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 C
HYDROGEOLOGY AND GROUNDWATER RESOURCES

December, 1995

Yachiyo Engineering Co., Ltd.
Tokyo, Japan

and

Nippon Koei Co., Ltd.
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COMPOSITION OF FINAL REPORT

1. EXECUTIVE SUMMARY

2. MAIN REPORT
   - I. Strategy for Paraná State
   - II. Master Plan for Iguaçu River Basin
   - III. Master Plan for Tibagi River Basin

3. SECTORAL REPORT
   - A. Socio-economy
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4. DATA BOOK

THE MASTER PLAN STUDY ON
THE UTILIZATION OF WATER RESOURCES IN PARANÁ STATE
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Short Report for Seminor II

UMA ABORDAGEN PARA O DESENVOLVIMENTO SUSTENTÁVEL DE RECURSOS HIDRICOS SUBTERRÁNEOS NO ESTADO DO PARANÁ

CHAPTER 1. INTRODUCTION

1.1 Scope

The scope of the Study of Hydrogeology and Groundwater resources covers the following items with consideration of sustainable development :

1) to assess groundwater resources and to formulate strategy for Parana State
   - Geological and hydrogeological settings,
   - Borehole inventory survey,
   - Water quality test of boreholes,
   - Describing and modeling of groundwater reservoirs and/or aquifers,
   - Estimation of groundwater productivity,
   - Assessment of groundwater resources in respective aquifers
   - Development of an implementation strategy for the permissive sustained yield
   - Preparation of recommendations for management policy of groundwater resources
2) to evaluate groundwater resources and to formulate master plan for the pilot basins;
   - Detailed modeling and description of groundwater resources
   - Estimation of spatial groundwater productivity
   - Assessment of spatial groundwater resources
   - Formulation of groundwater development plan for future water demand
   - Proposition of promising projects
   - Preparation of recommendations for urgent groundwater development

1.2 Contents of the Report

This report is composed of mainly three part, assessment of the existing conditions strategy for the whole Parana State and Master Plan for the selected two Pilot Basins :

Assessment of Existing Conditions

Chapter 2 Physical and social Circumstance

Chapter 3 Geology

Strategy

Master Plan

CHAPTER 2. PHYSICAL AND SOCIAL CIRCUMSTANCE

2.1 Location

Parana State is located within the central east side of the South America Continent and it occupies an southern part of Republic Brazil (Figure-2.1). It is bordered on the east by the Atlantic Ocean, the north by Sao Paulo State, the west by Matto Grosso do Sul State and Republic Paraguay, and the south by Santa Catarina State and Republic Argentine.

Parana State straddles approximately latitudes between 22°35'S and 26°45'S; and longitudes between 48°20'W and 54°50'W. It covers an area of about 200,000 km2.

2.2 Topography

The area of Parana State is bordered by the Atlantic Ocean in the east, the Parana River in the west, the Parana-Panema River in the north, and the Branches of Iguacu River in the south.

The topographic features of Parana State are generally characterized by the following four areas from east to northwest (Figure-2.2):

- the Coastal Range
- the First Plateau
- the Second Plateau
- the Third Plateau

The Coastal Range and the others are divided by the Coastal Mountains (named with "Serra Do Mar") composed of high mountains in altitude from 1,000 to 2,000 meters.

The Coastal Range is classified into the mountain areas and the Coastal planes. The Coastal planes consist of the Coastal terraces and fans ranging in altitude from 0 to 25 meters. In the mountain areas, the rivers and tributaries have steep gradients and flow into the Atlantic Ocean.

The First Plateau consists of the upland planes such as Curitiba City and hills with gentle gradients, and it is restricted to the Coastal Mountains in the east and the cuesta mountains in the west and/or northwest. The upland planes are ranging in altitude from 800 to 1,000 meters and the cuesta mountains show the inclination of the geological formations trending to the west and/or the northwest. Some of the rivers and tributaries are flowing into the Parana River and some of them are flowing into the Atlantic Ocean.

The Second Plateau consists of the planes and hills with gentle gradients ranging in altitude from 600 to 1,000 meters. It is restricted to two cuesta mountains in the east and the west. In this Plateau the rivers and tributaries are flowing into the Parana River in final.

The Third Plateau consists of the planes and hills ranging in altitude from 300 to 800 meters. It is restricted to the cuesta mountains in the east and the Parana River in the west. The hills in this Plateau are generally steeper than the hills of the other plateaus.

2.3 Climate

Parana State strides across the tropic of Capricorn. The climate condition is approximately divided into the following two zones :

- tropical zone ; the coastal range
- subtropical zone ;the other ranges(Figure-2.3).

There are four seasons in the subtropical zone.

The distribution of monthly rainfall at the selected rainfall gauging stations is shown in Figure-2.4. In Parana State, there is 1,400mm to 2,500mm of annual rainfall depth in the average of current twenty years (1974-1993) and there are moderate rainfalls through a year (Figure-2.4).

The specific discharge distribution in annual average is shown in Figure-2.5.

2.4 Vegetation and Surface Cover

The land use in Parana State is occupied with mainly cultivation fields, urban area and forest areas. The forest coverage in Parana State becomes about 5 to 8 % in the ratio.

2.5 Population

The present and projected future distribution of population in Parana State is summarized in Table-2.1.

2.6 Water Demand

The water demand is projected for the turget years of 2005 and 2015 as shown in Table-2.2.

CHAPTER 3. GEOLOGY

3.1 Geological Outline

The area of Parana State is underlain chiefly by Precambrian metamorphic rocks intruded by granitic intrusive rocks ranging Precambrian age to Paleozoic age, and sedimentary rocks of Paleozoic to Cenozoic with Mesozoic volcanics as shown in Figure-3.1.

Precambrian seems to occupy the core of geological units in Parana State and the younger groups of Paleozoic and Mesozoic are overlying on Precambrian. The core of it forms Precambrian Sheild and the latter ones form a Stable Platform in Palana State. Therefore, Precambrian is foundations of the First Plateau, and Paleozoic and Mesozoic are foundations of the Second Plateau and the Third Plataeu in individual.

The shape of the younger groups in the plane shows a Arc Structure inclining toward north and/or west side in the order of age(to see the geological profile in Figure-3.1).

The geological series from Middle Paleozoic to Mesozoic compose of a part of Parana Basin Structure which is the biggest Stable Platform in South America as shown in Figure-3.2. The Parana Basin occupies the catchment area of the Parana River and it forms a Stable Platform with the elongated axis of the basin structure along the Parana River trending to the NNE-SSW in direction. In Parana State, the formations of the Parana Basin show a arc structure named with Ponta Grossa Arc.

The all geological units from Precambrian to Paleozoic are cut by faults and/or they are intruded by dolerite dikes. The axis of arc structure is trending to NW-SE in direction and the arc is named with "Ponta Grossa Arc".

3.2 Stratigraphy and Permeability

3.2.1 Outline

The all geological complexes, groups and all formations are shown in Table-3.1. They are classified into sub-stages.

Precambrian are divided into the following three geological complexes :

- Archean series
- Proterozoic series
- Proterozoic (to lower Paleozoic) intrusive complex.

Paleozoic are divided into the following three stages :

- Lower Paleozoic

- Middle Paleozoic
- Upper Paleozoic.

3.2.2 Archean

Archean system is composed of Serra Negra granurite complex.

(1) Serra Geral Granulite Complex

This complex is restricted as blocks in an area of 510 square kilometers and it occurs in the coastal mountains area of inside of the First Plateau. The distribution of this complex is trending to NE-SW in direction.

This complex is composed of meta-dioritic rocks, serpentine, norite, gneissic granulites, gneiss, schists. The K-Ar age determination shows 2,530-2,710 m.a.(million years ago) analyzed by a rock sample of retrometamorphosed granodiorite. It shows granulite faces in the metamorphose stage.

This complex has no porous porosity and it shows little permeability.

3.2.3 Proterozoic

Proterozoic is divided into two stages (lower, and upper), and respective stages are composed of some complexes and groups. It occupies the main part of the First Plateau and Sheild in Parana State

(1) Lower Proterozoic

1) Pre-Setuva Complex

This complexes are composed of the following five (5) complexes :

- Pien Basic and Ultra Basic Complex
- Coastal Migmatic Gneiss Complex
- Morro Alto Gneiss
- Rio das Cobras Formation
- Layering Granitic Rocks

They are exposured in areas of about 6,760 square kilometers. They crop out in the main part of the First Plateau of Parana State and those distributions is trending to NE-SW in direction. Curitiba city is overlying on this complexes.

They consist of amphibole gneiss, serpentines, peridotites, migmatites, gneissic migmatites, granites, anatexites, granodiorites, mica schists, and foliated granites. The Rb-Sr age determination shows 2,200 m.a to analyzed by hornblende gneiss.

The complex is a important component of the Sheild structure in Parana State

They have no porous porosity, but Granitic rocks in this complexes form fractured reservoirs in some cases.

2) **Setuba Group**

This group is composed of the following three (3) formations :

- Perau Formation
- Turvo-Cajati Formation
- Agua Clara Formation.

This group is located in the central part of the first plateau. It is exposured in areas of about 1,610 square kilometers. The distribution of this group is elongating to NE-SW in direction and it is spattered in small geological units by faults and folding.

This group is composed of carbonate rocks(calcareous schists, marble, dolomite, limestone, and calc-silicate schist) and non-carbonate schists(quartz schists, amphibole schists, mica schists, graphite schists, green schists, and garnet-sillimanite schists). The respective results of age determination show 1,170 m.a-1,330 m.a by Rb- Sr method, 1,400-1,430 m.a. by Pb-Pb method.

This group has no porous porosity but carbonate parts in it are formed micro-caves and dolines by chemical corrosion. This group is one of geological units to form " Karst ".

(2) Upper Proterozoic

Upper Proterozoic in Parana State is composed of Acungui Group.

1) **Acungui Group**

Acungui Group occupys mainly two areas in the central part of the first plateau and it crops out in areas of 4,620 square kilometers. The distribution of this group is elongating to NE-SW in direction.

This group is classified into four (4) formations (Votuverava Formation, Capiru Formation, Itaiacoca Formation, Antinha Sequence Formation). Those formations are composed of alternations of carbonate rocks and non-carbonate rocks. The calcareous rocks consist of calcareous schist, calc-silicate schists, marbles, dolomites, meta-limestones, and meta-calc-silcate rocks. The non-carbonate rocks consist of meta-mudstones, meta-siltstones, quartzites, phyllites, meta-sandstones, meta-conglomelates, and mica schists. The results of age determination show 850-1,250m.a. of lead natural deposits by Pb-Pb (Promb-Promb) method, 1,100m.a. of amphibolite by Rb-Sr method, and 580m.a. of amphibolite by K-Ar method.

The parts of carbonate in this group include caves, micro-caves, and dolines in a shallow depth from the surface. Those occurrences form Karst of topography. This group occupies main part of Karst in Parana State.

3.2.4 Upper Proterozoic-Cambrian in Paleozoic

Upper Proterozoic- Cambrian is mainly located in the area of the first plateau, second and the coastal range and it crops out in a area of about 520 square kilometers. It is composed of the followings :

- migmatites, granites and Brazilian anatexites
- porphyritic granites and alaskitic granites (K-Ar; 610 m.a.)
- granites and syenites (K-Ar; 500 m.a.and 630 m.a.)
- sub-alkaline and alkaline granites (Rb-Sr; 600±10 m.a.-495 m.a.)

The above mentioned rock faces are consolidated and they have low porous porosity without fractured porosities.

3.2.5 Paleozoic

Paleozoics is classified into Lower Paleozoics, Middle Paleozoics, and Upper Paleozoics in order of older age. Paleozoics are located within the area of second plateau and they crop out in area of about 41,900 square kilometers. Paleozoics is overlain by younger groups in order of age. The overlying arrangement of groups forms a arc structure called Ponta Grossa Arc.

(1) Lower Paleozoics

This Palaeozoics is located within a core and they crop out in areas of about 300 square kilometers and it is composed of Cambrian and . It is a part of the core of Sheild in Parana State.

It is classified into the following formations :

- Cambrian, Ordovician and Silurian

1) Cambrian

It iscomposed of Camarinha Formation and Guaratubinha Formation, and areas of these formations are about 100 square kilometers and about 200 square kilometers respectively. Their lithologies are mentioned in Table- 3.1.

They has low porous porosity.

2) Ordovician-Silurian

It is composed of Castro Group, and this Group crops out in a area of about 860 square kilometers.

(2) Middle Paleozoics

Middle Paleozoics are located within the area of the second plateau and they crop out in a area of about 7,240 square kilometers.

It is classified into the two periods of Ordovician and Devonian. Ordovician is composed of Castro Group and Devonian is composed of Parana Group.

1) Ordovician (Castro Group)

- Castro Group crops a area of about 860 square kilometers and it is dipping to northwest in direction.
- The lithological faces are described in Table-3.1. It's faces shows low porous porosity.

2) Devonian (Parana Group)

- Parana Group crops an area of about 6,180 square kilometers and it is classified into the two formations of Furnas Formation and Ponta Grossa Formation. This Group forms an arc structure dipping to north - west in direction.
- The lithological faces about the two formations are described in Table-3.1. Sandstones of Furnas Formation are characterized by high porous porosity and they have potential to be good aquifers. On the other hand, mudstones of Ponta Grossa Formation have low permeability.

(3) Upper Paleozoics (Permian)

Upper Paleozoics are located within the western and northern marginal area of second plateau and they crop out in a area of about 20,910 square kilometers. They are classified into the following three periods :

- Lower Permian ; composed of Itarare Group
- Middle Permian ; composed of Guata Group
- Upper Permian ; composed of Passa Dois Group

They are trending to west - north in dipping and they form a big arc structure called Ponta Grossa Arc.

1) Lower Permian (Itarare Group)

Itarare Group occurs as a thick arc stripe and it crops out in areas of about 13,950 square kilometers. This Group is classified into three formations of Campo do Teniente Formation, Mafra Formation and Rio do Sul Formation.

Their lithological faces of this group are described in Table-3.1. Their lithological faces show that there are some porous beds and there are mainly low porous beds.

2) Middle Permian (Guata Group)

Guata Group occurs as a thin stripe and it crops out in areas of about 4,820 square kilometers. This Group is classified into the two formations of Rio Bonito Formation and Palermo Formations.

The lithology of the two formation are described in Table-3.1.

The sandstones and calcareous beds in Rio Bonito Formation have a potential to be porous media but the other beds are characterized with low porosity.

3) Upper Permian (Passa Dois Group)

Passa Dois Group is located outside the arc margin of Paleozoics in the west to the north area of second plateau, and crops out in a area of about 16,080 square kilometers.

This Group is classified into the four formations of Irati Formation, Serra Alta Formation, Terezina Formation and Rio do Rasto Formation.

The lithologies of their four formation are mentioned in Table-3.1.

There are mainly sandstone and calcareous beds in Rio do Rasto Formation in mainly and their bed has possibility to be porous beds.

3.2.6 Mesozoic

Mesozoic is located in the western to the northwestern area of Parana State and it covers the third plateau. It crops out in an area of about 132,030 square kilometers.

Mesozoics is classified into the following periods :

- Trias-Jurrassics : composed of Sao Bento Group
- Cretaceous : composed of Baura Group

(1) Trias-Jurrassics (Sao Bento Group)

Sao Bento Group is located within the third plateau and the rim of the second plateau, and it crops out an area of about 108,420 square kilometers.

It is classified into the following two formations :

- Piramboia Formation and Botucatu Formation (both called Botucatu Formation in Parana State)
- Serra Geral Formation

1) Botucatu Formation

Botucatu Formation is located within the thin rim of the end margin of the second plateau. It crops out in areas of about 2,870 square kilometers. Therefore, this Formation is underlain under areas of the third plateau and it is trending shallow to deep from east to west in direction.

It is composed of fine to medium whitish sandstones and reddish siltstones deposited in banks. They are characterized by the sedimentary texture of cross laminations and horizontal stratification.

These sandstones has a high porosity except baked zones caused by intrusions of doleritic dikes.

2) Serra Geral Formation

This Formation is located in main parts of the third plateau and it crops out in a area of about 105,540 square kilometers.

It is composed of tholeitic basalt lava flows with massive, amygdaroidal and aphanitic occurrences, few andesite lava flows and intercalations of fine grain sandstone lenses. The basalt volcanism is thought as continental fissure eruptions.

Respective Basalt lavas consist breciated zones in the bottom and top of flows in typically, and parts of this Formation in shallow depth from the surface is often weathered to obtain a secondary porosity.

(2) Cretaceous (Bauru Group)

Bauru Group is mainly located in the northwestern part of Parana State and it crops out in areas of about 23,620 square kilometers.

Bauru Group is composed of Caiua Formation and the other formations but there are few exposure of the other formations in Parana State. Therefore, Bauru Group in Parana State might be thought as Cretaceous consists of Caiua Formation in Parana State approximatively.

Caiua Formation is composed of alternations of very fine to medium grain whitish sandstones and reddish siltstones. The occurrences of alternations show small to large crossed laminations and large crossed stratifications. The sandstones is characterized by porous porosity.

3.2.7 Cenozoics

Cenozoics is located in spattered areas of river sides and marine side over Parana State and it crops out in areas of about 6,400 square kilometers. It is composed of Quaternary series. Quaternary series occur with thin thickness generally. Quaternary series is composed of recent alluvium deposits, fan deposits, lacustrine deposits, and marine terrace deposits which consist of gravels, sands, and silts.

There are only two named Cenozoic formations in all Cenozoics of Parana State. Their named formations are Alexandra Formation and Guabirituba Formation.

1) Alexandra Formation

This Formation is located in Coastal range. It deposited in delta and in fan.

It is composed of sands, silts and gravels.

This Formation is characterized with high permeability.

2) Guabirotuba Formation

This Formation is located in Curitiba Metropolitan area and it crops out in areas of about 920 square kilometers.

It is classified into the following two parts :

- Lower part of Guabirotuba Formation : composed of alternation of sands, silts and gravels deposited in alluvium.
- Upper part of Guabirotuba Formation : mainly composed of silts and fine sands with silt matrix.

The lower part is characterized with permeable beds.

3) Marine Terrace deposits

Those deposits is located in the coast side. This is composed of fine sands and silts deposited in beach.

The sands is characterized with porous porosity.

4) Recent Alluvium Deposits

Those deposits are restricted to river sides and they are composed of sands, silts, and gravels.

The sands and gravels are characterizes with high permeability generally.

3.3 Structural Geology

3.3.1 Lineament Structure Represented in Satellite Images

Lineaments of Edited Satellite Image is characterized with banded zonal structure due to Ponata Grossa Arc and dike swarms trending NW-SE in direction.

In addition, the image shows the presence of big faults which consist of faults trending to various directions and controlling recent drainage.

3.3.2 Fault

(1) Fault Occurrences

Faults could be recognized by the above image and field observations during reconnaissance field survey(Figure-3.3, and Figure- 3.4).

The discussion about faults in this section is considered with bigger faults and faults cutting to basalt dikes.

The bigger faults are classified into the following few faulting group due to trending in direction:

- NNE-SSW group ; This group is characterized to be concerned with formations of recent major topography like directions of Parana River, Coastal Mountains and Beach. Moreover, faults of this group are cutting and dislocating Caiua Formation and the other fault groups.
- The dislocations are recognized as a right lateral movement apparently.
- NWW- SEE group (to NW) ; This group is charcterized to cut the dike swarms and Caiua Formation, and to dislocate streams and dikes in left lateral of apparent fault sense.
- NE-SW group ; This group is characterized to cut Caiua Formtion in left lateral of apparent fault sense.

(2) Faulting stages

To sum up the former part, the stage of faulting among the above fault groups is confirmed as follows :

- the youngest faulting is presented by NNW- SSE group.
- the second younger faulting is presented by NWW-SEE group.
- the third younger faulting is presented by NE-SW group.

3.3.3 Fold

(1) Fold occurrences

Folding structure in outcrop scale are observed in Acungui Group and Setuba Group of Precambrian age. Therefore, the above mentioned Ponta Grossa Arc is considered of a bending structure which is a type of folding but this arc can not recognized in outcrop scale. In addtion, the bending structure of Ponta Grossa Arc influence the stucture of Serra Geral Formation but it is cut by the distribution of Caiua Formation.

(2) Folding stages

In consequence of the above occurences, two principle folding stages are revealed. The first principle folding stage is Precambrian age when the folds are characterized with tight and overturning fold axes to be accompanied with thurustings. The second principle folding stage is an age from Paleozoic age to Upper Jurrassic age, and before Cretaceous age. The second one is characterized by Ponta Grossa Arc and bending caused half doming uplift.

CHAPTER 4 STRATEGY OF GROUNDWATER RESOURCES

4.1 Strategy of Groundwater Resources Assessment

This study of groundwater resources in Parana State was conducted on the following two bases of considerations :

a) "Sustainable Development" was proposed by Rio-Summit of United Nations in 1992.

b) "Good Use" of groundwater resources, both quantitatively and qualitatively.

On the former viewpoint, the groundwater utilization should be based on the "Circulating Groundwater Resources" but not "Stored Groundwater Resources". Therefore, "Permissive Yield" was proposed in the groundwater resources assessment of this study and it included the meaning of permissive sustained yield. On the later viewpoint, groundwater resources in Parana State were characterized with variety in tri-dimensional distribution and water quality. The variety was studied to be useful for "Save Resources" of groundwater resources and good cost-benefit of groundwater development.

Sustainable yield for "Sustainable development" should be assessed by "Circulating Groundwater Resources". "Circulating Groundwater Resources" is represented with Transitional Recharge such as river baseflow and Deep Recharge. The former recharge is equivalent to river baseflow and the later one is the same as underground flows to vicinity reservoirs under the ground and/or to the Ocean, directly from their reservoirs. Their recharges are designated as groundwater resources which is circulating cycle of shorter range periods from the surface water to surface water through aquifers, in comparison with the circulation period of groundwater utilization from intake of water resources to the discharge of them. On the other hand, "Stored Groundwater Resources" is characterized by the longer circulating period of groundwater resources for the above mentioned human utilization.

The transitional recharge is equivalent to river baseflow and it is estimated as mean annual baseflow. In fact, there are no baseflow data in Parana State but there are Q7 data prepared by Parana state though some of them are insufficient. The Q7 data are represented as the annual minimum baseflow to be a continuity discharge of river for seven days within the dry season. But the biggest baseflow occurs during rainy season than during the dry season, annually. In terms of the above mentioned, Q7 data is thought to be a lower number than the number of annual mean baseflow at fluvial stations and it is considered to be a safety number of baseflow for groundwater utilization. Consequently, annual mean baseflow by fluvial stations is considered to be simulated with annual Q7 under the concept of "Sustainable Development of Groundwater Resources".

The estimation of groundwater resources by aquifer could be carried out by use of the analyzed mean annual Q7 (in the later, written by mQ7) shown in Figure-4.1. In this analysis, it is necessary to check data condition of monitoring by analyzing respective fluvial stations.

In addition, the results of pumping test such as borehole yield should be applied for the following two items for groundwater development but not for estimation of groundwater resources :

- Borehole productivity by aquifers and/or spatial borehole productivity by spatial aquifers
- Borehole intervals to keep non-interference distance for borehole.

4.2 Strategy of Groundwater Management

4.2.1 Groundwater Development

For groundwater development, it was studied that the consideration of "Good Use" was important and necessary for water demand, both quantitatively and qualitatively. Two samples were described as follows :

1st. sample : Curitiba Metropolitan

The groundwater in Karst area is generally marked by clean water with high hardness in chemistry. This kind of water resources is potable but not suitable for heating water systems of industry use. Moreover, the distribution of Karst area is close to housing area in the northern part of Curitiba Metropolitan Area but far from Araucaria of industrial area in Curitiba Metropolitan Area. On the other hand, the aquifer of Guabirotuba Formation is located near the industrial area, and it is characterized by low hardness in chemistry. The aquifer of Guabirotuba Formation is suitable, both in distribution and chemicals to supply for heating water systems of industrial use.

2nd. sample : Londrina

In Londrina, there are big coffee factory and it is using hydrothermal resources for boiling water of industrial use from Botucatu Formation by deep wells within the factory land. The aquifer is characterized by warm to hot water with alkalinity and deep sheeted resources in the third plateau. In the above connection, the temperature characteristics of the aquifer, its physical characteristics and distribution are effectively practiced as an good example of "Good Use" in the coffee factory.

The required water supply amount was estimated by the projected water demand for the respective municipalities. The supply amount should be supplied with considerations such as the above mentioned, both quantitatively and qualitatively and it should be supplied by borehole complexes consisting of several boreholes(1 to 7 boreholes) by each complex.

The yield amount of each borehole complex should be estimated based on the spatial groundwater potential assessed by Q7 data, and each well should keep an interval distance to check the well-interference. In addition, the developed area of groundwater resources is to be prevented by recharging area obtained by the calculation of specific recharge area.

In general, the specifications of borehole for groundwater development could follow SANEPAR's specifications at present. This is due a fact that SANEPAR has many experiments for groundwater development.

4.2.2 Groundwater Monitoring

At present, there are no continuous monitoring data for groundwater resources in Parana State. On the viewpoint of "Sustainable Groundwater Utilization", the arrangement of monitoring system for groundwater resources is one of the most important matters for groundwater management in Parana State. Purposes of monitoring for it are considered as follows :

- To adjust the yield of the groundwater development by each spatial areas for water supply,
- To study continuously the behaviors of groundwater resources, both quantitatively and qualitatively by sectored areas and groundwater basin,
- To prevent the over-pumping of groundwater resources, spatially and regionally,
- To manage groundwater basins, quantitatively and qualitatively,

Main monitoring items of groundwater resources consist on their quantity and quality.

The monitoring of quantity of groundwater resources could be done, considering the following items by respective aquifers in general :

- Piezometric observation of static level in borehole : All aquifers except "Karst",
- Fluvial discharge observation of river water to analyze the baseflow ; "Karst".

In actual operation of the monitoring, the above mentioned methods would be combined with the priority to choose main observation system.

The monitoring of quality of groundwater resources could be conducted by the chemical analysis of water samples taken from boreholes regularly and temporally.

The analyzed chemical components should follow the chemical standard components of domestic water and the analysis of components of presumed contaminant materials for groundwater resources such as agricultural chemicals should be added.

In the wider area such as Parana State, the monitoring operations for the resources would be expected to be conducted by developing project of groundwater such as "Karst Project" by SANEPAR. In addition, it is necessary to carry out the monitoring operation for high priority area of groundwater utilization (industrial use in Araucaria, Curitiba Metropolitan area) and borehole concentrated areas (such as the Center of Curitiba City).

CHAPTER 5. GROUNDWATER RESOURCES ASSESSMENT

5.1 Existing Borehole Data and Database

5.1.1 Existing Borehole Data

Boreholes have been drilled by SANEPAR, Parana governmental departments and related institutions, municipality offices, private firms and by individuals. Borehole drilling is preceded by the following procedure at present :

- Formatted request letter for drilling to IAP, with the following items ; owner of well, drilling company, purpose of drilling, daily discharge rate in plan, drilling site/depth/diameter, filter plan etc.
- Division of hydroresources management in IAP investigates the request letter.
- The division in IAP gives the authorization for the request drilling by judgment about the request drilling.
- The authorization requires report of drilling result.

However, this procedure had started from 1988 and many boreholes had drilled before this procedure without request letters and judgment by IAP.

Registered records were those received from 1988 to December 1993 accounted for 3,104 boreholes. The records consist of the followings :

- IAP's handling data accounted for 1,100 boreholes stored in IAP's database in governmental computer center without water quality data.
- SANEPAR's handling data accounted for 1,800 filed in respective drilling reports.
- IAP's records of the drilling requests accounted for 304 except the above boreholes.

In actually, the above boreholes data maybe cover the principle boreholes in Parana State but there are many boreholes without records in Parana governmental institutions.

5.1.2 New database of Well Inventory

The new database of well inventory was created to fulfill the following purposes discussed among counterparts of Parana State and JICA expert :

- Collection of all boreholes data and compilation into one system
- Integration of drilling data (including pumping test data) and water quality data
- Easy access to the new well inventory data to construct the new database of well inventory on the marketed database software " Access by Micro Software" in a personal computer.

On the basis of the above discussions, the new database of well inventory was decided to be composed of about 150 items for the each borehole in group meeting (refer Figure-4.1). The data input was conducted by a local consultant firm and all the inputted data have been cross-checked by the counterparts of Parana State.

The sub-contract covers followings :

- The disk of database of well inventory in Parana State (5 sets of disks); the size of database was about 5.8 megabits originally, which was compressed to about 1 megabits.
- The table of all inputted well data for database of well inventory was printed in A,B and C of data list books.
- Each well inventory is printed out in the 17 books of well inventory data as shown in Table-5.1.

5.2 Basic Characteristics Test of Groundwater Resources

5.2.1 Pumping Test of Selected Boreholes by This Study

This test was conducted in order to compare and cross-check the aquifer characteristics between the result of pumping tests and data of the new well inventory. The tests were carried out with the 8 sets of wells in four (4) principal aquifers in Parana State on the basis of the technical specifications attached to in the Report of Pumping Test (stored in JICA office of SEPLAN) conducted by a sub-conducted local consultant firm.

The comparisons and considerations were done between the result of above pumping test and the pumping data of the new well inventory, their aquifer characteristics are shown in Table-5.2.

In Table-5.2, there are differences among the values of critical yield, Specific Yield and Interference of Well between the well inventory data and the pumping test data conducted a local consultant. It is the reason why the former items are average of each aquifer and the latter ones are value of a particular tested well.

On the view of the regional development of groundwater resources, it is assumed reasonably for these three items to use the average value of the well inventory in each aquifer.

5.2.2 Water Quality Test of Selected Wells by This Study

(1) Result of water quality test

The well water quality tests were conducted to check and consider the present condition of groundwater pollution caused by human activities in urban areas. The test items are the following 7 (seven) components (described on Table-5.3) for 50 wells near from principal cities in Parana State including 15 wells in Metropolitan Curitiba :

1) N-NH3 ; Ammonium
2) N-NO3 ; Nitrate
3) N-NO2 ; Nitrite
4) P ; Phosphorus
5) COD ; Chemical Oxygen Demand
6) CCT ; Coliform Culture Test (should be analyzed within 24 hours after sampling)
7) CCF ; Coliform Confirmation Test (should be analyzed within 24 hours after sampling)

The tests were sub-contracted to a local consultant firm. The results of the tests were recorded in the report (5 sets of the report) edited by the local consultant and the result of the analysis is shown in Table-5.3

(2) Consideration of the result

The result of the analysis result is summarized as follows :

- Ammonium(N-NH3) / Nitrite(N-NO2) : These components indicate a contaminated condition of groundwater by animal excrement. The analyzed results show low value and potable.
- Nitrate(N-NO3) / Phosphor : These components are indicators of contamination of groundwater by agriculture fertilizers. The excessive N-NO3 component is known as a material of ill effect of health. In general, the analyzed results shows low value and potable. However, the content of Nitrate for Well No.1(Curitiba City) was analyzed to be 13 ppm which exceeds the maximum permitted value 10 ppm in Japan. It is important to monitor content of Nitrate in Curitiba City.
- CCF (Coliform Confirmation Test): Content of this item is not permitted but many water samples contain over the permitted value zero. Since, it took several days to transport long distance from the sampling points to the speified laboratory, the test results with the excess value are not reliable.

5.3 Groundwater Occurrences

5.3.1 Aquifer Classification by Geological Unit

In Parana State, there are the following various kinds of reservoirs such as cave in carbonate rocks, fractures in basalt and crystalline rocks, porous in sand stone and/or sand, etc.

Such characteristics of aquifers are based on the rock formation, so that the aquifers are able to be classified as set out below in order of older age (Figure-5.1, 5-2 and 5-3).

(1) the "Karst"

- Composed of carbonate rocks and intercalated with schists and quartzite.
- Exposure area of about 5,740 km^2 (the exposure area of carbonate rocks are about 3,480 km2 in it).
- Reservoirs consist of fractures, caves and dolines concerned with Quaternary sediment of river bed in general(Figure-5.4 & Figure-5.5).

(2) Crystalline rocks

- Composed of granitic rocks and metamorphic rocks.
- Exposure area ------------- about 7,540 km2.
- Reservoirs mainly consist of fractures.

(3) Early Paleozoics

- Composed of two(2) groups (Castro Group and Parana Group).
- Exposure area of about 7,150 km2.
- Reservoirs mainly consist of partial fracture in local, but Furnas Formation is composed of permeable sandstones

(4) Middle ~ Late Paleozoics

- Composed of two groups, Itarare Group and Guata Group.
- Exposure area of about 17,400 km^2.
- Reservoirs mainly consist of porous media of sand stone accompanied with partial fracture reservoirs.

(5) Late Paleozoic

- Aquifer is composed of Passa Dois Group.
- Exposure area of about 17,400 km^2.
- Reservoirs consist of porous media of sand stone accompanied with partial fracture reservoirs.

(6) Botucatu Formation

- The exposures of this formations are mainly overlain by Serra Geral Formation in the same area as shown in Figure-5.6, so that the water balance of the above two formations in this study of meteorological analysis and river discharge analysis should be estimated as alike same aquifer.
- Botucatu Formation is composed high permeable sandstones (effectiveporosity; ≥ 25 %, Figure-5.6).
- This Formation is distributed within Serra Geral Formation and Caiua Formation in underground and it forms deep sheeted oundwater aquifer.
- The deep sheeted aquifer consists of alkaline hydrothermal resources in 40-60°C.

(7) Serra Geral Formation

- Serra Geral formation is divided to two areas (the northern area and southern area) by geological setting and the well yield.
- Total exposure area of about 101,000 km^2
- Main aquifers of this Formation is made of weathered layers, porous breciated zones of lava flow unit and opening faults connecting porous parts and the faults form bigger reservoir in scale (Figure-5.7).

(8) Caiua Formation

- Composed of mainly sand stone intercalated with arglirous layers.
- Exposure area of about 30,450 km^2
- Reservoirs consists of porous media of sand stone.
- This aquifer is characterized by homogeneity of porosity (Figure-5.8)

(9) Metropolitan Curitiba Area (except the "Karst" area)

- The aquifers in this area are occupied by the followings; Guabirotuba Formation, the Alluvium sediments and Granitic rocks.
- Exposure area of about 1,130 km^2
- Reservoirs consist of coarser sediments and fracture in Granitic rocks

(10) Coastal Range

- The aquifers in this area are occupied by the marine terrace deposits and the Quaternary river bed sediments as shown in Figure-5.9.
- Exposure area of about 1,950 km^2
- Reservoirs consists of porous media of sand bed.

5.4 Groundwater Potential of Representive Aquifers

5.4.1 Calculation of Groundwater Potential Based on Pumping Test

The calculation of groundwater resources on the basis of pumping test data were roughly calculated by the following formula .

$$GR = A \times Qc / (3.14 \times rwi^2)$$

GR : Groundwater Resources of Respective Aquifer, A : Area of Aquifer

Qc : Critical Yield of Respective Aquifer, rwi : Radius of Borehole Interference.

However, the above formula is presented a part of groudwater resources which are a "Critical Pumping Yield" and not total volume of groundwater resources.

The calculation results on the basis of the above formula are shown in Table-5.5.

In the rough estimation of groundwater, the groundwater resources of Botucatu Formation was calculated as the bigger amount, because the aquifer of Botucatu Formation is highly confined. However its groundwater resources should be considered to be limited by a water balance of recharge volume.

In the rough estimation, the high potential aquifers in Parana State are as follows :

1) Botucatu Formation and Serra Geral Formation
2) the "Karst"
3) Caiua Formation

5.4.2 Estimation of Groundwater Storage Based Pumping Test

The total volume of groundwater resources were estimated on the basis of following formula and data summarized by the well inventory database as shown in Table-5.6:

$$QT = (A / Ai) \times Sc \times D \times (3.14 \times Ir^2)$$

$$Sc = Qt / (3.14 \times ds \times Ir^2)$$

A : Area of aquifer, Ai : Area of pumping interference,

D : Tickness of reservoir for each aquifer ; the tickness assumed by conceptional aquifer model

Sc : Coefficient of storage (= effective permeability)

Qt : Total volume of discharge from pumping start time to being time of critical yield

Ds : Drawdown of water level during pumping tests

Ir : Radius of well interference during pumping test

5.4.3 Permissive Yield Assessment of Groundwater Potential Based on Recharge

In general the groundwater resources are composed of circulating parts and storing parts. Their circulating parts, in their turn, were consisted of two parts : transitory recharge and deep recharge, but deep recharge parts are considered very small amount in the average of long period like as 20 years.

In this study, the amount of circulating groundwater resources was calculated to be equal to transitory recharge on the assumption that amount of deep recharge is zero, so that the data of meteorological and river discharge are used the average of for about twenty(17 ~ 20) years.

The transitory recharge of groundwater resources is estimated by the analysis of baseflow, because baseflow of river discharge is due to discharge of groundwater.

In the view of the above baseflow, the partial estimation of transitory groundwater resources for each aquifers and groundwater basins were studied using the low discharge data of 355 day's discharge in "Flow Regime" by JICA Team and the low discharge data of Q7 by IAP, and the mean base flows in respective exposure units of aquifers were decided by the relationship between the above mentioned low discharges (355 day's discharge and Q7) and the catchment areas corresponding to the discharge (Figure-4.1). Therefore, the average of Q7 for long years like as 17 years in a catchment areas was discussed almost same as baseflow analyzed by hydrograph, in the meeting of groundwater resources group. Therefore, the amount of baseflow in this study were adopted that average of Q7 and 355 day's discharge. By the above mentioned considerations, the groundwater potentials of respective aqufers in Parana state on the basis of water circulation are assessed as shown in Table-5.7.

In the assessed result, the baseflow of Curitiba Metropolitan area is smaller than the anothers. The reason is estimated that the all circulating flows of groundwater resources in Curitiba Metropolitan area are not trending to the Iguacu river basin but some of the flows are discharged to the Coastal range and the "Karst" area. In addition to the above, the discharge mechanism can be caused by the following two reasons :

(a) The altitude in Curitiba Metropolitan area is much higher than the the Coastal range and the "Karst".

(b) The opening fractures cutting through Pre-Cambrian Series are connecting their higher reservoirs to lower reservoirs and the regional circulation flows are tending from higher reservoirs to lower reservoirs (from the Upper Iguacu basin to the Coastal range and/or the Ribeira basin).

Therefore, the baseflow analysis shows high potential of transitory groundwater resources for the following aquifers :

(a) the area of Caiua Formation---------------------------------- 1,056 $m^3/d/km^2$

(b) the "Karst " area---785 $m^3/d/km^2$

(c) the northern area of Botucatu and Serra Geral Formations---672 $m^3/d/km^2$

Furthermore, the estimated results of circulating groundwater resources present the total yields of a circulating groundwater, and the areal permissive yield appears to be about 10 % of the yield from experimental estimation. However, the permissive percentages of aquifers in the " Karst " and Serra Geral Formation (consists two parts; the Northern part and the southern part) are can be estimated muchhigher by approximately 30 %, 20% and 15%. That is because their aquifers structures are very suitable for transposition of groundwater resources, and the critical yield of well in the above areas are bigger.

The total storage volumen of groundwater resources are estimated about 10,000 times of permissive recharge (in day rate) and about several ten times to a hundred times of groundwater resouces calculated by critical yield of well and others.

CHAPTER 6 MASTER PLAN FOR PILOT BASINS

6.1 Methodology of Master Plan Study

Master Plan Study was conducted for the following two (2) items:

a) Assessment of spatial potential of groundwater development

- Analysis of specific mean Q7 (mQ7) by aquifer in the pilot basins.
- Assessment of potentiality of groundwater development for classified municipalities.

b) Planning of groundwater management

- Listing and plotting the existing well sites and discharge rate (yield) on the selected municipalities.
- Collection of the latest spatial data of mean borehole yield and interference radius mainly from SANEPAR.
- Borehole site selection and planning of pipeline systems for the selected municipalities.
- Collection of the current cost data for the on-going "Karst" groundwater development and others by SANEPAR.
- Implementation schedule of urgent groundwater development

6.2 Definition of Boundary of Study Area

The major municipal urban areas located in the Iguaçu and Tibagi river basins straddle over the boundary of other river basins. Therefore, the pilot basins for the study of the groundwater resources are delineated including a part of the neighboring groundwater basins related to the major urban demand centers as defined below:

1) Iguaçu Pilot Basin (Figure-6.1)

Iguaçu river, Karst basin on the right bank of Ribeira river, a part of the left bank of Piquiri river, and Paraná III rive basin ,

2) Tibagi Pilot Basin (Figure-6.2)

Tibagi river, a part of the left bank of Cinzas river, and upstream of Pirapo river.

6.3 Assessment of Spatial Groundwater Potential in Pilot Basins

6.3.1 Assessment of Iguaçu Pilot Basin

The Iguaçu Pilot Basin is composed of Karst, Crystalline Rocks, Furnas Formation, Upper-Middle Paleozoic, Upper Paleozoic, Botucatu Formation, Serra Geral Formation north, Serra Geral Formation south, Guabirotuba Formation as shown in Figure-6.1.

In Iguacu Pilot Basin, reliable data of mQ7 and catchment areas at fluivial stations are listed in Table-6.1. On the basis of the above data, the spatial groundwater potentials in Iguacu Pilot Basin are estimated by same way as the permissive yield assessment mentioned in the former chapter and they are shown in Table-6.2.

Of these aquifers Furnas Formation is treated as an independent aquifer in the Master Plan study, while it was analyzed together with other formation in consideration of distribution area in the study for Strategy. The site importance of this aquifer is not so high but its groundwater potential is higher than common potential of aquifers in Paraná State.

The specific mean discharge which is defined as the specific mean of the annual minimum of average discharge of continuous 7 days (mQ_7) is used for the key data for the assessment of groundwater potential in this study. The specific mean discharge based on base flow is not able to be estimated for Furnas Formation because its distribution area within the pilot basin is very small and an appropriate river discharge gauging station to be used to calculate the base flow of aquifer does not exist. The specific mean discharge of Guabirotuba Formation is also not available due to the same reason.

An statistical analysis of base flow data of these aquifer was conducted, and even one data or data having large dispersion are utilized based on an overall assessment. However, the same result of the study for Strategy is adopted for some aquifers of which specific mean discharges was disqualified by the statistical analysis. The same rule was applied to the Tibagi pilot river basin.

<u>Karst</u>

Groundwater potential of Karst is high as evaluated in the study for Strategy. The Karst area included in the pilot basin has a drainage area of 3,500 Km^2, and about 8.75m^3/s can be developed within the permissible yield. This groundwater resource is appropriate for large scale development since its borehole productivity (borehole yield) is extremely large as 0.44 l/s/ borehole.

The water quality of this aquifer is adequate for drinking water. In fact it is actually utilized as the mineral water source for Curitiba. However, it is assessed to be not adequate for such industrial water resources as hydro-thermal and steam resources because of its high hardness and the Total Dissolved Solid (TDS).

<u>Botucatu Formation</u>

The permissible yield of Botucatu Formation can not be estimated in this study, and it is difficult to apply the concept of permissible yield to this formation at present. Its permissible yield can be technically estimated by use of the drawdown data of groundwater table, but the drawdown data are not available. The specific mean discharge also cannot be applied to this formation because of the nature of its geologic structure.

However, the amount of its groundwater is assessed to be very large based on its extraordinarily large borehole productivity (124 l/s; average of 9 boreholes) and storage volume. Its storage volume is assessed to be more than 20 times larger than that of Karst and a little less than 10 times of that of Serra Geral Formation.

This aquifer forms layering, and its water temperature becomes 40-60 °C at the depth of deeper than 800 m. The average potential of hydrogen is pH 8.01 (alkaline), and the mean natrium (Na) content is 29.2mg/l. This groundwater resource, therefore, is assessed to have high potential of industrial water use with appropriate control of pH and Na by mixing with other fresh water resources in consideration of confined water pressure, pH level and content of natrium.

<u>Serra Geral Formation north</u>

This aquifer is broadly distributed from near Cascavel to the north, but the study area within the Pilot basin is limited to the area of 1900 km^2 near Cascavel. Though the spatial permissive yield and mean productivity of borehole of this formation is less than a half of those of Karst, its potential is relatively large and is assessed to be an adequate groundwater resource for medium scale development.

The water quality of this aquifer is appropriate for both domestic and industrial water supply.

<u>Guabirotuba Formation</u>

This aquifer is distributed in Curitiba metropolitan area (CMA) with a basin area of 900 Km2, and its groundwater resource is widely used for the domestic and industrial water in CMA. Monitoring of groundwater of this formation is required with high maneuverability because it is distributed in the urban area.. It will be required to measure promptly chemical contents in response to necessity not limiting to the standard observation items for drinking water because there is a possibility of contamination of groundwater.

The total permissive yield of the whole aquifer is estimated to be about 0.7 m3/s (average of CMA). Various kind of adverse effects on the use of wells will be expected in the central urban area of Curitiba city in the near future because present groundwater use for industries is estimated to be very high in this area.

<u>Serra Geral Formation south</u>

The aquifer of Serra Geral Formation is broadly distributed with a basin area of 32,000 Km2 in the area middle reach to downstream of the Iguaçu Pilot Basin. The groundwater resource of this aquifer is assessed to be appropriate for small to medium scale development based on its spatial permissive yield and productivity.

<u>Furnas Formation</u>

The aquifer of Furnas Formation is assessed to be appropriate for small scale development based on its productivity of borehole.

<u>Other Aquifers</u>

Groundwater development of other aquifers not aforementioned is assessed to be unfeasible except for the rural areas facing shortage or lack of other fresh water sources because of its low permissive yield and productivity.

6.3.2 Assessment of Tibagi Pilot Basin

Tibagi Pilot Basin is composed of Crystalline Rocks, Furnas Formation, Upper-Middle Paleozoic, Upper Paleozoic, Botsucatu Formation, Serra Geral Formation north, Serra Geral Formation north as shown in Figure-6.2.

In this Piot Basin, the spatial groundwater potentials are estimated by the same way as Iguacu Pilot Basin. The data of mQ7 and catchment areas are shown in Table-6.3 and the estimation of spatial groundwater potential in Tibagi Pilot Basin is shown in Table-6.4.

Botucatu Formation

The aquifer of Botucatu Formation is exposed on the ground surface in a limited area, but it lies broadly under Serra Geral Formation in the northern part of the Tibagi Pilot Basin.

The development potential of groundwater of this aquifer is assessed to be high as well as that in the Iguaçu Pilot Basin. Its groundwater is used as hot water in coffee production factories in Londrina, and is anticipated to be widely used in the future.

Serra Geral Formation north

The aquifer of Serra Geral Formation north is distributed broadly in the north of the Tibagi Pilot Basin. Its development potential of groundwater is assessed to be high and appropriate for medium to large scale because its permissive yield and productivity is higher than those of the Iguaçu Pilot Basin.

Furnas Formation

The aquifer of Furnas Formation is assessed to be appropriate for small scale groundwater development based on productivity of borehole as well as that in the Iguaçu Pilot Basin.

Other Aquifers

Groundwater development of other aquifers not aforementioned is assessed to be unfeasible except for the rural areas facing shortage or lack of other fresh water sources because of its low permissive yield and productivity as well as those in the Iguaçu Pilot Basin.

6.4 Mater Plan for Groundwater Management

6.4.1 Classification and Zoning of Region for Groundwater Development

The urban areas are classified into the following categories by considering characteristics of each area.

(1) Type-A: Large urban areas

The large urban areas are defined that their population will be more than approximately 100,000 in 2015.

The following urban areas belong to Type-A as large urban areas:

A) Iguacu River Basin
- Curitiba metropolitan area
- Cascavel
- Foz do Iguacu
- Guarapuava

B) Tibagi River Basin
- Ponta Grossa
- Londrina
- Apucarana

The urban areas included in Curitiba Metropolitan Area are as shown below:

- Curitiba, Almirante Tamandare, Colombo, Piraquara, Sao Jose dos Pinhais, Araucaria, Campo Largo, Pinhais, Fazenda Rio Grande, Quarto Barras, Campina Grande do Sul, Balsa Nova, Contenda, Mandirituba.

(2) Type-B: Middle urban areas

The middle urban areas are defined that their population will be more than approximately 50,000 in 2015.

The following urban areas belong to Type-B as middle urban areas:

A) Iguacu River Basin
- Francisco Beltrao
- Pato Branco
- Medianeira
- Dois Vizinhos
- Palmas
- Uniao da Vitoria

B) Tibagi River Basin
- Castro
- Telemaco Borba
- Cornelio Procopio
- Arapongas
- Cambe
- Ibipora
- Irati

(3) Type-C: Other urban areas

The other urban areas are classified into the following zoning by considering topographic conditions:

1) Zone-a: Urban areas located nearby main streams

These areas locate nearby main stream or downstream of tributaries, therefore problems of the shortage of intake rate and water quality are few.

2) Zone-b: Urban areas located upstream of second or third tributaries

Although there are problems of possible water development volume and intake method, water quality problems are quite few.

3) Zone-c: Urban areas located at top or ridge of mountains

These areas require to intake the water from the downstream of urban town, and water volume, water quality and intake method are involved in many problems.

One hundred and one municipalities belong to the Iguacu river basin, out of which 17 urban areas are classified into Type-A and other 6 urban areas are classified into Type-B. Therefore, 78 urban areas belong to Type-C urban areas.

Forty-three municipalities belong to the Tibagi river basin, out of which 3 urban areas are classified into Type-A and other 7 urban areas are classified into Type-B. Therefore, 33 urban areas belong to Type-C urban areas.

6.4.2 Groundwater Management for Municipalities

(1) Municipalities subject to master plan study and methodology

The study on the groundwater management was carried out for the municipalities ranked at the Type-A and B. The study of groundwater management for the municipalities ranked at the Type-C was not done and should be carried out by such as future feasibility studies in each individual case, because the amount of newly required water demand of them were studied too small to construct a new borehole or new intake facilities.

In this study, the master plan of groundwater development was conducted on the basis of the following items :

- All amount of the required water demand of the municipalities except Curitiba Metropolitan Area was supplied by groundwater development,
- For Curitiba Metropolitan Area, the Master Plan Study was done to develop four (4) m^3/s of groundwater development within 7.235 m^3/s of newly required water demand,
- The groundwater development plan for each municipalities was based on the spatial permissive yield and spatial borehole productivity within each municipality area,
- The spatial borehole productivity was estimated by mean productivity of present SANEPAR boreholes within each minicipality except small diameter boreholes of personal use,
- The number of required drilling boreholes was estimated by the following formula :

$$N = Q / Pb$$

N : number of required drilling boreholes,

Q : required water demand (m^3/s),

Pb : mean borehole productivity (m^3/s),

- The developing area of new drilling boreholes was estimated by the following formula :

$$Ad = Q / Yp$$

Ad : Developing area of new drilling

Q : required water demand (m^3/s),

Yp : Permissive yield ($m^3/s/km^2$),

- The drilling sites of required boreholes were arranged within into the developing area of new drilling boreholes in iso-distance under the consideration of pipe line arrangement,
- The groundwater development for each municipality was scheduled to supply the sub-section of water demand step by step,
- Monitoring system was planned for sustainable groundwater development, the permissive yield was estimeted in tentative and it's yield should be decided as standard value to conserve the groundwater resources and to develop groundwater resources in good use.

In this Sectoral Report, the required water demand was studied to be supplied by only groundwater resources, but in the actual plan the combined development plan of the surface water and groundwater resources was examined in the other Sectoral Report of Water Resources Development).

(2) Groundwater demand and potential for the municipalities

In planning of the development of the groundwater resources, it is assumed that the water demands for domestic and industrial uses and agricultural water requirement are supplied by development of the groundwater resources in order to evaluate the dependability of the ground water resources for the water supply to the municipalities.

Tables-6.5 and 6.6 indicate the aforesaid water demands in the municipalities with the Type-A and B. In the both pilot basins, the municipalities have a sufficient amount of the permissive yield comparing with the water demands at 2015 in general. The groundwater management plan for the municipalities with the Type-A is summarized hereunder:

a) Iguaçu pilot basin

Curitiba Metropolitan Area (CMA)

The incremental water demands during 20 years till 2015 is estimated at

7.235 m^3/s and the aquifers in this area are the Karst, Guabirotuba Formation and Crystalline Rocks.

The groundwater resources in Karst aquifer is able to meet the aforesaid water demands during 20 years till 2015 in CMA. The development in this aquifer requires observation of river water level and discharge along the river reaches and piezometric monitoring of groundwater table in order to manage and control the groundwater development within the permissive yield.

In the aquifer of Guabirotuba Formation, there exist many boreholes in the central part of Curitiba City. Therefore, it is considered that the total extracted water amount is currently over the permissive yield in this aquifer taking into account a number of bore holes and productivity. In order to use effectively the available groundwater, establishment of piezometric monitoring network and rearrangement of location and number of the existing boreholes based on the result of monitored data and its analysis are strongly desired to be undertaken immediately.

In CMA, Crystalline Rocks lies under Guabirotuba Formation and new provision of a borehole at the open fractures in the rock layer is able to develop some amount of water corresponding to a little water demands or industrial water demand for a few factories. But, it is low possibility to identify the open fractures. From the mentioned aspects, this rock layer is excluded from planning.

Cascavel, Foz do Iguaçu and Guarapuava

The incremental water demands during 20 years till 2015 is estimated at 0.542 m^3/s for Cascavel, 1.043 m^3/s for Foz do Iguaçu and 0.292 m^3/s for Guarapuava. The aquifers for theses municipalities are the Serra Geral Formation north and underlying Botucatu Formation. Both the aquifers have groundwater potential to meet the incremental water demands during 20 years till 2015. It is proposed to develop both the aquifers in order to reduce the length of pipeline system in a water supply zone by extracting large amount of water at a location within permissive yield of these Formations.

b) Tibagi Pilot Basin

Ponta Grossa

The incremental water demand during 20 years till 2015 is 0.433 m^3/s in total. The aquifer for this municipality are the Middle Paleozoic and the permissive yield almost corresponds to the incremental water demand at 2015. However, its productivity of a borehole is low level and therefore, a lot of boreholes are required to be provided for satisfying the aforesaid water demands.

Londrina and Apucarana

The incremental water demand during 20 years till 2015 is 0.950 m^3/s for Londrina and 0.232 m^3/s for Apucarana. The aquifers for theses municipalities are the Serra Geral Formation north and underlying Botucatu Formation. The combination of development of both the aquifers, which are applied for development for Cascavel is also proposed for these areas.

(3) Groundwater development for municipalities

The groundwater resources development plan for the municipalities is established as shown Tables-6.7 and 6.8.

The main features and draft implementation schedule of the proposed projects are summarized in Tables-6.7 and 6.8 and the main features for each municipalities are represented in Figures-6.3~6.16.

Among the mentioned projects, the groundwater development projects for Curitiba Metropolitan Area and the municipality of Cascavel are required to be urgently implemented taking into account the present water demand/supply balance situation. The detail of these projects are described as follows:

a) Curitiba Metropolitan Area (CMA) (Figure-6.3)

Groundwater development in the Karst aquifer

The Karst aquifer is the most prospective one as water source for the domestic and industrial water supply. Assuming the stagewize development of the Karst aquifer, this aquifer is divided into four (4) areas as shown in Figure-6.3 and these areas are planned to be developed in order of distance from CMA. The main features of bore holes planned to be provided in the respective area are as follows:

Descriptions	Main Features
a) Permissive yield	1.1 m^3/s
b) Diameter	10 inches
c) Drilling depth	60 m
d) Average productivity	160 m^3/h
e) Number of productive boreholes	26 holes
f) Success ratio of borehole	75 %
g) Catchment area	400 km^2
h) Number of observation stations for river water level	5 sites

The main features in the table are based on the following considerations:

The number of boreholes was determined by the data of permissive yield, borehole productivity and new demand.

Drilling location is planned to be made at a site, where the surface layer is not affected by the karstification, in order not to induce land subsidence or cave-in due to extraction of groundwater.

It is necessary to review the specific mQ7 and determine the optimum permissive yield based on the result of monitoring on the river flow discharge and extraction amount from boreholes.

Management of groundwater uses and development in the aquifer of Guabirotuba Formation

In order to effectively use and develop the groundwater resources in this aquifer, it is required to establish an monitoring system for the groundwater table and water quality. The proposed monitoring system shown in Figure-6.3 is comprised of piezometric monitoring borehole of 20 locations among which fifteen (15) boreholes are planned to be located surrounding the central area of CMA and the other five (5) ones are installed in the central area. The water quality is also planned to be observed at monitoring boreholes in order to monitor water pollution due to infiltration of sewage and/or industrial waste water. Based on the data obtained through monitoring of groundwater table, it may be necessary to rearrange or integrate the existing boreholes in order not to induce the adverse effects such as land subsidence, lowering of ground water table, reduction of extraction of groundwater amount, and so on.

b) Cascavel (Figure-6.4)

The city area of Cascavel is located around the watershed boundary of the Iguaçu and Piquiri river basins, and therefore it is necessary for use of surface water to provide pumping-up facilities with significant hydraulic head which needs high construction cost and operation and maintenance cost. While, the Serra Geral Formation north and Botucatu Formation, rich groundwater aquifers, is underlying in the city area.

Taking into account the water resources conditions in Cascavel, the groundwater development of the aforesaid aquifers is proposed for domestic and industrial water supply for Cascavel as shown in Figure-6.4.

Since it is considered that the confined water table of aquifer of the Botucatu Formation is at about 600 m in elevation around the city area of Cascavel, the ground elevation at the drilling site is planned to be selected at EL. 600 m lower than the elevation of the city area and the drilling depth of the boreholes are required to be about 1,300 m. It is required to identify the open fractures in the aquifer of Serra Geral Formation based on the aerial photographs and fault analysis in order to decide the location of the boreholes. The piezometric monitoring boreholes are also provided at the up- and downstream of the boreholes along the open fractures.

(3) Water Development for Rural Domestic Water

In rural areas, it is difficult to supply the piped treated water systematically by surface water, because demand of domestic water is scattered due to topographical and social condition. Therefore, supply for domestic water will be done by groundwater development.

The following study items should be discussed with municipality wise in the future study:

- intake rate
- cost for water development

(4) Water Development for Agricultural Water

Supply method of agricultural water in rural areas is generally a pipeline method with a direct intake using a pipeline and headworks. Therefore, supply for agricultural water will be done by surface water development.

The following study items should be discussed with municipality wise in the future study:

- intake rate
- cost for water development

6.5 Unit Cost for Groundwater Development

The unit cost with borehole construction is listed in Table-6.9.

CHAPTER 7 RECOMMENDATIONS

It is recommended to improve the following two main components of Groundwater Management which are basic necessity in Sustainable Groundwater Development:

- Comprehensive groundwater management
- Integrated monitoring of groundwater resources

7.1 Recommendation on Comprehensive Groundwater Management

The comprehensive groundwater management in "Sustainable Development' is composed of two main component: i.e., Groundwater Development and Monitoring.

(1) Permissive Yield

It is most important for Groundwater Management to determine "Permissive Yield" under the consideration of water balance for respective aquifers and for respective developing areas. The groundwater development should be planned within Permissive Yield. Therefore review of the permissive yield should be conducted by the following ways since the permissive yield in this study has been tentatively determined:

- To review the mQ7 at the river discharge stations,
- To monitor the groundwater table, water balance and water quality by the observation holes and/or the river base flow in the surroundings of the developing areas,
- To set up the good site arrangement of production boreholes and monitoring posts on the basis of the groundwater circulation mechanism,
- To review and analyze the recorded monitoring data.

(2) Guidelines for Development and Management

The groundwater management should establish the following guidelines for groundwater development and monitoring:

- To determine the permissive yield of each borehole,
- To determine the spatial permissive yield in each developing area,
- To determine non-interference distance among pumping boreholes,
- To set up the site arrangement of monitoring posts of observation boreholes and/or fluvial river stations,
- Design and construction method of the monitoring system.

(3) Long Term Plan of Groundwater Development

It is recommended to prepare and review a Long Term Plan of Groundwater Development for the major urban areas in Paraná State every 5 years.

(4) Long Term Plan for Groundwater Monitoring System

It is recommended to prepare a long term plan for the integrated monitoring system of groundwater for the superintendence of regional management of large urban areas in addition to the mandatory monitoring system for respective groundwater projects.

It is also recommended to issue a management report which deals with the conditions of groundwater use, problems and needs in Paraná State once in 5 years.

(5) Legal and Institutional Arrangement

The following legal and institutional arrangement is recommended:

- Legal provision for responsibility of submission of necessary information from government, private and related institutions and organizations, and penal code,
- Legal provision for registration and license for drilling companies and penal code for conditions of concession and permission for groundwater development,
- Legal provision for the mandatory monitoring data including pumping and water quality tests at presence of authorized inspectors for renewal of concession and permission for groundwater use, and penal code such as closure of wells,
- Cost recovery system for the operation and maintenance of the integrated monitoring system by the expense of beneficiaries

7.2 Recommendation on Integrated Database of Borehole Inventory

It is recommended to improve the existing database and to upgrade it to a comprehensive database of borehole inventory for Sustainable Groundwater Development in Paraná State. It covers basic information of productivity, hydrogeology (geology, chemistry, hydraulic characteristics), location information, utilization information. The following work items are to be supplemented to achieve this purpose.

- To record the information of borehole locations, geological profiles and borehole profiles by scanner,
- To record the elevation of borehole site,
- To record systematically and annually and to supplement the data of newboreholes and new chemical analysis of water samples taken from boreholes,
- To conduct statistical analysis and review of the stored data including analyses of groundwater utilization, borehole productivity and water quality once in 3 years up to the year 2005 and once in 5 years thereafter.

Provision of a personal computer system with a scanner for exclusive use of database of borehole inventory is necessary.

TABLES

Table-2.1 Population Distribution of Parana State

Year / No. and NAME of MRH	1993			2005			2015		
	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
01. MRH 268/CURITIBA	1,960,500	126,400	2,086,900	2,406,100	114,200	2,520,300	2,664,300	96,200	2,760,500
02. MRH 269/L. PARANAENSE	146,600	33,700	180,300	179,800	32,300	212,100	207,400	28,900	236,300
03. MRH 270/ALTO RIBEIRA	5,500	24,400	29,900	8,000	21,500	29,500	11,000	17,900	28,900
04. MRH 271/A. RIO NEGRO	6,500	33,500	40,000	10,700	36,200	46,900	16,200	35,800	52,000
05. MRH 272/ C. LAPA	60,900	46,000	106,900	73,300	45,900	119,200	83,800	42,300	126,100
06. MRH 273/C.PONTA GROSSA	350,600	65,300	415,900	463,300	55,300	518,600	572,400	44,700	617,100
07. MRH 274/C.JAGUARIAIVA	43,900	20,900	64,800	91,300	16,100	107,400	168,300	12,100	180,400
08. MRH 275/S. MAT. do SUL	20,200	34,500	54,700	26,200	34,600	60,800	31,100	31,900	63,000
09. MRH 276/Col. IRATI	72,100	103,600	175,700	90,000	102,200	192,200	104,600	93,500	198,100
10. MRH 277/ALTO IVAI	24,100	72,400	96,500	32,500	59,500	92,000	39,200	47,000	86,200
11. MRH 278/N. V. WENCESLAU BRAZ	97,000	71,300	168,300	122,800	44,500	167,300	143,900	27,800	171,700
12. MRH 279/N. V. JACAREZINHO	221,600	86,300	307,900	260,900	50,300	311,200	294,600	29,200	323,800
13. MRH 280/Alg. ASSAI	49,600	28,400	78,000	60,000	15,700	75,700	68,600	8,800	77,400
14. MRH 281/N. N. LONDRINA	741,200	94,900	836,100	982,800	48,000	1,030,800	1,215,700	24,900	1,240,600
15. MRH 282/N. N. MARINGA	406,800	35,700	442,500	576,800	16,600	593,400	731,600	8,000	739,600
16. MRH 283/N. Novis. PARANAVAI	206,500	65,100	271,600	239,200	34,600	273,800	268,300	18,700	287,000
17. MRH 284/N. N. APUCARANA	214,800	104,600	319,400	256,800	53,300	310,100	293,600	28,000	321,600
18. MRH 285/N. Novis. UMUARAMA	261,700	137,500	399,200	310,700	67,800	378,500	353,500	34,600	388,100
19. MRH 286/C. MOURAO	242,900	132,300	375,200	309,200	71,100	380,300	364,200	38,900	403,100
20. MRH 287/PITANGA	34,000	91,800	125,800	59,500	78,600	138,100	94,900	64,500	159,400
21. MRH 288/Extr. Oeste PARANAENSE	769,800	265,100	1,034,900	1,125,100	158,900	1,284,000	1,454,700	96,200	1,550,900
22. MRH 289/Sudoeste PARANAENSE	235,200	238,800	474,000	304,200	173,300	477,500	361,900	123,400	485,300
23. MRH 290/ C. GUARAPUAVA	180,500	157,600	338,100	229,800	158,100	387,900	272,600	147,100	419,700
24. MRH291/ MEDIO IGUACU	105,600	75,900	181,500	131,200	70,100	201,300	152,900	60,700	213,600
TOTAL OF PARANA STATE	6,457,900	2,145,900	8,603,800	8,350,200	1,558,700	9,908,900	9,969,300	1,161,100	11,130,400

Table-2.2 Studied Water Demand

Projected Domestic and Industrial Water Demands by Region (MRH)

No. and NAME of MRH	1993			2005						2015					
	Demand			Base Case			Alternative case			Base Case			Alternative case		
	Urban	Industrial	Toatal	Urban	Industrial	Total	Urban	Industrial	Total	Urban	Industrial	Total	Urban	Industrial	Total
01 MRH 268/CURITIBA	281.73	223.92	505.65	456.55	315.29	771.84	456.55	293.10	749.65	679.51	409.68	1,089.19	607.31	355.03	962.34
02 MRH 269/L. PARANAENSE	20.73	2.56	23.29	28.63	1.57	30.20	28.63	1.57	30.20	41.35	0.54	41.89	41.35	0.54	41.89
03 MRH 270/ALTO RIBEIRA	3.44	0.76	4.20	3.98	0.92	4.90	3.98	0.92	4.90	5.06	1.13	6.19	5.06	1.13	6.19
04 MRH 271/A. RIO. NEGRO	4.60	0.27	4.87	6.33	0.44	6.77	6.33	0.44	6.77	9.10	0.60	9.70	9.10	0.60	9.70
05 MRH 272/C. LAPA	12.29	6.32	18.61	16.09	9.83	25.92	16.09	9.83	25.92	22.07	13.26	35.33	22.07	13.26	35.33
06 MRH 273/C. PONTA GROSSA	47.83	35.84	83.67	66.78	50.58	117.36	66.78	53.44	120.22	97.67	65.79	163.46	107.99	73.66	181.65
07 MRH 274/C. JAGUARIAIVA	7.45	7.24	14.69	14.50	14.30	28.80	14.50	14.30	28.80	31.57	14.30	45.87	31.57	20.68	52.25
08 MRH 275/S. MAT. do SUL	6.29	0.40	6.69	8.21	0.45	8.66	8.21	0.45	8.66	11.03	0.45	11.48	11.03	0.52	11.55
09 MRH 276/Col. IRATI	20.21	2.60	22.81	25.95	3.96	29.91	25.95	3.96	29.91	34.67	3.96	38.63	34.67	5.30	39.97
10 MRH 277/ALTO IVAI	11.10	0.17	11.27	12.42	0.24	12.66	12.42	0.24	12.66	15.09	0.24	15.33	15.09	0.32	15.41
11 MRH 278/N.V. WENCESLAU BRAZ	19.35	0.74	20.09	22.59	1.18	23.77	22.59	1.18	23.77	30.05	1.18	31.23	30.05	1.61	31.66
12 MRH 279/N.V. JACAREZINHO	35.41	10.59	46.00	42.01	14.95	56.96	42.01	14.95	56.96	56.67	14.95	71.62	56.67	19.45	76.12
13 MRH 280/Alg. ASSAI	8.97	1.77	10.74	10.22	1.56	11.78	10.22	1.56	11.78	13.55	1.56	15.11	13.55	1.55	15.10
14 MRH 281/N.N. LONDRINA	96.15	39.43	135.58	132.30	56.36	188.66	132.30	62.04	194.34	195.16	56.36	251.52	217.11	90.38	307.49
15 MRH 282/N.N. MARINGA	50.89	26.72	77.61	76.01	44.86	120.87	76.01	48.69	124.70	116.22	44.86	161.08	129.43	72.05	201.48
16 MRH 283/N.Novis. LONDRINA	31.23	4.81	36.04	36.96	7.60	44.56	39.96	7.60	47.56	50.23	7.60	57.83	50.23	10.30	60.53
17 MRH 284/N.N. APUCARANA	36.73	10.94	47.67	41.86	18.25	60.11	41.86	18.25	60.11	56.28	18.25	74.53	56.28	25.16	81.44
18 MRH 285/N.Novis. UMUARAMA	45.91	6.42	52.33	51.10	9.56	60.66	51.10	9.56	60.66	67.92	9.56	77.48	67.92	12.68	80.60
19 MRH 286/C. MOURAO	43.15	8.02	51.17	51.34	12.26	63.60	51.34	12.26	63.60	70.54	12.26	82.80	70.54	16.42	86.96
20 MRH 287/PITANGA	14.47	0.50	14.97	18.64	0.93	19.57	18.64	0.93	19.57	27.90	0.93	28.83	27.90	1.33	29.23
21 MRH 288/Extr.Oeste PARANAENSE	119.01	52.06	171.07	165.21	101.55	266.76	165.21	111.35	276.56	245.14	101.55	346.69	271.41	166.36	437.77
22 MRH 289/Sudoeste PARANAENSE	54.51	12.99	67.50	64.46	23.62	88.08	64.46	23.62	88.08	84.93	23.62	108.55	84.93	33.41	118.34
23 MRH 290/C. GUARAPUAVA	38.88	16.59	55.47	52.37	29.41	81.78	52.37	29.41	81.78	73.45	29.41	102.86	73.45	41.31	114.76
24 MRH 291/MEDIO IGUACU	20.87	8.95	29.82	27.18	13.26	40.44	27.18	13.26	40.44	37.38	13.26	50.64	37.38	17.57	54.95
TOTAL OF PARANA STATE	1,031.21	480.60	1,511.81	1,431.70	732.93	2,164.63	1,431.70	732.93	2,164.63	2,090.49	732.93	2,823.42	2,072.04	980.59	3,052.63

Table-3.1 General Stratigraphy of Parana State

ERA	SYMBOL	PERIOD	GROUP	FORMATION	LITHOLOGY (MAIN FOSSILS)
CENOZ. < 65 m.y.	Qa	QUATERNARY < 1.8 m.y.			alluvium.
	Qm				inconsolidated marine sediments.
	Qg			GUABIROTUBA	clays, arkoses, loams, sands and gravels.
MESOZOIC 230 to 65 m.y	Kba	CRETACEOUS 140 to 65 m.y.	BAURU	ADAMANTINA	thin sandstones, siltstones and brownish laminites.
	Kbsa			SANTO ANASTACIO	sandstones and laminites.
	Kbc			CAIUÁ	violet sandstones (Theropoda)
	Kλs				doleritic dikes and sills, syenite plutons, phonolite and carbonatites.
	JKsg	JURASSIC TRIASSIC 140 to 230 m.y.	SÃO BENTO	SERRRA GERAL	basalt lavas and sills, with andesite lavas.
	JTpb			PIRAMBÓIA AND BOTUCATU	sandstones and siltstones with few conglomerates (Collurousaria and Therapsida)
PALEOZOIC 570 to 230 m.y.	Pb	PERMIAN 280 to 230 m.y. — UPPER			gabbro intrusions with alkaline differentiations green or red siltstones, snadostones and
	Pprr		PASSA DOIS	RIO DO RASTO	calcarenite (Endothiodon, Leinzia, Terraiopsis, Phyloteca and Calamites)
	Ppt			TEREZINA	siltstones and calcarious rocks (Pinzonella neotropica)
	Ppsai	MEDIUM		SERRA ALTA	laminites and shales (Maackia, Tholonotus, Acantholeaia)
				IRATI	mudtones, shales and pyrobitumenous shales (Mesosaurus brasiliensis)
	Pg		GUATA	PALERMO	gray siltstones (Cardiocarpus and Dadoxylon)
				RIO BONITO	sandstones, siltstones, shales, limestone and and coal beds (Plicoplasia sp; Sanguinolites brasiliensis, Glossopteris and Gangamopteris)
	Pi	LOWER	ITARARÉ	RIO DO SUL	gray shales and siltstones, sandstones and dynmictites (Chonetes sp; Langella imbituvensis; Warthia sp; Heteropectem catharina)
				MAFRA	sandstones, siltstones and laminites (Elonicthys gondwanus)
				CAMPO DO TENENTE	coarse sandstones, siltstones, dyamictites.
	Dppg	DEVONIAN 345 to 395 m.y.	PARANÁ	PONTA GROSSA	gray shales and siltstones (Australocoelia tourteloti and Metacryphaeus australis)
	Dpf			FURNAS	sandstones and siltstones (Rounaltia furnai)
	Oc	ORDOVICIAN 500 to 435 m.a	CASTRO		siltstones, sandstones, arkose, conglomerates, rhyolite, rhyolitic pyroclastics; few andesites.
	Cg	CAMBRIAN 570 to 500 m.y.		GUARATUBINHA	rhyolites, andesites, siltstones, sandstones and conglomerates.
	Cc			CAMARINHA	siltstones, mudston, conglomerates and arkose.
	Cya		GRANOTOIDS		alkaline granites, syenites and alaskites.
	Cym				gray hornblend and hornblend + biotite granodiorites, monzonites and granites
	Cyg				creamy and reddish gneissose granites, with megacrystals of K feldspars.
PROTEROZOIC 2500 to 570 m.y.	PSygn	UPPER PROTEROZOIC 1000 to 570 m.y.			gneissose granites of anatexite.
	PSaa		AÇUNGUI	ANTINHA SEQUENCE	metaritmites, metasandstones and metalimestones. few metaconglomerates.
	PSai			ITAIACOCA	metasiltstones, metaritmites, dolomitic marbles, dolomites, metasandstone, quartzites and micaschists.
	PSac			CAPIRU	metasiltstones, metamudstones, graphitic phyllites, dolomitic marbles, dolomits, metasandstones.
	PSav			VOTUVERAVA	metasiltstones, metamudstones, metaritmites, slates, metarenites and micaschists. limestones and dolomites.
	PSm				banded migmatites, micaschists and quartzites.
	PIsac	LOWER PROTEROZOIC 2500 to 1800 m.y.	SETUVA	ÁGUA CLARA	calcareous schists, marbles, micaschists, metabasite. manganese rocks.
	PIstc			TURVO-CAJATI	garnet-sillimanite schists, actinolite-biotite schist, calc-silicate schists, dolomitic marbles and calc-silicate rocks.
	PIsp			PERAU	calcareous-schists, micaschists, metabasites, amphibolites and qartzites. metavolcanics.
	PIpsm		PRESETUVA COMPLEX		banded migmatites, gneisses on strips, ocelar gneisses, quartzite to magnetite.
	PIpss				amphibolites, metabasites, serpentines and talcschists.
ARCHEAN 2,500 m.y.	Asn		SERRANEGRA COMPLEX		charnockites, granulites, magnesian schists, amphibolites, micaschists and quartzites.

Table-5.1 Print-out Format of Informations for Each Borehole

CADASTRO DE POCOS

COD.POCO: 1 Nº SIRIE: 2

COOPERACIO JICA TEAM E GV. DO PARNA

UTIRIZACÃO E CONSERVACÃO DOS RECRUSOS HIDRICOS SUBTERRÂNEOS DO ESTADO DO PARANA

I. IDENTIFICACÃO DOS DADOS

Classe do Dado : 3
Data de Cadastro : 4

II. LOCALIZACÃO DO POCO

Latitude : 5
Longitude: 6
Altitude : 9 | CEP : 10
Municipio: 11
Localizacão : 12

III. DOCUMENTO DO POCO

Nome do Proprietirio : 13
Nome Empresa Prefurecão :
14
Uso do Agua : 15
Demanda Utilizada: 16 m³/D
Tipo do Bomba: 17
Profundidade : 18 m
Potencia da Bomba e Outoros :
19

VI. PERFURACAO

Data Inic/Conc : 39
Metodo/Perf. : 40

Dilmetros(pol) :

φ1: 41 ,de 0 m ate 42 m
φ2: 43 ,de 42 m ate 44 m
φ3: 45 ,de 44 m ate 46 m
φ4: 47 ,de 46 m ate 48 m
φ5: 48 ,de 48 m ate 50 m
φ6: 51 ,de 50 m ate 52 m

Revestiment :

φ1: 53 ,de 0 m ate 54 m
φ2: 56 ,de 56 m ate 57 m
φ3: 58 ,de 59 m ate 60 m
φ4: 61 ,de 62 m ate 63 m
φ5: 64 ,de 65 m ate 66 m
φ6: 66-1,de 66-2m ate 66-3m

Cimentacao : Tipo 67
Ate: 67

Filtro : Tipo: 68

F-1 de: 69 m ate 70 m
F-2 de: 71 m ate 72 m
F-3 de: 73 m ate 74 m
F-4 de: 75 m ate 76 m
F-5 de: 77 m ate 78 m
F-6 de: 79 m ate 80 m
F-7 de: 81 m ate 82 m
F-8 de: 83 m ate 84 m

Comentario: 85

① CROQUI DE LOCALIZACÃO :

② PERFIL LITHOLÓGICO, CONSTRUTIVO E PERFILAGEM :

IV. CARACTERISTICAS DE AQUIFEROS

Aquif.Principal
Tipo: 22 Era: 20
Formacão: 21

Aquif.Secundario
Tipo: 25 Era: 23
Formacao: 24

Afinamento Lama Principal (L/min)
de 26 m ate 27 m, Qip 28

Afinamento Lama Secundario (L/min)
de 29 m ate 30 m, Qis 28'

Nivel Estatico(N.E.): 31 m

V. LITOLOGIA

Litologia 1:de 32-1 m, ate 32-2 m
32

Litologia 2:de 33-1 m, ate 33-2 m
33

Litologia 3:de 34-1 m, ate 34-2 m
34

Litologia 4:de 35-1 m, ate 35-2 m
35

Litologia 5:de 36-1 m, ate 36-2 m
36

Litologia 6:de 37-1 m, ate 37-2 m
37

Litologia 7:de 38-1 m, ate 38-2 m
38

VII. TESTES DE PRODUCÃO

Equipament/Tipo-Profund. :
86 86-1 m

Data Teste/Inic. e Conc. : 87 hs
de 87-1 ate 87-2

1ªEtapa: Q1 88 m³/h, m³/h
N.E. 89 m N.D. 90 m T1 91

2ªEtapa: Q2 92 m³/h, m³/h
N.E. 93 m N.D. 94 m T2 95

3ªEtapa: Q3 96 m³/h m³/h
N.E. 97 m N.D. 98 m T3 99

4ªEtapa: Q4 100 m³/h m³/h
N.E. 101 m N.D. 102 m T4 103

Recuperacão: 103-1 hs. /Tr 103-2 m³/h

IX. QUALIDADE DA AGUA Temperatura:Tar: 111-1°C

Tagua: 111 °C Sabor/Odor/Cor: 112
Turbid.: 113 Dureza: 117

VIII. CARACTERISTICAS HIDRAULICAS

Transmissividade(T:) 104 m²/h
Capacidade Especifica(Sc:) 106-1 m³/h/m
Permeabilidade (K:) 106 cm/s
Coeficiente de Armazenamento(S:) 105 x10⁻³ ; α= 105-1 β= 105-2

Data	pH	C_E	TDS	COD	T-Al	Bica	CO_2L	NO_3	AmN	OrgN
110	114	115	116	135	118	119	120	121	122	123
Cl^-	SO_4	HCO_3	F^-	SiO_2	T-Fe	Mn^{++}	Ca^{++}	Mg^{++}	Na^+	K^+
124	125	126	127	128	129	130	131	132	133	134

	Datas	87-2
M	Regine/Bomba. (h)	87
A	Profund/Crivo (m)	86-1
X	Vazio (Q:m3/h)	107
I	Nivel Dinamico (m)	109
M	〃 Estatico (m)	31
A	Sv (m)	108
	Q/Sv (≒T: m2/h)	107/108

Table-5.2 Summarized Result of Pumping Test Done for This Study

Aquifer	Well Inventory Data			Pumping Test Data				
Name	Critical Yield	Specific Capacity	Interference Radius of Well	Test Well No	Well Name	Critical Yield	Specific Capacity	Interference Radius of Well
the Karst	160 m3/h	72 m3/h/m	395 m	5	Colombo No.1	204 m3/h	59 m3/h/m	unknown
				6	Rio Branco SulNo.1	20.8 m3/h	25.2 m3/h/m	440 m
Serra Geral Formation(North)	42 m3/h	2 m3/h/m	402 m	3	Apucarana No.1	43.8 m3/h	1.3 m3/h/m	520 m
				4	Rolandia	53.5 m3/h	2.3 m3/h/m	370 m
Caiua Formation	30 m3/h	1.5 m3/h/m	297 m	1	Sao Jorge Do Patrocinio	4.2 m3/h	3.3 m3/h/m	520 m
				2	Querencia do Norte	23.3 m3/h	0.73 m3/h/m	330 m
Guabirituba Formation	12 m3/h	2 m3/h/m	492 m	7	Penhais	51.4 m3/h	3.4 m3/h/m	240 m
				8	Fazenda Cangiri	24.5 m3/h	3.0 m3/h/m	220 m

Table-5.3 Result of Water Quality Test of Wells Done by This Study

Well	Location	$N\text{-}NH_3$	$N\text{-}NO_3$	$N\text{-}NO_2$	P	COD	CCT	CCF
1	Ed. Tunis - Casa Blanca	-	13	-	-	-	-	-
2	Tereza Pazini	-	0,8	0,04	-	-	2	-
3	Ed. Saxoni	-	4.6	-	-	41	-	-
4	Coca -Cola	-	-	-	-	-	-	-
5	Ed. Helvética	-	0,2	-	0,07	5	-	-
6	Acquasul	-	8	-	-	-	-	-
7	Ed. Jaraguá	-	0,7	0,03	-	-	-	-
8	Rest. Veneza	-	3,9	-	-	-	13	8
9	Betontex	-	-	-	-	-	2	-
10	Melissatur	0,6	0,4	0,013	-	1	170	9
11	Ferraria	0,08	0,4	0,15	-	-	8	-
12	Guatupê	-	1	-	-	-	-	-
13	Araucária - Rodoviária	-	3,8	-	-	-	-	-
14	Fazenda Rio Grande	-	-	-	0,05	-	3	-
15	Santa Mônica	0,06	-	-	-	2	30	-
16	Tranqueira	0,04	0,3	-	-	-	-	-
17	Almirante Tamandaré	0,05	0,5	-	-	-	2	-
18	Colombo Várzea Capivari	0,02	0,7	-	-	-	-	-
19	Itaperussú	0,07	0,7	-	-	-	-	-
20	Colombo - Calcem	-	1,6	-	-	-	-	-
21	Mandaguari	-	0,7	-	-	-	50	-
22	Paiçandu	-	1,1	-	0,03	-	50	-
23	Campo Mourão	0,03	0,2	-	-	-	17	-
24	Maringá	-	0,6	-	-	-	23	-
25	Dr. Camargo	-	0,7	-	-	-	240	-
26	Nova Olímpia	-	0,6	-	0,03	-	-	-
27	Maria Helena	-	1,8	0,005	0,13	-	13	2
28	Pérola	-	0,9	-	-	-	50	2
29	Xambrê	-	0,1	-	-	-	21	-
30	Altônia	-	0,4	-	-	-	8	-
31	Loanda	-	1,4	-	-	-	-	-
32	Toledo	-	1,3	-	0,03	1	-	-
33	Santa Cruz	-	0,1	-	-	3	-	-
34	Periolho	-	0,5	-	-	1	-	-
35	Sede Alvorada	-	0,4	-	-	4	-	-
36	Santa Tereza	-	1,4	-	0,03	-	-	-
37	Juvinópolis	-	0,4	-	-	6	11	-
38	Altamira do Paraná	-	0,2	-	-	4	-	-
39	Clevelândia	-	0,2	-	-	-	-	-
40	Rolândia	-	3,2	-	-	-	1600	-
41	Apucarana	-	0,6	-	-	-	-	-
42	1° de Maio	-	2,3	-	-	-	1600	-
43	Palmeira	0,06	-	0,07	-	-	4	-
44	Salto Itararé	-	-	-	-	-	110	-
45	Ipiranga	-	-	-	-	-	21	6
46	Porto Amazonas	-	-	0,1	-	2	-	-
47	Antonio Olinto	-	-	-	-	-	-	-
48	Arapoti	-	-	-	-	1	110	-
49	Imbituva	-	-	-	-	3	2	-
50	Teixeira Soares	-	-	-	-	2	2	2

	$N\text{-}NH_3$	$N\text{-}NO_3$	$N\text{-}NO_2$	P	COD	CCT	CCF
MPV	0.08	6	0.02	--	3.5		
MNP						0	0

Note:

MPV: Maximum permitted value - according to: Decree N° 12.486 of 10/20/78 - NBA - 60 São Paulo State.

MPN: Most Probable Number

Bacteriological analyses were made according to the 18th edition of the "Standard Methods for the Examination of Water and Wastewater, 1992".

Chemical Analyses were made according methods 8038, 8171, 8000, 10013 and 8507, HACH CHEM. Co.

Conclusion: According to the Decree above listed, this sample is potable

Table-5.4 Chemical Components of Respective Aquifers (1/2)

Formação	Cor	Turb	pH	STD	Dur	Alc.Tot	HCO3	CO2	NO2	NO3	N.Amo	N.Org	Cl	SO4	F	SiO2	Fe	Mn	Ca	Mg	Na	K
CAIUA																						
Média	12.37	4.68	6.60	76.26	21.33	20.95	21.09	10.30	0.90	0.01	0.04	0.16	1.92	1.43	0.23	21.20	0.28	0.08	4.82	2.35	3.05	2.97
Maxima	400.00	120.00	9.40	439.00	172.00	180.00	180.00	142.97	17.25	0.18	0.56	5.60	20.00	14.20	16.00	86.80	9.75	7.00	57.70	26.20	30.00	8.65
Minima	0.00	0.08	4.50	4.00	0.40	2.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.33	0.33
Moda	2.50	1.00	6.80	53.00	7.00	9.00	9.00	0.00	0.00	0.00	0.01	0.01	1.00	0.00	0.00	20.00	0.00	0.00	1.60	0.97	2.70	2.60
Número	339	337	339	203	339	339	338	319	255	215	135	143	323	79	161	125	298	191	317	317	106	105
AÇUNGUI																						
Média	12.20	5.52	7.60	165.16	116.57	131.41	118.40	8.85	0.66	0.01	0.06	0.30	2.76	2.10	0.02	13.97	1.08	0.05	29.91	16.20	3.69	0.93
Maxima	60.00	32.00	8.60	366.00	260.00	594.00	594.00	56.21	11.61	0.04	0.50	1.94	14.00	8.00	0.18	45.50	23.00	0.37	260.00	57.80	14.80	2.41
Minima	2.50	0.11	5.20	45.00	6.00	4.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.02	0.50	0.20
Moda	2.50	11.00	7.70	136.00	143.20	17.40	17.40	17.40	0.03	0.00	0.01	0.00	2.00	0.00	0.00	#N/A	0.00	0.00	27.30	17.40	#N/A	1.20
Número	40.00	40.00	38.00	38.00	40.00	39.00	37.00	36.00	38.00	35.00	17.00	16.00	36.00	30.00	18.00	16.00	38.00	27.00	40.00	40.00	13.00	13.00
BOTUCATU																						
Média	5.64	2.42	7.05	127.17	56.92	77.30	72.82	16.88	0.14	0.00	0.04	0.07	2.04	3.20	0.20	21.48	0.16	0.01	17.21	4.62	11.82	2.07
Maxima	40.00	15.00	9.50	268.00	188.70	228.00	197.00	92.70	0.41	0.03	0.20	0.25	6.00	13.20	0.60	58.00	1.30	0.05	52.90	28.60	40.00	6.40
Minima	0.72	0.25	5.40	19.00	2.90	4.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00	0.00	0.48	0.26	0.70	0.50
Moda	2.50	0.80	7.30	152.00	46.00	#N/A	#N/A	12.20	0.00	0.00	0.00	0.00	1.00	0.00	0.30	10.00	0.00	0.00	#N/A	2.40	12.20	2.80
Número	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	24.00	23.00	19.00	20.00	25.00	23.00	16.00	9.00	25.00	13.00	25.00	25.00	14.00	14.00
FURNAS																						
Média	10.16	4.82	6.86	119.91	50.65	63.66	66.51	9.11	0.77	0.01	0.04	0.20	2.13	1.89	0.92	12.52	1.03	0.01	7.65	4.29	4.80	1.28
Maxima	55.00	22.00	8.40	601.00	176.30	223.00	223.00	21.63	6.60	0.08	0.28	0.60	9.00	4.00	4.40	30.00	9.60	0.07	32.50	21.50	18.20	3.64
Minima	0.00	0.08	4.50	4.00	0.40	2.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.16	0.20
Moda	2.50	0.50	6.60	21.00	#N/A	3.00	3.00	18.54	0.02	0.00	0.01	0.07	0.00	0.00	0.00	7.00	0.10	0.00	#N/A	#N/A	#N/A	0.46
Número	16	16	16	16	16	16	16	16	13	11	12	12	15	9	5	11	15	7	13	13	8	8
ITARARE																						
Média	11.12	5.12	7.56	177.51	58.78	99.51	104.27	10.37	0.32	0.01	0.04	0.13	2.25	22.08	0.26	24.07	0.54	0.12	16.80	4.90	22.70	2.42
Maxima	130.00	97.00	11.15	553.00	330.00	535.00	535.00	103.80	3.90	0.13	0.60	0.90	15.50	329.40	3.80	58.52	8.50	4.00	123.40	40.04	95.65	53.10
Minima	0.00	0.10	5.40	26.00	0.10	6.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.60	0.26	0.10	0.60
Moda	2.50	0.50	7.90	161.00	68.00	118.00	101.00	0.00	0.00	0.00	0.01	0.00	1.00	3.00	0.00	25.00	0.10	0.00	16.00	5.30	0.66	0.90
Número	110	113	114	110	113	113	99	98	94	86	76	74	98	72	45	70	102	48	100	100	61	61
PASSA DOIS																						
Média	12.66	8.18	7.89	242.79	70.49	157.59	156.06	9.44	0.29	0.01	0.05	0.20	1.94	9.56	0.58	27.22	0.55	0.05	19.04	6.55	52.81	1.76
Maxima	175.00	145.00	9.93	929.00	282.00	809.00	725.00	73.91	3.38	0.10	0.60	1.34	29.30	98.00	5.00	58.43	6.06	0.45	75.30	36.67	486.96	5.18
Minima	0.00	0.12	5.70	29.60	1.40	11.50	11.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.80	0.00	0.00	0.68	0.08	1.50	0.40
Moda	5.00	1.50	7.70	159.00	42.00	99.00	136.00	0.00	0.00	0.00	0.00	0.00	1.00	2.00	0.10	25.00	0.00	0.00	3.10	0.50	1.50	1.00
Número	103	103	103	98	103	102	88	81	93	80	64	57	95	64	56	64	90	50	95	94	60	60

Table-5.4 Chemical Components of Respective Aquifers (2/2)

Formação	Cor	Turb	pH	STD	Dur	Alc.Tot	HCO3	CO2	NO2	NO3	N.Amo	N.Org	Cl	SO4	F	SiO2	Fe	Mn	Ca	Mg	Na	K
PRE-CAMB.																						
Média	8.81	3.91	7.30	139.89	63.14	78.86	75.85	10.63	0.57	0.08	0.12	0.21	3.69	3.53	1.45	30.12	0.60	0.22	15.16	7.55	8.18	2.12
Maxima	120.00	48.00	10.60	526.50	319.30	361.80	300.80	76.26	8.05	9.00	4.20	4.20	159.30	89.00	37.80	98.00	23.00	8.00	86.09	73.50	27.50	15.80
Minima	0.00	0.05	0.28	32.60	0.44	3.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.40
Moda	2.50	1.00	7.30	138.00	112.00	44.00	44.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	25.00	0.10	0.00	7.10	1.60	1.90	2.40
Número	149	153	155	144	155	149	137	135	143	125	95	88	145	94	62	88	137	73	146	144	79	75
RIO BONITO																						
Média	4.36	1.17	8.06	155.16	51.79	90.30	103.92	2.15	0.05	0.00	0.05	0.06	0.92	3.95	0.19	31.39	0.12	0.03	17.39	2.17	29.62	1.67
Maxima	10.00	2.50	8.70	198.00	75.50	150.00	158.60	3.90	0.12	0.03	0.15	0.15	1.94	6.00	0.25	61.00	0.53	0.12	27.80	3.80	51.17	2.80
Minima	2.50	0.12	7.40	84.00	24.00	29.00	29.00	0.00	0.00	0.00	0.01	0.01	0.00	0.60	0.14	18.31	0.00	0.00	6.50	0.19	3.00	0.80
Moda	5.00	2.00	8.00	#N/A	#N/A	29.00	#N/A	#N/A	0.00	0.00	0.01	0.01	1.00	5.00	#N/A	#N/A	0.10	0.00	#N/A	2.40	#N/A	#N/A
Número	11	11	11	11	11	11	9	8	11	9	4	4	10	8	3	7	10	7	11	11	7	7
S.GERAL N																						
Média	8.55	3.10	7.60	145.97	54.17	75.38	68.68	8.17	0.94	0.06	0.03	0.14	3.17	6.60	0.34	32.21	0.29	0.14	15.15	4.86	15.72	1.44
Maxima	1250.00	200.00	10.20	1855.00	663.00	427.70	427.70	135.00	56.80	15.00	0.75	12.00	130.00	662.00	50.70	120.00	19.10	22.50	260.60	176.05	286.35	110.00
Minima	0.00	0.00	1.00	0.00	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
Moda	2.50	1.00	7.40	120.00	40.00	40.00	60.00	0.00	0.00	0.00	0.01	0.00	1.00	0.00	0.00	25.00	0.00	0.00	2.40	1.90	2.10	0.50
Número	866	875	879	706	877	877	835	747	687	590	520	523	792	404	483	449	751	353	821	816	432	423
S.GERAL S																						
Média	10.73	3.72	8.04	149.74	46.45	83.80	71.69	5.22	0.91	0.02	0.03	0.64	1.55	2.05	0.16	32.23	0.27	0.04	13.07	4.12	19.13	1.86
Maxima	700.00	110.00	10.23	901.60	145.00	195.00	164.70	89.70	48.00	1.15	1.30	82.00	47.80	51.00	5.10	67.89	8.00	2.70	61.30	17.00	88.00	152.00
Minima	0.00	0.03	5.74	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Moda	2.50	0.20	7.30	181.00	10.00	80.00	40.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	25.00	0.00	0.00	2.40	1.40	14.00	0.50
Número	311	315	311	277	316	316	273	221	222	198	157	157	305	141	202	158	295	180	295	291	131	126

Table-5.5 Calculated Result of Groundwater Potential by Pumping Tast Data

[1]	[2] Aquifer	[3]	[4] Aquifer Type	[5]	[6] Area	[7] Borehole Depth	[8] Diameter of Borehole	[9] Critical Yield	[10] Spacific Capasity	[11] Radius of Interference	[12] Groundwater Potential in 1 km 2	[13]	[14] Total Groundwater Potential for Respectative Aquifer	[15]	[16] Principal Municipalities
			porous	fracture	km2	m	mm	m3/h	m3/h/m	m	m3/h/km2	l/s/km2	million m3/h/km2	m3/km2	
1	(the Karst) in Acungui & Setuva G.		A	AAA (CAVE)	5,740 (3,480)	80	250	160	70	400	320	89	27 (3,480km2 of the area) *3	313 (3,480km2 of the area) *3	Curitiba, Campo Largo, (Metropolitan Curitiba)
2	Crastaline rocks in Pre-Ordovician		X	b~c	17,500	120	150	20	1	500	25	6.9	11	121	Pirai do Sul, Doutor Ulysses Mandirituba, Campo do Tenente
3	Early Paleozoic ; Castro/Parana Group		X	b~c	7,150				0,7	500	13	3.6	2.2	25.7	Ponta Grossa, Tibagi, Pirai do Sul
4	Middle-Late Paleozoic Itarare/Guata Group		X	b~c	17,400	150	150	10	1	400	20	5.6	8.4	97.4	Taxeira Soares, Lapa
5	Late Paleozoic Passa Dois Group		X	b~c	15,700				0.5	500	13	3.6	4.9	56.5	Joaquim Tavora, Sapopema, Ivai, Irati, Sao Madeus do Sul
6/7	Botucatu & Serra Geral Fs.							(124 L/s) Deep Borehole					2,000	28,000	
6~7	Botucatu F. : recharge zone		AA	X	12,560	100	200	50	3	200	398	110	120	1400	Ponta Grossa, Castro, Pirai do Sul, Tibagi
6~7	Botucatu & Serra Geral Fs. : confined aquifer zone		AAA	A	24,080	200	250	150	5	300	531	150	300	3,600	Tomazina, Telmaco Barba, Ipiranga, Taxeira Sores, Lapa
6~7	Botucatu & Serra Geral Fs. : deep sheeted & confined a.zone		AAA	-	105,480	1,100	200	200	12	300	708	200	1,800	21,100	Joaquim Tavora, Saponema, Curiuva, Reserva, Ivai, Irati, Sao Mateus do Sul
6	Serra Geral F.	Norte	X	AA	59,050	150	200	40	2	400	80	22	110	1,300	Londrina, Cornelio Procopio, Apucarana Maringa, Cascavel, Camp Mourao, Toledo
7		Sula	X	A	42,060	180	150	12	0.8	500	15	4.2	15	180	Guarapuava, Palmas, Laranjeiras do sul Foz do Iguacu, Pato Branco
8	Caiua Formation		A	X	30,450	120	200	30	1.5	300	110	31	80	51	Paranavai, Loanda, Tapira, Icarama, Umuarama, Cianorte,
9	(Metropolitan Curitiba Area)				1,130								>0.25		Metropolitan Curitiba
10	Guabirotuba F. sd bed		B	X	950(300)*2	60	100	12	2	500	15	4.2	0,1	1.3	
11	Aluvium System in Flood Plane		AA	X	180				-	-					
12	Granitic rocks		X	C	(300)	120	100	15	1	500	19	5.3	0,1	0.1	
13	(Quaternary Sys. in Coastal Range)				1,950 *1								>2.9		Paranagua, Guaraquecaba, Morretes, Guaratuba,
14	Quat. River Bed (Delta/River B.		AA	X	380	8	40	20	20	150	280	80	2.6	190	Antonina, Alexandra, Serra Negra,
15	Marine Terrace Deposit		A	X	1,570	8	150	1	3	200	8	2.2	0.3	3.5	Praia de Leste, Ilha do Mel, Ipanema

Legend in Items of Aquifer Type : AAA; very high potencial, AA; higher potential, A; high potential, B; moderate potential, C; low potential, X; no potential, b~c; partial

*1 : Aquifer in Quat. River Bed is recharged by upper streams in area of Crystalline rocks.

*2 : Aquifer of Guabirotuba F. is composed of sd. layers underlain in about 1/3 area in the exposured area of Guabirotuba F.

*3 : Area of cabonate rocks in the "Karst"

[11]: Interfernce radius of drawdown during pumping test

Table-5.6 Estimated Result of Groundwater Storage by Pumping Tast Data

[1] Aquifer	[2] Area	[3] Borehole Yield	[4] Specific Capacity	[5] Interference Radius	[6] Apparent Potential	Total Storage
	km2	x 10-3 m3/s	m3/h/m	m	x 10-3 m3/s/km2	x million m3
1. Karst	5,740	44.40	70	400	89.0	*2 1,200
2. Crystalline Rocks	7,540	5.56	1	500	6.9	5,200
3. Early Paleozoic	7,150			500	3.6	
4. Middle-Late Paleozoic	17,400	0.00	1	400	5.6	3,500
5. Late Paleozoic	15,700			500	3.6	
. All of Botucatu F. & Serra Geral F.	101,110	*1 124	-	-	-	*2 130,000
6. Botucatu F. & Serra Geral F. north	(59,050)	11.11	2	400	22.0	24,000
7. Botucatu F. & Serra Geral F. south	(42,060)	3.33	1	500	4.2	2,100
8. Caiua F.	30,450	8.33	2	300	31.0	7,300
9. Curitiba Metro. Area	1,130	-	-	-	-	-
10. Guabirotuba F.	(920)	3.33	2	500	4.2	1.2
11. Alluvium System	(180)	-	-	-	-	-
12. Granitic Rocks	(300)	4.17	1	500	5.3	75
13. Quaternary System in Coastal Range	1,950	-	-	-	-	-
14. Quaternary River Bed(Delta/River b	(380)	5.56	20	150	80	4.5
15. Marine Terrace Deposit	(1,570)	0.28	3	200	2.2	0.63

Note

[5]: Interference Radius at the pumping time of Borehole Yield

[6]: Apparent aquifer potential of confined aquifers

*1: Borehole Yield of Confined Botucatu Aquifer

*2: estimated by effective porosity, thickness and area of Botucatu Formation

Table-5.7 Assessment Result of Groundwater Potential by Data of Water Circulation

[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
Aquifer	Location in River Basin	Study Area	Spatial mQ7	Permissive Yield		Required Recharge	Total Permissive Yield	Productivity of Borehole
		km2	m3/km2 *1	%	x 10-3m3/skm2	km2/s/3 *2	m3/s	
Cristalline Rocks	Upper Tibagi	7500	6.00	10	0.64	1600	4.8	5.56
Lower Paleozoic	Middle Tibagi	900	3.61	10	0.36	2800	0.32	2.78
Furnas Formation	Middle to Upper Tibagi	3500	-	15	-	-	-	8.33
Lower-Middle Paleozoic	Middle to Upper Tibagi	2500	6.37	10	0.64	1600	1.6	2.78
Middle-Upper Paleozoic	Middle to Upper Tibagi	12000	4.6	10	0.46	2200	5.5	2.78
Upper Paleozoic	Upper to Middle Iguacu	11000	4.6	10	0.46	2200	5.1	2.78
Botucatu Formation	Middle Tibagi and mainly L. Tibagi in underground	11000	-	-	-	-	-	124
Serra Geral Formation north	Lower Tibagi	10800	7.7	20	1.5	670	16.2	11.1

*1 same meaning as transitory Recharge of Groundwater
[4] - Spatial Specific mQ7
[7] - Total Permissive Yield of Aquifer in Study Area

Table-6.1 Mean Q7 & Q10,7 at Fluvial Stations in Iguacu River Basin, Ribeira River Basin and the Related River Basins

River Basin	small river basin	Aquifers	Station No	Catchment Area km2	Mean Q7 Observ. Period	Mean Q7 m3/s	Q10,7 Observ. Period	Q10,7 m3/s
Ribeira		Karst	81019300	38	83/10-93/12	1.70	-	-
do		Karst	81019350	540	81/05-93/12	4.76	82-93	2.62
do		Karst	81019550	114	77/03-82/12	0.78	-	-
do		Karst	81020000	176	77/03-88/12	1.22	77-88	0.51
do		Granite	81125000	392	46/01-93/12	4.24	46-93	2.96
do		Karst	81080000	1,285	81/05-93/12	11.54	82-93	7.51
do		Karst	8110200-81019550-8102000	1,461	-	11.91	-	-
do		Karst	81102000	1,751	78/08-93/12	13.91	79-93	9.97
do		Karst	81120000	402	78/08-93/12	3.67	79-93	2.45
do		Karst	81140000	435	30/08-93/12	2.85	31-93	1.95
Capivari r.		Karst	81299000	536	85/01-93/12	4.95	85-93	3.30
Alt Iguacu		Karst	65020995	15	85/01-93/12	0.19	85-93	0.06
Alt Iguacu		Karst	65021000	23	85/01-93/12	0.28	85-93	0.22
Alt Iguacu		Karst	65021770	25	85/01-93/12	0.12	85-93	0.04
Alt Iguacu		Karst	65021800	77	85/01-93/12	0.52	85-93	0.36
Alt Iguacu		Lower Paleozoic	65034000	58	77/01-93/12	0.10	77-93	0.05
Rio Negro	Negro	Granite	65090000	800	67/05-93/12	7.80	68-93	4.95
Rio Negro	Negro	Middle Paleozoic	65094500	868	76/05-93/12	5.07	77-93	1.44
Rio Negro	Negro	Middle Paleozoic	65100000	3,379	30/05-93/12	21.41	31-93	13.01
Rio Negro	Negro	Granite	65135000	602	39/08-93/12	3.88	40-93	2.51
Rio Negro		Middle Paleozoic	(65136550-65135000)	966	-	4.20	-	1.76
Rio Negro		#	65136550	1,568	80/09-93/12	8.08	81-93	4.27
Rio Negro		Middle Paleozoic	(65155000-65136550)	444	-	4.11	-	3.11
Rio Negro		#	65155000	2,012	30/05-93/12	12.19	31-93	7.38
Rio Negro		Upper Paleozoic	65208000	2,190	74/02-92/12	9.76	-	-
Meio Iguacu		Upper Paleozoic	(65220000-65208000-6517500)	8,140	-	40.63	-	-
Meio Iguacu		#	65220000	18,300	63/08-93/12	97.22	64-93	59.06
Meio Iguacu		#	65175000	7,970	64/01-92/12	46.83	64-92	26.62
Meio Iguacu	Palmital	Serra Geral Sul	65415000	323	45/11-93/12	1.75	46-93	0.77
Meio Iguacu	Areia	Serra Geral Sul	65764000	1,010	80/08-92/12	6.14	81-92	3.54
Meio Iguacu		Serra Geral Sul	65770000	1,645	63/08-93/12	8.65	-	-
Meio Iguacu	Iratim	Serra Geral Sul	65775900	1,550	87/01-92/12	11.38	-	-
Meio Iguacu	Jordao	Serra Geral Sul	65809000	306	85/03-93/12	0.49	85-93	0.23
Meio Iguacu		Serra Geral Sul	65810000	731	36/11-67/12	2.57	-	-
Meio Iguacu	Jordao	Serra Geral Sul	65811000	1,040	74/02-92/12	5.31	74-92	2.08
Meio Iguacu	Jordao	SerraGeral Sul	65815000	2,200	60/03-83/12	16.26	-	-
Meio Iguacu	Jordao	Serra Geral Sul	65825000	3,913	63/01-93/12	25.05	65-92	12.80
Meio Iguacu	Cavernoso	Serra Geral Sul	65855000	1,500	64/01-92/12	14.81	65-92	3.52
Baixo Iguacu	Guarani	Serra Geral Sul	65970000	1,024	78/08-93/12	1.56	79-93	0.66
Baixo Iguacu	Chopin	Serra Geral Sul	65925000	1,782	65/03-92/12	9.89	65-92	4.33
Baixo Iguacu	Chopin	Serra Geral Sul	65927000	3,410	63/01-92/12	18.56	65-92	10.39
Baixo Iguacu	Chopin	Serra Geral Sul	65945000	545	63/01-92/12	3.55	65-92	2.06
Baixo Iguacu	Chopin	Serra Geral Sul	65948000	270	65/01-92/12	1.20	65-92	0.104
Baixo Iguacu	Chopin	Serra Geral Sul	65955000	1,720	63/01-92/12	5.65	65-92	2.97
Baixo Iguacu	Chopin	Serra Geral Sul	65960000	6,696	63/01-92/12	35.34	65-92	17.79
Baixo Iguacu	Chopin	Serra Geral Sul	65962000	7,130	63/01-92/12	34.41	62-92	19.64
Baixo Iguacu		Serra Geral Sul	65970000		78/08-93/12	1.56		
Baixo Iguacu	Andadas	Serra Geral Sul	65979000	1,309	76/07-92/12	6.76	76-92	2.25
Baixo Iguacu	Capameno	Serra Geral Sul	65981500	1,740	76/07-92/12	3.76	76-92	0.80
Bixo Piquiri		Serra Geral Nort	64780000	288	65/01-79/12	2.77	-	-
Bixo Piquiri	Galo Bang	Serra Geral Nort	64785000	1,350	67/06-92/12	10.15	-	-
Bixo Piquiri	Sapuca	Serra Geral Nort	64790000	535	66/01/94/12	5.53	65-92	3.11
Bixo Piquiri	Sapuca	Serra Geral Nort	64797000	288	57/10-61/11	2.77	-	-
Parana III	Arroja	Serra Geral Nort	64849000	1,169	77/02-80/09	7.54	-	-
Parana III	Sao Francisco	Serra Geral Nort	64854000	64	88/01-89/05	2.44	-	-

#:data of the station should be applied the calcuration of Q7 for the localizied aquifer catchment
- : nul data

Table-6.2 Spatial Groundwater Potential of Iguacu Pilot Basin Estimated on the basis of Water Circulation

[1] Aquifer	[2] Location in River Basin	[3] Study Area	[4] Spatial mQ7	[5] Permissive Yield		[6] Required Recharge	[7] Total Yield	[8] Productivity of Borehole
		km2	x 10-3 m3/km2	%	x 10-3m3/s/km2	km2/s/m3	m3/s	x10-3 m3/s
Karst	mainly Ribeira nad Upper Iguacu	3500	8.29	30	2.49	400	8.75	44.4
Cristalline Rocks	Upper Iguacu	4500	6.37	10	0.64	1600	2.88	5.56
Furnas Formation	Upper Iguacu	350	-	15	-	-	-	11.1
Middle-Upper Paleozoic	Upper Iguacu	3900	4.69	10	0.47	2100	1.83	2.78
Upper Paleozoic	Upper to Middle Iguacu	3100	4.9	10	0.49	2000	1.52	2.78
Botucatu Formation	Middle to Lower Iguacu	32000	-	-	-	-	-	124
Serra Geral Formation north	Lower Iguacu	1900	5.32	20	1.1	610	3.12	19.2
Serra Geral Formation south	Middle to Lower Iguacu	32000	5.26	15	0.79	1300	11.9	3.33
Guabirotuba Formation	Upper Iguacu	920	3.53	20	0.76	1300	0.699	3.33

Note
[4]: Spatial and specific mQ_7
[6]: Required Rechargeing Area by 1m3/s of groundwater yield
[7]: Total Permissive Yield of Aquifer in Study Area

Table-6.3 Mean Q7 & Q10,7 at the Fluvial Stations, in Tibagi River Basin and the Related River Basin

River Basin	small river basin	Aquifers	Station No	Catchment Area km2	Mean Q7		Q10,7	
					Observ. Period	m3/s	Observ. Period	m3/s
Alto Tibagi	Imbi	Middle Paleozoic	64442800	1,319	80/11-94/12	6.09	81-93	2.41
Alto Tibagi	Pitanqui	Lower Paleozoic	64450000	523	42/01-88/12	2.68	42-83	0.92
Medio Tibagi	Cativari	Middle Paleozoic	64460000	722	41/04-93/12	3.22		
Alto Tibagi	Iapo	Granitic R.	64477600	1,604	80/11-93/12	7.38		
Medio Tibagi	Iapo	Lower Paleozoic	64481000-64477600	576	-	5.27		
Medio Tibagi	Iapo	#	64481000	2,180	74/02-93/12	12.65		
Medio Tibagi	Iapo	Granitic R.	64477020	210	80/06-89/01	1.56	81-89	0.58
Medio Tibagi	Tibagi	Middle Paleozoic	64491000-64482000	1,600		14.03		
Medio Tibagi	Tibagi	#	64482000	14,000	80/01-93/12	75.42		
Medio Tibagi	Tibagi	#	64491000	15,600	41/11-94/11	89.45		
Medio Tibagi		Upper Paleozoic	64497012	513	77/09-93/12	4.12		
Medio Tibagi		Serra Geral Nort	64500000	59	57/01-93/12	0.57		
Baixo Tibagi		Serra Geral Nort	64504500	290	77/06-86/07	2.62		
Baixo Tibagi		Serra Geral Nort	64504550	290	87/09-94/10	1.65		
Baixo Tibagi		Serra Geral Nort	64550000	4,627	67/10-92/12	37.17		
Baixo Tibagi		Serra Geral Nort	64508500	1,054	75/01-94/12	6.44		

#:data of the station should be applied the calcuration of Q7 for the localizied aquifer catchment

- : nul data

Table-6.4 Spatial Groundwater Potential of Tibagi Pilot Basin Estimated by Water Circulation

[1] Aquifer	[2] Location in River Basin	[3] Study Area	[4] Spatial mQ7	[5] Permissive Yield		[6] Required Recharge	[7] Total Yield	[8] Productivity of Borehole
		km2	m3/km2	%	x 10-3m3/skm2	km2/s/3	m3/s	
Cristalline Rocks	Upper Tibagi	7500	6.00	10	0.64	1600	4.8	5.56
Lower Paleozoic	Middle Tibagi	900	3.61	10	0.36	2800	0.32	2.78
Furnas Formation	Middle to Upper Tibagi	3500	-	15	-	-	-	8.33
Lower-Middle Paleozoic	Middle to Upper Tibagi	2500	6.37	10	0.64	1600	1.6	2.78
Middle-Upper Paleozoic	Middle to Upper Tibagi	12000	4.6	10	0.46	2200	5.5	2.78
Upper Paleozoic	Upper to Middle Iguacu	11000	4.6	10	0.46	2200	5.1	2.78
Botucatu Formation	Middle Tibagi and mainly L. Tibagi in underground	11000	-	-	-	-	-	124
Serra Geral Formation north	Lower Tibagi	10800	7.7	20	1.5	670	16.2	11.1

[4] : Spatial and Specific mean Q_7
[6]: Riquired Recharge Area to produce 1 m3/s of groundwater
[7] –Total Permissive Yield of Aquifer in Study Area

Table-6.5 Master Plan of Groundwater Development for Projected Municipalities in Iguacu Pilot Basin

Type & Municipality	Required Water Supply *1 2005 m3/s	Required Water Supply *1 2015 m3/s	Target Aquifer	Productivity of Boreholes x10-3 m3/s	Success Ratio of Borehole	Developing Aquifer and Total Number of Developing Borehole	Total Number of Developing Stages	1st. Stage of Development Borehole number and establishing year		x10-3 m3/s	2nd. Stage of Develoment Borehole number and establishing year		x10-3 m3/s	3rd. Stage of Development Borehole number and establishing year		x10-3 m3/s	4th. Stage of Development Borehole number and establishing year		x10-3 m3/s	5th. Stage of Development Borehole number and establishing year		x10-3 m3/s	Implementation Schedule 1996 2000 2005 2010 2015
A Curitiba Metropolitan	3.211	7.235	Karst Ouabirotube F.	44.40 3.33	75% 80%	Karst : 101 boreholes	4 Stages *3	Karst : 29 boreholes -year of 199	29x44.4= 1288	1290	Karst : 24 boreholes -2001	24x44.4= 1066	1070	Karst : 24 boreholes -2004	24x44.4= 1066	1070	Karst : 24 boreholes -2009	24x44.4= 1066	1070				I II III IV
A Cascavel	0.268	0.542	Botucatu F. Serra Geral F.north	124.00 19.17	100% 80%	Serra Geral F.north : 18 boreholes Botucatu F.: 2 boreholes	4 Stages	Serra Geral F. north: 5 Botucatu F.: 1 -1998	5x19.17=96 124	220	Serra Geral F. north: 4 -2001	4x19.17=76.7 77	77	Serra Geral F. north: 5 Botucatu F.: 1 -2005	5x19.17=96 124	220	Serra Geral F. north. 4 -2011	4x19.17=76.7 77	77				I II III IV
A Guarapuava	0.127	0.292	Serra Geral F.south Botucatu F.	5.83 124.00	80% 100%	Serra Geral F.south : 35 boreholes Botucatu F.: 1 borehole	5 Stages	Serra Geral F. south 7 -year of 1997	7x5.83=40.8	41	Serra Geral F. south 7 -1999	7x5.83=40.8	41	Serra Geral F. south 7 Botucatu F.: 1 -2001	7x5.83=40.8 124	165	Serra Geral F. south 7(9) -2006	7x5.83=40.8	41	Serra Geral F. south 7(9) -2011	7x5.83=40.8	41	I II III IV V
B Francisco Beltrao	0.099	0.233	Serra Geral F.south Botucatu F.	2.22 124.00	80% 100%	Serra Geral F south : 5 boreholes Botucatu F.:2 boreholes	3 Stages	Serra Geral F. south 5 -year of 1996	5x2.22=11.1	11	Botucatu F.: 1 -1997	1x124=124	124	Botucatu F.: 1 -2007	1x124=124	124							I II III
B Medianeira	0.038	0.066	Serra Geral F.south Botucatu F.	4.44 124.00	80% 100%	Serra Geral F.north: 5 boreholes Botucatu F.: 1 borehole	2 Stages	Serra Geral F.south 5 -year of 1997	5x4.44=22.2	22	Botucatu F.: 1 -2001	1x124=124	124										I II
B Palmas	0.028	0.065	Serra Geral F.south Botucatu F.	3.33 124.00	80% 100%	Serra Geral F.south : 20 boreholes	2 Stages	Serra Geral F.south 10 -year of 1997	10x3.33= 33.3	33	Serra Geral F.south 10 -2005	10x3.33= 33.3	33										I II
B Dois Vizinhos	0.061	0.134	Serra Geral F.south Botucatu F.	4.17 124.00	80% 100%	Serra Geral F. south : 7 boreholes	2 Stages	Serra Geral F.south 4 -year of 1996	4x4.17=16.7	17	Serra Geral F.south 3 Botucatu F.: 1 -1998	3x4.17=12.5 124	137										I II
B Pato Branco	0.053	0.112	Serra Geral F.south Botucatu F.	4.17 124.00	80% 100%	Serra Geral F.south: 6 boreholes Botucatu F.: 1 borehole	2 Stages	Serra Geral F.south 6 -year of 1998	6x4.17=25.0	25	Botucatu F.: 1 -2000	124	124										I II

*1: Required water supply amount based on "Base Case"

*2: Total permissive yield of whole area of Ouabirotube Formation

*3: composed of 4 or 5 developing units

Table-6.6 Master Plan of Groundwater Development for Projected Municipalities in Tibagi Pilot Basin

[1] Municipality Type and Name	[2] Required Water Supply Demand In 2005 m3/s	[3] In 2015 m3/s	[4] Target Aquifer	[5] Productivity of Borehole x10-3 m3/s	Success Ratio of Boreholes	[6] Developing Aquifer and Total Number of Boreholes	[7] Number of Developing Stages	[8] 1st. Stage of Development and Borehole number	[9]	[10] x10-3 m3/s	[11] 2nd. Stage of Development and Borehole number	[12]	[13] x10-3 m3/s	[14] 3rd. Stage of Development and Borehole number	[15]	[16] x10-3 m3/s	[17] 4th. Stage of Development and Borehole number	[18]	[19] x10-3 m3/s	[20] 5th. Stage of Development and Borehole number	[21]	[22] x10-3 m3/s	Implementation Schedule 1996 2000 2005 2010 2015
A Londrina	0.451	0.966	Serra Geral F.north Botucatu F.	16.47 (124LA)	80% 100%	Serra Geral F.north ; 30(39) Botucatu F. ; 4	5 Stages	Serra Geral F.north ; 6(8) Botucatu F. ; 1 ~1997	6x16.47=98.8 124	223	Serra Geral F.north ; 6(8) Botucatu F. ; 1 ~2000	6x16.47=98.8 124	223	Serra Geral F.north ; 6(8) Botucatu F. ; 1 ~2004	6x16.47=98.8 124	223	Serra Geral F.north ; 6(8) Botucatu F. ; 1 ~2008	6x16.47=98.8 124	223	Serra Geral F.north ; 6(7) ~2011	6x16.47=98.8	99	I II III IV
A Apucarana	0.113	0.231	Botucatu F. Serra Geral F.north	(124LA) 33.06	100% 80%	Serra Geral F.north ; 8(10)	2 Stages	Serra Geral F.north ; 4(5) ~1997	4x33.06=132	132	Serra Geral F.north ; 4(5) ~2005	4x33.06=132	132										I II
B Cornelio Procopio	0.026	0.068	Serra Geral F.north Botucatu F.	7.22 124(LA)	80% 100%	Serra Geral F.north ; 4(5) Botucatu F. ; 1	2 Stages	Serra Geral F.north ; 4(5) ~1997	4x7.22=29	29	Botucatu F. ; 1 ~2000	124	124										I II
B Arapongas	0.061	0.142	Serra Geral F.north Botucatu F.	13.33 124(LA)	80% 100%	Serra Geral F.north ; 5(7) Botucatu F. ; 1	2 Stages	Serra Geral F.north ; 5(7) ~1997	5x13.33=66.7	66	Botucatu F. ; 1 ~2005	124	124										I II
B Cambe	0.096	0.258	Serra Geral F.north Botucatu F.	16.76 124(LA)	80% 100%	Serra Geral F.north ; 9(11)	3 Stages	Serra Geral F.north ; 6(7) ~1997	6x16.76=100.6	100	Botucatu F. ; 1 ~2005	124	124	Serra Geral F.north ; 3(4) ~2009	3x16.76=50.3	50							I II III
B Ibipora	0.043	0.10[illegible]	Serra Geral F.north Botucatu F.	16.67 124(LA)	80% 100%	Serra Geral F.north ; 6(8)	2 Stages	Serra Geral F.north ; 3(4) ~1997	3x16.67=50.0	50	Serra Geral F.north ; 3(4) ~2005	3x16.67=50.0	50										I II

Note

[2][3]: Required aggregate water Demand excluding existing supply capacity for "Base Case"

[4]: Spatial aquifer potential (spatial and specific mean Q7)

Table-6.7 Master Plan of Groundwater Development for Iguacu Pilot Basin

Municipalities	Geological Formation to be Developed	Number of Productive Boreholds	Stages for Development till 2015
Curitiba type A	Karst	112 (60 m)	4 stages for development in the Karst aquifer a establishment of monitoring system (monitori boreholes of 20 in Guabirotuba formation and 5 wa level gauge in 5 tributaries in the Karst) (piezometric borehole:17(60m, φ 80mm))
Cascavel type A	Bortucatu Formations	2 (1300 m)	2 stages
	Serra Geral Formation north	18 (180 m)	(piezometric borehole:6(180m, φ 80mm))
Guarapuava type A	Botucatu Formation	1(800m)	4 stages
	Serra Geral Formation south	35 (180 m)	(piezometric borehole:10(180m, φ 80mm))
Francisco Beltrao type B	Botucatu Formation	2(1000m)	3 stages
	Serra Geral Formation south	6(180m)	(piezometric borehole:2(180m, φ 80mm))
Medianeira type B	Botucatu Formation	1(850m)	2 stages
	Serra Geral Formation south	5(180m)	(piezometric borehole:10(180m, φ 80mm))
Dois Vizinhos type B	Botucatu Formation	1(1200m)	3 stages
	Serra Geral Formation south	7(180m)	(piezometric borehole:3(180m, φ 80mm))
Palmas type B	Serra Geral Formation south	10(180m)	2 stages (piezometric borehole:2(180m, φ 80mm))
Pato Branco type B	Botucatu Formation	1(1200m)	2 stages
	Serra Geral Formation south	6(180m)	(piezometric borehole:2(180m, φ 80mm))

Table-6.8 Master Plan of Groundwater Development for Tibagi Pilot Basin

Municipalities	Geological Formation to be Developed	Number of Productive Boreholds	Stages for Development till 2015
Londrina type A	Serra Geral Formations north	36 (180 m)	5 stages
	Botucatu Formation	4 (1300 m)	(10 piezometric boreholes; 180m, φ80mm)
Apucarana type A	Serra Geral Formations north	30 (180 m)	2 stages
	Botucatu Formation	1 (800m)	(2 piezometric boreholes; 180m, φ80mm)
Cornelio Procopio	Serra Geral Formations north	4 (180m)	2 Stages
	Botucatu Formation	1 (800m)	(2 Piezometric boreholes: 180m, φ80mm)
Arapongas	Serra Geral Formations north	5 (180m)	2 Stages
	Botucatu Formation	1 (1000m)	(2 Piezometric boreholes: 180m, φ80mm)
Ibipora	Serra Geral Formations north	6 (180m)	2 Stages (2 Piezometric boreholes: 180m, φ80mm)
Cambe	Serra Geral Formations north	9 (180m)	3 stages (4 piezometric boreholes; 180m, φ80mm)
	Botucatu Formation	1 (1000m)	

Table-6.9 Unit Cost of Drilling

Aquifer	*Unit Cost (US$/m)	Method	**Diameter (mm)	Depth (m)
Botucatu Formation	1,000	rotary	300	1,000
Furnas Formation	100	rotary	200	150
Guabirotuba Formation	200	rotary	150	80
Karst	600	rotary	250	60
Serra Geral Formation (north)	150	rotary	200	180
Serra Geral Formation (south)	150	rotary	200	180

*: Cost includes transportation, setting, operation, casing and test.

**: Bottom of Borehole

Source: adapted and enlarged from SANEPAR's cost data as of August, 1994

FIGURES

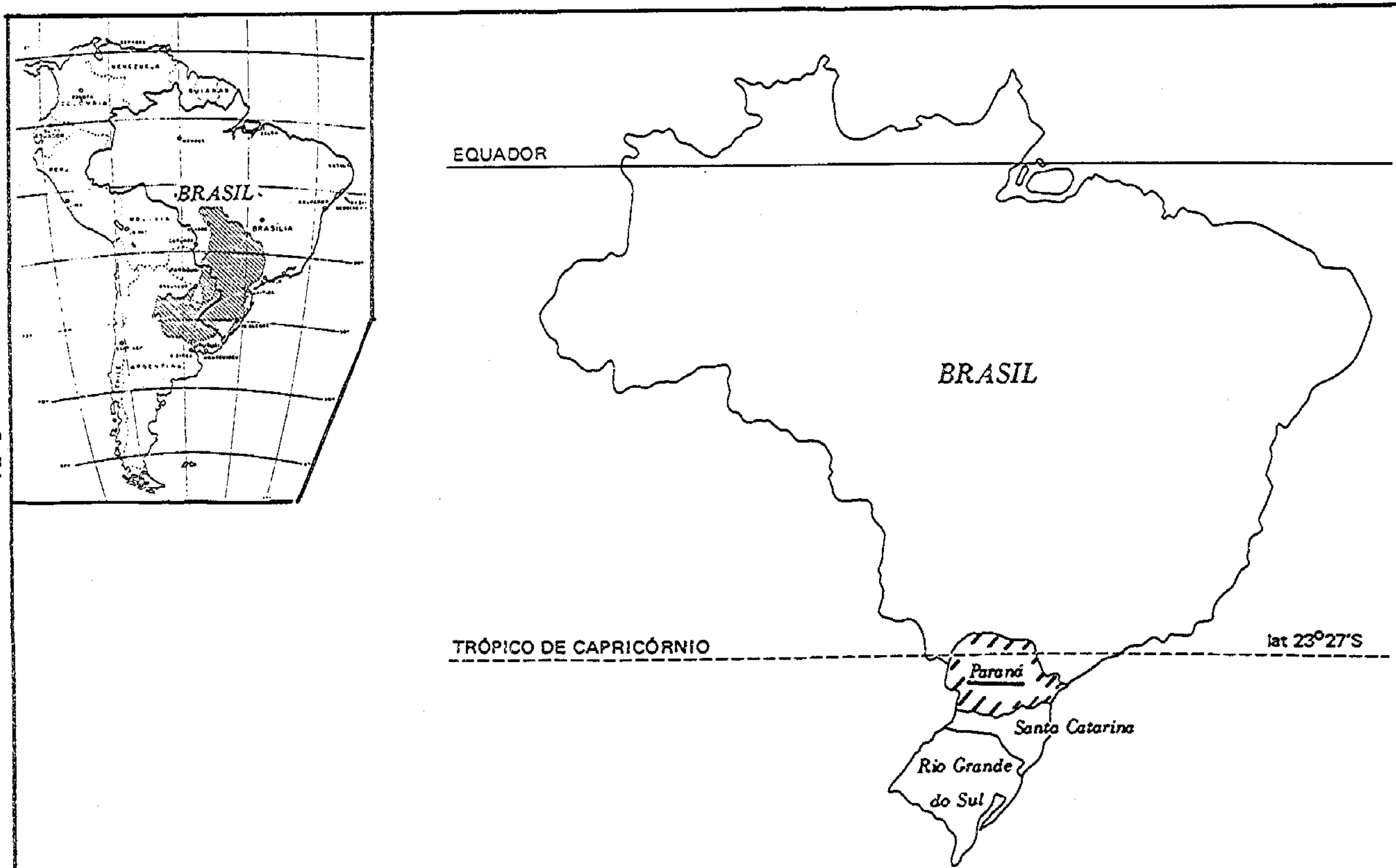

Figure-2.1 Location Map of Parana State

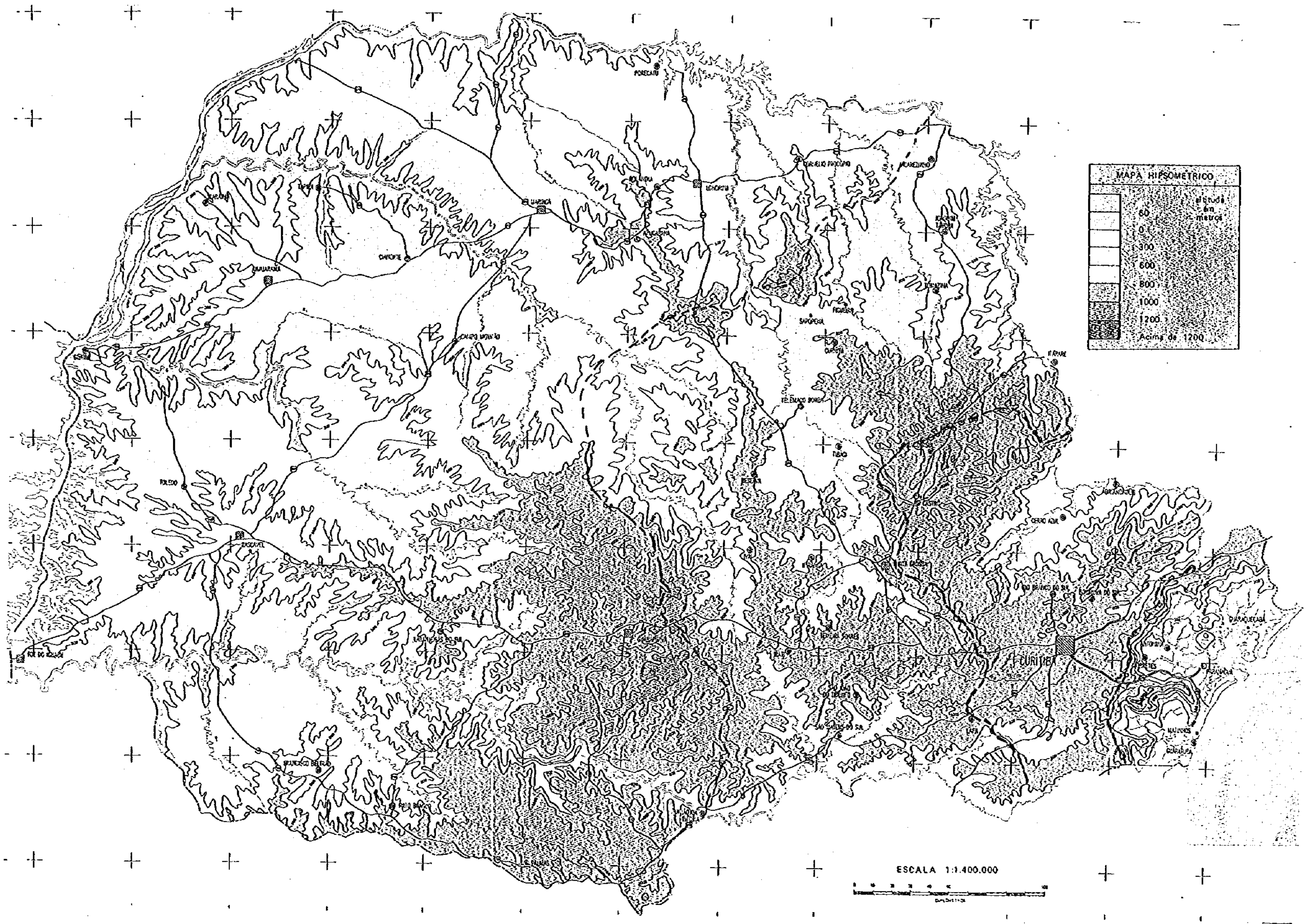

Figure-2.2 Topography Map of Parana State

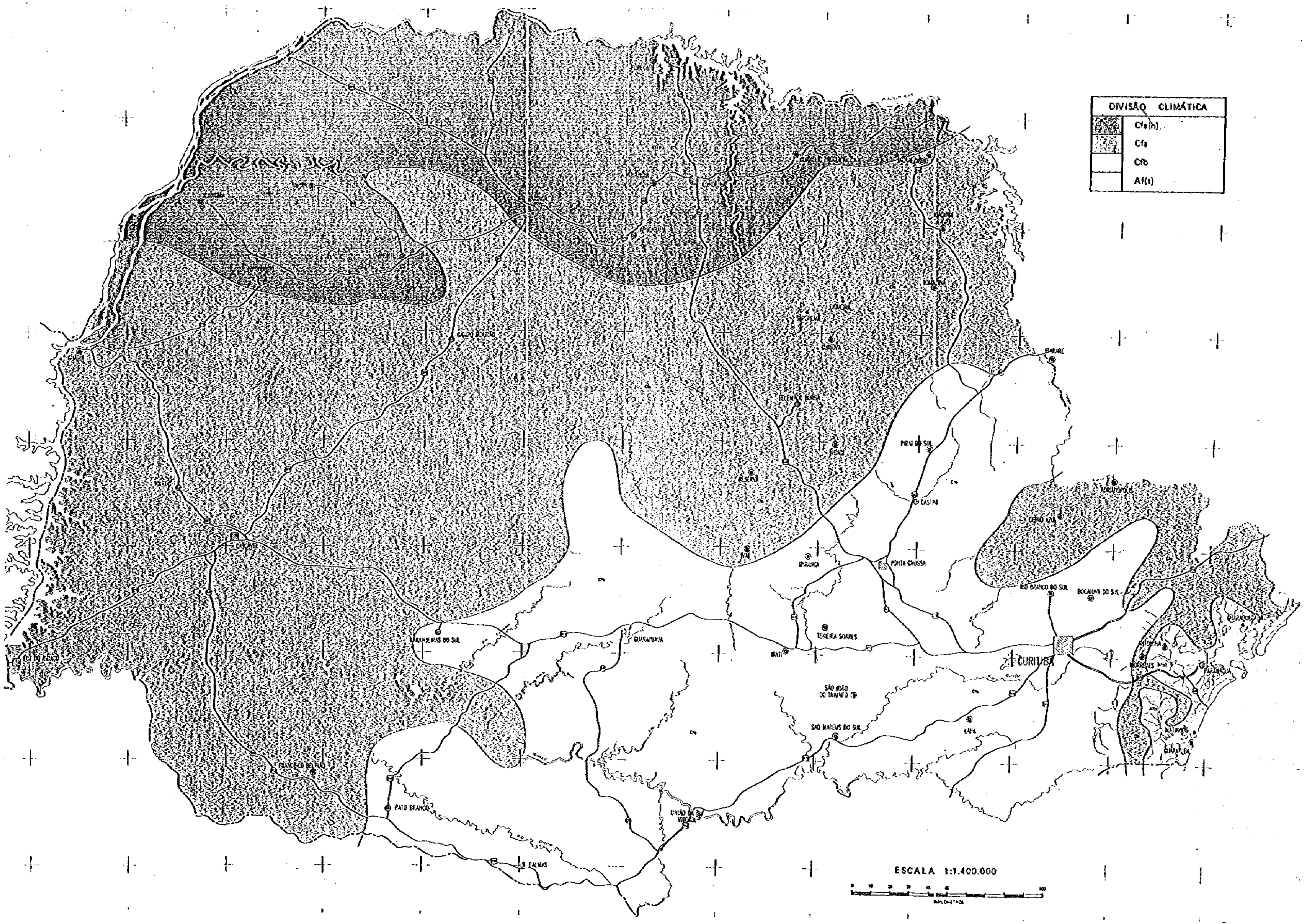

Figure-2.3 Climatic Zone in Parana State

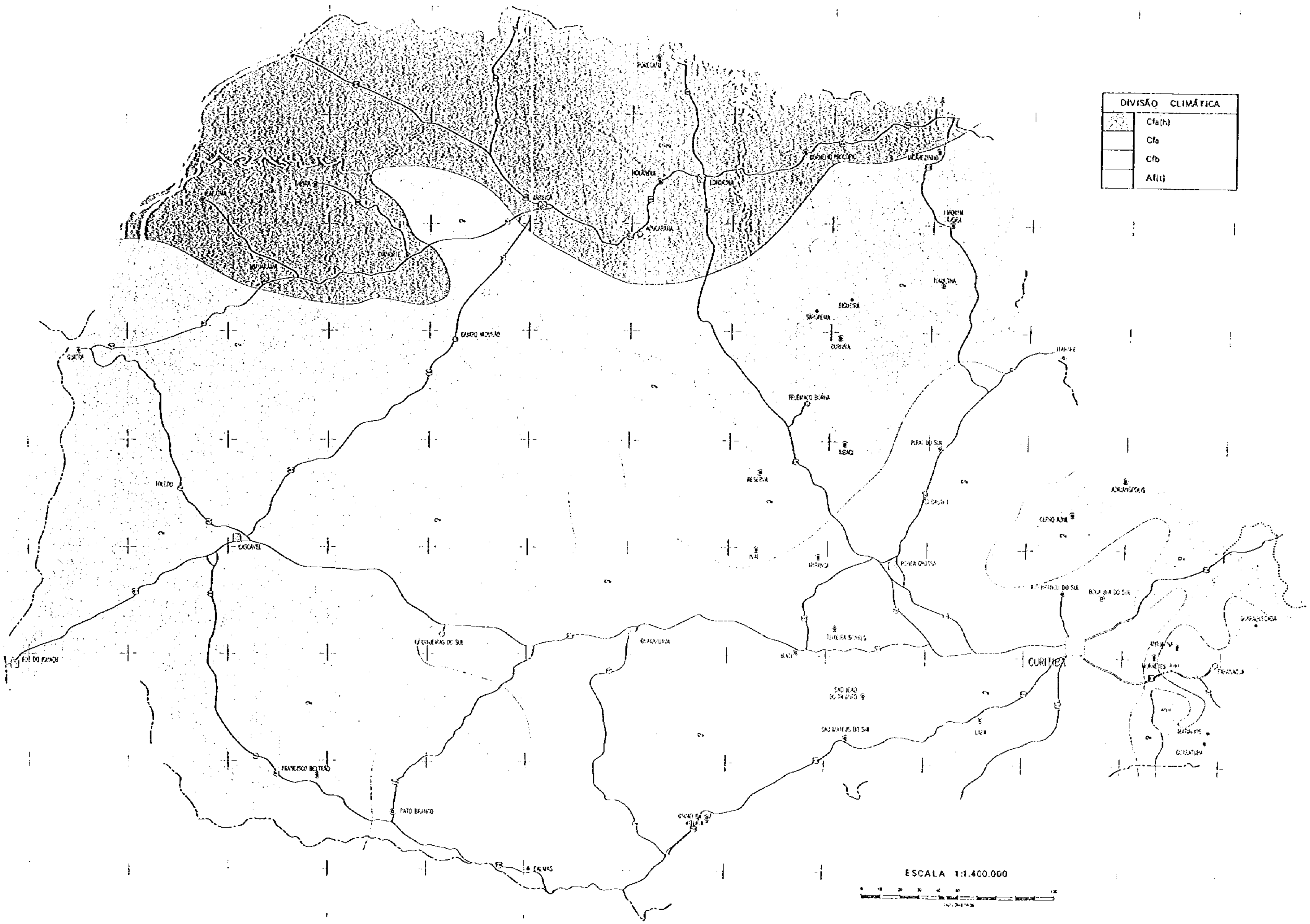

Figure-2.3 Climatic Zone in Parana State

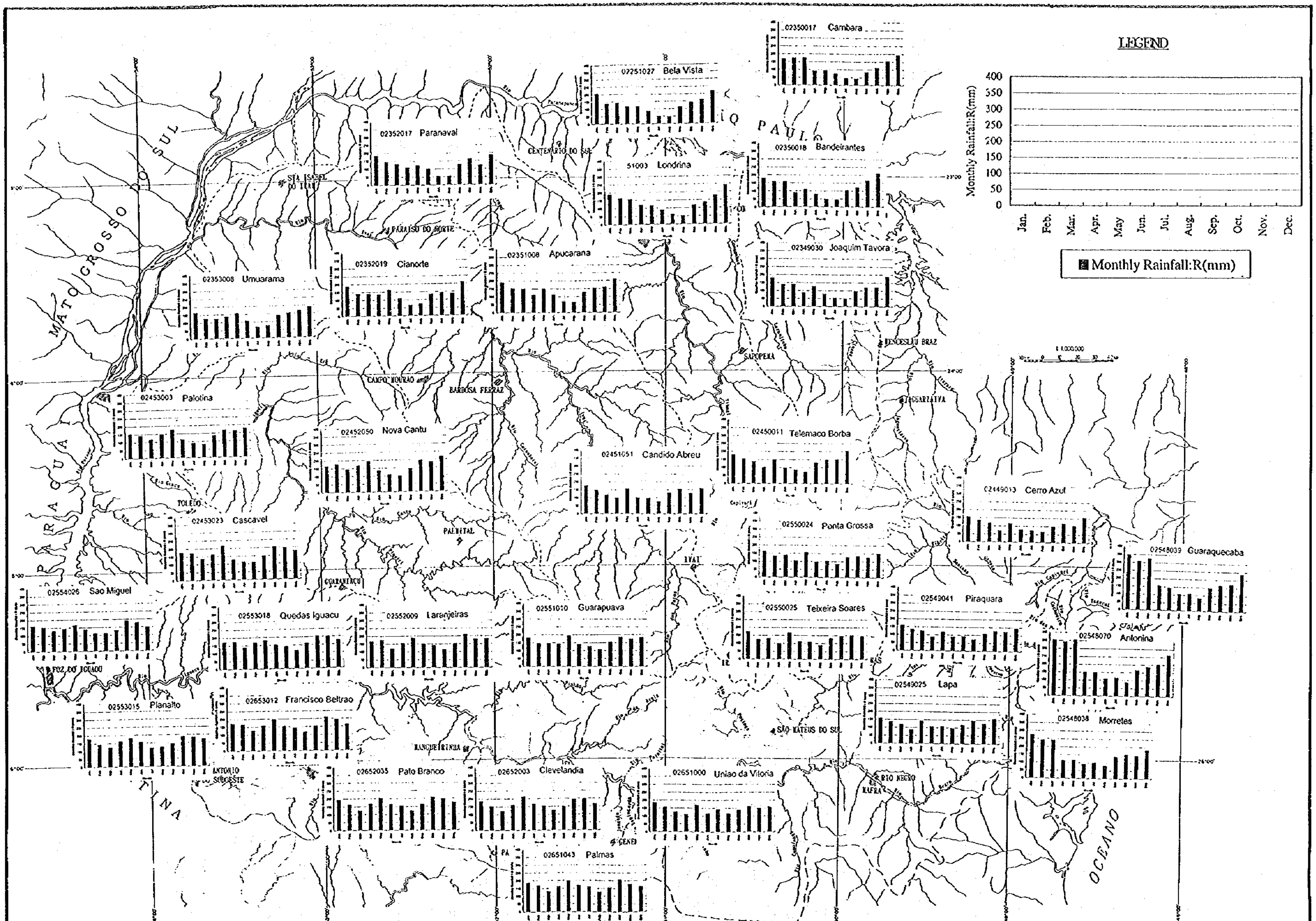

Figure-2.4 Monthly Average Rainfall in Parana State