JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

STATE SECRETARIAT OF PLANNING AND GENERAL COORDINATION,
PARANÁ STATE, THE FEDERATIVE REPUBLIC OF BRAZIL

THE MASTER PLAN STUDY ON THE UTILIZATION OF WATER RESOURCES IN PARANÁ STATE IN THE FEDERATIVE REPUBLIC OF BRAZIL

FINAL REPORT

SECTORAL REPORT VOLUME II

FLOOD CONTROL

December, 1995

Yachiyo Engineering Co., Ltd.
Tokyo, Japan

and

Nippon Koei Co., Ltd.
Tokyo, Japan

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   - II. Master Plan for Iguaçu River Basin
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3. SECTORAL REPORT
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4. DATA BOOK

THE MASTER PLAN STUDY ON
THE UTILIZATION OF WATER RESOURCES IN PARANÁ STATE
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Sectoral Report Vol. II
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CHAPTER 1 INTRODUCTION

1.1 Purpose

Flood control is referred to as the management of water excess. The main purpose of flood control is to mitigate the damage caused by floods. It is divided into two concepts: 1) flood plain management and 2) urban storm water management. Flood plain management considers, on a comprehensive scale, the integrated view of all structural, non-structural, and administrative measures for minimizing the damage caused by floods. Urban storm water management considers the integrated view of urban sewage and storm drainage in addition to the framework of flood plain management. In this study, urban storm water management mainly deals with the increase of flood peak and waste discharge caused by the exponential growth of urban population and the expansion of urban areas.

1.2 Methodology

The flood control study in Phase II comprised the following components:

1) Analysis of flood runoff
2) Study of the design flood discharge
3) Flood inundation and damage analysis
4) Study of alternative flood control measures
5) Formulation of the Strategy for the long-term flood control

The analysis of flood runoff deals with objective flood and corresponding rainfall events. It is jointly conducted with the hydrology study. The study of design flood discharge determines the peak water level and flood discharge based on the criteria for improvement of water environment. The flood inundation and damage study made an analysis of the existing damage data and estimates the inundation-damage relationship for selected flood prone areas.

The study of alternative flood control measures includes prospective structural and non-structural measures for flood plain and urban storm water management. The structural measures include engineering works such as reservoirs, retarding basins, levees or dikes, flood walls, channel improvement and, diversion or floodways. Non-structural measures are referred to as modification of the damage susceptibility of flood prone areas such as flood proofing, relocation, flood warning and evacuation, and land use control. The long-term plan for flood control is formulated as a part of the Strategy taking into consideration other sectors' long-term plans.

CHAPTER 2 HISTORIC FLOOD RECORDS IN PARANÁ STATE

2.1 General

Record of monetary damage, detailed description of social, economic and structural damage, and maps of flood inundation areas are not available in Paraná State, except for some fraction of information kept in several municipal offices and states institutions. The National Department of Sanitation Works (DNOS) was in charge of the flood control management at national level. The DNOS had a function of flood investigation, study and keeping flood damage record. The historic record and investigation reports made by DNOS seems to be disappeared. After DNOS was abolished in 1990, the Civil Defense (CD) is the only institution that has officially kept historic record of floods in Paraná State. However, the record of CD is limited to number of persons, houses, buildings and bridges that suffered flood damage, since it takes charges of security of people and rescue activities, instead of flood control management.

The National Department of Water and Electric Energy (DNAEE) keeps a few secondary information about flood obtained from other organizations including photographs and newspaper articles. The Superintendency of Erosion Control and Environmental Sanitation (SUCEAM) is in charge of flood control in Paraná State. SUCEAM keeps some information on flood which are related to the Environmental Sanitation Program of Curitiba Metropolitan Region (PROSAM), but those information do not include monetary damage. The Coordination of the Metropolitan Area of Curitiba (COMEC) assesses flood control projects in terms of change in land value, since there is not available record of monetary damage caused by floods. The Institute of Investigation and Planning of Urban Curitiba (IPPUC) made a partial survey of the damage caused by major floods in Curitiba city.

2.2 Flood Records by Civil Defense

The historic record of flood damage kept by the Civil Defense covers number of people dislodged, injured and dead, number of houses damaged or destroyed, and damage to bridges and roads. Table-2.1 summarizes the historic distribution of damage caused by floods in Paraná State in terms of number of affected people (total number of people dislodged, injured, and dead) in the period from 1980 to 1993. Table 2.2 shows the number of dislodged people caused by the flood inundation of January and February 1995. The 1983 and 1992 floods are the two largest floods in Paraná State since 1932. It is difficult to make a precise assessment of the magnitude of floods that occurred in a year other than 1983, 1992 and 1995 because of the scarcity of damage data.

2.3 Flood Prone Areas in Paraná State

The location distributions of municipalities which suffered the floods of 1983 and 1992, the two major floods in Paraná State during the last two decades, are shown in Figure-2.1 and Figure-2.2 respectively. The location distribution of municipalities affected by floods in a year other than 1983 and 1992 are shown in Figure-2.3. From Figures-2.1, 2.2 and 2.3 it can be seen that the majority of urban flood prone areas of Paraná State are located within the Iguaçu river basin.

Since flood inundation maps are not available in the institutions of Paraná State, JICA Study Team conducted a reconnaissance survey in the flood susceptible areas. The areas surveyed were scooped from the historic flood record kept by the Civil Defense and the information obtained from the counterparts. The field surveys were conducted during the periods from early July to early August, 1994 and from the beginning of February to mid March of 1995. The following listed areas were covered by the reconnaissance:

Iguaçu river basin

Region-1: Curitiba metropolitan area
Region-2: Porto Amazonas, São Mateus do Sul
Region-3: Reboucas, Guarapuava, Irati (Tibagi river basin)
Region-4: União da Vitoria, Porto União (Santa Catarina state), Porto Vitoria
Region-5: Rio Negro, Mafra (Santa Catarina state)
Region-8: Capanema

Paraná river basin

Region-6: Foz do Iguaçu, Del Este city (Paraguay), Upstream of Itaipu dam

Coastal basin (Litoranea region)

Region-7: Morretes

The location map of these regions is shown in Figure-2.4.

Ipiranga and Ivai cities were investigated as a part of the Tibagi river basin in Phase III.

2.4 Description of Flood Inundation and Maps

2.4.1 General

The available records of flood in Paraná State indicate that flood inundation causing significant economic and social damage occurred generally in urban or semi-urban flood prone areas. Those urban flood prone lands are of relatively small size. In many cases the flood prone areas in Paraná State are occupied by low income families. Most of the urban flood prone areas are located within the Iguaçu river basin. Interview with the authority from the Department of Agriculture confirmed that there is not significant flood inundation affecting large agricultural land area in Paraná State; There are only verbal reports of relatively small and scattered flood inundation damage to agriculture and livestock.

2.4.2 Region-1: Curitiba Metropolitan Area

The Region-1 comprises those flood prone areas located in the upper stretch of the Iguaçu river basin, principally the flood prone areas of Curitiba Metropolitan region. Floods in this region are caused by the runoff from the main streams of the Iguaçu river and its tributaries such as Atuba river, Irai river, Palmital river, Itaqui river, Pequeno river, Belem river, Ivo river and Barigui river. In Region-1 for the last fourteen years there are reports of flood inundation occurring in 1980, 1981, 1982, 1983, 1988, 1992, 1993 and 1995 respectively. Floods in this region are of relative short duration, lasting from few days to about one week.

The largest recorded flood occurred in 1983. The maximum inundation water level registered in 1983 at a block named Jardim Triangulo was 877.2 meters above sea level, the ground level at that point is between 876.3 meters to 876.6 meters (i.e.; the maximum inundation water depth was about 1 m). The maximum water level at Jardim city block, in Sao Jose dos Pinhais, was 872 above sea level, the ground level at that point is between 868 to 871 meters above sea level. The flood inundation of January 1995 covered a land area similar to that of 1983 flood. Figure-2.5 shows the recorded annual maximum gauge water level of the Iguaçu river at DNAEE gauge in Curitiba Metropolitan Region from 1977 to January 1995. Figure-2.6 shows the most significant areas inundated in Region-1 during the flood of 1983. In January 1995 the upper Iguaçu river basin, the upstream of the junction with the Belem river recorded the highest rainfall depth.

In the reports of 1983 COMEC and IPPUC suggested that the main cause of inundation within Region-1 seems to be insufficient capacity and interruption of the rivers and drainage systems (Refs: Relatorio sobre Enchentes Ocorridas na Região Metropolitana, Curitiba en 1983, COMEC; and Enchentes em Curitiba 1983, IPPUC-DOG-1983).

2.4.3 Region-2: Sao Mateus do Sul and Porto Amazonas

Region-2 includes the two urban flood prone areas of Porto Amazonas and Sao Mateus do Sul. This region is located in the upper stretch of the Iguaçu river basin. Both cities are located at the margin of the Iguaçu river. The significant flood inundation in these two cities are caused directly by the water of the main stream of the Iguaçu river. In Sao Mateus do Sul the two small tributaries, the Canoas river and the Taquara river contribute also to the flooding of the urban area, in addition to the flooding water of the Iguaçu river. Significant floods occurred in Sao Mateus do Sul in 1983, 1987, 1989, 1992, 1993, and January 1995. The major flood inundation was in 1983 with the maximum recorded gauge water level of 7.5 meter (El. 762.9 m). The recorded maximum gauge water level during flood inundation of 1992 and 1995 were 6.69 meter and 6.07 meter respectively. The 1992 flood lasted for about three weeks, and the flood of January 1995 also lasted for three weeks.

The long-term water level record of DNAEE at Sao Mateus do Sul show in Figure-2.7 indicates that since 1931 the annual maximum gauge water level exceeded the 5 meter mark in 13 times: i.e., 2 times from 1931 to 1950 (20 years), 4 times from 1951 to 1979 (29 years), and 7 times from 1980 to 1995 (16 years).

Since 1931 the annual maximum gauge water level at Sao Mateus do Sul registered the level above the 6 meter mark only three times: 1983, 1992 and January 1995. Figure-2.7 shows the recorded annual maximum gauge water level of the Iguaçu river at DNAEE gauge in Sao Mateus do Sul. Figure-2.8 shows the most significant area inundated in Sao Mateus do Sul during the flood inundation of 1992.

The significant flood inundation in Porto Amazonas were in 1983, 1992, 1993 and January 1995. The maximum gauge water level during the major flood inundation of 1983 was 9.5 meter measured at DNAEE gauge. The 1992 and 1995 (January) flood water levels at the same gauge were 7.98 and 7.86 meters respectively. The average ground level at the flood prone area of Porto Amazonas is between 775 to 780 meter above sea level. The inundation at Porto Amazonas last for approximately one week.

The long-term water level record of DNAEE at Porto Amazonas shows that since 1936 the annual maximum gauge water level exceeded the 6 meter mark 10 times: i.e., 5 times from 1936 to 1979 (44 years), and 5 times from 1980 to 1995 (16 years).

Since 1936 the annual maximum gauge water level at Porto Amazonas registered the level above the 7 meter mark only three times: 1983, 1992 and January 1995. Figure-2.9 shows the recorded annual maximum gauge water level of the Iguaçu river at DNAEE gauge in Porto Amazonas from 1936 to January 1995. Figure-2.10 shows the area inundated in Porto Amazonas by the flood of 1983.

2.4.4 Region-3: Reboucas, Guarapuava, Irati

Region-3 is located about 180 km west of Curitiba, in the tributaries of the upper stretch of the Iguaçu river basin, southern part of the Tibagi river basin. The areas that suffered significant flood within Region-3 are Reboucas, Guarapuava and Irati. Irati belongs to Region-3 in the Tibagi river basin. The flood inundation in Reboucas are caused by the Potinga and Riozinho rivers, two tributaries of the Iguaçu river. In Reboucas during the last fourteen years significant flood inundation occurred in 1983 and 1992. It occurred within the urban area of Reboucas. The 1992 flood in Reboucas lasted for about one week. The maximum level of flood water is estimated to be approximately 785 meters above the sea level. Figure-2.11 shows the major flood inundation area in Reboucas during the flood of 1992.

The significant flood reported in Guarapuava occurred in 1992. No detail is known about the characteristic of the flood that affected Guarapuava.

Floods in Irati are caused by the das Antas river, a tributary of the Tibagi river. The significant flood inundation in Irati city occurred in 1981, 1983 (two floods), 1986, 1987, and 1992. The major flood inundation was in 1983. The maximum flood water level raised about 3 meters above the normal low water level. The flood lasted only for one to two days. The significant urban flood prone area of Irati is shown in Figure-2.12.

2.4.5 Region-4: União da Vitoria, Porto União, Porto Vitoria

Region-4 is located in the middle reach of the Iguaçu river basin. This region comprises the cities most severely affected by flood inundation within the Study Area. The significant flood inundation of Region 4 occurred in the urban areas of the twin cities União da Vitoria and Porto União, and the city of Porto Vitoria. Porto União belongs to Santa Catarina State. Flood inundation in the urban areas of these cities are caused directly by the runoff of the main stream of the Iguaçu river.

The long-term water level record of DNAEE at União da Vitoria shows that since 1930 the annual maximum gauge water level exceeded the 6 meter mark in 14 times :i.e., 3 times from 1930 to 1950 (21 years), 4 times from 1951 to 1979 (29 years), and 7 times from 1980 to 1995 (16 years).

The recorded gauge water level at União da Vitoria shows that maximum floods inundation depth with gauge water level higher than 7 meter have occurred in 1935, 1957, 1983 (the recorded highest), 1992 and 1993. The maximum flood water level of 1983 reached 750.03 meters above sea level, and the inundation lasted for 62 days. In 1992 the maximum water level was 748.51 meters above the sea level, 1.5 meter lower than the flood of 1983, and the inundation lasted for 65 days. In 1993 the maximum water level was 747.86 meters above the sea level and the inundation lasted for 22 days.

The major flood inundation damage reported by the Civil Defense occurred in 1980, 1982 (two floods in 1982, June and November), 1983, 1984, 1987, 1992, 1993 and 1995. Figure-2.13 shows the recorded annual maximum gauge water level at DNAEE gauge in União da Vitoria. Figure-2.14 shows the flood inundation area in the urban perimeter of União da Vitoria and Porto União by the flood of 1983. Figure-2.15 shows the flood inundation area in urban perimeter of União da Vitoria by the flood of 1992.

Significant floods in Porto Vitoria were reported in 1983 and 1992 but no detail is known about the characteristics of floods in Porto Vitoria.

2.4.6 Region-5: Rio Negro and Mafra

Region-5 is located in the Negro river, a major tributary of the upper Iguaçu river basin. This region comprises one of the flood prone area that have suffered very severe degree of flood inundation within the Study Area. The areas are the twin cities of Rio Negro and Mafra. Mafra belongs to Santa Catarina state. The flood inundation in Rio Negro and Mafra cities is caused by the Negro river. In Mafra city the da Lanca river also causes significant flood inundation, in addition to the flood inundation of the Negro river. The high water level of the Negro river causes backwater in the da Lanca river.

The long-term water level record of DNAEE at Rio Negro shown in Figure- 2.16 indicates that since 1931 the annual maximum gauge water level exceeded the 7 meter mark 24 times: i.e., 13 times from 1931 to 1979 (50 years) and 11 times from 1980 to 1995 (16 years).

Gauge water level higher than the 8 meter mark in Rio Negro were recorded in 1946,1953, 1954, 1957, 1970, 1973, 1980, 1983, 1984, 1989, 1992 and 1993. The maximum gauge water level registered in Rio Negro city was 14.63 meters in 1983. The peak gauge water level in 1992 was only 21 centimeter lower than that of 1983.

In Rio Negro city the inundation of 1983 lasted for about twelve days, while in 1992 the inundation lasted for less than one week. The flood inundation damage in 1983, 1984, 1989 and 1992 was reported to be significant by the Civil Defense. Figure-2.17 shows the flood inundation area in the urban perimeter of Rio Negro and Mafra cities by the flood of 1992.

2.4.7 Region-6: Foz do Iguaçu, Del Este City, Upstream of Itaipu Dam

Region-6 comprises the areas inundated by the main stream of the Paraná river in the downstream of the Itaipu dam, principally Foz do Iguaçu city and Del Este city. Del Este city belongs to Paraguay. The available data on significant flood inundation around Foz do Iguaçu city indicate that the peak flood occurred in 1992, when the water reached the level of 126.75 meters above sea level, some 4 centimeters higher than the flood level of 1983. Small flood inundation was also reported in Porto Meira in the lower end of the Iguaçu river, near of its confluence with the Paraná river. Table-2.3 shows the annual maximum water level recorded by Itaipu Binational since 1983. Figure-2.18 shows the location of some areas which suffered flood inundation in Region-6.

There are some other municipalities that have suffered from flood inundation along the riverine of the Paraná river upstream of the Itaipu dam. There are very little data about the characteristics of floods in those municipalities. Among those municipalities that suffered floods are: Marilena, Porto Rico, Sao Pedro do Paraná, Querencia do Norte, Icaraima, Altonia, and Guaira. Flood inundation in these municipalities are caused by the Paraná river in the many small islets (islands) that are within the Paraná river regime and in the communities located along the riverine. In the municipalities of Marilena, Porto Rico, Sao Pedro do Paraná, and Querencia do Norte there are about 38 islets of different sizes. Those islets are inhabited by some 3,000 people. The population per islet varies from 1,400 people in the largest one to few person in the smallest one (Ref: State Coordinator of Civil Defense, 1974).

A report of the Civil Defense about a major flood inundation of the Paraná river in 1974 indicates that water level in that area raised some 8 meters above the normal low water level. Almost all the inhabitants of those islets were affected by that flood inundation, causing damage to the agriculture, livestock and houses. Floods in that region have been also caused directly by the runoff of the tributaries of the Paraná and Paranapanema rivers, but there is no available data on the characteristics of flood caused by the tributaries rivers.

2.4.8 Region-7: Morretes

The significant flood in Region-7 occurred in the municipality of Morretes which is located in the coastal area of the Paraná state. The flood inundations in this municipality are caused by the Nhundiaquara river which originates in the mountain range named Serra do Mar. Morretes is located at an average altitude of 7 meters above the sea level. The high tide water at Paranagua bay causes back water of the Nhundiaquara river. Because of the low elevation where Morretes is located, the combination of increased river discharge with the back water causes the inundation of the city. In Morretes significant flood inundation have been reported in 1948, 1969, 1972, 1989 and February of 1995. The maximum flooding water level were 5.70, 5.87, 5.1, 4.70 and 5.10 meters above the sea level for the floods inundation of 1948, 1969, 1972, 1989 and 1995 respectively. The duration of flood inundation in 1989 and 1995 was only one day in both cases. Figure 2.19 shows the annual maximum water level recorded at DNAEE gauge in Morretes. Figure 2.20 shows the Flood Inundation Area in the Urban Perimeter of Morretes by the flood of February 1995.

2.4.9 Region-8: Capanema

The significant flood inundation in Region-8 occurred in the municipality of Capanema, located in the lower Iguaçu river basin. There is a verbal report on significant damage caused by flood inundation to the agricultural and livestock of this region, but quantification of damage and the specific areas that suffered inundation were not clarified by the data obtained during survey, except for the village of Porto Lupion. Porto Lupion is a small community located at the margin of the Iguaçu river. Significant floods occurred in Porto Lupion in 1983 and 1992. Figure-2.21 shows the location of Porto Lupion and Capanema.

2.4.10 Flood Prone areas in Tibagi river basin

The flood inundation damage record of Civil Defense includes some areas within the Tibagi river basin where large number of people were dislodged due to the flood inundation of 1983. Ipiranga and Ivai cities were reported as having 3,000 and 3,200 affected people respectively by the flood inundation of 1983. This two cities were surveyed during in February of 1995 to clarify the flood prone area and the magnitude of damage. However the interview result to local authorities at each prefecture indicated that the flood of 1983 inundated only 10 houses in Ipiranga city and that no significant flood inundation have occurred in Ivai city. Figure 2.22 shows the area inundated in Ipiranga city by the flood of 1983.

2.5 Estimation of Flood Damage

2.5.1 Available flood damage data

The inundation-damage relationship is the basis for a sound evaluation and selection of alternative measures for flood management and reduction of flood damage. A comprehensive quantification of all significant damage, tangible and intangible damage, caused by flood inundation is required to estimate the inundation-damage relationship at each flood prone area. However, the available data on flood inundation damage in Paraná state are very scarce and incomplete. Comprehensive evaluation of tangible damage, specially monetary damage, has not been done yet in Paraná state. Some municipal offices have gathered partial data on monetary flood damage. Another limitation found for evaluating the flood inundation damage is that existing data are kept as cumulative total damage within a municipality. For example, the total number of bridges broken or the total length of road damaged in the past within the entire municipality. This make difficult to clarify which damage occurred at each specific flood prone area.

The Civil Defense has kept partial data on flood inundation damage, especially the number of people affected by flood inundation, number of houses affected, and partial quantification of damage to buildings and infrastructure. Table 2.1 presents the data kept by the Civil Defense on the number of people affected by flood inundation within the Study Area from 1980 to 1993, including the number of dislodged, injured, and dead people caused by flood inundation. Table 2.2 summarizes the dislodged people due to the flood inundation of January and February 1995 as reported by Civil Defense.

The available monetary damage reported by official institutions does not include all items of tangible flood inundation damage, therefore most of available monetary damage data shows values lower than the actual total damage. The most comprehensive evaluation of monetary flood inundation damage is the one made in União da Vitoria and Porto União by officials of the respective municipality and CORPRERI. A part of monetary inundation damage of 1983 and 1993 in Curitiba city was given by IPPUC. A part of monetary inundation damage of 1983 and 1995 was given by COMEC. Tables from 2.4 to 2.8 present the available partial monetary flood inundation damage in the flood of 1983, 1993 and 1995 in Paraná State.

The most significant kinds of damages include: damaged houses of low income families and other type of buildings because of the long standing flooding water; damage to the families' furniture and various house items; damage to small and medium industries; damage to the commercial sector; damage to the road systems, mainly bridges and asphalt pavement; and expenses incurred for emergency relief, including dislodging and re-lodging the affected families, provision of food and medicine for the affected families, etc.

The increase in occurrence of some diseases due to flood inundation have being reported by the mass media and verbal reports, but no detailed official written report was found during the survey.

2.5.2 Estimation of flood damage

Probable flood damage was roughly estimated with reference to the data and information gathered during the field survey done during Phase II and III of the Flood Control Study. Probable direct flood damage rates were estimated as a function of the probable number of inundated houses and buildings, after making a relationship between the inundation water level and probable number of inundated houses. Indirect damage were assumed as fifty percent of total direct damage. The probable number of affected houses and buildings were interpolated between the minimum and maximum number of actually reported values at each flood prone area. The relationship of flood water level and probable number of affected houses and buildings was made for those flood prone areas where at least few data were available. Figures 2.23 to 2.29 show the relationship between flooding water level and number of inundated houses at each main flood prone area. (The relationship of flood damage and corresponding return period is not available at this stage.)

The results of estimated probable flood inundation damage are simply notional to get a general idea of the magnitude of probable flood inundation damage for different flood level at each selected flood prone area. Table 2.9 shows the assumed unit flood damage as a function of the number of houses flooded. The estimated probable range of monetary flood damage at price level of July 1994 are presented in Tables 2.10 to 2.16.

For Curitiba metropolitan region the estimated probable flood damage are as high as US $ 20 million for a flood similar to that of 1993, and some US $ 44 million for a large flood similar to that of January 1995. For União da Vitoria-Porto União area the estimated probable flood damage are in the range of US $ 10 million for a flood inundation event similar to that of 1982 to

US $ 78 million for a flood event similar to that of 1983. For Rio Negro-Mafra area the range of estimated probable flood damage is US $ 3 million for a flood event similar to that of 1984 and US $ 17 million for large flood event similar to that of 1983. For Sao Mateus do Sul the estimated range of probable flood damage is US $ 0.1 million for a small flood event similar to that of 1993 and US $ 9 million for large flood event similar to that of 1983. For Porto Amazonas area the estimated flood damage are in the range between US $ 0.23 million for a relatively small flood similar to that of 1993, to some US $ 2 million for a relatively large flood similar to that of 1983. For Foz do Iguaçu area the estimated probable flood damage are in the range between US $ 0.02 million for relatively small flood of maximum water level reaching the 119 meter counter and some US $ 3 million if relatively large flood occur, Up to the 130 meter level. For Morretes area the estimated probable flood damage are in the range between US $ 5 million if relatively small flood occur, and some US $ 10 million for a large flood similar to that of February 1995.

CHAPTER 3 DESIGN FLOOD DISCHARGE

3.1 Probable Peak Flood Discharge

The frequency analysis of the maximum daily mean discharge was made for the selected stream flow gauging stations and the 10, 50 and 100 year specific peak discharges are shown in Table - 3.1. The 100 year peak flood discharges of the selected stations are plotted in Figure- 3.1 with comparison to the Creager's curve. The corresponding specific discharges are plotted in Figure- 3.2.

3.2 Design Flood Discharge

It is practically difficult to apply the recorded maximum flood as the design flood discharge in Paraná State. Practical flood control level is to be determined based on damage level, social significance, regional development policy, etc. The recurrence interval of the design flood for the urban areas in the major municipalities is assumed tentatively to be 100 years as a target for the future.

CHAPTER 4 PROBLEMS AND NEEDS IN FLOOD CONTROL MANAGEMENT

4.1 General

Flood control management deals with water excess that endangers human lives, causes economic damage and disrupt the normal socioeconomic human activities. Concept of flood control management is broadly divided into Flood Plain management and Urban Storm Water management. Flood plain management considers the integrated views of all structural and non-structural measures for minimizing the damage caused by floods on a comprehensive scale. Urban storm water management, besides the above framework of flood plain management, also considers the integrated view on urban sewage and storm drainage management. For the purpose of flood control study in Phase II, the flood prone areas of Paraná state were divided into eight regions as previously described. Flood plain management issues were identified in all the eight regions. At present urban storm water management issues are identified only in Region 1, specifically in Curitiba metropolitan area.

Curitiba metropolitan region has experimented an exponential growth of the urban population and expansion of urban areas. Because of topographic constraint and increasing occupancy of low income population in flood prone areas the existing urban drainage systems became not enough for handling the urban flood runoff of large magnitude. Beside this, some of the fast growing areas in the peripheries of the metropolitan region are not provided with the basic infrastructures required for management of urban storm.

In all eight regions, the most significant flood inundation damage occur in urban flood prone areas. In many cases the urban flood prone areas along rivers regime are occupied by low income families. In few cases, such as União da Vitoria-Porto União and Rio Negro-Mafra areas, the urban flood prone areas are occupied with relatively high cost infrastructures, important industries, commercial establishments, and high value houses.

4.2 Assessment of Problems and Needs

Problems and Needs in flood control were assessed by region, taking as main criteria the magnitude of damages caused by the past flood inundation. The major flood inundation events in Paraná state were the floods of 1983 and 1992. During the last fourteen years the largest damage caused by flood inundation occurred within the Iguaçu river basin. The regional assessment of flood inundation damage and related issues are summarized as described in Tables- 4.1 in terms of flood region and in Table- 4.2 in term of each river basin.

4.3 Institution in Charge of Flood Control

The Brazilian constitution defines that flood control is a mater under the responsibility of the federal government. The National Department of Sanitation Works (DNOS), within the organizational structure of the Ministry of Agriculture, used to be the institution in charge of flood control at national level. DNOS was abolished in 1990, and since then in Paraná state there is not any specific institution responsible for planning, designing, promoting, constructing, operating and maintaining projects, structures and activities for flood control and mitigation of flood damage. Some institutions have projects or activities related to flood control for some specific areas, such as PROSAM in Curitiba metropolitan region. The National Department of Water and Electric Energy (DNAEE) has responsibility on flood warning, while the Civil Defense has responsibility for rescue activities.

In Paraná state there is a need for establishing an institution in charge at state level of coordinating all the aspects related to flood control and mitigation of flood inundation damage, including plan, design, promotion and implementation of projects, operation and maintenance of structures, flood warning, rescue of people affected by flood, and keeping systematic record of flood inundation damage. SUCEAM has taken over the position after the re-organization in February, 1995, but its power and specific function is not clarified clearly yet.

CHAPTER 5 ALTERNATIVE FLOOD CONTROL MEASURES

5.1 General

The study of flood control considers both, structural and non-structural means as alternative to provide protection from flood inundation and to reduce the risk of flooding and the magnitude of damage caused by floods. The prospective structural flood control measures include flood control dams or gates, retarding basins, levees or dikes, flood walls, river channel improvement, and diversion or floodways. The prospective non-structural measures include flood proofing, flood forecasting, resettlement or relocation, flood warning and evacuation, and land use control.

5.2 Structural Measures

The prospective structural measures will be chosen among the alternatives set out below, according to the need for protection against flood inundation and mitigation of damage.

Dam: Construction of flood control dams or gates.
Dike: Construction of dikes systems including levee, concrete walls, and sluices
Channel improvement: Channel improvement including a short cut.
Floodway: Construction of floodways, bypasses, rain drainage channels separated from the sewerage systems.
Retarding basin: Construction of flood retarding basins and delineation of swampy areas as retarding basins or parks.
First flush: First flush control facilities consisting of retarding basins or regulation ponds, and treatment facilities for polluted water and solid wastes and sediments.

5.3 Non-Structural Measures

Prospective non-structural measures will be chosen among the alternatives set out below.

Zoning: Zoning for land use control, such as 1) restricted area including river regime and flood prone areas; 2) preservation park with functions of recreational areas; 3) retarding basins, and 4) control of waste disposal.
Resettlement: Resettlement or relocation of illegal residents occupying the river regime, and legal residents in the flood prone areas.
Forecasting: Improvement of flood forecasting and warning system.
Evacuation: Enhancing the flood warning, evacuation, and rescue activities.
Proofing: Flood proofing modifies the damage potential of individual structures susceptible to flood damage such as elevating structures, water proofing exterior walls and re-arrangement of structural working space.
Rules: Operation rule of reservoirs

CHAPTER 6 STRATEGY FOR WATER EXCESS MANAGEMENT

6.1 Strategy

6.1.1 Goal and Principle of Water Excess Management

The goal of the flood control (broadly water excess management) is to protect the people in the flood prone areas from the risk of death, injuries and property damages including infrastructures.

Non-structural measures with appropriate combination of land use control and flood forecasting, warning and evacuation systems are to be principal flood control measures in Paraná State because present population density is generally not significantly high in the flood prone areas and alternative land resources are expected to be available in Paraná State.

Structural measures are also to be provided in addition to the non-structural measures for the areas where existing land use is highly enhanced and property value in the flood prone areas is significantly high.

6.1.2 Flood Control Level and Design Standard

The flood control (or protection) level must be determined appropriately taking into account social significance of damage level and efficiency of benefit and cost with the Principle of Risk and Benefit (refer to the Sectoral Report Water Environment Management).

The same concept of flood control level is applied in several countries as shown in Table- 6.3.

6.1.3 Model Area

It is recommended to designate the following regions as the Model Area for Water Excess Management to which specific monitoring and / or financial arrangement and support are to be provided in long term:

Region-1: Curitiba Metropolitan area
Region-2: Porto Amazonas, São Mateus do Sul
Region-4: União da Vitoria
Region-5: Rio Negro
Region-6: Foz do Iguaçu, Upstream of Itaipu Dam
Region-7: Morretes

The location map is shown in Figure-2.4.

6.2 Long Term Plan for Water Excess Management

6.2.1 Flood Plain Management

Combination of structural and non-structural measures will be necessary for the municipalities of the Curitiba metropolitan area, São Mateus do Sul, União da Vitoria/Porto União and Morretes. Non-structural measures are to be primarily employed for the flood prone areas of the other municipalities.

6.2.2 Urban Storm Water Management

Integrated view of urban sewage, flood protection, storm drainage and environmental protection will be required for the Curitiba metropolitan area. Environmental protection includes waste disposal control, water quality control, protection of aqua ecosystem, and preservation of riverine landscape. View of urban storm water management might be evolved in other municipalities after the year 2005.

6.2.3 Non-structural Measures

Zoning for land use control is the most effective measure for all the flood prone areas in and around the urban areas in Paraná state (Region - 1 to 8). Zoning for land use control includes restricted area, river regime, natural preservation and recreational park, and retarding basin area. Zoning and resettlement are a tandem for implementation. Resettlement includes relocation of illegal residents occupying the river regime and legal residents in the flood prone areas. Zoning and resettlement have been widely applied in several municipalities in Paraná State such as the Curitiba metropolitan area, São Mateus do Sul, Porto Amazonas, Reboucas, Guarapuava, Irati, União da Vitoria, Rio Negro, etc.

Improvement of the existing flood forecasting and warning system will be necessary in the future together with enhancement of flood warning, evacuation and rescue activities which are mainly executed by the Civil Defense.

Flood proofing will be effective for some locally inundated areas.

Review of the operation rule of the existing and planned dams and reservoirs will be necessary taking flood control function into consideration for integrated and effective operation.

6.2.4 Structural Measures

(1) Curitiba metropolitan area

Continuation and extension of the flood control and drainage improvement projects of PROSAM is the first priority. Supplemental provision of dams, dikes, floodways, retarding basins, and channel improvement may be necessary together with the first flush treatment facilities after the year 2005 depending on the expansion of the urban area and the deterioration of the urban environment.

(2) São Mateus do Sul

A dike system on the right bank of the Iguaçu river may be effective for the flood prone area where demand of development of low cost housing for low income people are very high in spite of the city's zoning requirement. A detailed engineering study will be necessary for technical evaluation.

(3) Porto Amazonas

Excavation of a natural rock drop, which exists in the low water channel and interrupts the stream flow of the Iguaçu river, will improve flood discharge capacity, but it will not be financially viable.

(4) União da Vitoria and Porto União

There is no appropriate sites for flood control dams and retarding basins having sufficient regulation capacity in the upstream of União da Vitoria. It is recommended to conduct a feasibility study on provision of a set of structural measures which are composed of a dike system, channel improvement and sluice gates, because the property value and town function in the inundated areas affected during the 1983 and 1992 floods are significant. The channel improvement treats a series of natural rock drops along the main channel of the Iguaçu river in the upstream of the Foz do Areia dam just downstream of Porto Vitoria for improvement of channel discharge capacity. Flood protection for this area will not be materialized by the provision of non-structural measures only.

(5) Rio Negro and Mafra

Non-structural measures are most effective in particular by zoning in this area. Structural measures for the mainstream of the Negro river will not be financially viable due to topographic constraints in this area. However channel improvement of the Passa Tress in Rio Negro municipality side and the da Lanca river in Mafra municipality side may be effective in the future.

(6) Morretes

Channel improvement including a short cut and channel excavation may be effective for the flooding along the Nhundiaquara river. However, some detailed engineering study will be necessary for technical evaluation because there is a back water effect by the high tide of the Paranagua bay.

6.2.5 Flood Forecasting and Warning Systems

The strategy for the flood forecasting and warning system (FFWS) in Paraná State aims to up-grade the existing system as a part of the integrated telemetric monitoring and operation system discussed in the Sectoral Report Water Environment management . It will also aims to reinforce a part of the nationwide flood forecasting and warning system under DNAEE which fulfills the following objectives in the future:

i) FFWS for Resident's Protection from Flood Incident
It aims to secure the life of people and to minimize flood damages in the flood prone area by enhancing prompt flood protection activities which necessitate sufficient and accurate information, through institutions concerned. It necessitates advanced forecast of extreme flood which may exceed the capacity of existing river facilities.

ii) FFWS for Flood Operation
It aims to execute promptly effective and safe operation of the flood control facilities such as dams , floodways and retarding basins by forecasting the magnitude of flood inflow into these facilities in advance. It also aims to avoid artificial flood disasters by disseminating in advance to the people information concerning flood release from those facilities.

iii) FFWS for Basin wide Flood Management
It aims to execute effective basin wide flood management and administration by integrated real time operation of all the flood control facilities. It necessitates real time access to the information on river and basin conditions.

6.2.6 Implementation Schedule

The implementation schedule for the water excess management is tentatively recommended in two stages as shown in Table - 6.1. for non-structural measures and in Table - 6.2 for structural measures.

CHAPTER 7 MASTER PLAN FOR WATER EXCESS MANAGEMENT

7.1 Master Plan for Iguaçu River Basin

7.1.1 Planning Criteria

Within the context of the goal and principle of water excess management of the Strategy the flood control model areas and design standard for the Master Plan are established as set out below.

(1) Model areas

Iguaçu River Basin
Region-1: Curitiba Metropolitan area
Region-2: Porto Amazonas, São Mateus do Sul
Region-4: União da Vitoria
Region-5: Rio Negro
Region-6: Foz do Iguaçu
Tibagi River Basin

No model area is designated in the Tibagi river basin, though some flood inundation is reported in the municipalities of Irati, Ivai and Ipiranga. The flood damage in these areas is minor.

(2) Flood Plain Management and Urban Storm Water Management

As a part of flood plain management, combination of structural and non-structural measures will be necessary for the Curitiba metropolitan area and municipalities of São Mateus do Sul and União da Vitoria/ Porto União. Non-structural measures are to be primarily employed for the flood prone areas in the other municipalities. Integrated view of urban sewage, flood protection, storm drainage and environmental protection is necessary for the Curitiba metropolitan area as urban storm water management. Environmental protection includes waste disposal control, water quality control, protection of aqua-ecosystem, and protection of riverine landscape.

(3) Design Standard

The flood control (or protection) level must be determined appropriately taking into consideration of social significance of damage level and efficiency of benefit and cost with the principle of risk and benefit. Appropriate combination of flood control level for zoning and structural measures must be also determined.

7.1.2 Non-structural Measures

Zoning for land use control is the most effective measures for all the flood prone areas in and around the urban areas in Paraná State (Region -1 to 8). Zoning for land use control includes restricted area, river regime, natural preservation and recreational park, and retarding basin area. Zoning and resettlement are a tandem for implementation and have been widely applied in the Curitiba metropolitan area (CMA), São Mateus do Sul, Porto Amazonas, Reboucas, Guarapuava, União da Vitoria, Rio Negro, etc. in the Iguaçu river basin. Resettlement includes relocation of illegal residents occupying the river regime and legal residents in the flood prone areas.

The existing flood forecasting and warning system (FFWS) is planned to be upgraded by the provision of the new lightening censoring and rainfall monitoring system under SIMEPAR. This upgraded system will provide basic warning information required for rescue activities for the time being. This system will be necessary to be upgraded for a basin wide real time flood management and operation to avoid both natural and artificial flood disaster in the future when number of water rescues and flood control facilities is increased significantly.

Flood proofing such as elevating ground level and structures is effective for some locally inundated areas in CMA and other flood prone areas. Review of the operation rule of the existing and planned dams and reservoirs will be necessary taking flood control function into consideration for the integrated and effective operation.

The proposed non-structural measures and their implementation schedule are listed in Table-7.1.

7.1.3 Structural Measures

The structural measures are proposed only for CMA, São Mateus do Sul and União da Vitoria - Porto União region.

The proposed structural measures and their implementation schedule are listed in Table-7.2.

(1) Curitiba Metropolitan Area

Non-structural measures are most effective in particular by zoning with resettlement and park in the Curitiba Metropolitan Area (CMA). Continuation and extension of the flood control and drainage improvement projects of PROSAM which is composed of structural and non-structural measures is the first priority. PROSAM is composed of the following components:

i) 15 km long flood channel excavation of the main stream of the Iguaçu river parallel to the existing channel (about 1.3 million m^3),
ii) Landscape restoration and park development of river bank area,
iii) Irai dam for flood control and to guarantee 1.8 m^3/s to Curitiba water supply,

iv) Relocation and resettlement of houses located in risky areas including occupying river flood plains, and
v) Expropriation of 7,000 plots of land and rights needed for environmental protection along rivers and environmentally sensitive areas.

The total project cost was estimated to be 34.3 million US dollars in 1992 excluding the Irai dam. A part of the channel excavation (11 Km) shown in Figure-7.1 is now under construction, and the resettlement and park plans are in progress.

The extension program of PROSAM will be composed of the following components:

i) Channel excavation and maintenance of the flood channel of the main stream of the Iguaçu river by Curitiba City Hall and COMEC, and
ii) Piraquara II, Pequeno, Alto Miringuava dams for water supply (planned by SANEPAR) with flood control function.

In order to maintain the flood discharge capacity of the Iguaçu river a strong regulation to control extraction of sand and gravel in and around the water course of the Iguaçu rive is necessary. Modification and maintenance of the two existing and on-going parallel flood channels will also be continuously necessary.

The dams which are newly planned as water supply projects are to be reviewed as multipurpose having flood control function. The Piraquara II, Pequeno, Alto Miringuava dams may have a function to mitigate floods in the flood prone areas in the municipalities of Curitiba, Pinhais, Piraquara and São Jose dos Pinhais. The location map of the planned dams is shown in Figure-7.1.

Integrated view of urban sewage, flood protection (including floodways, retarding basins and channel improvement), storm drainage, and environmental protection is now in practice in CMA, and it will be more significant in the 21 st century depending on the expansion of urban area and the deterioration of urban environment.

(2) São Mateus do Sul

In the 1983 flood 5,800 people evacuated from houses and food of 22,858 tons was provided to the affected people in São Mateus do Sul. In the 1992 flood 970 people evacuated, 570 people lost houses and 1,200 houses were damaged.

Non-structural measures are most effective, and zoning with a combination of resettlement and park is first priority in São Mateus do Sul. However, a dike system on the right bank of the Iguaçu main stream may be effective in the future after the year 2006 for the flood prone area where demand of development of low cost housing for low income people are very high in spite of the city's zoning requirement. Channel improvement will not be financially feasible.

An idea of a prospective dike system with a sluice gate is preliminarily planned as follows.

a) Design flood - the recorded maximum flood (1983 flood, return period of around 100 years, peak discharge of 1,670 m^3/s)
b) Design flood water level - 762.9 m
c) Design crest elevation - 763.9 m with freeboard of 1.0 m
d) the dike system is to be aligned at elevation 760.4 m to 761.4 m
e) Total length of dike - about 2.5 km
f) Total volume of dike - about 110,000 m^3
g) Sluice with manual gate - 1 site

A conceptual alignment of the dike system is illustrated in Figure-7.2. Feasibility study will be necessary for financial and technical evaluation.

(3) Porto Amazonas

Non-structural measures are most effective, and zoning with a combination of resettlement and park is first priority in Porto Amazonas. Excavation of a natural rock drop, which exists in the low water channel and interrupts the stream flow of the Iguaçu river, will improve flood discharge capacity, but it will not be financially viable.

(4) União da Vitoria and Porto União

União da Vitoria in Paraná State and Porto União in Santa Catarina State experienced significant flood inundation in 1983 (flood water level of 750.03 m; DNAEE gauge water level 10.42 m), 1992 (flood water level of 748.51 m), 1993 (flood water level of 746.86 m) and 1995 (flood water level of 746.36 m). In the 1983 flood about 30,000 people evacuated from their houses and food of 122,673 tons were provided to the affected people in União da Vitoria according to the report from the Civil Defense of Paraná State. In the 1992 flood 14,129 people evacuated from their houses, 3,736 people lost houses and 4,500 houses were damaged in União da Vitoria only. The flood inundation area is shown in Figure-2.14 for 1983 and Figure-2.15 for 1992.

Flood protection for this region will not be materialized by the provision of non-structural measures only. It will be practically and financially not acceptable for these municipalities to apply zoning by resettlement to the elevation of 750 m (1983 flood water level) because the property value in the flood prone area is extremely high and the town function in this area is significant. The land value is shown in Figure-2.15.

At present the municipality of União da Vitoria restricts the land use below the elevation of 744.5 m in the urban area and 745.0 m in the rural area as the dispossessed area coordinated with COPEL. In Porto União (Santa Catarina State) construction of public buildings (schools, hospitals, etc.) are prohibited in the area below 750.0 m by law. The flood water level exceeded the elevation 744.5 m 36 times, 745.0 m 26 times in the period 1930 - 1995 (66 years) as shown in Figure-2.13. If the elevation of restricted area is raised to 746.5 m the chance of exceeding this level will be reduced to 5 times during 66 years.

An alternative study including a channel improvement plan, a dike system plan and a combined plan of channel improvement and dike assessed that only dike system plan would be financially feasible with combination of zoning with resettlement.

The Study Team recommends the following zoning and structural measures

Zoning

a) Restricted Area
No private and public buildings and houses are allowed to exist below the ground elevation 746.5 m. The existing houses and buildings are to be resettled to the designated safe areas.
b) Conditional Area
Construction of new private and public buildings and houses is not allowed in the ground elevation between 746.5 m and 748.5 m before dike construction. Flood proofing such as elevating structures is to be enhanced as necessary.

Structural Measures

A dike system with sluice gates is to be provided to protect urban areas of both municipalities.

a) Design flood - the recorded maximum flood (1983 flood, return period of about 120 years, peak discharge of 4,980 m^3/s)
b) Design flood water level - 750.0 m
c) Design crest elevation - 751.2 m with freeboard of 1.2 m
d) the dike system is to be aligned at elevation 746.5 m to limit the maximum dike height less than 5 m.
e) Total length of dike - 17 km
f) Total volume of dike - 1.4 million m^3
g) Sluice with manual gate and drainage pump - 8 sites

The channel improvement including excavation of a series of natural rock drops along the main stream of the Iguaçu river in the stretch upstream of the Foz do Areia dam just downstream of Porto Vitoria to União da Vitoria will not be financially feasible because of its extremely large excavation volume (over several million m^3).

It is recommended to conduct a feasibility study on provision of the dike system and sluice gates. The total project cost of the dike system plan is approximately estimated to be about 86 million US dollars excluding cost for zoning. The conceptual alignment is illustrated in Figure-7.3.

(5) Rio Negro and Mafra

Rio Negro in Paraná State and Mafra in Santa Catarina State experienced severe flood inundation in 1983 and 1992. The recorded maximum gauge water level was 14.63 m at the DNAEE station in Rio Negro in 1983 which was higher than the normal water level by about 10 m. The peak flood water level of the 1992 flood was only 21 centimeters lower than that of 1983.

Non-structural measures by zoning are most effective in this region. Zoning with resettlement and park is in practice, but about 400 houses are still remained partly in the Negro river and partly in the Lança river the tributaries of the Negro river. A channel excavation of the Lança river in Mafra is in progress. Structural measures for the main stream of the Negro river will not be financially viable due to topographic constraints.

7.1.4 Alternative Flood Control Study for União da Vitoria

(1) Frequency analysis of peak flood discharges

COPEL conducted the frequency analysis of the peak flood discharge at DNAEE station in União da Vitoria using the historic record since 1891. The ploting position was estimated by the Weibull formula for censored data (Stedinger et al,1993). The used 68 data and result are shown in Table-7.3 and Figure-7.4 respectively. The return period of the 1983 and 1992 floods is estimated to be 123 years and 31 years respectively.

COPEL also conducted the frequency analysis of the annual maximum of 6 to 10 day rainfall by use of the rainfall records of 5 stations located upstream of União da Vitoria from 1941 to 1995 which were weighted by Thiessen method. The weighted maximum rainfall and Thiessen weight is shown in Table- 7.4 and the result is shown in Table- 7.5. The return period of the maximum 10 day rainfall in 1983 (383.8 mm) is estimated to be a little over 100 years. That of 1992 (369.9 mm) is estimated to be a little over 50 years.

(2) Probable flood damage

The relationship between probable flood damage and peak flood discharge is assumed for the União da Vitoria - Porto União area as shown in Figure-7.5 by use of the flood inundation damage estimated in Section 2.5.2. The annual average probable flood damage for the same area is also assumed as shown in Table-7.6. The corresponding damage in 1983 and 1992 are as follows:

	Probable Damage (million US dollars)	Accumulated Annual Average Probable Damage (million US dollars)
1983 flood	78.1	9.8
100 year flood	70.7	9.6
50 year flood	56.8	9.0
1992 flood	54.6	8.3

(3) Alternative flood control measures

1) Possible alternatives

Possible combination of non-structural and structural measures are listed below.

	Non-structural	Structural
Case-1	Zoning with resettlement only	
Case-2	Zoning with resettlement	Channel excavation only
Case-3	Zoning with resettlement	Channel excavation and Dike system
Case-4	Zoning with resettlement	Dike system only
Case-5		Channel excavation only
Case-6		Dike system only
Case-7		Channel excavation and Dike system

Case-1 zoning with resettlement up to the elevation 750 m will be practically and politically not acceptable to this municipality. The total number of 2,298 families (population of 9,860) occupy the prospective restricted area, and there are 2,239 units of buildings consisting of 832 brick houses, 1,376 wooden houses and 85 apartment buildings even below El. 746.5 m. There are 103 commercial establishments and 126 sheds.

Case-2, Case-3, Case-5 and Case-7 will not be financially feasible due to very costly rock excavation. Channel excavation of about 2 million m^3 (excavation-1) to 7 million m^3 (excavation -2) is examined but reduction of flood water level is not significant (refer to Section 7.1.5 (2)).

Case-6 dike system only will be technically possible, but it may not be acceptable to the residents because the dike height becomes higher than 5 m (about 6.5 m for 1983 flood) and risk of dike failure becomes high. Accordingly Case-4 zoning with dike system is assessed to be most appropriate and chosen for further review.

2) Flood protection level

The following combination of flood protection level for the structural measures by a dike system is reviewed for Case-4 assuming that the restricted area will be extended up to the elevation 746.5 m.

Design flood	Design water level(m)	Dike height (m)	Dike volume (million m3)	Approximate project cost (US$ million)
1983 (123 years)	750.0	4.7	1.4	86
100 year flood	749.5	4.2	1.0	61
50 year flood	748.6	3.3	0.7	40
1992 (31 years)	748.5	3.2	0.6	39

7.1.5 Non-uniform flow calculation

(1) Purpose

Non-uniform flow calculation was conducted to estimate the flood water level in the stretch from Foz do Areia to São Mateus do Sul in the Iguaçu river during the 1983 and 1992 floods, and evaluate an effect of natural river bed elevation and the reservoir water level of Foz do Areia on the flood water level in the stretch from União da Vitoria to São Mateus do Sul. It also estimates an effect of river bed excavation on the flood water level at União da Vitoria and São Mateus do Sul.

(2) Assumed calculation conditions

The design flood distribution of the stretch from Foz do Areia (at D1-78) to São Mateus do Sul (DNAEE station) for the 1983 and 1992 flood is assumed as shown in Figure-7.6 although there was a time lag among the assumed peak flood distribution in reality.

The roughness coefficient of Manning is assumed as follows:

Reservoir area (Section D1 to M1)	0.04
Low water channel in Section PV3 to B3 (the stretch of rock drops in Porto Vitoria)	0.05
Low water channel in other sections	0.03
High water channel with trees and irregular vegetation	0.11

(Reference: Ven Te Chow," Open Channel Hydraulics", McGRAW-HILL, 1981, Section 5-7 to 5-10)

The reservoir water level at Foz do Areia (Section D1) is assumed as follows:

1983 flood	El. 744.0 m, 742.0 m, 739 m
1992 flood	El. 742.0 m, 739 m
1983 flood with riverbed excavation	El. 744.0 m, 742.0 m, 739 m

(3) River cross section data

Out of the following 119 river cross section survey data 117 sections are used for this calculation.

COPEL No.1 Foz do Areia to União da Vitoria
41 cross sections, CN011 (D1-77) to CN381 (UV1-78) surveyed in the period 1973 - 1992

COPEL No.2 União da Vitoria to Fluviopolis
27 cross sections, CF011 (FINFL-27) to CF271 (FINFL-01) surveyed in 1995

JICA Site A Downstream to Upstream of União da Vitoria
21 cross sections, JT011 (01.GPF) to JT211 (21 GPF) surveyed in 1995

JICA Site B Fluviopolis to São Mateus do Sul
30 cross sections, JS011 (S-01.GPF) to JS301 (S-30GPF) surveyed in 1995

The location of FINFL-25 and 21.GPF and that of FINFL-01 and S-01.GPF are overlapped, and thus FINFL-25 and FINFL-01 are used for the calculation. The used cross section number and distance between sections are listed in Table-7.7. The total length of the river stretch is 242.6 km.

(4) Flood water level

The calculated flood water level is not definitive value but only notional due to insufficient topographic, hydrologic and hydraulic data and characteristics of the non-uniform flow model. However, the calculated results and their interpretation will indicate some tendency with some error range.

1) Flood water level with natural river bed

The result of flood water level of 1983 and 1992 with the existing natural river bed is shown in Table-7.7 and summarized in Table-7.8. The 1983 flood water level (with 744 m reservoir water level), 1992 flood water level (with 742 m reservoir water level), and average river bed elevation of the stretch are shown in Figure-7.7 and Table 7.7. The result indicates that the effect of the reservoir water level in Foz do Areia does not reach to Fluviopolis and São Mateus do Sul if the water level is kept at least lower than El. 744 m. The effect of reservoir water level to União da Vitoria seems to be a little if the reservoir water level is kept lower than El 744 m. It also seems to be that the key factor to cause increase of the flood water level at União da Vitoria is increase of flood discharge (size of flood) rather than the reservoir water level of Foz do Areia if the reservoir is operated within the calculated conditions. However the amount of contribution of the reservoir water level of Foz do Areia to the 1983 flood water level can not be quantified by this calculation model only.

It is guessed that the effect may be minimized if the reservoir water level is kept lower than El. 739 m. However the adopted non-uniform flow calculation model can not deal with the extent to which level the reservoir water level is to be lowered.

2) Flood water level with channel excavation

The 1983 flood water level was estimated for the conditions with two cases of channel excavation. Under excavation - 1 (with excavation) the river bed of the low water channel is excavated to El. 737.0 m at Porto Vitoria (BAT-1B) and 738.4 m at União da Vitoria (13.GPF) with average river bed gradient of about 1: 20,000. Under excavation - 2 (with large excavation) the river bed is excavated to El. 735.0 m at Porto Vitoria (BAT-1B) and 736.5 m at União da Vitoria (13.GPF) with average river bed gradient of about 1: 20,000. The cross sections BAT-1B and 13.GPF are shown in Figure - 7.8.

The used cross section number and the result for the case with reservoir water level 742 m are shown in Table-7.9. The summary of the results for the reservoir water level from 739 m to 744 m is shown in Table-7.8. It lindicates that the excavation of the low water channel in the stretch from Porto Vitoria (PV3-78) to União da Vitoria (17.GPF) does not contribute effectively to reduction of flood water level in União da Vitoria because flow areas of the low water channel is relatively small in comparison to those of the high water channel (flood plain) during a large flood. The effect of excavation does not reach to Fluviopolis and São Mateus do Sul due existence of many rock drops in the low water channel in the stretch. The calculated 1983 water levels (reservoir water level 744 m and 742 m) and the bottom excavation line are shown in Figure-7.9.

The foregoing calculation results infer that there are three key factors to cause large flood inundation in the stretch from Porto Vitoria to São Mateus do Sul:

a) The flood discharge is extremely large comparing to the flow area of the channel of the Iguaçu river.
b) The gradient of river bed in this stretch is very low (1 : 10,000 to 20,000).
c) There are many sections where their high river bed elevation interrupts discharge of flood in this stretch.

The reservoir operation of Foz do Areia will be required to be continued carefully taking into consideration of these characteristics in the future too.

7.2 Master Plan for Tibagi River Basin

7.2.1 Planning Criteria

Within the context of the goal and principle of water excess management of the Strategy the flood control model areas and design standard for the Master Plan are established as set out below.

(1) Model areas

Model areas are designated in the Iguaçu river basin as shown below, but no model area is designated in the Tibagi river basin, because the flood damage in these areas is minor though some flood inundation is reported in the municipalities of Irati, Ivai and Ipiranga.

<u>Iguaçu River Basin</u>
Region-1: Curitiba Metropolitan area
Region-2: Porto Amazonas, São Mateus do Sul
Region-4: União da Vitoria
Region-5: Rio Negro
Region-6: Foz do Iguaçu

(2) Flood Plain Management and Urban Storm Water Management

Non-structural measures are to be primarily employed for the flood prone areas in the municipalities in the Tibagi river. Integrated view of urban sewage, flood protection, storm drainage and environmental protection may be necessary for the urban area in the future after the year 2006. Environmental protection includes waste disposal control, water quality control, protection of aqua-ecosystem, and protection of riverine landscape.

(3) Design Standard

The flood control (or protection) level for zoning must be determined appropriately taking into consideration of social significance of damage level and efficiency of benefit and cost with the principle of risk and benefit for the municipalities in the Tibagi river basin.

7.2.2 Non-structural Measures

(1) General

Zoning for land use control is the most effective measures for all the flood prone areas in and around the urban areas in Paraná State (Region -1 to 8). Zoning and resettlement are a tandem for implementation and have been widely applied in the municipalities in the Iguaçu river basin, and Irati in the Tibagi river basin. Resettlement includes relocation of illegal residents occupying the river regime and legal residents in the flood prone areas.

The existing flood forecasting and warning system (FFWS) is planned to be upgraded by the provision of the new lightening censoring and rainfall monitoring system under SIMEPAR. This upgraded system will provide basic warning information required for rescue activities for the time being. This system will be necessary to be upgraded for a basin wide real time flood management and operation to avoid artificial flood disaster in the future when number of water rescues and flood control facilities is increased significantly.

Flood proofing such as elevating ground level and structures is effective for some locally inundated areas.

Review of the operation rule of the existing and planned dams and reservoirs will be necessary taking flood control function into consideration for the integrated and effective operation in the Tibagi river in the future.

(2) Master Plan

There was a report of flood inundation in 1983 in the municipalities of Irati, Ipiranga and Ivai in the Tibagi river basin. However the damage of these municipalities was assessed to be rather light in accordance with the reconnaissance by the study team done in 1994 and 1995. Therefore, the Master Plan for the Tibagi river basin is limited to non-structural measures by zoning for land use control with resettlement and parks only as shown below.

Municipality	Non-Structural Measures	1st Stage Present - 2005	2nd Stage 2006 - 2015 onward
Irati	Zoning	Improvement of present method	Improvement of Present method
	Evacuation	Extension of Present method	Improvement of Present method
Ipiranga	Zoning	Improvement of present method	Improvement of Present method
	Evacuation	Extension of Present method	Improvement of Present method

CHAPTER 8 FUTHER STUDY REQUIREMENT

The following studies are recommended to be conducted for the municipalities where some flood control structural measures are expected to be necessary in the future:

a) Curitiba Metropolitan Area; feasibility study on the prospective multipurpose dams such as Piraquara II, Pequeno and Alto Miringuava
b) São Mateus do Sul; prefeasibility study and feasiblity study on non-structural and structural measures
c) União da Vitoria; feasibility study on combination of zoning and structural measures
d) Morretes; prefeasibility study and feasibility study on possible flood control measures

TABLES

Table 2.1 Number of People Affected by Historic Floods in Parana State

Municipality	1980	1981	1982	1983	1984	1986	1987	1988	1989	1990	1991	1992	1993
Uniao da Vitoria	1151		*3572	30003	140		815					14129	1378
São Mateus do Sul				5800			50		55			970	70
Rio Negro				5502	800				50			5001	
Curitiba	2000	2000	547	5000				500				281	405
Francisco Beltrao				4000								60	
Ivai				3200									
Porto Vitória				3150								130	
Itapejara do Oeste				3000									
Ipiranga				3000									
Irati		4		2892		160	90					700	
Coronel Vivida				2001								50	
São Jose dos Pinhais	1000	1000	4000	2062									300
Piraquara	1000	1000	2038	2000									
Paula Freitas				1500								240	
Porto Amazonas				1301			80		20			352	130
Capanema				1200								400	
Tres Barras do Parana				1200								150	
Ortigueira				1002									
Bituruna				1000								18	
Palmas				700									
Vitorino				600									
Chopinzinho				600								197	
Sao Joao				600									
São Jorge do Oeste				502									
Mangueirinha				500								120	
General Carneiro				500								12	
Cruz Machado				500								1140	
Araucaria				500									
Candido de Abreu				400									
Reboucas				350								450	
Dois Vezinhos				340								305	
Quitandinha				300								228	
Alto Piquiri				250									
Imbituva				252									
Balsa Nova				241									
Veré				240								120	
Campo Tenente				200								240	
Castro				200									
Paulo Frontim				200								42	
Pien				200									
Mariópolis				102									
Mallet				50								278	
Colombo	400	400											600
Santa Mariana										7660			
Cambará											2000		
Foz do Iguacu												830	
Atonia		80											
Marilena		200											
Sao Pedro de Parana		230									75		
Porto Rico		350											
Laranjeiras do Sul							100						
Capitao L. Marques												239	
Guarapuava												587	
Suliria												90	
Rio Azul												50	
Lapa												200	
N. Prata Iguacu												150	
Pinhais													400
Salto do Lontra												10	
Realeza												12	

Source: CIVIL DEFENSE,

Note: The data represent the total number of people affected by floods (total of dislodged, injured, and dead).

* In two flood events, June and November 1982

Table 2.2 Number of People Dislodged by Flood inundation of January-February 1995

Location	Number of People Dislodged
Curitiba	11,300
Sao Jose dos Pinhais	10,000
Pinhais	20,000
Piraquara	3,000
Campo Largo	20
Araucaria	150
Campo Grande do Sul	1,000
Sao Mateus do Sul	600
Porto Amazonas	400
Guarapuava	160
A. Tamandare	150
Jacarezinho	32
Castro	40
Uniao da Vitoria	2,410
Morretes	1,500

Source: Civil Defense,1995

Table 2.3 Maximum Annual Water Level in the Parana River downstream of ITAIPU dam

Order of Magnitude	Date	Location of measuring point	
		*Section R-11	Amistad Bridge
2	13-Jul.-83	126.71	127.47
9	11-Jan.-84	110.55	111.88
11	17-Feb.-85	109.24	110.48
12	22-May-86	107.54	108.52
4	22-May-87	121.05	121.79
7	25-May-88	110.99	111.59
6	15-Sep.-89	116.27	116.92
3	27-Jan.-90	121.49	122.79
10	13-Apr.-91	110.51	111.84
1	31-May-92	126.75	127.70
5	04-Oct.-93	117.31	118.32
8	23-Jun.-94	110.90	111.93

Source: ITAIPU Binational

Note: *Located down stream of the confluence of Iguacu and Parana rivers

Table 2.4 Monetary Damage Caused by the Flood Inundation of 1983, 1992 and 1993 in Uniao da Vitoria and Porto Uniao

ITEMS	Sum of Losses of Uniao Vitoria and Porto Uniao		
	1983	1992	1993
Number of Houses and Building Flooded	7,537	5,266	2,502
Emergency Relief			
Dislodging and Re-lodging	60,330	39,285	20,040
Meals	1,456,767	1,097,337	92,096
Medicine	1,181	1,185	618
Repairing of Roads and Bridges	3,235,318	168,630	107,890
Damages to Water Supply System	144,317	206,267	106,221
Damages to Energy distribution System	945,020	400,694	31,116
Repairing of Houses and Buildings	15,074,000	10,532,000	5,004,000
Residential Furniture and other Goods	6,878,480	4,709,530	na
Losses of Goods by the Commercial Sector	10,640,000	3,718,400	18,406
Losses suffered by Industries	12,225,346	5,026,664	2,487,685
Agriculture and Livestock	1,308,395	3,076,260	520,265
Others	105,165	435,034	65,340
TOTAL (US $)	52,074,319	29,411,286	8,453,677

Source: Municipal Comission of Civil Defense of respective municipalities and CORPRERI, 1994

Note: Monetary value are in US $ at price level of July 1993 na : not available

Table 2.5 Partial Monetary Damage Caused by Flood Inundation of 1983 in Curitiba City

Place Affected	Houses Flooded	Partial Estimate of Monetary Losses		
		Repair of Houses	Movable Goods	Reconstruction of Public Infrastructures
CURITIBA CITY Total	2065	US $ 1,608,600	US $ 1,032,500	US $ 5,759,103
Low Boqueron Sector	1335			
Cajuru Sector	171			
Barrio Alto Sector	132			
Santa Candida Sector	44			
Vila Diana Sector	65			
Barigui Sector	318			
Total Manetary Damage				US $ 8,400,203

Source: Institute of Investigation and Planning of Urban CURITIBA (IPPUC), 1983

Monetary value are in US $ at price level of July 1993

Table 2.6 Partial Monetary Damage Caused by Flood of 1983 in Metropolitan Cities Except Curitiba

Municipality Affected	Number of Houses Flooded	Monetary Losses Including Repair of houses and Infrastructure
PIRAQUARA Municipality	1331	10,721,763
SAO JOSE DOS PINHAIS	2986	2,991,215
ARAUCARIA	195	316,323
BALSA NOVA	56	172,540
Tota Monetary Damage		14,201,841

Source: COMEC Monetary value are in US $ at price level of June 1993

Table 2.7 Partial Monetary Damage Caused by Flood of 1993 in Curitiba City

Place Affected	Houses Flooded	Partial Estimate of Monetary Losses		
		Repair of Houses	Movable Goods	Reconstruction of Public Infrastructures
CURITIBA CITY Total	1,220	US $ 2,355,000	US $ 650,450	US $ 4,402,136
Boa Vista Sector	310			
Cajuru Sector	300			
Portao Sector	550			
Santa Felicidade Sector	60			
Total Monetary Damage				US $ 7,407,586

Source: Institute of Investigation and Planning of Urban CURITIBA (IPPUC)

Monetary value are in US $ at price level of July 1993

Table 2.8 Partial Monetary Damage Caused by Flood Inundation of January 1995 in some Municipalities of the Metropolitan Area

Type of Damage	Monetary Damage
Emergency Relief	587,349
Rehabilitation of Road and Drainage infrastructure	6,060632
Total	6,647,981

source: COMEC, 1995 Monetary value are in US $ at level of February 1995

Note: Include only the municipalities of Sao Jose dos Pinhais, Pinhais, Piraquara and Campina Grande do Sul

Table-2.9 Estimated Unit Flood Damage Value as function of Number of Inundated Houses

Unit: US $/House Flooded

ITEMS	Uniao da Vitoria	Rio Negro	Porto Amazonas	Foz do Iguacu	Curitiba MR	Morretes	Sao Mateus
Characteristics of Inundation and Flood Prone Area							
Relative Inundation Depth inside houses	Very High	Very High	High	Medium	Low	Low	Medium
Maximum Number of Inundation days	2 months	2 weeks	2 weeks	1 week	1 week	1 day	2 weeks
Relative economic activities and propieties value within the Flood Prone Area	High	High/Low	Medium/Low	Low	Medium/Low	Medium	Medium/Low
Estimated Unit Damage Value							
Emergency Relief	350	150	150	100	100	50	150
Repairing of Roads and Bridges	350	200	200	100	200	100	200
Damage to Water Supply System	60	60	60	25	60	25	60
Damage to Energy distribution System	80	80	80	50	80	50	80
Repairing of Houses and Buildings	2500	2000	2000	1000	1000	1000	2000
Residential Furniture and other Goods	1200	750	750	500	500	750	750
Losses of Goods by the Commercial Sector	1100	900	900	500	500	500	900
Losses suffered by Industries	1200	800	800	500	800	500	800
Damage to Agriculture and Livestock	350	350	350	100	100	100	350
Others Direct Monetary Damage	70	70	35	35	70	35	70
Indirect Damages as % of Direct Damages	50%	50%	50%	50%	50%	50%	50%

Source: Own estimation based on available data and field Survey

Table-2.10 Estimated Flood Inundation Damage for Curitiba Metropolitan Region

Items					
Flood Inundation Level similar to that of Year	Interpolated	Interpolated	1993	1983	1995
Flooding Water Level (m.a.s.l)	(no clarified)	(no clarified)	(no clarified)	(no clarified)	(no clarified)
Number of Houses and Buildings Affected	1750	3000	3950	6633	8800
Estimated Monetary Damage					
Emergency Relief	175,000	300,000	395,000	663,300	880,000
Repairing of Roads and Bridges	350,000	600,000	790,000	1,326,600	1,760,000
Damage to Water Supply System	105,000	180,000	237,000	397,980	528,000
Damage to Energy distribution System	140,000	240,000	316,000	530,640	704,000
Repairing of Houses and Buildings	1,750,000	3,000,000	3,950,000	6,633,000	8,800,000
Residential Furniture and other Goods	875,000	1,500,000	1,975,000	3,316,500	4,400,000
Losses of Goods by the Commercial Sector	875,000	1,500,000	1,975,000	3,316,500	4,400,000
Losses suffered by Industries	1,400,000	2,400,000	3,160,000	5,306,400	7,040,000
Damage to Agriculture and Livestock	175,000	300,000	395,000	663,300	880,000
Others Direct Monetary Damage	122,500	210,000	276,500	464,310	616,000
Subtotal	5,792,500	9,930,000	13,074,500	21,955,230	29,128,000
Indirect Damage (50% of Direct Damage)	2,896,250	4,965,000	6,537,250	10,977,615	14,564,000
Total Estimated Monetary Damage US $	8,688,750	14,895,000	19,611,750	32,932,845	43,692,000

Table-2.11 Estimated Flood Inundation Damage for Uniao da Vitoria-Porto Uniao Area

Items					
Flood Inundation similar to that of Year	1982	1993	1992	1983	(Extrapolated)
Flooding Water Level (m.a.s.l)	746.06	746.86	748.51	750.03	
Number of Houses and Buildings Affected	1000	2502	5266	7537	8500
Estimated Monetary Damage					
Emergency Relief	350,000	875,700	1,843,100	2,637,950	2,975,000
Repairing of Roads and Bridges	350,000	875,700	1,843,100	2,637,950	2,975,000
Damage to Water Supply System	60,000	150,120	315,960	452,220	510,000
Damage to Energy distribution System	80,000	200,160	421,280	602,960	680,000
Repairing of Houses and Buildings	2,500,000	6,255,000	13,165,000	18,842,500	21,250,000
Residential Furniture and other Goods	1,200,000	3,002,400	6,319,200	9,044,400	10,200,000
Losses of Goods by the Commercial Sector	1,100,000	2,752,200	5,792,600	8,290,700	9,350,000
Losses suffered by Industries	1,200,000	3,002,400	6,319,200	9,044,400	10,200,000
Damage to Agriculture and Livestock	350,000	875,700	1,843,100	2,637,950	2,975,000
Others Direct Monetary Damage	70,000	175,140	368,620	527,590	595,000
Subtotal	6,910,000	17,288,820	36,388,060	52,080,670	58,735,000
Indirect Damage (50% of Direct Damage)	3,455,000	8,644,410	18,194,030	26,040,335	29,367,500
Total Estimated Monetary Damage US $	10,365,000	25,933,230	54,582,090	78,121,005	88,102,500

Table-2.12 Estimated Flood Inundation Damage for Rio Negro-Mafra Area

Items			
Flood Inundation Level similar to that of Year	1984	1992	1983
Flooding Water Level (m.a.s.l)	776.09	780.4	780.64
Number of Houses and Buildings Affected	400	2000	2200
Estimated Monetary Damage			
Emergency Relief	60,000	300,000	330,000
Repairing of Roads and Bridges	80,000	400,000	440,000
Damage to Water Supply System	24,000	120,000	132,000
Damage to Energy distribution System	32,000	160,000	176,000
Repairing of Houses and Buildings	800,000	4,000,000	4,400,000
Residential Furniture and other Goods	300,000	1,500,000	1,650,000
Losses of Goods by the Commercial Sector	360,000	1,800,000	1,980,000
Losses suffered by Industries	320,000	1,600,000	1,760,000
Damage to Agriculture and Livestock	140,000	700,000	770,000
Others Direct Monetary Damage	28,000	140,000	154,000
Subtotal	2,084,000	10,420,000	11,462,000
Indirect Damage (50% of Direct Damage)	1,042,000	5,210,000	5,731,000
Total Estimated Monetary Damage US $	3,126,000	15,630,000	17,193,000

Table-2.13 Estimated Flood Inundation Damage for Sao Mateus do Sul

Items			
Flood Inundation similar to that of Year	1993	1992	1983
Flooding Water Level (m.a.s.l)	760.92	762.06	762.87
Number of Houses and Buildings Affected	15	194	1160
Estimated Monetary Damage			
Emergency Relief	2,250	29,100	174,000
Repairing of Roads and Bridges	3,000	38,800	232,000
Damage to Water Supply System	900	11,640	69,600
Damage to Energy distribution System	1,200	15,520	92,800
Repairing of Houses and Buildings	30,000	388,000	2,320,000
Residential Furniture and other Goods	11,250	145,500	870,000
Losses of Goods by the Commercial Sector	13,500	174,600	1,044,000
Losses suffered by Industries	12,000	155,200	928,000
Damage to Agriculture and Livestock	5,250	67,900	406,000
Others Direct Monetary Damage	1,050	13,580	81,200
Subtotal	78,150	1,010,740	6,043,600
Indirect Damage (50% of Direct Damage)	39,075	505,370	3,021,800
Total Estimated Monetary Damage US $	117,225	1,516,110	9,065,400

Table2.14 Estimated Flood Inundation Damage for Porto Amazonas

Items			
Flood Inundation Level similar to that of Year	1993	1992	1983
Flooding Water Level (m.a.s.l)	760.14	761.52	763.2
Number of Houses and Buildings Affected	30	70	260
Estimated Monetary Damage			
Emergency Relief	4,500	10,500	39,000
Repairing of Roads and Bridges	6,000	14,000	52,000
Damage to Water Supply System	1,800	4,200	15,600
Damage to Energy distribution System	2,400	5,600	20,800
Repairing of Houses and Buildings	60,000	140,000	520,000
Residential Furniture and other Goods	22,500	52,500	195,000
Losses of Goods by the Commercial Sector	27,000	63,000	234,000
Losses suffered by Industries	24,000	56,000	208,000
Damage to Agriculture and Livestock	10,500	24,500	91,000
Others Direct Monetary Damage	1,050	2,450	9,100
Subtotal	155,250	362,250	1,345,500
Indirect Damage (50% of Direct Damage)	77,625	181,125	672,750
Total Estimated Monetary Damage US $	232,875	543,375	2,018,250

Table2.15 Estimated Flood Inundation Damage for Foz do Iguacu Area

Items					
Flood Inundation similar to that of Year			1992		
Flooding Water Level (m.a.s.l)	119	120	126	129	130
Number of Houses and Buildings Affected	5	156	175	217	717
Estimated Monetary Damage					
Emergency Relief	500	15,600	17,500	21,700	71,700
Repairing of Roads and Bridges	500	15,600	17,500	21,700	71,700
Damage to Water Supply System	125	3,900	4,375	5,425	17,925
Damage to Energy distribution System	250	7,800	8,750	10,850	35,850
Repairing of Houses and Buildings	5,000	156,000	175,000	217,000	717,000
Residential Furniture and other Goods	2,500	78,000	87,500	108,500	358,500
Losses of Goods by the Commercial Sector	2,500	78,000	87,500	108,500	358,500
Losses suffered by Industries	2,500	78,000	87,500	108,500	358,500
Damage to Agriculture and Livestock	500	15,600	17,500	21,700	71,700
Others Direct Monetary Damage	175	5,460	6,125	7,595	25,095
Subtotal	14,050	438,360	491,750	609,770	2,014,770
Indirect Damage (50% of Direct Damage)	7,025	219,180	245,875	304,885	1,007,385
Total Estimated Monetary Damage US $	21,075	657,540	737,625	914,655	3,022,155

Table2.16 Estimated Flood Inundation Damage for Morretes

Items			
Flood Inundation similar to that of Year	1969	1995	Extrapolated
Flooding Water Level (m.a.s.l)	5.87	5.1	6.5
Number of Houses and Buildings Affected	1000	1925	2100
Estimated Monetary Damage			
Emergency Relief	50,000	96,250	105,000
Repairing of Roads and Bridges	100,000	192,500	210,000
Damage to Water Supply System	50,000	96,250	105,000
Damage to Energy distribution System	50,000	96,250	105,000
Repairing of Houses and Buildings	1,000,000	1,925,000	2,100,000
Residential Furniture and other Goods	750,000	1,443,750	1,575,000
Losses of Goods by the Commercial Sector	500,000	962,500	1,050,000
Losses suffered by Industries	500,000	962,500	1,050,000
Damage to Agriculture and Livestock	100,000	192,500	210,000
Others Direct Monetary Damage	35,000	67,375	73,500
Subtotal	3,085,000	5,938,625	6,478,500
Indirect Damage (50% of Direct Damage)	1,542,500	2,969,313	3,239,250
Total Estimated Monetary Damage US $	4,627,500	8,907,938	9,717,750

Table-3.1 Summary of Probable Peak Discharge at Typical Discharge Reference Points Estimated by Gumbel's Method

Unit : m³/s

River Basin	No.				Period	Catchment Area (km²)	Return Period 10	50	100
Itarare: Jaquariavia	1	64-242-000		Tamandua	1976-1993	1,622	646.0	998.6	1,147.7
Cinzas	2	64-360-000		Tomazina	1931-1993	2,015	477.3	692.6	783.9
	3	64-370-000		Andira	1931-1993	5,622	1,134.8	1,614.2	1,816.9
Tibagi	4	64-444-000		Uvaia	1974-1993	4,450	614.4	864.8	970.7
	5	64-465-000		Tibagi	1931-1993	8,948	1,317.4	1,891.5	2,134.1
	6	64-491-000	*1)	Barra Rib das Antas	1934-1993	15,600	2,313.1	3,268.9	3,673.0
	7	64-507-011		Jataizinho (Extendido)	1931-1993	21,955	4,000.9	5,824.1	6,594.9
Pirapo	8	64-550-000		Vila Silva Jardim	1967-1993	4,627	521.2	705.6	783.6
Ivai	9	64-625-000		Tereza Cristina	1957-1992	3,572	1,753.0	2,431.0	2,717.6
	10	64-645-000		Porto Espanhol	1965-1993	8,600	3,010.2	4,144.2	4,623.6
	11	64-675-002		Porto Bananeiras	1974-1993	24,200	5,428.1	7,072.2	7,767.2
	12	64-685-000		Porto Paraiso do Norte	1953-1993	28,427	5,621.3	7,383.9	8,129.0
	13	64-693-000		Novo Porto Taquara	1974-1993	34,432	6,121.1	7,874.8	8,616.3
Piquiri	14	64-771-500		Porto Guarani	1976-1993	4,223	2,316.4	3,020.5	3,318.2
	15	64-795-000	*2)	Porto do Piquiri	1970-1993	11,303	5,894.9	8,000.4	8,890.5
	16	64-820-000		Porto Formosa	1966-1993	17,500	5,403.3	7,456.4	8,324.4
	17	64-830-000	*2)	Balsa do Santa Maria	1969-1993	20,982	5,305.5	7,036.2	7,767.9
Iguacu:	18	65-010-000		Fazendinha	1955-1993	110	NU	NU	NU
Iguacu	19	65-025-000		Guajuvira	1976-1993	2,304	491.4	746.7	854.7
	20	65-035-000		Porto Amazonas	1935-1993	3,662	558.7	793.2	892.4
	21	65-060-000		Sao Mateus do Sul	1930-1993	6,065	724.3	1,025.3	1,152.6
	22	65-310-000		Uniao da Vitoria	1930-1993	24,211	2,659.9	3,711.5	4,156.1
	23	65-895-002		Salto Osorio	1940-1993	45,824	10,438.5	15,829.2	18,108.1
	24	65-993-000		Salto Cateratas	1926-1993	67,317	18,088.6	26,676.0	30,590.9
Negro	25	65-175-000		Divisa	1964-1993	7,970	NU	NU	NU
Timbo	26	65-260-000		Foz do Cachoeira	1974-1993	693	283.1	422.5	481.6
Jordao	27	65-825-000		Santa Clara	1949-1993	3,913	1,408.3	2,103.6	2,397.9
Chopin	28	65-960-000		Aguas do Vere	1956-1993	6,696	2,971.8	4,354.6	4,939.2
Ribeira	29	81-200-000		Capela do Ribeira	1936-1993	7,252	1,216.2	1,707.4	1,915.1
Litoranea: Nhundiaquara	30	82-170-000		Morretes	1938-1993	217	180.4	240.8	266.4
Marumbi	31	82-195-002		Morretes	1975-1993	53	93.4	127.0	141.2

Note: *1) : The data period from 1947 to 1973 are not available.

*2) : These results are not accurate enough, because of the data source.

NU : Not used. SOURCE: COPEL

Table-4.1 Assessment of Flood Damage by Region in Paraná State

River Basin	Region	Degree of Flood Damage	Main Related Issues
Iguaçu river	From region 1 to region 5	4 for the entire basin	Resettlement, reservoirs operation
	Region 1 (Curitiba metropolitan area)	4	Resettlement
	Region 2 (São Mateus do Sul)	4	Resettlement
	Region 3 (Reboucas area)	2	Resettlement
	Region 4 (União da Vitoria)	5	Reservoir operation of Foz do Areia dam; Zoning and Resettlement
	Region 5 (Rio Negro area)	5	Resettlement
	Region 8 (Capanema)	2	Resettlement
Paraná river	Region 6 (Foz do Iguacu area)	3 for the entire basin	Resettlement, reservoirs operation related to ITAIPU dam, and those dams on Iguaçu river
	Upstream of ITAIPU dam	2	Resettlement
Costal basin	Region 7 (Morretes area)	3	
Ivai river		1 for the entire basin	
Tibagi river		1 for the entire basin	
Others	Itarraré, Cinzas, Pirapó, Piquiri, Ribeira, Paranapanema	1 for all these basins	

Note : The degree of flood damage are classified as follows:
Degree 5 is serious damage; Degree 4 is high level of damage;
Degree 3 is medium level of damage; Degree 2 is low level;
Degree 1 is negligible level; and Degree 0 is no damage.

Table- 4.2 Assessment of Flood Damage by Basin in Parana State

River Basin	Degree of Flood Damage	Management Issues
IGUACU	High level of significance	1) Resettlement of resident in river regime and flood prone areas 2) Zoning for restricted areas and preservation parks 3) Operation of existing reservoirs 4) Flood forecasting, warning, evacuation, and rescue activities 5) Establishment of institution in charge of flood management 6) Implementation of flood control projects
PARANA	Medium level of significance	Measures as 1), 2), 3), 4), and 5) above
IVAI	Negligible level of significance	Flood forecasting, warning, evacuation, and rescue activities
TIBAGI	Negligible level of significance	Flood forecasting, warning, evacuation, and rescue activities
Litoranea	Medium level of significance	Measures as 1), 2), 3), 4), and 5) above
Others	Negligible	Flood forecasting, warning, evacuation, and rescue activities

Table-6.1 Proposed Non-structural Flood Control Measures and Implementation Schedule for Paraná State

Region	Municipalities	Non-Structural Measures	1st Stage Present - 2005	2nd Stage 2006-2015 onward
1.	Curitiba Metropolitan Region	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	Δ	Δ
		•Proofing	Δ	Δ
		•Operation Rule	Δ	O
2.	São Mateus do Sul	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
	Porto Amazonas	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
3.	Rebouças, Guarapuava Irati, Ipiranga	•Zoning	-	-
		•FFWS	Δ	Δ
		•Evacuation	-	Δ
4.	União da Vitória	•Zoning	Δ	Δ
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
		Operation Rule	Δ	O
5.	Rio Negro	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
6.	Foz do Iguaçu	•Zoning	Δ	Δ
		•FFWS	Δ	O
		•Evacuation	Δ	Δ
		•Proofing	Δ	Δ
		•Operation Rule	Δ	O
7.	Morretes	•Zoning	Δ	Δ
		•FFWS	-	-
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
8.	Capanema	•Zoning	-	-
		•FFWS	-	-
		•Evacuation	-	Δ

Notes

(1) Zoning = zoning for land use control with resettlement and parks;
FFWS = Flood Forecasting and Warning Systems ; Evacuation = evacuation and rescue activities;
Proofing = raising of ground level and buildings, etc.; Operation Rule = operation rule for reservoirs, flood control facilities, etc.

(2) - = Extention of present method; Δ = Improvement of present method; O = Employment of new concept

Table-6.2 Proposed Structural Measures and Implementation Schedule for Flood Control

Region	Municipality	Structural Measures	Project Cost (US$ 10^6)	Implementation Schedule 1st Stage Present - 2005	Implementation Schedule 2nd Stage 2006 - 2015 onward
1.	Curitiba Metropolitan Area	Continuation of PROSAM - 15 km long channel excavation (about 1.3 million m^3); - landscape restoration and park development of river bank area; - Irai dam for flood control and to guarantee 1.8 m^3/s to Curitiba water supply; - relocation and resettlement of 1,400 houses located in risky areas including occupying river flood plains; - expropriation of 7,000 plots of land and rights needed for environment protection along rivers and environmentally sensitive areas;	Total 34.3 excluding Irai dam (1992 price)	O	-
		Extension of PROSAM - channel excavation by Curitiba municipality - Piraquara II, Pequeno, Alto Miringuava dams for water supply with flood control function	NA	O Δ	O
2.	Sao Mateus do Sul	Dike system with a sluice	11.1	-	O
4.	Uniao da Vitoria	Dike system with sluices	85.9	O	
7.	Morretes	channel improvement and dike	NA	Δ	O

Note : Δ : Partial Operation O : Full operation NA : Not available in this study phase

Table-6.3 Example of Rational Methods of Flood Control Planning and Measures (1/2)

Nation	Law Concerning Flood Control	Structural Measures & Assessment	Non-Structural Measures & Assessment	Basin Development & Flood Control Level
Austria	• Federal law concerning water use right (1959) • Federal law concerning assistance to construction of water use facilities	• Priority on river improvement of the rivers experiencing large flood damage • Flood control plan varies with adjustment of demand of people	• No permission of development of flood prone areas • Disaster fund • automatic water level gauging at major sites	• Human life and properties with high cultural and economic value (1/100) • Transportation facilities depends importance and damage valve • Agricultural land depends risk level
Russia	• Basic laws for water	• Multipurpose reservoir, dike • Comprehensive federal plan for water use and flood control	• Identification of dangerous inundation areas • (National insurance)	• Minimization of total amount of investment (1/5~1/100)
France	• River law • Domestic navigation law	• Optimum improvement with traditional and modern technologies and calculations • Multipurpose dam	• Atomization of flood warning system • Rainfall radar	• Benefit shall be larger than investment
Greece	• No information	• Dike, dam, reservoir, drainage	• No information	• Urban (1/1,000) Industrial land (1/100) Agricultural land (1/50)

Source : United Nations, "Rational Methed of Flood Control Planning in River Basin Development," 1976.

Table-6.3 Example of Rational Methods of Flood Control Planning and Measures (2/2)

Nation	Law Concerning Flood Control	Structural Measures & Assessment	Non-Structural Measures & Assessment	Basin Development & Flood Control Level
USA	• 1936 law (Flood control of navigable rivers, flood control against hurricane, flood insurance, official announcement of flood inundation areas)	• Continuous investment since 1936	• Flood inundation area map • Flood forecasting and warning system	• Implementation based on the effectiveness of flood control facilities (flood damage reduction)
Rumania	• Water law (1974)	• Dike, multipurpose dam, afforestation and watershed management	• Identification of flood inundation area (by special law) • Flood forecasting and warning system is effective for very large rivers	• Determination by cost-benefit analysis depending on importance of society and economic facilities
Japan	• River law • Manual for river works	• Comprehensive flood control plan (dike, multipurpose dam, retarding basin, flood way)	• Comprehensive flood control plan with structural measures	• Flood control level is determined based on social significance and necessity of the region (generally 1/100~1/200)

Source : United Nations, "Rational Methed of Flood Control Planning in River Basin Development," 1976.

Table-7.1 Proposed Non-structural Flood Control Measures and Implementation Schedule for Iguaçu River Basin

Region	Municipalities	Non-Structural Measures	1st Stage Present - 2005	2nd Stage 2006-2015 onward
1.	Curitiba Metropolitan Region	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	Δ	Δ
		•Proofing	Δ	Δ
		•Operation Rule	Δ	O
2.	São Mateus do Sul	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
	Porto Amazonas	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
3.	Rebouças, Guarapuava Irati, Ipiranga	•Zoning	-	-
		•FFWS	Δ	Δ
		•Evacuation	-	Δ
4.	União da Vitória	•Zoning	Δ	Δ
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
		Operation Rule	Δ	O
5.	Rio Negro	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
6.	Foz do Iguaçu	•Zoning	Δ	Δ
		•FFWS	Δ	O
		•Evacuation	Δ	Δ
		•Proofing	Δ	Δ
		•Operation Rule	Δ	O
8.	Capanema	•Zoning	-	-
		•FFWS	-	-
		•Evacuation	-	Δ

Notes

(1) Zoning = zoning for land use control with resettlement and parks;
FFWS = Flood Forecasting and Warning Systems ; Evacuation = evacuation and rescue activities;
Proofing = raising of ground level and buildings, etc.; Operation Rule = operation rule for reservoirs, flood control facilities, etc.

(2) - = Extention of present method; Δ = Improvement of present method; O = Employment of new concept

Table-7.2 Proposed Structural Measures and Implementation Schedule for Iguaçu River

Region	Municipality	Structural Measures	Project Cost (US$ 10^6)	Implementation Schedule			
				1st Stage		2nd Stage	
				1996 ~ 2000	2001 ~ 2005	2006 ~ 2010	2011 ~ 2015
1.	Curitiba Metropolitan Area	Continuation of PROSAM	Total 34.3 (1992 price)				
		Extension of PROSAM - channel excavation by Curitiba municipality - Piraquara II, Pequeno, Alto Miringuava dams with flood control function	Not Available				
2.	São Mateus do Sul	Dike system with a sluice	11.1				
4.	União da Vitoria	Dike system with sluices	85.9				

Table-7.3 Historic Peak Flood Discharges at União da Vitoria 1891-1995

	year	Peak Flood Discharge m3/s	Return Period years
1	1983	4,980	122.59
2	1891	4,030	61.30
3	1905	3,900	40.86
4	1992	3,810	30.65
5	1911	3,440	24.52
6	1935	3,270	20.43
7	1957	2,680	13.88
8	1993	2,640	11.49
9	1971	2,430	9.80
10	1954	2,400	8.55
11	1938	2,380	7.58
12	1995	2,340	6.81
13	1946	2,330	6.18
14	1982	2,160	5.66
15	1990	2,110	5.21
16	1987	2,080	4.84
17	1955	1,980	4.51
18	1984	1,850	4.22
19	1932	1,830	3.97
20	1972	1,830	3.75
21	1981	1,800	3.55
22	1989	1,800	3.37
23	1947	1,780	3.21
24	1961	1,780	3.06
25	1973	1,760	2.93
26	1939	1,720	2.81
27	1975	1,710	2.69
28	1988	1,680	2.59
29	1980	1,640	2.49
30	1950	1,610	2.40
31	1979	1,560	2.32
32	1953	1,550	2.24
33	1970	1,500	2.17
34	1965	1,470	2.10
35	1931	1,450	2.04
36	1948	1,440	1.98
37	1976	1,420	1.92
38	1937	1,400	1.87
39	1966	1,400	1.81
40	1994	1,300	1.77
41	1969	1,290	1.72
42	1941	1,270	1.68
43	1936	1,240	1.64
44	1956	1,230	1.60
45	1945	1,220	1.56
46	1967	1,210	1.52
47	1986	1,210	1.49
48	1942	1,200	1.46
49	1951	1,190	1.43
50	1991	1,100	1.40
51	1952	1,090	1.37
52	1960	1,090	1.34
53	1963	1,050	1.31
54	1977	1,050	1.29
55	1958	1,030	1.27
56	1974	1,020	1.24
57	1962	1,000	1.22
58	1944	956	1.20
59	1964	914	1.18
60	1943	902	1.16
61	1933	836	1.14
62	1934	820	1.12
63	1978	816	1.10
64	1959	804	1.08
65	1949	800	1.06
66	1968	745	1.05
67	1985	734	1.03
68	1940	568	1.02

Table-7.4 6-10 Day Rainfall by Thiessen Method for Upstream of União da Vitoria

	6 days	7 days	8 days	9 days	10 days
1941	118.7	126.6	131.6	143.8	171.6
	102.5	109	116.7	130	152.8
	81.4	83	105.9	111.4	113.2
	93	95.2	105.9	106	106.1
	115.6	124.8	127.3	133.1	134.9
	163	174.3	185	193.6	200.6
	137.8	145.3	167.9	178.1	183.5
	102.4	114.9	124.5	134.3	142.2
	111.4	118	120.5	120.7	121.6
	130.8	132.1	134.7	139.2	144
	152.6	176.3	182.4	184.5	185.8
	114.3	114.3	114.3	123.7	136.1
	95.3	108.5	110	110.6	123.1
	191.6	204.7	219.2	238.9	252
	141	142.2	147.1	166.5	171
	106.7	120.1	128.5	135.2	144.2
	168.3	171.6	174	178.4	182.4
	79	82.4	94	106.6	127.4
	78.6	90.5	94.9	95	95
	124.5	127.2	127.3	127.3	127.4
	127.2	141.4	153.7	153.9	154.4
	99.5	100.8	101.7	104.5	109.9
	122	129.2	132.7	134.3	145.3
	113.1	119.8	120.4	123.6	127.7
	115.5	118.6	128.9	138.6	146.2
	94.1	103.7	111.7	118.9	122.4
	84.1	90.9	94	105.4	109.2
	113.8	131.7	142.6	149.9	154.1
	114.6	114.6	115.5	118	131.7
	172	173.5	178.4	202.1	216.2
	100.6	105	107.7	107.8	108.1
	131.9	132.7	154.9	172.4	179.3
	110.3	111.4	120.1	133.5	135,.
	101.6	104.9	106.8	106.9	106.9
	134.1	135.1	135.8	135.9	135.9
	98.7	108.5	112.7	114.7	123
	110.4	118.5	125.1	133.2	137.3
	79.8	94.3	101.9	116.4	122.5
	176	189.1	194.5	200.5	203.6
	144.4	150.4	151.7	161.3	177.9
	80.5	122.2	127.1	127.7	145.9
	155.9	162.2	171.5	172.7	179.2
	319	354.6	380.2	383.7	383.8
	163.5	176.2	176.4	176.9	176.9
	91.6	94.1	103.5	112.6	116.4
	108.2	108.3	116.4	137	140.9
	149.6	159.1	164.8	199	204.2
	106.4	130.9	131.5	131.6	131.7
	161.8	169.5	175.7	177.3	177.4
	178.2	179.6	179.6	190.7	194
	127.7	128.8	134.8	139	142.3
	321.3	323.3	323.6	364	369.9
	179.6	183.1	184.2	203.8	222.6
	93.6	93.8	93.9	96.8	105.3
1995	171.8	192.5	197.6	203.4	214

Station	Thiessen Weight
1) Porto Amazonas	0.08
2) Rio da Varzea dos Limas	0.14
3) Curitiba	0.10
4) Sao Mateus do Sul	0.25
5) Rio Negro	0.23
6) Uniao da Vitoria	0.20
	1.00

Source: COPEL

XMED	130.2	138.4	144.8	152.8	159.3
S	47.9	50.1	51.4	54.9	55.2
C.VAR.	.3681	.3619	.3552	.3596	.3464
C.ASS	2.338	2.470	2.622	2.504	2.355

Table-7.5 Frequency Analysis of 6-10 day Rainfall Upstream of Uniao da Victoria

Return Period	6 days	7days	8 days	9 days	10 days
2	115.5	123.1	129.0	136.0	142.4
5	159.4	169.0	176.1	186.3	193.0
10	192.6	203.7	211.8	224.4	231.3
20	225.8	238.4	247.4	262.5	269.6
25	236.5	249.6	258.9	274.7	281.9
30	245.3	258.7	268.3	284.8	292.0
50	269.7	284.3	294.5	312.8	320.2
100	303.0	319.0	330.2	350.9	358.4
500	380.1	399.6	413.0	439.3	447.3
1000	413.3	434.4	448.6	477.4	485.6
10000	523.6	549.7	567.0	603.9	612.7

SOURCE: COPEL

AJUSTE DA DISTRIBUICAO EXPONDENCIAL AOS DADOS					
PARAMETROS ESTIMADOS PELO METODO DOS MOMENTOS					
	6 days	7 days	8 days	9 days	10 days
XMED	130.1982	138.2436	144.7873	152.8145	159.3836
S	47.92067	50.09318	51.42868	54.94634	55.21326
BETA	47.92067	50.09318	51.42868	54.94634	55.21326
ALFA	82.27751	88.33045	93.35859	97.86821	104.1704

Table-7.6 Annual Average Probable Flood Damage

Return Period	Peak Flood Discharge	Annual Mean Prability of Exceedence	Annual Mean Occurrence Probability	Probable Flood Damage at a Event	Average Probable Flood Damage of Two Event	Average Probable Flood Damage	Accumulated Average Probable Flood Damage
year	m3/s			x10 3 USS	x10 3 USS	x10 3 USS	x10 3 USS
1.05	745	0.9524		0			
2	1436	0.5000	0.4524	6,254	3,127	1,415	1,415
5	2079	0.2000	0.3000	12,076	9,165	2,750	4,164
10	2577	0.1000	0.1000	23,894	17,985	1,799	5,963
20	3117	0.0500	0.0500	37,622	30,758	1,538	7,501
30.65(1992)	3810	0.0326	0.0174	54,582	46,102	801	8,302
50	3921	0.0200	0.0126	56,807	55,694	703	9,005
100	4610	0.0100	0.0100	70,679	63,743	637	9,642
122.59(1983)	4980	0.0082	0.0018	78,121	74,400	137	9,779
200	5382	0.0050	0.0032	86,209	82,165	259	10,039

Table-7.7 River Cross Section Number and Calculated Flood Water Level in 1983 and 1992 (1/2)

Original Section name	Section No.	Distance (m)	Accumulated Distance (m)	Average Original River Bed Elevation (m)	Calculated 1983 Water Level (m)	Calculated 1992 Water Level (m)
D1-77	CN011	9230.000	0.000	664.129	744.000	742.000
D2-77	CN021	9230.000	9230.000	676.636	744.001	742.001
D3-77	CN031	12300.000	18460.000	681.506	744.001	742.000
D4-77	CN041	10000.000	30760.000	692.566	744.004	742.000
D5-77	CN051	11540.000	40760.000	701.539	744.003	741.996
PV8-78	CN061	2160.000	52300.000	715.789	744.012	742.003
PV7-78	CN071	3840.000	54460.000	722.196	743.956	741.959
PV6-78	CN081	400.000	58300.000	723.849	744.061	742.049
PV5A-78	CN091	1400.000	58700.000	727.227	744.065	742.052
PV5-78	CN101	1420.000	60100.000	726.772	743.939	741.947
PV4-78	CN111	100.000	61520.000	727.191	744.032	742.039
M1-73	CN121	3040.000	61620.000	731.129	743.805	741.793
PV3-78	CN131	640.000	64660.000	735.357	745.014	743.256
PV2-78	CN141	500.000	65300.000	737.397	745.375	743.735
PV1-78	CN151	70.000	65800.000	740.164	746.637	745.307
BAT-1A	CN152	70.000	65870.000	740.563	746.622	745.312
BAT-1B	CN153	60.000	65940.000	739.703	746.743	745.447
BAT-2	CN154	50.000	66000.000	738.286	746.716	745.439
B3-84	CN161	260.000	66050.000	738.367	746.730	745.458
R5-94	CN171	1200.000	66310.000	737.910	746.759	745.497
R4-94	CN181	300.000	67510.000	741.174	746.939	745.646
M2-73	CN191	690.000	67810.000	741.312	747.011	745.707
UV8-78	CN201	1400.000	68500.000	740.570	747.117	745.835
UV7-78	CN211	1400.000	69900.000	742.092	747.321	746.017
UV6-78	CN221	1600.000	71300.000	743.596	747.505	746.171
M3-73	CN231	1400.000	72900.000	740.348	747.619	746.337
UV5A-78	CN241	300.000	74300.000	743.269	747.634	746.402
R3-94	CN251	300.000	74600.000	742.154	748.296	747.026
UV5-78	CN261	2170.000	74900.000	742.690	748.162	746.910
R2-94	CN271	230.000	77070.000	743.089	748.647	747.330
UV4-78	CN281	1200.000	77300.000	743.125	748.665	747.348
M4-73	CN291	1400.000	78500.000	742.782	748.761	747.445
UV3-78	CN301	1368.559	79900.000	743.316	748.952	747.624
01.GPF	JT011	999.116	81268.559	741.289	749.104	747.778
02.GPF	JT021	232.325	82267.675	741.194	749.203	747.866
UV2-78	CN311	762.845	82500.000	743.346	749.211	747.868
03.GPF	JT031	737.155	83262.845	742.016	749.187	747.866
R1-94	CN321	174.458	84000.000	744.554	749.268	747.935
04.GPF	JT041	725.542	84174.458	741.043	749.295	747.966
M5-73	CN331	308.594	84900.000	744.169	749.374	748.021
05.GPF	JT051	999.700	85208.594	740.880	749.349	748.016
06.GPF	JT061	91.706	86208.294	740.106	749.395	748.062
M6-73	CN341	736.650	86300.000	744.647	749.550	748.171
07.GPF	JT071	263.350	87036.650	740.876	749.544	748.184
M7-73	CN351	735.024	87300.000	744.300	749.576	748.203
08.GPF	JT081	988.412	88035.024	741.374	749.607	748.244
09.GPF	JT091	986.009	89023.436	739.971	749.502	748.181
10.GPF	JT101	890.555	90009.445	741.192	749.680	748.318
M8-73	CN361	95.809	90900.000	743.951	749.749	748.355
11.GPF	JT111	990.253	90995.809	741.678	749.815	748.435
12.GPF	JT121	955.756	91986.062	742.957	749.969	748.562
13.GPF	JT131	758.182	92941.818	743.317	750.033	748.638
UV-92	CN371	214.332	93700.000	746.141	750.110	748.702
14.GPF	JT141	185.668	93914.332	742.433	750.072	748.700
UV1-78	CN381	804.008	94100.000	746.548	750.107	748.710
15.GPF	JT151	295.992	94904.008	742.873	750.222	748.824
FINFL-27.ENT	CF011	712.720	95200.000	744.477	750.290	748.884
16.GPF	JT161	990.062	95912.720	742.282	750.274	748.882
17.GPF	JT171	1005.718	96902.782	743.076	750.323	748.938

Table-7.7 River Cross Section Number and Calculated Flood Water Level in 1983 and 1992 (2/2)

18.GPF	JT181	291.500	97908.500	742.648	750.463	749.073
FINFL-26.ENT	CF021	699.237	98200.000	744.311	750.551	749.148
19.GPF	JT191	998.171	98899.237	742.981	750.510	749.126
20.GPF	JT201	1002.592	99897.408	743.280	750.645	749.251
FINFL-25.ENT	CF031	3300.000	100900.000	744.780	750.722	749.329
FINFL-24.ENT	CF041	3500.000	104200.000	745.096	750.904	749.532
FINFL-23.ENT	CF051	9950.000	107700.000	745.533	751.186	749.803
FINFL-22.ENT	CF061	4650.000	117650.000	748.157	751.839	750.505
FINFL-21.ENT	CF071	3900.000	122300.000	747.286	752.180	750.886
FINFL-20.ENT	CF081	5000.000	126200.000	748.311	752.492	751.220
FINFL-19.ENT	CF091	2000.000	131200.000	747.692	752.797	751.559
FINFL-18.ENT	CF101	2000.000	133200.000	747.528	752.976	751.750
FINFL-17.ENT	CF111	5750.000	135200.000	749.973	753.390	752.092
FINFL-16.ENT	CF121	3250.000	140950.000	746.560	754.008	752.715
FINFL-15.ENT	CF131	3500.000	144200.000	748.492	754.361	753.055
FINFL-14.ENT	CF141	2250.000	147700.000	749.700	754.766	753.470
FINFL-13.ENT	CF151	3250.000	149950.000	749.288	755.005	753.706
FINFL-12.ENT	CF161	5050.000	153200.000	750.727	755.186	753.905
FINFL-11.ENT	CF171	3050.000	158250.000	750.188	755.587	754.317
FINFL-10.ENT	CF181	2950.000	161300.000	751.385	755.928	754.639
FINFL-09.ENT	CF191	4550.000	164250.000	751.790	756.099	754.822
FINFL-08.ENT	CF201	4400.000	168800.000	751.703	756.458	755.196
FINFL-07.ENT	CF211	4850.000	173200.000	752.721	756.880	755.627
FINFL-06.ENT	CF221	1700.000	178050.000	751.088	757.383	756.123
FINFL-05.ENT	CF231	3950.000	179750.000	753.563	757.525	756.261
FINFL-04.ENT	CF241	2225.000	183700.000	753.115	757.675	756.421
FINFL-03.ENT	CF251	4775.000	185925.000	750.880	757.901	756.639
FINFL-02.ENT	CF261	7000.004	190700.000	751.505	758.204	756.938
FINFL-01.ENT	CF271	1805.800	197700.004	754.577	758.979	757.671
S-02.GPF	JS021	1552.490	199505.804	752.546	759.146	757.837
S-03.GPF	JS031	1762.610	201058.294	752.867	759.259	757.953
S-04.GPF	JS041	2644.140	202820.904	753.358	759.402	758.101
S-05.GPF	JS051	2191.590	205465.044	752.866	759.594	758.306
S-06.GPF	JS061	2388.090	207656.634	752.581	759.847	758.533
S-07.GPF	JS071	3521.930	210044.724	752.193	759.941	758.632
S-08.GPF	JS081	1817.230	213566.654	753.634	760.111	758.823
S-09.GPF	JS091	2028.390	215383.884	755.011	760.243	758.990
S-10.GPF	JS101	2469.990	217412.274	755.567	760.557	759.399
S-11.GPF	JS111	1076.570	219882.264	755.280	761.053	760.009
S-12.GPF	JS121	2390.910	220958.834	756.625	760.995	760.012
S-13.GPF	JS131	2077.590	223349.744	756.995	762.640	761.628
S-14.GPF	JS141	2319.950	225427.334	757.179	763.006	761.987
S-15.GPF	JS151	1916.490	227747.284	756.478	763.248	762.227
S-16.GPF	JS161	2866.920	229663.774	757.104	763.458	762.426
S-17.GPF	JS171	1134.620	232530.694	756.811	763.650	762.615
S-18.GPF	JS181	1295.530	233665.314	757.203	763.705	762.670
S-19.GPF	JS191	737.220	234960.844	758.317	763.772	762.747
S-20.GPF	JS201	998.120	235698.064	757.558	763.924	762.890
S-21.GPF	JS211	391.560	236696.184	757.216	764.096	763.050
S-22.GPF	JS221	1191.210	237087.744	757.659	764.117	763.072
S-23.GPF	JS231	487.750	238278.954	758.231	764.195	763.156
S-24.GPF	JS241	557.770	238766.704	757.782	764.268	763.227
S-25.GPF	JS251	436.940	239324.474	758.438	764.334	763.285
S-26.GPF	JS261	516.210	239761.414	757.891	764.441	763.379
S-27.GPF	JS271	512.410	240277.624	757.985	764.447	763.385
S-28.GPF	JS281	919.310	240790.034	759.013	764.440	763.382
S-29.GPF	JS291	875.150	241709.344	757.964	764.479	763.425
S-30.GPF	JS301	0.000	242584.494	758.218	764.482	763.432

Table-7.8   Summnany of Calculated Flood Water Level

without Excavation

Unit: water level in meters

Case	Flood	Foz do Areia (D1-77) CN011	Porto Vitoria (BAT-1B) CN153	Uniao da Vitoria (14.GPF) JT141	Fluviopolis (FINFL-01) CF271	Sao Mateus do Sul (S-25.GPF) JS251
A1	1983	744.0	746.7	750.1	759.0	764.3
A2	1983	742.0	746.3	750.0	759.0	764.3
A3	1983	739.0	746.1	749.9	759.0	764.3
A4	1992	742.0	745.4	748.7	757.7	763.3
A5	1992	739.0	745.3	748.7	757.7	763.3

1983 Flood Water Level with Excavation

Unit: water level in meters

Case	Foz do Areia (D1-77) CN011	Porto Vitoria (BAT-1B) SC153	Uniao da Vitoria (14.GPF) JS141	Fluviopolis (FINFL-01)	Sao Mateus do Sul (S-25.GPF)
Excavation -1 (with excavation)					
	744.0	746.1	749.8	759.0	764.3
	742.0	745.4	749.7	759.0	764.3
	739.0	745.3	749.7	759.0	764.3
Excavation - 2 (with large excavation)					
	744.0	745.7	749.5	759.0	764.3
	742.0	744.7	749.4	759.0	764.3
	739.0	744.2	749.3	759.0	764.3

Table-7.9 Calculated Flood Water Level in 1983 with Excavations (1/2)

Original Section name	Section No.	Distance (m)	Accumulated Distance (m)	Average Original River Bed Elevation (m)	with excavation Water Level (m)	with large exc. Water Level (m)
D1-77	CN011	9230.000	0.000	664.129	742.000	742.000
D2-77	CN021	9230.000	9230.000	676.636	742.001	742.001
D3-77	CN031	12300.000	18460.000	681.506	742.001	742.001
D4-77	CN041	10000.000	30760.000	692.566	742.004	742.004
D5-77	CN051	11540.000	40760.000	701.539	742.003	742.003
PV8-78	CN061	2160.000	52300.000	715.789	742.015	742.015
PV7-78	CN071	3840.000	54460.000	722.196	741.951	741.951
PV6-78	CN081	400.000	58300.000	723.849	742.080	742.080
PV5A-78	CN091	1400.000	58700.000	727.227	742.085	742.085
PV5-78	CN101	1420.000	60100.000	726.772	741.931	741.931
PV4-78	CN111	100.000	61520.000	727.191	742.063	742.063
M1-73	CN121	3040.000	61620.000	731.129	741.696	741.696
PV3-78	CN131	640.000	64660.000	735.357	743.318	743.256
PV2-78	CN141	500.000	65300.000	737.397	743.713	743.600
PV1-78	CN151	70.000	65800.000	740.164	745.405	744.682
BAT-1A	CN152	70.000	65870.000	740.563	745.374	744.648
BAT-1B	CN153	60.000	65940.000	739.703	745.435	744.699
BAT-2	CN154	50.000	66000.000	738.286	745.348	744.611
B3-84	CN161	260.000	66050.000	738.367	745.335	744.574
R5-94	CN171	1200.000	66310.000	737.910	745.383	744.594
R4-94	CN181	300.000	67510.000	741.174	745.646	744.919
M2-73	CN191	690.000	67810.000	741.312	745.766	745.020
UV8-78	CN201	1400.000	68500.000	740.570	745.866	745.003
UV7-78	CN211	1400.000	69900.000	742.092	746.177	745.383
UV6-78	CN221	1600.000	71300.000	743.596	746.432	745.640
M3-73	CN231	1400.000	72900.000	740.348	746.669	746.032
UV5A-78	CN241	300.000	74300.000	743.269	746.746	746.057
R3-94	CN251	300.000	74600.000	742.154	747.687	747.315
UV5-78	CN261	2170.000	74900.000	742.690	747.522	747.123
R2-94	CN271	230.000	77070.000	743.089	748.114	747.794
UV4-78	CN281	1200.000	77300.000	743.125	748.137	747.818
M4-73	CN291	1400.000	78500.000	742.782	748.255	747.953
UV3-78	CN301	1368.559	79900.000	743.316	748.483	748.206
01.GPF	JT011	999.116	81268.559	741.289	748.667	748.409
02.GPF	JT021	232.325	82267.675	741.194	748.772	748.489
UV2-78	CN311	762.845	82500.000	743.346	748.777	748.489
03.GPF	JT031	737.155	83262.845	742.016	748.757	748.478
R1-94	CN321	174.458	84000.000	744.554	748.845	748.539
04.GPF	JT041	725.542	84174.458	741.043	748.876	748.544
M5-73	CN331	308.594	84900.000	744.169	748.960	748.632
05.GPF	JT051	999.700	85208.594	740.880	748.937	748.625
06.GPF	JT061	91.706	86208.294	740.106	748.990	748.661
M6-73	CN341	736.650	86300.000	744.647	749.156	748.836
07.GPF	JT071	263.350	87036.650	740.876	749.154	748.836
M7-73	CN351	735.024	87300.000	744.300	749.180	748.853
08.GPF	JT081	988.412	88035.024	741.374	749.228	748.906
09.GPF	JT091	986.009	89023.436	739.971	749.115	748.783
10.GPF	JT101	890.555	90009.445	741.192	749.301	748.989
M8-73	CN361	95.809	90900.000	743.951	749.371	749.059
11.GPF	JT111	990.253	90995.809	741.678	749.456	749.185
12.GPF	JT121	955.756	91986.062	742.957	749.604	749.302
13.GPF	JT131	758.182	92941.818	743.317	749.709	749.401
UV-92	CN371	214.332	93700.000	746.141	749.750	749.414
14.GPF	JT141	185.668	93914.332	742.433	749.719	749.377
UV1-78	CN381	804.008	94100.000	746.548	749.751	749.407
15.GPF	JT151	295.992	94904.008	742.873	749.882	749.534
FINFL-27.ENT	CF011	712.720	95200.000	744.477	749.957	749.604
16.GPF	JT161	990.062	95912.720	742.282	749.937	749.620
17.GPF	JT171	1005.718	96902.782	743.076	749.983	749.642

Table-7.9 Calculated Flood Water Level in 1983 with Excavations (2/2)

18.GPF	JT181	291.500	97908.500	742.648	750.126	749.720
FINFL-26.ENT	CF021	699.237	98200.000	744.311	750.223	749.827
19.GPF	JT191	998.171	98899.237	742.981	750.181	749.787
20.GPF	JT201	1002.592	99897.408	743.280	750.330	749.958
FINFL-25.ENT	CF031	3300.000	100900.000	744.780	750.414	750.057
FINFL-24.ENT	CF041	3500.000	104200.000	745.096	750.621	750.300
FINFL-23.ENT	CF051	9950.000	107700.000	745.533	750.993	750.647
FINFL-22.ENT	CF061	4650.000	117650.000	748.157	751.695	751.447
FINFL-21.ENT	CF071	3900.000	122300.000	747.286	752.059	751.854
FINFL-20.ENT	CF081	5000.000	126200.000	748.311	752.388	752.212
FINFL-19.ENT	CF091	2000.000	131200.000	747.692	752.707	752.558
FINFL-18.ENT	CF101	2000.000	133200.000	747.528	752.895	752.758
FINFL-17.ENT	CF111	5750.000	135200.000	749.973	753.318	753.198
FINFL-16.ENT	CF121	3250.000	140950.000	746.560	753.954	753.862
FINFL-15.ENT	CF131	3500.000	144200.000	748.492	754.315	754.233
FINFL-14.ENT	CF141	2250.000	147700.000	749.700	754.756	754.688
FINFL-13.ENT	CF151	3250.000	149950.000	749.288	754.988	754.935
FINFL-12.ENT	CF161	5050.000	153200.000	750.727	755.171	755.122
FINFL-11.ENT	CF171	3050.000	158250.000	750.188	755.573	755.532
FINFL-10.ENT	CF181	2950.000	161300.000	751.385	755.916	755.880
FINFL-09.ENT	CF191	4550.000	164250.000	751.790	756.087	756.053
FINFL-08.ENT	CF201	4400.000	168800.000	751.703	756.447	756.419
FINFL-07.ENT	CF211	4850.000	173200.000	752.721	756.872	756.849
FINFL-06.ENT	CF221	1700.000	178050.000	751.088	757.376	757.358
FINFL-05.ENT	CF231	3950.000	179750.000	753.563	757.518	757.501
FINFL-04.ENT	CF241	2225.000	183700.000	753.115	757.669	757.654
FINFL-03.ENT	CF251	4775.000	185925.000	750.880	757.897	757.881
FINFL-02.ENT	CF261	7000.004	190700.000	751.505	758.201	758.187
FINFL-01.ENT	CF271	1805.800	197700.004	754.577	758.975	758.965
S-02.GPF	JS021	1552.490	199505.804	752.546	759.142	759.133
S-03.GPF	JS031	1762.610	201058.294	752.867	759.255	759.248
S-04.GPF	JS041	2644.140	202820.904	753.358	759.399	759.393
S-05.GPF	JS051	2191.590	205465.044	752.866	759.590	759.583
S-06.GPF	JS061	2388.090	207656.634	752.581	759.842	759.837
S-07.GPF	JS071	3521.930	210044.724	752.193	759.937	759.930
S-08.GPF	JS081	1817.230	213566.654	753.634	760.109	760.102
S-09.GPF	JS091	2028.390	215383.884	755.011	760.241	760.234
S-10.GPF	JS101	2469.990	217412.274	755.567	760.557	760.551
S-11.GPF	JS111	1076.570	219882.264	755.280	761.053	761.062
S-12.GPF	JS121	2390.910	220958.834	756.625	760.995	761.003
S-13.GPF	JS131	2077.590	223349.744	756.995	762.640	762.642
S-14.GPF	JS141	2319.950	225427.334	757.179	763.006	763.009
S-15.GPF	JS151	1916.490	227747.284	756.478	763.248	763.249
S-16.GPF	JS161	2866.920	229663.774	757.104	763.458	763.461
S-17.GPF	JS171	1134.620	232530.694	756.811	763.650	763.652
S-18.GPF	JS181	1295.530	233665.314	757.203	763.705	763.706
S-19.GPF	JS191	737.220	234960.844	758.317	763.772	763.774
S-20.GPF	JS201	998.120	235698.064	757.558	763.924	763.925
S-21.GPF	JS211	391.560	236696.184	757.216	764.096	764.097
S-22.GPF	JS221	1191.210	237087.744	757.659	764.117	764.120
S-23.GPF	JS231	487.750	238278.954	758.231	764.195	764.198
S-24.GPF	JS241	557.770	238766.704	757.782	764.268	764.269
S-25.GPF	JS251	436.940	239324.474	758.438	764.334	764.335
S-26.GPF	JS261	516.210	239761.414	757.891	764.441	764.440
S-27.GPF	JS271	512.410	240277.624	757.985	764.447	764.447
S-28.GPF	JS281	919.310	240790.034	759.013	764.440	764.440
S-29.GPF	JS291	875.150	241709.344	757.964	764.479	764.479
S-30.GPF	JS301	0.000	242584.494	758.218	764.482	764.482

FIGURES

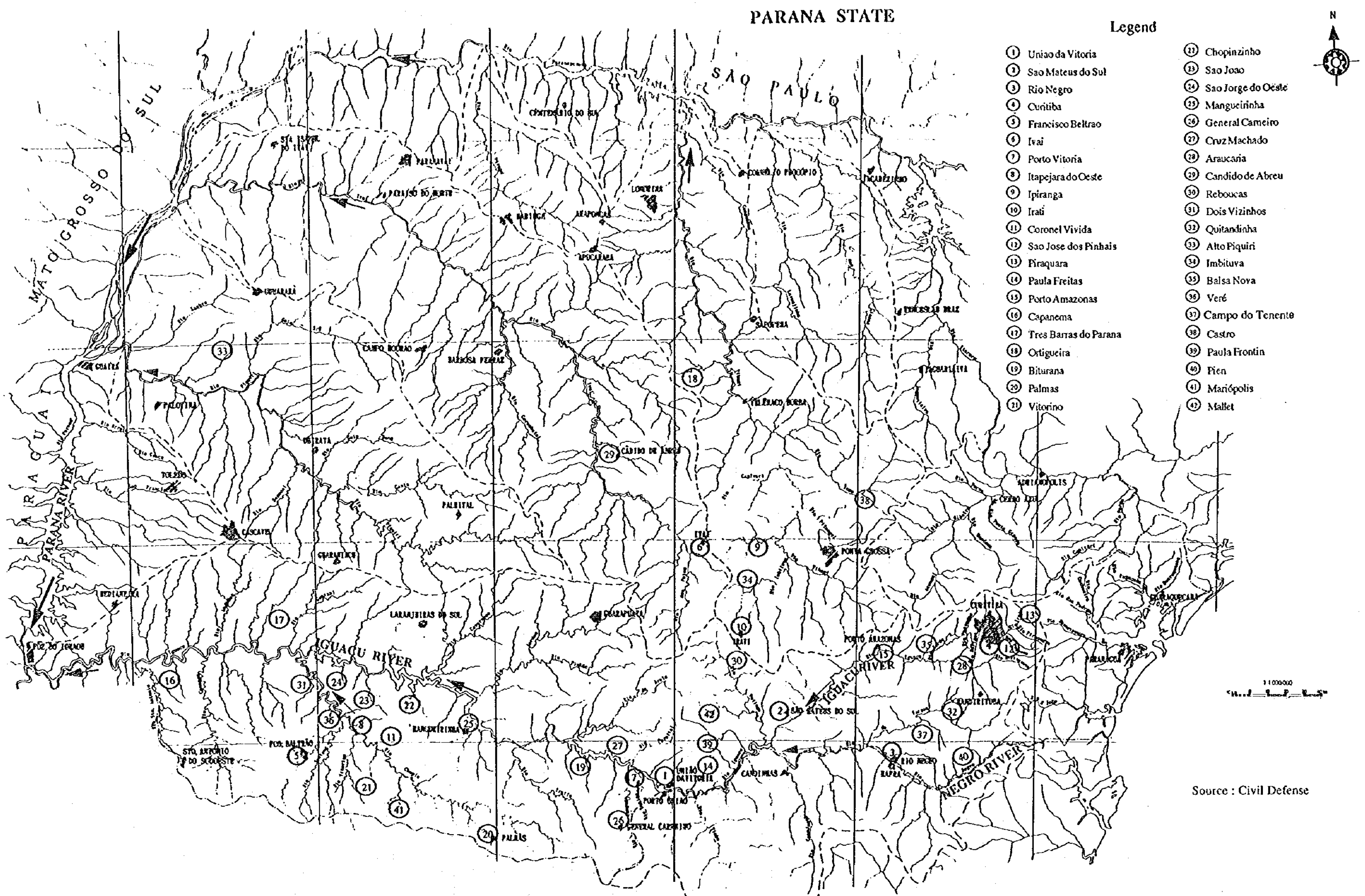


Figure-2.1 Location Distribution of Municipalities which Suffered Flood in 1983

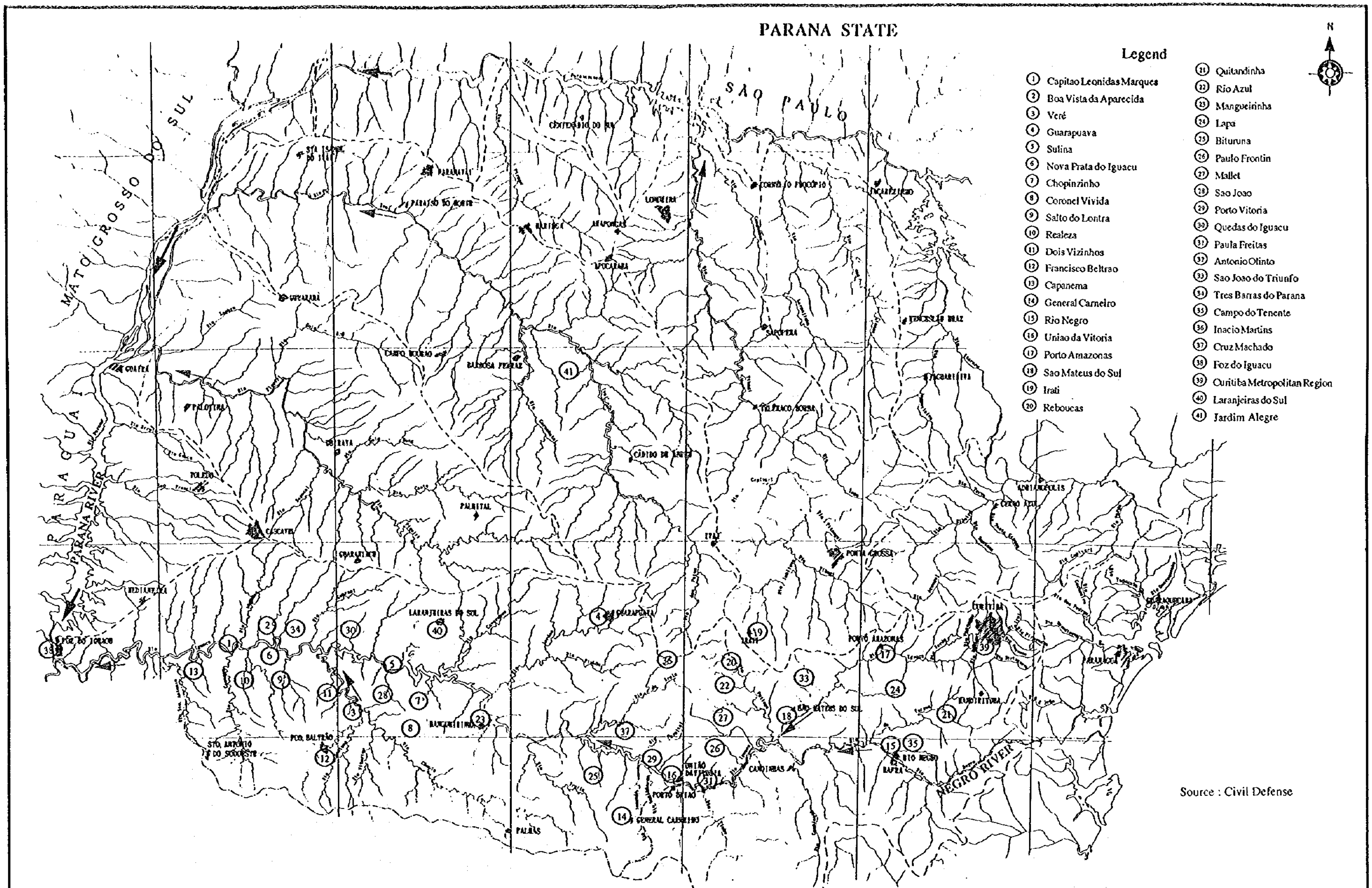
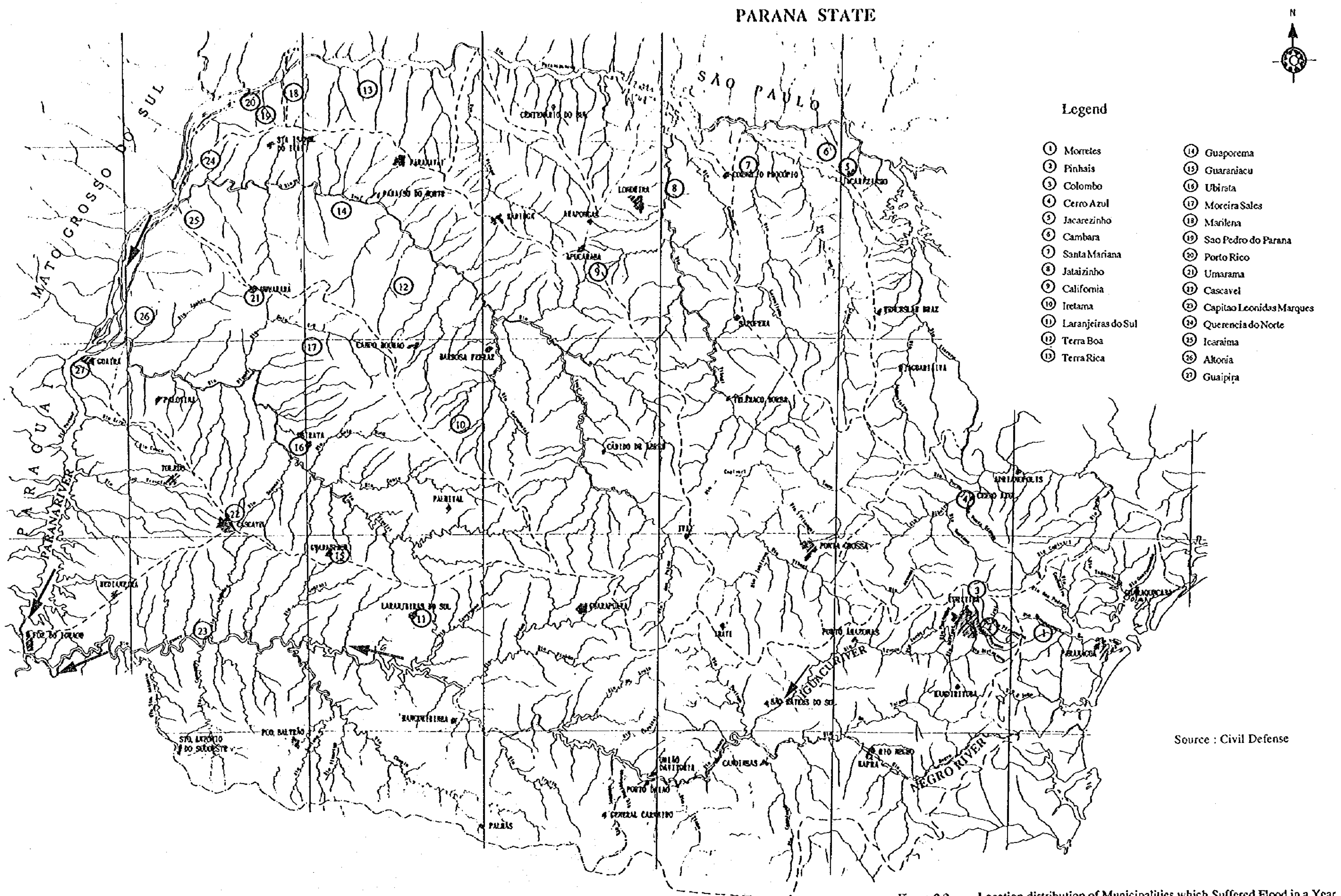


Figure-2.2 Location Distribution of Municipalities which Suffered Flood in 1992



Source : Civil Defense

Figure-2.3 Location distribution of Municipalities which Suffered Flood in a Year Other than 1983 and 1992

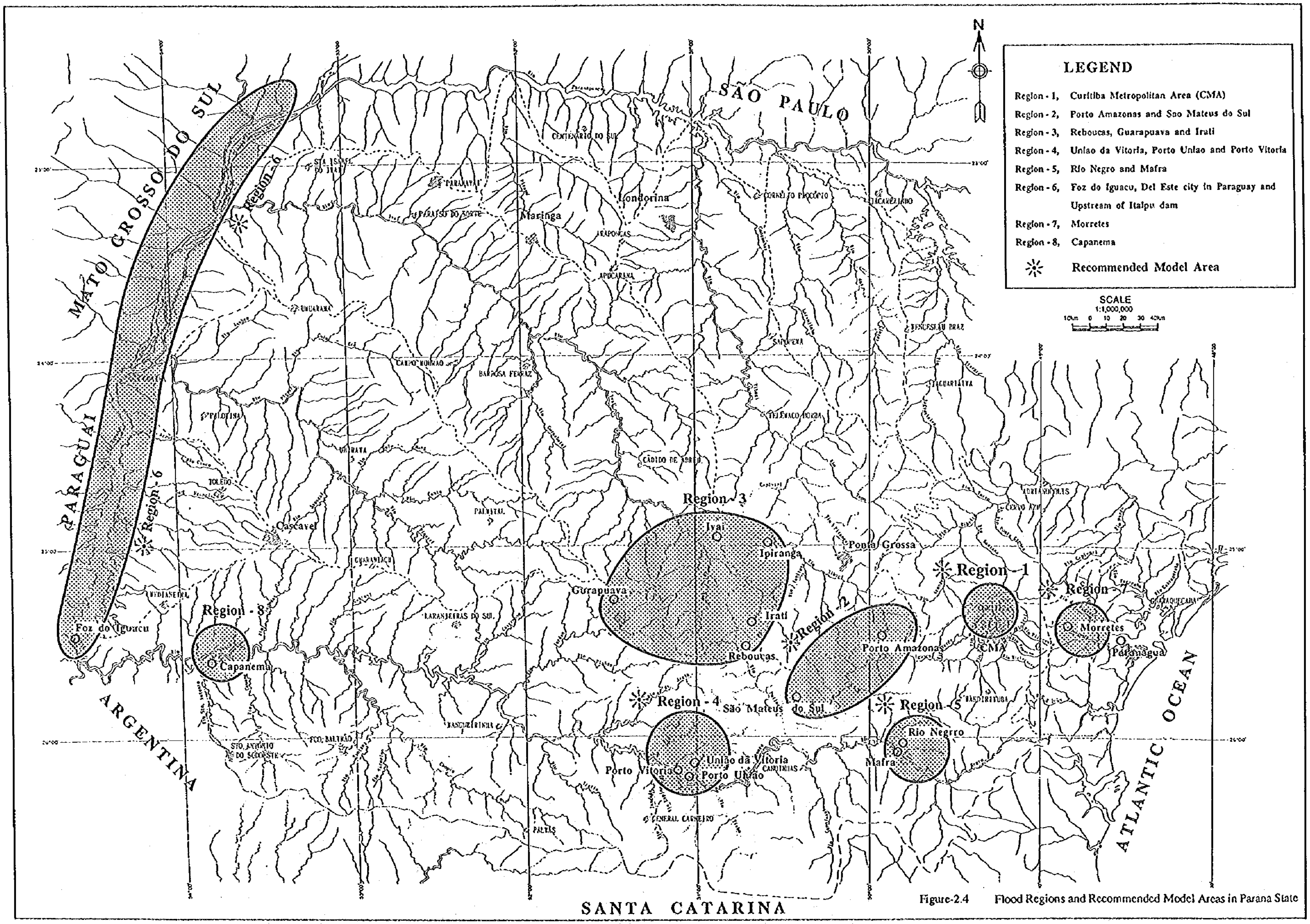
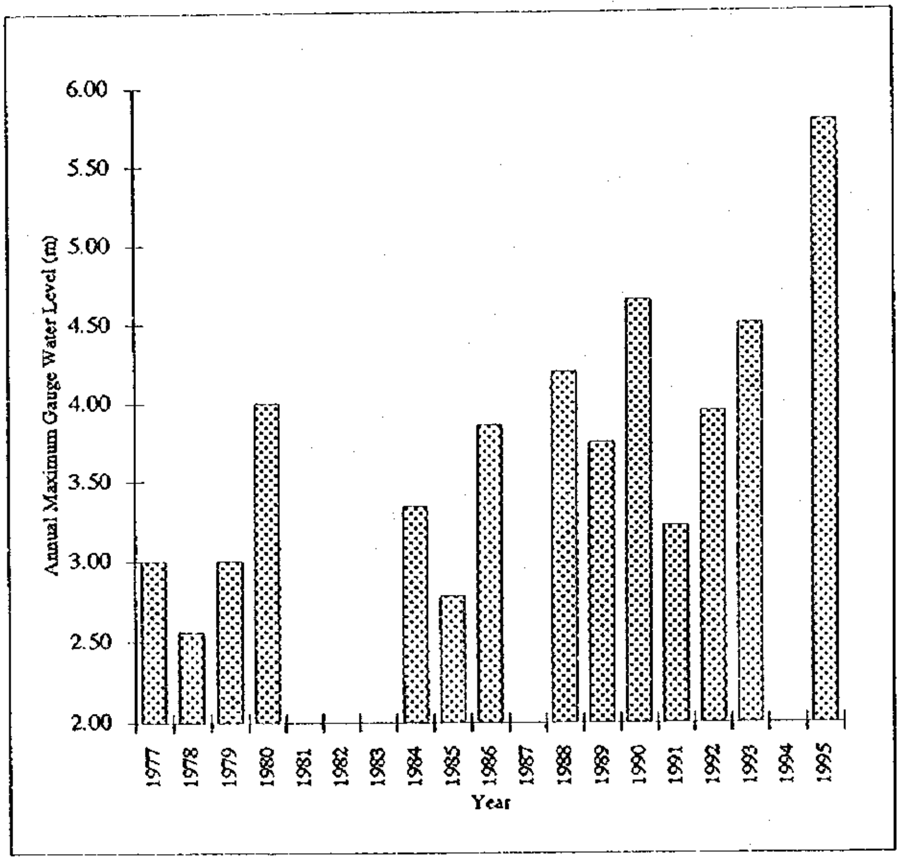


Figure-2.4 Flood Regions and Recommended Model Areas in Parana State



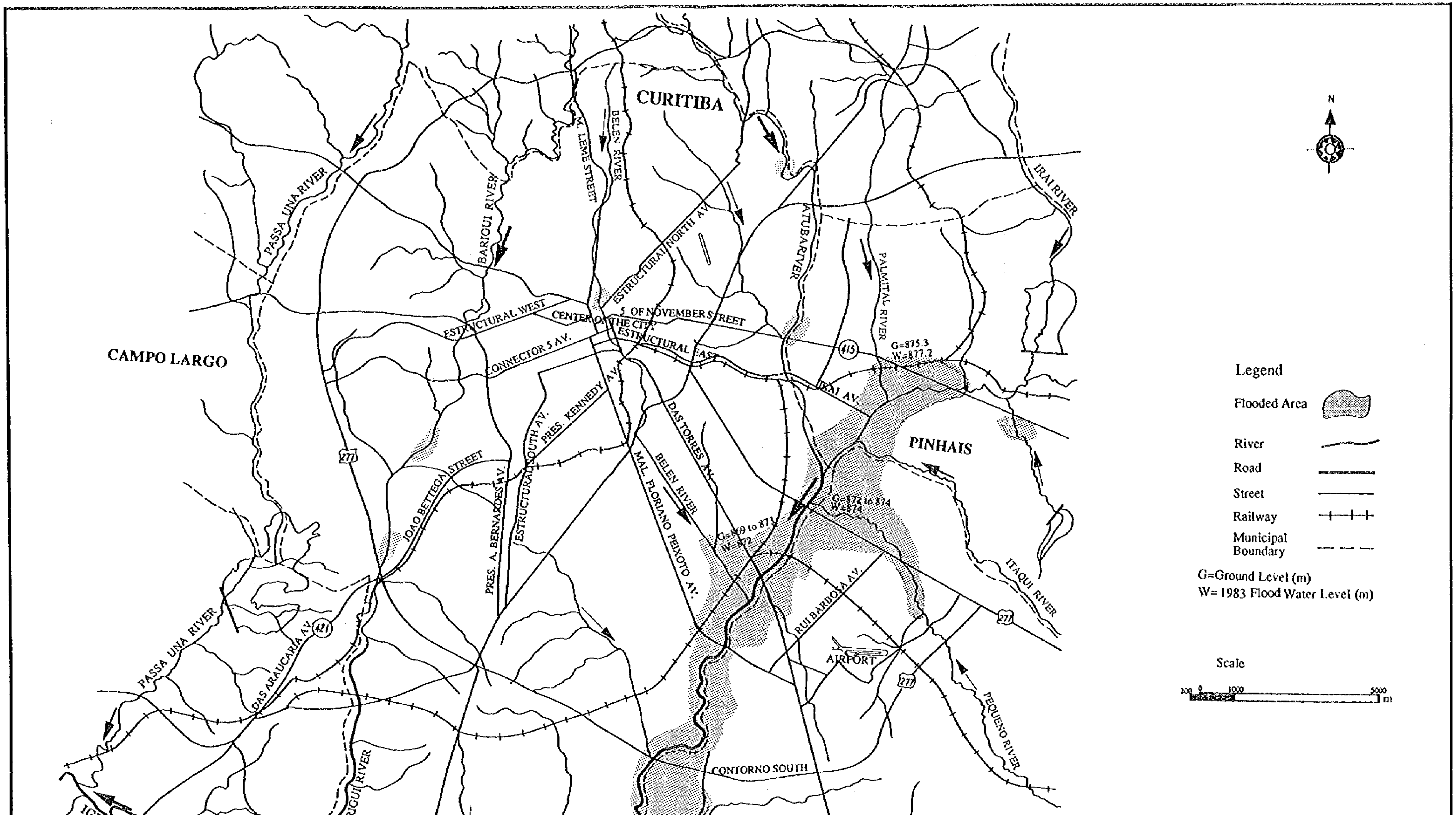
Year	Annual Maximum Gauge Water Level	Year	Annual Maximum Gauge Water Level
1977	3.00	1987	n.a
1978	2.56	1988	4.20
1979	3.00	1989	3.75
1980	4.00	1990	4.65
1981	n.a	1991	3.22
1982	n.a	1992	3.95
1983	n.a	1993	4.50
1984	3.34	1994	n.a
1985	2.78	1995	5.78
1986	3.86		

Source: DNAEE

n.a: no available

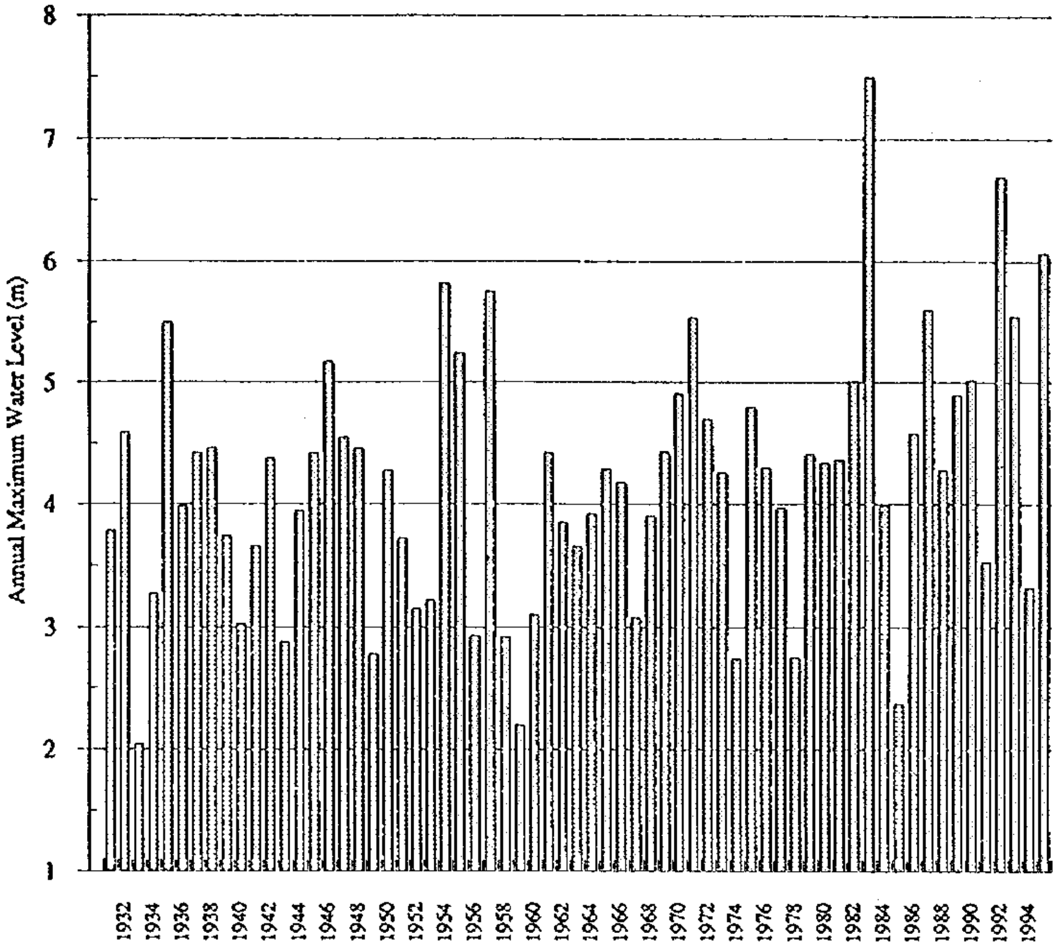
Gauge Station of Iguacu river at Bridge on Road BR-277

Figure 2.5 Annual Maximum Gauge Water Level at Iguacu River in Curitiba



Source: The Flood Prone Area is prepared by use of the 1983 Flood Record of COMEC

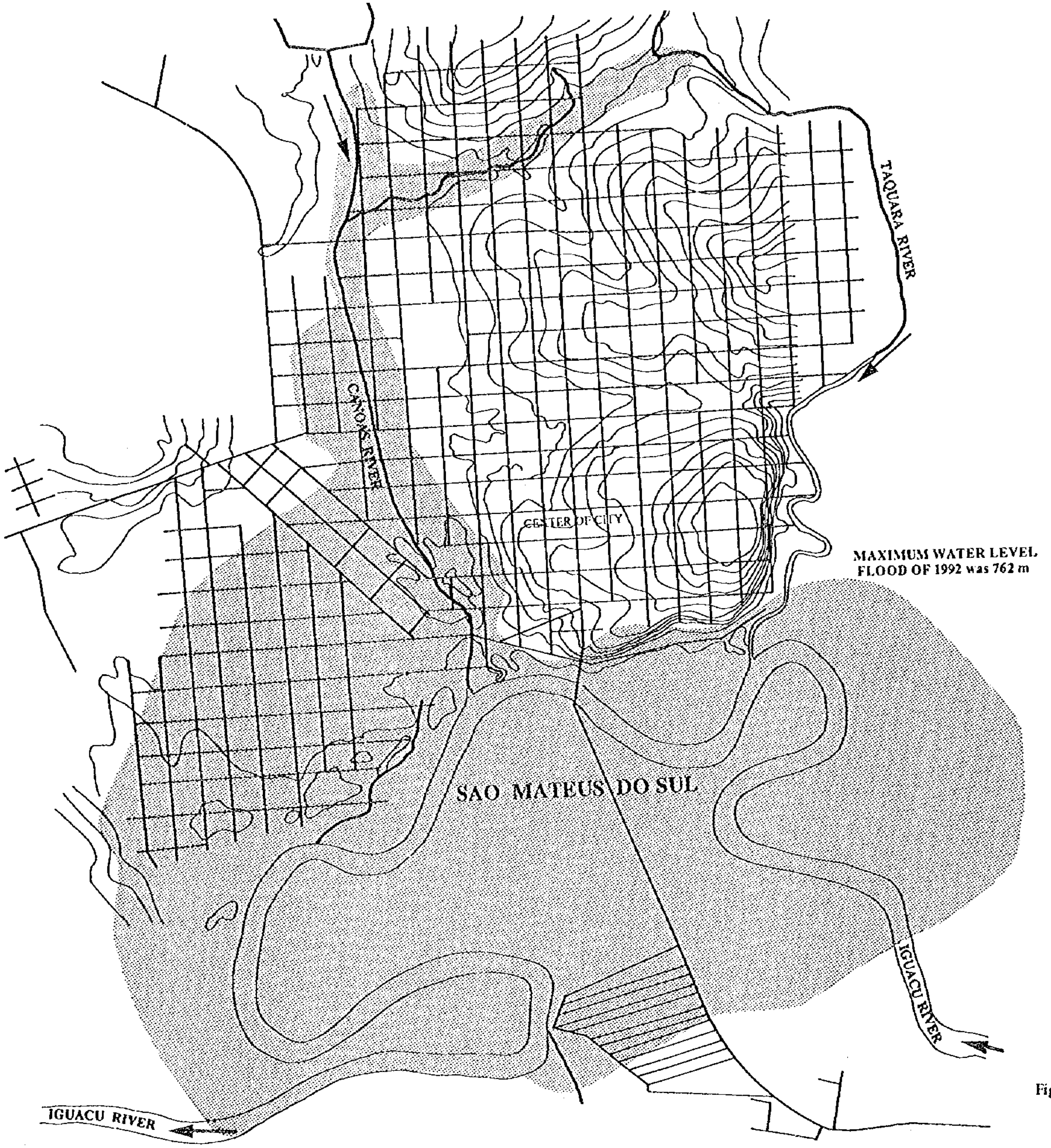
Figure-2.6 Flood Prone Area in Metropolitan Curitiba, Region-1

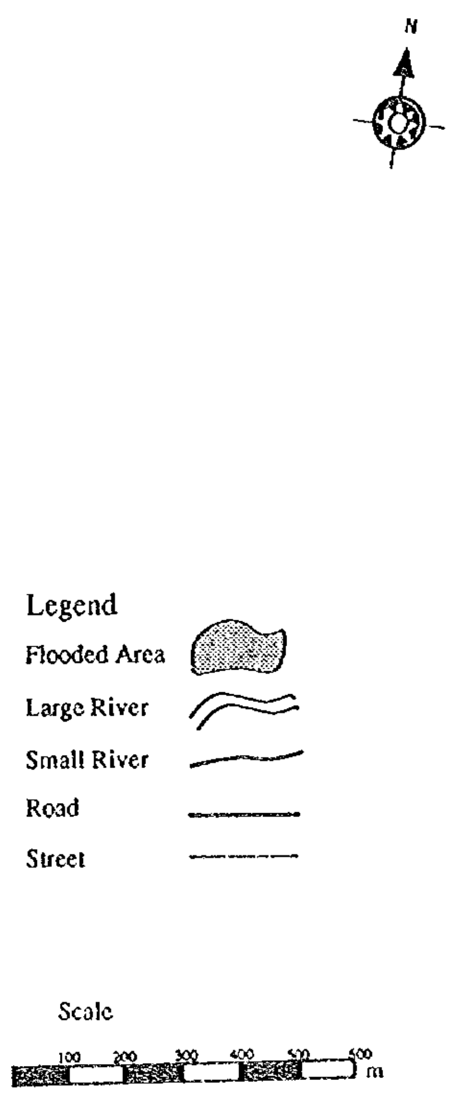


Year	Annual Maximum Gauge Water Level	Year	Annual Maximum Gauge Water Level	Year	Annual Maximum Gauge Water Level	Elevation (m)
1931	3.78	1953	3.22	1975	4.80	
1932	4.59	1954	5.82	1976	4.30	
1933	2.04	1955	5.24	1977	3.97	
1934	3.27	1956	2.93	1978	2.75	
1935	5.50	1957	5.75	1979	4.41	
1936	3.98	1958	2.92	1980 *	4.34	
1937	4.42	1959	2.20	1981	4.36	
1938	4.46	1960	3.10	1982	5.01	
1939	3.74	1961	4.42	1983	7.50	762.9
1940	3.03	1962	3.85	1984 *	3.99	
1941	3.66	1963	3.66	1985	2.37	
1942	4.38	1964	3.92	1986	4.58	
1943	2.88	1965	4.29	1987	5.60	
1944	3.94	1966	4.18	1988	4.28	
1945	4.42	1967	3.08	1989	4.90	
1946	5.17	1968	3.90	1990	5.02	
1947	4.55	1969	4.43	1991	3.53	
1948	4.46	1970	4.91	1992 *	6.69	762.09
1949	2.78	1971	5.54	1993	5.55	
1950	4.28	1972	4.70	1994 *	3.32	
1951	3.72	1973	4.26	1995	6.07	
1952	3.15	1974	2.74			

Source: DNAEE
The values with * are estimated by COPEL.

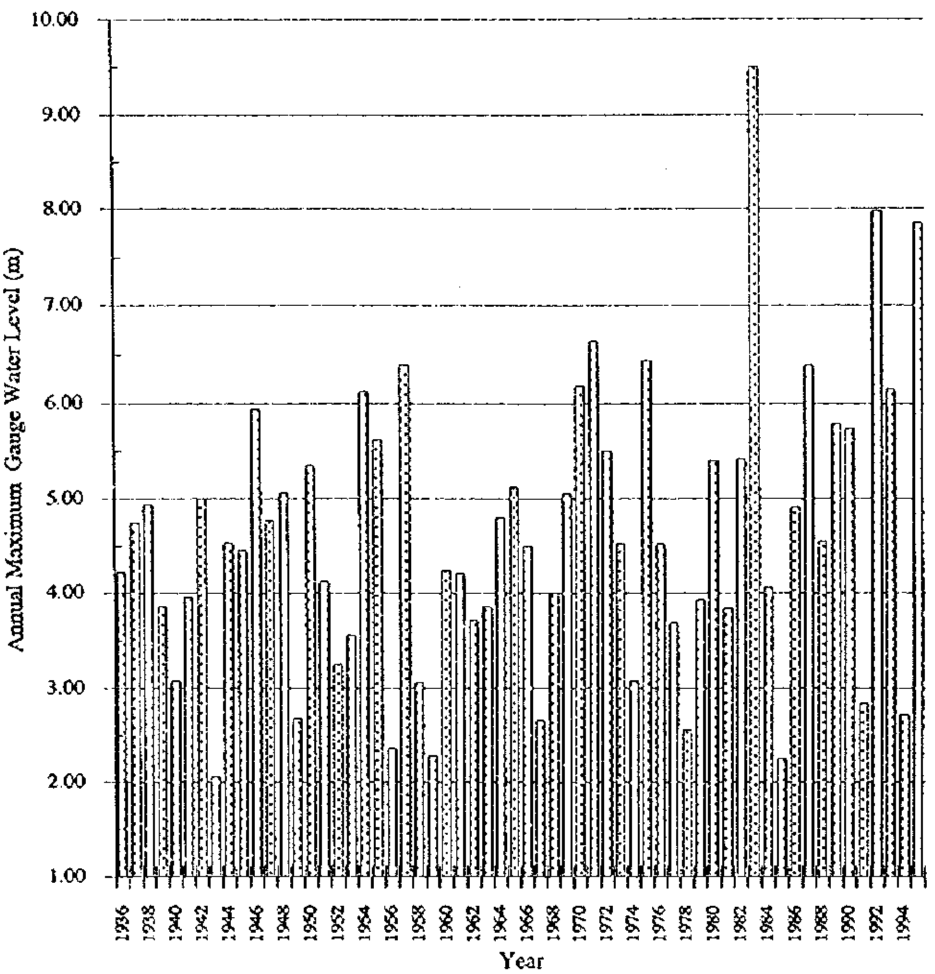
Figure 2.7 Annual Maximum Gauge Water Level at Sao Mateus do Sul





Source: The Flood Prone Area is prepared by use of the 1992 Flood Record of the Prefecture of Sao Mateus do Sul

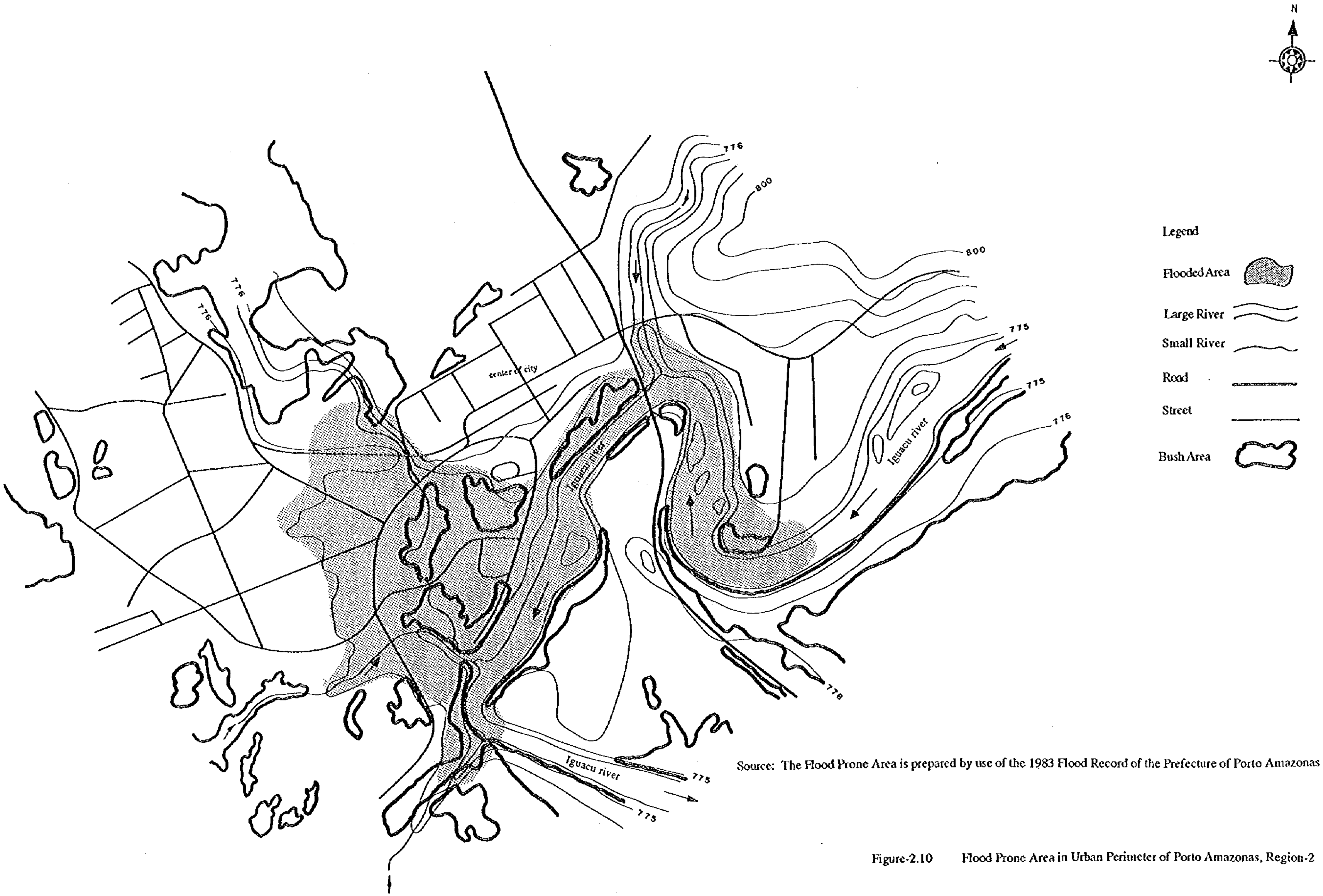
Figure-2.8 Flood Prone Area in Urban Perimeter of Sao Mateus do Sul, Region-2



Year	Annual Maximum Gauge Water Level	Year	Annual Maximum Gauge Water Level	Year	Annual Maximum Gauge Water Level
1936	4.22	1956	2.36	1976	4.52
1937	4.74	1957	6.40	1977	3.69
1938	4.94	1958	3.06	1978	2.56
1939	3.86	1959	2.28	1979	3.93
1940	3.08	1960	4.24	1980	5.40
1941	3.96	1961	4.21	1981	3.84
1942	5.00	1962	3.72	1982	5.42
1943	2.06	1963	3.86	1983	9.50
1944	4.53	1964	4.80	1984	4.06
1945	4.45	1965	5.12	1985	2.25
1946	5.94	1966	4.50	1986	4.91
1947	4.77	1967	2.66	1987	6.40
1948	5.06	1968	4.00	1988	4.55
1949	2.68	1969	5.05	1989	5.79
1950	5.35	1970	6.18	1990	5.74
1951	4.12	1971	6.64	1991	2.84
1952	3.25	1972	5.50	1992	7.98
1953	3.56	1973	4.52	1993	6.14
1954	6.12	1974	3.08	1994	2.72
1955	5.62	1975	6.44	1995	7.86

Source: DNAEE unit: meter

Figure 2.9 Annual Maximum Gauge Water Level at Porto Amazonas



Source: The Flood Prone Area is prepared by use of the 1983 Flood Record of the Prefecture of Porto Amazonas

Figure-2.10 Flood Prone Area in Urban Perimeter of Porto Amazonas, Region-2