It should be noted that the municipalities of Itajai, Timbo, Indaial, Ilhota, Rio do Sul and Ibirama are also playing an important part in the industrial production. The municipality of Itajai, with production structure oriented toward food products, non-metallic products and paper products, occupies the fourth position in the basin with production of 6.2% of the total in 1980. The other municipalities listed above, although with a lower production value, represent important economic roles in their respective micro-regions.

The tertiary sector of the state is characterized by a large number of small establishments in general. In 1980, the average annual sales amount of commercial sub-sector in the basin was Cr$65.1 billion and that of service sub-sector was Cr$6.2 billion. These accounted for 29.2% and 20.9% of the state sales amount, respectively. Total amount of these two sub-sectors accounted for 28.2% of that of the state. The basin also had 21.8% of the employed persons in the state and 20.1% of the number of establishments. The total sales amount of the state was Cr$223 billion in 1980 and GVA of the commercial sector in the state was Cr$41,636 million.

The Colonial de Blumenau is the most important in services' sector in the basin, both in commercial activity and in services activity; in the number of establishments, total employed persons and total sales amount. It occupies, in state terms, the first place in the commercial activity and the second place in the services' activity.

From the point of view of the tertiary sector, the major municipalities are Blumenau and Brusque, which account for approximately 85.5% of the total sales amount of the sector in the micro-region. Like other industrial sectors, Blumenau plays the most important role in this sector's activity, with total sales amount of Cr$24,843 million in 1980. This amount occupies about 34.8% of the total sales amount in the basin. Blumenau also accounts for 26.3% of the number of establishments in the basin and 36.3% of the employed persons.

The second municipality in importance in the basin is Itajai in Litoral de Itajai micro-region, which participated with Cr$27,365 million, 1,537 establishments and 7,317 employed persons in 1980. Of this total sales amount, Cr$26,147 million came from the commercial sector. In particular, wholesale commerce contributed Cr$19,113 million or 61.8% of the commercial sector. The amount of wholesale was much bigger than that in Blumenau of Cr$5,571 million. Fuel and lubricant are the principle components, representing the greatest wholesale income.

The third municipality in importance in the basin is Rio do Sul, with Cr$5,371 million in total sales amount, 738 establishments and 3,960 employed persons in 1980. It is the most important in the Colonial do Alto Itajai micro-region, playing a leading role in economic activity for neighboring municipalities of Aurora, Agronomica, Laurentino, Rio do Oeste and Lontras.

2.4.6 Transportation

The Itajai river basin is located between national highways BR-101 and BR-116, the most important interconnecting routes between north and south regions of the country. BR-101 cuts the basin near its river mouth along the seashore line. BR-116 cuts the western neighborhood municipalities from the basin and connects the two southern capital cities, Porto Alegre and Curitiba. The railway transportation does not exist anymore in the basin. In the basin, the dominant transportation might mainly rely not on public mass transportation system but on private vehicles.

Along the course of the Itajai river, BR-470 connects these two important highways. BR-470 plays an important role as a stem road of connecting major municipalities along the Itajai river. It also connects the basin to western parts of the state over BR-116.

As of 1985, the existing road network in the basin summed up to 14,604 km, which comprised national (205 km), state (926.7 km) and municipal (13,472 km) roads. Of this total length, paved roads accounted for 610.4 km or 4.2%, broken down as follows: national, 205 km; state, 379 km; and municipal, 26 km. Others are still gravel or earth roads, of which 3,998 km is already improved but is not paved yet. Road density in the basin registered 0.959 km/km2, which is slightly denser than that in the state average of 0.923 km/km2.

2.5 Flood Problem and Flood Damage

2.5.1 Present river condition and river characteristics

The Itajai river is characterized by its irregular river bed slope as illustrated in Fig. 4. It will be widely classified into three groups, namely, upstream river stretch with gentle river bed slope in the upstream of Lontras city, middle river stretch with remarkable steep river bed slope between the downstream of Lontras city and Subida, and rather steep river bed slope between Subida and upstream of Blumenau city, and lower river stretch with remarkably gentle river bed slope between Blumenau city and river mouth.

The river bed slope in about 70 km long upstream river stretch is about 1 to 2000. Existing Oeste dam is located on Itajai do Oeste river at about 78 km upstream of the Itajai confluence. The river bed slope in the Itajai do Oeste is 1 to 4,000. The river width of the upstream river stretch is about 100 m and its river depth is 10 m.

In the middle river stretch, the river bed slope varies widely, namely about 16 km long V-shaped river stretch with the river bed slope of 1 to 60 between Salto Pilao and Subida, 49 km long river stretch with river bed slope of 1 to 700 between Subida and Indaial city, and 15 km long river stretch with river bed slope of 1 to 400 between Indaial city and upstream of Blumenau city. The river width is 120 to 280 m in Subida - Indaial stretch and 180 to 350 m in Indaial - Blumenau stretch.

In the lower river stretch, the river bed slope becomes so gentle as about 1 to 10,000 to 1 to 15,000. The Blumenau city is located along V-shaped meandered Itajai river stretch. The river width in this stretch is about 140 m and its depth is about 20 m. The river width in the downstream of the Blumenau city is 200 to 300 m on an average and its depth is 15 to 20 m at Gaspar city, 17 m at Ilhota city and 10 m in the upstream stretch of Itajai city.

The Itajai Mirim river, which originates from mountain zone in the northern part of the basin, flows down to northeastward passing through Botuvera town and Brusque city. Remarkably meandered river stretch between Brusque and Itajai cities was improved straightly by means of short cutting 15 years ago. The Itajai Mirim river divides into two stretches at the southwestern part of the Itajai city, namely, one is largely meandered existing river channel and other is short cut channel connected with the meandered river channel straightly. Immediately after joining these two channels, the Itajai Mirim debouches to Itajai river at the north part of the Itajai city. The river slope of the endmost Itajai Mirim river is about 1:10,000. River width of the Itajai Mirim in Brusque-Itajai stretch is about 50 m and its depth is 4 to 8 m.

River width, depth, bed slope and flow capacity in the main stream of the Itajai river and its major tributaries in their confluences with the Itajai river are given in Figs. 5. and 6. respectively. Present bankful flow capacity in major river stretches is summarized as follows:

River stretch	Flow capacity (m^3/sec)
Ilhota - Blumenau	2,000 to 4,000
Downstream from Ilhota city	800 to 1,500
Blumenau city	3,000
Indaial city	6,000
Ascurra town	3,000 to 4,500
Rio do Sul city	1,000
Lowermost of Itajai Mirim	400 to 500

2.5.2 Past large scale of floods and their rainfall characteristics

After the construction of the Sul and Oeste dams, large scale of floods occurred in July 1983 and August 1984.

In July 1983, the rain started from the night on July 5th and continued for 7 days up to July 12th in the entire Itajai river basin. The recorded maximum hourly rainfall is 22 mm/hour at Dr. Pedorinho in the Benedito river basin and the basin mean rainfall amount in 1, 4, and 7 days are estimated to be 65 mm, 216 mm and 324 mm respectively. Flood peak discharges at the major level gauging stations are 1,500 m^3/sec at the Sul dam, 1,000 m^3/sec at the Oeste dam, 2,000 m^3/sec at Rio do Sul, 2,500 m^3./sec at Ibirama, 4,400 m^3/sec at Apiuna, 4,800 m^3/sec at Indaial and 540 m^3/sec at Brusque.

In August 1984, the rain started from the morning on Aug. 5th to Aug. 8th and the maximum hourly rainfall was 25 mm recorded at Blumenau city. The basin mean rainfall in 1 and 3 days are 110 mm and 216 mm respectively and the heavy rainfall of around 150 mm/day occurred in the Itajai Mirim basin. Since rainfall pattern in 1984 is more intensive than rain storm in 1983, the shape of flood hydrograph is sharp and flood peak discharge is larger than in 1983. Flood peaks at major sites are 2,500 m^3/sec at the Sul dam, 1,200 m^3/sec at the Oeste dam, 1,860 m^3/sec at Rio do Sul, 400 m^3/sec at Ibirama, 4,400 m^3/sec at Apiuna, 860 m^3/sec at Timbo and 5,100 m^3/sec at Indaial.

2.5.3 Flood flow analysis

(1) Introduction

In the Itajai river basin, the large flood occurred in 1983 and 1984. Therefore, DNOS studied the magnitude of flood discharge in these floods and planned river improvement works at Blumenau and Rio do Sul. Design discharge based on the flood mark in these floods and non-uniform flow calculation are 6,000 m3/sec at Blumenau and 3,000 m3/sec at Rio do Sul.

Flood flow analysis aims at estimating the flood peak discharge at major points in the entire Itajai river basin as a design discharge of flood control facilities such as river improvement, flood control dam, floodway and so on, which is considered to affect to flood hydrograph and its peak discharge. Therefore simulation study using mathematic model and hourly rainfall records is needed to estimate flood discharge hydrograph and its peak discharge.

In this section, hydrological data, methodology and results of this study are summarized. Details are mentioned in ANNEX II HYDROLOGY.

(2) Flood records

Design discharge simulated by rainfall-runoff model is evaluated by using occurrence probability of rainfall since hourly rainfall and flood hydrograph records are limited. Therefore, probable flood discharge is estimated by enlarging observed rainfall amount, which is selected from availability of hourly rainfall/discharge and magnitude/shape of flood hydrograph, to probable rainfall amount.

In this study, four floods after construction of Sul and Oeste dams are selected from the preceding reason. They are floods on December 1978, December 1980, July 1983 and August 1984 according to Table 2 which shows the flood water level at Blumenau. Basin mean hourly rainfall distribution and flood hydrographs at the major sites are shown in Figs.7 and 8.

(3) Methods and procedures

Probable flood discharges are estimated from probable rainfall using storage function method. The flood analysis consists of construction of a model, rainfall analysis and flood discharge calculation including establishing the storage function model.

(i) River system model

In addition to the 42 sub-basin divisions, components having retarding effects are incorporated. Fig.9 shows the river system model for flood analysis. The river course of Itajai river is modelled by 26 river channels and the existing / proposed flood control dams and floodway are linked to the river system model. Base point is set at river mouth of the Itajai river since this study objects to prevent from the flood occurring in the entire Itajai river basin.

(ii) Rainfall analysis

As for the design rain storm duration, a period of 4 days is selected, considering the characteristics of the past rain storms.

The annual maximum basin mean 4 days are sampled as shown in Table 3 from basin mean daily rainfall calculated by the Thiesen method and regression analysis for the period from 1951 to 1984. From the above, the probable basin mean 4 days rainfall is calculated by Pearson III type method as shown in Table 4. Frequency curve of annual maximum are described in Fig.10.

Hourly rainfall distribution of probable rainfall is constructed by enlarging the selected storm rainfall to probable rainfall.

(iii) Flood discharge calculation

(a) Flood runoff coefficient

Relation between storm rainfall and flood runoff depth at the major water level gauging station are shown in Fig.11. From the figure, preliminary runoff coefficient is set at 0.5 and the maximum limit of rainfall to saturate the ground surface, depression, etc. is set at 200 mm.

(b) Calibration of storage function model

Constants of storage function of sub-basin are calibrated through trial and error in comparison between the estimated flood hydrographs and the hydrographs observed on Dec.1978, Dec.1980, Jul.1983 and Aug.1984. Finally, constants of sub-basins are taken up by multiplying 1.3 times to the initial K-value estimated by the empirical formula. Tables 5 and 6 show the best set of constants of storage function for sub-basins and river channels.

(c) Reservoir operation study

Reservoir operation study is carried out to evaluate the effect of flood peak reduction to the downstream by using four floods. The operation methods are summarized as follows;

- Existing operation method
- All the outlet conduits installed at dams are closed, when flood discharge at Blumenau exceeds 1,000 m^3/sec.
- Outlet conduits installed at dams are fully opened.
- Additional conduit at Sul dam is installed.
- Spillway gates are newly installed at dams.

The results are shown in Fig.12. From the results, the existing operation method is recommendable taking into account the effect not only against large flood but also against small and middle flood. This method is applied for estimation of probable flood.

(d) Base flow

Base flow for probable flood discharge is estimated from the average monthly discharge at the major water level gauging station during wet season from July to December. The specific discharge of 0.033 m^3/sec/km^2 which corresponds to average monthly discharge is distributed into sub-basins.

(e) Probable floods

The probable flood with/without the existing flood control dams are estimated by incorporating the probable rainfalls with 2, 5, 10, 25, 50, 80, 100 years return periods into the established storage function model. Since there are four rainfall patterns in 1978, 1980, 1983 and 1984, four kinds of flood hydrograph are obtained as shown in Fig.13. The peak discharges at the major sites are shown in Table 7. Taking the biggest one among four hydrographs, the probable flood discharge distribution with/without the existing flood control dams are shown in Fig.14. From the figure, probable flood peak discharges at Blumenau are summarized as follows;

Return Period (year)	Without F.C.D. (m^3/sec)	With F.C.D. (m^3/sec)
2-year	3,300	2,300
5-year	4,100	2,800
10-year	4,700	3,200
25-year	5,400	3,800
50-year	6,200	4,900
80-year	6,600	5,200
100-year	7,000	5,500

Note: F.C.D. means the existing flood control dams.

(f) Check of estimated probable floods and evaluation of past flood

The estimated probable flood is compared with the recorded flood discharge at Blumenau converted from rating curve based on the non-uniform flow calculation as shown in Fig.15. The estimated probable flood discharges are fit for the plotted flood records with return period more than 10 years. But the estimated values less than 10 years probability are greater than the observed flood. This difference is considered to be caused by the reason why the selected four flood patterns are grearter than 2 years flood. From the mentioned, the results of this study is applicable for making the flood control plan.

Relation between the magnitude of actual peak discharge of the flood in 1978, 1980, 1983 and 1984 and their probability was studied assuming that all of the floods are not controlled by the existing dams. The flood peak discharge at Blumenau and its probability of the selected four floods under the above assumption are estimated as follows.

Flood	Without F.C.D. (m^3/sec)	Probability (year)
Dec.1978	2,920	Around 2
Dec.1980	4,310	5-10
Jul.1983	5,930	Around 50
Aug.1984	5,730	Around 50

Note: F.C.D. means the existing flood control dams.

2.5.4 Flood damage estimate

Enumeration of flood damage amount in the area along the Itajai river and its tributaries, which is caused by different magnitude of floods is a vital step of this flood control study in terms of assessing not only which area severely suffers from flood damage, but also flood control benefit for project evaluation.

The deficiency of existing records of actual flood damages makes it difficult to depict damage-frequency curve as standard method of damage calculation because such records are only confined to both floods occurred in 1983 and 1984, and do not cover all damage components.

Analytical methods of simulating probable flood damage is, as a result, adopted for flood damage estimate by assessing various kinds of properties value and analyzing area-depth-duration through hydrological simulation.

For that purpose, probable inundation area covering flooding area caused by whatever scale of flood is required to be estimated on the basis of inundation area due to 1983 and 1984 floods and topographic conditions. Probable inundation area is segmented into a number of river stretch by which probable flood damage by different scale of flooding is estimated.

The flood damage was estimated in the following procedures;

(1) Probable inundation area is divided by meshes having intervals with 500 m which is equivalent to 25 ha.

(2) The components of damageable properties are paddy, sugarcane, maize, livestock, buildings, indoor movables inside buildings, and infrastructure. They are projected at present and future level at 1986 price. Furthermore, indirect damages expressed by loss of economic activities are also taken into account.

(3) Hydrological study aws simulated for four type of flood runoff occurred in 1978, 1980, 1983, and 1984, from which area-depth-duration is analyzed. Based on area-depth-duration analysis as well as damage rate corresponding to each damageable property, probable flood damage is estimated by different magnitude of flood and river stretch.

The results of flood damage estimate were summarized as follows:

(1) In the area from Gaspar to Rio do Sul along the Itajai river, the degree of damage measured by annual mean flood damage is outstanding in case of 1983 flood. The corresponding figures in Itajai Mirim and other tributaries are outstanding in case of 1984 flood.

(2) Most of flood damages is derived from damages to building and indoor movables. Crop damage is mostly attributed to paddy, whereas damages to sugarcane and maize is scarcely identified.

(3) Blumenau is the hardest damage-hit area where annual mean flood damage is estimated to be about 7 % of all property value.

2.6 Existing Flood Control Facilities

2.6.1 Existing dams and their flood control effect

In order to cope with the repeating inundation, the Sul and Oeste dams were constructed in 1975 and 1972 respectively and besides, Norte dam is being constructed. These three dams have been designed as flood control use and flood releasing facilities consisting of gated outlet conduits in the dam bottom and non-gated spillway are provided.

These dams have been operated in such a way that all the outlet values are closed when heavy rainfall is observed at dam site and/or reservoir water level is over 10 m in depth from the river bed.

The effect of the flood peak reduction by the existing Sul and Oeste dams was examined by simulation study and it was clarified that flood peak at the Blumenau and Itajai was reduced by 830 m^3/sec and 660 m^3/sec for the flood in 1983 and 530 m^3/sec and 610 m^3/sec for the flood in 1984 respectively.

In order to find out the most effective flood control method for these three dams, study on the flood control effect was made for the following four methods;

(1) Flood control by means of the present operation method.

(2) Flood control by means of operation method in case that all of the existing outlet conduits are fully opened.

(3) Flood control by means of operation method in case that an additional outlet conduit is provided for the Sul dam and all of the outlet conduits are fully opened.

(4) Flood control by means of operation method in case that the spillway gates are provided for three dams and flood is released through fully opened outlet conduits and gated spillway.

The flood control effect by these four methods was examined using the flood discharge data in 1978, 1980, 1983 and 1984. The result of the examination shows that;

(1) By an application of the revised and/or modified operation method, more effective flood peak reduction can be made comparing with the case of the present operation method in case of 1983's flood which has a long duration of flood peak.

(2) While in case of the floods in 1978, 1980 and 1984 which have a short flood duration period, the flood peak discharges in the downstream stretch in case of the application of the revised and/or modified operation method increase comparing with the case of the present operation method.

Since occurrence of large scale of flood with a long duration of flood peak such as the flood in 1983 is very rare case and consequently probable 4-day continuous rainfall is applied to the estimation of the design flood in the following chapter, present operation method was selected as the most effective flood control method by the existing dams.

2.6.2 River improvement work and plan

DNOS is now implementing the river improvement work and plan in Blumenau - Gaspar stretch and Rio do Sul - Lontras stretch in the Itajai river and Itajai - Brusque stretch in the Itajai Mirim river at present.

In about 22 km long Blumenau - Gaspar stretch, the river improvement work is being executed by local contract basis under the design condition that the river channel is widened to 220 m to discharge the design flood of 6,000 m^3/sec. The estimated excavation volume is 27.5 million m3 and working period is estimated at 18 months from January 1985 to July 1986. The work is now executed at three sections using dredgers and drugline in parallel with the detailed design work. The excavated volume by February 1986 is 1.3 million m3. The progress of the work is, however, largely delayed due to financing problem.

In 17.4 km long Rio do Sul - Lontras stretch, river improvement plan was worked out under the condition that the river channel is widened to 90 to 110 m to discharge the design flood of 2,800 m^3/sec. The estimated excavation volume is 7.2 million m^3 and construction cost is estimated at US$14.9 million.

Since the occurrence of large scale of flood in 1961, river improvement including the widening of the river channel and construction of short cut channels was commenced in Brusque - Itajai stretch in the Itajai Mirim river. However, since large scale inundation took place due to the flood in August 1984, extension work of river channel was commenced at the short cut channel near Itajai city and also at the existing river channel at Brusque city. Excavated volume during the period from January 1985 to February 1986 is about 460,000 m^3. Definite plan regarding design flood, design river channel and so on is, however, not yet established.

2.7 Existing River Structures and Related Structures

A revetment is provided only at the river bank along the Blumenau and Brusque cities. They are 1.2 km long concrete type revetment in the right bank of the Blumenau stretch and about 200 m long gabion type revetment at Ireneu Bornhausen bridge in Brusque city in the Itajai Mirim river.

At the left river bank of the Itajai river mouth, stone pitch groyne with an interval of 130 m is installed for the river length of 1.3 km.

Any levee is not provided for all of the Itajai river and its tributaries.

The related structures such as bridge, pumping stations for municipal and industrial water supply, hydro electric power station, ferry port and harbour have been located in the Itajai river and its tributaries.

More than 100 nos of concrete bridges cross over the Itajai river and its tributaries. Majority of them are roadway bridges connecting the national road and local road. For most of the bridges, water supply pipe is attached and no aqueduct is provided. Majority of substructure of these bridges is constructed by concrete pile foundation. Although it is not clear about the scouring phenomena at flood time in 1983 and 1984, a serious scouring at the bridge foundation site is not found at present.

There are three small scale hydro electric power stations in the Itajai river basin. One of them is located at 10 km upstream of Blumenau city and others are situated in the upstream of the Benedito river respectively.

Many drainage pipes with small size diameter have been installed along the river near city area.

There are two ferry sites in the Itajai river near its river mouth. A harbour is located at the river mouth of the Itajai. This harbour is utilized as shipping port for agricultural products and timber and as a fishing port. In addition, there are many small and large scale shipyards in the Itajai river near the harbour.

Location of the river structures and related structures is shown Fig. 16.

2.8 Existing Flood Forecasting and Warning System in the Basin

After the flood in 1983, DNAEE implemented a flood forecasting and warning system in the Itajai river basin and started its preliminary operation in August of 1984. The system operates with data supplied by a radio system composed of five rainfall and water level gauging stations which are located at Taio, Ituporanga, Ibirama, Apiuna and Blumenau. These locations are shown in Fig.17.

Prediction of flood water level is made for Rio do Sul, Indaial and Blumenau by means of the data supplied by the radio system mentioned above, eventually supplemented with information from the existing Sul, and Oeste dams. The water levels and rainfall at the stations of Taio and Ituporanga, as well as eventual information on the flows from Oeste and Sul dams, will permit estimation of the levels at Rio do Sul. The same information, supplemented with the water levels and rainfall at Apiuna and Ibirama will permit evaluation of the levels at Indaial and Blumenau.

The warning system has central operating stations (CEOPS) in Blumenau and Curitiba, equipped for the control and processing and dissemination of data and information. The stations can be interrogated both from Curitiba (CEOPS) and from Brasilia (DNAEE) by telephone.

The data processed in Curitiba (CEOPS) are transmitted by telex to state coordination of civil defense (CEDEC) in Florianopolis, in which the necessity of warning is judged. CEDEC has the criteria of the attention, warning and critical water level for each city above mentioned, and transmits the results of judgement for warning to Blumenau (CEOPS). The announcement of warning to the public is held by COMDEC, which is subordinate to CEDEC and organized by each municipal unit, and emergency measures are taken also by COMDEC.

III. CONCEPTIONAL PLAN FOR FLOOD CONTROL

3.1 General

An inundation takes place over the vast areas along the Itajai river and its tributaries. It is impracticable from the viewpoints of the economical effectiveness and budgetary fund to realize perfect flood control works for entire stretches of the Itajai river basin. Therefore, it should be contemplated to minimize the flood damage to a practical extent by applying structural measures and non-structural measures.

The structural measures will be adopted in due consideration of their economic effectiveness, safety of livelihood of the riparian people and social urgent requirement.

Non-structural measures will be considered as possible means of supplementing the structural measures. In the areas where no effective structural measures will be applied, mitigation of flood damage by means of non-structural measures will be considered. Recommendation for the non-structural measures will be made for the areas where an effective structural measures will not be applied.

A feasibility study to be carried out in the following stage will be performed for the structural measures.

3.2 Conceivable Structural Measures

The following structural measures were contemplated for flood control planning for the Itajai river basin in view of the river channel profiles, inundation conditions and basin topography;

- Widening of river channel
- Dredging (excavation)
- Levee construction and/or filling of excavated material from river channel
- Floodway
- Flood retardation basin
- Flood control dams

The respective structural measures are presented below.

(1) River improvement including widening of existing river channel, dredging, levee construction and/or filling of excavated material from river channel.

Existing river channel of the Itajai and its tributaries are single cross section without levee. For this river stretch, river improvement plan by combining the widening of existing river channel, dredging, levee construction and/or filling of excavated river bed material will be adopted in due consideration of river characteristics, hydraulic situation of river channel and topography of the river stretch.

(2) Floodway

The flow capacity in the Itajai river in its endmost stretch is too small to discharge the flood coming from the catchment area of 15,220 km^2. The flood flow exceeding the flow capacity of the river channel overflows from the existing river channel and inundates along both banks every flood time. In order to mitigate these inundations, a floodway connecting with sharp bend portion of the downstream of the Itajai river and Atlantic Ocean near Picarras city has been proposed.

(3) Flood retardation basin

Habitual inundation area downstream of Ilhota city is conceivable to be utilized as a flood retardation basin. It is, however, not recommendable to utilize it as the flood retardation basin due to the following reasons;

(i) The habitual inundation takes place in low land areas and they are utilized as cultivation area of sugarcane, pasture, etc, and

(ii) All of these areas belong to private owned lands and consequently it is rather difficult to control the cultivation activity by governmental law, and it is impractical to purchase these areas to use them as the flood retardation area.

Due to these reasons, the plan of the flood retardation basin as the flood control facility was deleted.

(4) Flood control dams

The effective operation method by the existing Sul, Oeste and Norte dams to reduce the flood peak in the downstream flood prone areas was studied, and it was clarified that the operation method by means of closing of the outlet facility when heavy rainfall occurred at the damsite is the most effective for flood peak reduction in the downstream river stretches. The effect to the flood peak reduction for the case of floods in 1983 and 1984 was examined under the condition that these floods are regulated by adopting the proposed operation method to the existing three dams. It was clarified from this examination that although flood peak is largely regulated by the Norte dam, flood peak is still large such as 5000 m^3/sec and 4330 m^3/sec at the Blumenau stretch for respective 1983 and 1984's floods.

The conceivable flood control dams schemes to protect flood prone areas in the basin are as follows:

(i) Ascurra dam : Middle of the Itajai river. Catchment area is 9,581 km^2.

(ii) Trombudo dams (A) and (B) : Upstream of Trombudo river. Catchment area is 300 km^2 for the dam (A) and 116 km^2 for the dam (B).

(iii) Benedito dam : Upstream of Benedito river. Catchment area is 730 km^2.

(iv) Mirim dam : Upstream of Itajai Mirim river. Catchment area is 640 km^2.

DNAEE proposed alternative scheme for Ascurra dam by combining Salto Pilao, Subida and Neisse dams. However, since the reservoir efficiency (construction cost/effective storage) is inferior to the Ascurra dam, these alternative schemes were deleted.

3.3 Flood Control Method by Structural Measures

Since much flood damages take place in major cities along the Itajai river and its tributaries, it was contemplated to protect the river stretches along these cities from flood by combining the foregoing structural measures.

3.3.1 Flood control for Blumenau city

The Blumenau city is located along V-shaped river meandering stretch. This river stretch is a bottleneck in view of flood control planning because houses and buildings approach up to both river banks and it is practically impossible to increase the flow capacity of the river channel by its widening or by constructing of high levee.

In consideration of the these situations, following flood control method was contemplated;

(1) River improvement by means of widening of the existing river channel between the downstream end of the Blumenau river stretch and downstream of the Gaspar city, and also about 6.5 km long river stretch upstream of the Blumenau stretch. These measures are necessary to lower the flood water level at the downstream and of the Blumenau river stretch and sharpening of hydraulic gradient of flood water level in the Blumenau river stretch by minimizing rise of flood water level as far as possible.

(2) Widening of the several left river bank portions along the Blumenau city, arrangement of river bank slope in the Blumenau stretch and provision of the slope protection for the arranged river bank.

(3) Provision of concrete parapet for about 600 m long right river bank along the Blumenau city in the upstream from the confluence with a tributary, Garcia river, which is locally low elevation. In view of scenery of the Blumenau city, height of the concrete parapet should be limited less than 1.5 to 2.0 m.

The flow capacity of the river channel along the Blumenau city by means of the above methods is calculated at about 5000 m^3/sec which corresponds to 50 year probable flood.

To protect major cities downstream from the Blumenau city from flood, flood control method by combination of river improvement and proposed Ascurra dam is conceivable.

3.3.2 Flood control for Itajai city

Many houses and harbor facilities approach up to the river banks along the Itajai city and it is practically impossible to widen the river channel and to construct high levee. When flood water level is raised to increase the flow capacity of the Itajai river stretch, drainage from Itajai Mirim river joining to the Itajai river at its endmost stretch becomes impossible. Considering these situations, following method was contemplated;

(1) Construction of the floodway to be provided connecting with the Itajai river upstream of the Itajai city and Atlantic Ocean near Picarras city to discharge the flood exceeding the discharge capacity in the Itajai river.

(2) Widening of the existing short cut channel in the Itajai Mirim river at its endmost stretch to flow down the flood from the Itajai Mirim river to the Itajai main stream.

3.3.3 Flood control for other cities

Flood control method for Gaspar Ilhota, Ascurra, Rio do Sul, Ituporanga and Brusque cities was contemplated as follows;

(1) It is practically impossible to widen the river channel and to construct high levee in the river stretch along the Gaspar city because many houses approach up to the river banks. To protect the Gaspar city from flood, the flood discharge more than the flow capacity of the river channel along the Gaspar city will be flown down through a proposed flood diversion channel to be provided connecting with the upstream and downstream ends of V-shaped meandering Gaspar river stretch.

(2) Since there are many outcrop of rocks on river bed along Rio do Sul, Ascurra and Ituporanga cities, river improvement plan by means of widening of the river channel will be adopted and supplementally, levee and/or filling of excavated material from river channel will be provided for the river bank which is locally low elevation.

(3) To protect major cities downstream from the Rio do Sul cities from flood, flood control method by combination of river improvement and proposed Trombudo dams is conceivable.

(4) It is necessary to work out the flood control plan which does not rise the flood water level in the Blumenau and Itajai river stretches. Then river improvement plan by means of widening of the river channel will be applied to the Ilhota river stretch and supplementally, levee and/or filling of excavated material from river channel will be provided for the river bank which is locally low elevation.

(5) For flood control for Brusque city in the Itajai Mirim river, two methods are conceivable. One is the river improvement by means of widening of the river channel. Other is the combination plan of the river improvement and proposed Mirim dam.

3.4 Establishment of Flood Control Level

In consideration of the flood control method by structural measures, it was contemplated to work out the flood control plan in the Itajai river basin based on the following three flood control levels;

(1) Long-term plan

To ensure the safety of facility and long term stability and livelihood of the riparian people concerned, a long-term plan was assumed to be introduced for target plan for future phase of flood control, and 50-year probable flood was applied as the design flood due to the reason that if the river improvement work to cope with 50-year probable flood is finished, flood peak discharge with the same scale as that in 1983 can be safely flown down through the river channel along the Blumenau city.

(2) Mid-term plan

In order to realize the long-term plan, much construction cost and long term construction period are needed. To attain the final target plan of flood control as earlier as possible, stage wise flood control plan was contemplated and mid-term plan was assumed to be introduced. A 25-year probable flood was taken as the design flood due to the reasons that;

(i) After the river improvement plan to cope with 25-year probable flood is completed, the second largest flood in 1984 can be safely discharged.

(ii) The mid-term plan can complete the work schedule corresponding to almost half of the work quantities for the long-term plan.

(3) Provisional plan

In order to realize the flood control plan as earlier stage as possible and to meet with the urgent social requirement, provisional plan was assumed to be introduced, and 10-year probable flood was applied as the design flood considering the present flow capacity of the river channel along flood prone areas, work quantities for flood control and extent of the compensation of lands and houses.

3.5 Selection of Flood Protection Areas

In order to carry out flood analysis and to select the flood protection areas to be protected by structural measures, Itajai main stream and its tributaries were divided by stretches in consideration of location of the tributaries and major cities. The river stretches thus divided are shown in Fig.18.

In order to know the degree of level of importance for flood prone areas along the respective divided river stretches, preliminary selection of the priority protection areas was made under the following criteria:

Proposed structure	Area/place to be protected	Selection criteria
River improvement	River stretch	Priorities given by damage potential of each stretch (damage cost and inundation population per km and per km^2)

Result of the preliminary selection of the priority protection area is given in Table 8. This table shows that the river stretches classified as Level-1 are the most important protective areas and next priority is given to a stretch of Level-2, then Level-3. Based on this classification by level, it was assumed that the river stretches with Level-1 and Level-2 are protected by structural measures.

3.6 Non-Structural Measures

Non-structural measures will be considered as a possible means of supplementing the structural measures. In the areas where no effective structural measures are not applied, mitigation of flood damage by means of non-structural measures will be considered and recommendation for the following non-structural measures will be made;

(1) Flood plain management

(2) Structural change to houses and restriction of new house building

(3) Restriction of land use along river course

(4) Flood forecasting and warning system

(5) Land conservation and reforestation

IV. FORMULATION OF PROVISIONAL PLAN

4.1 General

The provisional flood control plan was formulated by means of river improvement method including the proposed floodway at the endmost Itajai river and taking into account the flood control effect by the existing Sul, Oeste and Norte dams.

The river improvement plan was studied under the following procedures;

(1) Selection of protective river stretch

(2) Formulation of river improvement plan

The economic evaluation for river improvement structural plan was made based on the following criteria;

(1) Construction cost; Cost in 1986 basis.

(2) Economic cost; The economic cost is calculated as 85% of the financial cost.

(3) Flood control benefit; Benefit accrued from the reduction of flood damage.

(4) Construction period; The construction period is estimated based on the annual earth work of 0.5 to 0.6 million m^3.

(5) Discount rate for evaluation; 8% per annum.

4.2 Selection of Protective River Stretch

The flow capacity in the river stretch along the Blumenau and Itajai cities is too small to discharge the flood from the upstream river basin, and if the flood control work in the upstream reaches from the Blumenau city is exclusively materialized, flood peak discharge in the downstream stretch will increase remarkably and consequently, huge amount of the cost for flood control work to cope with such increased flood peak will be obliged to be disbursed. To avoid such situation, selection of the protective stretch was studied under the following procedures:

(1) Selection of the protective river stretch in the downstream from Indaial.

(2) Selection of the protective stretch in the upstream from Indaial under the concept that the influence to the flood control plan in the downstream due to the flood control in the upstream from Indaial should be minimized.

Based on the result of preliminary selection of the priority protection area as shown in Table 8, the river stretches along the Blumenau, Gaspar, Ilhota, Itajai and Brusque cities are selected as the improvement stretch and other stretches are left as unprotected stretch. This scheme is herein called as Alternative 1. The flood discharge distribution for Alternative 1 is shown in Fig.19.

Fig.19 also shows the flood discharge distribution for Alternatives 2 which include the river improvement in Rio do Sul stretch. This figure shows that the flood peak discharge in the downstream stretch is increased due to the river improvement work for Rio do Sul stretch and its increased discharge is 100 m^3/sec. The flood water level corresponding to the additional increased flood discharge of 100 m3/sec is only around 0.10 m at the Blumenau and Itajai river stretches. Since it is considered that the increase in the river improvement cost due to this increase of the flood water level is negligible small, Alternative 4 was selected for planning of river improvement for provisional plan.

4.3 Formulation of Provisional Plan

4.3.1 River improvement structural plan

The river improvement structural plan for the selected Alternative 4 was carried out based on the flood control method by structural measures as stated in sub-section 3.3. Details of the river structural plan are as follows.

(1) To protect the Blumenau city from flood, the following plan was contemplated;

(i) River improvement by widening of the river channel in about 18 km long stretch between the downstream end of the Blumenau river stretch and downstream of the Gaspar city and also in about 6.5 km long stretch upstream of the Blumenau stretch.

(ii) Construction of levee and/or filling work of the excavated material from river channel for the river bank which is locally low elevation. The levee is provided to the river bank side where houses are located and elevation is locally low. Location of the levee in river bank is decided considering the river cross section which is able to flow down 50-year probable flood. The clearance between toe of the levee and edge of the excavated river slope is 5 m. Height of levee is decided based on the water level corresponding to 50-tear probable flood. Freeboard of the levee is 0.5 m. The filling of the excavated materials from river channel is adopted to the river bank side where no house is located and elevation is locally low.

(iii) Widening of the river channel in several portions of the left bank side in the Blumenau stretch.

(iv) Arrangement of the left river bank slope in the Blumenau stretch and protection of the arranged river bank slope.

(v) Construction of about 1.5 m high and 600 m long concrete parapet in the right river bank along the Blumenau city in the upstream from confluence with Garcia river.

(vi) Construction of levee along the inundated river stretch of tributaries flowing into the Blumenau city and construction of pumping station at the confluence portion of the main stream to drain forcibly the flood water from the tributaries.

To lower the flood water level at the Blumenau river stretch, about 1.4 km long flood diversion tunnel plan by connecting with the upstream and downstream ends of V-shaped meandering river stretch was studied. However flow capacity of the tunnel in case of one lane with a diameter of 12 m is only about 200 m^3/sec due to only 0.8 m of difference of water level between inlet and outlet of the tunnel for about 2,400 m^3/sec of present flow capacity of Blumenau stretch, and small hydraulic gradient of 1/2,000 to 1/2,500. Since design flood for provisional plan is 3,400 m^3/sec, five lanes of tunnel with the diameter of 12 m is needed to discharge 1,000 m^3/sec of flood discharge. However, much construction cost is needed for such large scale of tunnel works and besides, long construction period is also required. Due to these reasons, this tunnel plan was deleted from the planning.

(2) The following works were planned to protect the Itajai city from flood;

   (i) Construction of about 10 km long floodway and,

   (ii) River improvement by means of widening of about 3.8 km long existing short cut channel in the Itajai Mirim river at its endmost stretch and levee construction for widened short cut channel and existing meandering river channel along the Itajai city.

Among these flood control plans, several alternative studies as stated in the followings were carried out for the floodway. In this study, 50-year probable flood was applied;

   (i) Alternative-1 which is natural flood diversion method by construction of only floodway.

   (ii) Alternative-2 which is the flood diversion method by providing a closure dam with outlet facilities at the Itajai river side.

   (iii) Alternative-3 which is the flood diversion method by providing a closure dam with gated overflow weir at the Itajai river side, and

   (iv) Alternative-4 which is the flood diversion method by providing a closure dam with gated overflow weir at the Itajai river side and gated weir at the floodway side.

Details of the explanation for flood diversion methods and problems for these alternatives are given in the supporting report. Among these alternatives, Alternative-3 seems to be the most suitable method in this planning stage considering flood diversion method to effectively utilize the limited flow capacity of the river stretch along the Itajai city and to minimize the frequency of use of the floodway and obtaining of social agreement for this plan from inhabitant in Picarras city, though technical justification for this plan by means of model test, study on hydrological matters and so on. Thus, Alternative-3 is recommended to be adopted to this study.

In order to minimize the influence to the Picarras city due to provision of the floodway, it is contemplated by DNOS to lessen the frequency of utilization of the floodway by increasing the flow capacity in the downstream of Itajai river by means of earth filling of the low bank and/or construction of levee. However, rising of the flood water level to increase the flow capacity is economically not feasible because once the flood water level is raised, high earth levee or high concrete parapet wall have to be constructed along the whole stretch of the Itajai river downstream of the floodway confluence and also further upstream of the Itajai Mirim river, besides, modification of the harbour facility along the Itajai river, heightening of about 10 km long BR-101 road in the upstream of Itajai Mirim river and inner water treatment in the Itajai city will be needed.

The structural plan of floodway and gated overflow weir for provisional plan is as follows;

   (i) Construction of about 10 km long and 180 m wide floodway having a compound sections providing levee on both side.

(ii) Construction of the gated overflow weir with earth filling dam and riprap at both side slopes of dam, and

(iii) Construction of jetty by stone piling at the outlet of the floodway.

(3) River improvement for other protective stretches was planned as follows;

(i) For Gaspar river stretch; River dredging in about 1.3 km long Gaspar river stretch and construction of about 1.3 km long and 80 m wide flood diversion channel connecting with upstream and downstream ends of V-shaped meandering Gaspar river stretch.

(ii) For Ascurra, Rio do Sul, Ituporanga and Brusque river stretches; River improvement by means of widening of the river channel, levee construction and/or filling work of excavated material from river channel in the river bank with locally low elevation.

(iii) For Ilhota river stretch; River improvement by means of widening of the river channel and river dredging in about 8 km long stretch upstream from the confluence with Luis Alves river.

Fig.20 shows the longitudinal profile of the design river bed and design flood water level. General plan of river channel alignment is shown in Figs.21 to 28. Standard cross sections for protective stretches are given in Fig. 29.

For estimation of the river improvement cost, direct cost such as the costs for earthworks and related river structures including revetment, drainage facility, and bridges to be modified or reconstructed, and indirect cost such as compensation cost for lands and houses, relocation cost of public road, engineering fee for investigation and design and physical contingency are considered.

4.3.2 Economic evaluation for provisional plan

The construction cost for river improvement for the protective stretch was estimated as shown in Table 9 based on the unit prices in similar project near project site and estimated work quantities. Annual flood control benefit which accrues from reduction of the flood damage was estimated from the result of the flood damage study.

The result of the economic evaluation is shown in Table 10. This table shows that economic internal rate of return (EIRR) for the river improvement plan except Ilhota and Ascurra stretches is almost more than 8% and the highest one is the Blumenau - Gaspar stretch, but EIRR for river improvement plan for Ilhota and Ascurra stretches is remarkably small.

V. FORMULATION OF MID-TERM PLAN

5.1 General

The mid-term flood control plan was formulated by means of river improvement method. The procedure of planning is the same as that for the provisional plan.

5.2 Flood Discharge Distribution

The influence to the downstream river stretch due to the river improvement in the upstream from Indaial was studied. Fig.30 shows the flood discharge distribution in case that Blumenau - Gaspar, Ilhota, Itajai and Brusque stretches are protected and that for the cases that respective Rio do Sul, Ascurra and Ituporanga stretches are protected exclusively. This figure shows that the flood discharge in the downstream river stretch increased due to river improvement work in Rio do Sul stretch is 100 m^3/sec. Since it is considered that this increased water level is negligible small, Alternative 4 was selected for flood control plan.

5.3 Formulation of Mid-Term Plan

5.3.1 River improvement structural plan

The following works were planned for flood control for respective protective stretches.

(1) Blumenau river stretch; Widening of river channel in about 18 km long Blumenau - Gaspar stretch and also 6.5 km long stretch upstream of the Blumenau river stretch.

(2) Itajai river stretch; Widening of the floodway and existing short cut channel in the Itajai Mirim river.

(3) Gaspar river stretch; Widening of the flood diversion channel

(4) Rio do Sul, Ilhota and Brusque river stretches; Widening of the river channel.

(5) Ituporanga and Ascurra stretches; River improvement by means of widening of river channel and levee construction and/or filling of excavated material from river channel for river bank with locally low elevation.

Fig. 20 shows the longitudinal profile of the design river bed and design flood water level. General plan of river channel alignment is shown in Figs.21 to 28. Standard cross sections for protective stretches are given in Fig.29.

5.3.2 Economic evaluation for mid-term flood control plan

The construction cost for river improvement for protective stretches was estimated as shown in Table 9. The result of the economic evaluation is shown in Table 10. This table shows that EIRR for the river improvement plan except Ilhota and Ascurra stretches is higher than 8% and net benefit for the river improvement for Blumenau - Gaspar stretch is the highest among the selected protective stretches.

VI. FORMULATION OF LONG TERM PLAN

6.1 General

The long term flood control plan was studied for both cases of river improvement plan and combination plan of river improvement and flood control dam.

The proposed Ascurra dam with a catchment area of 9,581 km2 located in the Itajai river at about 3 km upstream from Ascurra city seems to be effective for flood control mainly for river stretch downstream from the Blumenau city. The proposed Benedito dam with a catchment area of 726 km2 located in the Benedito river at about 8 km upstream from the Timbo city is limited its dam height less than 40 m because Benedito Novo city is located in the upstream of the damsite. Since the storage capacity of the dam in this case is so small as about 2 million m3 and effective flood control effect is not expected, this dam scheme was deleted from flood control planning. The proposed Trombudo dams with a catchment area of 300 km2 for dam (A) and 116 km2 for dam (B) located in the Trombudo river at about 28 km upstream from the confluence with Itajai do Sul seems to be effective for flood control to the river stretch downstream from Rio do Sul city. The proposed Mirim dam with a catchment area of 640 km2 located in the Itajai Mirim river at about 30 km upstream from the Brusque city seems to be effective for flood control for the Brusque city and endmost Itajai Mirim stretch along the Itajai city.

Taking into account the foregoing expected flood control effect by the proposed dams, formulation of the long-term plan by means of the combination plan of river improvement and flood control dam was made by dividing into flood control for river stretch along the Itajai main stream and flood control for river stretch along the Itajai Mirim river.

6.2 Flood Control by River Improvement Plan

6.2.1 River improvement structural plan

Influence to the downstream stretch due to the river improvement in the upstream stretch was studied in the same way as the mid-term plan and consequently the flood discharge distribution plan in case that all of the protective river stretches are improved as shown in Fig. 31 was selected in this study. To discharge the flood peak shown in this distribution diagram, following measures were planned for the respective protective stretches.

(1) Widening of the river channel to discharge the design flood for Blumenau - Gasp[ar stretch, 6.5 km long river stretch upstream from Blumenau stretch, Rio do Sul - Lontras stretch, Ascurra stretch, Ituporanga stretch, Ilhota stretch, and Brusque stretch.

(2) Widening of the flood diversion channel at the Gaspar stretch, floodway and existing short cut channel in the Itajai Mirim river.

Fig. 20 shows the longitudinal profile of the design river bed and design flood water level. General plan of river channel alignment is shown in Figs. 21 to 28. Standard cross sections for protective stretches are given in Fig.29.

6.2.2 Economic evaluation for river improvement plan

The construction cost required for the long term plan by means of the river improvement plan is given in Table 9.

The result of the economic evaluation for the long term plan by means of the river improvement plan is given in Table 10. This table shows that EIRR for the river improvement plan for Rio do Sul - Lontras stretch slightly decreases comparing with that for the mid-term plan but it is still higher than about 8%, while EIRR for the river improvement plan for Ilhota stretch is negligible small. When the increase in the flood damage potential in the future is taken into account for the economic evaluation, EIRR for the river improvement plan for Ascurra stretch in this case is 8.5%.

6.3 Flood Control by Combination Plan of River Improvement and Flood Control Dam

6.3.1 Flood control for river stretch along Itajai main stream

Two alternative flood control methods by combination of river improvement and flood control dam were contemplated for river stretch along the Itajai main stream. Alternative 1 is the flood control method by combination of river improvement and proposed Ascurra dam. Alternative 2 is the flood control method by combination of river improvement and proposed Trombudo dams.

Fig. 32 shows the flood discharge distribution for Alternative 1 under the condition that the flood peak discharge larger than 25-year probable flood at the Blumenau stretch is regulated by the Ascurra dam. Fig. 33 shows the flood discharge distribution for Alternative 2 under the condition that all of the flood from the upstream of the proposed Trombudo dams is stored in the reservoirs.

The proposed Ascurra dam was planned as concrete gravity dam in consideration of geological condition and topographic condition for dam structure and flood releasing facilities. While the Trombudo dams (A) and (B) were planned as earth fill dam considering the geological and topographic conditions of the dam sites.

Table 11 shows the cost comparison for Alternatives 1 and 2 and only river improvement plan. It clarifies that only river improvement plan is the most economical for flood control in the stretch along the Itajai main stream. Thus, the combination plan of the river improvement and flood control dam for the river stretch along the Itajai river was deleted from the study.

6.3.2 Flood control for river stretch along Itajai Mirim

To protect the Brusque city and endmost Itajai Mirim stretch along the Itajai city, flood control method by combination of river improvement and proposed Mirim dam was studied.

Fig. 32 shows the flood discharge distribution under the condition that the flood discharge larger than 25-year probable flood at the Brusque stretch is regulated by the Mirim dam. The proposed Mirim dam was planned as a rock fill dam considering the topographic and geological conditions.

Table 12 shows the comparison of the cost for the combination plan of river improvement and Mirim dam and for only river improvement plan. It clarifies that only the river improvement plan is more economical than the combination plan. Thus, flood control by combination of river improvement and Mirim dam was deleted from the study.

VII. IPLEMENTATION PROGRAM OF FLOOD CONTROL PROJECTS

7.1 Formulation of Flood Control Project

The flood control plans worthly of implementation were contemplated in Chapters 4 to 6 within the frameworks of long-term, mid-term and provisional plans.

The promising flood control projects are summarized bellow;

Promising Project	Provisional plan	Mid-term plan	Long-term plan
Design Flood	10-year	25-year	50-year
River Improvement			
- Blumenau-Gaspar stretch	24.5 km (E)	24.5 km (E)	24.5 km (E)
- Floodway and down-stream of Itajai Mirim	14.5 km	14.5 km (E)	14.5 km (E)
- Rio do Sul-Lontras and, Ituporanga stretches	17.4 km (E)	17.4 km (E)	17.4 km (E)
- Brusque stretch	9.0 km (E)	9.0 km (E)	9.0 km (E)
- Ilhota stretch	-	-	3.7 km (E)
- Ascurra stretch	-	-	4.0 km (E)

Note; E means enlargement of channel

Among three stages of the plan, first priority for implementation should be given to the provisional plan since it plays an important role for raising safety factor for flood control in an early stage.

7.2 Outline of the Proposed Flood Control Project

The followings show the outline and purpose of the proposed flood control projects;

(1) Provisional plan stage

The river improvement in this stage comprises the following work items;

(i) Blumenau - Gaspar stretch (24.5 km)

The river channel in 18 km long stretch between the downstream of the Blumenau stretch and downstream of the Gaspar stretch is widened to lower the flood water level in the Blumenau and Gaspar stretches. The river channel in 6.5 km long stretch in the upstream of the Blumenau stretch is widened. Levee and/or filling of excavated material from river channel is provided only at the river bank with locally low elevation. About 1.3 km long and 80 m wide flood diversion channel is constructed detouring the Gaspar city. Several left river bank portions in the Blumenau stretch are widened. The river bank slope in the Blumenau stretch is arranged and surface slope protection work is executed. About 1.5 m high and 600 m long concrete parapet is provided in the right river bank along the Blumenau city. To protect the lowland along the inundated river stretch in the tributaries flowing into the Blumenau city, levee is provided, and pumping station is provided at the confluence portion of the main stretch.

(ii) Floodway and downstream of Itajai Mirim

Floodway scheme

About 10 km long and 180 m wide floodway will be constructed to Atlantic Ocean near Picarras city and jetty consisting of stone piling will be provided at the outlet of the floodway to prevent the flowing the sedimented river water into the coastal area in the Picarras city. To divert the flood from the Itajai river, a gated overflow weir with earth filling dam and riprap at its outside slope will be constructed in the Itajai river at just downstream of the confluence with the floodway.

Downstream of Itajai Mirim (3.8 km)

About 3.8 km long existing short cut channel in the Itajai Mirim river will be widened and levee will be provided for the widened short cut channel and existing meandering river stretch along the Itajai city.

(iii) Rio do Sul - Lontras stretch and Ituporanga stretch (14 km)

The river channel will be widened and supplementally levee and/or filling of excavated material from river channel will be provided for the river bank with locally low elevation.

(iv) Brusque stretch (9 km)

The river channel will be widened and supplementally levee and/or filling of excavated material from river channel will be provided for the river bank with locally low elevation.

(2) Mid-term plan stage

The river channel in Blumenau - Gaspar stretch, river stretch upstream of the Blumenau stretch, Rio do Sul - Lontras stretch, Ituporanga stretch, Brusque stretch, short cut channel in Itajai Mirim river and floodway is further widened.

(3) Long-term plan stage;

(i) River channel in Ituporanga stretch, Rio do Sul - Lontras stretch, Blumenau - Gaspar stretch, river stretch upstream from Blumenau stretch, Brusque stretch, existing short cut channel in the Itajai Mirim river and floodway will be further widened.

(ii) Ilhota stretch (3.7 km)

The river channel is widened and supplementally levee and/or filling of excavated material from river channel is provided for the river bank with locally low elevation. To lower the flood water level in this stretch, river dredging is executed to excavate locally rised river bed in about 8 km long stretch upstream from the confluence with a tributary, Luis Alves river.

(iii) Ascurra stretch (4 km)

The river channel is widened and supplementally levee and/or filling of excavated material from river channel is provided for the river bank with locally low elevation.

7.3 Implementation Program

Taking into account the result of economic evaluation , degree of social urgent requirement and extent of compensation of lands and houses, implementation schedule of the flood control projects was worked out as shown in Fig.34.

7.4 Cost Estimate of Flood Control Project

The construction cost necessary for each stage was estimated. The estimated cost was summarized as follows;

	Total (10^6 Cz$)
Provisional plan stage	
River improvement	
- Blumenau-Gaspar stretch	507
- Floodway and downstream of Itajai Mirim	737
- Rio do Sul-Lontras and Ituporanga stretches	879
- Brusque stretch	105
Sub-total	2,222
Mid-term plan stage	
River improvement	
- Blumenau-Gaspar stretch	261
- Floodway and downstream of Itajai Mirim	119
- Rio do Sul-Lontras and Ituporanga stretches	378
- Brusque stretch	13
Sub-total	771
Long-term plan stage	
River improvement	
- Blumenau-Gaspar stretch	391
- Floodway and downstream of Itajai Mirim	197
- Rio do Sul-Lontras and Ituporanga stretches	283
- Brusque stretch	22
- Ilhota stretch	237
- Ascurra stretch	95
Sub-total	1,225
Grand total	4,218

Note; Cost is estimated on 1986 basis.

VIII. RECOMMENDATION FOR NON-STRUCTURAL MEASURES

8.1 General

Non-structural measures were contemplated to supplement the structural measures and to minimize the flood damage for the areas where no effective structural measures are applied. Recommendation for non-structural measures was made for the following items;

- Flood plain management
- Structural change to houses and restriction of new house building
- Restriction of land use along river course
- Flood forecasting and warning system
- Land conservation and reforestation

The recommendation of non-structural measures was studied assuming the situation after the provisional plan was completed.

8.2 Recommendation for Non-Structural Measures

(1) Flood plain management

The flat lands in the flood vulnerable area along the Itajai river and its tributaries have been utilized as an agricultural land. It is predicted that these flat lands will be also utilized as the agricultural land as it is even in the future stage.

This measure intends to minimize the agricultural flood damage by regulating the agricultural activity in the area where the structural measures are not applied. General procedure for an application of this measure is as follows;

- Selection of flood prone area where agricultural production has been damaged.
- Designation of flood prone zone with ranks in consideration of intensity of flood such as flood depth and frequency, and
- Setting forth of regulation for agricultural activity in the designated flood prone areas.

The result of the flood damage survey clarifies that among the agricultural productions, rice and upland crops have been seriously damaged by flood. Then the river stretches with cultivation area of paddy and upland crops even in the future stage were selected from the river stretches in which the structural measures are not applied. They are listed as follows;

Symbol	River stretch	
IT5	Upstream of	Ilhota city
IO2	"	Rio do Sul city
IM1	"	Itajai city
IM2	"	"
IM3	"	"
IM4	"	"

In order to examine the suitability of land use for paddy and upland crops cultivation in the flood prone areas along these river stretches, inundation area in each stretch was estimated assuming that 2-year and 5-year probable flood take place after the river improvement work to cope with the provisional plan is finished. The estimated inundation area was divided into two divisions assuming that water depth is area division - 1 is 0.0 to 0.5 m for 2-year probable flood and 0.0 to 1.0 m for 5-year probable flood and water depth for area division - 2 is more than 0.5 m for 2-year probable flood and more than 1.0 m for 5-year probable flood.

Zoning map of each stretch is illustrated in Fig.35. Based on this zoning map and land use map in the basin area, it is recommended that;

(i) Present agricultural lands in area division-1 are mainly utilized for uplands crop and sugar cane cultivation and pasture land. In order to decrease flood damages on agricultural production, a counter-measure for the cultivation of upland crop is necessary, which is the most vulnerable among agricultural production mentioned above. Accordingly, it is recommended that the cultivation of vegetable and vulnerable products be converted to grain crops such as maize and wheat.

(ii) Present agricultural lands in area division-2 are mainly utilized for paddy production. This is because these lands are located in flat areas along the Itajai river and its tributaries depending on their abundant water resources and because paddy is relatively tough for flood as compared with other crops. Although area division-2 has higher potential of vulnerability on flood than area division-1, extensive land use alteration of paddy cultivation will be practically difficult, considering the reasons mentioned above. Thus, it is recommended to establish official relief measures to relieve flood victims.

(2) Structural change to houses and restriction of new house building

These measures intend to mitigate the flood damage in flood prone area by applying structural change to houses such as house with high floor, diking around houses and/or elevating ground by land filling, and by restricting new house building.

It is considered that the structural change to houses is effective for the area with relatively few resident and shallow inundation depth, while restriction of new house building is applied to the area with deeper inundation depth and frequent inundation.

The river stretches with the areas to apply these measures were selected as follows from among the river stretches in which structural measures are not applied.

Symbol	River stretch	
IT 3	Upstream of Itajai city	
IT 4	Ilhota city	
IT 5	Upstream of	Ilhota city
IT 12	"	Ascurra city
IO 2	"	Rio do Sul city
IM 1	"	Itajai city
IM 2	"	"
IM 3	"	"
IM 4	"	"

For these selected river stretches, inundation area was estimated assuming that 2-year and 5-year probable floods take place after the river improvement work for the provisional plan is finished. The estimated inundation areas were divided into two divisions, assuming that water depth in area division - 1 is 0 to 0.5 m for 2-year probable flood and 0 to 1 m for 5-year probable flood and water depth for area division -2 is deeper than the area division - 1. Fig.35 shows two divisions thus classified.

Based on this study result, it is recommended from the view point of the inundation depth that;

(i) Structural change to houses is applied to the area division - 1.

(ii) Restriction of new house building is adopted to the area division - 2 and in case that existing houses are located in the area division - 2, structural change to house is to be applied.

(3) Restriction of land use along river course

This measure intends to prevent disaster for houses and inhabitant due to side erosion of river bank and falling down of river bank slope by restricting the construction of houses and buildings along the river course.

There are existing regulation for land use along the river bank, namely, land use of river bank in the stretch between the Itajai river mouth and Blumenau is controlled by navy and land use in 33 m wide from the edge of river bank is restricted, while the land use in 15 m wide from the edge of river bank is restricted in the river stretch upstream of Blumenau.

These regulations are considered to be fairly effective in view of operation and maintenance of the river channel if the land use in the river bank is strictly controlled by these regulations. However actually, many houses are being built up to river bank at present.

The disaster due to side erosion of river bank and falling down of river bank slope does not take place in the Itajai main stretch in the past but the disaster took place in the tributaries flowing into the Blumenau city.

It is anticipated to increase the houses along the river course in future stage. To prevent the disaster for houses and inhabitant along the river banks, it is recommended to reinforce restriction by foregoing existing regulations, especially for the following stretches;

- Ituporanga stretch
- Confluence portion of Itajai do Oeste and Itajai do Sul rivers
- Blumenau stretch
- Gaspar stretch
- Ilhota stretch
- Endmost stretch of Itajai Mirim river
- Tributaries flowing into Blumenau city.

(4) Flood forecasting and warning system

This measure is effective to mitigate the flood damage to properties as well as casualty in the areas to be protected by the structural measures and in the areas where no structural measure is applied, if flood warning is given in advance.

DNAEE planned and implemented the flood forecasting and warning system in the Itajai river basin since occurrence of flood in 1983 and its preliminary operation was started in August 1984. The flood forecasting and warning effect by this system is still unknown because of no occurrence of large scale flood since its operation stage.

In order to work out the flood forecasting and warning system in the basin consistent with the flood control plan in this study, improvement of the following matters is required to the existing system;

- To improve the data transmission method from radio system to telemetering system,
- To obtain rainfall data in the mountainous areas of the Norte, Sul and Benedito river basins, and
- To collect rainfall data in tributaries following into the Blumenau city to cope with the back swamp problem in the city area.

In due consideration of these problems, it is recommended to install additional telemetering stations as shown in Fig.36 to the existing system.

(5) Land conservation and reforestation

Although forest plays an important role for flood control as well as soil conservation, it seems that deforestation in the Itajai river basin is now progressing judging from IBGE census in 1980 that the estimated deforested area in the basin is about 3,111 ha while the reforested area is only 1,900 ha.

It is considered that inundation may take place by increasing runoff coefficient due to large scale deforestation and land slide will be caused by deforestation in steep slope zone. It was intended in this study to minimize the disaster due to deforestation by investigating the relationship between progress of the deforestation and occurrence of disaster. However the data showing the location and acreage of annual deforestation are not available at all.

It was clarified that gentle undulating area in the Norte river basin has been deforested and now deforestation is progressing in the mountainous areas in the left bank of the Norte river and between the Itajai and Itajai Mirim rivers. Several places in these areas consist of steep slope zone and deforestation in that places is prohibited by law but the deforestation is still progressing. Besides, since the mountainous area between the Itajai and Itajai Mirim rivers is very fragile against land sliding, permanent reservation of the forest is needed.

In view of these situations, it is recommended to IBDF, which is a federal authority and is a charge of management of forest resources, to take the following measures;

(i) Reinforcement of forest conservation to restrain progress of the deforestation, and

(ii) Promotion of reforestation in non-utilized area of hilly and mountainous area, and deforested area by informing the importance of forest function to flood for inhabitant and campaigning the enlightenment to reforestation.

To proceed with the above measures, it is firstly requested to IBDF to investigate present situation of the deforestation in the basin area including topography, geology, vegetation, etc. by cooperating with other organization and agency.

IX. SELECTION OF FLOOD PROTECTIVE STRETCH FOR FEASIBILITY STUDY

The protective river stretch and flood control facility to be selected for the feasibility study was decided taking into account the following factors;

- High economic effectiveness
- Degree of social urgent requirement
- Influence to downstream reach due to realization of flood control project,
- Extent of compensation for lands, houses, public facilities, etc.
- Degree of difficulty for execution works

Among the proposed flood control projects, the river improvement project in the Blumenau - Gaspar stretch was selected for the feasibility study due to the following reasons;

(1) Among the proposed flood control projects, the river improvement project in this stretch has the highest economic viability.

(2) Among population in the flood prone areas for whole Itajai river basin, about 36% concentrates in this area and consequently urgent social requirement to realize the flood control project is strongly requested.

(3) Even if the river improvement work in this stretch is realized, flood discharge to the downstream stretch is not increased.

(4) The river improvement work in the Blumenau - Gaspar stretch is partly executed by DNOS and a part of the compensation problem was already solved. Especially, it is considered that there are no problem for compensation for lands and houses to early realize the provisional plan.

(5) Major works in this river improvement project comprise widening of the existing river channel and river dredging to arrange the river channel and these works can be easily executed using common construction equipment.

The river improvement project involves the following works;

(1) Widening of the existing river channel and levee construction for the river banks with locally low elevation.

(2) Construction of concrete parapet wall in the Blumenau stretch.

(3) Slope protection for several portions of river bank by revetment and sod facing.

(4) Drainage work for tributary to minimize back swamp problem.

(5) River dredging to excavate partially rised river bed.

LIST OF COUNTERPARTS, ADVISORY COMMITTEE AND JICA STUDY TEAM MEMBERS

(1) Member of Advisory Committee and Coordinator

NO.	Name		Agency
Advisory Committee Member			
1.	T. Inoue	Chairman	Ministry of Construction
2.	K. Shimada		Ministry of Construction
3.	M. Fukuda		Ministry of Construction
4.	T. Hamaguchi		Ministry of Construction
5.	A. Nakamura		Ministry of Construction
6.	S. Tsuboka		Ministry of Construction
Coordinator			
1.	H. Kutsuna		Japan International Coorporation Agency
2.	A. Matsuda		Japan International Coorporation Agency

(2) Member of JICA Study Team and Counterpart

NO.	Sector	Name of Members	
		JICA Study Team	Counterpart
1.	Team Leader	S. Ohnuma	Nelson Sant'Anna Feveira Azambuja
2.	Co-Leader	J. Yamamoto Y. Kaneko	Jose Carlos Bauer
3.	Structure Engineer	O. Nakahira	Marcelo Rodrigues Beosa Paulo Roberto Verissimo
4.	Hydrologist	M. Sakamoto	Renato Klueger
5.	Construction Planner	K. Yamasaki	Idilon Parente Dorvino Piovesan
6.	Geologist	H. Tamura H. Mitsui	
7.	Agronomist/Land Use Planner	T. Kimishima	Marnei Soccas Ribeiro
8.	Socio-Economist	T. Tashino	Nelson Jacomel Junior Manoel Machuca Neto
9.	Drainage Engineer	M. Kanai	Marnei Soccas Ribeiro
10.	Survey Expert	Y. Hayashi	
11.	Environmental Engineer	S. Tsuru	
12.	Project Economist	M. Tada	Nalcir Salome Silva

Tables

Table 1 INUNDATION AREA DUE TO 1983 AND 1984 FLOODS

(Unit : ha)

River / Stretch No.	Paddy	Sugar Cane	Other Crops	Residential Area		Pasture Land	Not Utilized	Total
				Urban	Rural			
Itajai River								
IT 1	0.0	0.0	0.0	637.5	0.0	0.0	250.0	887.5
IT 2	0.0	1,120.0	52.5	265.0	97.5	0.0	225.0	1,760.0
IT 3	0.0	2,237.5	0.0	25.0	47.5	412.5	100.0	2,822.5
IT 4	0.0	177.5	0.0	25.0	25.0	225.0	0.0	452.5
IT 5	132.5	182.5	0.0	5.0	12.5	850.0	25.0	1,207.5
TI 6	407.5	0.0	82.5	347.5	90.0	705.0	100.0	1,732.5
IT 7	0.0	0.0	112.5	790.0	52.5	7.5	475.0	1,437.5
IT 8	0.0	0.0	17.5	80.0	145.0	0.0	230.0	472.5
IT 9	0.0	0.0	282.5	147.5	77.5	7.5	532.5	1,047.5
IT 10	0.0	0.0	217.5	0.0	75.0	467.5	207.5	967.5
IT 11	417.5	0.0	30.0	122.5	45.0	325.0	137.5	1,077.5
IT 12	40.0	0.0	277.5	52.5	107.5	965.0	1,812.5	3,255.0
IT 13	175.0	0.0	432.5	390.0	92.5	1,020.0	105.0	2,215.0
Itajai do Sul River								
IS 1	0.0	0.0	90.0	57.5	67.5	180.0	40.0	435.0
IS 2	0.0	0.0	65.0	12.5	7.5	95.0	87.5	267.5
IS 3	0.0	0.0	0.0	112.5	0.0	0.0	30.0	142.5
Itajai do Norte River								
IN 1	0.0	0.0	32.5	130.0	0.0	32.5	50.0	245.0
Itajai do Oeste River								
IO 1	0.0	0.0	70.0	80.0	27.5	137.5	0.0	315.0
IO 2	252.5	0.0	307.5	107.5	37.5	182.5	22.5	910.0
Benedito Novo River								
BN 1	25.0	0.0	190.0	177.5	20.0	150.0	120.0	682.5
Itajai Mirim River								
IM 1	15.0	0.0	0.0	485.0	57.5	232.5	1,147.5	1,937.5
IM 2	137.5	0.0	17.5	212.5	12.5	542.5	375.0	1,297.5
IM 3	377.5	0.0	32.5	0.0	0.0	162.5	725.0	1,297.5
IM 4	295.0	0.0	87.5	0.0	62.5	527.5	410.0	1,382.5
IM 5	0.0	0.0	145.0	255.0	142.5	27.5	100.0	670.0
Total	2,275.0	3,717.5	2,542.5	4,517.5	1,302.5	7,255	7,307.5	28,917.5

Table 2 PAST LARGE FLOOD WATER LEVEL AT BLUMENAU

Year	Date	Water Level (m)	Year	Date	Water Level (m)
1852	Nov.16	16.00	1954	May.18	8.90
1855	Nov.20	13.00	1954	Oct.22	11.84
1864	Sep.17	10.00	1955	May.19	9.96
1868	Nov.28	13.00	1957	Jul.21	8.68
1869	Jul.22	11.00	1957	Aug.20	12.42
1870	Nov.10	10.00	1961	Sep.13	9.52
1880	Sep.23	16.80	1961	Sep.30	8.98
1891	Jun.18	13.50	1961	Nov. 1	11.70
1898	May. 3	12.00	1962	Sep. 9	8.64
1898	Dec.24	11.00	1963	Sep.30	8.58
1900	Jun. 2	12.50	1966	Feb.13	9.42
1911	Oct. 2	16.60	1967	Feb.18	10.20
1911	Oct.30	9.56	1969	Apr. 6	9.00
1925	May.15	9.80	1971	Jun. 9	9.50
1925	May.24	10.00	1972	Aug.16	10.40
1926	Jan.13	9.70	1972	Aug.29	10.65
1927	Nov. 9	12.00	1973	Jun.25	10.55
1928	Jun.18	11.46	1973	Jul.22	8.70
1928	Aug.15	10.52	1973	Aug.29	11.84
1928	Sep.17	10.00	1975	Oct.3	12.15
1930	Feb.16	9.05	1976	May.29	10.55
1931	Apr. 1	10.90	1978	Dec.26	11.05
1931	May. 2	10.44	1979	May.10	9.30
1931	Sep.14	10.62	1979	Oct. 9	9.78
1931	Nov.17	12.30	1980	Dec.22	12.95
1932	May.25	8.90	1983	Mar. 4	9.95
1933	Oct. 4	10.90	1983	May.20	12.06
1935	Sep.24	10.60	1983	Jul.8-18	15.37
1939	Nov.27	11.08	1983	Aug. 2	11.20
1943	Aug. 3	9.82	1983	Sep.24	11.10
1946	Feb. 2	8.80	1984	Aug.6-9	15.46
1948	May.18	11.20			
1950	Oct.17	8.80			
1953	Nov. 1	9.30			

Source : " Bacia do Rio Itajai " , DNAEE

Table 3 ANNUAL MAXIMUM BASIN MEAN 4 DAYS / 7 DAYS RAINFALL

Year	Date	4-day (mm)	Date	7day (mm)	(7-day)-(4-day)	(4-day)/(7-day) %
1951	OCT. 15	90	OCT. 14	145	55	62.1
1952	SEP. 3	87	OCT. 13	103	16	84.5
1953	OCT. 28	93	OCT. 27	101	8	92.1
1954	MAR. 31	101	OCT. 16	137	36	73.7
1955	MAY. 16	115	MAY. 15	126	11	91.3
1956	SEP. 16	56	SEP. 14	94	38	59.6
1957	AUG. 16	118	AUG. 13	133	15	88.7
1958	MAR. 13	121	MAR. 13	152	31	79.6
1959	AUG. 30	88	AUG. 29	124	36	71.0
1960	JUL. 31	89	JUL. 30	97	8	91.8
1961	SEP. 9	138	SEP. 6	193	55	71.5
1962	SEP. 18	89	SEP. 17	100	11	89.0
1963	SEP. 26	138	SEP. 25	176	38	78.4
1964	APR. 28	57	OCT. 20	66	9	86.4
1965	AUG. 16	91	AUG. 16	104	13	87.5
1966	FEB. 9	121	FEB. 9	166	45	72.9
1967	SEP. 18	56	SEP. 18	86	30	65.1
1968	DEC. 22	103	DEC. 20	115	12	89.6
1969	FEB. 16	93	MAR. 30	110	17	84.5
1970	FEB. 2	69	FEB. 1	96	27	71.9
1971	MAY. 5	66	APR. 16	100	34	66.0
1972	AUG. 25	146	AUG. 22	165	19	88.5
1973	AUG. 26	108	AUG. 22	149	41	72.5
1974	JUL. 22	99	JUL. 19	115	16	86.1
1975	SEP. 30	102	SEP. 27	127	25	80.3
1976	MAY. 26	90	MAY. 23	108	18	83.3
1977	AUG. 15	125	AUG. 13	137	12	91.2
1978	DEC. 25	118	DEC. 24	122	4	96.7
1979	MAY. 7	106	MAY. 8	141	35	75.2
1980	DEC. 19	151	DEC. 18	164	13	92.1
1981	DEC. 21	99	DEC. 21	102	3	97.1
1982	FEB. 3	96	FEB. 4	111	15	86.5
1983	JUL. 6	216	JUL. 6	324	108	66.7
1984	AUG. 5	213	AUG. 2	259	46	82.2

Table 4 PROBABLE RAINFALL AND ENLARGING RATIO

Return Period (year)	Probable Rainfall (mm)	Observed Rainfall (mm)			
		Dec.1978 118	Dec.1980 151	Jul.1983 216	Aug.1984 213 /1
2	110	0.932	0.728	0.509	0.516
5	140	1.186	0.927	0.648	0.657
10	160	1.356	1.060	0.741	0.751
25	185	1.568	1.225	0.856	0.869
50	210	1.780	1.391	0.972	0.986
100	230	1.949	1.523	1.065	1.080

Note : /1 Actual 4-day rainfall

Table 5 STORAGE FUNCTION OF SUB-BASIN

Basin NO.	Catchment Area (sq.km)	River Length (km)	River Bed Slope	Coeff. of Storage Function K	P	Lag-time (hour)
1	860.0	45.0	1/130	35.87	0.549	4.0
2	725.0	56.0	1/90	40.05	0.504	4.0
3	866.0	70.0	1/1,300	17.98	0.944	9.0
4	116.0	20.0	1/220	30.63	0.622	3.0
5	300.0	35.0	1/100	38.81	0.516	3.0
6	183.0	22.5	1/250	29.48	0.641	3.0
7	440.0	26.0	1/100	38.81	0.516	2.0
8	850.0	32.4	1/425	25.14	0.726	4.0
9	159.0	28.5	1/220	30.63	0.622	4.0
10	326.0	28.2	1/200	31.52	0.608	3.0
11	217.0	28.0	1/170	33.10	0.585	3.0
12	174.0	26.6	1/60	45.23	0.458	2.0
13	854.0	43.1	1/435	24.97	0.730	6.0
14	584.0	48.4	1/170	33.10	0.585	4.0
15	880.0	32.8	1/140	35.08	0.559	3.0
16	611.0	44.9	1/355	26.54	0.696	6.0
17	431.0	59.8	1/285	28.34	0.661	8.0
18	348.0	17.9	1/95	39.41	0.510	1.0
19	657.0	41.1	1/105	38.24	0.522	3.0
20	50.4	7.5	1/100	38.81	0.516	1.0
21	314.0	29.1	1/120	36.74	0.539	3.0
22	205.0	34.4	1/65	44.16	0.467	3.0
23	606.0	43.0	1/100	38.81	0.516	3.0
24	779.0	52.4	1/55	46.43	0.449	4.0
25	64.9	8.9	1/540	23.40	0.768	1.0
26	71.1	9.0	1/165	33.39	0.581	1.0
27	405.0	37.7	1/305	27.77	0.671	5.0
28	262.0	38.2	1/160	33.70	0.577	4.0
29	197.0	21.6	1/220	30.63	0.622	3.0
30	191.0	22.9	1/270	28.81	0.652	3.0
31	15.2	3.2	1/180	32.53	0.593	0.0
32	61.2	7.1	1/670	21.93	0.808	1.0
33	590.0	49.0	1/980	19.57	0.883	6.0
34	111.0	11.4	1/210	31.06	0.615	2.0
35	640.0	66.0	1/145	34.71	0.564	6.0
36	457.0	58.0	1/675	21.88	0.809	8.0
37	170.0	15.7	1/55	46.43	0.449	1.0
38	179.0	15.0	1/55	46.43	0.449	1.0
39	116.0	14.1	1/145	34.71	0.564	1.0
40	122.0	20.1	1/510	23.80	0.757	3.0
41	14.5	1.7	1/240	29.84	0.634	0.0
42	18.4	1.5	1/500	23.95	0.754	0.0

Total Catchment Area : 15,220.7 sq.km

Table 6 STORAGE FUNCTION OF RIVER CHANNEL

Name of Stretch	River Length (km)	River Bed Slope	Coeff. of Storage Function K	P		Lag-time Tl (hr)
IT1	7.6	1/12,000	21.519	0.704	Q < 1,000	1.0
			0.677	1.204	Q > 1,000	
IT2	11.7	1/12,000	27.915	0.749	Q < 1,000	2.0
			0.581	1.307	Q > 1,000	
IT3	15.0	1/12,000	46.457	0.700	Q < 1,200	2.0
			0.329	1.398	Q > 1,200	
IT4	3.7	1/12,000	12.910	0.671	Q < 1,200	0.0
			0.403	1.160	Q > 1,200	
IT5	8.0	1/12,000	34.066	0.642	Q < 1,600	1.0
			0.512	1.211	Q > 1,600	
IT6	13.0	1/12,000	37.507	0.629	Q < 2,700	2.0
			0.662	1.140	Q > 2,700	
IT7	14.0	1/12,000	42.507	0.675	Q < 2,500	2.0
			1.307	1.120	Q > 2,500	
IT8	19.0	1/500	27.443	0.681		3.0
IT9	4.2	1/1050	6.261	0.669		1.0
IT10	18.0	1/1050	24.006	0.677		2.0
IT11	4.0	1/2,500	6.479	0.683	Q < 2,500	1.0
			2x10-7	2.870	Q > 2,500	
IT12	42.0	1/100	9.239	0.711		3.0
IT13	22.0	1/5,000	29.626	0.740	Q < 800	1.0
			0.141	1.540	Q > 800	
Benedito river			0.000			
BN1	8.6	1/1,000	10.531	0.657		1.0
Itajai do Norte river			0.000			
IN1	7.5	1/240	8.274	0.637		1.0
Itajai do Oeste river			0.000			
IO1	6.0	1/5,000	14.853	0.738	Q < 200	1.0
			0.777	1.317	Q > 200	
IO2	15.1	1/5,000	15.801	0.745	Q < 800	2.0
			0.060	1.578	Q > 800	
Itajai do Sul river			0.000			
IS1	12.0	1/4,000	20.552	0.781	Q < 700	2.0
			0.060	1.648	Q > 700	
IS2	13.0	1/1,000	12.898	0.669		2.0
IS3	3.4	1/600	5.262	0.683	Q < 800	1.0
			0.111	1.190	Q > 800	
Itajai Mirim river			0.000			
IM1	8.4	1/10,000	11.309	0.805	Q < 100	1.0
			0.040	2.032	Q > 100	
IM2	8.4	1/2,300	7.515	0.735	Q < 200	1.0
			0.001	2.341	Q > 200	
IM3	9.2	1/2,900	0.201	1.559	Q < 200	1.0
			0.077	1.740	Q > 200	
IM4	13.4	1/2,600	2.403	1.087	Q < 200	2.0
			1.104	1.234	Q > 200	
IM5	9.0	1/2,000	0.966	1.211	Q < 200	1.0
			0.250	1.466	Q > 200	
Luiz Alves river			0.000			
LA1	2.0	1/10,000	4.853	0.610	Q < 100	1.0
			0.001	2.810	Q > 100	

Table 7 PROBABLE FLOOD PEAK DISCHARGES WITH/WITHOUT EXISTING FLOOD CONTROL DAMS (1/2)

WITHOUT DAMS

(Unit : cms)

Name of stretch	Catchment Area (km2)	2-Year 1978	2-Year 1980	2-Year 1983	2-Year 1984	5-Year 1978	5-Year 1980	5-Year 1983	5-Year 1984	10-Year 1978	10-Year 1980	10-Year 1983	10-Year 1984
IT1	15,221	3,050	3,120	3,100	3,190	3,770	3,850	3,830	3,940	4,260	4,330	4,310	4,420
IT2	13,504	2,800	2,930	2,870	2,930	3,450	3,620	3,550	3,600	3,980	4,070	3,990	4,020
IT3	13,393	2,870	3,020	2,880	3,000	3,550	3,750	3,370	3,700	3,990	4,230	4,020	4,140
IT4	12,741	2,950	3,180	2,840	3,070	3,660	4,000	3,550	3,820	4,130	4,550	4,010	4,300
IT5	12,726	2,950	3,190	2,850	3,080	3,660	4,010	3,560	3,830	4,130	4,560	4,020	4,300
IT6	12,535	2,950	3,210	2,840	3,080	3,670	4,040	3,560	3,830	4,140	4,610	4,030	4,320
IT7	12,338	2,950	3,230	2,830	3,070	3,670	4,080	3,550	3,840	4,140	4,650	4,020	4,320
Garcia river	157	48	32	40	56	64	48	48	72	72	48	56	88
Itoupava river	93	28	18	21	32	35	21	21	43	39	25	32	50
Velha river	56	17	21	14	20	23	17	17	26	26	17	20	31
IT8	12,076	2,960	3,240	2,820	3,050	3,650	4,090	3,540	3,810	4,120	4,670	4,010	4,290
IT9	11,671	2,860	3,150	2,750	2,970	3,550	3,990	3,450	3,700	4,110	4,550	3,910	4,160
IT10	9,945	2,440	2,690	2,380	2,590	3,030	3,390	3,000	3,230	3,430	3,860	3,400	3,620
IT11	9,631	2,390	2,620	2,350	2,590	2,960	3,310	2,950	3,160	3,350	3,770	3,350	3,540
IT12	9,591	2,370	2,620	2,340	2,530	2,970	3,330	2,970	3,170	3,370	3,810	3,390	3,570
IT13	5,570	1,360	1,380	1,250	1,640	1,700	1,750	1,580	2,040	1,930	1,980	1,790	2,280
IM1+IM2	1,699	450	410	270	490	560	500	330	590	630	560	370	660
IM1		130	120	90	140	160	150	100	170	180	160	120	180
IM2		330	290	190	350	400	360	230	430	450	400	260	480
IM3	1,562	440	390	250	490	550	490	310	600	620	550	350	670
IM4	1,446	440	390	240	510	560	490	300	650	640	550	340	740
IM5	1,267	400	350	220	480	510	440	270	610	580	500	310	690
Mirim dam	640	210	160	110	290	270	210	140	380	320	240	160	450
		(210)	(160)	(110)	(290)	(270)	(210)	(140)	(380)	(320)	(240)	(160)	(450)
BN1	1,521	440	440	390	410	560	600	520	550	640	700	600	650
IN1	3,360	1,010	1,250	1,130	980	1,250	1,610	1,460	1,200	1,420	1,860	1,670	1,470
Norte dam	2,318	680	900	830	660	840	1,170	1,070	860	950	1,350	1,230	990
		(680)	(900)	(830)	(660)	(840)	(1,170)	(1,070)	(860)	(950)	(1,350)	(1,230)	(990)
IO1	3,050	860	890	780	1,000	1,080	1,120	1,000	1,270	1,220	1,290	1,130	1,440
IO2	599	160	150	140	210	200	190	180	270	220	210	210	310
Trombudo	300	70	80	70	120	90	100	90	160	110	120	110	190
dam (A)		(70)	(80)	(70)	(120)	(90)	(100)	(90)	(160)	(110)	(120)	(110)	(190)
Trombudo	116	40	30	30	50	50	40	40	60	60	50	40	70
dam (B)		(40)	(30)	(30)	(50)	(50)	(40)	(40)	(60)	(60)	(50)	(40)	(70)
Oeste dam	860	260	310	320	340	330	400	410	450	370	460	480	520
		(260)	(310)	(320)	(340)	(330)	(400)	(410)	(450)	(370)	(460)	(480)	(520)
IS1	2,166	550	560	530	770	770	770	870	930	780	810	1,080	1,050
IS2	1,992	520	540	510	740	660	690	890	960	750	790	1,090	1,100
IS3	1,775	500	490	500	640	620	630	860	880	700	720	1,040	1,000
Sul dam	1,290	400	370	440	500	490	470	760	650	560	540	900	750
		(400)	(370)	(440)	(500)	(490)	(470)	(760)	(650)	(560)	(540)	(900)	(750)

Return Period (Year)

Name of stretch	25-Year 1978	25-Year 1980	25-Year 1983	25-Year 1984	50-Year 1978	50-Year 1980	50-Year 1983	50-Year 1984	80-Year 1978	80-Year 1980	80-Year 1983	80-Year 1984	100-Year 1978	100-Year 1980	100-Year 1983	100-Year 1984
IT1	4,910	4,990	5,070	5,020	5,680	5,780	6,090	5,830	6,030	6,120	6,600	6,110	6,400	6,520	7,110	6,470
IT2	4,430	4,660	4,710	4,520	5,070	5,150	5,670	5,170	5,370	5,660	6,230	5,400	5,690	6,030	6,600	5,720
IT3	4,570	4,850	4,730	4,660	5,220	5,570	5,710	5,330	5,530	5,890	6,190	5,560	5,870	6,280	6,670	5,870
IT4	4,740	5,240	4,620	4,860	5,440	6,040	5,670	5,530	5,760	6,400	6,180	5,750	6,120	6,840	6,680	6,040
IT5	4,750	5,260	4,620	4,870	5,450	6,050	5,680	5,540	5,770	6,410	6,240	5,750	6,130	6,860	6,690	6,040
IT6	4,760	5,320	4,630	4,890	5,460	6,120	5,670	5,560	5,780	6,480	6,170	5,770	6,160	6,940	6,670	6,060
IT7	4,760	5,360	4,630	4,900	5,460	6,170	5,630	5,570	5,790	6,530	6,130	5,790	6,260	6,990	6,630	6,070
Garcia river	72	56	72	96	88	64	80	112	96	72	88	120	104	72	104	129
Itoupava river	46	28	43	57	53	35	50	67	53	35	50	71	57	39	57	75
Velha river	26	20	26	34	31	23	28	40	34	26	31	43	37	26	37	45
IT8	4,730	5,380	4,610	4,870	5,430	6,180	5,590	5,540	5,760	6,530	6,080	5,750	6,150	6,990	6,560	6,030
IT9	4,590	5,260	4,490	4,720	5,260	6,040	5,430	5,370	5,580	6,390	5,890	5,570	5,970	6,830	6,350	5,820
IT10	3,930	4,450	3,920	4,100	4,570	5,170	4,580	4,650	4,660	5,500	4,940	4,820	5,180	5,890	5,330	5,050
IT11	3,850	4,350	3,860	4,010	4,480	5,080	4,530	4,550	4,760	5,400	4,880	4,710	5,070	5,790	5,240	4,940
IT12	3,880	4,440	3,940	4,040	4,550	5,200	4,740	4,600	4,860	5,560	5,130	4,780	5,200	6,000	5,530	5,020
IT13	2,190	2,270	2,210	2,580	2,550	2,610	2,550	3,020	2,710	2,770	2,700	3,190	2,890	2,980	2,840	3,430
IM1+IM2	710	640	420	730	820	730	520	860	870	780	560	900	920	820	610	960
IM1	200	180	130	200	230	210	160	240	240	230	170	250	260	240	190	260
IM2	520	460	300	530	590	520	360	630	630	550	400	660	670	590	430	700
IM3	720	630	400	760	840	730	490	900	900	780	540	960	960	830	580	1,020
IM4	760	640	390	840	870	740	480	1,010	940	800	520	1,070	1,020	860	570	1,160
IM5	690	580	350	790	790	670	420	950	860	720	460	1,020	940	780	500	1,110
Mirim dam	400	280	180	520	470	310	210	620	520	330	220	650	550	350	230	710
	(400)	(280)	(180)	(520)	(470)	(310)	(210)	(620)	(520)	(330)	(220)	(650)	(550)	(350)	(230)	(710)
BN1	750	840	720	780	870	980	1,000	930	960	1,040	1,130	980	1,010	1,110	1,270	1,040
IN1	1,600	2,180	1,950	1,710	1,960	2,630	2,370	2,000	2,120	2,870	2,620	2,090	2,320	3,170	2,860	2,200
Norte dam	1,080	1,580	1,450	1,160	1,290	1,900	1,920	1,360	1,370	2,080	2,110	1,420	1,490	2,290	2,280	1,500
	(1,080)	(1,580)	(1,450)	(1,160)	(1,290)	(1,900)	(1,920)	(1,360)	(1,370)	(2,080)	(2,110)	(1,420)	(1,490)	(2,290)	(2,280)	(1,500)
IO1	1,400	1,480	1,310	1,660	1,640	1,750	1,510	1,920	1,760	1,860	1,620	2,000	1,910	2,050	1,740	2,150
IO2	250	240	230	360	290	280	280	420	310	290	310	450	340	310	340	490
Trombudo	120	140	130	220	140	160	160	260	140	170	170	270	150	180	180	290
dam (A)	(120)	(140)	(130)	(220)	(140)	(160)	(160)	(260)	(140)	(170)	(170)	(270)	(150)	(180)	(180)	(290)
Trombudo	70	50	50	80	70	60	70	90	80	60	70	90	90	70	80	110
dam (B)	(70)	(50)	(50)	(80)	(70)	(60)	(70)	(90)	(80)	(60)	(70)	(90)	(90)	(70)	(80)	(110)
Oeste dam	430	540	560	610	490	720	670	720	500	800	760	750	530	910	850	790
	(430)	(540)	(560)	(610)	(490)	(720)	(670)	(720)	(500)	(800)	(760)	(750)	(530)	(910)	(850)	(790)
IS1	870	920	1,300	1,200	1,040	1,040	1,470	1,420	1,100	1,080	1,550	1,520	1,190	1,140	1,620	1,650
IS2	850	920	1,330	1,270	1,060	1,050	1,540	1,510	1,140	1,100	1,630	1,610	1,240	1,170	1,720	1,740
IS3	790	840	1,290	1,160	1,010	960	1,490	1,370	1,080	1,010	1,570	1,450	1,160	1,060	1,660	1,570
Sul dam	630	630	1,120	880	840	720	1,290	1,020	910	760	1,370	1,100	1,000	800	1,450	1,210
	(630)	(630)	(1,120)	(880)	(840)	(720)	(1,290)	(1,020)	(910)	(760)	(1,370)	(1,100)	(1,000)	(800)	(1,450)	(1,210)

Note : ' ( ) ' means outflow discharge from dam.

Table 7 PROBABLE FLOOD PEAK DISCHARGES WITH/WITHOUT EXISTING FLOOD CONTROL DAMS (2/2)

WITH DAMS

(Unit : cms)

Name of stretch	Catchment Area (km2)	Return Period (Year) 2-Year				5-Year				10-Year				25-Year				50-Year				80-Year				100-Year			
		1979	1980	1983	1984	1979	1980	1983	1984	1979	1980	1983	1984	1979	1980	1983	1984	1979	1980	1983	1984	1979	1980	1983	1984	1979	1980	1983	1984
IT1	15,221	2,450	2,320	2,260	2,570	3,050	2,870	2,780	3,190	3,430	3,230	3,110	3,560	3,940	3,700	3,940	4,040	4,530	4,250	5,160	4,690	4,810	4,490	5,650	4,920	5,100	4,790	6,110	5,220
IT2	13,504	2,130	2,110	2,020	2,220	2,610	2,580	2,480	2,730	2,940	2,890	2,810	3,050	3,350	3,280	3,690	3,440	3,810	3,730	4,800	3,930	4,040	3,940	5,200	4,110	4,280	4,200	5,580	4,360
IT3	13,393	2,170	2,170	2,010	2,280	2,690	2,660	2,470	2,810	3,010	2,990	2,880	3,140	3,450	3,390	3,750	3,550	3,920	3,840	4,860	4,060	4,150	4,050	5,240	4,230	4,410	4,320	5,610	4,470
IT4	12,741	2,180	2,240	1,930	2,290	2,710	2,770	2,390	2,830	3,040	3,120	2,900	3,170	3,490	3,570	3,760	3,600	3,970	4,050	4,900	4,100	4,190	4,260	5,220	4,260	4,440	4,530	5,530	4,480
IT5	12,726	2,190	2,240	1,930	2,290	2,710	2,770	2,390	2,830	3,040	3,120	2,900	3,180	3,490	3,580	3,760	3,610	3,970	4,050	4,910	4,100	4,200	4,260	5,230	4,270	4,450	4,530	5,530	4,490
IT6	12,535	2,190	2,240	1,910	2,280	2,700	2,770	2,360	2,820	3,030	3,130	2,890	3,170	3,480	3,600	3,750	3,610	3,960	4,070	4,900	4,100	4,170	4,280	5,210	4,260	4,420	4,550	5,520	4,470
IT7	12,338	2,160	2,230	1,870	2,260	2,660	2,760	2,320	2,800	3,000	3,130	2,890	3,150	3,450	3,610	3,730	3,600	3,930	4,080	4,880	4,090	4,130	4,290	5,190	4,250	4,390	4,550	5,490	4,460
Garcia river	157	48	32	40	56	64	48	48	72	72	48	56	88	72	56	72	96	88	64	80	112	96	72	88	120	104	72	104	128
Itoupava river	93	28	18	21	32	35	21	21	43	39	25	32	50	46	28	43	57	53	35	50	67	53	35	50	71	57	39	57	75
Velha river	56	17	21	14	20	23	17	17	26	26	17	20	31	26	20	26	34	31	23	28	40	34	26	31	43	37	26	37	45
IT8	12,076	2,120	2,200	1,820	2,220	2,620	2,740	2,270	2,750	2,950	3,120	2,860	3,100	3,380	3,620	3,690	3,550	3,860	4,070	4,030	4,050	4,060	4,260	5,130	4,210	4,340	4,520	5,420	4,410
IT9	11,671	2,030	2,120	1,750	2,120	2,490	2,630	2,190	2,630	2,800	3,000	2,790	2,960	3,200	3,470	3,600	3,370	3,630	3,890	4,700	3,840	3,830	4,090	4,990	3,980	4,110	4,350	5,270	4,170
IT10	9,945	1,590	1,660	1,390	1,720	1,900	2,020	1,810	2,110	2,130	2,290	2,360	2,360	2,430	2,630	3,120	2,680	2,810	2,950	4,050	3,020	3,020	3,110	4,290	3,140	3,240	3,310	4,530	3,320
IT11	9,631	1,510	1,590	1,330	1,660	1,820	1,940	1,790	2,040	2,040	2,190	2,310	2,290	2,320	2,570	3,060	2,610	2,710	2,840	3,960	2,920	2,900	3,000	4,200	3,030	3,110	3,200	4,430	3,200
IT12	9,581	1,510	1,580	1,330	1,650	1,810	1,920	1,780	2,030	2,020	2,170	2,300	2,270	2,300	2,480	3,060	2,560	2,700	2,830	3,970	2,920	2,900	2,990	4,220	3,030	3,110	3,200	4,450	3,190
IT13	5,570	840	880	790	1,040	1,030	1,100	1,300	1,300	1,160	1,240	1,710	1,470	1,320	1,420	2,160	1,670	1,600	1,710	2,510	1,960	1,790	1,880	2,650	2,140	1,990	2,100	2,790	2,430
IM1+IM2	1,699	450	410	270	490	560	500	330	590	630	560	370	660	710	640	420	730	820	730	520	860	870	780	560	900	920	820	610	960
IM1		130	120	90	140	160	150	100	170	180	160	120	190	200	180	130	200	230	210	160	240	240	230	170	250	260	240	190	260
IM2		330	290	190	350	400	360	230	430	450	400	260	480	520	460	300	530	590	520	360	630	630	550	400	660	670	590	430	700
IM3	1,562	440	390	250	490	550	490	310	600	620	550	350	670	720	630	400	760	840	730	490	900	900	780	540	960	960	830	580	1,020
IM4	1,446	440	390	240	510	560	490	300	650	640	550	340	740	760	640	390	840	870	740	480	1,010	940	850	520	1,070	1,020	860	570	1,160
IM5	1,267	400	350	220	480	510	440	270	610	580	500	310	690	690	580	350	790	790	670	420	950	860	720	460	1,020	940	780	500	1,110
Mirim dam	640	210	160	110	290	270	210	140	380	320	240	160	450	400	280	180	520	470	310	210	620	520	330	220	650	550	350	230	710
		(210)	(160)	(110)	(290)	(270)	(210)	(140)	(380)	(320)	(240)	(160)	(450)	(400)	(280)	(180)	(520)	(470)	(310)	(210)	(620)	(520)	(330)	(220)	(650)	(550)	(350)	(230)	(710)
BN1	1,521	440	440	390	410	560	600	520	550	640	700	600	650	750	840	720	780	870	980	1,000	930	960	1,040	1,130	980	1,010	1,110	1,270	1,040
IN1	3,360	540	570	520	510	640	680	620	610	700	760	690	690	770	860	800	760	940	990	1,300	870	1,020	1,060	1,380	900	1,120	1,160	1,720	940
Norte dam	2,319	680	900	830	660	840	1,170	1,070	860	950	1,350	1,230	990	1,080	1,580	1,450	1,160	1,290	1,900	1,920	1,360	1,370	2,080	2,110	1,420	1,490	2,290	2,280	1,500
		(220)	(240)	(260)	(220)	(240)	(260)	(290)	(240)	(250)	(270)	(320)	(250)	(270)	(290)	(500)	(260)	(280)	(310)	(950)	(270)	(290)	(320)	(1,020)	(260)	(300)	(330)	(1,240)	(280)
IO1	3,050	630	610	510	710	790	760	640	890	880	860	770	1,010	1,000	990	1,050	1,160	1,220	1,280	1,340	1,340	1,330	1,480	1,470	1,390	1,460	1,720	1,590	1,550
IO2	599	160	150	140	210	200	190	180	270	220	210	210	310	250	240	230	360	290	280	280	420	310	290	310	450	340	310	340	490
Trombudo	300	70	80	70	120	90	100	90	160	110	120	110	190	120	140	120	220	140	160	160	260	140	170	170	270	150	190	180	290
dam (A)		(70)	(80)	(70)	(120)	(90)	(100)	(90)	(160)	(110)	(120)	(110)	(190)	(120)	(140)	(120)	(220)	(140)	(160)	(160)	(260)	(140)	(170)	(170)	(270)	(150)	(180)	(190)	(290)
Trombudo	116	40	30	30	50	50	40	40	60	60	50	40	70	70	50	50	80	70	60	70	90	80	60	70	90	90	70	80	110
dam (B)		(40)	(30)	(30)	(50)	(50)	(40)	(40)	(60)	(60)	(50)	(40)	(70)	(70)	(50)	(50)	(80)	(70)	(60)	(70)	(90)	(80)	(60)	(70)	(90)	(90)	(70)	(80)	(110)
Oeste dam	860	260	310	320	340	330	400	410	450	370	460	480	520	430	540	560	610	490	720	670	720	500	800	760	750	530	910	850	790
		(0)	(0)	(70)	(0)	(0)	(70)	(180)	(20)	(0)	(180)	(250)	(50)	(40)	(360)	(340)	(110)	(60)	(510)	(520)	(260)	(90)	(570)	(570)	(300)	(130)	(670)	(630)	(270)
IS1	2,166	170	230	470	300	220	300	830	390	250	340	1,030	440	450	400	1,250	520	770	460	1,420	870	830	480	1,490	970	910	530	1,560	1,100
IS2	1,992	150	200	470	260	180	260	840	330	240	290	1,030	370	450	340	1,240	510	730	390	1,410	870	840	420	1,490	1,000	940	510	1,560	1,150
IS3	1,775	110	140	450	180	130	180	800	240	220	210	980	270	430	240	1,170	460	700	330	1,330	800	810	390	1,400	920	900	460	1,470	1,050
Sul dam	1,290	400	370	440	500	490	470	760	650	560	540	900	750	630	630	1,120	820	840	720	1,290	1,020	910	760	1,370	1,100	1,000	800	1,450	1,210
		(50)	(50)	(390)	(50)	(100)	(50)	(710)	(120)	(170)	(90)	(850)	(200)	(350)	(160)	(1,010)	(350)	(590)	(250)	(1,140)	(600)	(690)	(300)	(1,210)	(750)	(780)	(350)	(1,270)	(800)

Note : ' ( ) ' means outflow discharge from dam.

Table 8 SELECTION OF PROTECTION AREA

Municipality	River Stretch	Flood Prone Area (km2)	Affected Population	Annual Mean Damage thousand Cz$	Population per km2	Potential Flood Damage per km2 thousand Cz$	Damageability level
Itajai	IT1+2	53.1	106,000	259,520	2,000	4,890	1
Navegantes	IM1+2						
Ilhota	IT3	25.1	0	50	0	2	3
Ilhota	IT4	4.4	800	1,100	180	250	2
Gaspar	IT5	10.1	10	18	1	2	3
Gaspar/Blumenau	IT6+IT7	27.4	105,870	228,660	3,860	8,350	1
Indaial	IT8	0.0	0	0	0	0	3
Indaial	IT9	0.0	0	0	0	0	3
Indaial/Rodeio	IT10	5.7	10	35	2	6	3
Ascurra	IT11	9.4	3,800	8,350	400	890	2
Apiuna/Lontras	IT12	4.3	0	33	0	8	3
Lontras/ Rio do Sul	IT13	24.8	36,400	267,169	1,470	10,770	1
Aurora	IS1						
Agronomica	IO1						
Aurora	IS2	1.5	0	70	0	45	3
Ituporanga	IS3	2.2	4,800	13,390	2,180	6,090	2
T.Central	IO2	4.0	100	210	25	50	3
Timbo	BN1	1.5	100	110	65	70	3
Itajai	IM3	12.1	0	520	0	40	3
Itajai/Brusque	IM4	11.5	10	750	1	65	3
Brusque	IM5	6.0	18,640	50,600	3,110	8,430	1
Ibirama	IN1	0.0	0	0	0	0	3
Total		203.1	276,540	830,585			

Note : (1) Flooding area means estimated inundated area at 100-year scale flood.

(2) Affected population means estimated number of population affected by 100-year scale flood.

(3) Criteria of levelling damageability by stretch

	Population per km2	Damage per km2
Level 1	1,000 over	1,000 over
Level 2	100-1,000	100-1,000
Level 3	below 100	below 100

(4) Simulation of affected population and annual mean flood damage in river stretch of IN-1 is based on the condition that Norte dam is constructed

Table 9 CONSTRUCTION COST FOR RIVER IMPROVEMENT

(Unit : Million Cz$)

Stretch	Provisional Plan	Mid-Term Plan	Long-Term Plan
IT-1 /1	0.11	0.11	0.11
IT-2 /1	3.77	3.77	3.77
Floodway	680.58	796.70	986.32
IT-4	135.49	168.58	236.40
IT-6	202.89	339.22	544.46
IT-7	298.06	422.50	608.08
IT-11	13.60	58.05	94.68
IT-13	678.32	1,011.04	1,235.91
IO-1	112.31	128.05	159.32
IS-1	52.71	69.09	83.58
IS-3	34.73	47.69	59.95
IM-1 /1	23.47	23.47	23.47
IM-2A (0-0.8 km)	15.18	15.64	16.53
IM-2B (0.8-3.8 km)	13.40	15.27	20.98
IM-5	104.85	117.96	140.42

Note : /1 For these stretches, the works for Long-Term Plan is to be taken from the stage of Provisional Plan as the difference of required quantities is negligibly small among Provisional, Mid-Term and Long-Term Plans.

Table 10 RESULT OF ECONOMIC EVALUATION

(Unit:Million Cz$)

Stretch	Symbol	Design Scale (year)	Economic Construction /1 Cost	Present Worth /2		B-C	EIRR (%)
				Benefit	Cost		
Itajai	IT1+2	10	580.7	514.8	444.1	70.7	9.2
	IM1+2	25	682.3	655.0	506.6	148.4	10.2
		50	853.3	720.5	596.9	123.6	9.6
Ilhota	IT4	10	110.8	4.5	92.2	-87.7	(-)
		25	139.3	8.4	111.7	-103.3	(-)
		50	197.7	9.9	146.4	-136.5	(-)
Blumenau Gaspar	IT6+7	10	368.2	501.3	305.4	195.9	12.7
		25	592.8	708.1	434.0	274.1	12.6
		50	929.3	783.0	559.6	223.4	11.3
Ascurra	IT11	10	8.3	0.0	8.0	-8.0	(-)
		25	46.5	29.2	34.2	-5.0	(6.8)
		50	78.1	56.6	53.2	3.4	(8.5)
Rio do Sul	IT13	10	660.2	586.0	553.9	32.1	8.5
	IS1	25	974.4	818.6	763.7	54.9	8.6
	IO1	50	1,207.4	907.2	839.7	67.5	8.3
Ituporanga	IS3	10	27.5	33.6	25.7	7.9	10.8
		25	38.7	49.6	35.5	14.1	11.7
		50	49.2	55.3	43.3	12.0	10.6
Brusque	IM5	10	75.2	70.1	68.2	1.9	8.2
		25	86.5	132.2	76.3	55.9	13.7
		50	105.8	161.9	88.8	73.1	14.3

Note: /1 Economic construction cost
Economic cost of main civil works is 85 % of financial cost.
Economic cost of compensation is evaluated by production foregone of crops or buildings.
Engineering/administration service is evaluated by financial cost.

/2 Discount rate 8%

/3 Parentheses indicates economic evaluation at future level.

Table 11 COST COMPARISON OF STRUCTURAL MEASURES FOR LONG-TERM PLAN

(Unit; Million Cz$)

Stretch	Itajai river			Itajai Mirim river	
	AL-1	AL-2	R/I	Mirim dam +R/I	R/I
IT 1	-	-	-	0.1	0.1
IT 2	-	-	-	4.0	4.0
Floodway	785	950	987	-	-
IT 4	169	230	237	-	-
IT 6	339	530	545	-	-
IT 7	423	575	608	-	-
IT 11	58	86	95	-	-
IT 13	1,236	1,160	1,236	-	-
				-	-
IO 1	159	128	159	-	-
IS 1	84	84	84	-	-
IS 3	60	60	60	-	-
IM 1	-	-	-	24	24
IM 2	-	-	-	31	38
IM 5	-	-	-	118	141
Ascurra dam	1,271	-	-	-	-
Trombudo					
(A) dam	-	334	-	-	-
(B) dam	-	214	-	-	-
Mirim dam	-	-	-	313	-
Total	4,584	4,351	4,011	490	207

Notes;
AL-1: Alternative 1 (Ascurra dam + River Improvement)
AL-2: Alternative 2 (Trombudo (A),(B) dam + River Improvement)
R/I : River Improvement

Table 12 ADDITIONAL TELEMETERIC STATIONS

Location	Main Protection Area
1.Lomba Alta	Sul dam and its downstream
2.Sul dam	Rio do Sul
3.Rio do campo	Oeste dam and its downstream
4.Oeste dam	Rio do Sul
5.Barra do Prata	Norte dam
6.Norte dam	Ibirama, and its downstream
7.Dr. Pedolinho	Timbo, its downstresm
8.Garcia	Blumenau
9.Porto Escalvado	Picarras

Figures

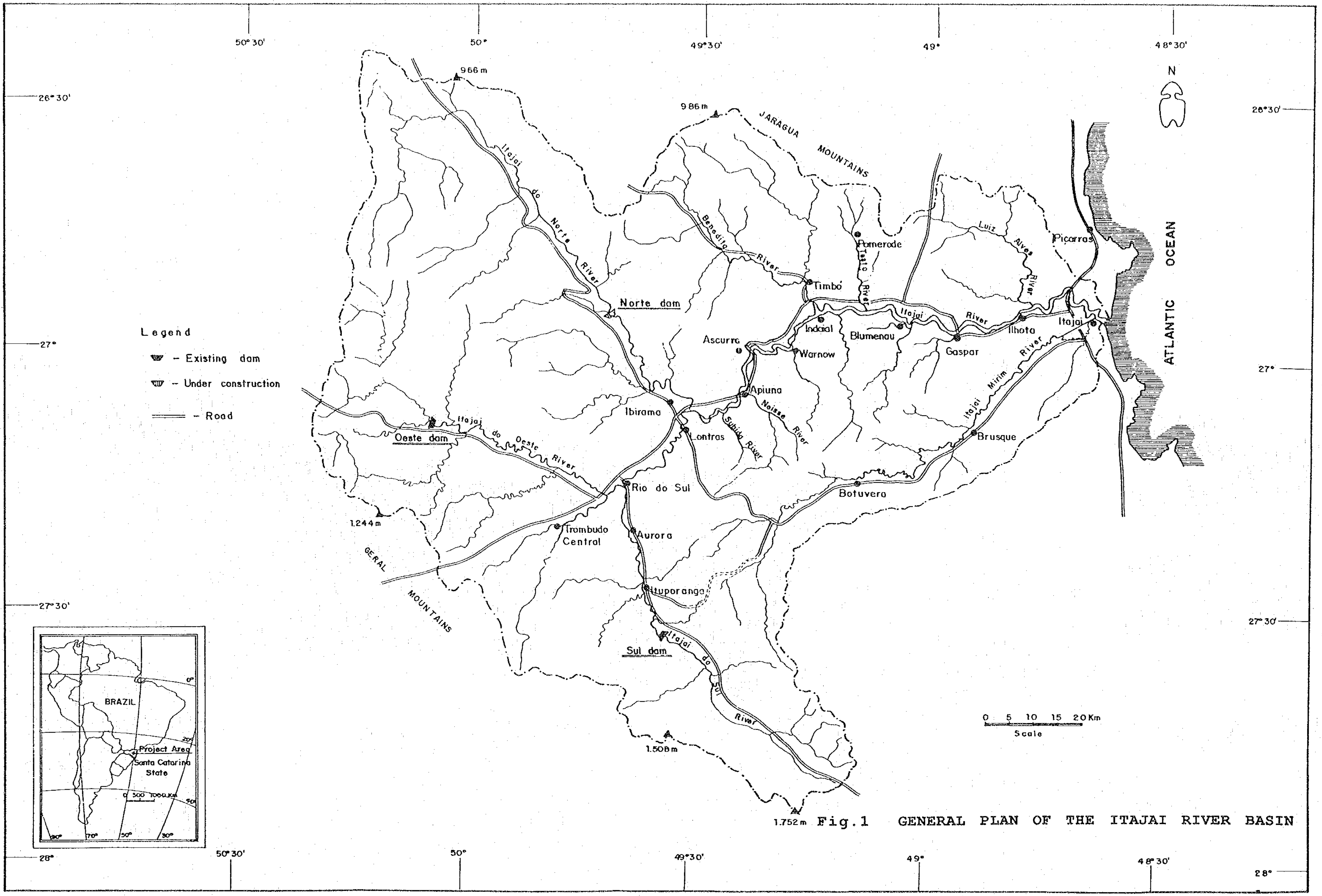
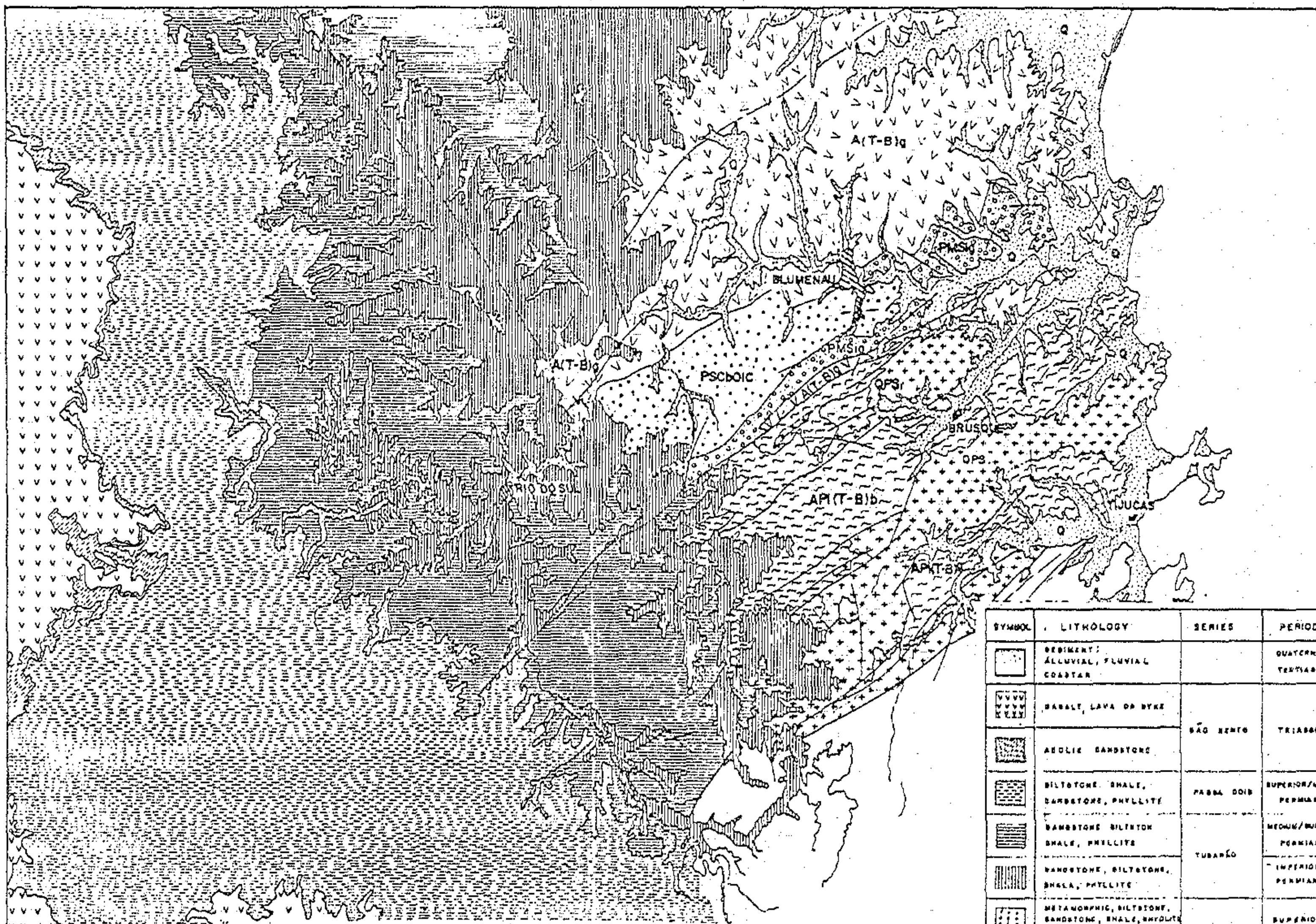


Fig.1 GENERAL PLAN OF THE ITAJAI RIVER BASIN



SYMBOL	LITHOLOGY	SERIES	PERIOD	ERA
	SEDIMENT; ALLUVIAL, FLUVIAL COASTAR		QUATERNARY TERTIARY	CENZOIC
	BASALT, LAVA OR DYKE	SÃO BENTO	TRIASSIC	MESOZOIC
	AEOLIC SANDSTONE			
	SILTSTONE SHALE, SANDSTONE, PHYLLITE	PASSA DOIS	SUPERIOR/MEDIUM PERMIAN	PALAEOZOIC
	SANDSTONE SILTSTON SHALE, PHYLLITE	TUBARÃO	MEDIUM/SUPERIOR PERMIAN	
	SANDSTONE, SILTSTONE, SHALE, PHYLLITE		INFERIOR PERMIAN	
	METAMORPHIC, SILTSTONE, SANDSTONE, SHALE, RHYOLITE PHILLITE	ITAJAI	SUPERIOR	PROTEOZOIC
	METAMORPHIC SANDSTONE AND CONGLOMERATE PHYLLITE		MEDIUM	
	MICASCHIST, METAVOLCANIC SEDIMENTARY ROCKS	BRUSQUE	INFERIOR	
	GNEISSES MIGMATITED		ARCHAEN	ARCHAEOZOIC
	GRANITE	GUSIDA INTRUSIVE SUITE / ARCHAEN	CAMBRIAN ORODOVIC / INFERIOR / PROTEOZOIC	

Fig.2 GEOLOGICAL MAP OF THE ITAJAI RIVER BASIN

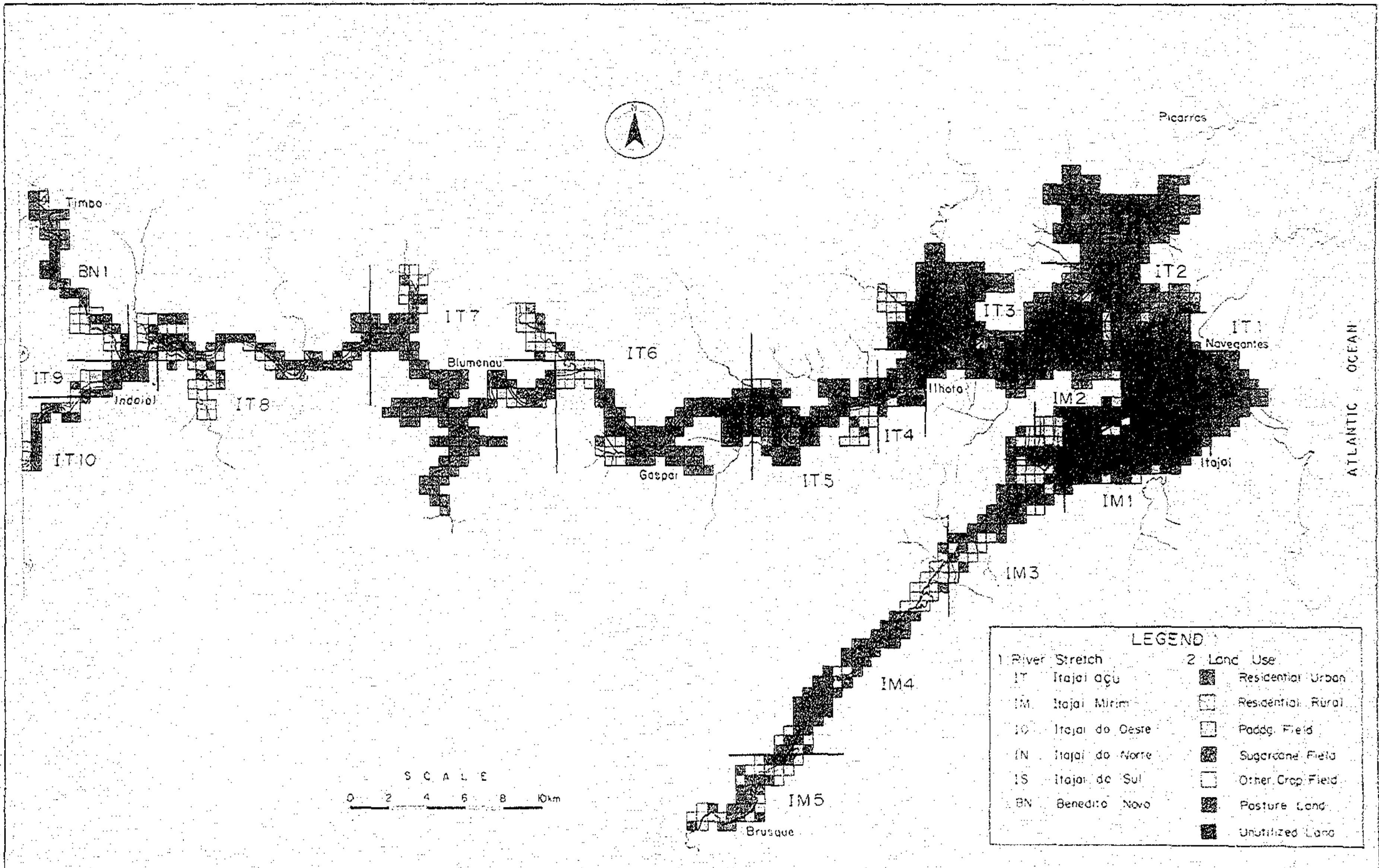


Fig.3 PRESENT LAND USE ALONG THE ITAJAI RIVER (1/2)

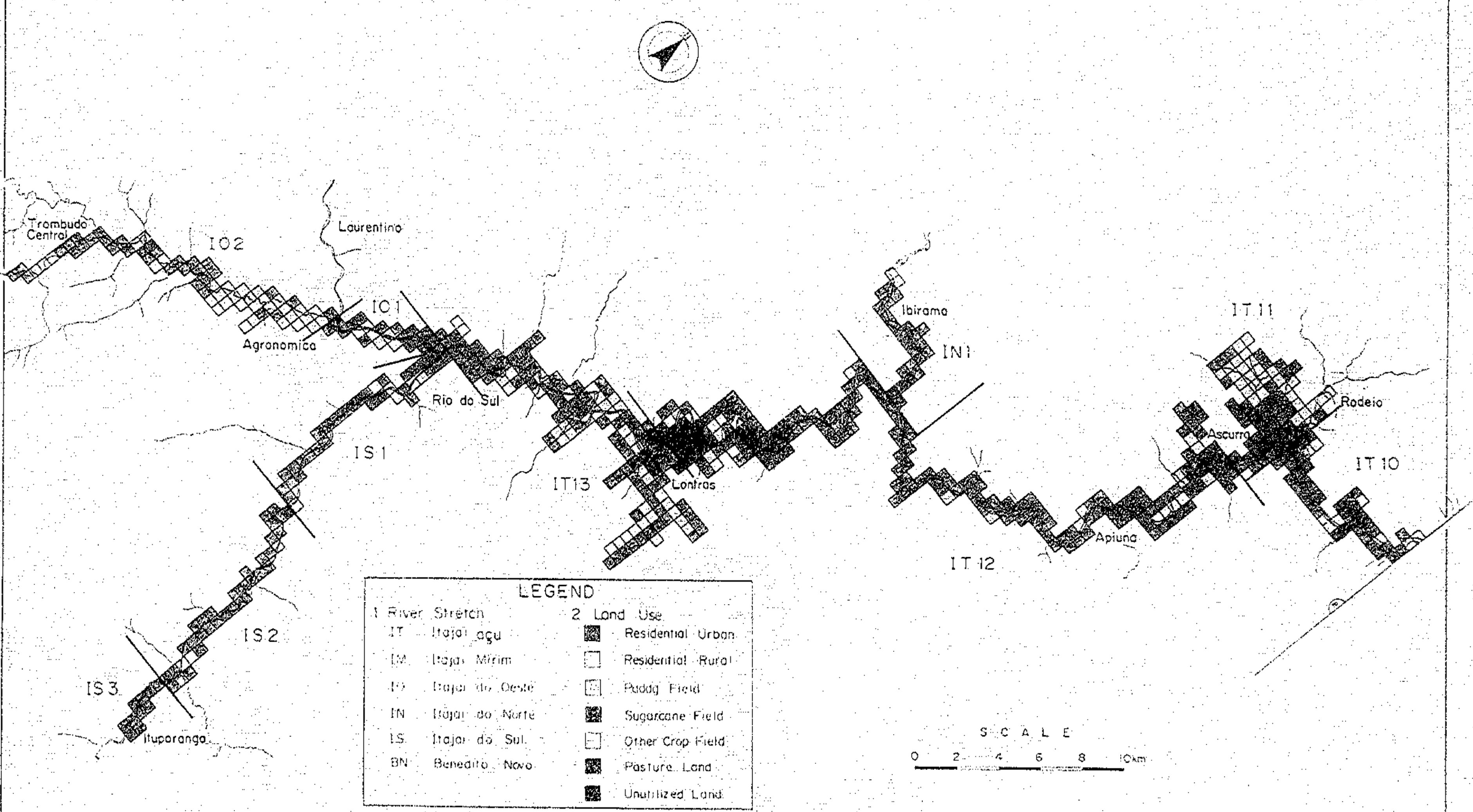


Fig.3 PRESENT LAND USE ALONG THE ITAJAI RIVER (2/2)

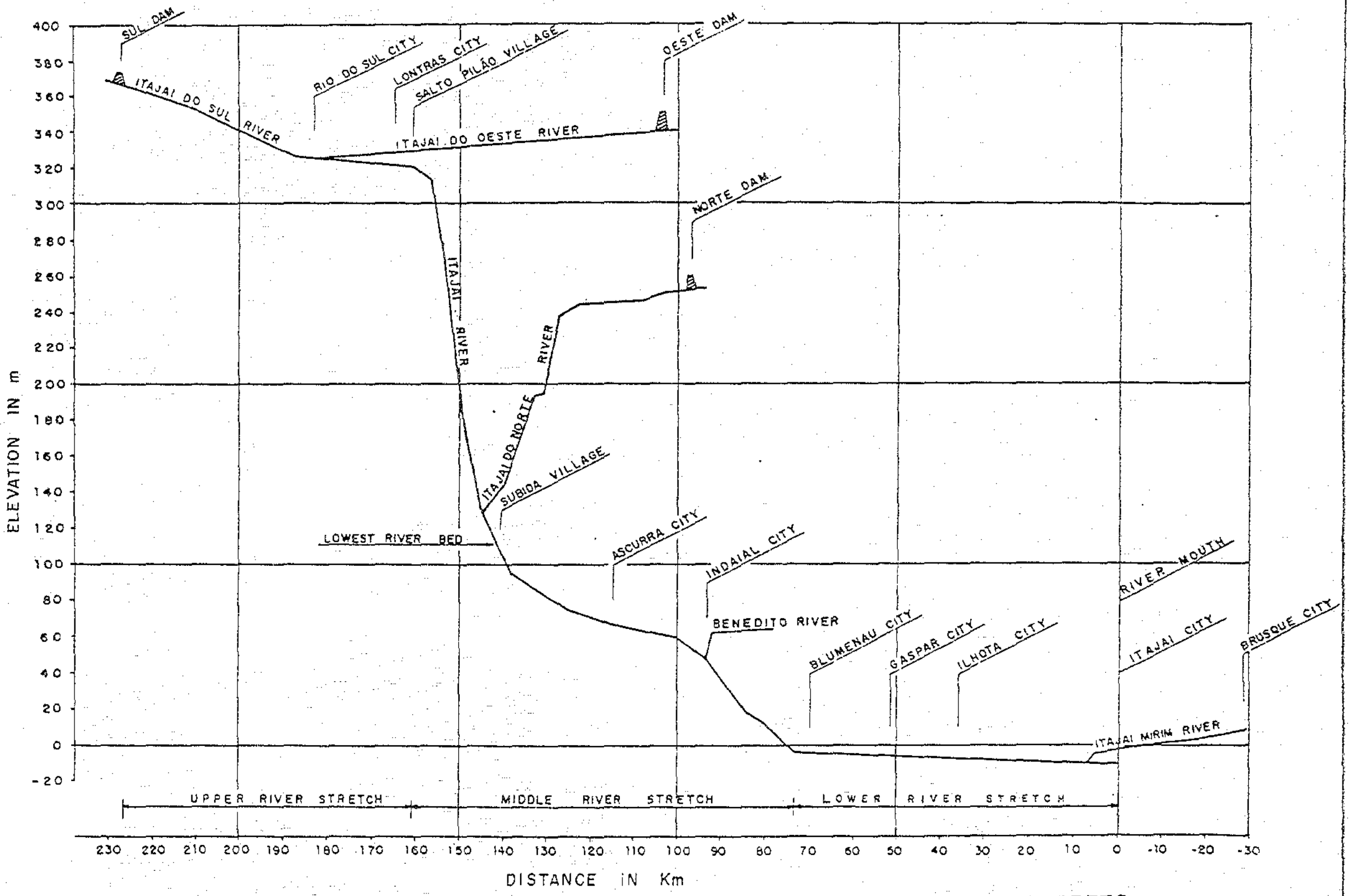


Fig.4 LONGITUDINAL PROFILE OF ITAJAI RIVER AND ITS TRIBUTARIES

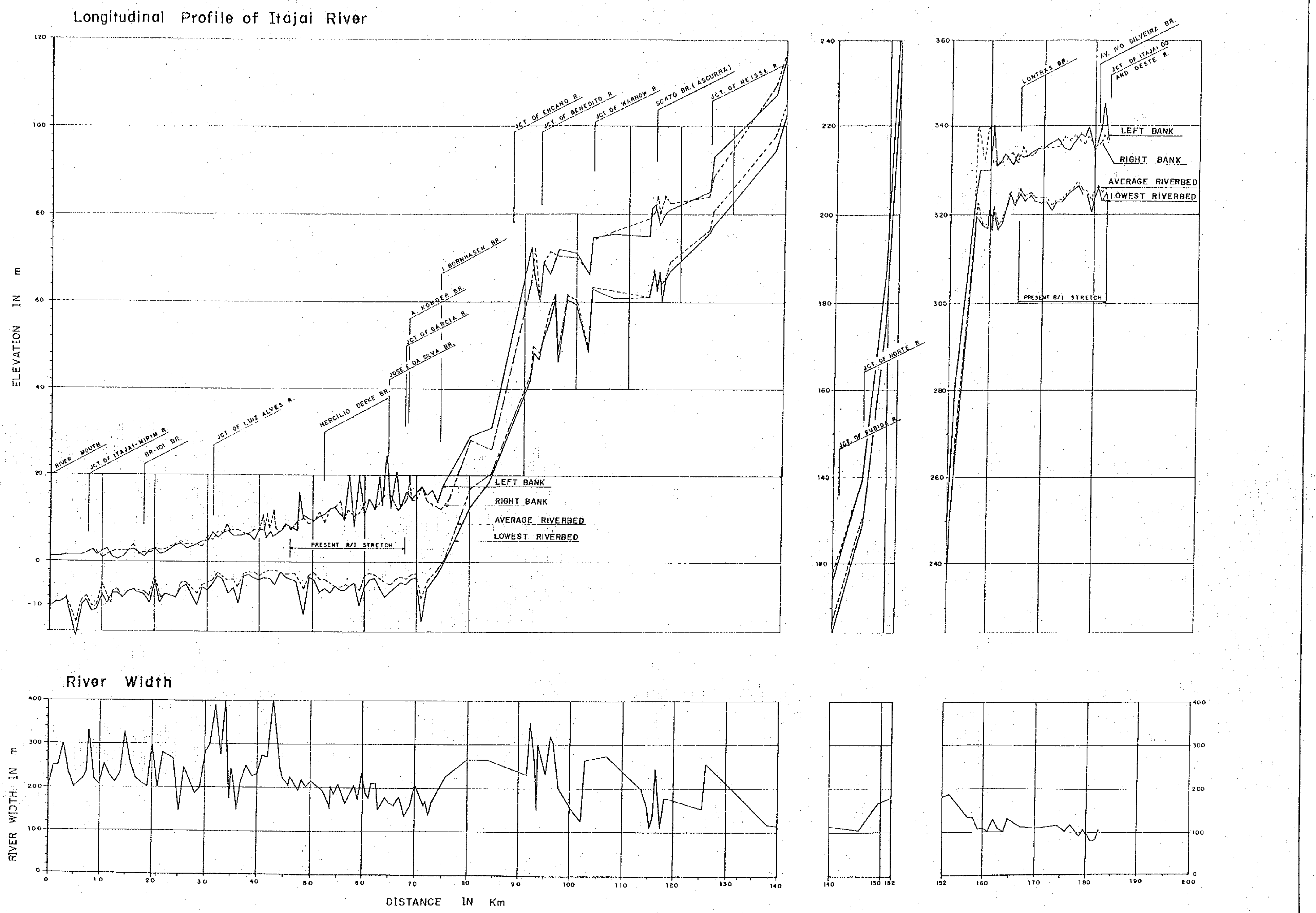


Fig.5 CHARACTERISTICS OF ITAJAI RIVER

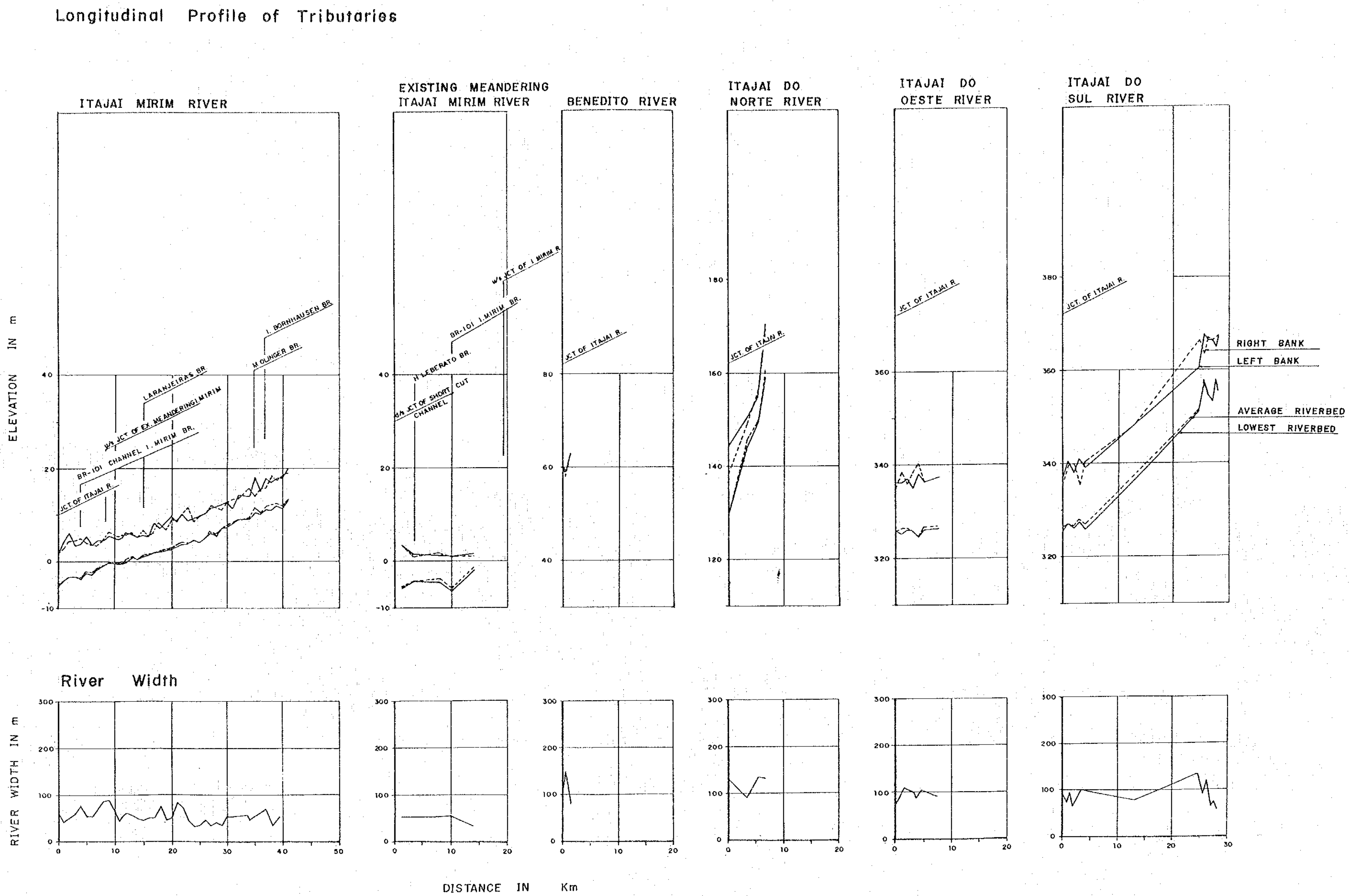


Fig.6 CHARACTERISTICS OF TRIBUTARIES

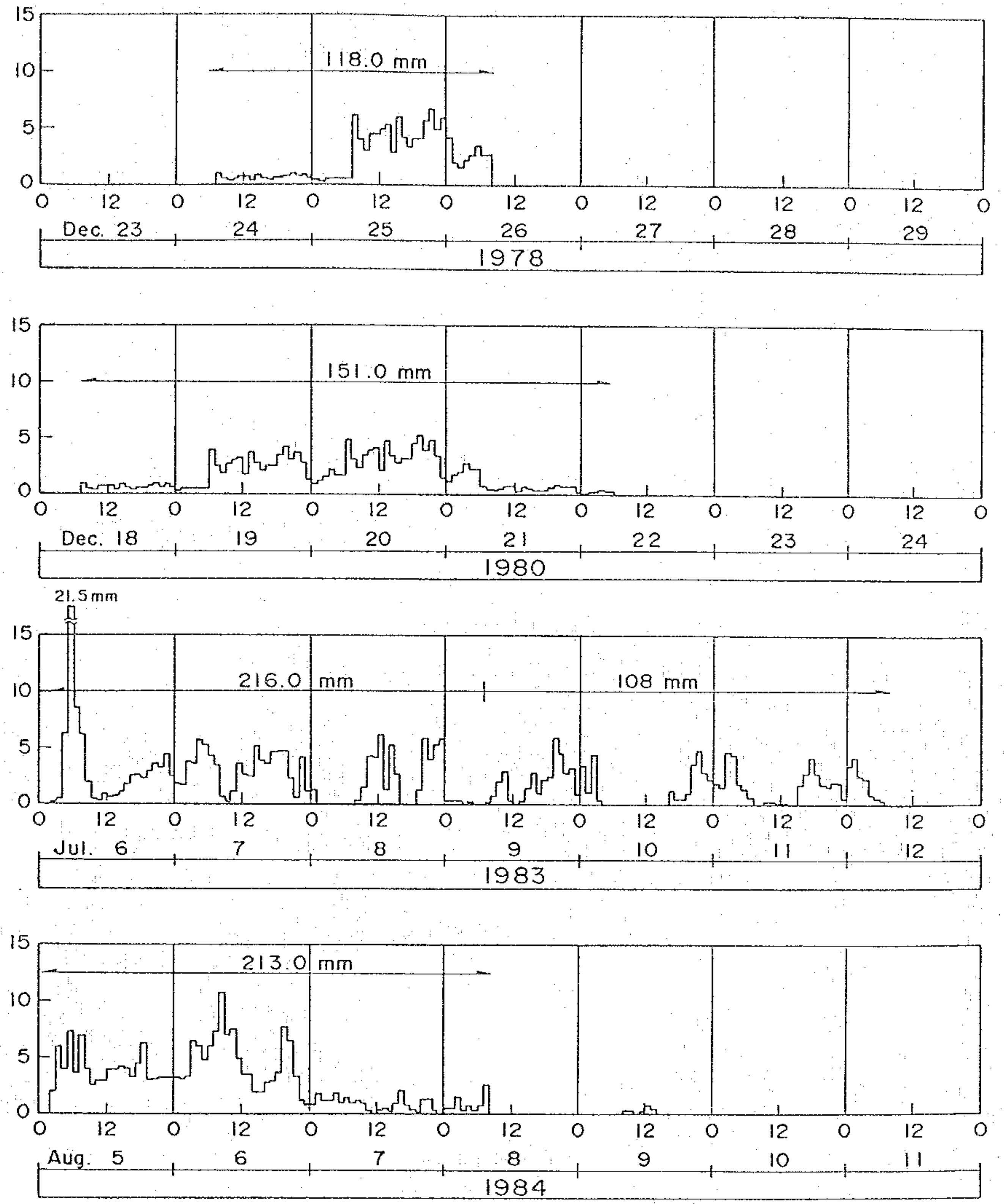


Fig.7 BASIN MEAN HOURLY RAINFALL DISTRIBUTION

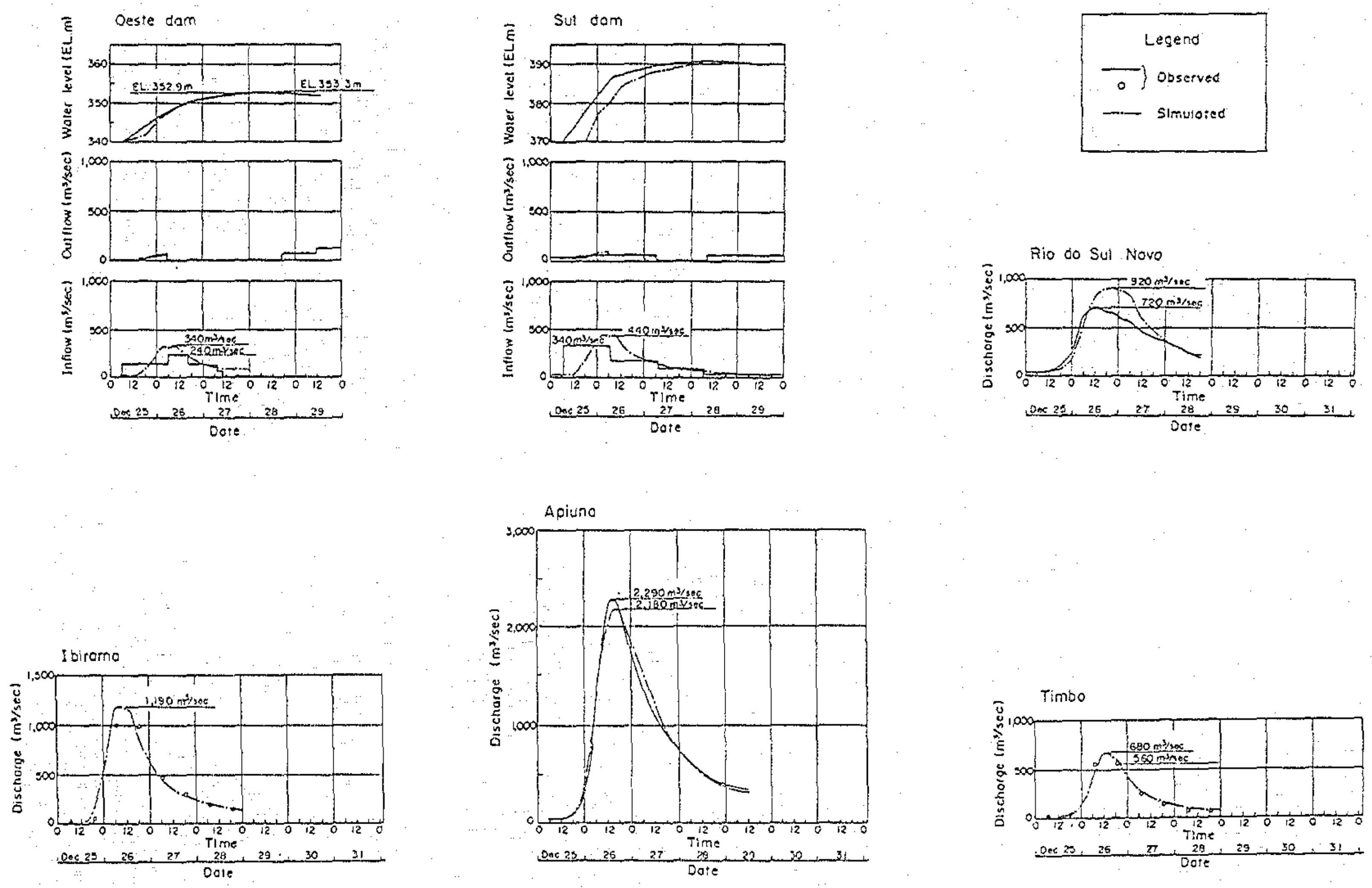


Fig.8 OBSERVED AND SIMULATED FLOOD HYDROGRAPHS (1/8) DEC.1978

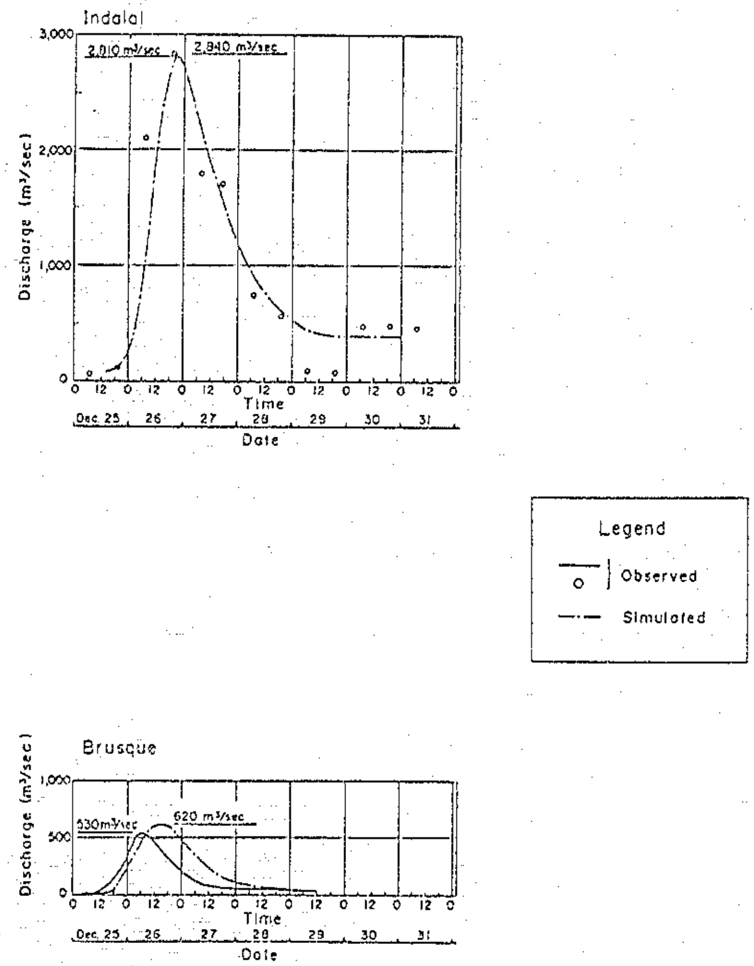


Fig.8 OBSERVED AND SIMULATED FLOOD HYDROGRAPHS (2/8) DEC.1978

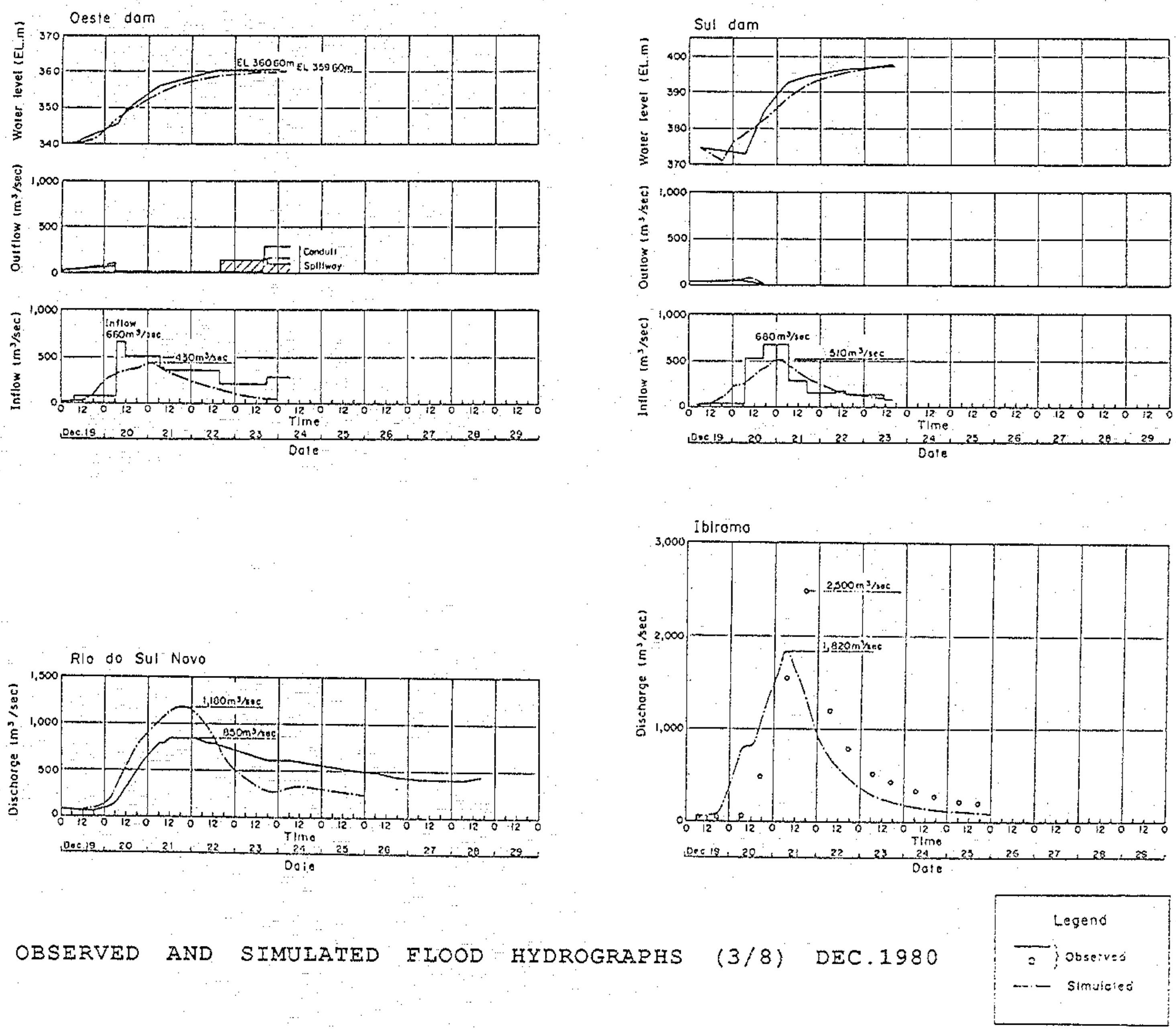


Fig.8 OBSERVED AND SIMULATED FLOOD HYDROGRAPHS (3/8) DEC.1980

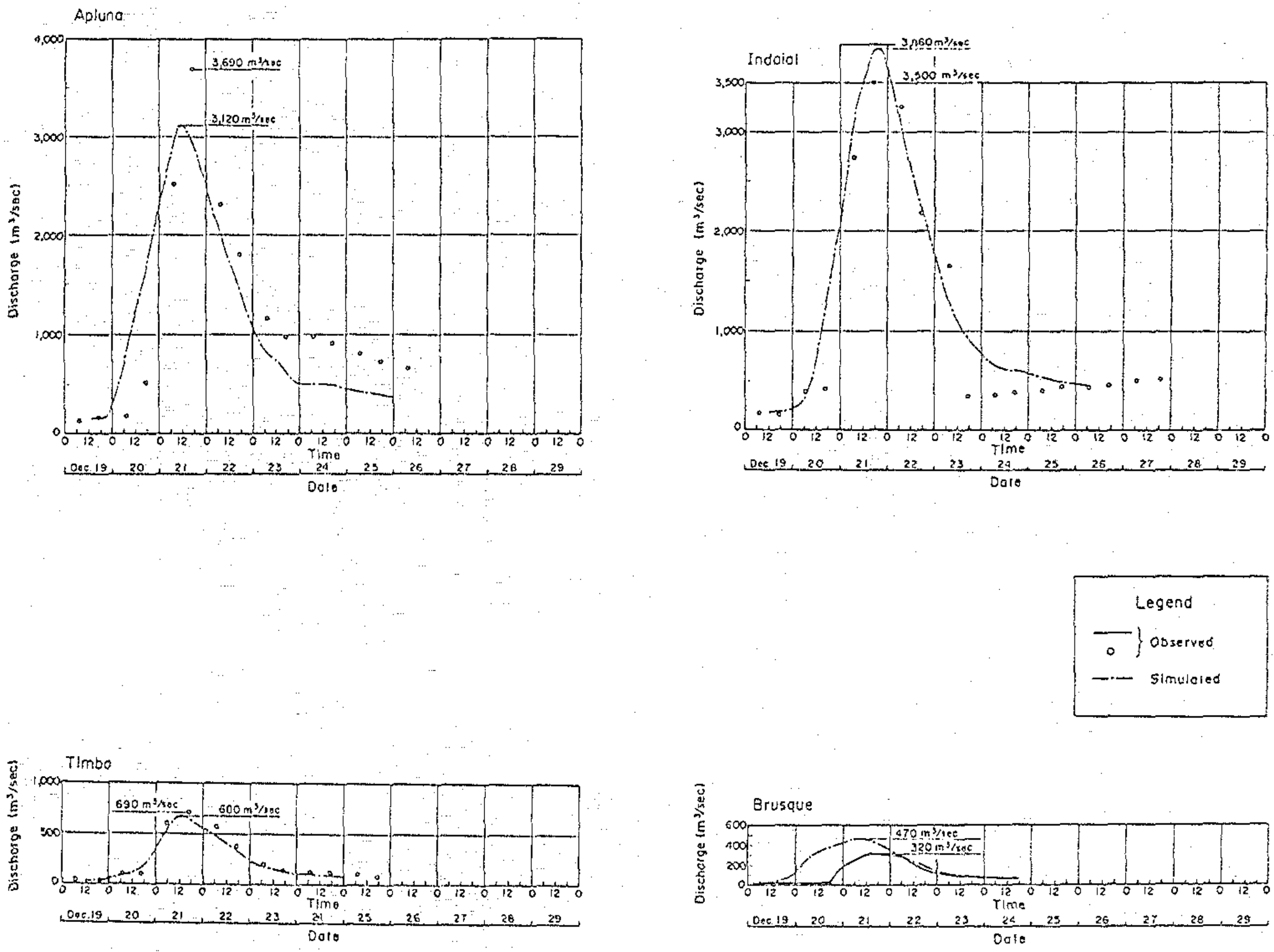


Fig.8 OBSERVED AND SIMULATED FLOOD HYDROGRAPHS (4/8) DEC.1980

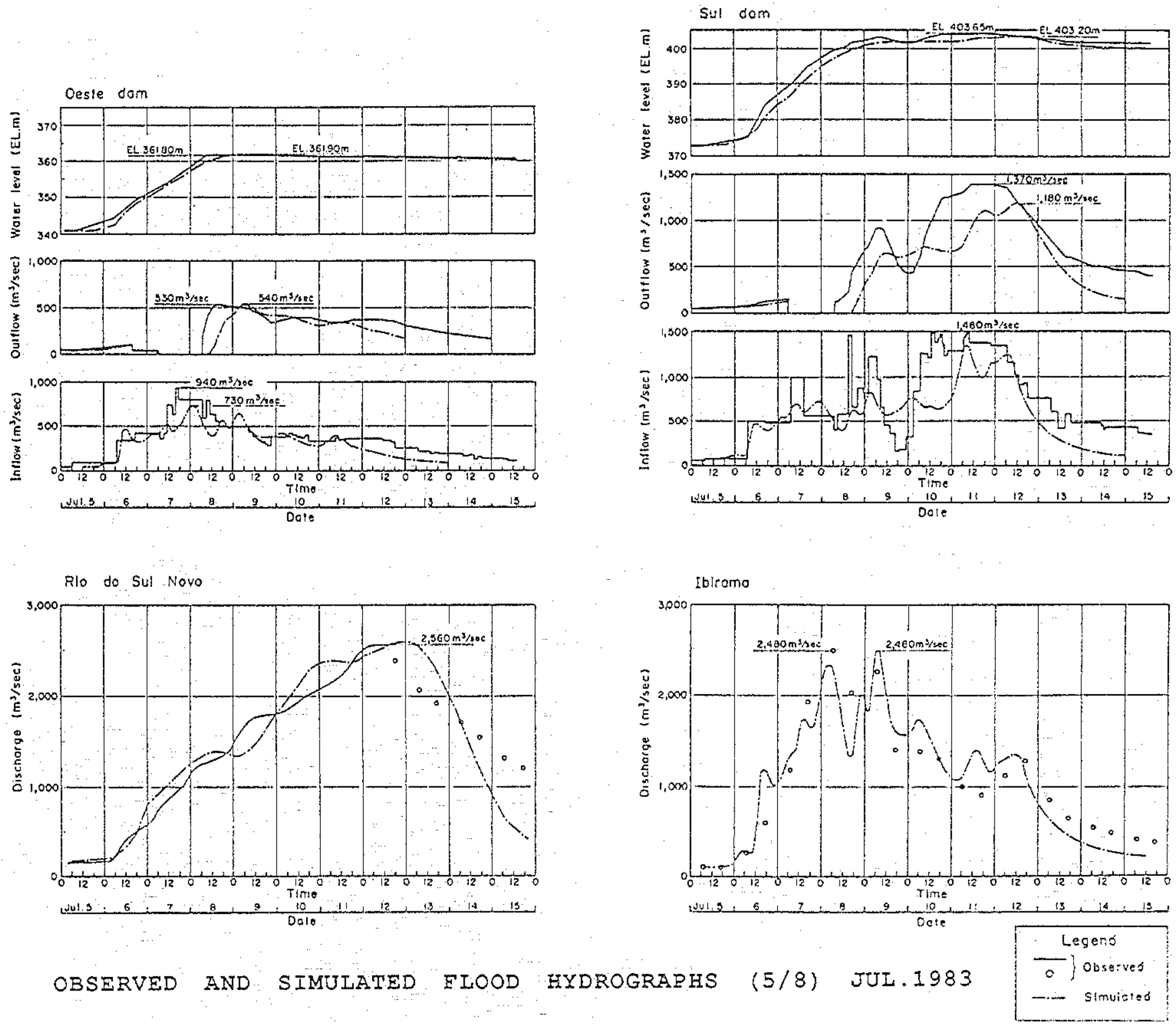


Fig.8 OBSERVED AND SIMULATED FLOOD HYDROGRAPHS (5/8) JUL.1983

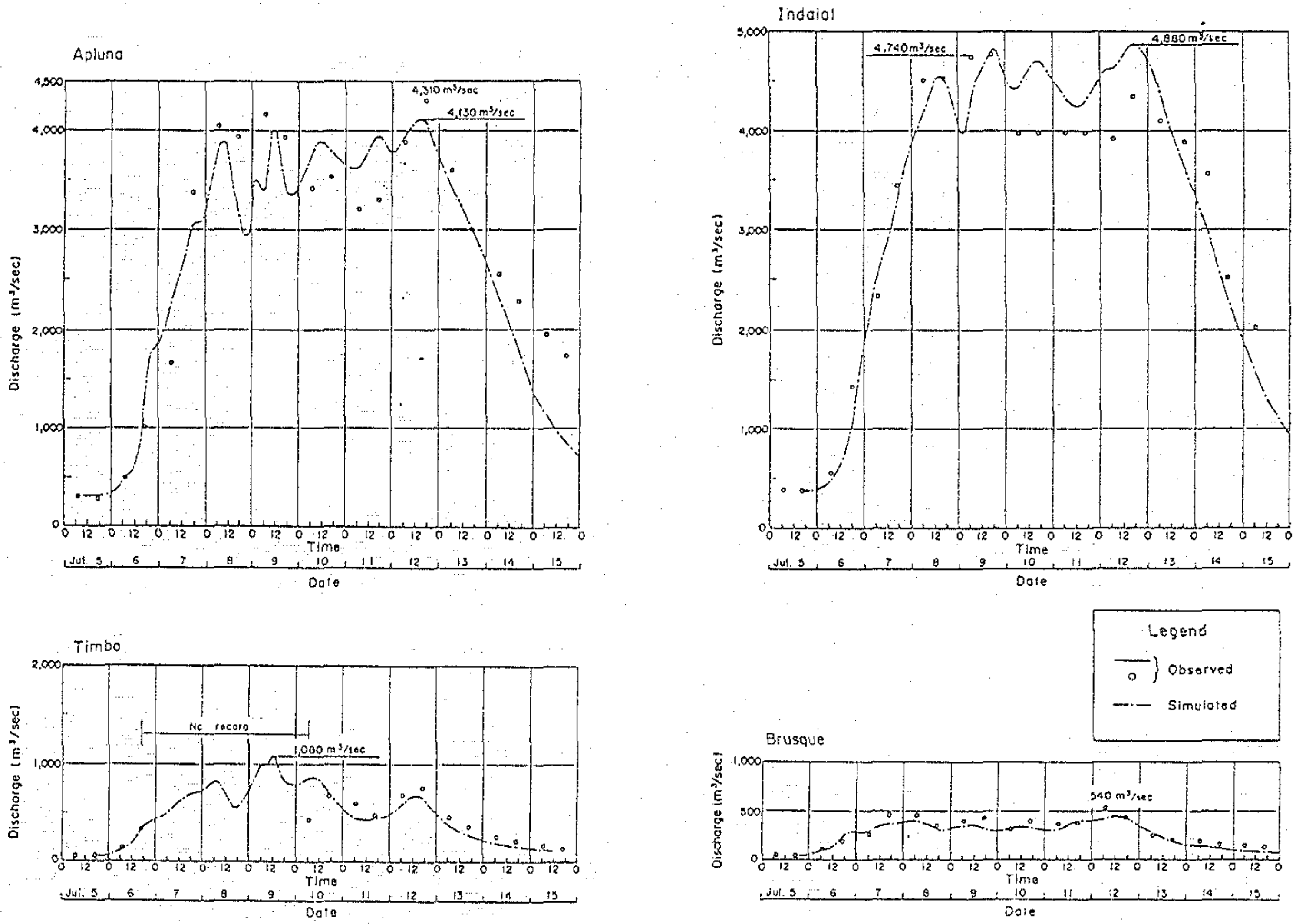


Fig.8 OBSERVED AND SIMULATED FLOOD HYDROGRAPHS (6/8) JUL.1983

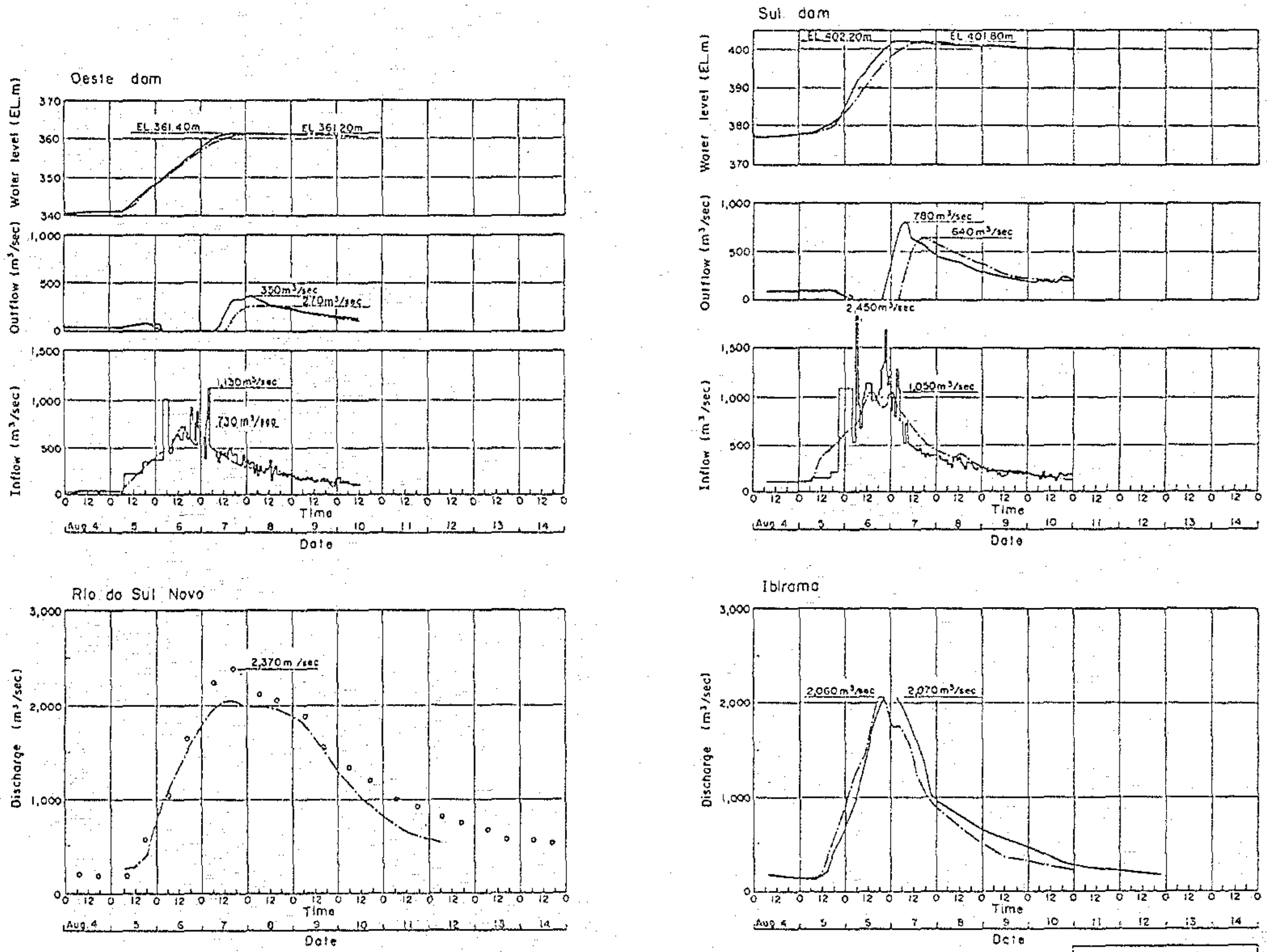


Fig.8 OBSERVED AND SIMULATED FLOOD HYDROGRAPHS (7/8) AUG.1984

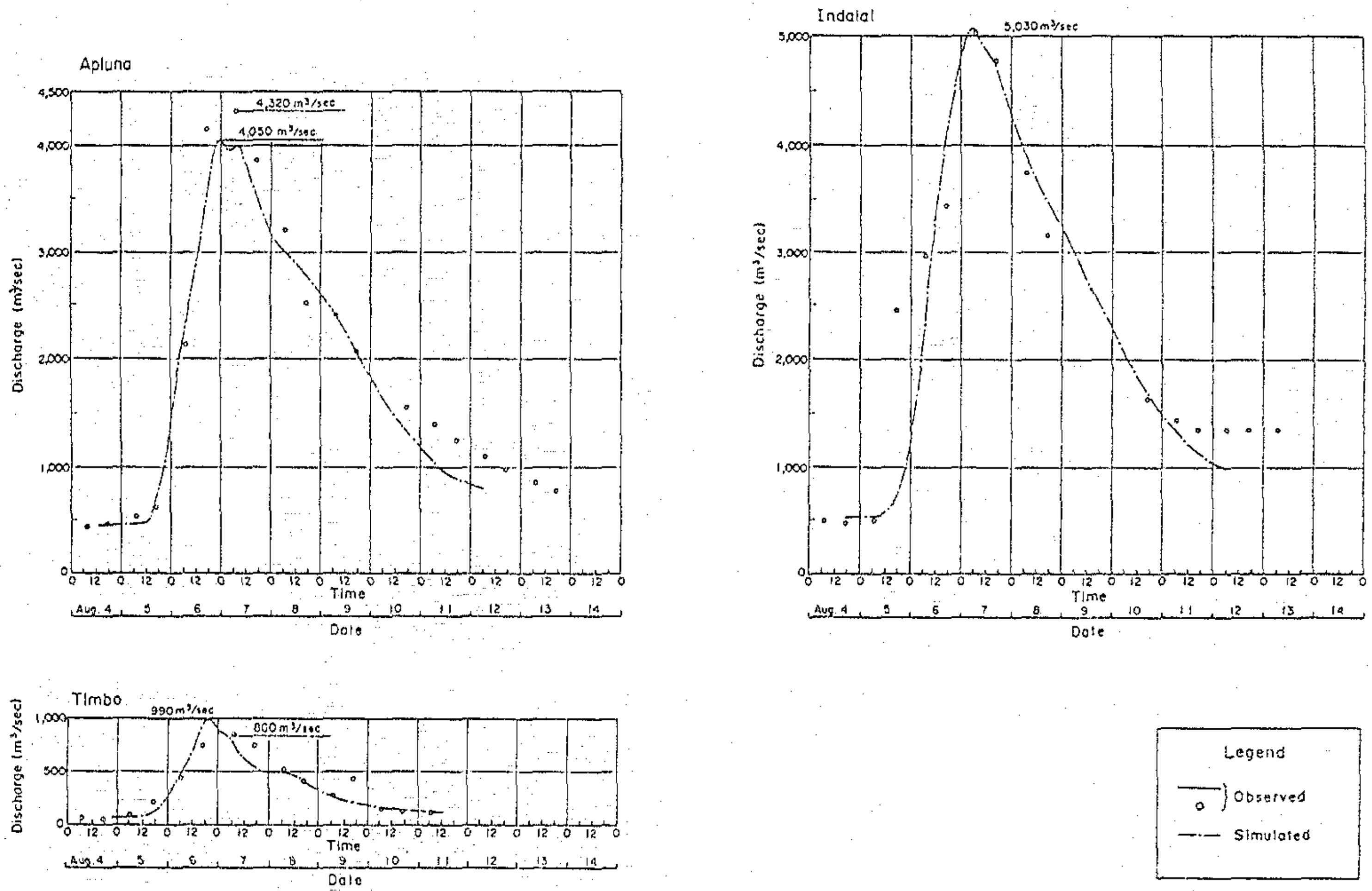


Fig.8 OBSERVED AND SIMULATED FLOOD HYDROGRAPHS (8/8) AUG.1984

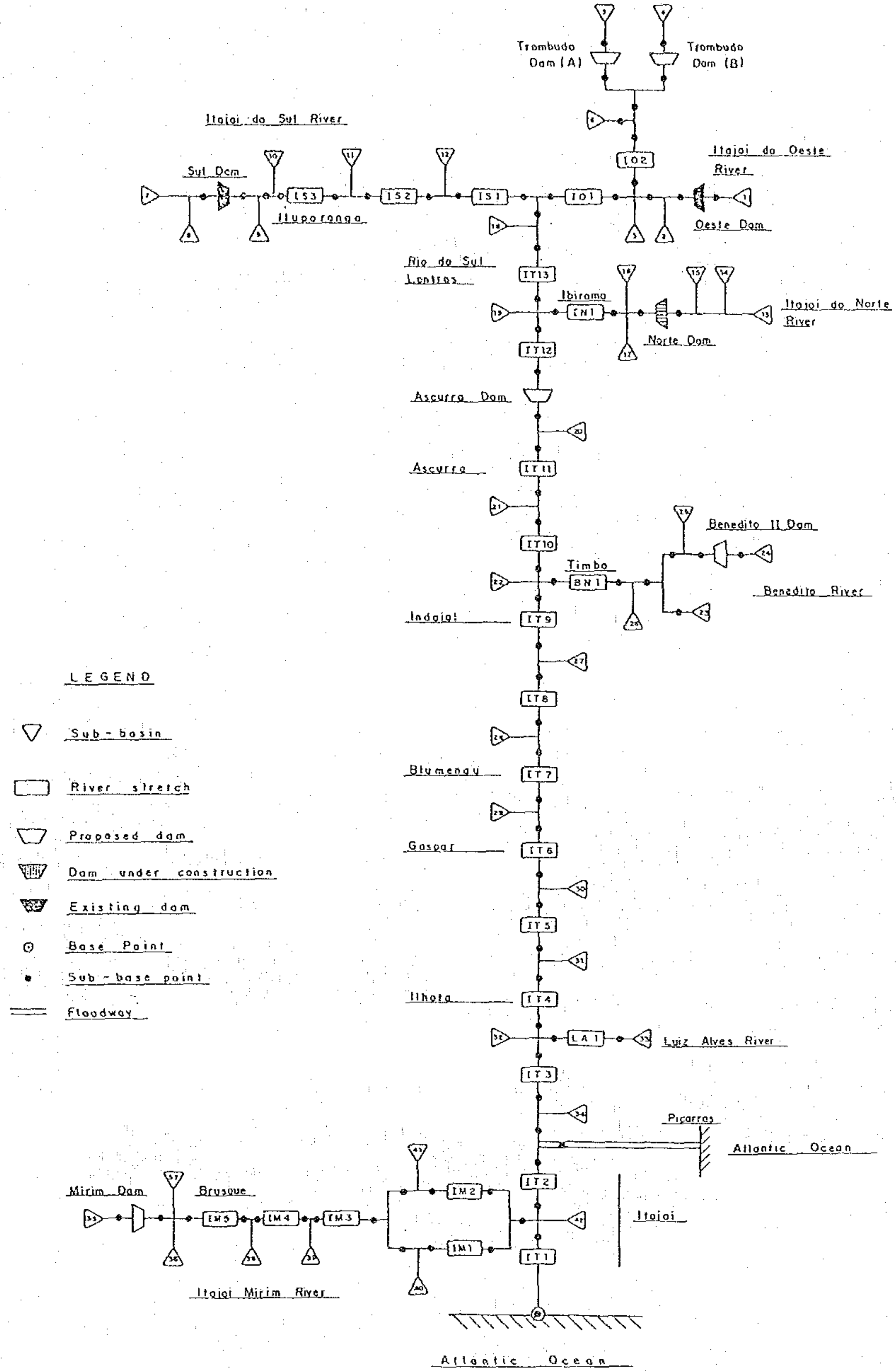


Fig.9 RIVER SYSTEM FOR FLOOD ROUTING

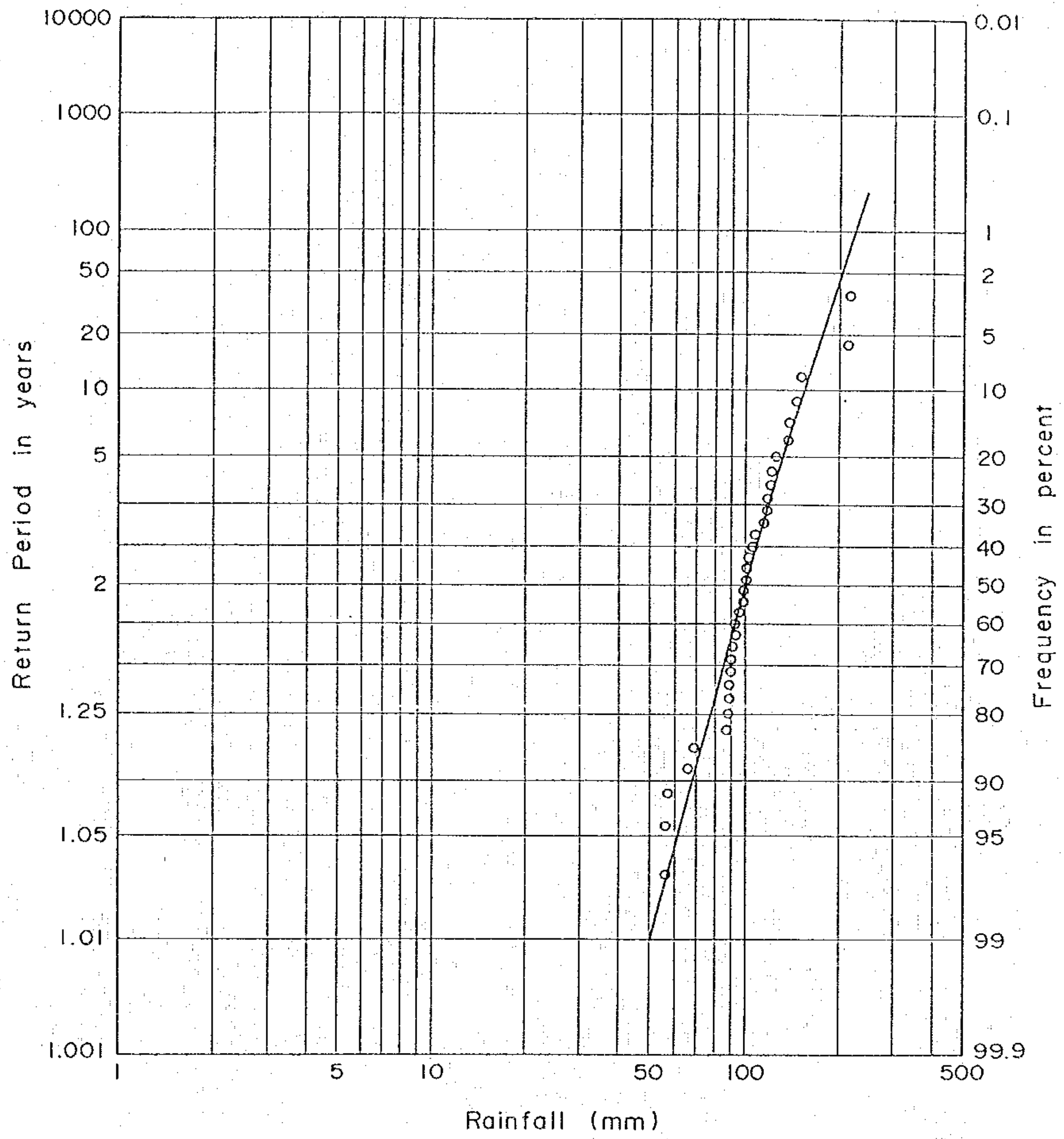


Fig.10 FREQUENCY CURVE OF ANNUAL MAXIMUM 4 DAYS RAINFALL

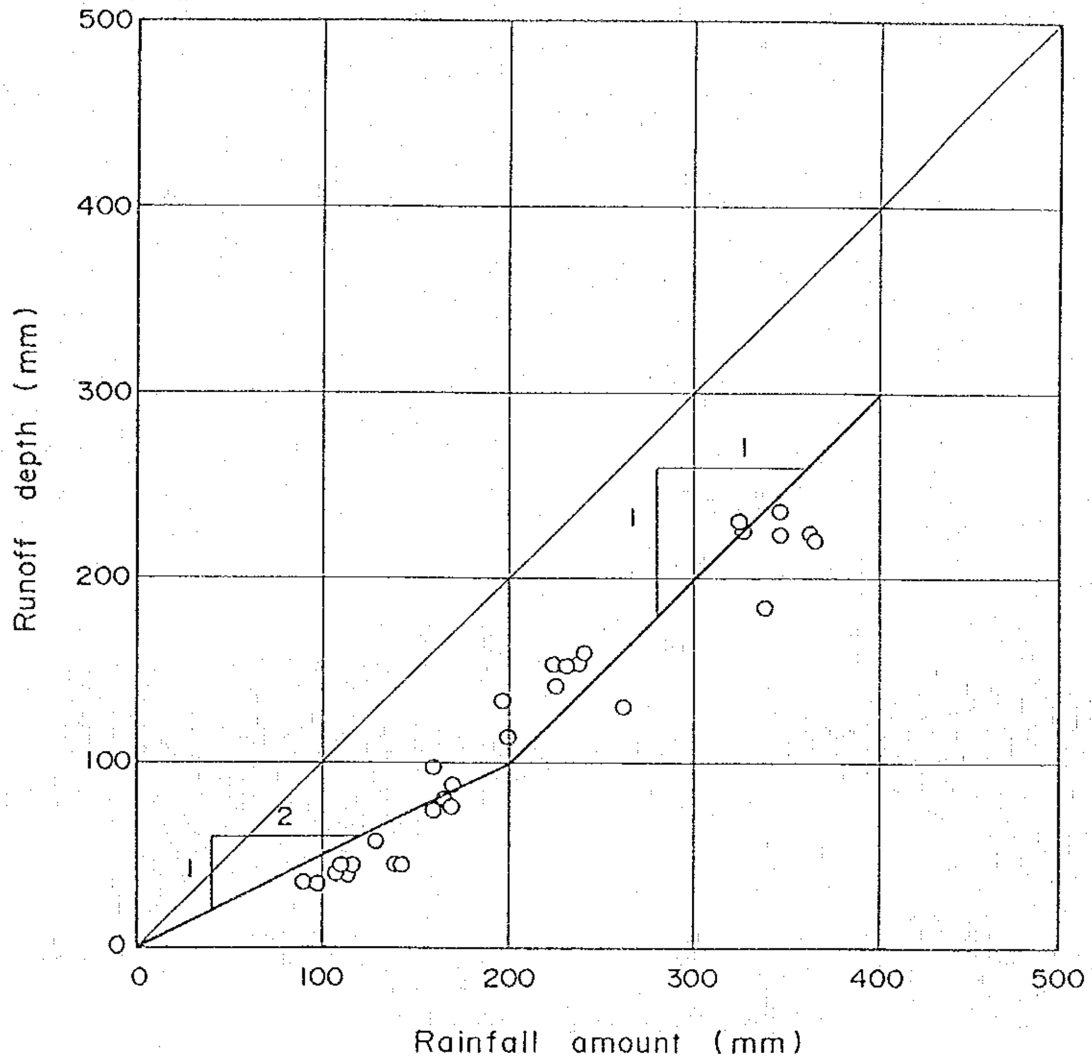


Fig.11 RELATION BETWEEN RAINFALL AMOUNT AND RUNOFF DEPTH