CL-7	0.5	1.4	4.9	5.5	15.1	3.4	39.1
CL-8	0.0	0.0	0.0	0.0	4.0	0.0	5.3
Basin Mean	0.3	0.8	1.2	1.2	4.0	1.8	11.6
Total Basin Mean	0.4	1.9	2.7	1.7	8.0	1.9	20.4

TABLE H.6 CHANGE IN SLOPE FAILURES NUMBER OF EACH CLASSIFIED GROUP

Unit:number

group	Area(Km2)	1962	1971	1976	1980	1985	1988
A	8.0	9 (1.1)	20 (2.5)	131 (16.4)	47 (5.9)	195 (24.4)	50 (6.3)
B	31.9	9 (0.3)	120 (3.8)	134 (4.2)	109 (3.4)	518 (16.2)	79 (2.5)
C	18.5	9 (0.5)	38 (2.1)	7 (0.4)	12 (0.7)	152 (8.2)	26 (1.4)
D	17.4	5 (0.3)	3 (0.2)	2 (0.1)	4 (0.2)	25 (1.4)	45 (2.6)
E	37.3	8 (0.2)	37 (1.0)	29 (0.8)	15 (0.4)	15 (0.4)	15 (0.4)
Total	113.1	40 (0.4)	218 (1.9)	303 (2.7)	187 (1.7)	905 (8.0)	215 (1.9)

Note: ( ) means number of slope failures per Km2

TABLE H.7 NUMBER AND AREA OF PAST FAILURES IN 1962-1989 IN DIFFERENT SLOPE GRADIENT

Area: Unit (Km2)

Section Name	i < 20°		20° < i < 30°		30° < i < 40°		40° < i	
	Nos.	Area	Nos.	Area	Nos.	Area	Nos.	Area
MOJI RIVER								
MR-1	3	0.6	186	8.4	383	7.1	92	1.1
MR-2	0	0.3	43	0.8	75	1.1	37	0.4
MR-3	1	0.4	117	1.9	141	2.1	83	0.9
MR-4	0	0.4	0	1.2	2	0.1	0	0.1
MR-5	0	0.13	8	1.2	10	0.4	0	0
ML-1	0	0	105	7.8	82	3.6	65	0.9
Sub-Total	4	2.8	459	21.4	695	14.3	277	3.4
CUBATAO RIVER								
CR-1	1	1.2	6	5.1	23	3.2	13	0.6
CR-2	0	0.6	4	2.6	11	2.8	11	0.8
CR-3	0	0.1	1	0.4	3	0.6	0	0
CL-1	0	0.6	1	3.5	4	4.2	16	1.8
CL-2	0	1	2	2.2	22	3.4	8	0.8
CL-3	0	1.2	3	3.1	37	4.5	24	1.3
CL-4	0	1.7	13	2.8	26	1.1	6	0.2
CL-5	0	0.3	9	0.8	22	1.5	37	0.8
CL-6	3	0.4	41	1.7	46	1.1	24	0.2
CL-7	5	1	189	5.2	122	3.5	130	1.7
CL-8	0	0.1	6	1.2	2	0.2	0	0
Sub-Total	9	8.2	275	28.5	318	26	269	8.2
Total	13	11.1	734	49.9	1011	40.3	546	11.6

Note: i means slop gradient

TABLE H.8 NUMBER AND AREA OF PAST FAILURES OF 1962-1989 IN DIFFERENT SLOPE CONFIGURATION

Area: Unit (Km2)

Section Name	Rectilinear		Convex		Others	
	Nos.	Area	Nos.	Area	Nos.	Area
MOJI RIVER						
MR-1	398	9	253	5.3	13	2.8
MR-2	91	1.3	57	0.8	7	0.6
MR-3	247	3.3	101	1.5	2	0.4
MR-4	1	0.3	1	0.3	0	1.2
MR-5	14	0.8	4	0.6	0	0.3
ML-1	154	4.8	70	3.1	28	5.5
Sub-Total	905	19.5	486	11.6	50	10.8
CUBATAO RIVER						
CR-1	19	3	12	5.1	12	2
CR-2	17	2.1	3	3.1	6	3.5
CR-3	3	0.7	1	0.1	0	0.3
CL-1	17	4.5	4	4.9	0	0.7
CL-2	25	3	7	2.8	0	1.6
CL-3	26	3.7	32	4.1	6	2.2
CL-4	39	2	6	1.6	0	2.2
CL-5	51	2.2	15	0.9	2	0.4
CL-6	65	1.5	37	1.4	12	0.4
CL-7	325	6	114	4.3	7	1.1
CL-8	4	0.3	4	0.6	0	0.6
Sub-Total	591	26.9	235	29	45	15.1
Total	1496	48.4	721	40.6	95	25.9

TABLE H.9 NUMBER AND AREA OF SLOPE FAILURES IN AFFECTED VEGETATION AREA IN 1962-1989 (1/2)

Year : 1962

SECTOR	a		b		c		d		TOTAL	
	Nos.	Area	Nos.	Area	Nos.	Area	Nos.	Area	Nos.	Area
MR-1	3	17.2	0	0	0	0	0	0	3	17.2
MR-2	7	2.7	0	0	0	0	0	0	7	2.7
MR-3	2	5.3	0	0	0	0	0	0	2	5.3
MR-4	0	1.8	0	0	0	0	0	0	0	1.8
MR-5	0	1.7	0	0	0	0	0	0	0	1.7
ML-1	9	13.4	0	0	0	0	0	0	9	13.4
CL-4	0	5.8	0	0	0	0	0	0	0	5.8
CL-5	0	3.4	0	0	0	0	0	0	0	3.4
CL-6	0	3.3	0	0	0	0	0	0	0	3.3
CL-7	6	11.4	0	0	0	0	0	0	6	11.4
CL-8	0	1.5	0	0	0	0	0	0	0	1.5
TOTAL	27	67.4	0	0	0	0	0	0	27	67.4

Year : 1972

SECTOR	a		b		c		d		TOTAL	
	Nos.	Area	Nos.	Area	Nos.	Area	Nos.	Area	Nos.	Area
MR-1	100	17.2	0	0	0	0	0	0	100	17.2
MR-2	7	2.7	0	0	0	0	0	0	7	2.7
MR-3	13	5.3	0	0	0	0	0	0	13	5.3
MR-4	0	1.8	0	0	0	0	0	0	0	1.8
MR-5	0	1.7	0	0	0	0	0	0	0	1.7
ML-1	36	13.3	2	0.1	0	0	0	0	38	13.4
CL-4	0	5.8	0	0	0	0	0	0	0	5.8
CL-5	0	3.4	0	0	0	0	0	0	0	3.4
CL-6	4	3.3	0	0	0	0	0	0	4	3.3
CL-7	16	11.4	0	0	0	0	0	0	16	11.4
CL-8	0	1.4	0	0.1	0	0	0	0	0	1.5
TOTAL	176	67.1	2	0.2	0	0	0	0	178	67.4

Year : 1977

SECTOR	a		b		c		d		TOTAL	
	Nos.	Area	Nos.	Area	Nos.	Area	Nos.	Area	Nos.	Area
MR-1	0	3.3	32	8.2	45	5.7	0	0	77	17.2
MR-2	0	0.1	14	1.3	29	1.3	0	0	43	2.7
MR-3	2	0.4	47	2.3	39	2.6	0	0	88	5.3
MR-4	0	0	0	0	2	1.8	0	0	2	1.8
MR-5	0	0.3	0	1.4	0	0	0	0	0	1.7
ML-1	0	1.7	0	10.7	1	1.1	0	0	7	13.4
CL-4	0	5.4	0	0.4	0	0	0	0	0	5.8
CL-5	0	2.2	0	0.3	0	0.9	0	0	0	3.4
CL-6	1	2.3	0	1.5	0	0.6	0	0	1	3.3
CL-7	0	0	43	8.6	13	2.9	0	0	56	11.4
CL-8	0	0.4	0	0.5	0	0.6	0	0	0	1.5
TOTAL	3	15.2	142	34.9	129	17.3	0	0	274	67.4

TABLE II.9 NUMBER AND AREA OF SLOPE FAILURES IN AFFECTED VEGETATION AREA IN 1962-1989 (2/2)

Year : 1980

SECTOR	a Nos.	a Area	b Nos.	b Area	c Nos.	c Area	d Nos.	d Area	TOTAL Nos.	TOTAL Area
MR-1	5	3.3	0	3.4	40	10.4	0	0	45	17.2
MR-2	0	0.1	0	0	16	2.6	0	0	16	2.7
MR-3	0	0.4	10	2.1	21	2.7	0	0	31	5.3
MR-4	0	0	0	0	0	1.8	0	0	0	1.8
MR-5	0	0	0	0	0	1.7	0	0	0	1.7
ML-1	0	1.6	10	6.0	0	5.8	0	0	10	13.4
CL-4	0	5.4	0	0.4	0	0	0	0	0	5.8
CL-5	1	2.2	0	0.4	1	0.8	0	0	2	3.4
CL-6	1	1.2	0	1.1	0	1	0	0	1	3.3
CL-7	0	0	52	7.8	11	3.6	0	0	63	11.4
CL-8	0	0	0	0	0	1.5	0	0	0	1.5
TOTAL	7	14.2	72	21.3	89	31.9	0	0	168	67.4

Year : 1985

SECTOR	a Nos.	a Area	b Nos.	b Area	c Nos.	c Area	d Nos.	d Area	TOTAL Nos.	TOTAL Area
MR-1	0	0	40	3.3	246	11.3	16	2.6	302	17.2
MR-2	0	0	0	0	41	1.6	16	1.1	57	2.7
MR-3	0	0	31	1.3	96	2.9	11	1.0	138	5.3
MR-4	0	0	0	0	0	0.6	0	1.2	0	1.8
MR-5	0	0	0	0	1	0.6	7	1.1	8	1.7
ML-1	0	0.4	55	3.2	63	9.8	0	0	118	13.4
CL-4	0	1.0	3	2.4	0	2.4	0	0	3	5.8
CL-5	0	0	21	2.6	5	0.9	0	0	26	3.4
CL-6	0	0	34	1.7	10	1.6	0	0	44	3.3
CL-7	0	0	138	7.3	32	4.0	2	0.1	172	11.4
CL-8	0	0	0	0	2	0.3	4	1.2	6	1.5
TOTAL	0	1.4	322	21.7	496	36	56	8.3	874	67.4

Year : 1989

SECTOR	a Nos.	a Area	b Nos.	b Area	c Nos.	c Area	d Nos.	d Area	TOTAL Nos.	TOTAL Area
MR-1	0	0	2	3.3	23	11.0	1	2.9	26	17.2
MR-2	0	0	0	0	5	1.6	5	1.1	10	2.7
MR-3	0	0	10	1.3	27	2.9	3	1.0	40	5.3
MR-4	0	0	0	0	0	0.6	0	1.2	0	1.8
MR-5	0	0	0	0	0	0.6	0	1.1	0	1.7
ML-1	0	0.4	7	3.2	5	9.8	0	0	12	13.4
CL-4	3	1.0	19	2.4	2	2.4	0	0	24	5.8
CL-5	0	0	12	2.6	2	0.9	0	0	14	3.4
CL-6	0	0	6	1.7	8	1.6	0	0	14	3.3
CL-7	0	0	28	7.3	8	4.0	3	0.1	39	11.4
CL-8	0	0	0	0	0	0.3	0	1.2	0	1.5

TABLE H.10 CHANGE IN NUMBER OF PAST MAJOR SLOPE FAILURES IN AFFECTED VEGETATION AREA BY AIR POLLUTION

Date			Total number of slope failures in objective area	Percentage of affected vegetation area (%)				Number of slope failures each area (per Km2)			
Year	Month	Date		a	b	c	d	a	b	c	d
1962	-	-	27	100.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
1971	2	24-27	178	99.7	0.3	0.0	0.0	2.6	9.1	0.0	0.0
1976	1	27-29	274	22.5	51.9	25.6	0.0	0.2	4.1	7.5	0.0
1980	2	18-19	168	21.2	31.6	47.3	0.0	0.5	3.4	2.8	0.0
1985	1	22-24	874	2.0	32.2	53.4	12.3	0.1	14.8	13.8	6.7
1988	12	20-22	179	2.0	32.2	53.0	12.8	2.2	3.9	5.0	13.0

Note: Objective area consistis of 9 sectors sellected by the Special Commission.
a: not affected vegetation by air pollution
b: moderetly affected vegetation by air pollution
c: affected vegetation by air pollution
d: strongly affected vegetation by air pollution

TABLE H.11 HOURLY RAINFALL DATA OF MAJOR PAST SEDIMENT RUN-OFF

1976 28-29				1980 18-19				1985 22-24				1988 20-22			
DAY	HOUR	RAINFALL (mm)	ACCUMULATED RAINFALL (mm)	DAY	HOUR	RAINFALL (mm)	ACCUMULATED RAINFALL (mm)	DAY	HOUR	RAINFALL (mm)	ACCUMULATED RAINFALL (mm)	DAY	HOUR	RAINFALL (mm)	ACCUMULAT RAINFALL (mm)
28	8	0.8	0.8	18	6	0.0	0.0	22	13	1.2	1.2	20	9	0.0	0.0
	9	1.7	2.5		7	0.0	0.0		14	0.6	1.8		10	0.0	0.0
	10	4.3	6.8		8	0.0	0.0		15	2.8	4.6		11	0.0	0.0
	11	14.1	20.9		9	0.0	0.0		16	3.6	8.2		12	0.0	0.0
	12	38.8	59.7		10	0.0	0.0		17	7.9	16.1		13	0.0	0.0
	13	18.8	78.5		11	0.0	0.7		18	0.6	16.8		14	0.0	0.0
	14	14.8	93.3		12	0.0	0.7		19	0.0	16.8		15	0.0	0.0
	15	26.9	120.2		13	2.4	3.1		20	0.1	16.9		16	9.8	9.8
	16	20.9	141.1		14	6.3	9.3		21	0.6	17.5		17	8.9	18.7
	17	12.8	153.8		15	16.6	26.0		22	1.4	19.0		18	4.4	23.2
	18	7.1	161.0		16	20.7	46.7		23	0.9	19.9		19	25.3	48.4
	19	3.0	164.0		17	23.4	70.1		24	20.8	40.6		20	23.5	71.9
	20	4.4	168.4		18	16.8	86.9	23	1	12.3	52.9		21	13.8	85.8
	21	15.7	184.1		19	15.3	102.1		2	6.8	59.7		22	6.2	92.0
	22	5.1	189.2		20	9.0	104.3		3	4.5	64.2		23	2.0	94.0
	23	6.1	195.2		21	32.7	143.9		4	3.3	67.5		24	4.5	98.5
	24	8.3	203.6		22	19.6	163.5		5	2.9	70.5	21	1	5.3	103.9
29	1	7.5	211.0		23	27.7	191.2		6	10.0	80.4		2	2.9	106.8
	2	0.5	211.6		24	12.7	203.8		7	84.3	164.7		3	0.7	107.5
	3	16.5	228.1	19	1	10.4	214.2		8	16.7	181.4		4	8.8	116.3
	4	4.2	232.3		2	2.5	216.7		9	36.5	217.9		5	6.9	123.2
	5	33.8	266.1		3	0.8	217.5		10	25.2	243.1		6	5.9	129.1
	6	2.7	268.8		4	0.1	217.6		11	0.0	243.1		7	2.8	131.9
	7	2.4	271.2		5	0.1	217.7		12	0.0	243.1		8	2.0	133.9
	8	0.2	271.4		6	1.8	219.6		13	0.0	243.1		9	0.3	134.2
	9	6.6	278.0		7	1.8	221.4		14	4.0	247.1		10	0.7	134.9
	10	1.1	279.1		8	1.4	222.8		15	1.7	248.8		11	0.0	134.9
	11	0.5	279.7		9	1.1	223.9		16	1.4	250.2		12	0.0	134.9
	12	0.5	280.2		10	10.5	224.1		17	2.9	253.1		13	0.0	134.9
	13	0.2	280.4		11	0.0	224.1		18	6.9	260.0		14	0.0	134.9
	14	0.8	281.2		12	0.0	224.1		19	4.5	264.5		15	0.0	134.9
	15	31.0	312.2		13	0.0	224.1		20	4.6	269.1		16	0.0	134.9
	16	4.0	316.2		14	0.0	224.1		21	7.2	276.3		17	0.0	134.9
	17	3.1	319.3		15	0.0	224.1		22	4.5	280.8		18	0.0	134.9
	18	2.5	321.8		16	0.0	224.1		23	4.0	284.8		19	0.0	134.9
	19	0.0	321.8		17	0.0	224.1		24	1.9	286.7		20	0.0	134.9
	20				18	0.0	224.1	24	1	0.6	287.3		21	0.0	134.9
	21				19	0.0	224.1		2	7.3	294.6		22	0.0	134.9
	22				20	0.0	224.1		3	4.5	299.1		23	0.0	134.9
	23				21	0.0	224.1		4	2.3	301.4		24	0.0	134.9
	24				22	0.0	224.1		5	1.7	303.1	22	1	0.0	134.9
	1				23	0.0	224.1		6	0.4	303.5		2	0.0	134.9
	2				24	0.0	224.1		7	0.3	303.7		3	0.0	134.9

TABLE H.12 ACTUAL N-HOUR MAXIMUM RAINFALL

Year	Actual N-hour Maximum Rainfall (mm)							Total Slope Failure Area (m^2/km^2)		
	1-hour	2-hour	3-hour	4-hour	6-hour	12-hour	24-hour	Group A	Group B	Group C
1976	38.8	57.6	72.4	99.3	134.3	182.4	275.5	40,900	11,700	10,200
1980	32.7	52.3	80.0	92.3	117.0	211.2	233.7	17,400	8,500	5,500
1985	84.3	101.0	137.5	162.7	175.6	224.2	265.0	49,600	32,100	21,600
1988	25.3	48.8	62.6	68.8	82.1	107.3	134.7	9,500	4,000	2,300

TABLE H.13 CRITERIA AND CLASSIFICATION OF SUSCEPTIBILITY MAP TO SLOPE FAILURES

CRITERIA	Type of Group		
	a	b	c
Slope gradient	>40^o	30^o-40^o	30^o>
Slope configuration	Rectilinear	Convex	Others
Vegetation condition	Strougly affected	affected + Moderately affected	Not affected

Note: Vegetation condition is based on the data of 1985.

Classification	Types of Slope					
High potential	aaa	aab	aba	abb	baa	bab
Potential	aac	abc	aca	acb	acc	bac
	bba	bbb	bbc			
Not Potential	bca	bcb	bcc	caa	cab	cac
	cba	cbb	cbc	cca	ccb	ccc

TABLE II.14 SEDIMENT YIELD OF SABO SUB-BASIN

Number of Sabo Sub-Basin	Catchment Area (km2)	Sediment Yield of Slope Failures (10^3m3)				Sediment Yield of Torrent Deposit (10^3m3)				Potential Sediment Yield			
		1/5	1/25	1/50	1/100	1/5	1/25	1/50	1/100	1/5	1/25	1/50	1/100
1	2.39	66.3	112.9	132.3	151.4	35.1	44.2	46.8	47.2	101.4	157.1	179.1	198.6
2	3.79	105.1	179.1	209.9	240.1	67.6	85.8	91.4	91.8	172.7	264.9	301.3	331.9
3	1.29	35.8	61.0	71.4	81.7	20.6	26.1	27.6	27.7	56.4	87.1	99.0	109.4
4	8.42	121.4	228.7	273.5	317.7	253.0	328.0	353.9	362.7	374.4	556.7	627.4	680.4
5	0.90	13.0	24.4	29.2	34.0	10.9	13.5	14.3	14.5	23.9	37.9	43.5	48.5
6	1.73	24.9	47.0	56.2	65.3	31.1	39.0	41.4	41.7	56.0	86.0	97.6	107.0
7	2.64	38.1	71.7	85.7	99.6	50.5	62.9	66.5	67.0	88.6	134.6	152.2	166.6
8	0.41	4.2	7.8	9.3	10.8	3.5	4.3	4.5	4.5	7.7	12.1	13.8	15.3
9	0.73	7.4	13.9	16.6	19.3	6.3	7.9	8.3	8.4	13.7	21.8	24.9	27.7
10	1.26	12.8	24.0	28.7	33.3	15.0	18.6	19.7	19.8	27.8	42.6	48.4	53.1
11	0.62	6.3	11.8	14.1	16.4	8.4	10.5	11.1	11.1	14.7	22.3	25.2	27.5
12	1.11	11.3	21.1	25.3	29.4	13.2	16.2	17.2	17.4	24.5	37.3	42.5	46.8

TABLE II.15 TRANSPORT MODE

Mode of Transport	Slope Gradient	Mode of Flow	Size of Gravels	Roundness of Gravels	Grading of Sediment	Bedding Structural Grading	Characteristics
Debris Flow	tanθ>1/4	Mass Transport	Bit	Semi-angular	Poor	Poor	* Abrupt waves with big particles segregated and concentrated at the tip portion. * Sediment with heaping at the center in cross sections.
Sediment flow	1/4≧tanθ	Mass in bed-load mode	Medium	Semi-angular to semi-spherical	Rather well	Rather well	* No big conspicuous abrupt wave. * The flow is headed by water. * Sediment layers is rather dense. * Distinction between two layers of water/sediment is clear when the water depth is rather deep.

TABLE II.16 SEDIMENT RUN-OFF DISCHARGE

Number of Sabo Sub-Basin	Discharge Ratio Method				Stream Power Method				Takahashi's Method			
	1/5	1/25	1/50	1/100	1/5	1/25	1/50	1/100	1/5	1/25	1/50	1/100
1	50.8	78.6	89.6	99.4	157.6	299.7	371.7	450.9	76.1	121.3	139.4	155.5
2	77.8	119.3	135.7	149.5	331.3	630.0	781.3	947.8	77.6	124.2	142.9	159.4
3	35.3	54.5	62.0	68.5	53.1	100.9	125.1	151.8	79.7	127.9	147.2	164.2
4	132.2	196.6	221.5	240.3	755.4	1436.5	1781.6	2161.0	72.9	119.8	139.9	158.7
5	15.9	25.1	28.9	32.2	20.8	39.5	49.0	59.5	19.1	30.2	34.6	38.7
6	33.4	51.3	58.3	63.9	69.6	132.3	164.1	199.0	38.4	62.1	71.6	80.1
7	45.0	68.3	77.2	84.5	146.0	277.7	344.4	417.8	83.0	130.5	149.8	167.2
8	6.5	10.1	11.6	12.8	5.1	9.7	12.0	14.5	7.5	11.8	13.6	15.2
9	10.4	16.5	18.9	21.0	17.3	33.0	40.9	49.6	15.5	24.4	28.0	31.3
10	16.4	25.1	28.5	31.2	42.9	81.5	101.1	122.6	18.7	29.4	33.7	37.7
11	11.6	17.5	19.8	21.6	20.2	38.3	47.5	57.7	13.0	20.4	23.4	26.1
12	16.7	25.4	29.0	31.9	75.8	144.1	178.7	216.7	71.2	114.4	132.1	147.9

Note ;	Sabo sub basin	1	2	3	4	5	6	7	8	9	10	11	12
	Area(kn2)	2.37	3.79	1.29	8.42	0.90	1.73	2.64	0.41	0.73	1.26	0.62	1.11
Discharge ratio method	I (tanθ)	0.274	0.265	0.352	0.215	0.340	0.362	0.298	0.411	0.427	0.298	0.431	0.404
	R (mm)	1/5 : 187.6, 1/25 : 258.7, 1/50 : 288.1, 1/100 : 317.3											
Stream power method	I (tanθ)	0.280	0.256	0.301	0.174	0.270	0.257	0.244	0.293	0.304	0.277	0.386	0.418
Takahashi's fomula	I (tanθ)	0.070	0.095	0.080	0.036	0.141	0.149	0.105	0.143	0.143	0.098	0.141	0.152

TABLE II.17 DESIGN SEDIMENT RUN-OFF DISCHARGE

Sabo Sub-basin	Design Sediment Run-off Discharge			
	1/5	1/25	1/50	1/100
1(2.39)	0	0	0	0
2(3.79)	77,600	124,200	142,900	159,400
3(1.29)	56,400	87,100	99,000	109,400
4(8.42)	72,900	119,800	139,900	158,700
5(0.90)	19,100	30,200	34,600	38,700
6(1.73)	38,400	62,100	71,600	80,100
7(2.64)	83,000	130,500	149,800	166,600
8(0.41)	7,500	11,800	13,600	15,200
9(0.17)	13,700	21,800	24,900	27,700
10(1.26)	18,700	29,400	33,700	37,700
11(0.62)	13,000	20,400	23,400	26,100
12(1.11)	24,500	37,300	42,500	46,800

Note ; ( ) means Sabo sub-basin area in km2

TABLE H.18 LENGTH OF INUNDATION AREA OF DESIGN SEDIMENT RUN-OFF

Sabo Sub-basin	1	2	3	4	5	6	7	8	9	10	11	12
Average gradient	0.071	0.024	0.025	0.018	0.075	0.052	0.020	0.100	0.076	0.040	0.040	0.100
Length of debris flow (m)												
1/5	0.0	406.9	362.0	351.2	364.4	419.0	387.7	277.7	318.7	277.4	238.1	456.5
1/25	0.0	495.7	434.5	432.7	441.7	512.7	468.8	335.9	387.4	335.4	287.7	544.7
1/50	0.0	525.8	458.5	461.8	467.7	544.3	496.8	356.5	409.6	355.2	304.8	575.4
1/100	0.0	550.5	478.7	487.0	490.2	570.5	519.5	373.6	428.4	372.4	319.1	599.1

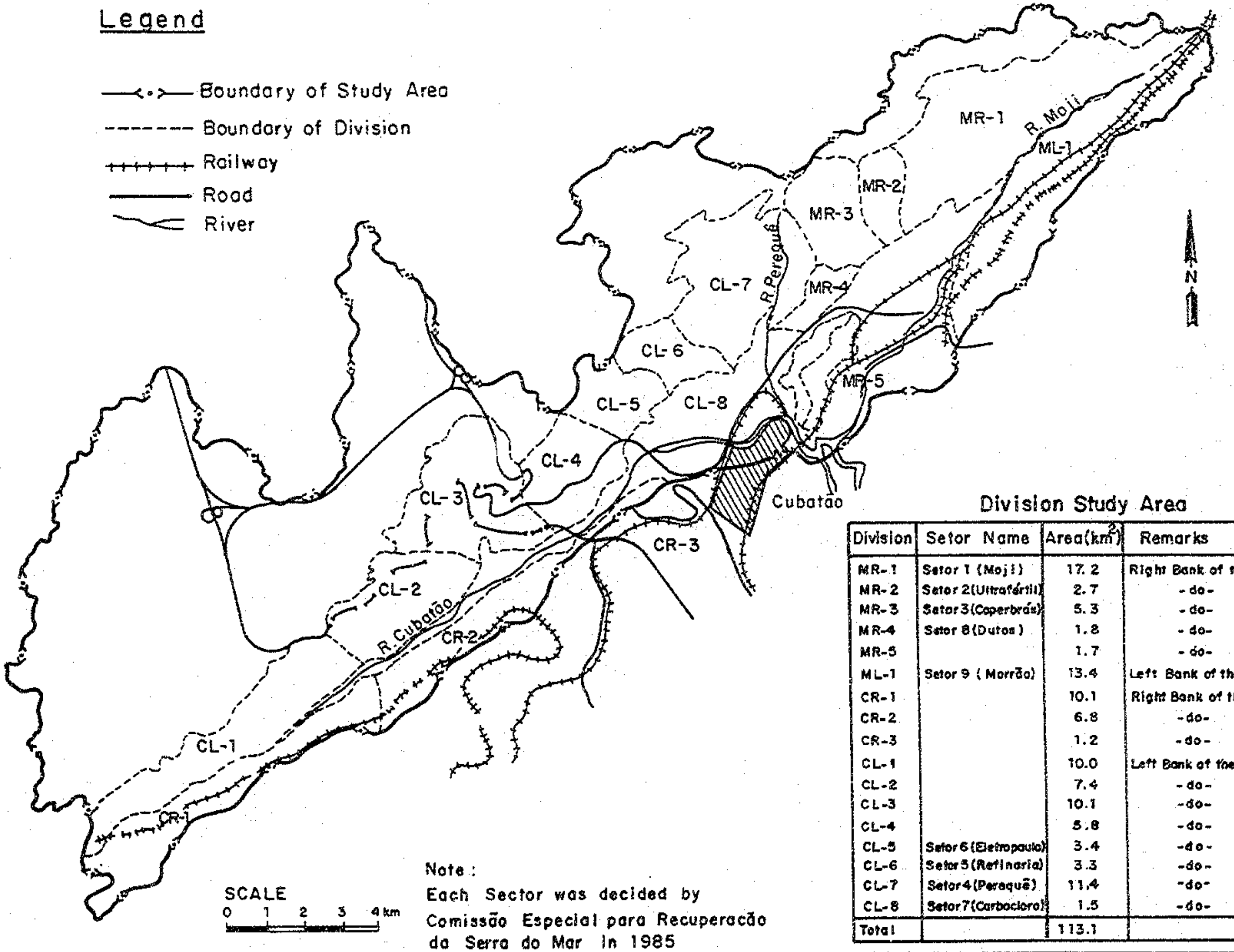
TABLE H.19 DIMENSION OF STRUCTURAL MEASURES

(Unit:m3)

Sub-basin No.	Sediment Run-off Discharge	Existence Structural Measures				Design Sediment Run-off Discharge	Proposed Structural Measures (Sabo-dam)						
		1st	2nd	3rd	Total		1st	2nd	3rd	4th	5th	6th	Total
1	155,500	(H=8) 24,800	(H=10) 138,200	(H=10) 44,200	207,200	0	(H=10)* 7,400						7,400
2	159,400	(H=4) 70,000				159,400	(H=7) 124,800	(H=10)* 16,200	(H=10)* 19,300				160,300
3	109,400	(H=4) 82,000				109,400	(H=10) 85,800	(H=10)* 28,500					114,300
4	158,700					158,700	(H=8) 120,000	(H=10)* 45,000					165,000
5	38,700					38,700	(H=10) 38,100	(H=5)* 2,300					40,400
6	80,100					80,100	(H=10) 36,700	(H=10) 41,600	(H=10)* 2,400				80,700
7	166,600					166,600	(H=10) 44,600	(H=10) 20,300	(H=10) 35,700	(H=10) 49,500	(H=10)* 8,500	(H=10)* 8,600	167,200
8	15,200					15,200	(H=7) 12,000	(H=10)* 3,600					15,600
9	27,700					27,700	(H=10) 21,800	(H=10)* 3,600	(H=10)* 3,300				28,700
10	37,700					37,700	(H=8) 34,000	(H=10)* 4,000					38,000
11	26,100					26,100	(H=10) 20,000	(H=10) 6,000	(H=10)* 2,000				28,000
12	46,800					46,800	(H=9) 37,800	(H=10) 5,500	(H=10)* 4,500				47,800

Note ; * : means control amount

FIGURES



Note :
Each Sector was decided by Comissão Especial para Recuperacão da Serra do Mar in 1985

Division Study Area

Division	Setor Name	Area(km²)	Remarks
MR-1	Setor 1 (Moji)	17.2	Right Bank of the Moji River
MR-2	Setor 2(Ultrafértil)	2.7	-do-
MR-3	Setor 3(Coperbrás)	5.3	-do-
MR-4	Setor 8(Dutos)	1.8	-do-
MR-5		1.7	-do-
ML-1	Setor 9 (Morrão)	13.4	Left Bank of the Moji River
CR-1		10.1	Right Bank of the Cubatão River
CR-2		6.8	-do-
CR-3		1.2	-do-
CL-1		10.0	Left Bank of the Cubatão River
CL-2		7.4	-do-
CL-3		10.1	-do-
CL-4		5.8	-do-
CL-5	Setor 6 (Eletropaulo)	3.4	-do-
CL-6	Setor 5 (Refinaria)	3.3	-do-
CL-7	Setor 4 (Perequê)	11.4	-do-
CL-8	Setor 7 (Carbocloro)	1.5	-do-
Total		113.1	

FIG.H.1
DIVISION MAP OF STUDY AREA

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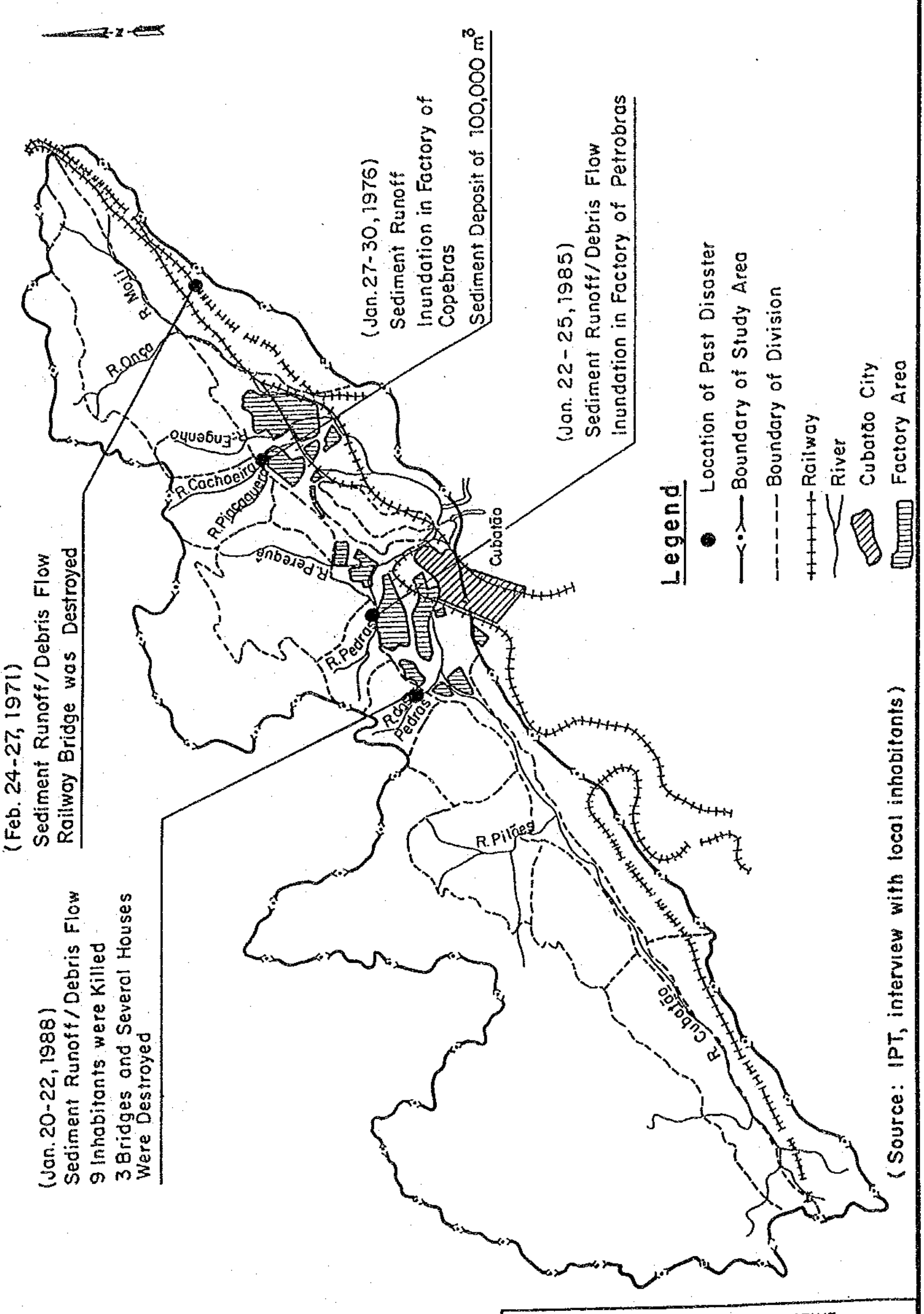

FIG.H.2
LOCATION MAP OF PAST
MAJOR DISASTERS

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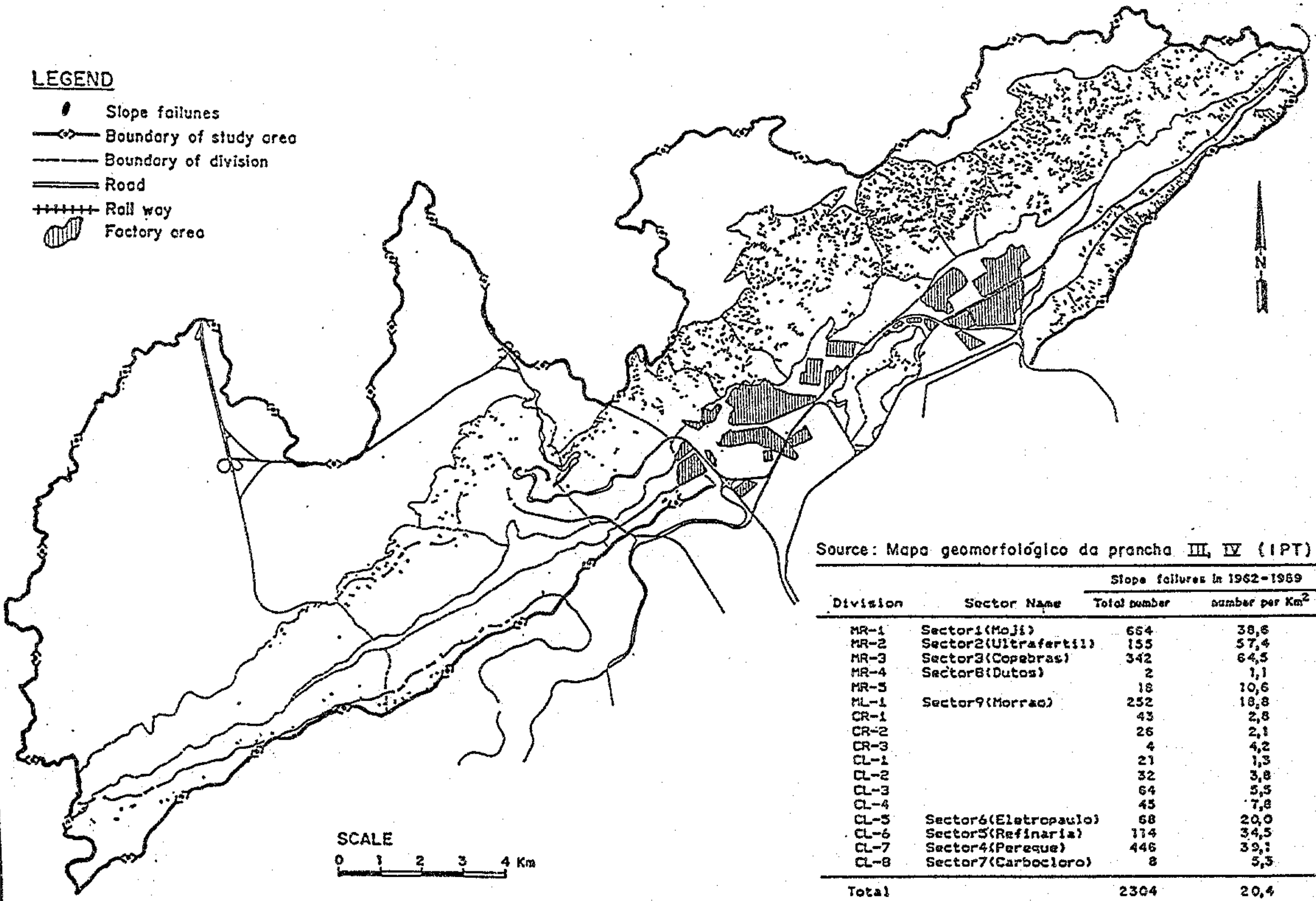

Source: Mapa geomorfológico da prancha III, IV (IPT)

Division	Sector Name	Slope failures in 1962-1989 Total number	number per Km^2
MR-1	Sector1(Moji)	664	38,6
MR-2	Sector2(Ultrafertil)	155	57,4
MR-3	Sector3(Copebras)	342	64,5
MR-4	Sector8(Dutos)	2	1,1
MR-5		18	10,6
ML-1	Sector9(Morrao)	252	18,8
CR-1		43	2,8
CR-2		26	2,1
CR-3		4	4,2
CL-1		21	1,3
CL-2		32	3,8
CL-3		64	5,5
CL-4		45	7,8
CL-5	Sector6(Eletropaulo)	68	20,0
CL-6	Sector5(Refinaria)	114	34,5
CL-7	Sector4(Pereque)	446	39,1
CL-8	Sector7(Carbocloro)	8	5,5
Total		2304	20,4

FIG.II.3
DISTRIBUTION MAP OF TOTAL
SLOPE FAILURES OF 1962-1989

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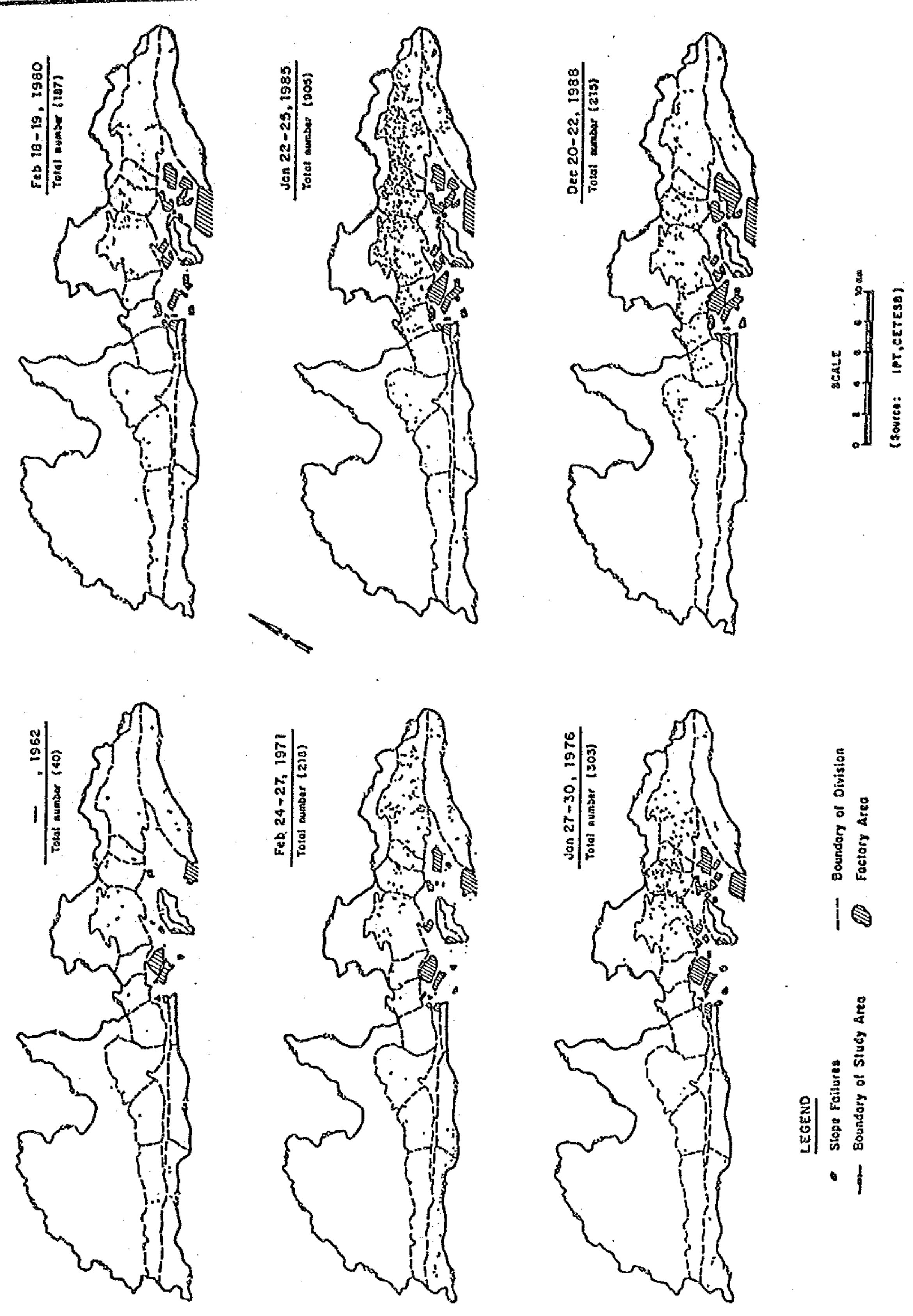

FIG.II.4
DISTRIBUTION MAP OF
INDIVIDUAL PAST MAJOR
SLOPE FAILURES

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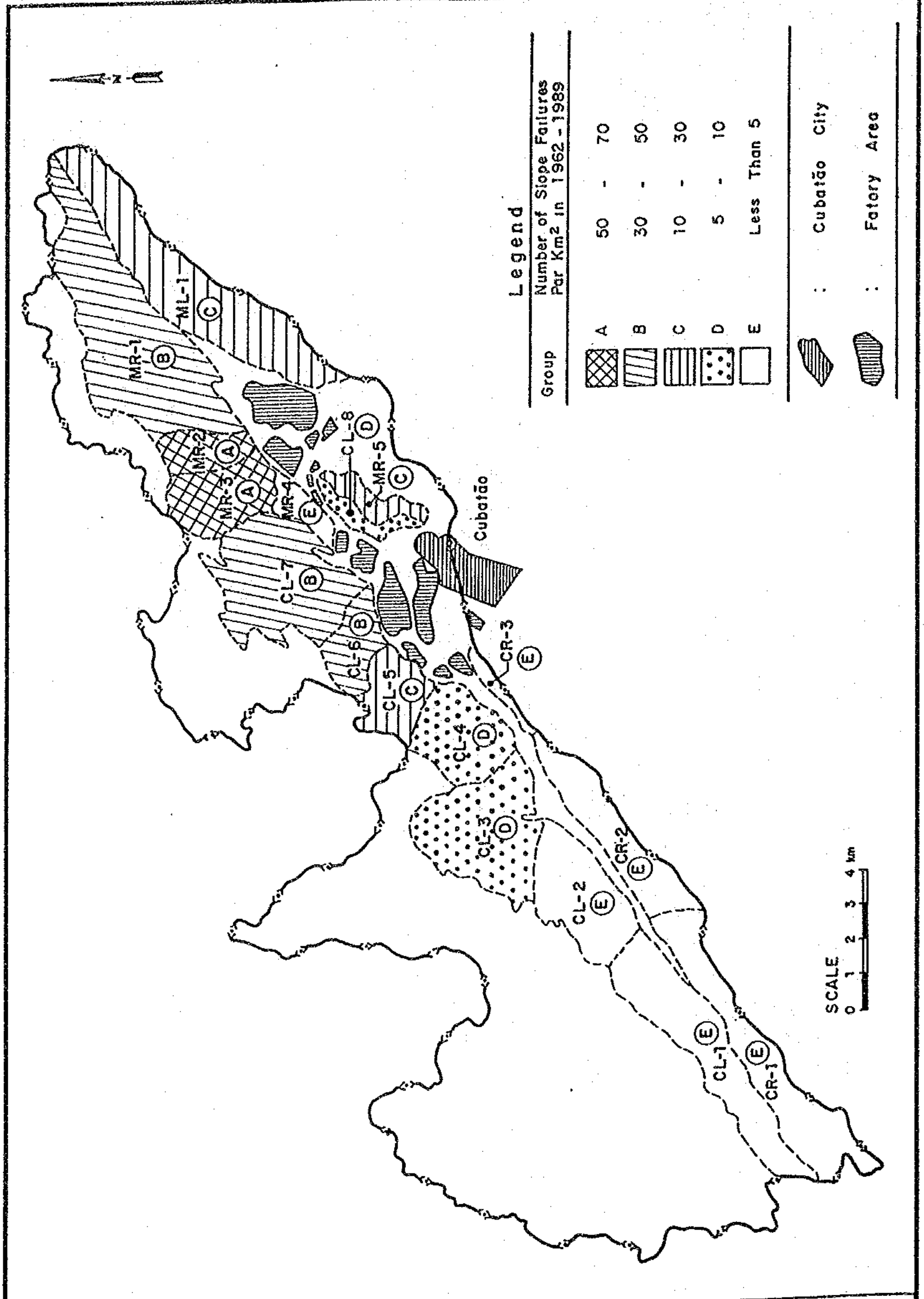

FIG.II.5
CLASSIFICATION MAP
OF SLOPE FAILURES

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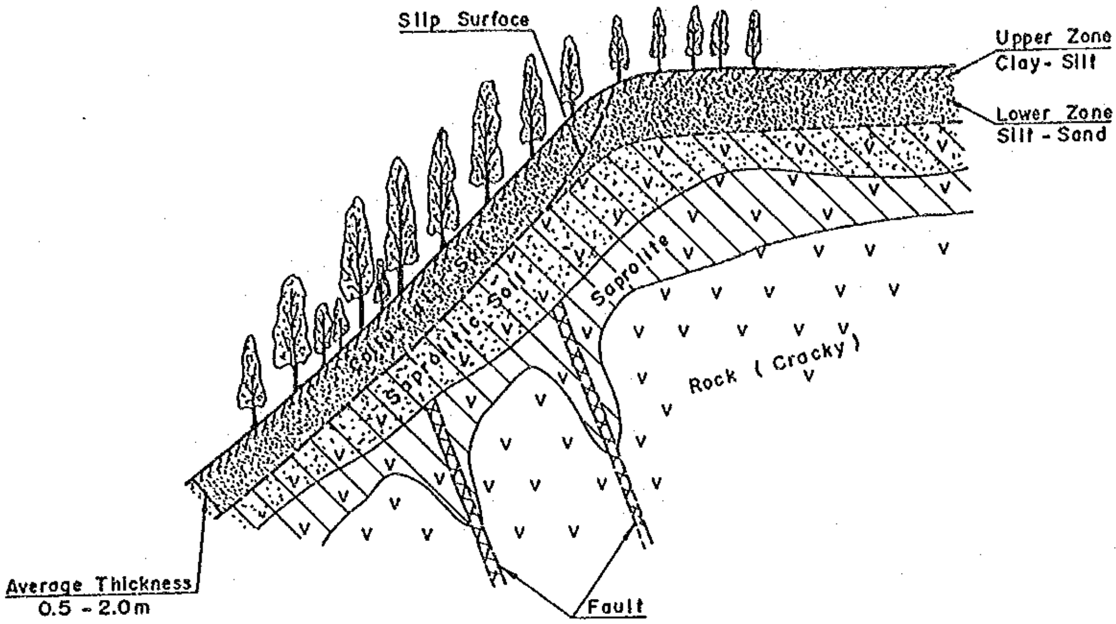

Source: Rain-Induced Landslides in Southeastern Brazil (Wolfe 1988)

FIG.H.6
SCHEMATIC PROFILE OF
TYPICAL SLOPE FAILURE

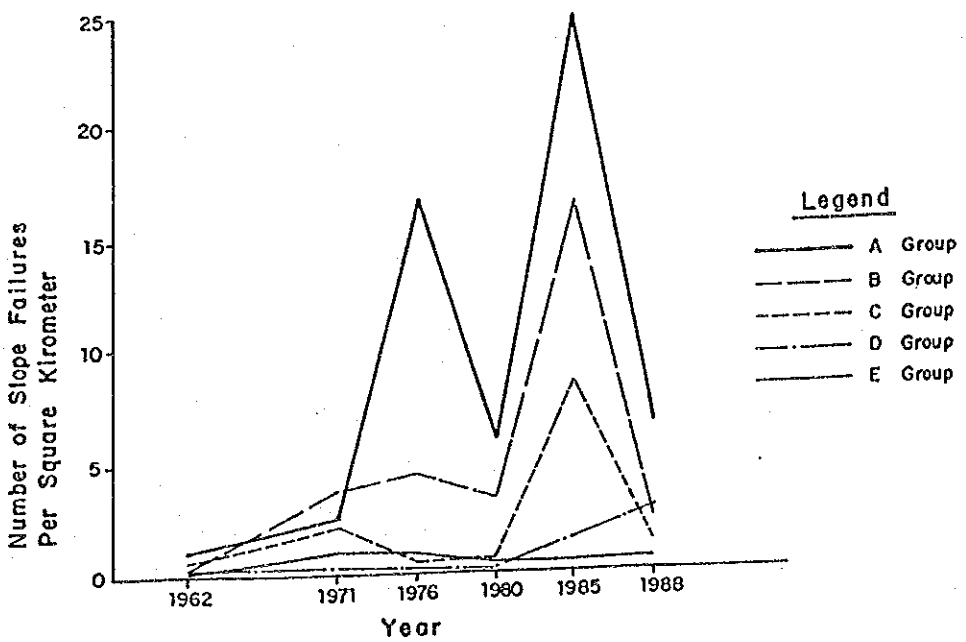

FIG.H.7
CHANGE IN SLOPE FAILURES
IN CLASSIFIED GROUP

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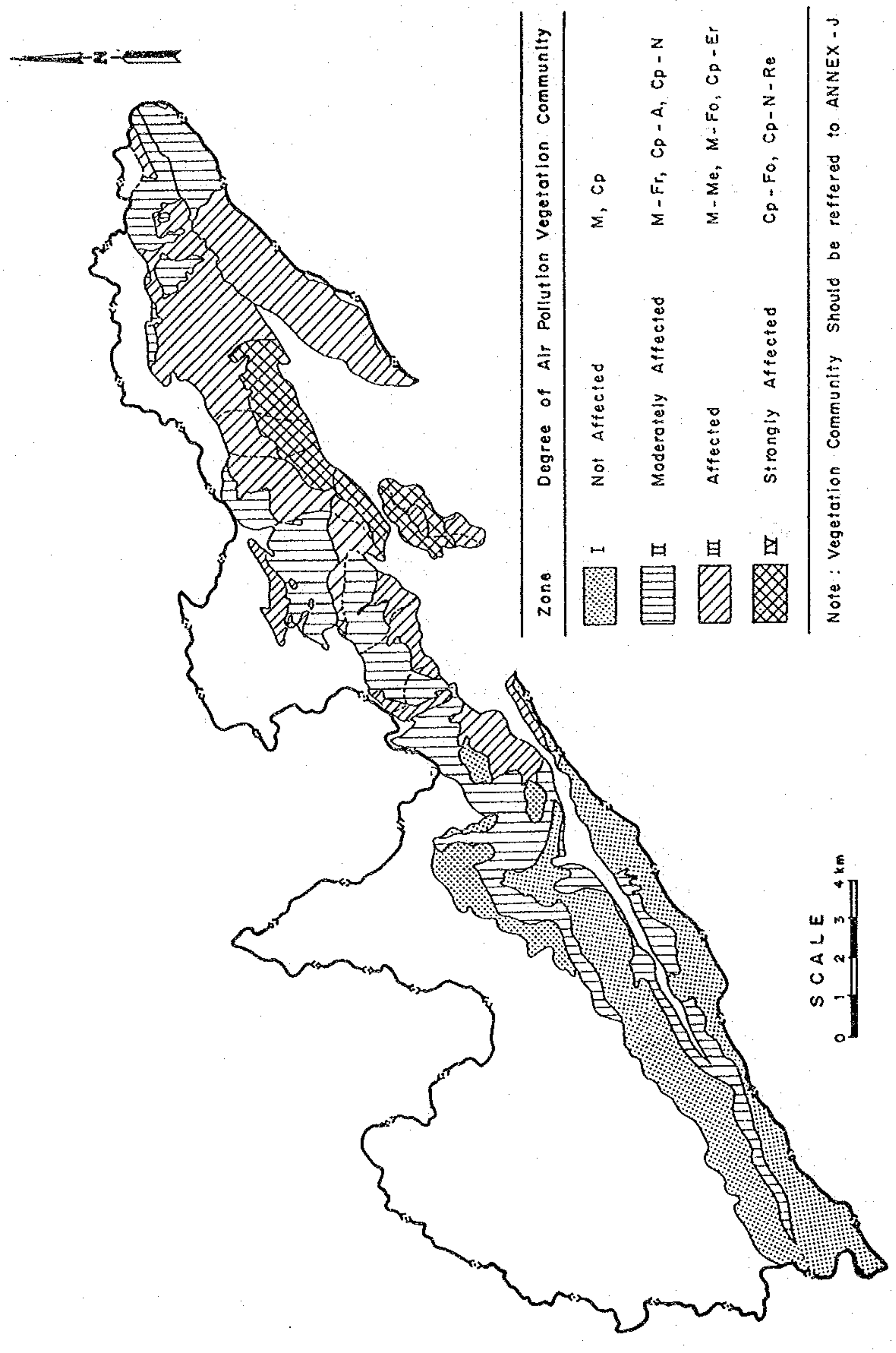

FIG.H.8
VEGETATION MAP OF
THE STUDY AREA

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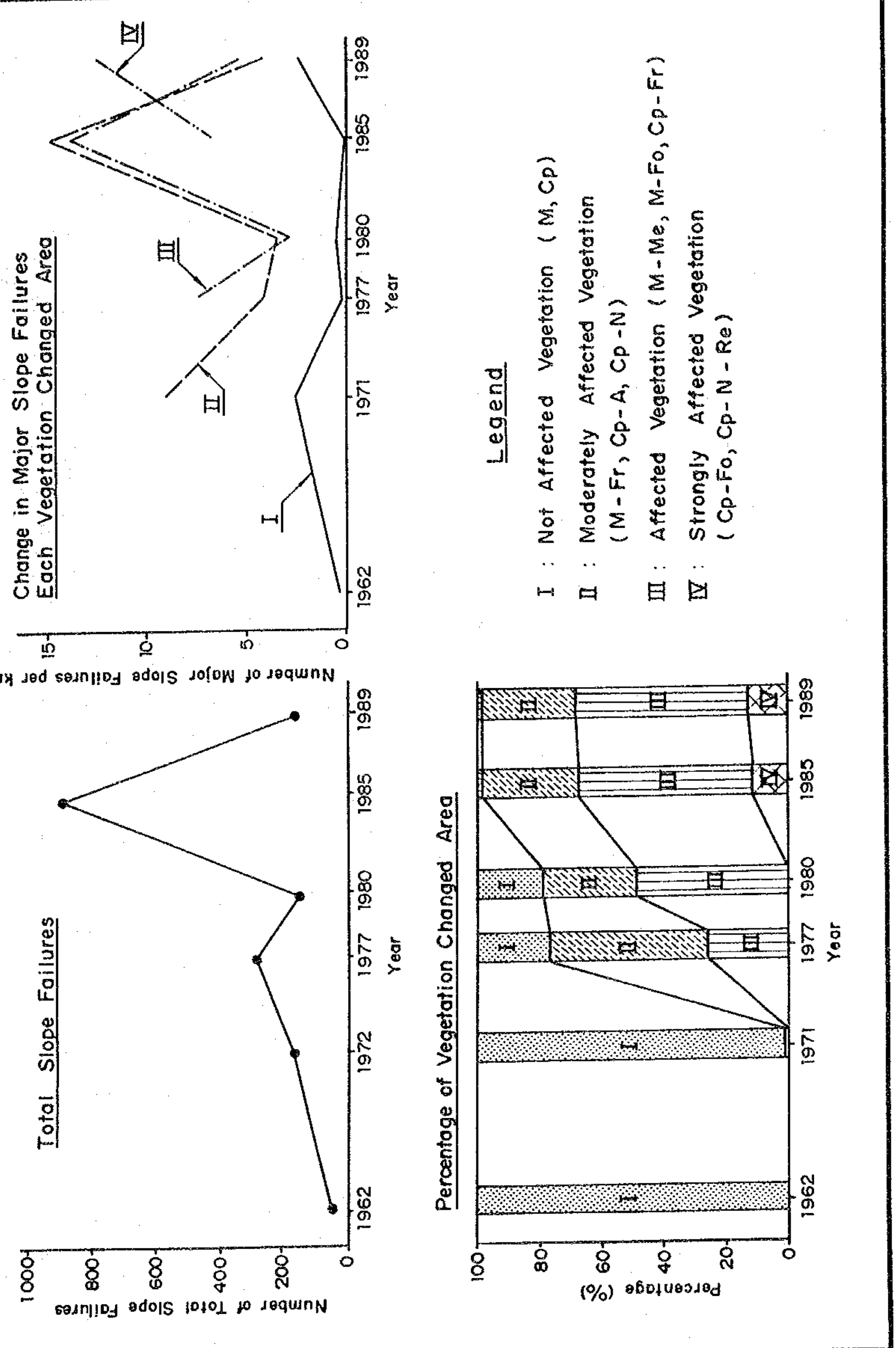

FIG.H.9
RELATIONSHIP OF VEGETATION CHANGES AFFECTED AIR POLLUTION AND SLOPE FAILURES

GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL

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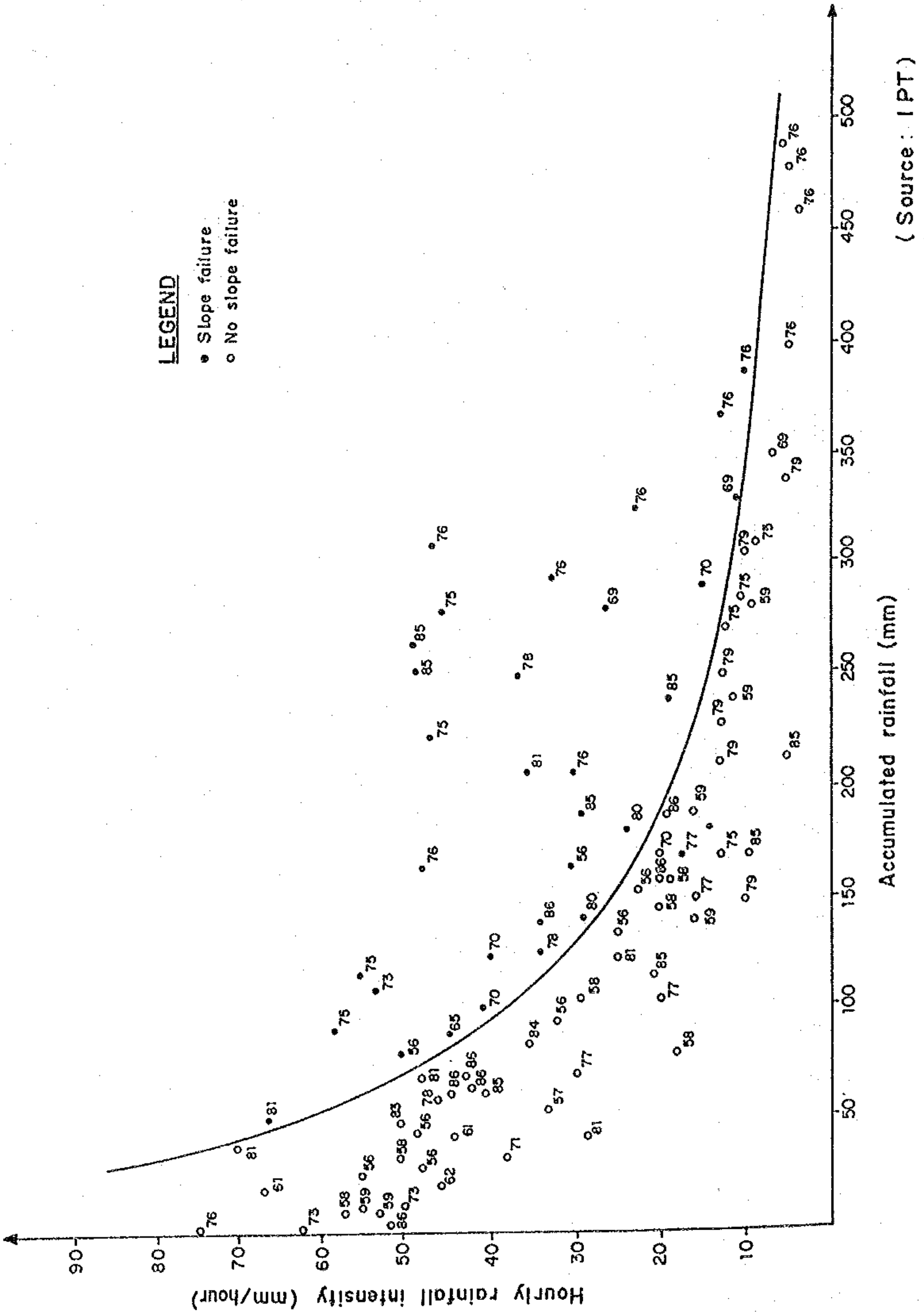

FIG.H.10
RELATIONSHIP BETWEEN
RAINFALL AND OCCURANCE
OF SLOPE FAILURES

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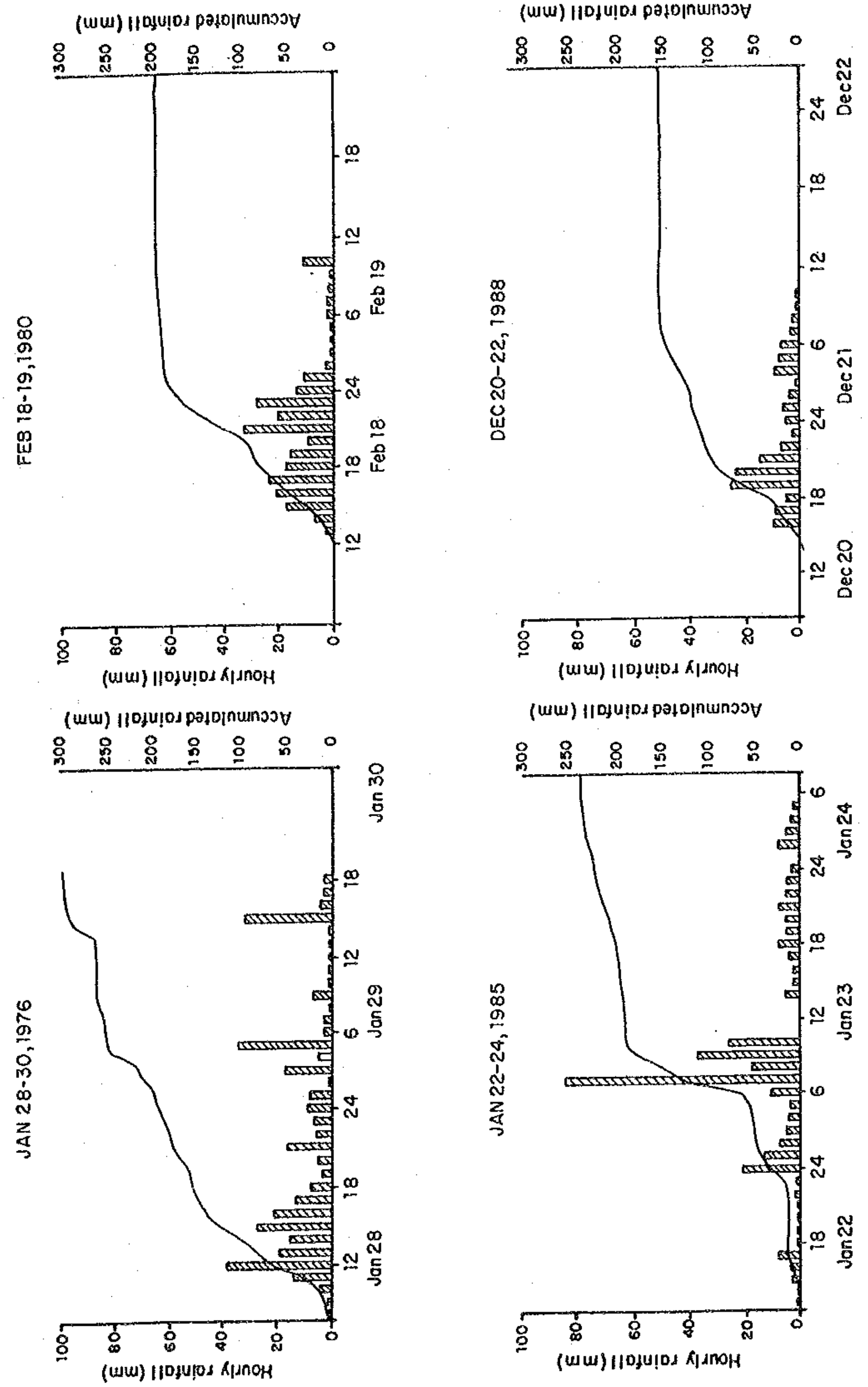

FIG.II.11
HYETGRAPH OF MAJOR
PAST SEDIMENT RUN-OFF

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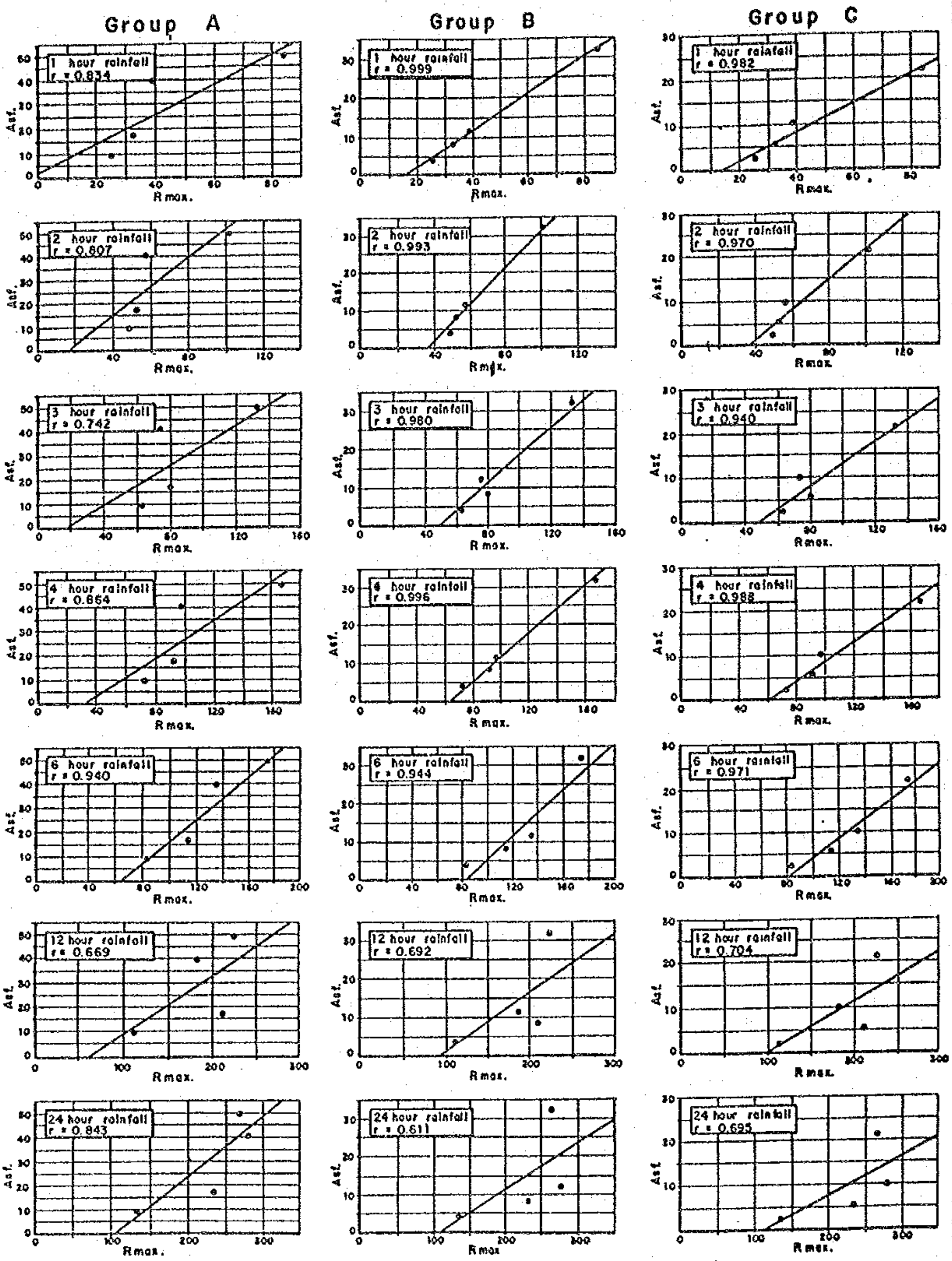

Note: Asf. : Total Slope Failure Area (Unit : $10^3 \times m^2$)

R max. : Maximun Rainfall (Unit : mm.)

r : Correnlation Coefficient

FIG.H.12
CORRELATION OF TOTAL AREA OF SLOPE FAILURES AND N-HOUR RAINFALL

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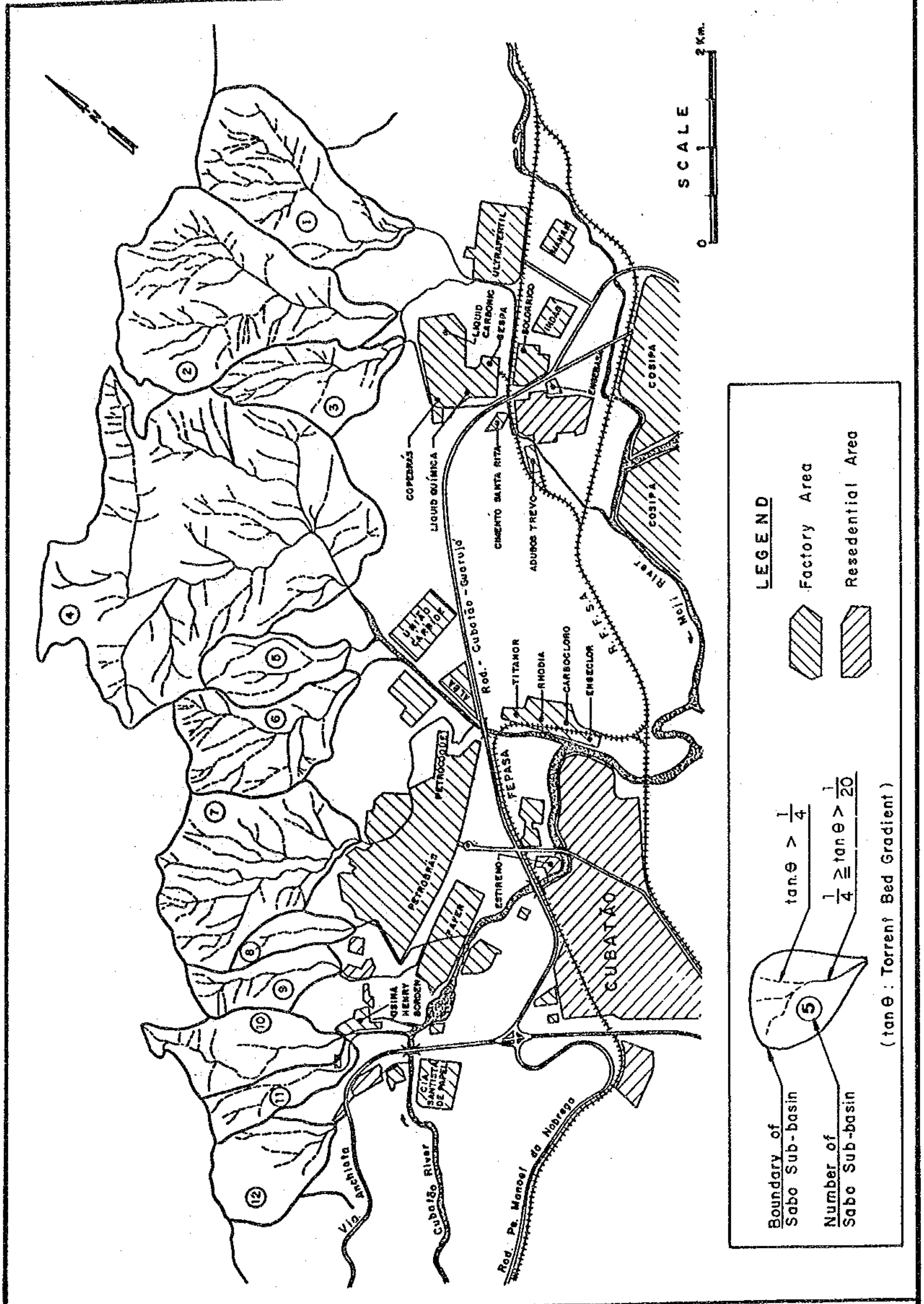

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FIG.II.13
DISTRIBUTION MAP OF
TORRENT BED DEPOSITS

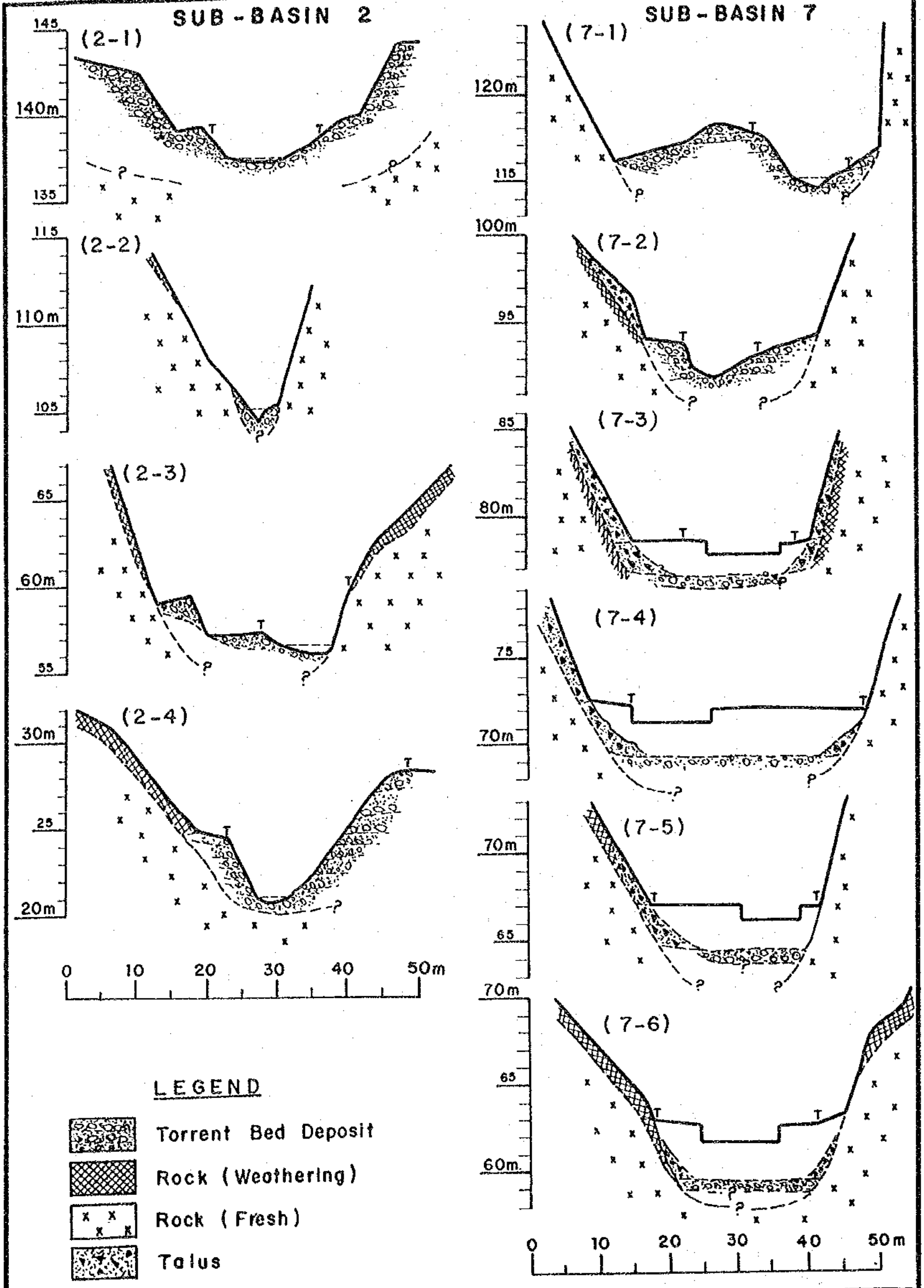

FIG.II.14
CROSS SECTION OF
TORRENT BED DEPOSIT

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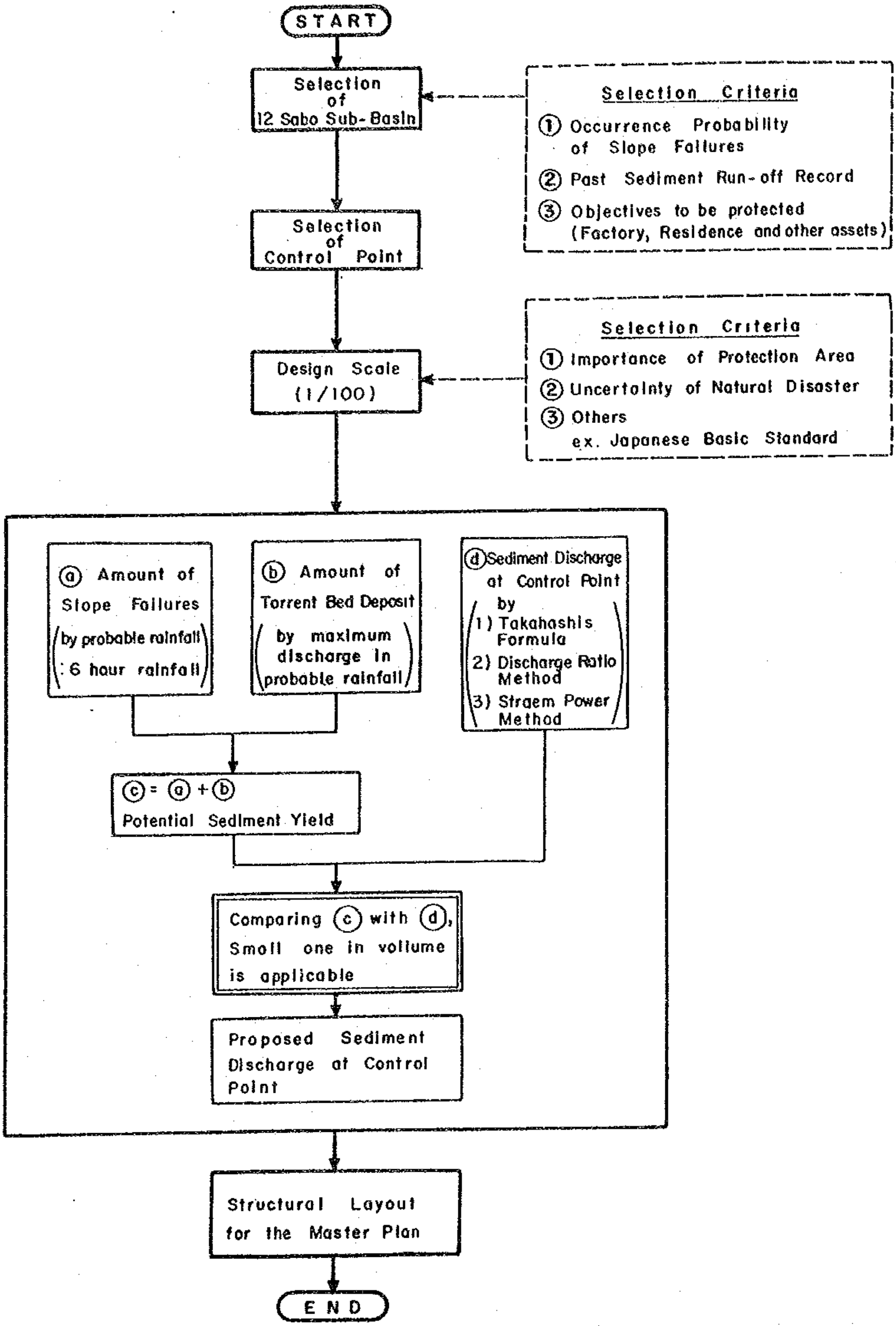

FIG.H.15
WORK FLOW OF FORMULATION OF MASTER PLAN

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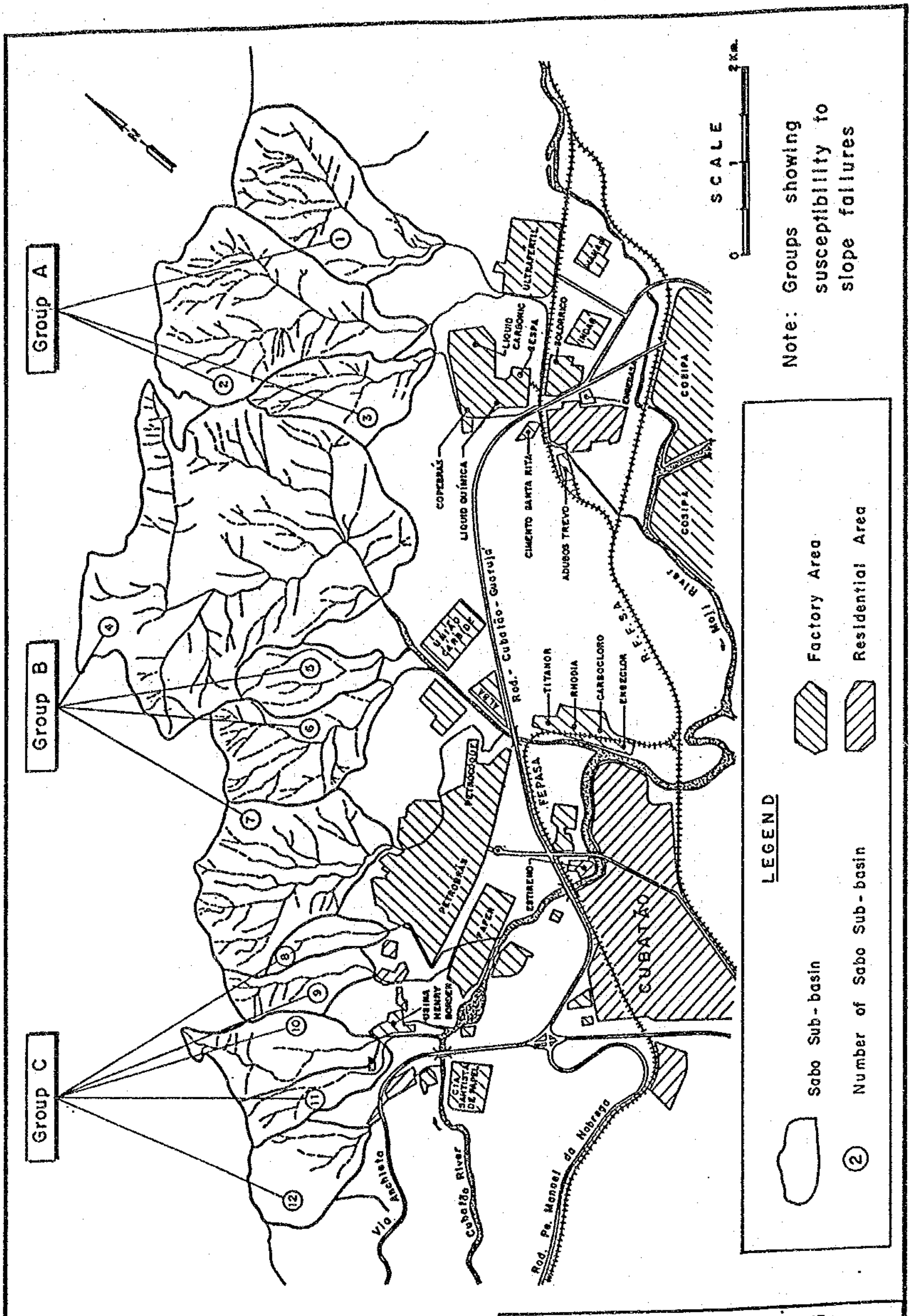

FIG.II.16
LOCATION MAP OF SABO SUB BASINS OF PROTECTION AREA

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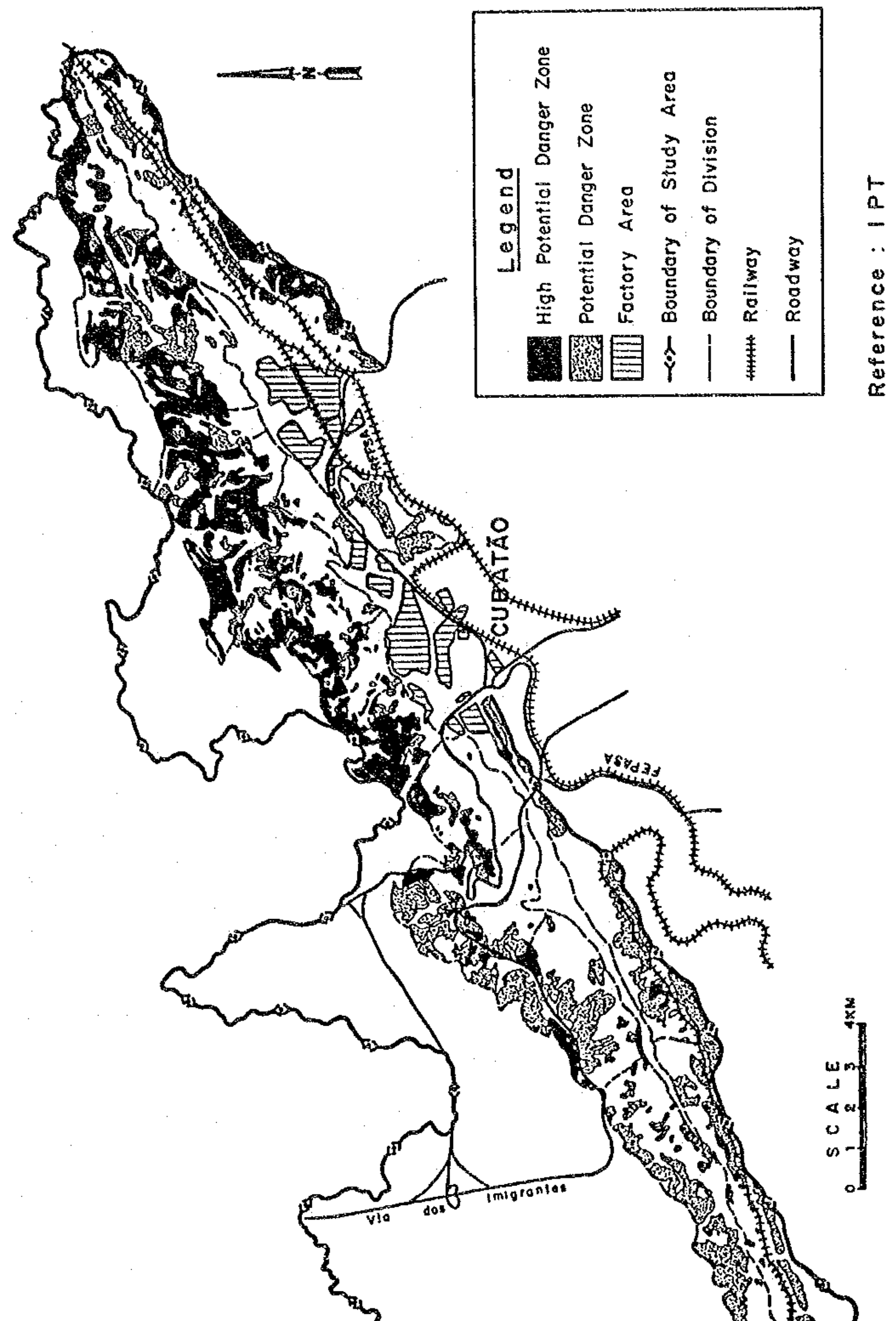

FIG.H.17
SUSCEPTIBILITY MAP TO
SLOPE FAILURE

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CUBATÃO REGION, STATE OF SÃO PAULO

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FIG.II.18
SEDIMENT YIELD FROM TORRENT BED DEPOSIT

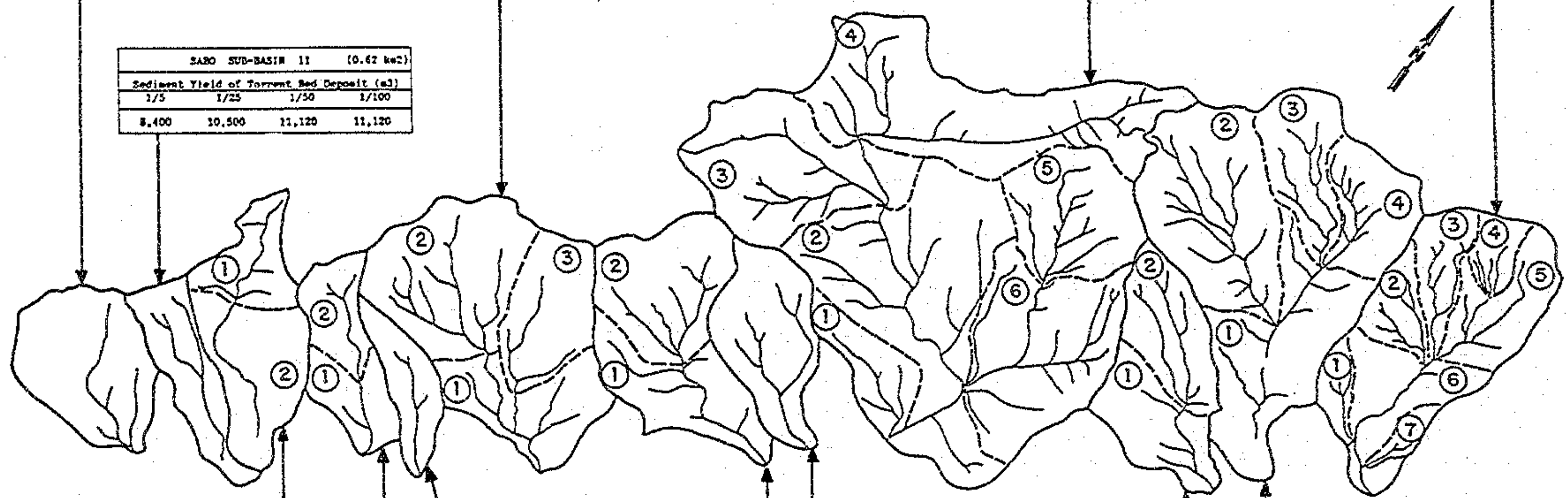
SABO SUB-BASIN 12 (1.11 km2)			
Sediment Yield of Torrent Bed Deposit (m3)			
1/5	1/25	1/50	1/100
13,200	16,220	17,220	17,360

SABO SUB-BASIN 11 (0.62 km2)			
Sediment Yield of Torrent Bed Deposit (m3)			
1/5	1/25	1/50	1/100
8,400	10,500	11,120	11,120

SABO SUB-BASIN 7 (2.64 km2)				
Divided Area	Sediment Yield of Torrent Bed Deposit (m3)			
No.	1/5	1/25	1/50	1/100
1	22,350	27,740	29,320	29,480
2	21,470	26,740	28,330	28,560
3	6,720	8,370	8,830	8,920
Total	50,540	62,850	66,480	66,960

SABO SUB-BASIN 4 (8.42 km2)				
Divided Area	Sediment Yield of Torrent Bed Deposit (m3)			
No.	1/5	1/25	1/50	1/100
1	4,400	5,700	6,200	6,300
2	108,090	140,250	151,390	155,100
3	60,690	78,540	84,730	86,870
4	37,190	48,160	52,070	53,240
5	13,850	18,180	19,490	20,140
6	28,780	37,210	40,010	41,070
Total	253,000	328,040	353,890	362,720

SABO SUB-BASIN 1 (2.39 km2)				
Divided Area	Sediment Yield of Torrent Bed Deposit (m3)			
No.	1/5	1/25	1/50	1/100
1	1,680	2,150	2,280	2,280
2	4,620	5,730	6,130	6,130
3	6,660	8,350	8,870	9,010
4	2,730	3,430	3,640	3,710
5	8,440	10,680	11,210	11,340
6	12,220	12,950	13,730	13,810
7	700	900	930	950
Total	37,050	44,170	46,790	47,230



SABO SUB-BASIN 10 (1.28 km2)				
Divided Area	Sediment Yield of Torrent Bed Deposit (m3)			
No.	1/5	1/25	1/50	1/100
1	6,910	8,530	9,020	9,100
2	8,100	10,050	10,660	10,660
Total	15,010	18,580	19,680	19,760

SABO SUB-BASIN 8 (0.41 km2)			
Sediment Yield of Torrent Bed Deposit (m3)			
1/5	1/25	1/50	1/100
3,550	4,280	4,530	4,530

SABO SUB-BASIN 9 (0.73 km2)				
Divided Area	Sediment Yield of Torrent Bed Deposit (m3)			
No.	1/5	1/25	1/50	1/100
1	3,400	4,230	4,460	4,510
2	2,910	3,650	3,820	3,880
Total	6,310	7,880	8,280	8,390

SABO SUB-BASIN 5 (0.90 km2)			
Sediment Yield of Torrent Bed Deposit (m3)			
1/5	1/25	1/50	1/100
10,880	13,530	14,330	14,460

SABO SUB-BASIN 6 (1.73 km2)				
Divided Area	Sediment Yield of Torrent Bed Deposit (m3)			
No.	1/5	1/25	1/50	1/100
1	14,740	18,540	19,610	19,760
2	16,390	20,450	21,750	21,900
Total	31,130	38,990	41,360	41,660

SABO SUB-BASIN 2 (3.79 km2)				
Divided Area	Sediment Yield of Torrent Bed Deposit (m3)			
No.	1/5	1/25	1/50	1/100
1	17,340	21,680	23,190	23,190
2	33,400	42,750	45,420	45,760
3	9,880	12,620	13,380	13,520
4	6,980	8,720	9,370	9,370
Total	67,600	85,770	91,360	91,840

SABO SUB-BASIN 3 (1.29 km2)				
Divided Area	Sediment Yield of Torrent Bed Deposit (m3)			
No.	1/5	1/25	1/50	1/100
1	8,780	11,070	11,800	11,900
2	11,800	15,000	15,840	15,840
Total	20,580	26,070	27,640	27,740

Legend

- Boundary of Sub-basin
- Boundary of Divided Area in Sub-basin
- Areal Distribution of Torrent Bed Deposit

Scale 1 : 50.000

0 1 2 Km

GOVERNMENT OF FEDERATIVE REPUBLIC OF BRAZIL

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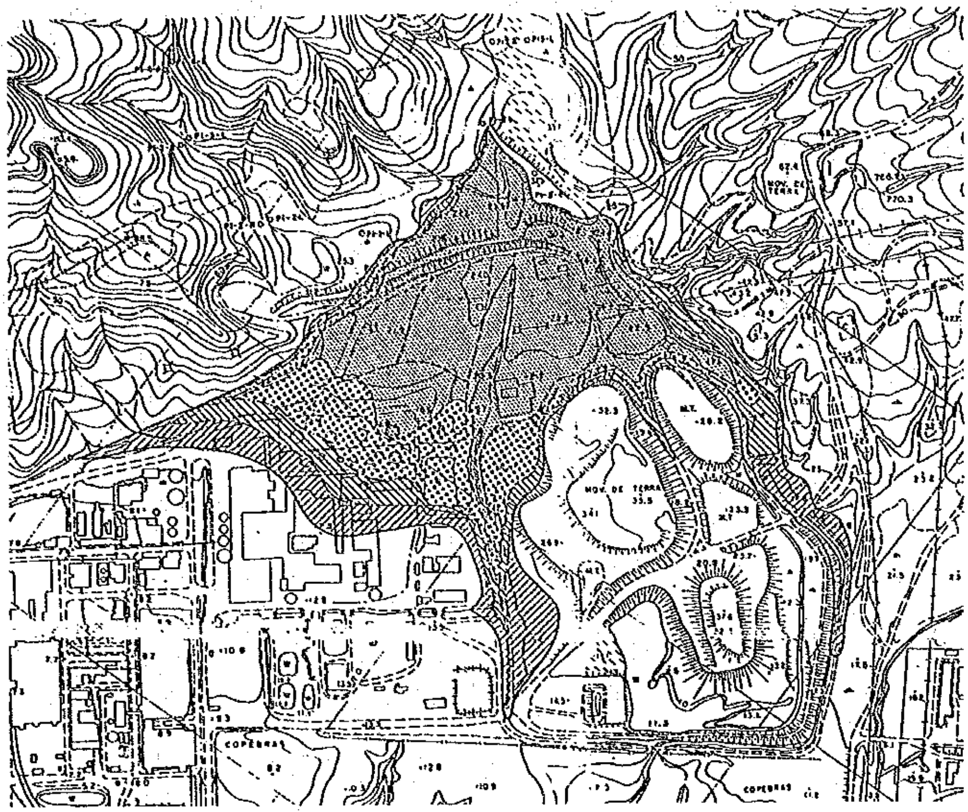
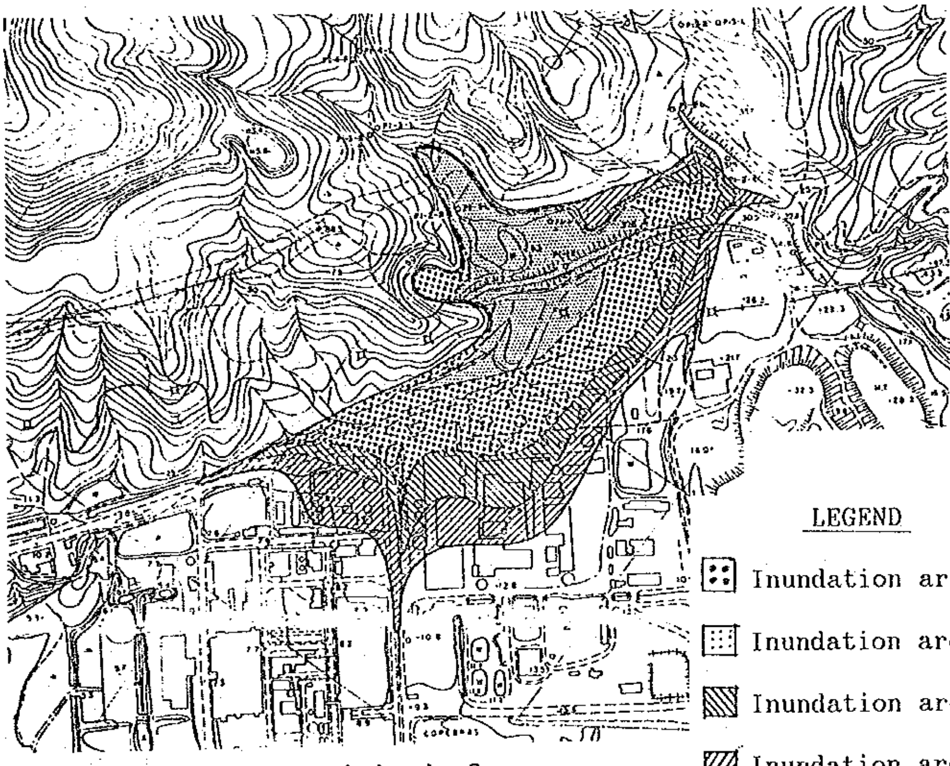


Sub basin 2



Sub basin 3

LEGEND

- Inundation area (1/ 5)
- Inundation area (1/25)
- Inundation area (1/50)
- Inundation area (1/100)

FIG.H.19
INUNDATION AREA OF DESIGN SEDIMENT RUN-OFF DISCHARGE (Subbasin 2 and 3)

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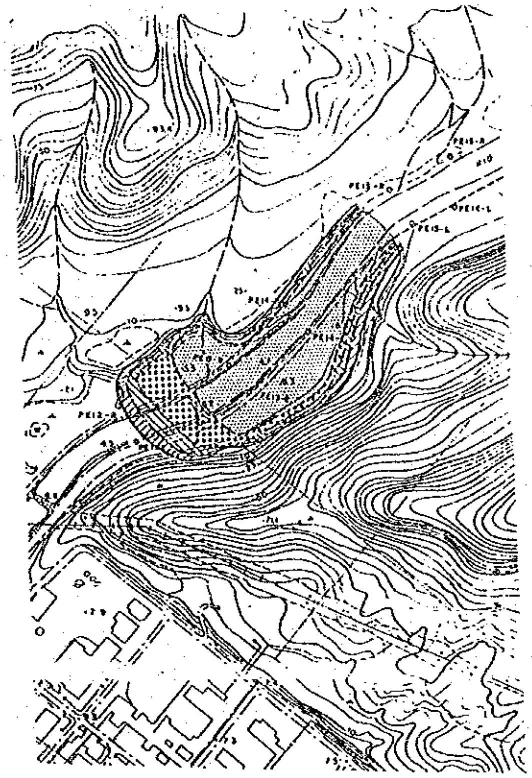
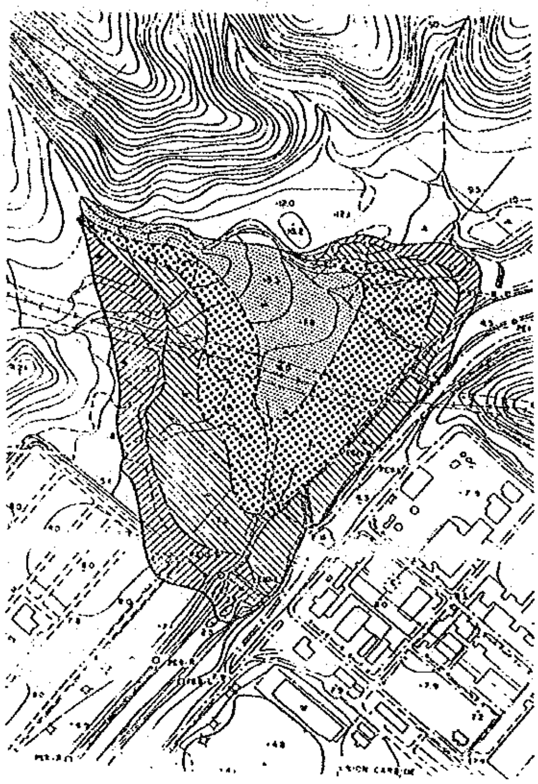
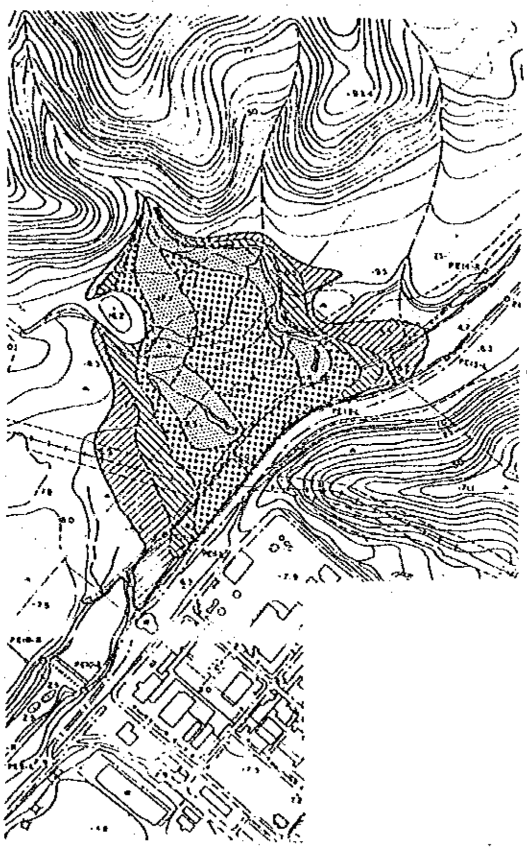


Sub basin 4



Sub basin 5



Sub basin 6

LEGEND

Inundation area (1/ 5)

Inundation area (1/25)

Inundation area (1/50)

Inundation area (1/100)

FIG.H.20
INUNDATION AREA OF DESIGN SEDIMENT
RUN-OFF DISCHARGE (Sub basin 4,5 and 6)

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

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