II. PROJECT AREA

2.1 Natural Condition

2.1.1 Topography and river feature

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

The river bed slope of the Itajai becomes remarkably gentle as being 1:10,000 to 1:15,000 at just upstream of the Blumenau city. The Blumenau city is along V-shaped meandered Itajai river stretch at about 70 km upstream of the river mouth and houses have been densely built up to both river banks. The river width is about 150 m and its depth is 15 m. Major tributaries, Itoupava, Velha and Garcia rivers flow into the Itajai river in up and downstream of the V-shaped meandered river stretch.

The Itajai river flows down to eastward meandering gently. The both banks are occupied by flat plain with pasture. The Itajai river passes through the Gaspar city which has been developed closely to the river banks along also V-shaped river stretch and located at about 16 km downstream of the Blumenau city. River width in this stretch is 200 to 300 m and its depth is around 15 to 20 m.

The total length of the project river stretch between about 10 km upstream of the Blumenau city and about 6 km downstream of the Gaspar city is 32 km. The longitudinal profile of the river channel including its width and depth is shown in Fig.1. Present bankful flow capacity in the project river stretch calculated by non-uniform steady flow using the river cross sections with an interval of 300 m is shown in Fig.2. This figure shows that bankful flow capacity in the project stretch varies from 2,000 to 5,000 m^3/sec. The river channel at the Gaspar and Blumenau stretches is so small as being 2,000 to 3,000 m^3/sec which corresponds only to 2 to 5 year probable flood..

2.1.2 Meteo-hydrology

According to the monthly mean meteorological records at Blumenau city which locates in the project area, climatical conditions in the Blumenau-Gaspar river stretch are stated as follows;

Annual mean temperature is 20.0°C and the variation of air temperature in a year ranges from 15.5°C in July in 24.5°C in January.

Annual mean rainfall at Blumenau for the period from 1944 to 1986 is 1,542 mm ranging from 919 mm in 1968 to 2,534 mm in 1983.

Mean annual evaporation amount is 544 mm which is corresponding to the evaporation rate of 1.5 mm/day. The monthly evaporation amount ranges from 31 mm to 61 mm which are corresponding to the evaporation rate of 1.0 mm/day and 2.0 mm/day respectively.

Annual mean relative humidity is 84.2%, and monthly mean relative humidity ranges between 81% in December and 87.2% in June and the variation in a year is rather small.

Annual mean discharge in the Itajai river at Indaial which locates in the Itajai river at 5 km upstream from Blumenau city is 286 m^3/sec ranging from 137 m^3/sec in April to 423 m^3/sec in August. Based on the monthly mean discharge for a period from 1935 to 1966 at Garcia water level gauging station in the Garcia river, annual mean discharge is 3.4 m^3/sec. Comparing the catchment area of tributaries with that of 127 km^2 at Garcia water level gauging station, annual mean discharges in the tributaries flowing into the Itajai river through Blumenau city, namely, Garcia (157 km^2), Velha (56 km^2) and Itoupava (93 km^2) rivers are estimated at 4.2 m^3/sec, 1.5 m^3/sec and 2.5 m^3/sec respectively.

2.1.3 Geology

The geology in and around the project area comprises mainly the Recent alluvial deposits, the Proterozoic ankymetamorphic sand stones accompanied with the conglomerates, and the Archaeozoic gneisses. The alluvial deposits consist of mainly cleyey soils and fine sands, depth of which ranges from 12 m to 31 m or deeper and which have a tendency to become deeper toward the downstream in the project area. The Paleozoic rocks are completely weathered superficially at most 5 m deep from the ground surface, on the hill slopes which surround the alluvial plain and form the residual soils.

Major structures such as bridges, pump stations, etc., proposed along the Itajai main river and nearby the confluences with three tributaries, Garcia, Velha, and Itoupava rivers are planned to be founded principally on the base rocks , which are distributed approximately 12 m to 24 m deep in the Blumenau and its vicinities. While the structures such as regulating ponds and their related structures and pump stations proposed in the vicinities of the same three tributaries as above are to be founded on the firm layers or base rocks which will be developed at around 10 m deep or less beneath the ground surface.

The cut slopes which will be formed in the ultra-soft deposits distributed sporadically along the proposed flood diversion channel alignment in the Gaspar city, are to be gentler than those in the other subsoil conditions to secure their long term slope stability.

The earth materials for the levee embankment are obtainable chiefly from the residual soils which are developed on the Paleozoic rocks forming the low hills along the main river banks. The quality of those earth materials is generally thought to be suitable for the levee embankment because they have low permeability of approximately 1×10^{-6} cm/s, relatively high shear strength of 0.7 kg/cm^2 of cohesion and 23 degree of internal friction angle, and low compressibility, although those have relatively higher natural moisture contents which may require some moisture control during construction. The excavated earth materials from the river channel widening could be used for minor filling in the locally low elevation along the river stretch.

2.2 Land Use

2.2.1 Present Land Use

The study area, two municipalities of Blumenau and Gaspar, of 870 km^2 is divided into urban area of 174 km^2 or 20% of the total area and rural area of 696 km^2 or 80%. The probable inundation area of 69 km^2 is divided into urban area of 42 km^2 or 60% of the total area and rural area of 27 km^2 or 40% as well. In this way, most of the probable inundation area is occupied by urban area, so its character is identified as an urban characteristic. The land use of 174 km^2 in the urban area within the study area is classified as follows: residential use with an area of 8,627 ha or 50% of the total urban area; industrial use, 1,038 ha or 6%; commercial use, 941 ha or 5%; green space, 6,270 ha or 36%; and not utilized area, 554 ha or 3%.

The land use map in the probable inundation area was formulated on the mesh of 200 m x 200 m on the basis of the aforesaid land use information. Fig.3 shows the present land use in the probable inundation area. Present land use in the area is classified as shown in Table 1. It is divided into 14 blocks, which are formulated along the Itajai river and its tributaries. The total lands in the probable inundation area are used as follows: residential use with an area of 2,508 ha or 36.5% of the total area; industrial use, 369 ha or 5.4%; commercial use, 599 ha or 8.7%; paddy field, 950 ha or 13.8%; crop land, 362 ha or 5.3%; pasture land, 485 ha or 7.1%; green space, 993 ha or 14.5%; and not utilized area, 594 ha or 8.7%.

2.2.2 Land Use Plan

Population and regional economy in the study area within the Itajai river basin is expected to increase at comparatively high speed, although the pace is lower than before, as shown in the next table (refer to section 2.3).

	Average annual growth rate (%)		
	1970-1980	1980-2000	2000-2020
Urban population	5.8	3.5	1.9
Regional economy	13.1	5.5	4.0

Accordingly, the urban population in 2020 becomes about 2.9 times of urban population in 1980 and regional economy 6.4 times. In order to support this growth, the urban area would have to be improved so much by the year 2020. Blumenau, in particular, has no vast plains in its territory, so existing urban area should be improved to utilize its limited land at high degree. Even if the high improvement is brought about, the urbanization could not help expanding to the hinterland of the existing urban area. Then, some of this future population will be absorbed in expanded urban areas.

Of the total urban population of 460 thousand in 2020, 413 thousand or 90% will be absorbed in the existing urban areas. Population of 41 thousand have to be absorbed in newly developed residential areas outside of the existing urban areas. The new residential area would amount to 1.5 thousand ha. As a result, built-up areas would increase from 10.5 thousand ha in 1986 to 12.5 thousand ha in 2020, so its increment becomes 2.0 thousand ha. The newly developed areas will be settled in the hinterlands of the existing urban areas over 5 km from the center of Blumenau. They are free from flood disaster because of their altitude. They would spread along the Itoupava river (or SC-474) and along BR-470 in hilly parts in Blumenau as the municipal government intends.

2.3 Socio-Economy

2.3.1 General

The population in probable inundation area lies across the two municipalities of Blumenau and Gaspar. It covers the municipal area of approximately 69 km^2, comprising 29 km^2 of Blumenau municipality and 40 km^2 of Gaspar municipality. One part of the area in Blumenau lies in an urban area, and the other part in Gaspar spread over both urban and rural areas.

In the study area, two municipalities of Blumenau and Gaspar occupies 867 km^2, i.e., 531 km^2 in Blumenau and 336 km^2 in Gaspar. Both municipalities are divided into urban areas and rural areas. An urban area is further divided into a "bairro" (city ward). Blumenau has 30 bairros and Gaspar 11 bairros. Bairros do not have any autonomous administration. They have existed only in customary communities.

The study area within the Itajai river basin is smaller than the study area mentioned above, which is connected to the master plan study. The reason is that the municipality of Blumenau is physically divided into 2 parts by the watershed of the Moema mountain range. Although most of Blumenau exists in the Itajai river basin, some parts of rural areas and bairro Vila Itoupava, a part of urban area, are located outside of the basin. Of the total area of Blumenau, 410 km^2 is included in the basin, so the study area within the basin comes into 746 km^2.

2.3.2 Population

According to the 1980 census by IBGE, the study area had a population of 182,864. The population increased by 101,180 as compared to 1960 census. During the 60's, the average annual growth rate was recorded at 3.8%. In the 70's, however, it was accelerated to 4.4%, which was bigger than the basin's growth rate of 2.08%. The population in probable inundation area in 1980 was estimated at 65,500. This corresponds to about 36% of that of the study area, despite the fact that the project area occupied only 8% of the study area.

Population density in the study area was 211 persons/km^2 in 1980, which is much greater than that of the basin of 4.4 persons/km^2. In probable inundation area, density of 949 persons/km^2 was recorded. This is because most of the area lies in urban areas of both municipalities.

The urban population of the study area reached to 159,726 in 1980, which accounted for 87.3% of the total population. That of the probable inundation area was 63,253 in the same year. It accounted for about 97% of the urban population of 65,500 and also for about 40% of urban population of the study area. This means that the probable inundation area is quite urbanized. Urban population in Blumenau has continuously increased at 6.1% of average annual growth rate during 60's and at 5.4% during 70's. In Gaspar, urban population increased at extremely high speed of 11.9% annually during 70's, although its absolute number of increment was comparatively small. The urban population in Gaspar might be influenced by the urban agglomeration of Blumenau.

The number of gainful workers registered at 84,130 in 1980. Of this total, 46,843 or 55% worked in the industrial sector. Manufacturing sub-sector especially absorbed the largest number of 40,566, which accounted for 48.2% of the total. The number in the industrial sector has grown at 9.0% annually during the 70's. The tertiary sector had 33,590 in 1980, the second big share among three sectors, accounting for 39.9% of the total. It has grown at 6.3% annually during the 70's. On the other hand, the primary sector occupied only 2,357 or 2.8% of the total in 1980. It has decreased at the rate of 4.8% annually during the same period. Accordingly, it is said that the study area has industrialized at a quite high speed during the 70's.

A population in the study area in 2020 grows to 484 thousand, or 2.6 times of the population in 1980 of 182,864. A population in the study area within the basin in 2020 grows to 478 thousand, or 2.7 times of the population in 1980 or 178,124, as well. The population of 478 thousand is divided into two municipal population as follows: 422 thousand or 88.4% in Blumenau and 55 thousand or 11.6% in Gaspar. The urban population in the study area within the basin in 2020 accounts for 96% of the total population, although the urban population accounted for 89% in 1980. As a result, the total population and the urban population in the study area within the basin grows at 2.5% and 2.7% of average annual growth rate from 1980 to 2020, respectively. On the contrary, the rural population decreased at the average annual rate of 0.3% for the same period of 40 years.

2.3.3 Economic profile

The study area is identified as an industrialized district in the basin as well as in the state. Corresponding to the industrialization since 70's, commercial and services industry in the study area has also played an important role as the marketing base in the basin. On the contrary, the primary sector has correspondingly declined in the study area. The total product has actually increased at a quite high growth rate. Accordingly, the living standard of inhabitants would be improved in proportion to the economic growth.

(1) Primary sector

The primary sector is generally divided into five sub-sectors: crop production, livestock production, fishery, forestry and rural industry. Since the study area has not had any inland fishponds as well as not bordered upon the seashore, the fishery sub-sector does not exist there. The total production of the four sub-sectors amounted to Cr$467 million in 1980 at current prices, accounting for only 3.5% of the basin's total.

The main crops cultivated in the study area are rice, cassava, sugar-cane and maize in order of production value. Rice is cultivated with the area of 2,300 ha in 1980 mainly in the flat low land along the river courses. The production was 8,600 tons, which shared about 8.2% of the basin. The rice production amounted to Cr$81 million at current prices, accounting for 7.6% of the basin. The production of other main crops such as cassava, sugar-cane and maize aggregated 13,800 tons, 18,800 tons and 2,200 tons, respectively. The amount of their production reached Cr$64 million, Cr$29 million and Cr$4 million, respectively. The harvested areas of sugar-cane are located outside of the project area. On the other hand, rice fields spread over the project area along the Itajai river and its tributaries.

The important livestock and its products in the study area are milk, egg and pig in order of production value. The amount of milk production attained to Cr$136 million, accounting for 20.8% of the basin's production.

The forestry production in the study area shared the comparatively important role in the basin. Production of firewood was 176 thousand m^3 from natural forest and one thousand m^3 from reforested area. It amounted to Cr$28 million and Cr$0.7 million accounting for 14.8% and 37.6% of the basin, respectively. Timber from reforested area recorded the high share of 16.6%.

The main products of rural industry in the study area were custard, cheese and cassava-related in order of production value. They accounted for 29.7%, 13.0% and 8.9%, respectively. Although production of spirit sugar cane, butter and rice-related occupied a big share in the basin, its amount is small as compared with other agricultural products.

(2) Secondary sector

The secondary sector is usually divided into four sub-sectors. In the study area, the manufacturing sub-sector is the most descriptive and representative industry not only in the secondary sector but in the whole industrial structure. According to the industrial census in 1980, the manufacturing and mining sub-sectors recorded 684 establishments, 38,067 employees and a production value of Cr$69,246 million at current prices, accounting for 25.3%, 44.9% and 59.4% of the corresponding figure in the basin.

The main industrial types in the study area are (1) textile and (2) clothing, shoes and woven articles on the basis of production value. They account for 46.0% and 27.3% of the total production of the manufacturing and mining sub-sectors in the study area, respectively. In terms of employees, they absorb 42.7% and 23.3%, respectively. With regard to the number of establishments, however, they occupy only 11.5% and 9.5%, respectively. Accordingly, the production value per an establishment of these types achieves the sizeable amounts of Cr$505.5 million and Cr$248.5 million respectively, which succeeds the chemistry type. The number of employee per an establishment comes into the great figures of 258.2 and 116.8 respectively, which get the top-notch position in the study area.

In terms of production value, the following industrial types succeed the two types mentioned above in the study area: chemistry (4.7%); food products (4.4%); and metallurgy (3.5%); and paper (2.2%). Figures in parentheses are the rates of production value of each industrial type to that of the whole types in the study area.

The production of the manufacturing and mining sub-sectors has grown at the average annual real growth rate of 37.9% during the first 5 years in 70's and at 16.3% during the second 5 years. During the second five years, the economic growth moderated as compared with that during the first five years, but it was still high. The remarkable industrial types with regard to economic growth during the last decade were (1) clothing, shoes and woven articles; (2) textile; (3) chemistry; (4) electric and communication products; (5) plastic product; (6) machinery; (7) mining; and (8) paper.

(3) Tertiary sector

The tertiary sector consisting of two sub-sectors of commerce and services is characterized as a large number of medium and small establishments in general. In 1980, the annual sales amount of commercial sub-sector in the study area was Cr$2,443 million and that of service's sub-sector was Cr$25,682 million at current prices. Since the number of establishment of these two sub-sectors registered 1,195 and 2,840, sales amount per establishment was Cr$18.8 million and Cr$9.0 million, respectively. An average production value of manufacturing and mining sub-sectors was Cr$101.2 million, so that the tertiary sector is recognized to be smaller than that of the industrial sector. Since the number of employee of the two sub-sectors registered at 8,665 and 15,761, sales amount per an employee was Cr$2.6 million and Cr$1.6 million, respectively.

The service's sub-sector occupied 52% of the basin's sales amount in 1980. Industrial activities of this sector is highly concentrated on the study area. The share of the commercial sub-sector's sales amount in the study area out of that in the basin accounted for 34.4%. This was because the sales amount of wholesale sector was comparatively small. In the basin, in terms of sales amount of wholesale, Itajai municipality is ahead of Blumenau. Itajai, having a harbor and being located along the national freeway of BR-101, plays an important part as a base of merchandise distribution in the Sul grand-region as well as in the basin. From this point of view, the wholesale in Blumenau would cover only the basin and its surroundings.

The sales amount of these sub-sectors has grown up at 37.7% annually during the first half of the decade in 70's and decreased by 3.1% during the second half. Although the growth rate during the last decade was 15.5%, it was lower than that of the industrial sector of 26.6%.

2.3.4 Gross regional domestic product

The record of GRDP in the study area is not available. Therefore, GRDP is estimated on the basis of the production value of each economic sector mentioned above. According to this estimation, the primary sector has declined at quite high speed as compared with that of the state. The secondary sector recorded high growth rate of 12.2% annually in the first five years in 70's and of 20.4% in the second five years. The tertiary sector got the more remarkable annual growth rate of 25.0% in the first five years but declined at 4.4% in the second five years. As a result, the secondary sector had an extremely big share of 74.1% in 1980, in spite of the fact that its share went down to 44.3% in 1975 from 51.6% in 1970. Although the tertiary sector recorded also rapid growth and got share of 51.6% in 1975, it paced down and decreased its share to 25.2% in 1980. The primary sector continuously lost its percentage share from 11.4% in 1970 to 0.7% in 1980.

Per capita GRDP in the study area was Cr$261 thousand at current prices in 1980. It was about 2.4 times larger than both per capita GDP and GRDP of the state of Cr$110 thousand. In 1970, the disparity was not so big, i.e., almost 1.7 times of the state and 1.5 times of the country. This was because the economic growth in the study area was achieved higher than those in the state and in the country. From the point of view of living standard, people in the study area might improve their living style and might enjoy a higher cultural life than before.

GRDP in the study area are estimated to reach Cr$189 billion in the year 2000 and Cz$413 billion in 2020 at 1987 constant prices corresponding to 2.9 times in 2000 and 6.4 times in 2020 bigger than GRDP in 1980. GRDP in 1980 at 1987 constant price is estimated based on implicit deflater (1,352 between 1980 and 1987) and denomination (Cr$1,000=Cz$1). Per capita GRDP in the study area, which is calculated by GRDP and the aforesaid population projection, will grow from Cz$352 thousand in 1980 to Cz$553 thousand in 2000 and to Cz$835 thousand in 2020. These figures correspond to 1.6 times in 2000 as large as per capita GRDP in 1980 of Cz$352 thousand at 1987 constant prices and 2.4 times in 2020. This growth of per capita seems to be somewhat moderate as compared with the growth of the entire state. This is because population grows faster than the economic production. As a result, the difference between per capita GRDPs reduces from 2.4 times in 1980 which is the ratio of the per capita GRDP of the study area (Cz$352 thousand) to the one of the state area (Cz$149 thousand), to 2.0 times (Cz$835 thousand to Cz$486 thousand) in 2020.

2.3.5 Transportation

As of 1986, the existing paved road network in the study area sums up to 149 km, which comprised national road (27 km), state road (88 km) and municipal road (34 km). The federal road is BR-470, which lies across the study area from east to west along the Itajai river. The state installed following four lines in the study area: SC-411 connecting Gaspar to Brusque; SC-418, Blumenau to Pomerode; SC-470, Blumenau to Ilhota; and SC-474, Blumenau to Massaranduba.

2.4 Flood Problem and Flood Damage

2.4.1 Past large scale of flood and its rainfall characteristics

Large scale of floods occurred in the whole Itajai river basin in July 1983 and August 1984 after the construction of the Sul and Oeste dams, and those flood caused large flood damage in Blumenau-Gaspar river stretch. Rainfall characteristics and flooding condition in 1983 and 1984 floods are stated as follows;

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/hr at Dr. Pedorinho in the Benedito river basin and the basin mean rainfall amounts in 1, 4, and 7 days are estimated to be 65 mm, 216 mm and 324 mm respectively. Flood peak discharges at the major water level gauging stations upstream from Blumenau city 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 and 4,800 m^3/sec at Indaial. Floods occurred in the upstream from Blumenau city flowed into Blumenau and Gaspar cities and caused the inundation in the both cities. According to the water level data at Adolfo Konder bridge in Blumenau city, the maximum water level was recorded at 15.34 El.m and the maximum inundation depth reached to around 6 m in Zona Central in Blumenau city. The inundation depth at Gaspar city was between 0.5 m and 1.0 m on the right side bank and a part of left side bank in the downstream from confluence of Seltao river. Inundation area was 39 km^2 in Blumenau and Gaspar cities and its duration at the flood time in 1983 was averagely 10 days in both cities.

In August 1984, the rain started from the morning on Aug. 5th to Aug. 8th and the maximum hourly rainfall was 25 mm/hr 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. The maximum flood water level at Adolfo Konder bridge was 15.46 El.m due to 1984 flood and the inundation depth in Blumenau and Gaspar cities was same magnitude as in 1983 flood. However, duration of inundation was averagely 5 days because of shorter rain storm duration as mentioned in the above.

2.4.2 Flood flow analysis

(1) Objectives

The hydrological study on the master planning for entire Itajai river basin flood control was concentrated mainly for estimation of probable flood discharge for flood control planning. In the feasibility study for Blumenau-Gaspar river stretch, the following studies are carried out;

- Review of the flood discharge distribution through meteo-hydrological data collection, analyses of these data and examination of the flow capacity of river course in the main Itajai river based on the result of river cross-section survey executed by JICA Team in this stage.

- Flood flow analysis for the proposed drainage network plan in the Blumenau city along the Itajai river and the tributaries flowing into the Itajai river through Blumenau city.

The details of the above studies are stated in the Supporting Report, ANNEX III.

(2) Review of flood discharge distribution

According to the collected additional data including the water level observation, the maximum water level at Blumenau water level gauging station was recorded at 7.22 El.m on May 21st, 1987 after 1984 flood occurred. This water level is estimated to be around 1,200 m^3/sec based on non-uniform flow calculation.

As for the review of the flood discharge distribution for the provisional plan, the flow capacity examination which is one of important factor constructing river channel model was only executed in the feasibility study since large scale floods which exert effect to the preceding flood discharge distribution did not occur in the basin after master planning study.

The examination of flow capacity in Blumenau-Gaspar river stretch was executed by non-uniform flow calculation using the result of river cross sections with 300 m in an interval in order to review the river channel model established in the master plan study. Consequently, it was clarified that the flow capacity of Blumenau-Gaspar river stretch does not change the feature estimated in the master plan stage and therefore it is judged that the river channel model of Blumenau-Gaspar river stretch studied in the master plan study is applicable to this study.

(3) Flood flow analysis for urban drainage plan in Blumenau city

The flood flow analysis was carried out to estimate the design discharge of drainage facilities such as regulating pond, pump and connecting pipe/canal to the existing drainage network in Blumenau city for making the urban drainage plan in Blumenau city area along Blumenau-Gaspar river stretch and tributaries.

In order to grasp the relation between water levels in main stream of Itajai river and tributaries, water level and rainfall gauges were newly installed in the tributary areas by DNOS and their observation were commenced in March 1987. However, floods did not occur during field survey period from March to August in 1987. Therefore, the methods and procedures in flood runoff analysis are adopted taking into account the availability of meteo-hydrological data.

The concept of flood runoff analysis for the urban drainage planning are as follows;

(i) As a runoff model, rational formula is applied to the estimation of probable flood hydrograph and peak discharge from drainage district.

(ii) In order to evaluate the increase of flood discharge due to the urbanization of Blumenau city area, runoff coefficient is examined on the basis of future land use map planned by the Blumenau municipality assuming runoff coefficient of 0.9 in city area, 0.7 in forest area and 0.6 in pasture, unutilized and farm lands. Runoff coefficients in drainage districts based on the preceding assumption are ranging from 0.75 to 0.90.

(iii) As a design duration time of rainfall for regulating pond and pump, 4 days are applied and actual rainfall patterns on July 1983 and August 1984 are adopted in simulation of flood hydrograph. From the obtained flood hydrograph, relation between pump capacity and required volume in regulating pond is examined as shown in Fig.4 assuming that flood water level in the main stream of Itajai river is set at design high water level since high flood water level in Itajai river continues for around 4 days in normal condition and rain storm in Blumenau city is sufficiently considered to occur during high flood water level in Itajai river.

(iv) Probable flood peak discharge estimation by rational formula was carried out incorporating the runoff coefficient in future stage, probable rainfall intensity-duration curve based on the rainfall records from 1935 to 1968 at Blumenau, and concentration time based on topographic data on drainage district. Flood peak discharges from drainage districts with selected return periods are shown in Table 2.

2.4.3 Flood damage

A statement of actual flood damage focuses on characteristics of past large scale of flood occurred in 1983 and 1984. Inundation area caused by 1983 and 1984 floods was about 39 km^2 for both cases consisting of 13 km^2 in Blumenau and 26 km^2 in Gaspar. Inundation area is identified along not only the Itajai river, but also tributaries. Inundation along tributaries are considered to be caused by overflow from these rivers due to high water level of the main river :t the flooding time.

Blumenau has a long history of floods. Water level measured at Adolfo Konder Bridge reached to near 16 m in 1983 and 1984 flood. In central part of Blumenau having an elevation between 10.5 m and 13.5 m, water depth ranged from nearly 6 m to 3 m at the maximum water level. In Gaspar, water depth was between 0.5 m and 1.0 m. This shallow low water depth is caused due to the reason that water overflown from the main river or tributaries extended to the depression areas located widely along the both banks in Gaspar.

Duration of inundation at the flood time in 1983 and 1984 was averagely 10 days and 5 days as a result of interview survey to local people in Blumenau and Gaspar. Duration of inundation depends on ground elevation of the inundation area.

The magnitude of both floods was so large that population affected by inundation in Blumenau-Gaspar stretch was about 94,000.

Actual records of flood damage is broadly composed of damage to private and public sectors. The sector of manufacturing industry in Blumenau and Gaspar was the most seriously damaged field in terms of the amount of direct flood damage since industrial sector has been the major economic activity. About a half of industrial establishments in Blumenau and 40% of total ones in Gaspar was damaged in 1983. The rate of direct damage to yearly value added due to 1983 flood in Blumenau and Gaspar was estimated to be about 3.3% and 8.5% respectively.

Flood damage to public sectors consists of various types of public facilities. As to damageability of road system, long duration of inundation due to consecutive rainfall in 1983 caused the landslip of shoulders of urban and rural streets, whereas damage brought by 1984 flood was characterized by erosion of road foundation and destruction of drainage system. Damage to public utility such as supply system of water and electricity caused a serious social disturbance since stoppage of both utility services extend to 10 days in 1983.

As conducted in flood damage study in Master Plan, simulation of probable flood damage was carried out to enumerate flood damage amount by different scale of flood in Blumenau-Gaspar stretch. Procedures of estimating probable flood damage are as follows;

- Estimation of probable inundation area,
- Economic study of damageable value at present and in the future condition, and
- Simulation of probable flood damage by different scale of flood in four types of flooding occurred in 1978, 1980, 1983 and 1984.

As a result of hydrological simulation, inundation area, depth and its duration due to 1978's and 1980's flood patterns is almost the same as the equivalent results caused by 1984's flood since probable flood peak discharge represents the similar results by return period. Flood pattern in 1983 is characterized by long duration and an extensive size of inundation area where the magnitude of flooding reaches to return period more than 50 years.

Annual mean flood damage is calculated at about Cz$611 million at maximum among the above four flood patterns. Since this amount of flood damage is valued at 1987 development level, it is estimated to be about 0.6% of projected GRDP (Cz$ 90,854 million) in Blumenau and Gaspar in 1987.

The probable flood damage was assessed for four types of flood in 1978, 1980, 1983 and 1984. Among them, the 1984 type of flood demonstrates the maximum amount of probable flood damage in case of 10 year scale of flood which is the design flood to be applied to the provisional flood control plan. The direct flood damage at 1987 development level is projected to be about Cz$ 1,220 million which corresponds to 1.3% of projected GRDP in Blumenau-Gaspar area. Damage to buildings plus their indoor movables belonging to the secondary and tertiary sectors shares about 64% of total direct damage, while crop damage is utterly negligible. Area characteristics of direct flood damage is explained in such that damage to commercial sector and residences are outstanding in the area along Garcia and Velha rivers. Damage to industrial establishments is mostly identified in area along Itoupava river. Direct flood damage amount at 2000 development level is projected to be about Cz$ 4,500 million in Blumenau-Gaspar stretch. The increase of flood damage in future level is caused by the augment of properties' value.

2.5 River Improvement Work

The major cities along the Itajai river suffered from large magnitude of flood in 1983 even after the regulation of flood by existing Sul and Oeste dams. In order to supplement the flood control effect by the existing dams, river improvement plan aiming at lowering the flood water level by about 3 m at the upstream end of the project river stretch by means of mainly widening of the existing river channel was planned in the Itajai river.

In line with this plan, the river improvement work in the Blumenau-Gaspar stretch has been implemented since January 1985. The work is now executed by local contract basis at the river stretches at about 5 km downstream and 5 km to 9 km upstream from Gaspar city respectively where the detailed design and compensation of lands and houses were completed. The work is performed using dredger and common construction equipment. The excavated earth volume by July 1987 is about 3.5 million m^3 which is 13% of the planned volume.

2.6 Existing River Structures and Related Structures along River Stretch

There are no river structures in the project river stretch except a revetment which is provided along about 1.4 km long river bank in the right side of V-shaped meandering stretch of the Blumenau city.

The related structures such as bridge, drainage gate, pumping station and hydro electric power station have been located in the project area as shown in Fig.5. In the project area, 33 bridges cross over the Itajai river and its tributaries. Most of them are concrete type of roadway bridges connecting the national road to local road and local roads themselves. The pumping stations with capacity of 60 lit/s to 130 lit/s to supply the municipal water have been provided along the river stretch in the Blumenau and Gaspar cities. The drainage gate to drain inner water is provided at three sites along the Blumenau river stretch. There is a hydro electric power station with the installed capacity of 6,300 kW in the project Itajai river stretch at about 10 km upstream of the Blumenau city. It has been used as an emergency purpose to supplement of deficit of the electric power in the existing supply network.

III. RIVER IMPROVEMENT PLAN IN BLUMENAU-GASPAR STRETCH

3.1 General

To protect the riparian area along the Blumenau-Gasper river stretch from flood, stage-wise river improvement plan comprising provisional plan,, mid-term plan and long-term plan was worked out in the master plan stage. Among these stage-wise plans, the river improvement plan for the provisional plan was studied in this feasibility stage.

3.2 Principle of River Improvement Plan

3.2.1 Proposed flood discharge distribution

The proposed flood discharge distribution for the provisional plan was established against 10-year probable flood under the following conditions and assumptions;

(1) Flood peak discharge in the upstream reaches is regulated by the existing Sul and Oeste dams and under constructing Norte dam. In this case, present operation method is applied.

(2) The river stretches along urban areas in the upstream from the Blumenau city are improved against 10-year probable flood.

(3) Flood peak discharge with 10-year probable flood from the tributaries flowing through the Blumenau city flows into the Itajai river.

The proposed flood discharge distribution thus established is illustrated in Fig.6.

3.2.2 Principle of river improvement plan

The river improvement plan in the Blumenau-Gaspar stretch for the provisional plan was worked out under the following principle;

(1) Since it is practically impossible to widen the river channel along the Blumenau city, it was contemplated to increase the flow capacity by steepening hydraulic gradient of flood water level and by minimizing rise of flood water level as far as possible, applying the following methods;

   (i) To lower the flood water level at the downstream end of the Blumenau river stretch by means of widening of the river channel in the project stretch.

   (ii) To widen the left river bank along the Blumenau city as far as possible, and

   (iii) To reduce roughness coefficient of the river channel along the Blumenau city by arranging the river bank slope and providing river bank slope protection by means of sodding.

(2) Large scale floods occurred in 1983 and 1984 correspond to 50-year probable flood. To protect the Blumenau city against the same scale floods as those in 1983 and 1984, a concrete parapet wall is provided at the right river bank along the Blumenau city for about 420 m long stretch in the upstream from the confluence with Garcia river, which is locally low elevation. In view of the landscape of

the Blumenau city, height of the concrete parapet will be limited to 1 m.

(3) It is also practically impossible to widen the river channel and to construct high levee in the river stretch along the Gaspar city because many houses have been built up close to the river banks. To protect the Gaspar city from flood and to lower the flood water level in the upstream stretch, a flood diversion channel is provided by connecting with the upstream and downstream ends of the V-shaped meandering Gaspar river stretch.

(4) Levee or filling of the excavated earth material from river channel is provided only at the river bank which is locally low elevation in the project river stretch.

3.3 River Improvement Structural Plan

3.3.1 Design of river improvement structural plan

The river improvement structural plan in the Blumenau-Gaspar stretch was designed based on the topographic maps with a scale of 1:10,000 and contour interval of 1 m and river cross sectional maps with an interval of 300 m, which were surveyed in 1987. The design conditions applied to this structural plan are as follows;

(1) Alignment of the design river channel is set along the existing river channel and widening side of the river channel is determined taking into account the topographic condition and compensation of houses.

(2) Design flood water level is set lower than the elevation of river bank considering especially the elevation of urban river stretch along the Blumenau city.

(3) Design river bed slope is set almost the same as the existing average river bed slope.

(4) Single cross section is applied as the design cross section. The width of the low water channel is decided at 155 m for the downstream of the Gaspar stretch and 140 m for the upstream of the Gaspar stretch.

(5) The flood diversion channel at the Gaspar stretch was designed under the following conditions;

(i) The design flood water level at the Gaspar stretch is lower than the existing river bank, and

(ii) The design flood water level at the existing bridge site at the Gaspar city does not exceed the lowest elevation of the bridge girder.

The designed discharge to be flown down through the proposed flood diversion channel determined under the above conditions is 600 m^3/sec for the long term plan. The width of this low water channel in the provisional plan is 10 m. It was clarified that soft alluvial deposits mainly consisting of clayey soil and fine sand are developed along the proposed flood diversion channel route. Considering this geological situation, a berm with 2 m in width is provided for the flood diversion channel. Side slope of the excavated river channel is 1:2.

(6) Levee or filling of the excavated material from river channel is provided only at the river bank which is locally low elevation. Criteria for these works are as follows;

(i) The levee is provided to the river bank where houses are densely located.

(ii) 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.

(iii) Height of levee is decided based on the water level corresponding to 50-year probable flood. Freeboard of the levee is 0.5 m.

(iv) The shape of levee is a trapezoid type with crest width of 4 m and side slope of 1:2 on both sides.

(v) The embankment material for levee is obtained from residual soil widely distributed superficially on most of hills in the project area.

(vi) The filling of excavated material from the river channel is applied to the river bank where house is only partly located. No freeboard is provided for this filling.

(7) The compensation for lands and houses at the levee embankment site is carried out for the river width necessary for a long term plan. The existing road to be shifted should be reconstructed considering the river width for the long term plan.

Based on these design conditions, design of the river improvement plan was carried out. General plan of the designed river channel alignment is shown in Fig.7. Fig.8 shows the longitudinal profile of the design river bed and design flood water level. Standard cross sections for the protective river stretches are given in Fig.9. Proposed concrete parapet wall along Blumenau stretch is shown in Fig.10.

3.3.2 Design of related structure

It was planned to construct a new bridge on the proposed flood diversion channel and to heighten the existing bridge on the Itajai main stream if necessary. The established design condition are as follows;

(1) For design of the bridge to be newly constructed on the proposed flood diversion channel, the following design conditions should be applied;

(i) Length of bridge is determined considering the cross section against 50-year probable flood. Freeboard of 0.5 m is provided between the lowest elevation of bridge girder and flood water level corresponding to 50-year probable flood.

(ii) Bridge width of 7.2 m for roadway and 0.5 m for sidewalk in both sides is applied. Design standard which is applied to the bridge design for national road in Brazil is employed in this study.

(2) The existing bridge should be heightened if the lowest elevation of the existing bridge girder is lower than the design flood water level corresponding to 50-year probable flood in the Itajai river. In this case, freeboard is 0.5 m. The existing Ireneu Bornhausen bridge which crosses over the Itajai river at about 7 km upstream of the Blumenau city is lower than the flood water level corresponding to 50-year probable flood. However, since new bridge plan at just downstream of the existing bridge is now worked out by the Blumenau municipality, this existing bridge was planned to be heightened after the new bridge is constructed and all of the traffic volume is shifted to the new bridge.

Fig.11 shows the general plan and profile of the bridge to be newly constructed on the proposed flood diversion channel.

IV. RIVER IMPROVEMENT PLAN FOR TRIBUTARIES

4.1 General

The riparian area along the Blumenau river stretch has been inundated not only by the flood water overflowing from the Itajai river bank and also by the flood water overflowing from the tributaries, Garcia, Velha and Itoupava rivers due to higher water level in the main river. In order to protect this riparian area from flood, river improvement plan for these three tributaries was worked out to the extent of river stretch that will be affected due to flood water level corresponding to 10-year probable flood in the Itajai river.

4.2 Principle of River Improvement Plan

The river improvement plan for the Garcia, Velha and Itoupava rivers was worked out under the following principle;

(1) Design flood in the tributaries is 10-year probable flood.

(2) To prevent the flood water in the Itajai river from flowing into the urban area of the Blumenau city, levee and/or filling of the excavated material is provided along the affected stretch of the Garcia and Velha rivers. For the Itoupava river, levee and/or filling of the excavated material is provided only at its endmost river stretch, where houses are densely located. Since riparian area along further upstream stretch is occupied mainly by pasture and non-use lowland areas, these areas are elevated by filling the excavated earth material from the river channel.

(3) A short cut channel is provided for extremely meandered river stretch and the area to be surrounded between the exiting river channel and short cut channel is utilized as the regulating pond for inner drainage plan for Blumenau city.

4.3 River Improvement Structural Plan

4.3.1 Design of river improvement structural plan

The river improvement plan for the endmost stretch of the Garcia, Velha and Itoupava rivers was designed based on the topographic maps with a scale of 1:10,000 and 1:2000 and contour interval of 1 m, and river cross sectional maps with an interval of 300 m. The applied design conditions are as follows;

(1) It is assumed that the design flood water level in the affected stretch in three tributaries is the same as that corresponding to 10-year probable flood in the Itajai river.

(2) Design river bed slope is set almost the same as the existing average river bed slope.

(3) Height of levee is determined against the flood water level corresponding to 50-year probable flood in the Itajai river. Freeboard of the levee is 0.5 m.

(4) The shape of levee is a trapezoid type with crest width of 3 m and side slope of 1:2 for both sides.

(5) The residual soil widely distributed on most of hills in the project area is used as the levee embankment material.

General plan of the river channel alignment is shown in Figs.12 to 14. Fig.15 shows the longitudinal profile of the design river bed and design flood water level. Standard river cross sections are given in Figs.16 to 18.

4.3.2 Design of related structure

More than 30 bridges cross over the tributaries, Garcia, Velha and Itoupava rivers flowing into the Itajai river through the Blumenau city and the tributaries, Gaspar Grande and Gasparinho rivers flowing through the Gaspar city. Among them 11 bridges were planned to be heightened, or reconstructed under the following design conditions:

(1) The existing bridge should be heightened if the lowest elevation of the bridge girder is lower than the design flood water level corresponding to 50-year probable flood in the Itajai river. In this case, freeboard is 0.5 m.

(2) In case that the substructure and superstructure are constructed separately, the substructure is only heightened. In case that the substructure and superstructure are constructed as one unit structure, the substructure is heightened after the superstructure and substructure is separated.

(3) The existing road connecting with the bridge to be modified is also reconstructed to the extent of the stretch that the longitudinal slope is 4%.

The name of bridge to be heightened in accordance with the above design conditions are as follows;

Garcia river

PONTE DA RUA 7 DE SETEMBRO

Velha river

PONTE DA RUA SAO PAULO

PONTE DA RUA PARAIBA

PONTE DA RUA 7 DE SETEMBRO

PONTE DA RUA MARIANA BRONNEMANN

PONTE DA RUA ALBERTO STEIN

RUA DA MARECHAL DEODORO

Gaspar Grande river

PONTE DE RUA GEL ARISTILIANO RAMOS (BR-470)

PONTE DA AVENIDA DAS COMUNIDADES

Gasparinho river

PONTE DA RODOVIA JORGE LA CERDA

PONTE DA RODOVIA GASPAR - BRUSQUE

V. URBAN DRAINAGE PLAN IN BLUMENAU

5.1 General

The riparian area along the Blumenau river stretch will be relieved from flood from Itajai river by implementation of river improvement plan in the Itajai main stream and also in the endmost stretch of the tributaries, Garcia, Velha and Itoupava rivers. However, some parts of the urban area in the Blumenau city which are lower elevation than the design flood water level in the Itajai river will be still remained as depression area.

In this study, drainage plan for these areas including their catchment area was worked out by combining several drainage facilities such as regulating pond, pump and gate.

5.2 Existing Urban Drainage System

The existing drainage network as shown in Fig.19 has been provided in the urban area in the Blumenau city. This drainage system is gradually expanded in keeping pace with the development of urbanization of the Blumenau district. Consequently, the existing capacity of the network in its downstream area is in insufficient condition to drain outflow from the basin area.

Regarding to the urban drainage plan in the Blumenau city, two kinds of study was made in the past by the Blumenau municipality. One is the urban drainage plan prepared in 1975. However, influence of the water level in the Itajai river is not taken into account in this study. This plan is not valid but the expansion plan of the drainage system is made referring to this plan. The other is inner water treatment plan for the urbanized area of the Blumenau city prepared in 1985. This plan contemplates several alternative methods including flood control dam in the upstream reaches, flood diversion channel/tunnel, polder and pumping station, and among them combination plan of the polder and pumping station was selected. However, this plan is very costly because inner water is planned to be directly drained without reducing the peak of outflow by regulating pond and consequently large scale pump capacity is needed.

5.3 Present Situation of Envisaged Drainage Districts

The envisaged drainage areas along the Garcia, Velha and Itoupava rivers are classified into 13 divisions as shown in Fig.20 considering the existing drainage network. The present situation of the drainage areas along the tributaries is presented in the followings.

5.3.1 Drainage areas along Garcia river

The drainage basin along the Garcia rivers is classified into four divisions;

(1) Drainage district; G-1

The drainage district, G-1 belongs to the drainage area of Frisco river which is a small stream joining with the Garcia river at just upstream of the Itajai confluence. The drainage area is 3.94 km^2 comprising 3.37 km^2 of undeveloped mountain area, 0.5 km^2 of residential area and 0.07 km^2 of field. Majority of the flat plain is occupied by the residential area and all of it was inundated at the flood time in 1983 and 1984.

(2) Drainage district; G-2

This district is located in the upstream side of G-1, and it is further divided into two zones, G-2-1 and G-2-2. G-2-1 with the drainage area of 0.32 km^2 is situated in the right bank of the Garcia river and majority of it is occupied by the residential area. G-2-2 is located in the southeast of G-2-1. The drainage area of G-2-2 is 2.18 km^2 and about 92% of it is occupied by mountainous area with an altitude of 150 to 200 m.

(3) Drainage district; G-3

This drainage area is located in the upstream of G-2 in the right bank along the Garcia river. The drainage area is 1.13 km^2 comprising 0.31 km^2 of the residential area, 0.68 km^2 of the mountainous area and 0.14 km^2 of fields. The low land area along the Garcia is occupied by the residential area but inundation often takes place due to insufficient drainage facility.

(4) Drainage district; G-4

This drainage area is located in the left bank of the Garcia river and it is further divided into two districts, G-4-1, and G-4-2. G-4-1 with the drainage area of 0.67 km^2 is located along the Garcia river and occupied by the residential and commercial areas of the Blumenau city. G-4-2 with the drainage area of 4.5 km^2 consists of hinterland of G-4-1 and is occupied by center of commercial area in its downstream area, residential and industrial areas in flat plain along the valley and mountainous area in its upstream area. Majority of urban area in G-4 is inundated due to flood water from Itajai river at the time of large scale of flood.

5.3.2 Drainage areas along Velha river

The drainage areas along the Velha river is classified into 7 districts;

(1) Drainage district; V-1

This drainage area is located in the right bank of the Velha river in its endmost stretch. The drainage area is 0.43 km^2 comprising mostly center part of the commercial area but due to insufficient drainage capacity and depression zone in the center of the area, inundation always takes place.

(2) Drainage district; V-2

This drainage area is situated in the upstream of V-1. The drainage area is 0.62 km^2 and majority of the area is occupied by the flat plain but it is inundated at the time of large scale of flood due to insufficient drainage facility.

(3) Drainage district; V-3

This drainage area is located in the upstream of V-2. The drainage area is 0.67 km^2 and occupies 55% of area by plain area and 45% by mountainous area. Majority of the plain area has been developed as the residential and commercial areas.

(4) Drainage district; V-4

The drainage area, V-4 having an acreage of 0.68 km^2 is located at upstream of V-3. The topographic and social conditions are almost same as those for V-3.

(5) Drainage district; V-5

This drainage area is located in the left side of the Velha river. The drainage area is 0.59 km^2 and occupied by urban area of the Blumenau city.

(6) Drainage district; V-6

This area is located in the upstream of V-5. The drainage area is 1.17 km^2 and more than 50% of it is utilized as the urban area.

(7) Drainage district; V-7

The drainage area, V-7 having the acreage of 2.34 km^2 is located along Jararaca river, a stream flowing into the Velha river. Majority of this area is utilized as the residential area.

5.3.3 Drainage areas along Itoupava river

The drainage basin along the Itoupava river in its downstream stretch is divided into two districts. Since there are no house in its further upstream flat plain, it is planned to utilize it as the residential and industrial areas by filling the excavated material from river channel.

(1) Drainage district; I-1

This drainage area is located in the left side of the Itoupava river. The area is 0.51 km^2 and majority of it is occupied by the residential area.

(2) Drainage district; I-2

This drainage area is situated in the right side of the Itoupava river. The area is 1.93 km^2 comprising 52% of flat plain and 48% of mountainous area. There are not residential area except only at the downstream area of this district.

5.4 Urban Drainage Plan

5.4.1 Principle of urban drainage plan

The urban drainage plan along the Garcia, Velha and Itoupava rivers was worked out under the following principle;

(1) In order to reduce peak discharge from the drainage basin, regulating pond as large scale as possible should be provided. Location of the regulating pond should be selected at the endmost area of the drainage basin considering flood regulation effect.

(2) Drainage using a pump is generally costly and much cost is necessary for its operation and maintenance. Thus, number of pumping station should be minimized and pump capacity should be reduced considering its spare part supply.

(3) In order to drain the inner water by gravity flow when water level of the tributaries or Itajai river is lower than that of the inner water level, flap type gate should be installed.

(4) The flap gate should be also installed at the outlet of the existing drainage network to prevent river water from flowing reversely to the urban area.

(5) Since only the downstream area in the Itoupava river is developed as the residential area, it should be protected by polder.

(6) The drainage facilities to be contemplated in this plan involve regulating pond, pumping station, gate facilities and extension of drainage pipe from the existing main drainage pipe to the proposed regulating pond. The improvement of the existing drainage pipe line network is not included in this plan.

5.4.2 Urban drainage plan

The design of urban drainage facilities such as pump, regulating pond and drainage pipe connecting the existing drainage pipe to the regulating pond was made under the following design conditions;

(1) Probable flood hydrograph and its volume to design the capacity of pump and regulating pond are estimated by rational formula using probable 4-day rainfall with 10-year probability at Blumenau and actual rainfall distribution record on July 1983 and August 1984.

(2) Probable flood peak discharge to design the connecting drainage pipe is estimated by rational formula incorporating probable rainfall intensity - duration curve with 10-year probability.

(3) Considering the increase in outflow discharge due to urbanization and development of the Blumenau city, runoff coefficient in future stage is estimated at 0.9 for city area, 0.6 for farm, pasture and non-use land and 0.7 for forest area.

(4) Design high water level in the regulating pond is set at the ground elevation at the pond site and pump capacity is designed so as to keep the pond water level equal or less than the design water level assuming that water level of the Itajai river is set at the design high water level.

(5) The connecting drainage pipe to the pond is designed so as to flow 10-year probable flood from the drainage district.

Main features of the regulating pond and pump designed in accordance with these design conditions are shown in Table 3. The proposed drainage facilities and drainage method are stated as follows;

(1) The regulating pond with the flap gate is provided for each drainage district along the Garcia river but the pumping station is provided only at the pond in G-2 area. It is planned that drainage water in G-1 and G-4 areas is collected to their own ponds and then conveyed to the pond in G-2 area by culvert and syphon respectively. For G-3

area, two ponds are provided and the drainage water once stored is drained by the flap gate.

(2) The regulating pond with flap gate is provided for each drainage district except for V-4 area along the Velha river. The pumping station is provided at the pond site for V-3, V-5, V-6 and V-7 areas. it is planned that drainage water in V-1 and V-2 areas is conveyed to respective ponds in V-5 and V-6 areas by siphon. The drainage water in V-4 area is conveyed to the pond in V-3 area by connected pipe. The drainage water coming through the Jararaca river in V-7 area is diverted to new channel and conveyed to the pond by closing the Jararaca confluence by the flap gate.

(3) The residential area in the endmost area in I-1 in the Itoupava river is protected by polder and a flap gate is provided to drain inner water. A part of the endmost area in I-2 is protected by filling up the excavated material from the river channel.

General plan of the foregoing drainage facilities is shown in Fig.21.

VI. ENVIRONMENTAL ASSESSMENT STUDY

6.1 General

The study area of Blumenau-Gaspar stretch is located in the downstream reach of the Itajai river. This stretch is composed of urban area of Blumenau, which is the biggest city in the basin and urban area of Gaspar, and rural area between two cities.

The Itajai river flows down through the Blumenau city, meandering largely in the Blumenau stretch. The river stretch along the Blumenau city is characterized by excellent landscape which is in harmony with German style building, trees along the river and mountains behind the urban area. This landscape is a main sightseeing resource of this city.

The Gaspar city also has a good landscape along the river stretch in up and downstream from the center of the city. In the Blumenau-Gaspar stretch, there are rural landscape among the natural gentle slope riverside as well as valley landscape with mountains closing to riverine area.

In order to reflect the environmental effect to the planning of river improvement project, the matters to be considered for the environmental aspect for river improvement planning in Blumenau-Gaspar stretch and construction planning were studied.

6.2 Prediction of Environmental Change and Its Measure

6.2.1 Study on environmental aspect for river improvement planning

The matters contemplated for environmental aspect for river improvement planning are as follows;

(1) Landscape

It was needed in the Blumenau river stretch to provide the facility having the function to secure the safety against flood and to keep landscape for the riverine area because the Blumenau city has been developed as a tourist resource area. To meet these requirements, several alternative plans were counterplated and among them, it was decided to apply the plan to construct 1 m high concrete parapet wall with 0.5 m high footway on the right bank along the Blumenau city. It is considered to be possible to preserve present landscape and to secure access to the waterfront even after the construction of the parapet wall.

(2) Area separation

The separation of town and road which connects village to village, owing to construction of the flood diversion channel at the Gaspar stretch will probably exert the influence to the way of living and communication, and it will be necessary to provide the compensation facility for them in the river improvement plan.

6.2.2 Study on environmental aspect for construction planning

It is presumed that influence to pollution of river water, air pollution, noises, vibration sliding, animal, vegetation and housing may take place due to widening of river channel, river dredging, levee embankment and treatment of the excavated material. Then the environmental impact study was performed concentrating to these problems.

(1) Water pollution, animal and vegetation

The pollution of water quality caused by river dredging and widening leads to temporary increase of suspended solid (turbidity) load. This high turbid water may affect some kinds of aquatic weeds in the river and may damage habitat conditions of fish.

The change of the riverbed and the riverside deprives the animals of riverside vegetation and affects also the habitat of fish and they will be forced to search for another place to live.

Therefore, it is necessary to make a research of valuable animals and vegetation to grasp the magnitude of influence on them, and depending on the results, an adequate countermeasure must be taken.

(2) Air pollution, noise, vibration

During the construction period, the air pollution, noises and vibrations mainly caused by vehicles for construction works will take place but those impacts can be reduced by cleaning and watering the access roads and by limiting the speed of the vehicles. In this way, the influence on the environment can be diminished.

(3) Land (sliding)

At the riverside where widening of river channel is being executed, sliding caused by erosion takes place in several places, but this can be avoided by providing sodding.

(4) Life (housing)

As for residences which are essential for people who live near the river, the river widening will influence them and this demands an administrative measure for it.

VII. CONSTRUCTION PLAN AND COST ESTIMATE

7.1 General

This chapter presents the construction plan and cost estimate for major works comprising river improvement works for Blumenau-Gaspar stretch, and for tributaries, the Garcia, Velha and Itoupava rivers, and urban drainage plan in the Blumenau city.

Since majority of the construction cost of this project work is occupied by the cost for earthmoving work for the excavated material from the river channel, study on the construction plan was made with emphasis on the minimization of the hauling distance for these excavated materials and effective utilization of these materials for land reclamation.

7.2 Construction Plan

7.2.1 Work items and quantities

The construction works required for the project comprise three categories, namely, river improvement work in the Blumenau-Gaspar stretch in the Itajai river, river improvement work in the endmost stretch of Garcia, Velha and Itoupava rivers and urban drainage works in the Blumenau city.

Major work items and its quantities are tabulated as follows;

(1) River improvement work for Itajai main stream

- Dredging of channel : 2.10 million m^3
- Excavation of channel : 2.20 million m^3
- Filling-up the low bank : 3.50 million m^3
- Levee embankment : 0.13 million m^3
- Concrete parapet : 620 m
- Revetment : 5,000 m^2
- Excavation of flood diversion channel : 1.50 million m^3
- Bridge construction : 1 set, 100 m in length
- Relocation of existing road : 1.50 km

(2) River improvement works for 3 tributaries

- Excavation of channel : 55,000 m^3
- Level-up the low bank : 290,000 m^3
- Levee embankment : 150,000 m^3
- Revetment : 12,200 m^2
- Bridge heightening : 11 sites

(3) Urban drainage works in Blumenau

- Construction of regulatingpond : 10 places
- Connecting pipe to the ponds : 2 places

- Drainage pipe : 3 places
- Inverted syphon : 3 places
- Construction of pumping station : 5 places
- Installation of flap type gate : 20 places
- T-wall, reversed : 1 place
- New water channel : 2,800 m

7.2.2 Conditions and assumptions for construction planning

The following conditions and assumptions were applied to the planning work for construction works:

(1) In order to implement the project work within the limited construction period, it is herein proposed to execute the project works by an international contract system. In consideration of the scale of the works and contract amount in case of the international contract basis, the project stretch was divided into two packages. They are package-A which covers the river improvement works for the Itajai river stretch of about 32 km in length between 46 km and 78 km including construction of flood diversion channel at Gaspar and Package-B which covers the river improvement for three tributaries, Garcia, Velha and Itoupava rivers, and urban drainage works in the Blumenau city. The construction works will be administered and supervised by DNOS, head and 14a branch office, in association with an international consulting firm.

(2) Based on the daily rainfall record at Blumenau gauge, annual working day for construction works was set at 229 days in which rainfall intensity is less than 10 mm per day. The daily working hour is set at 8 hour.

(3) Conventional method and type of equipment are principally applied considering their easily operation and maintenance and also supply of their spare parts.

(4) For the excavation in water of Itajai river, the dredging method is applied from the economical viewpoint, and soil and hydrological conditions. The workable day for dredger depends largely on the draft of the ship. Based on the hydrological record at Blumenau and rating curve at major river stretch sites, the workable day for dredger is set at 280 day assuming that the minimum draft of the dredger is 1.3 m.

7.2.3 River improvement works

(1) General

The river improvement work in the Blumenau-Gaspar stretch consists of excavation work for widening of the existing river channel, filling up the locally low river bank, levee construction and construction of flood diversion channel, river structures and related structures. The river improvement work for the tributaries comprises mainly the construction of levee and heightening work of the existing bridges. The construction plan of these works is presented hereinafter.

(2) Excavation work for widening of the existing river channel

Total volume to be excavated for about 32 km long project river stretch is estimated at around 4.3 million m^3. To minimize the construction cost, the construction plan for this work was worked out under the following principles;

(i) The hauling distance between the excavation site and spoil bank should be reduced as far as possible and,

(ii) The excavated material from the river channel should be effectively utilized for new land reclamation by elevating low land in the pasture and/or unused area along the river stretch.

In line with the above principles, and also considering new land use plan contemplated by Blumenau and Gaspar municipalities, 13 spoil banks were selected as shown in Fig.22. These spoil banks will be utilized as land reclamation area mainly for residential and industrial uses.

The river bank to be widened is composed of alluvial deposit mainly consisting of clayey soils and fine sand. It is judged that the excavation of the river bank can be made using common construction equipment and also dredger. The excavation work for widening of the river channel is planned based on the following criteria;

(i) The dredging method is applied to the excavation under the normal water level, and

(ii) The excavation method by use of common equipment is applied for excavation above the normal water level, and

The dredging volume estimated under the foregoing criteria is around 2.1 million m^3. The dredging work is planned to be carried out by pump dredger having the following type, considering soil characteristics to be excavated;

Type	: Cutter suction pump dredger
Power	: 650 Ps class
Capacity	: 70 m^3/hr
Quantity	: 2 units

Yearly operation hour is planned at 4,000 hours with 2 to 3 shifts of crew for the daily operation.

It is planned that majority of the dredged material is discharged directly to the disposal site within an average transporting distance less than 1,000 m.

The excavation volume above the high water channel is estimated at about 2.2 million m^3. The excavation works will be conducted using the following construction equipment;

Excavation	: Swamp bulldozer, 18 t class
Loading	: Crawler loader 1.5 m^3, 18 t class
Hauling	: Dump truck, 10 t class

Leveling at land reclamation site	: Swamp bulldozer, 13 t class

Dragline and backhoe will be used as the supporting equipment. It is planned that the excavated material is transported to the proposed spoil bank by dump truck. The earth moving volume by hauling distance is as follows;

Hauling distance	Volume (m^3)	Method
Dredged material		
< 1,000 m	1,707,700	Dredger
2,000 - 5,000 m	378,300	Dredger and dump truck
Sub-total	2,086,000	
Excavated material		
< 1,000 m	773,130	Dump truck
2,000 - 5,000 m	1,082,800	Dump truck
5,000 - 10,000 m	171,800	Dump truck
Sub-total	2,128,730	
Total	4,214,730	

(3) Levee embankment and/or filling of the excavated material from river channel

It is planned that the levee and/or filling of the excavated material from the river channel is provided only at the river bank with locally low elevation. The levee is planned to be constructed at the Itajai and 3 tributaries.

The total length of the proposed levee in the Itajai river stretch is 5,750 m in the following 3 sites.

River	Location	Length(m)	Volume (m^3)
Itajai	Right bank Section No. 5 - 14 (45.49 - 47.94 km)	2,560	53,820
Itajai	Right bank Section No. 17 - 23 (49.26 - 50.84 km)	1,910	44,773
Itajai	Left bank Section No. 88 - 91 (70.03 - 70.89 km)	1,280	28,014
	Total	5,750	126,607

Since the excavated material from the river channel is not suitable for levee embankment use, the borrow pit sites as shown in Fig.23

were selected. The proposed borrow pit sites are located at the hilly area in both river banks along the project river stretch.

A series of the levee embankment works including excavation at the borrow pit, loading, hauling, spreading and compacting will be performed using the following equipment;

Excavation at borrow pit	: Swamp bulldozer, 13t class
Loading at borrow pit	: Crawler loader, 1.5 m^3
Hauling	: Dump truck, 10t class
Spreading and compaction	: Bulldozer, 11t class, Vibration roller 5t class

Embankment criteria will be as follows.

Thickness of one layer	: 40 cm approx.
Passing number of compaction equipment	: 4 - 7 times/layer

The excavation slope of borrow pits is planned to avoid the steeper slope and to be covered by grass after extracting the embankment materials.

The filling of the excavated material from the river channel is planned to the locally low elevation area other than the levee embankment area.

(4) Construction of flood diversion channel

Major work item of the flood diversion channel at Gaspar is the excavation of around 1.5 million m^3. Swamp type of equipment is planned to be utilized for the excavation work considering the soil condition that ultra-soft deposit exists in the area. Three years construction period will be required for this diversion channel works.

A bridge having the following profile is proposed to be constructed newly crossing over the flood diversion channel.

Type	: P.C. T-beam
Length & span	: 100 m and 5 span
Width	: 9 m including 0.75 m x 2 side walk
Foundation	: R.C. pile, 400 x 400 mm

(5) Heightening work of bridges in tributaries

In order to cope with the design flood water level in the Itajai river, 11 numbers of existing bridges at the tributaries are planned to be heightened as tabulated below;

Tributary	Number of bridge to be heightened	Required heightening(m)
Garcia	1	3.79
Velha	6	1.50 - 4.29
Gspar Grande	2	0.93 and 1.56
Gasparinho	2	1.00 and 1.67

Only one set of bridge in Garcia river is heightened providing a temporary bridge considering the site conditions and public traffic. Heightening work will be carried out using the hydraulic jacks and supporting materials at 2 or 3 sites concurrently.

7.2.4 Urban drainage works

(1) General

The urban drainage works in the Blumenau city along the Garcia, Velha and Itoupava rivers are planned in this feasibility study for draining urban water to tributaries.

Main construction work proposed for this urban drainage is construction of regulating pond with flap gate at 10 sites and pumping station at 5 sites.

(2) Construction of regulating ponds

The regulating pond is planned to construct at 10 sites with 27.3 ha in total area along the Garcia and Velha rivers. Major works comprise the excavation of about 0.47 million m^3 and embankment of about 0.49 million m^3. It is planned that the excavated materials are to be used as the embankment material within the same site principally. Shortage volume of embankment material are planned to be supplied from the borrow pit.

The following equipment will be used for the construction of the ponds including related structures.

- Swamp bulldozer 13t class
- Backhoe 0.6 m^3 class
- Crawler loader 1.5 m^3 class
- Dump truck 8t class
- Concrete pump car 30 m^3/hr class
- Vibration hammer 22 kW class

Required construction period will be 2 years for 10 sites of the regulating ponds.

(3) Pumping station

It was planned to construct the pumping stations at the several the regulating pond sites. Total number of the pumping station is 5 comprising 1 site for the Garcia river stretch and 4 sites for the Velha river stretch.

Considering the convenience of the operation and maintenance of the pump, the following type of pump are selected;

Drainage district	Tributary	Main feature of pump			
		Capacity, total (m^3/sec)	Type	Discharge dia. (mm)	Q'ty (unit)
G-1, G-2 and G-4	Garcia	7.8	Vertical, mixed flow	1,350	3
V-1 and V-5	Velha	0.7	Submersible	500	2
V-2 and V-6	Velha	0.7	Submersible	500	2
V-3 and V-4	Velha	1.0	Horizontal, mixed flow	600	2
V-7	Velha	4.0	Horizontal, mixed flow	1,000	2

The civil works including foundation treatment of the pumping station will be carried out concurrently with the construction of regulating ponds by several crews using the construction equipment such as 30 tons class crawler crane, 22 kW class vibration hammer, 13 tons class swamp type bulldozer, 0.6 m^3 class backhoe, 8 tons class dump truck and concrete pump car of 30 m^3/hr class. Consequently, installation of pumps with related facilities and building works will be conducted using truck crane of 20 tons class in maximum lifting capacity. Those pumping stations at 5 sites will be executed during 2 years consisting of 12 months for civil works, 6 months for installation of pumps and appurtenant facilities and 6 months for building works.

7.2.5 Construction time schedule

Implementation period of this project is planned at 7 years including one year for the respective financing, detailed design, tender and contract and 4 years for construction works.

The construction works by the contract system of packages-A and B are scheduled to be commenced at the same time. The river improvement works for Itajai and tributaries, and urban drainage works in Blumenau city will be conducted simultaneously. It is scheduled to complete the construction of the regulating ponds and pumping stations within 2 years from the starting time, considering the site condition especially the traffics in the area.

The construction works for 4 years are shown in Fig.24.

7.3 Construction Fund to be Required

7.3.1 Condition for cost estimate

The construction cost of the project was estimated by dividing into foreign and local currency portions. The currency for cost estimate is presented by US dollar for foreign currency portion and Cz$ for local currency portion. The conditions for cost estimate are as follows;

(1) The cost is estimated on price level on August, 1987 for all of the works during full period of the project, and adjustment to cope with inflational effect during the construction period was made by introducing price escalation contingency. The annual rate of the price escalation is 5% for the foreign currency portion and 12% for the local currency portion.

(2) The exchange rate of 1 US$ = Cz$50 = ¥150 is applied.

(3) The cost is estimated on unit cost basis, which consists of direct and indirect costs. The direct cost comprises the cost of labour, materials, equipment, etc. The conditions and assumptions of the direct cost are as follows;

(i) All of the required labour are assumed to the local labour and its daily charge is estimated including the social charge.

(ii) It is assumed that 60% of price for reinforcement bar and cement, 80% of the price for P.O.L., and 70% of price for steel material are allocated to the foreign currency portion.

(iii) It is assumed that all of the construction equipment are purchased by use of the foreign currency. The equipment cost comprises the hourly depreciation cost, management cost, repairing cost, cost of consumable good and maintenance cost and they are divided into following foreign and local components;

Foreign component	Local component
- Depreciation cost	- Maintenance and repair cost (labour)
- Cost of spare parts and consumables for maintenance and repair	- Other local incidental

(4) The indirect cost consists of site expense, and overhead and profit of contractor, and 30% of direct cost is assumed as the indirect cost.

(5) Five % of total direct cost for foreign and local currency portions is estimated as the administration cost.

(6) Engineering service cost for detailed design and construction supervision is estimated at 9% of the total direct cost and it is divided into 80% of the foreign currency portion and 20% of the local currency portion.

(7) Physical contingency is estimated at 10% of the total cost except for land acquisition for foreign and local currency portions.

The direct construction cost divided into foreign and local currency portions was estimated by multiplying the work quantities by the respective unit cost. The bill of quantities with unit cost are tabulated in Table VIII.3.4 in the supporting report based on the foregoing condition.

7.3.2 Financial cost and annual disbursement schedule

The financial cost on the proposed provisional plan was estimated as presented in Table 4 and summarized as follows;

Cost items	F.C. (10^3 US$)	L.C. (10^3 Cz$)	Total (Equiv.10^3 US$)
- Direct cost (Construction cost including preparatory works)	24,720	821,000	41,140
- Indirect cost (Land acquisition, administration and engineering service cost)	2,962	372,876	10,420
- Contingency (Physical and price contingency)	6,002	387,040	13,743
Total	33,684	1,581,000	65,304

The direct construction cost of each package is estimated at 22.1 and 19.1 million US$ equivalent for packages-A and B respectively.

Based on the construction time schedule as shown in Fig.24, the annual disbursement schedule was prepared as given in Table 5.

VIII. ECONOMIC EVALUATION

8.1 General

Economic evaluation of the proposed flood control project based on benefit and cost is a guideline of assessing its economic feasibility. Economic benefit is defined as an amount of annual mean flood damage to be mitigated by the proposed project. Since design flood is determined to be 10 year probable flood at the stage of the provisional plan, flood control benefit corresponds to a reducible amount of annual mean flood damage after the structural plan against 10 years' scale of flood is implemented.

Economic cost differs from financial cost in the sense of value judgement since the former is valued at real resource cost and the latter is resource cost valued at market price. Following cost estimate in previous chapter, conversion from financial to economic cost is required by using conceivable adjustment factors.

Since the project area to be protected by the provisional flood control plan lies in Blumenau being the major industrial and commercial area, the effect of public investment on this project is expected to be in substantially favorable condition. As a method of project evaluation, economic internal rate of return (EIRR) is utilized as a tool of assessing economic feasibility of whether or not the proposed project is to be worth being invested. Sensitivity analysis is also added to economic evaluation to check if the feasibility of this project is sustainable under changing condition of cost and benefit.

8.2 Economic Cost

8.2.1 Conditions of cost estimate

Cost items evaluated in cost estimate of the previous chapter are broadly classified into three categories, namely, construction material plus equipment, labour, and compensation cost. Economic construction cost is valued by converting financial to economic cost with the following adjustment procedures:

- As far as material plus equipment is concerned, sales tax rate of about 10% on them in local currency portion and import duty tax rate on them in foreign currency portion are deducted from financial cost. However, no adjustment process is applied to foreign portion of them since they are originally valued at border price without duty tax.

- Real cost of labour in economic sense is difficult to be valued since value judgement about human resources cost depends on case by case where marginal product of labour is different by opportunity conceivable without the project. Therefore, assuming that the basic wage reflects economic labour cost, social charge consisting of social security and fringe benefit is subtracted from market wage to count on the basic wage.

- Economic sense of compensation cost focuses on value of materials to be sacrificed by land acquisition. In case of farm land, annual production value of crops is taken as value of production foregone. In this case, crops to be sacrificed are represented by maize. In case of residential area, building cost of houses in land to be acquired is taken as economic cost of residential land.

8.2.2 Economic cost

Conditions of economic construction costs are applied to cost categories such as direct, compensation, administration, engineering service, and physical contingency. Adjustment works of converting from financial to economic cost are only confined to local currency portion since cost of foreign portion is outside such adjustment works. Economic construction cost are calculated with the following procedures;

- Labour cost in financial term which is about 30 % of local currency portion in direct cost is converted to economic labour cost based on the basic wage.

- As to the rest of local currency portion in direct cost consisting mainly of construction material, sales tax rate about 10 % on term is deducted from financial cost.

- Physical contingency is 10 % of the sum of direct, administration, and engineering service costs in economic term.

- Economic compensation cost puts its basis on calculation items shown below;

	Area (ha)	Benefit/ha
Farm land	94.8	Cz$ 3,310

	Number of house	House value
Residence	379	Cz$ 490 thousand

- Economic construction costs are shown by local currency by using the exchange rate that 1 US$ is equivalent to Cz$ 50.

Economic construction costs are estimated to be Cz$ 2,543,260 thousand, which is shown in Table 6.

As to disbursement of economic construction costs, direct cost is disbursed on the basis of construction planning since economic cost must reflect resource cost, while disbursement in financial term is based on financial conditions with advance payment. Land acquisition is assumed to start in one year before construction. Gross value of houses in residencial land to be acquired is equally distributed during five years including preparatory period before construction. As far as compensation cost for farm land is concerned, annual net benefit of maize is disbursed linearly during construction period and reaches to full level at the final year of construction period. A full benefit of maize is assumed to continue during economic life of flood control facility.

Operation and maintenance costs assumed to be 0.5% of direct cost are disbursed after construction. Disbursement of other cost categories is based on financial cost plan. Disbursement of economic construction cost is shown in Tables 7.

8.3 Project Benefit

Since design flood to be protected by the provisional plan is against 10 years' return period, flood control benefit is defined as an amount of annual mean flood damage to be mitigated up to 10 years' scale of flood. Calculation of benefit is derived from detailed results of probable flood damage study where characteristics and damage amount by different scale of flood are simulated by flood pattern occurred in 1978, 1980, 1983 and 1984.

Subsequently, annual mean flood damage to be reduced up to 10 years' return period turns out to be the maximum value in 1984 type of flood. Flood control benefit thus estimated is 402 million Cz$ at 1987 development level.

As to treatment of indirect damage to be mitigated, damage rate of indirect to direct damage is assumed to be 10% in conservative way although indirect damages comprising of sales loss in the secondary and tertiary sectors was actually by far larger than direct damages in 1983 flood corresponding to 50 year probable flood.

8.4 Economic Evaluation

Based on cost stream explained in disbursement schedule, and benefit stream where annual benefit at 1987 development level is generated after construction, EIRR is calculated at 12.7%. Besides, taking into account the situation that about 40% of production in the secondary and tertiary sectors concentrates on Blumenau, this rate of return is justifiable and this project itself is worth being invested.

Although conditions of estimating benefit and cost is considered to be reasonable, cost and value of benefit tend to deviate from original estimate since uncertain factors are included into conditions of estimating cost and benefit. Sensitivity analysis is conducted under the condition that cost increases at 10%, and benefit decreases by 10%, and EIRR in this coordination is estimated at 10.6%. Consequently, economic feasibility of the proposed project is still in favorable condition.

IX. SOCIO-ECONOMIC IMPACT DUE TO IMPLEMENTATION OF THE PROJECT

Socio-economic impact to the river basin due to the implementation of the river improvement project was studied. The result of the study is presented as follows.

9.1 Enhancement of Land Use along River Course

In the river improvement works, it is planned to widen the existing river channel to discharge the design flood in the Blumenau-Gaspar stretch. In Blumenau, regulating ponds are planned to retard discharge from the drainage basin. From these civil works, a huge amount of excavated materials accrue, which are estimated at about 6 million m^3. Most of these materials are planned to be utilized for land reclamation in low lands in Blumenau and Gaspar. The land reclamation is expected to improve following depression area damaged by habitual inundation along river courses: (a) low lands along the Itoupava river, where houses and industrial facilities are being developed; (b) low lands in Gaspar along the Itajai river, where they are mostly used for pasture at present; and (c) some low lands in existing urban areas in two municipalities.

Developing areas along the Itoupava river are expected to be used as new industrial zone in Blumenau municipality. They are still sparse areas at present because of long distance (around 5 km to 10 km) from the center of Blumenau and depression by habitual floods. Therefore, the land reclamation would be very effective to enhance the value of land utilization. In addition to that, BR-470 will be completed in the near future, which is a trunk road for the Itajai river basin. The both activities, land reclamation and the national road, would accelerate to utilize these lands effectively.

At present, most of the riparian area in Gaspar are utilized as pasture. Since the lands are free from flood inundation, they would be utilized for more highly progressive activity. Furthermore, since they are close to the center of Gaspar, they could be used for crop production and for living purpose. Thus, they might function as a base of crop supply for urban areas and as a living quarter of commuters to urban areas of Blumenau and Gaspar.

Some low lands in existing urban areas in Blumenau and Gaspar will be improved by the land reclamation, where they are habitually damaged by floods. The improvement might foster to utilize these lands more densely and more highly than before, because the lands are quite convenient to the center areas. Therefore, high-rised buildings and apartment houses might be constructed in these areas after the implementation.

9.2 Creation of Job Opportunity and Activation of Regional Economy

The construction of the proposed projects creates opportunities of temporal jobs during the construction period. These temporal workers and some construction materials will be supplied from inside and outside of the basin, and supporting services and other materials for these construction works are produced in the basin. These supporting business results in creating job opportunity, and it will contribute to activation of the regional economy.

It is clear that construction investment derived from proposed projects induces new production from related economic sectors.

Incidentally, according to the Japanese inter-industrial relationship, one unit of construction investment induces about 2.36 times of production from related industries. In other wards, it creates about 1.36 times of value added as the original investment. Since the industrial structure in the study area is different from that in Japan, the coefficient of induced value added would be different from 2.36 in the study area. Anyhow, it is clear that one unit of construction investment can expect to induce another almost the same amount of value added as the original investment, according to input-output analysis.

9.3 Increase in Urban Problems

Rapid urbanization in the study area would be inevitable in the near future. The infrastructure still does not keep pace with the expansion of urban areas during the 70's and the 80's. Built-up areas in the study area have already revealed some typical urban problems so far. In the coming periods, new urban areas are predicted to expand to the hinterland of the existing urban areas. Once settlement of infrastructure is further behind the urbanization, urban areas would suffer from the following urban problems as seen in advanced big cities: urban squatter; security problems; urban disasters such as fire; inconvenience for commuting; lack of social infrastructure such as schools and hospitals; and environmental problems including landscape.

Countermeasures against urban problems must not be too late. To keep pace with the urbanization, the following countermeasures are taken into consideration in general: (1) amendment of taxation system for settlement of infrastructure; (2) compulsory development of necessary infrastructure to land settlers in urban areas; (3) intensification of regulation control; and (4) subsidy from the national and/or the state government for urban management. Implementation of flood control projects might give an impetus to urbanization in the probable inundation areas. Thus, urban problems might increase more seriously than before if active countermeasures are not introduced.

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	
8.	Agronomist/Land Use Planner	T. Kimishima	Marnei Soccas Ribeiro
9.	Socio-Economist	T. Tashino	Nelson Jacomel Junior Manoel Machuca Neto
10.	Drainage Engineer	M. Kanai	Marnei Soccas Ribeiro
11.	Survey Expert	Y. Hayashi	
12.	Environmental Engineer	S. Tsuru	
13.	Project Economist	M. Tada	Nalcir Salome Silva

Tables

Table 1 PRESENT LAND USE IN THE PROBABLE INUNDATION AREA BY BLOCK

(Unit : ha)

Block	Total	Built-up Area			Agricultural Area			Green Space	Not Utilized Area
		Residential	Industrial	Commercial	Paddy	Crop	Pasture		
IT	2,360	1,099	96	313	36	0	0	222	594
SA	132	90	27	8	0	0	0	7	0
IO	468	240	203	13	0	0	0	12	0
FO	236	190	0	19	0	0	0	27	0
VE	392	185	13	134	0	0	0	60	0
GA	440	280	26	98	0	0	0	36	0
BE	280	8	0	0	179	5	0	88	0
CS	100	8	0	0	0	48	0	44	0
U1	36	1	0	0	0	0	8	27	0
U2	44	5	0	0	0	0	0	39	0
GG	964	200	4	14	336	81	95	234	0
DS	308	83	0	0	133	0	75	17	0
AR	348	44	0	0	266	5	0	33	0
PG	752	75	0	0	0	223	307	147	0
Total	6,860	2,508	369	599	950	362	485	993	594
Percentage Distribution (%)	100.0	36.5	5.4	8.7	13.8	5.3	7.1	14.5	8.7

Table 2 PROBABLE FLOOD PEAK DISCHARGES FROM DRAINAGE DISTRICTS

Name of Drainage District	Catchment Area (km2)	Concentration Time (min.)	Rainfall Intensity (mm/hr)			Probable Flood Discharge (cms)		
			2	5	10 /2	2	5	10 /2
Itoupava river								
I-1	0.51	22	69	88	105	9 (17.3) /1	11 (22.0)	13 (26.2)
I-2	1.93	54	42	56	67	20 (10.2)	26 (13.5)	31 (16.1)
Velha river								
V-1	0.43	15	81	101	120	9 (20.2)	11 (25.2)	13 (29.9)
V-2	0.62	15	81	101	120	12 (20.2)	16 (25.2)	19 (29.9)
V-3	0.67	21	71	90	107	11 (17.1)	15 (21.7)	17 (25.7)
V-4	0.68	24	67	85	101	11 (15.6)	13 (19.8)	16 (23.6)
V-5	0.59	24	67	85	101	10 (16.7)	13 (21.2)	15 (25.3)
V-6	1.17	22	69	88	105	20 (17.3)	26 (22.0)	31 (26.2)
V-7	2.34	49	45	59	71	25 (10.8)	33 (14.1)	39 (16.9)
Garcia river								
G-1	3.94	58	40	53	64	33 (8.4)	44 (11.1)	52 (13.3)
G-2-1	0.32	16	79	99	117	6 (17.7)	7 (22.2)	8 (26.4)
G-2-2	2.18	40	51	66	79	25 (11.5)	33 (14.9)	39 (17.8)
G-3	1.13	31	59	76	90	15 (13.4)	19 (17.2)	23 (20.5)
G-4	5.17	98	28	37	44	30 (5.8)	40 (7.8)	48 (9.4)

Note : /1 Spesific discharge in cms/sq.km.
/2 Return period in year.

Table 3 MAIN FEATURE OF PROPOSED DRAINAGE FACILITIES (1/2)

(1) Regulating pond

Drainage District	Catchment Area (km^2)	Available Pond Capacity (10^3 m^3)	Design Bottom Elevation (m)	Design H.W.L. (m)	Effective Depth (m)	Present Land Use
Garcia River Basin						
G-1	3.94	204	2.6	9.5	6.9	Residential area
G-2	2.50	137	2.6	9.5	6.9	Unutilized area
G-3	1.13	240	3.5	10.5	7.0	Pasture
	-	169	4.1	10.5	6.4	Pasture
G-4	5.17	26	2.6	9.5	6.9	Unutilized area
Velha River Basin						
V-1	0.43	-	-	-	-	-
V-2	0.62	57	4.9	10.0	5.1	Unutilized area
V-3	0.67	57	7.5	10.5	3.0	Sports ground
V-4	0.68	-	-	-	-	-
V-5	0.59	50	3.6	10.1	6.5	Unutilized area
V-6	1.17	101	4.9	10.0	5.1	Unutilized area
V-7	2.34	15	6.7	10.0	3.3	Pasture
Total	19.24	1,056	-	-	-	

(2) Pumping station

Pumping Station	Design Discharge (m^3/sec)	Pump Unit: Type	Discharge per Unit (m^3/sec)	Diameter mm	Number of Unit	Total Head Difference (m)	Motor Output (PS.)
Garcia River Basin							
G-1,G-2 and G-4	7.8	VMF	2.60	1,350	3	9.5	460
Velha River Basin							
V-1 and V-5	0.7	I	0.35	500	2	8.9	65
V-2 and V-6	0.7	I	0.35	500	2	7.6	55
V-3 and V-4	1.0	HMF	0.50	600	2	5.0	55
V-7	4.0	HMF	2.00	1,000	2	5.8	230
Total	14.2				11		865

Note : Location of regulating pond and pumping station is shown in Fig.21.

VMF : Vertical Mixed Flow Pump

HMF : Horizontal Mixed Flow Pump

I : Submerged Pump

Table 3 MAIN FEATURE OF PROPOSED DRAINAGE FACILITIES (2/2)

(3) Connecting Culvert and Inverted Syphon

Location	Dimensions		
	Width (m)	Height (m)	Length (m)
Connecting Culvert			
R-1 - R-2	2.0	2.0	190
R-3 - R-4	2.0	2.0	85
Inverted Syphon			
R-2 - R-5	2.0	2.0	145
R-6 to the existing drainage channel	2.0	2.0	85
R-7 - R-8	2.0	2.0	132

Note : "R" means regulating pond shown in Fig.21.

(4) New Channel

Drainage District	Catchment Area (km^2)	Design Discharge (m^3/sec)	Channel Number	Catchment Area (km^2)	Channel Length (m)	Design Capacity (m^3/sec)	Dimension of New Channel Width (m)	Height (m)	Number of Box
Garcia River Basin									
G-1	3.94	52.0	-	3.94	-	-	-	-	-
G-2	2.50	47.0	-	2.50	-	-	-	-	-
G-3	1.13	23.0	-	1.13	-	-	-	-	-
G-4	5.17	48.0	(1)	5.17	200	48.00	2.5	2.0	4
Velha River Basin									
V-1	0.43	13.0	(1)	0.43	-	-	-	-	-
V-2	0.62	19.0	(1)	0.30	300	9.20	2.0	2.0	1
			(2)	0.32	450	9.80	2.0	2.0	1
V-3	0.67	17.0	(1)	0.30	150	7.60	2.0	2.0	1
			(2)	0.37	-	-	-	-	-
V-4	0.68	16.0	(1)	0.68	500	16.00	3.0	2.0	1
V-5	0.59	15.0	(1)	0.27	100	6.90	2.0	1.5	1
			(2)	0.32	250	8.10	2.0	1.5	1
V-6	1.17	31.0	(1)	0.72	350	0.72	2.5	2.0	2
			(2)	0.45	200	0.45	2.5	2.0	1
V-7	2.34	39.0	(3)	2.34	300	39.00	2.5	2.0	3
Total	19.24			19.24	2,800				

Note : Channel number is shown in Fig.21.

Table 4 SUMMARAY OF FINANCIAL COST

Cost Items	Foreign Currency (Thousand US$)	Local Currency (Thousand Cz$)	Total Equivalent (Thousand US$)
1. Direct cost	24,720	821,000	41,140
2. Land acquisition and compensation cost	-	233,000	4,660
3. Administration cost	-	102,850	2,057
4. Engineering service cost	2,962	37,026	3,704
5. Contingency			
Price contingency	2,940	264,500	8,230
Physical contingency	3,062	122,540	5,513
Total	33,684	1,581,000	65,304

Note : Exchange rate ; US$ 1 = Cz$ 50 = ¥ 150

Table 5 ANNUAL DISBURSEMENT SCHEDULE

	1st. Year		2nd. Year		3rd. Year		4th. Year		Total	
	F.C (US$)	L.C (Cz$)	F.C (US$)	L.C (Cz$)	F.C (US$)	L.C (Cz$)	F.C (US$)	L.C (Cz$)	F.C (US$)	L.C (Cz$)
A. Direct cost										
A.1 Annual allocation	/1 9,888,000	/1 328,400,000	/2 4,944,000	/2 164,200,000	/2 4,944,000	/2 164,200,000	/2 4,944,000	/2 164,200,000	24,720,000	821,000,000
A.2 Price contingency (F.C=5%,L.C=12%)	/3 247,200	/3 19,704,000	494,400	41,050,000	791,040	65,680,000	1,087,680	93,594,000	2,620,320	220,028,000
A.3 Physical contingency (F.C=10%,L.C=10%)	1,013,520	34,810,400	543,840	20,525,000	573,504	22,988,000	603,168	25,779,400	2,734,032	104,102,800
Sub-total	11,148,720	382,914,400	5,982,240	225,775,000	6,308,544	252,868,000	6,634,848	283,573,400	30,074,352	1,145,130,800
B. Land acquisition & compensation cost /4	-	233,000,000	-	-	-	-	-	-	-	233,000,000
C Administration cost										
C.1 Annual allocation	-	25,712,500	-	25,712,500	-	25,712,500	-	25,712,500	-	102,850,000
C.2 Price contingency (L.C=12%)	-	3,085,500	-	6,428,125	-	10,285,000	-	14,656,125	-	34,454,750
C.3 Physical contingency (L.C=10%)	-	2,879,800	-	3,214,063	-	3,599,750	-	4,036,863	-	13,730,476
Sub-total	-	31,677,800	-	35,354,688	-	39,597,250	-	44,405,488	-	151,035,226
D. Engineering service cost										
D.1 Annual allocation	/5 1,406,988	/5 17,587,350	518,364	6,479,550	518,364	6,479,550	518,364	6,479,550	2,962,080	37,026,000
D.2 Price contingency (F.C=5%,L.C=12%)	70,350	2,110,482	51,836	1,619,888	82,938	2,591,820	114,040	3,693,344	319,164	10,015,534
D.3 Physical contingency (F.C=10%,L.C=10%)	147,734	1,969,783	57,020	809,944	60,130	907,137	63,240	1,017,289	328,124	4,704,153
Sub-total	1,625,072	21,667,615	627,220	8,909,382	661,432	9,978,507	695,644	11,190,183	3,609,368	51,745,687
Total annual disbursement cost	12,773,792	669,259,815	6,609,460	270,039,070	6,969,976	302,443,757	7,330,492	339,169,071	33,683,720 (33,684,000)	1,580,911,713 (1,581,000,000)

Note : /1 Advance payment (20%) + Progress payment
/2 Progress payment
/3 Excluding advance payment of 20%
/4 Land acquisition cost is assumed to disburse in 1st. year.
/5 The cost for detailed design is included (30 % of total).
/6 Exchange rate : US$ 1= Cz$ 50 = ¥ 150
/7 F.C and L.C mean foreign and local currency respectively.

Table 6 SUMMARY OF ECONOMIC CONSTRUCTION COST

(Unit : Thousand Cz$)

Cost Item	Foreign Currency	Local Currency	Total
(1) Direct cost	1,236,000	645,600	1,881,600
(2) Administration cost	-	80,840	80,840
(3) Engineering service	148,100	29,120	177,220
Sub-total	1,384,100	755,560	2,139,660
(4) Physical contingency	138,410	75,556	213,966
(5) Compensation cost			
Residencial building	-	185,710	185,710
Farm land	-	3,924 /1	3,924
Grand total	1,522,510	1,020,750	2,543,260

Note : /1 Production foregone of maize in farm land, which is calculated as present worth of annual net benefit per ha at the discount rate of 8 %.

Table 7 DISBURSEMENT OF ECONOMIC CONSTRUCTION COST

(Unit : Thousand Cz$)

Cost Item	Year					Total
	1st	2nd	3rd	4th	5th	
(1) Direct cost	-	470,400	470,400	470,400	470,400	1,881,600
(2) Compensation cost						
Farm land	63	125	188	251	314	3,924 /1
Residence	37,142	37,142	37,142	37,142	37,142	185,710
(3) Administration cost	-	20,210	20,210	20,210	20,210	80,840
(4) Engineering service	-	77,680	33,180	33,180	33,180	177,220
(5) Physical contingency	-	56,829	52,379	52,379	52,379	213,966
Total	37,205	662,386	613,499	613,562	613,625	2,543,260

Note : /1 Disbursement of compensation cost for farm land is based on annual net benefit of maize, whereas the corresponding cost in "Total" indicates present worth of annual net benefit per ha at the discount rate of 8 %.

Figures

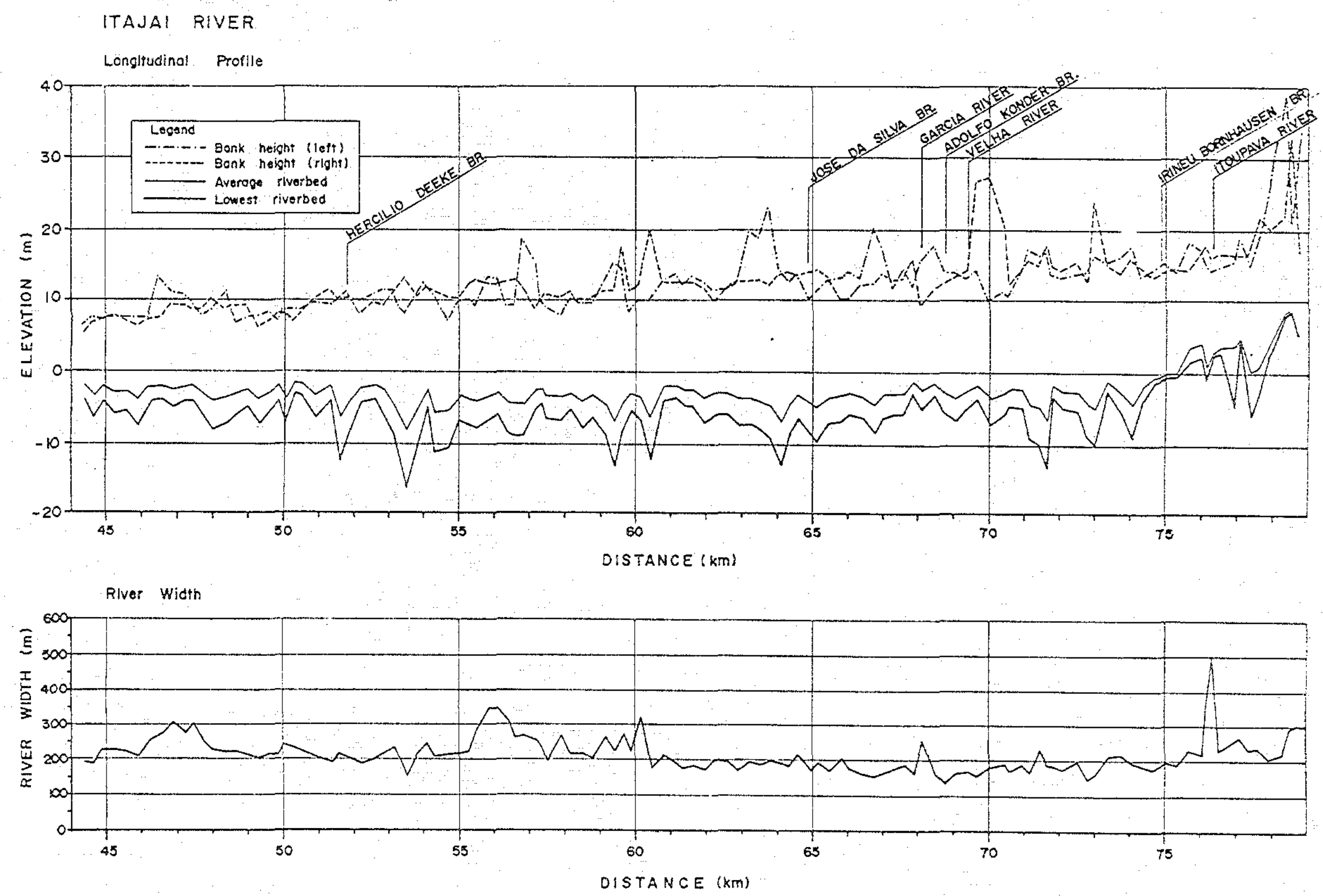


Fig.1 CHARACTERISTICS OF BLUMENAU-GASPAR STRETCH

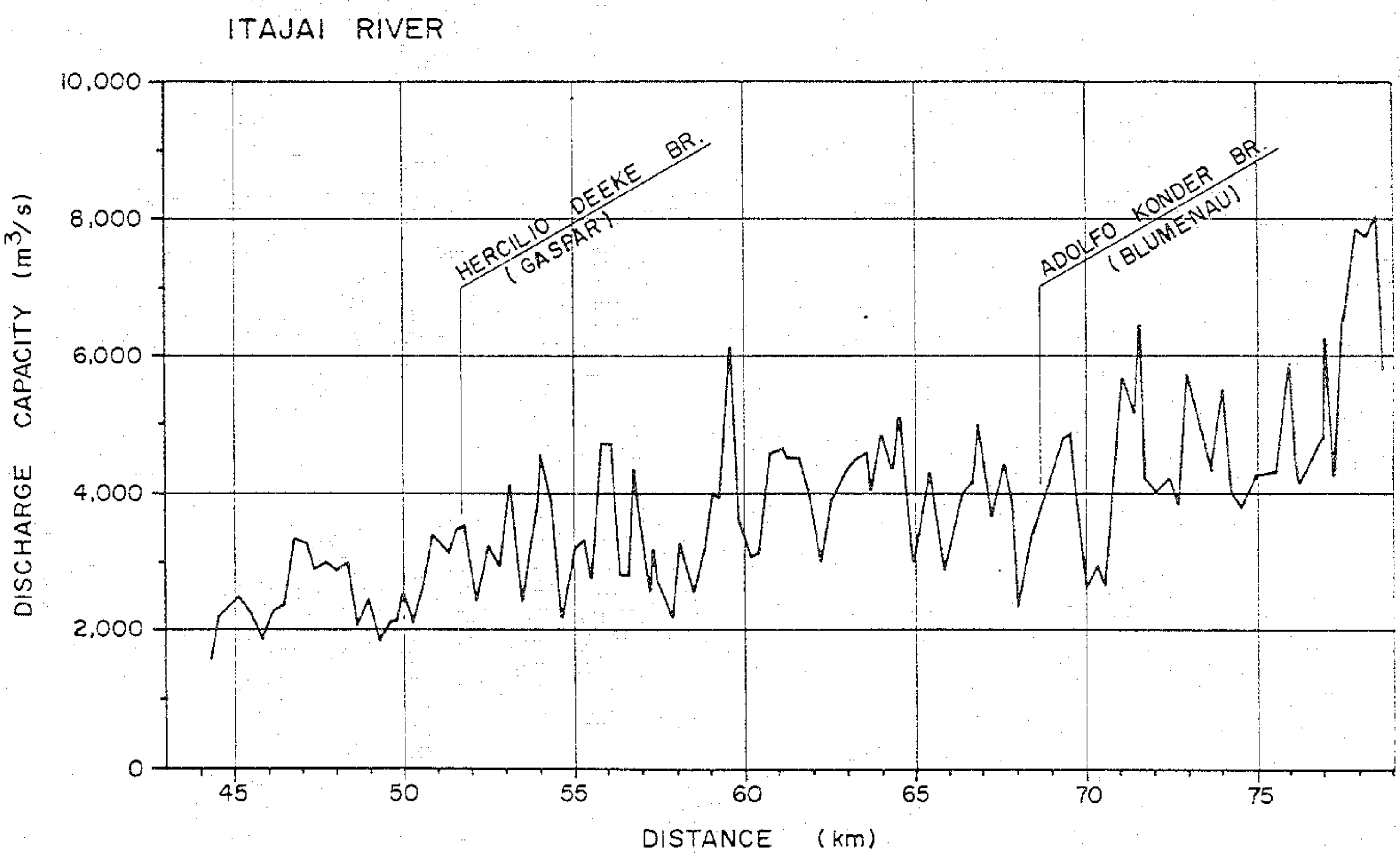


Fig.2 BANKFUL DISCHARGE CAPACITY OF BLUMENAU-GASPAR STRETCH

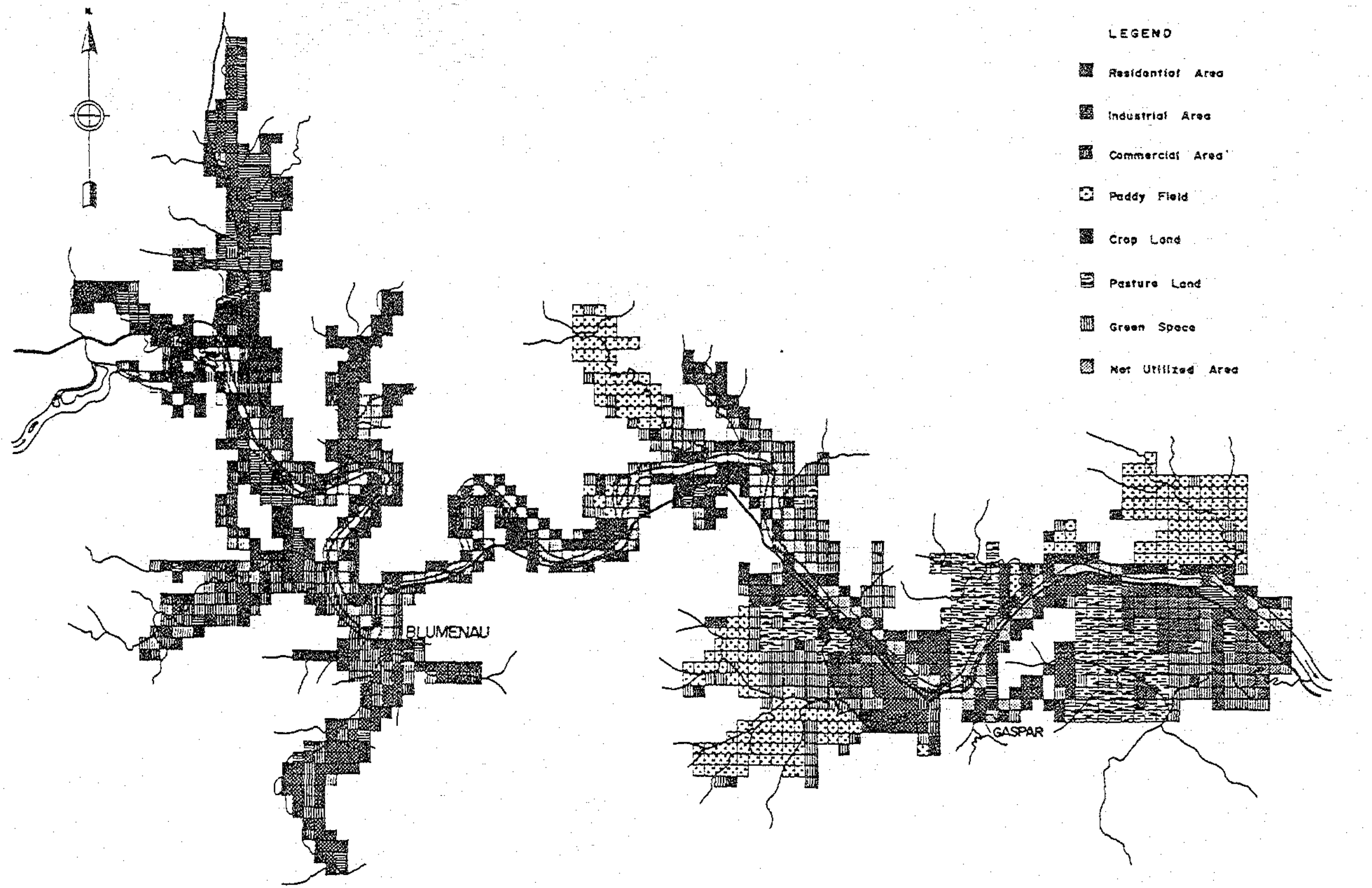
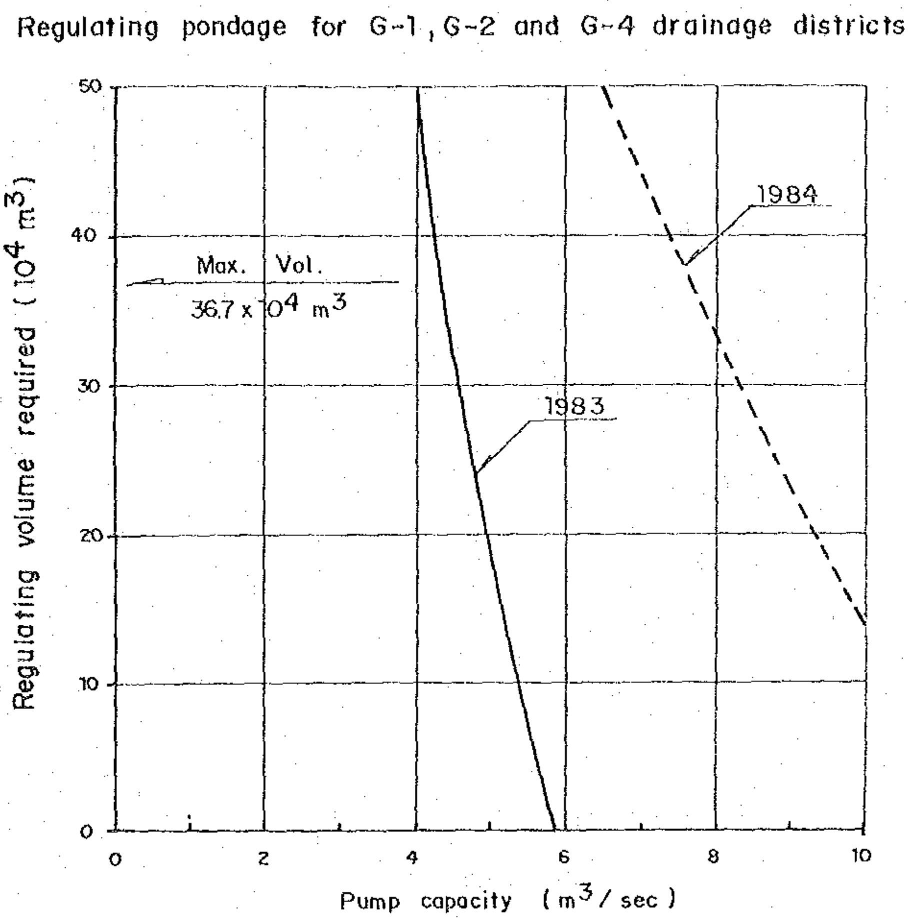


Fig.3 PRESENT LAND USE IN THE PROBABLE INUNDATION AREA



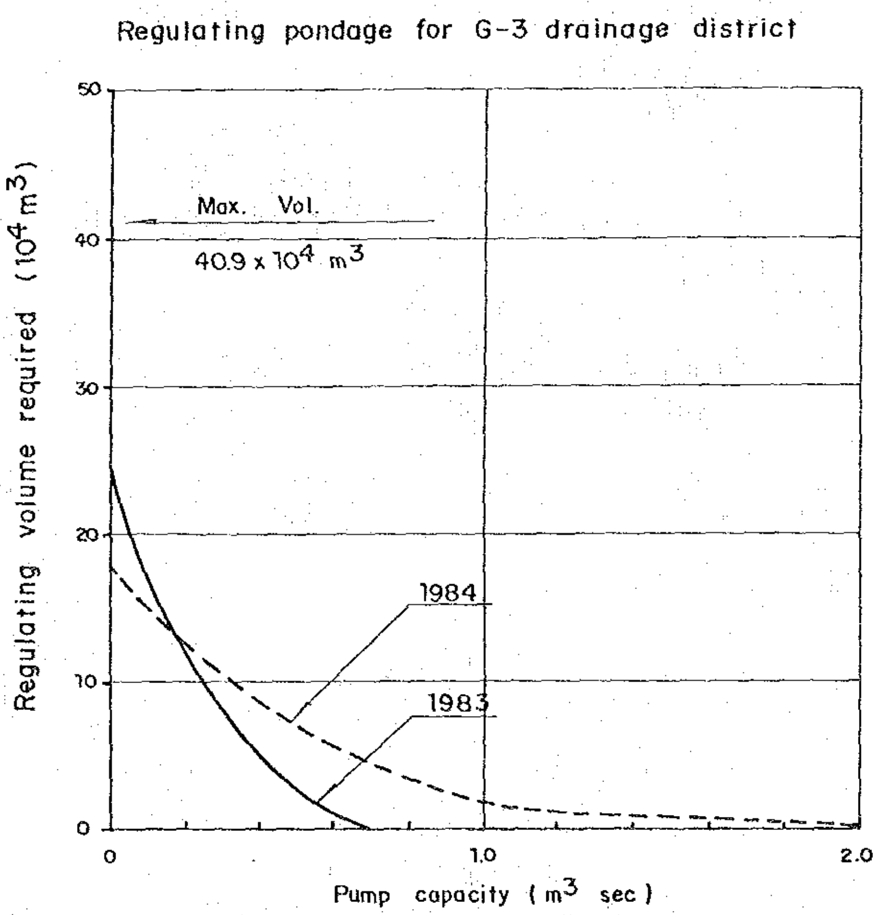
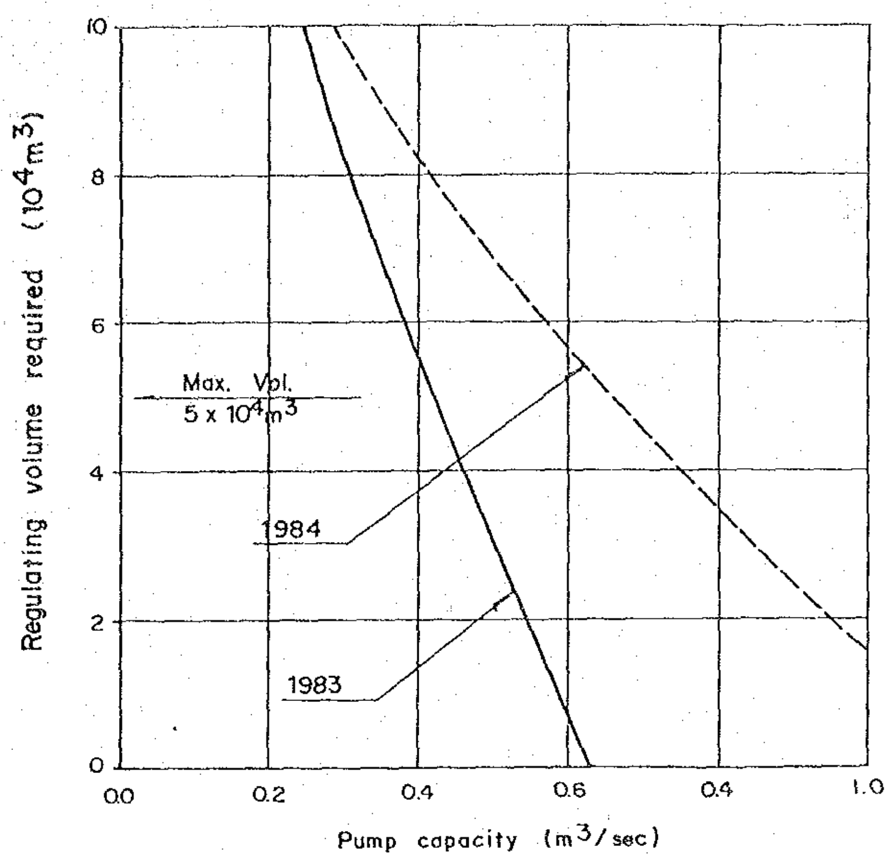


Fig.4 RELATION BETWEEN PUMP CAPACITY AND REGULATING VOLUME OF POND (1/3)

Regulating pondage for V-1 and V-5 drainage districts



Regulating pondage for V-2 and V-6 drainage districts

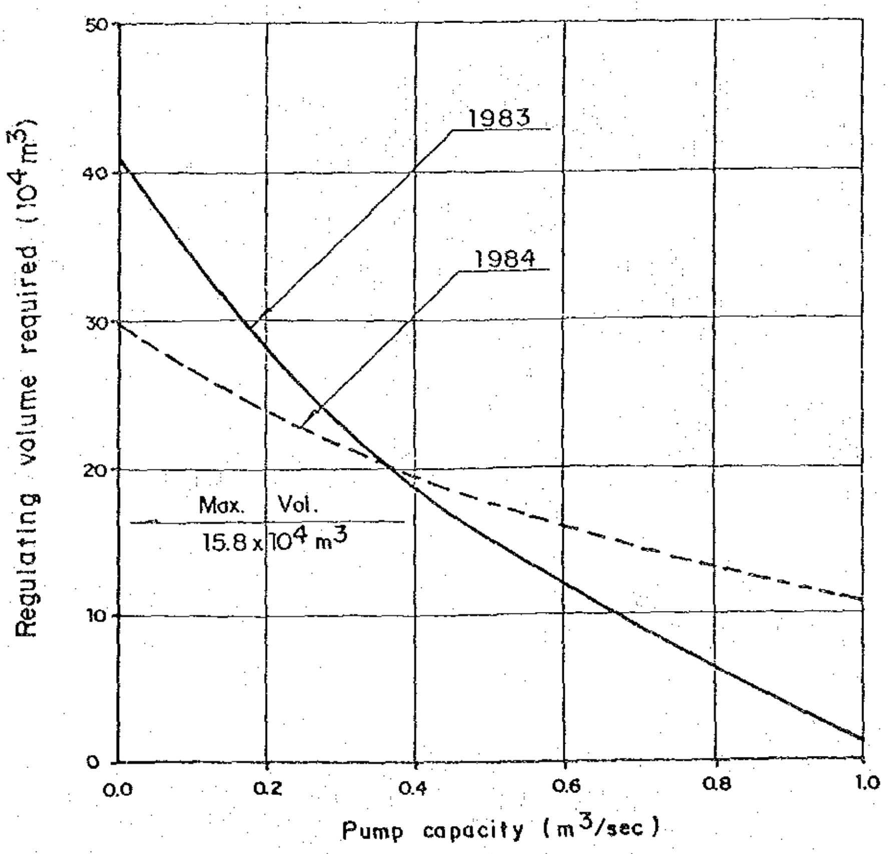
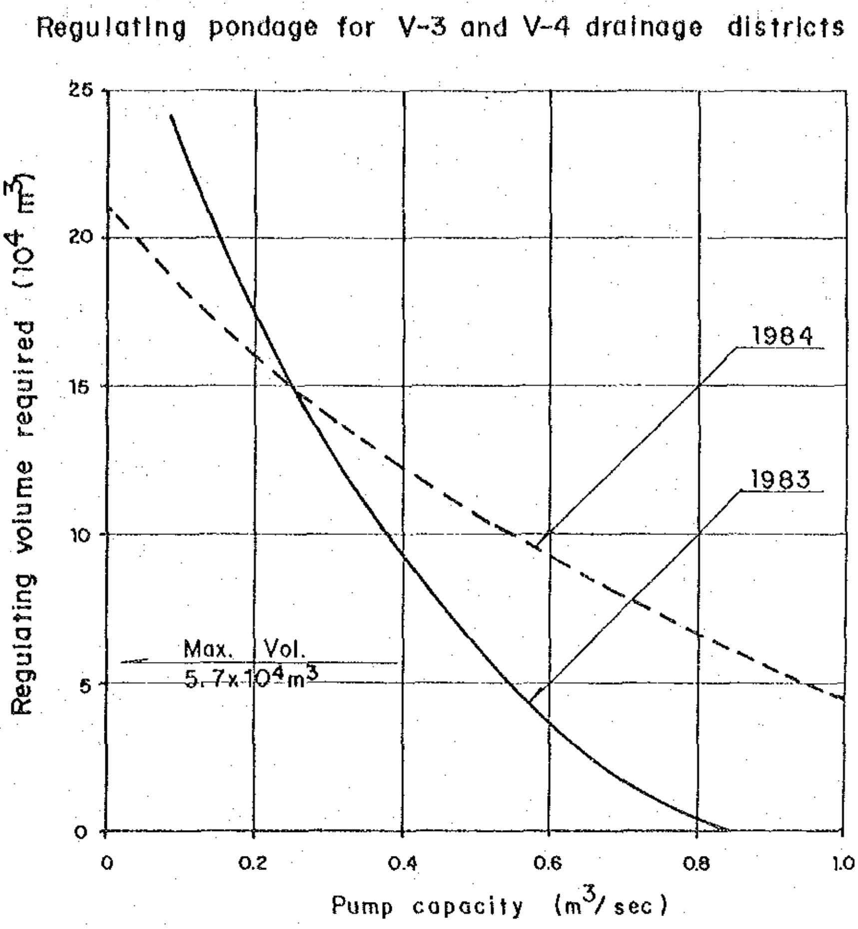


Fig.4 RELATION BETWEEN PUMP CAPACITY AND REGULATING VOLUME OF POND (2/3)



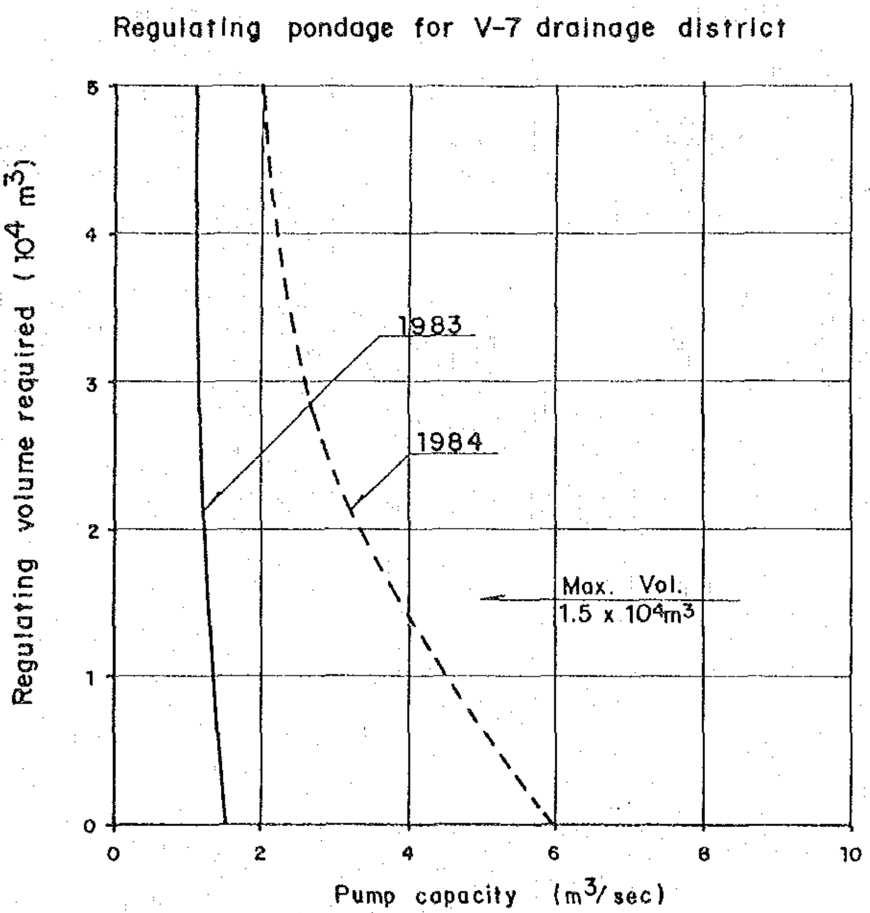


Fig.4 RELATION BETWEEN PUMP CAPACITY AND REGULATING VOLUME OF POND (3/3)

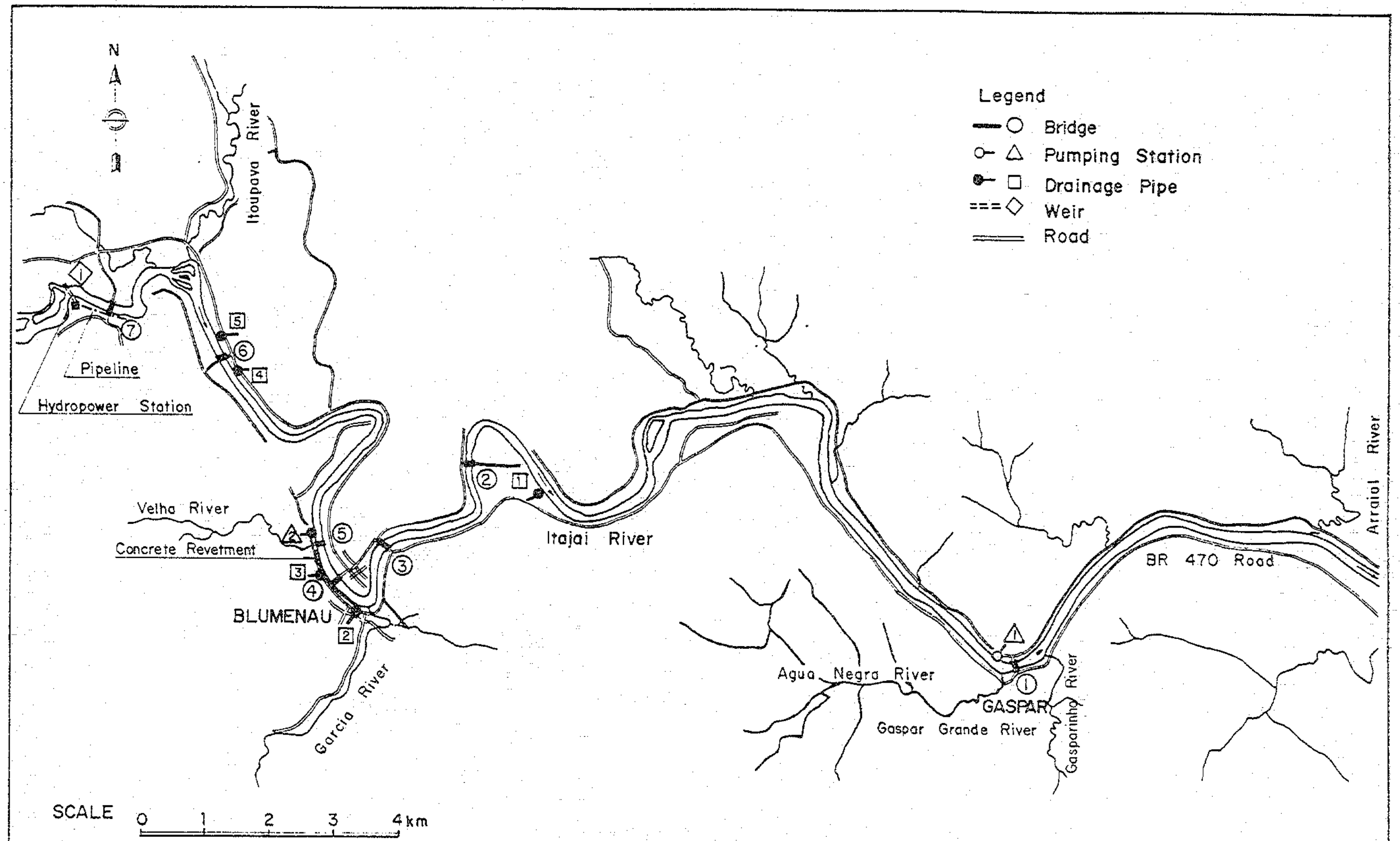


Fig.5 LOCATION MAP OF RIVER STRUCTURES AND RELATED STRUCTURES (1/5)

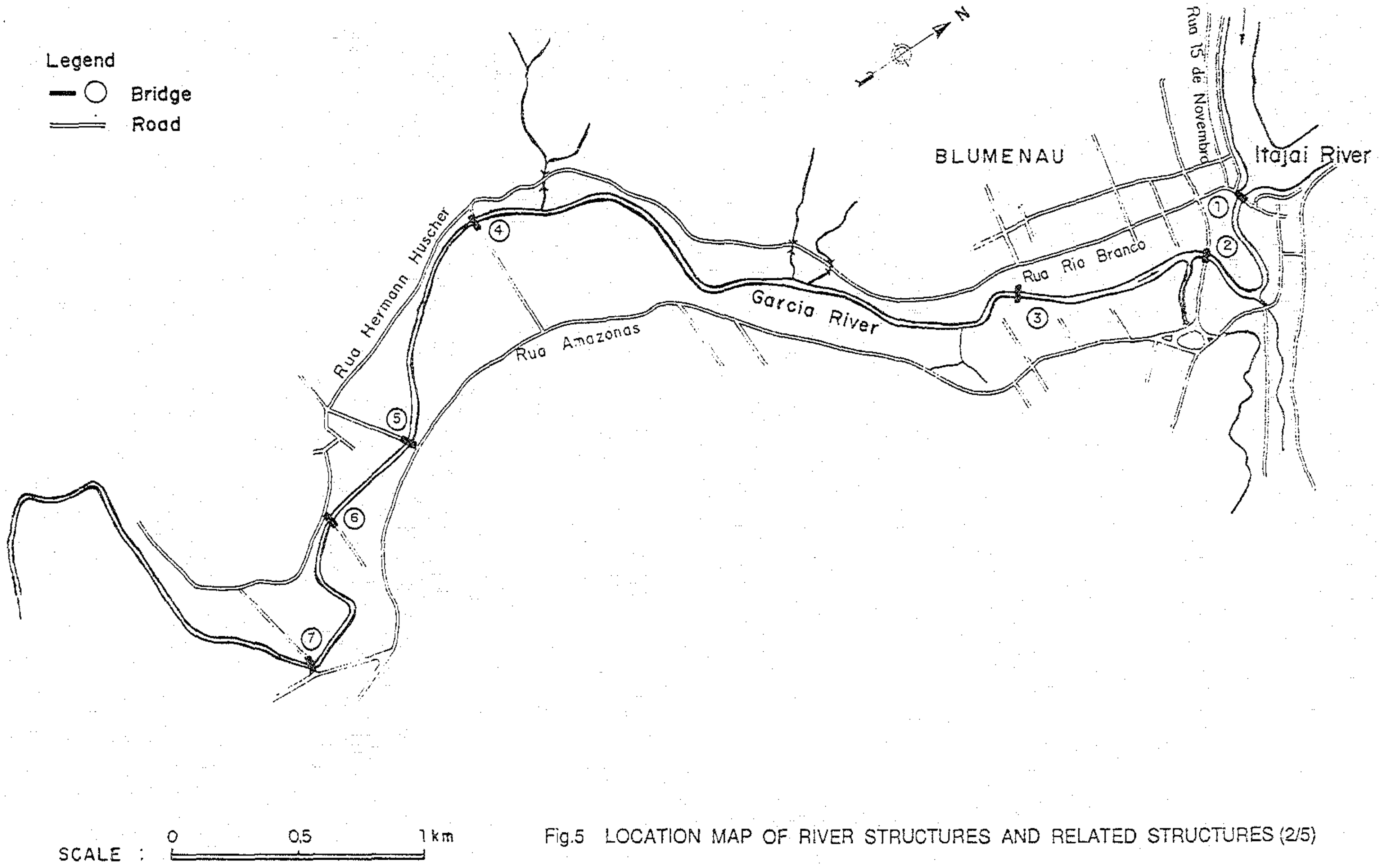


Fig.5 LOCATION MAP OF RIVER STRUCTURES AND RELATED STRUCTURES (2/5)

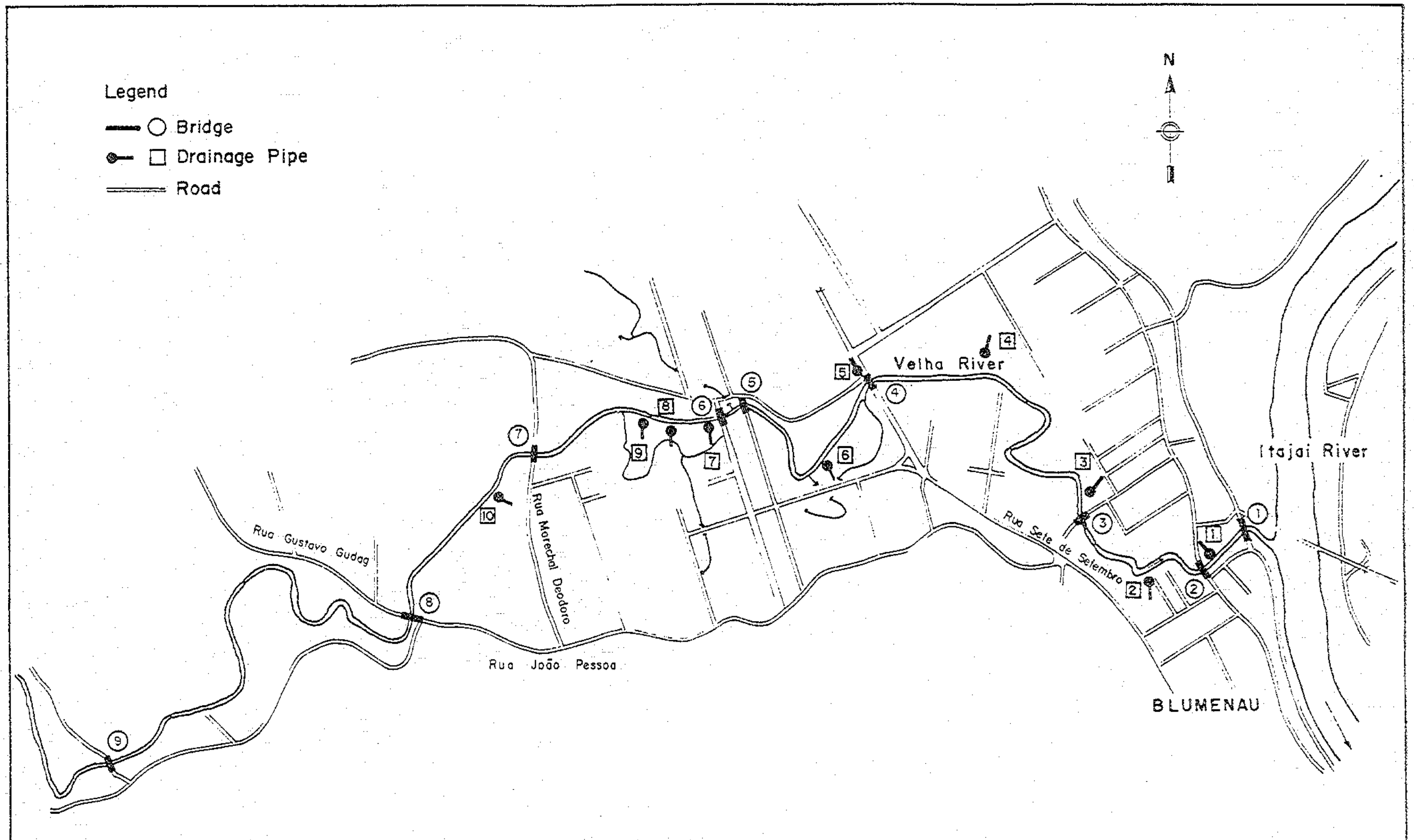


Fig.5 LOCATION MAP OF RIVER STRUCTURES AND RELATED STRUCTURES (3/5)

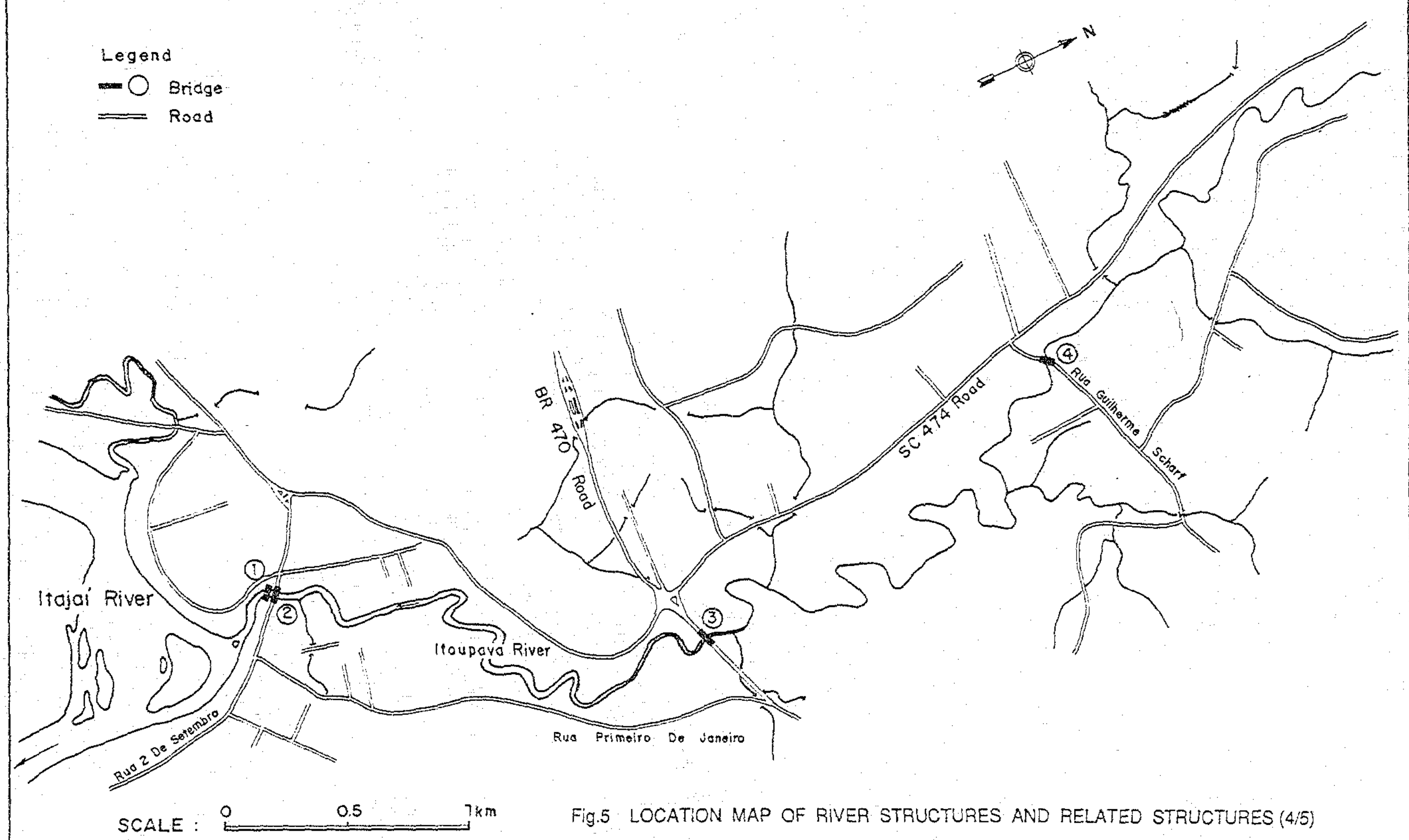
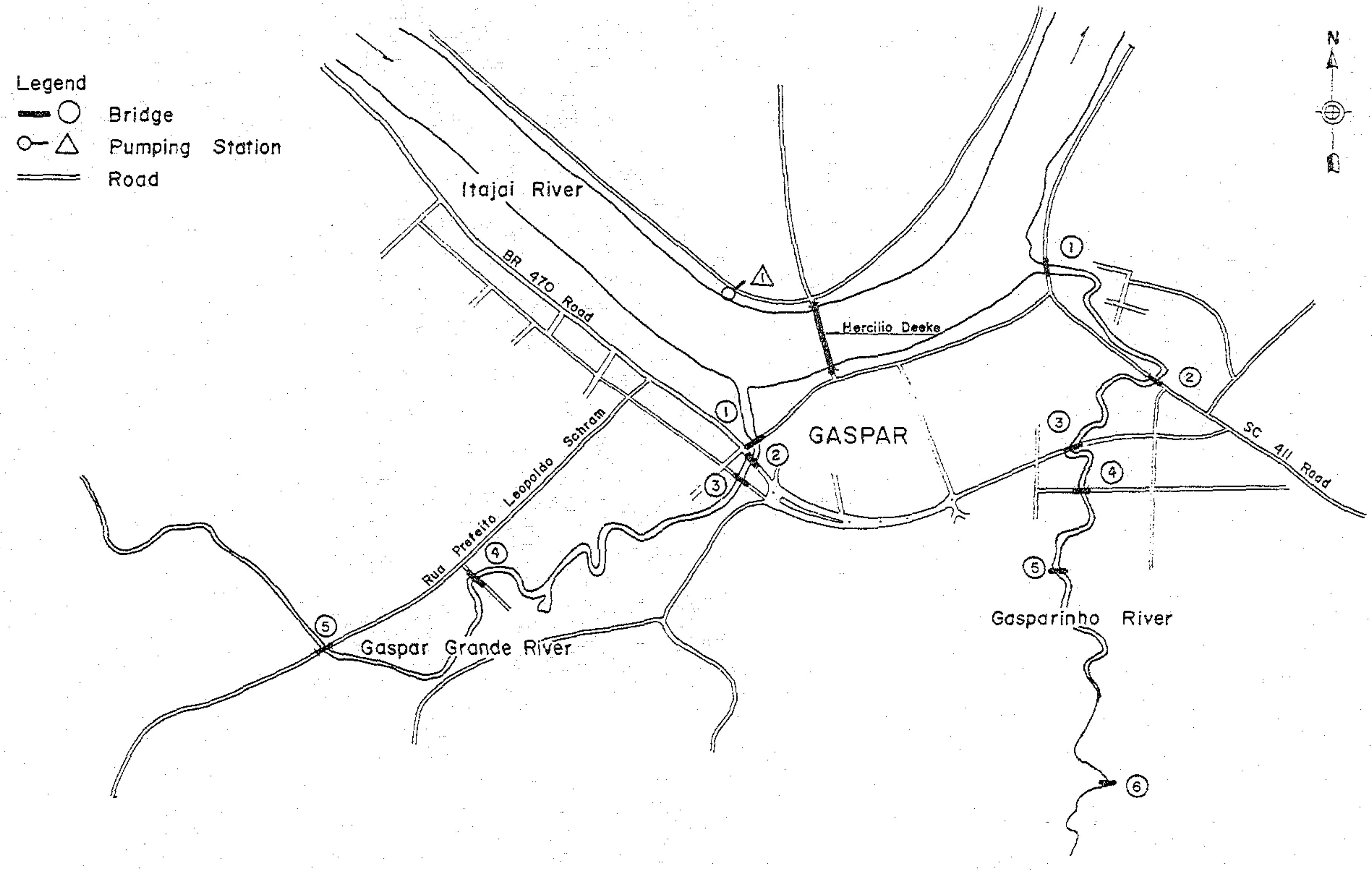


Fig.5 LOCATION MAP OF RIVER STRUCTURES AND RELATED STRUCTURES (4/5)



SCALE: 0 0.5 1km

Fig.5 LOCATION MAP OF RIVER STRUCTURES AND RELATED STRUCTURES (5/5)

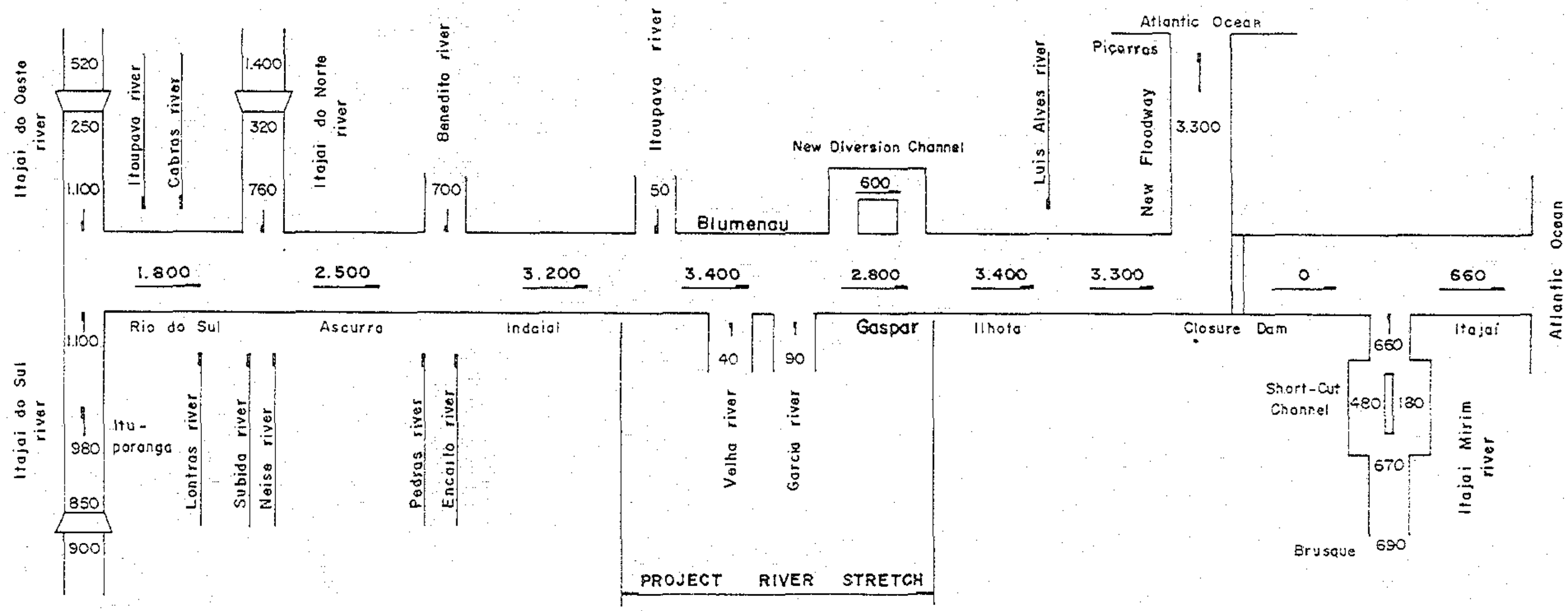


Fig.6 PROPOSED FLOOD DISCHARGE DISTRIBUTION