No.

Capital District of Bogotá and Soacha Municipality
The Republic of Colombia

THE STUDY ON MONITORING AND EARLY WARNING SYSTEM FOR LANDSLIDES AND FLOODS IN SELECTED AREAS IN THE CAPITAL DISTRICT OF BOGOTÁ AND SOACHA MUNICIPALITY IN THE REPUBLIC OF COLOMBIA

FINAL REPORT

VOLUME 2 MAIN REPORT

MARCH 2008

JAPAN INTERNATIONAL COOPERATION AGENCY

PACIFIC CONSULTANTS INTERNATIONAL

OYO INTERNATIONAL CORPORATION

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The Republic of Colombia

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The exchange rate applied in this Study is
US$ 1.00=Colombian Peso 2014.76
(T.R.M. for January 1, 2008)

PREFACE

In response to a request from the Government of Colombia, the Government of Japan decided to conduct a development study on Monitoring and Early Warning System for Landslides and Floods and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent to Colombia a study team headed by Mr. Kimio Takeya of the joint venture of Pacific Consultants International and OYO International Corporation, between June 2006 and March 2008. In addition, JICA set up a Monitoring Mission which examined the Study from specialist and technical point of view.

The Study Team held discussions with the officials concerned of the Government of Colombia, and conducted field surveys at the study area. Upon returning to Japan, the Study Team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of the project and promotion in Colombia, and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Colombia for their close cooperation extended to the Study Team.

March, 2008

Ariyuki MATSUMOTO
Vice-President
Japan International Cooperation Agency

March 2008

Mr. Ariyuki MATSUMOTO
Vice-President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

Dear Sir,
We are pleased to submit the final report entitled the “The Study on Monitoring and Early Warning System for Landslides and Floods”. This report compiles the results of the Study in accordance with the contracts signed on June 16, 2006 and May 1, 2007 between the Japan International Cooperation Agency and the joint venture of Pacific Consultants International and OYO International Corporation.

In the Study, the Study Team presents the plan on monitoring and early warning system based on the analysis of the existing conditions and problems. The report consists of the Summary, Main Report, Supporting Report and Data Book.

All members of the Study Team wish to express sincere appreciation to the personnel of your Agency, Monitoring Mission, and the Embassy of Japan in Colombia, and also to the officials concerned of the Government of the Republic of Colombia, the Government of Bogota City, the Government of Soacha Municipality and the Government of Cundinamarca Prefecture for their cooperation extended to the Study Team. The Study Team sincerely hopes that the results of the Study will contribute to the disaster prevention for Bogota and Soacha.

Yours Faithfully

Kimio Takeya
Team Leader
The Study on Monitoring and Early Warning System for Landslides and Floods
.

Composition of Final Report

English

Volume 1 : Summary

Volume 2 : Main Report

Volume 3 : Supporting Report

Volume 4 : Data Book 1,2 and 3

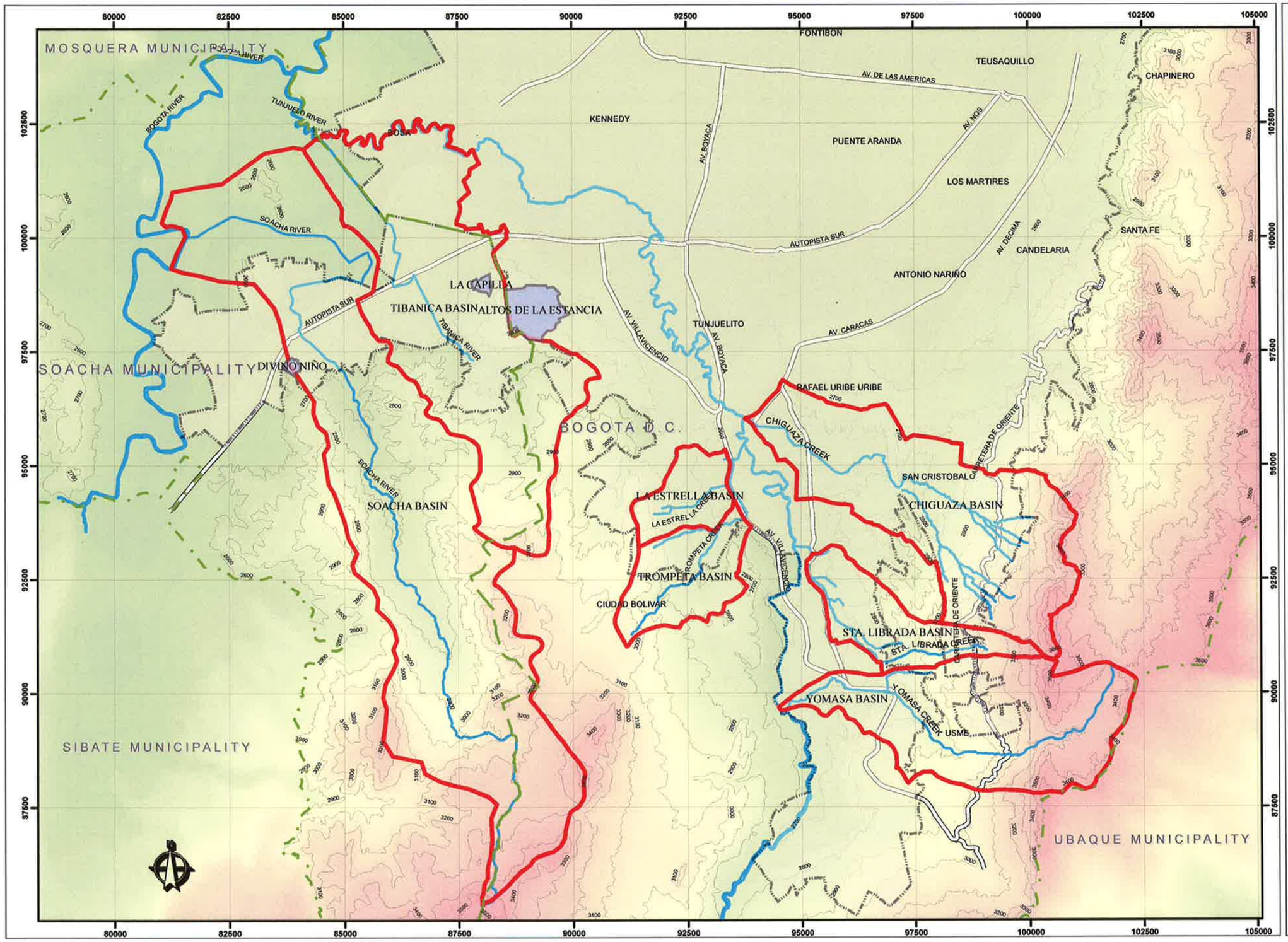
Spanish

Volumen 1 : Resumen

Volumen 2 : Reporte Principal

Volumen 3 : Reporte de Soporte

Volumen 4 : Libro de Datos 1,2 and 3



ALCALDIA MAYOR DE BOGOTA D.C.
Secretaría de Gobierno

ALCALDIA MUNICIPAL DE SOACHA

JICA Japan International Cooperation Agency

LEGEND

- MUNICIPALITY BOUNDARY
- BASIN STUDY AREA
- URBAN AREA
- HIDROGRAPHY
- LOCALITY BOGOTA
- CONTOUR LINES 100 m

0 0.4 0.8 1.6 2.4 3.2 4 Km.

1:85,000

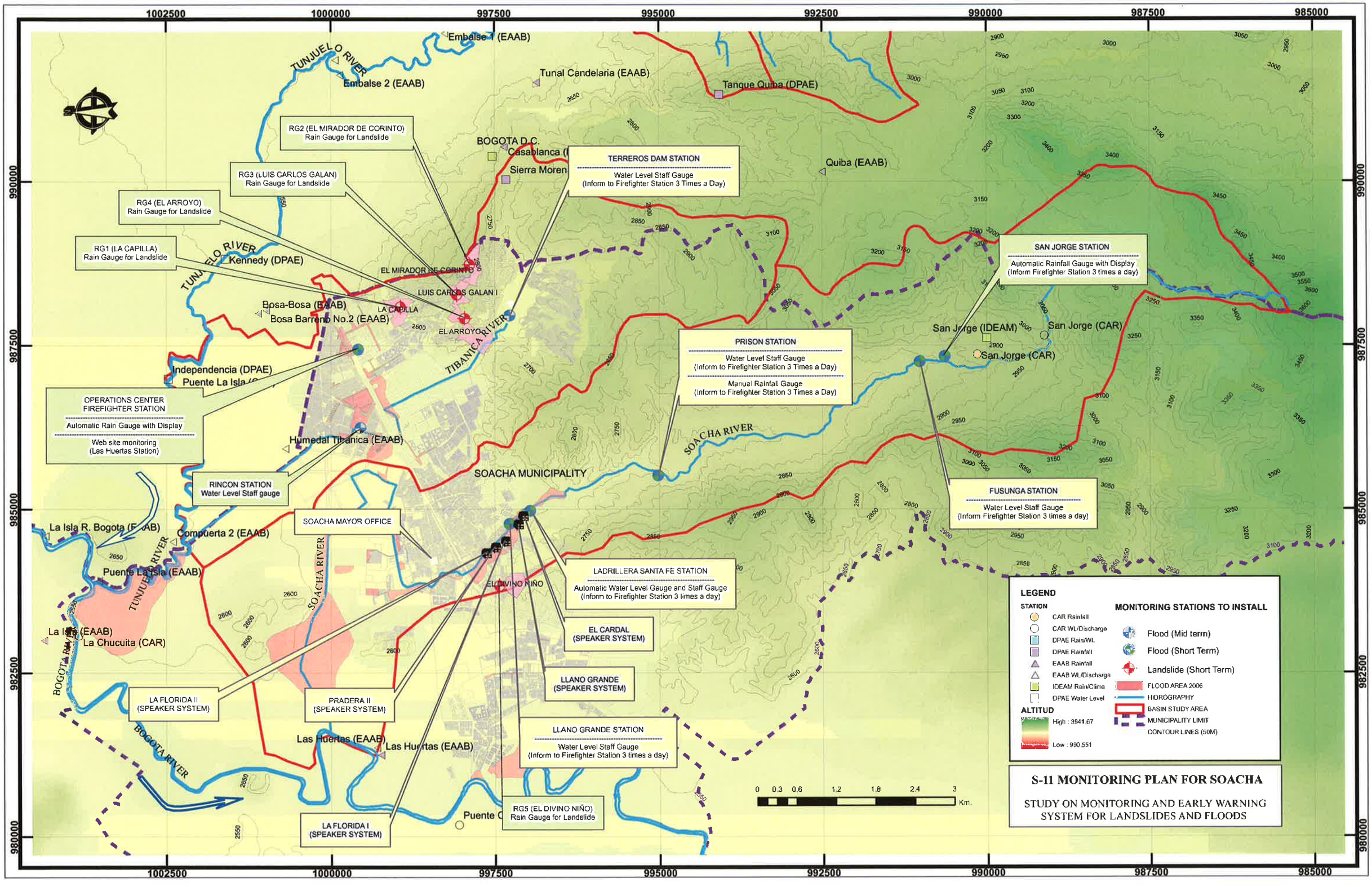
Proyection System Parameters

PCS_CarMAGBOG
Projection: Transverse_Mercator
False_Easting: 92334,879000
False_Northing: 109320,965000
Central_Meridian: -74,146592
Scale_Factor: 1,000000
Latitude_Of_Origin: 4,680486
Linear Unit: Meter

GCS_CartMAGBOG
Datum: CGS_CartMAGBOG

G-1 STUDY AREA

STUDY ON MONITORING AND EARLY WARNING SYSTEM FOR LANDSLIDES AND FLOODS


1002500
1000000
997500
995000
992500
990000
987500
985000
990000
987500
985000
982500
980000
Embalse 1 (EAAB)
TUNJUELO RIVER
Embalse 2 (EAAB)
Tunal Candelaria (EAAB)
Tanque Quiba (DPAE)
RG2 (EL MIRADOR DE CORINTO)
Rain Gauge for Landslide
BOGOTA D.C.
Casablanca (
Sierra Moren
TERREROS DAM STATION
Water Level Staff Gauge
(Inform to Firefighter Station 3 Times a Day)
Quiba (EAAB)
RG3 (LUIS CARLOS GALAN)
Rain Gauge for Landslide
RG4 (EL ARROYO)
Rain Gauge for Landslide
RG1 (LA CAPILLA)
Rain Gauge for Landslide
TUNJUELO RIVER
Kennedy (DPAE)
EL MIRADOR DE CORINTO
LUIS CARLOS GALAN I
LA CAPILLA
Bosa-Bosa (EAAB)
Bosa Barreno No.2 (EAAB)
EL ARROYO
TIBANICA RIVER
SAN JORGE STATION
Automatic Rainfall Gauge with Display
(Inform Firefighter Station 3 times a day)
San Jorge (IDEAM)
San Jorge (CAR)
San Jorge (CAR)
Independencia (DPAE)
Puente La Isla (
PRISON STATION
Water Level Staff Gauge
(Inform to Firefighter Station 3 Times a Day)
Manual Rainfall Gauge
(Inform to Firefighter Station 3 Times a Day)
OPERATIONS CENTER
FIREFIGHTER STATION
Automatic Rain Gauge with Display
Web site monitoring
(Las Huertas Station)
Humedal Tibanica (EAAB)
SOACHA RIVER
RINCON STATION
Water Level Staff gauge
SOACHA MUNICIPALITY
FUSUNGA STATION
Water Level Staff Gauge
(Inform Firefighter Station 3 times a day)
La Isla R. Bogota (F AB)
Compuerta 2 (EAAB)
SOACHA MAYOR OFFICE
TUNJUELO RIVER
Puente La Isla (EAAB)
SOACHA RIVER
LADRILLERA SANTA FE STATION
Automatic Water Level Gauge and Staff Gauge
(Inform to Firefighter Station 3 times a day)
EL DIVINO NIÑO
La Isla (EAAB)
La Chucuita (CAR)
BOGOTA RIVER
EL CARDAL
(SPEAKER SYSTEM)
LLANO GRANDE
(SPEAKER SYSTEM)
LA FLORIDA II
(SPEAKER SYSTEM)
PRADERA II
(SPEAKER SYSTEM)
LLANO GRANDE STATION
Water Level Staff Gauge
(Inform to Firefighter Station 3 times a day)
Las Huertas (EAAB)
Las Huertas (EAAB)
BOGOTA RIVER
RG5 (EL DIVINO NIÑO)
Rain Gauge for Landslide
Puente C
LA FLORIDA I
(SPEAKER SYSTEM)
0 0.3 0.6 1.2 1.8 2.4 3
Km.
LEGEND
STATION
CAR Rainfall
CAR WL/Discharge
DPAE Rain/WL
DPAE Rainfall
EAAB Rainfall
EAAB WL/Discharge
IDEAM Rain/Clima
DPAE Water Level
ALTITUD
High : 3941.67
Low : 990.551
MONITORING STATIONS TO INSTALL
Flood (Mid term)
Flood (Short Term)
Landslide (Short Term)
FLOOD AREA 2006
HIDROGRAPHY
BASIN STUDY AREA
MUNICIPALITY LIMIT
CONTOUR LINES (50M)
S-11 MONITORING PLAN FOR SOACHA
STUDY ON MONITORING AND EARLY WARNING
SYSTEM FOR LANDSLIDES AND FLOODS

74°10'45"W
74°10'30"W
74°10'15"W
4°35'0"N
4°34'45"N

HOUSE(ultimate)LV viewpoint
DISTviewpoint
LV1
LV3
LV2
MS14
MS15
BM5
MS13
BM4
MS12
MS11
MS10
MS9
MS8
CG3
PHASE 1
PHASE 2
PHASE 3
MS7
BM3
MS6
MS3
BM2
MS5
MS4
CG1
CG2
MS2
MS1
BM1

ALCALDIA MAYOR DE BOGOTA D.C.
Secretaría de Gobierno
ALCALDIA MUNICIPAL DE SOACHA
JICA Japan International Cooperation Agency

LEGEND

CLASS

- CRACK GAUGE
- DIST VIEWPOINT
- LV (BENCH MARK)
- LV VIEWPOINT
- MOVABLE STAKES
- TILT METER
- PHASE 1
- PHASE II
- PHASE III
- CONTOUR LINES 10M

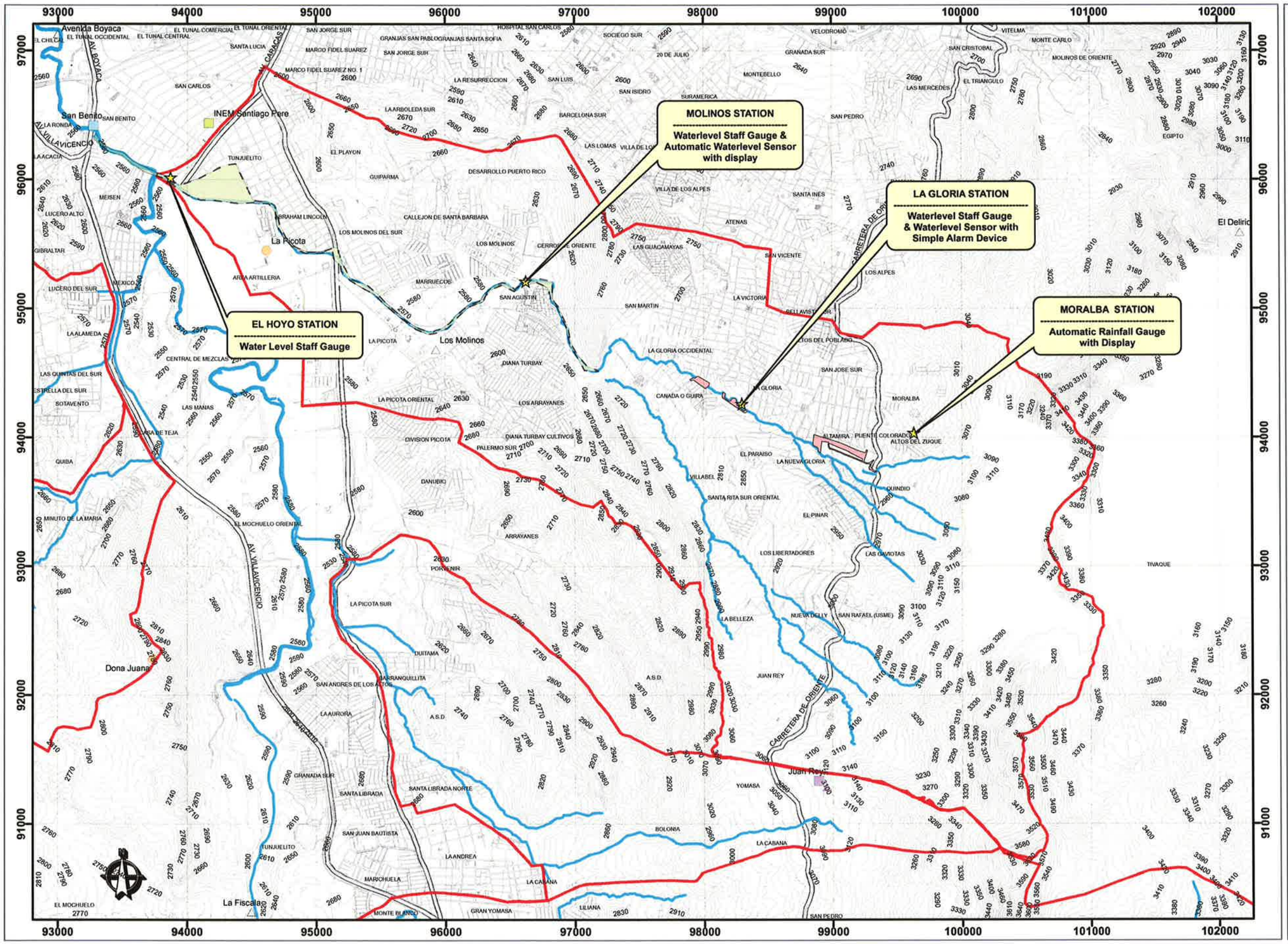
Projection System Parameters

PCS_CartMAGBOG
Projection: Transverse_Mercator
False_Easting: 92334,879000
False_Northing: 109320,965000
Central_Meridian: -74,146592
Scale_Factor: 1,000000
Latitude_Of_Origin: 4,680486
Linear Unit: Meter

GCS_CartMAGBOG
Datum: CGS_CartMAGBOG

B-3 MONITORING PLAN BY JICA STUDY

STUDY ON MONITORING AND EARLY WARNING SYSTEM FOR LANDSLIDES AND FLOODS



ALCALDIA MAYOR DE BOGOTA D.C.
Secretaría de Gobierno

ALCALDIA MUNICIPAL DE SOACHA

JICA Japan International Cooperation Agency

LEGEND

- AFFECTED AREA IF CLOG UP
- CHIGUAZA 25 YEARS
- BASIN STUDY AREA

STATIONS

- CAR Rainfall
- CAR WL/Discharge
- DPAE Rain/WL
- DPAE Rainfall
- EAAB Rainfall
- EAAB WL/Discharge
- IDEAM Rain/Clima
- DPAE Water Level
- HIDROGRAPHY
- CONTOUR LINES (10m.)

0 125 250 500 750 1,000 1,250 Meters

Proyection System Parameters

PCS_CarMAGBOG
Projection: Transverse_Mercator
False_Easting: 92334,879000
False_Northing: 109320,965000
Central_Meridian: -74,146592
Scale_Factor: 1,000000
Latitude_Of_Origin: 4,680486
Linear Unit: Meter

GCS_CarMAGBOG
Datum: CGS_CarMAGBOG

B-9 MONITORING PLAN OF CHIGUAZA CREEK

STUDY ON MONITORING AND EARLY WARNING SYSTEM FOR LANDSLIDES AND FLOODS

Study on Monitoring and Early Warning System for Landslides and Floods

Outline

1 Background of the Study

The Study Areas are landslide area and river/creeks catchment located on the southern part and edge of the Bogota city, the capital of the Republic of Colombia. The ground elevation is 2,500 m in the low area and 3,600 m as the highest point above mean sea level. The study area has been developed quite rapidly since 1970's as a marginal area of the Bogota city, where in poor condition's area such as steep slope around abandoned quarries and used to be wet land, people started to live densely, forming low income neighborhood (barrio). On the other hand, the area has suffered from landslides, steep slope failures and floods due to the topography and meteorological conditions. The Bogota city has already conducted a lot of studies and implemented some relocation. In the Tunjuelo river basin, along the main river course the monitoring and early warning system has been established, however, the system within some tributaries catchment has not been established yet, which is not enough from the viewpoint of saving people's life. The Soacha Municipality has a disaster prevention organization, however does not have any monitoring system.

Under the above situations, the Government of Colombia requested the Government of Japan to make a plan of monitoring and early warning system for landslides and floods for a part of Bogota city and Soacha Municipality. Responding to this request, Japan International Cooperation Agency (JICA) dispatched the Study Team headed by Mr. Kimio Takeya on June 2006.

2 Objectives of the Study

The objectives of the Study are:

- To prepare a Plan for monitoring and early warning system for the Study area for landslides and floods for the target year 2020.
- To establish, operate and maintain the monitoring and early warning system for landslides and floods for the selected areas through pilot projects relying on the initiative of community people in order to enhance the capacity on disaster prevention of the counterpart organizations and communities.
- To transfer technologies and knowledge to the Colombian personnel involved in the Study.

3 Study Area

The Study Area is one (1) landslide area and four (4) creek catchment located in the southern part of Bogota, and two (2) steep slope areas and two (2) river basins of Soacha city which is next to Bogota.

4 Plan on Monitoring and Early Warning System

4.1 Landslides of Bogota

Present Status of the Landslide

There is only one place for the landslide study area in Bogota and it is designated commonly by Altos de La Estancia, and is located southwest of Bogota, north of the Bolivar Locality. In Chapter 5, the landslide in the Sector Altos de La Estancia is referred to as "the Landslide". The Landslide includes two major masses, namely La Carbonera in the south and El Espino in the north, displaces hundred of thousand of cubic meters, and forces hundreds of families to resettlement in an approximate area of 100 ha. The type of the Landslide is related to a mass movement accompanied by some small different types of movement. DPAE divided the Landslide area in 3 zones, namely high alert, middle alert and

low alert [or Phase I area, Phase II area and Phase III area] with the purpose of relocation program. There were no residential houses in Phase I area, but still there were a lot of houses in Phase II area in Year 2007.

Table Areas in the Landslides

Area	Condition	Relocation program by Bogota
Phase I area	Surfaces of the land are deformed. Most active area in the landslide.	Relocation program has been completed
Phase II area	The areas locate above and below Phase I. The areas were not affected by the landslide, but recently some cracks and deformation on the ground were found in the areas.	Relocation program is being in progress.
Phase III area	The areas locate upper and lower part of the Phases I area and II area. The areas are regarded as safe.	Out of relocation program
Out of the Landslide Area	Out of the Landslide.	Out of relocation program

Target

Enhancement of capacity of DPAE on disaster prevention by implementation of the proposed plan in this study

Purpose of the Project

The purpose of the monitoring as the pilot project is to verify that the residential areas as for its safety. This concerns only the object areas of the monitoring of the residential area (Phase III area and the areas outside the landslide area) only as follows.

a. boundaries between Phase II and III areas
b. the areas above the heads of the main landslide in Phase II area
c. the house in which cracks and distortions were found.

With reference to “b” above, new collapses occurred recently near the heads of the main landslide blocks may show expanding of the landslide upward (toward Phase III area). In order to ascertain the movement of the ground above the main landslide blocks, the monitoring is carried out in the area above heads of the main landslide blocks in Phase II area. With reference to “c” above, some cracks and deformations of a house in safe area were found recently.

Monitoring

The following five kinds of monitoring works are carried out. Extent of the monitoring is shown below.

Table Extent of Monitoring

Location	Monitoring	Item	Quantity
Boundary between the Landslide and the Residential Area	Survey Point	Survey Points	15
		Fix Points (Bench Marks)	5
Phase II area	Crack Gauge	Crack Gauges	3
		Pegs (4 pegs for 1 set)	3 set
Uplift and Deformed House	Level Survey	Survey Points	3
	Tiltmeter	Sensor	1
		Logger	1
	Distance Meter	Laser Distance Meter	1
		Target Plate	2

The survey Points were installed along the boundary between the residential area and the Landslide in order to confirm the safe areas are still in safe. In case any movements on some survey points are

observed by the monitoring, the area around the survey points might be affected by the landslide. Exploration of the area is necessary to find any damages, distortions and cracks on the ground, houses or structures. A total of 15 the survey points were installed, and 5 fix points were installed as bench marks.

The movement of the cracks monitored by simple crack gauges can be summarized in graphs which show relations between time and movement. The graphs can show the movement of the head of landslide block, and then the velocity of the landslide movement may be estimated.

In the house which is object of the monitoring, some cracks were found by residents of the house in October 2006. The house locates in the safe area (outside the landslide) close to the boundary between relocation area, and at the place close to the uplift by the landslide movement. The following equipments were installed in and around the house to monitor the slow progress of tilting of the house and slow movement of uplift.

a. Tiltmeters on the basement floor of the house

b. Laser distance meter to monitor the distance between the house and the uplift

c. Logger which connected to the tiltmeters in the house

d. Level survey points to monitor uplifting of the uplift

For the monitoring of distance between the house and the uplift, laser distance meter is employed instead of extensometers which required wires on the ground.

Data Processing

Any significant movement has not been seen on all the monitoring during the pilot project. The results may show that the landslide has not reached the safe areas, and the residential areas may be still in safe status. However, the period of the monitoring is too short to judge the safety of the areas, the monitoring should be continued and accumulate the data to confirm the safety of the areas.

Hazard Map

DPAE did an area division in three areas named Phase I area, Phase II area and Phase III area based on available information and especially in the study of INGEOMINAS (2003) in order to relocate the population of all areas, and issued the map to public as Hazard Map. Almost all of the inhabitants in Phase I area actually have been relocated, and relocation of inhabitants in Phase II area is progressing. The Phase III area, which is counted as stable area and out of relocation plan, corresponds to the high slope part.

Early Warning and Evacuation Plan

The early warning systems using the automatic monitoring systems are not required in the Landslide in terms of saving human loss in the area, because of existing resettlement program and the movement speed of landslide. The most recommendable thing is to observe the ground conditions by the engineers with regular patrol or by the communities in their ordinary lives. This observation survey is performed to examine the extent, direction of movement, and the mechanism of landslides in detail when any sign of landslide motion such as slide scarps or cracks are found or when there is any possibility of the occurrence of landslides in the future.

4.2 Flood in Bogota Target Creeks

Past Floods in Target Creeks

The target creeks in Bogota are Chiguaza creek, Santa Librada creek, Yomasa creek and La Estrella Trompeta creek. The largest catchment area is that of the Chiguaza, 18.7 km^2. The bed slopes of these

creeks are quite steep whose main reach is steeper than 3 degree.

The interview survey was undetaken by the Study team about the past floods in the 4 creeks. In the Chiguaza, a flood disaster took place in May 19, 1994 which caused 4 victims, 800 people affected. In this flood, the Juan Rey rainfall station of EAAB located in the upstream of the creek catchment recorded the daily rainfall 22.9 mm and the maximum 30 minutes rainfall 19 mm. The flood damage was caused by the flooding on the street of the right side of the creek due to the clogging of culvert crossing the creek. In the study area, that is only flood disaster associated with victims and a lot of affected according to the survey during the study.

Also in the Chiguaza the inundation occurred in the most downstream reach near the Tunjuelo river confluence in the end of May 2002. This flood is considered that caused by runoff from the Chiguaza itself as well as high water of the Tunjuelo river. In the upstream of the Tunjuelo river EAAB's Cantarrana Dam (flood control purpose) was constructed in 2007. The Chiguaza downstream reach has been improved by EAAB, so that the safety level is increasing in the Chiguaza. However, since there is few monitored data, especially waterlevel data, the safety level is not confirmed yet based on the relationship between monitored rainfall data and waterlevel.

Objectives of the Plan

By implementing of the plan proposed in the Study, the capacity on disaster prevention of DPAE will be enhanced.

Planning Principle

The above-mentioned plan was prepared for short, middle and long term. The target year of the plan is set up in 2020, assuming that the implementation of the plan starts in 2007 and fourteen (14) years would be required for the completion. The reason for starting the said plan in 2007 is that the pilot project(s) in this Study was undertaken as a part of the proposed plan.

Definition of Short, Middle and Long Term Plan

Plan	Year	Definition
Short	2007-2008	It is urgently required and should be implemented as pilot projects which will become the basis of middle and long plan.
Middle	2008-2012	This is an extension for a short term plan in order to secure the target creeks.
Long	2013-2020	This is a fully advanced system based on the experience of short and middle plans.

The purpose of the proposed plan is to prevent the people in the previously affected area from the same flood damage in near future, or mitigate the future damage by the plan. Thus, as a tool for the above, monitoring of hydro-meteorological conditions by equipment and preparation of early warning system based on the monitored data are required. Therefore, it should be pointed out that the people who should evacuate in an event of flood understand the meaning of the early warning system and they take necessary actions are quite important. In this sense, unless the people understand the importance of the system and can make use of the system actually, any expensive equipment for the monitoring and early warning is meaningless.

Based on the purpose, the monitoring system of DPAE should be proceeded as following phases,

Monitoring and Data Gathering System

Phase 1 : data accumulating and people's training phase

The Chiguaza creek catchment is defined as the most important monitoring area and the following station were setup.

List of Station to be monitored for DPAE (Short –Team)

Location	Monitoring item	Purpose of Monitoring	Equipment	Person in charge of Monitoring
Moralba (school)	10 minutes rainfall	The short duration rainfall upper art of the affected area in 1994 will be monitored.	Rain gauge(tipping bucket), data logger with external display, solar panel, battery, cabinet and earth	Security guard of school Hourly monitoring
La Gloria	Waterlevel in upper reach	The affected people in 1994 flood should start the monitoring (waterlevel).	Staff gauge, waterlevel simple alarm device	3 times day monitoring by local people and recording time and waterlevel at high water.
Molinos (foot bridge next to school)	Waterlevel in middle reach	The affected people in 1994 flood should start the monitoring (waterlevel).	Staff gauge, Non-touch stage sensor (ultrasonic type), data logger with external display, solar panel, battery, cabinet and earth.	3 times day by people and security guard of the school
El Hoyo	Waterlevel in downstream	The affected people in 2002 flood should start the monitoring (waterlevel).	DPAE staff gauge	3 times day by Civil Defense

In this phase, the following thins should established.

- Accumulation of waterlevel monitoring experience of the downstream people and rainfall monitoring experience of upstream people. The collaboration between upstream and downstream is enhanced.
- Accumulation of data regarding the short duration rainfall in the upstream and the waterlevel response in the downstream
- Downstream people's understanding on the phenomena of waterlevel response by upstream rainfall(understanding on false alert)

Phase 2：Rainfall and waterlevel measurement in Yomasa creek catchment

The Yomasa creek has not suffered from flood damage like Chiguaza 1994, however, the present condition of the creek bed has remarkable unstable sediment deposit.

List of Station to be monitored for DPAE (Mid –Team)

Location	Monitoring item	Purpose of Monitoring	Equipment	Person in charge of Monitoring
Alemana	Rainfall	Measurement of upstream rainfall in the Yomasa creek	Rainfall gauge(automatic with external display)	3 time a day monitoring by people
Ave. Usme downstream (Monte Blanco)	waterlevel	Measurement of waterlevel response by the upstream rainfall	Staff gauge	3 time a day monitoring by people

Data Analysis and Processing

By measuring of waterlevel at Molinos continuously, the data on response of waterlevel for the upstream rainfall will be accumulated, as well as discharge measurement (by floating during flood) will be conducted to confirm the runoff from the upstream and analyze effective rainfall, which could

improve the warning criteria. The velocity measurement by float should be arranged by the people who monitored the staff gauge at Molinos in the Short Term.

Also, the waterlevel at Molinos and rainfall at Moralba will be transferred by telemeter system to DPAE, whose system will be included in the existing Tunjuelo River early warning system of DPAE.

Warning Criteria and Susceptibility Map

The flood map in May 1994 flood was made by the Study Team based on the flood interview survey for the affected people in 1994 in the Chiguaza creek. Also the probable flood area for 25 years return period was prepared for the Chiguaza downstream area.

The flood alert of the Study area was proposed to be daily rainfall 10 mm tentatively. This is based on the statistical analysis of rainfall and some kind of flood events in the study area from DPAE recent 5 years data. In the Chiguaza creek catchment, in recent 5 years, 38 flood events were reported to DPAE. The detailed phenomena of such flood was not recorded, however, it is a sum of various flood events such as overflow from ditch and inland flood based on people's information. Among them, 20 events (50 %) happened at the time of daily rainfall 10 mm. It means that in the Chiguaza creek catchment, when the daily rainfall is 10 mm, some kind of flood would occur with possibility of 50 %, so that this rainfall should be set as alert tentatively. In other 3 creeks, when the daily rainfall is 10 mm, the flood event possibility is lower, however, considering the small size of catchment, more detailed alert by area (catchment) can not be proposed.

The tentative warning criteria for the Chiguaza creek based on the monitoring and hydraulic study is as follows,

In the downstream reach between Caracas Avenue and Molinos street, there is critical section whose flow capacity is only 10 years return period. The discharge for 10 years return period can be brought by about 20 mm per 30 minutes. Therefore, the warning criteria is set as follows, alert level 6 mm per 10 minutes and warning level 20 mm per 30 minutes.

In the reach from middle stream to upstream of the Chiguaza, basically the channel capacity is quite high, however, as they can experienced in May 1994 flood, if crossing structure such as culvert is clogged, over flow could take place easily and unexpectedly. Six (6) locations were pointed out because they need periodical maintenance.

In the upstream, there is possibility that crossing structure will be clogged up by garbage and sediment deposition as they saw in May 1994. The warning criterion in terms of rainfall for this kind phenomenon is difficult because of lack of data. Tentatively based on the measured rainfall amount in May 1994, the past 15 days rainfall 78.1 mm and daily rainfall 22.9 mm are proposed as the first criteria. If the rainfall exceeds this value, patrol along the creek is recommended.

Information Transfer Plan

DPAE is in charge of information transfer to community based on the monitored data. The modification of warning criteria should be done by DPAE.

4.3 Landslides in Soacha Municipality

Status of Landslides

Landslides, mostly classified into rock fall and surface collapses, in the study areas occur frequently at abandoned quarries in Altos de Cazuca area where houses gathered in the upper and lower area close to steep slopes and landslide hazard areas. Also, houses gathered in landslide hazard area formed by a quarry in El Divino Niño area. According to the statistic record, the number of residential houses suffered from landslides especially in El Divino Niño area and La Capilla area of Altos de Cazuca area is the highest in Soacha Municipality. Prompt measures should be taken to save people in these areas.

Steep slopes in the abandoned quarries are the most critical conditions among many disasters in Altos de Cazuca area. In this study, only steep slopes in the abandoned quarries are the object of the studies.

Target

Enhancement of capacity of Soacha Municipality on disaster prevention by implementation of the proposed plan in this study

Purpose of the Project

Even some landslide disasters occur in dry condition, many landslide disasters have occurred during or after heavy rain in Altos de Cazuca area and El Divino Niño area in Soacha Municipality. It may be true that the rainfall causes many landslides in Soacha Municipality, but not certain without any support data. The information collection of precipitation and disasters are most important to take action against the landslide disasters. Accumulating the information about precipitation and occurrence of landslides, the relation between rainfall and occurrence of landslides should be studied.

In order to install the rain gauges as many as possible for the purpose, the simple gauges which are low cost and easy to be read were installed in the pilot project area. To monitor many rain gauges constantly, the monitoring works are left to the community in where the rain gauges are installed. It is expected also that community's awareness of disaster prevention becomes higher with the monitoring works. The record of landslide is being carried out by Soacha municipality, since recording of landslides requires more expertise.

Monitoring

Precipitation monitoring was carried out in the pilot project area where is Altos de Cazuca area and El Divino Niño area in Soacha Municipality. Five rain gauges were installed in five schools in the pilot project area.

The rain gauge consists of funnel and Cylinders and sub cylinder for reading minutely is attached. It is very simple rain gauge without any mechanical parts and electric power.

Basically, the monitoring works are carried out by a person in each school who is assigned by the principal of the school. The values indicated by the rain gauges are read three times a day at 6:30, 14:00, and 18:00. The records are submitted once a week to the Soacha municipality. In the case the accumulate rainfall is more than 20mm/24h, the person who read the rain gauge should call the firefighter station in Soacha Municipality.

All of landslides in Soacha Municipality should be recorded immediately after occurrence of the landslide using the record format. Especially, the pilot project areas, Altos de Cazuca area and El Divino Niño area, are emphasized. The formats are filled by the engineer immediately after he visited the landslide site. The report of monitoring contains an analysis of the relation between the rain fall and the landslide disasters. Record format which has been recorded should be filed in the engineer's office in Soacha Municipality.

Data Processing

Though the precipitation monitoring has been carried out for five months in 2007, the precipitation data must be accumulated for longer periods in order to have information on rainfall. At the moment, the following situation is observed in the monitoring.

a) Monthly precipitation in August is more than in September. It shows different trends from average normal year.

b) Monthly precipitation is different in each point in August, and is not different in each point in September.

c) Maximum monthly precipitation was observed with RG-4 by 141.8 mm in October 2007.

d) Maximum daily precipitation was observed with RG-4 by 58.2 mm on 13th October 2007.

e) The lower the altitude of the rain gauges is, the more it tends to rain both especially in August.

Three landslide disasters occurred in the period from 13th October to 15th October 2007 in Los Robbles, Terranova and La Capilla in Altos de Cazuca area. Rain continued intermittently from 6th October 2007 to 14th October 2007 in Altos de Cazuca area. Nearest rain gauge points to Los Robbles is RG-4, to Terranova is RG-3 and to La Capilla is RG-1. According to Figure 8-3 in Main Report, excess 20 mm of accumulate precipitation may be appropriate for Alert Level 1 and excess 50 mm of accumulate precipitation may be appropriate for Alert Level 2.

Hazard Map

Disaster inventory survey in Altos de Cazuca area and El Divino Niño area was carried out by aero photo analysis and site reconnaissance. The results of the disaster inventory survey are seen in Disaster Inventory Map. Steep slopes in the abandoned quarries are the most critical conditions among many disasters in Altos de Cazuca area. In this study, only steep slopes in the abandoned quarries are the object of the studies.

In the study area, Critical Zones has been set to verify the critical area in the "barrios". In barrios La Capilla in Altos de Cazuca area and El Divino Niño area where houses are dense, slopes are high and landslides occur frequently. The Critical Zones are set above and below the steep slopes. Critical Zone is defined as the area within the distance of twice the slope height (2h) from toe of the slope and the area within the same distance as the slope height from top of the slope. Critical Zone in El Divino Niño area and La Capilla is shown in Figures attached.

The Soacha Municipality introduced a scheme for relocation of houses from high risk areas in a disaster prevention program. The Critical Zone maps could provide useful information for the Soacha Municipality's relocation scheme. It is obvious, however, that the early relocation of houses in the Critical Zones in El Divino Niño area and La Capilla area is difficult, since many houses are settled in the Critical Zones. The Emergency Zone is set in the Critical Zones in El Divino Niño area where is found the most serious area in Soacha Municipality. It is imperative that the houses in Emergency Zones be relocated urgently. The criterion of Emergency Zone should be within the limits of 10 m or 2 houses from toe of the slope.

For the relocation program in El Divino Niño area, the relocation of all people from Critical Zones and even Emergency Zones may take a long time. Therefore, it is important to protect the people who stay in the Emergency Zones and Critical Zones until they are relocated. To this end, the people should know whether they are settled in the zones or not using by Critical Zone map (Hazard maps).

Early Warning and Evacuation

The steep slopes are covered by clayey material which was created in process of weathering of sandstone and mudstone. The surfaces of the steep slopes are sensitive. In addition, open cracks observed on the slopes indicate that the entire bodies of the slopes have been continuously moving from the past. Therefore, the steep slopes are delicate state and further cutting on steep slopes is equal to removal of toe of the slope and this activity increase the risk of mass movement. Any protection and stabilization works on steep slopes in abandoned quarries in El Divino Niño area and Altos de Cazuca area is impracticable to implement from the technical viewpoints.

It is recommendable to relocate from the Critical Zones as measures against slope disasters on steep slopes in abandoned quarries. The houses close to the steep slopes should be relocated to safe areas, out of Critical Zones.

4.4 Flood for Soacha

Flood Problems in Soacha

The study area for flood in Soacha is the Soacha river basin (a tributary of the Bogota river) and the Tibanica river basin (a tributary of the Tunjuelo River).

The Soacha river has 24 km length from the Bogota river confluence to the San Jorge in its origin. The river suffered from the most serious flood damage on recent 20 years on May 11, 2006. The most seriously affected areas were the left bank floodplain between 7K+877 and 9K+000. This reach used to be the floodplain (wetland) in 1940's and the urbanization was proceeded. The barrio called Llano Grande suffered from damage most seriously where the inundation depth was over 1 meter. The damage in the Tibanica river next to the Soacha river was comparatively small. The plan was focused on the Soacha river for the monitoring and early warning system.

The rainfall in may11, 2006 was observed only at San Jorge IDEAM station located 18km upstream from the Bogota river. The observed rainfall was only 7.5 mm (8:40AM to 9:40AM) while the daily rainfall was 20 mm.

According to the people in Llano Grande, the overflow started at 11:30 in the morning, which means the flood in Llano Grande took place 2 hours after the rainfall in San Jorge. The distance from Llano Grande to San Jorge is about 8 km, while the rainfall distribution in area is not clear, according to the people, the rainfall concentrated on the middle basin of the Soacha river.

The Firefighter Station started to monitor the rainfall from December 2006 in this Study. The correlation between the Firefighter Station and IDEAM San Jorge is quite low in terms of daily rainfall.

Objectives of the Plan

By implementing of the plan proposed in the Study, the capacity on disaster prevention of Soacha Municipality will be enhanced. Also it is expected that Soacha Municipality will train other municipalities in the Cundinamarca Government, which would enhance the capacity of the Government.

Planning Principle

The plan above was prepared with short, middle and long term plans. The target year of the plan is set up in 2020, assuming that the implementation of the plan starts in 2007 and takes fourteen (14) years for the completion. The reason why the said plan starts in 2007 is that the pilot project(s) in this Study was undertaken as a part of the proposed plan.

Definition of Short, Middle and Long Term Plan

Plan	Year	Definition
Short	2007-2008	It is urgently required and should be implemented as pilot projects which will become the basis of middle and long plan.
Middle	2008-2012	This is an extension of short term plan in order to secure the target creeks.
Long	2013-2020	This is a fully advanced system based on the experience of short and middle plans.

The purpose of the proposed plan is to prevent the people in the previously affected area from the same flood damage in near future, or mitigate the future damage by the plan. Thus, as a tool for the above, monitoring of hydro-meteorological conditions by equipment and preparation of early warning system based on the monitored data are required. Therefore, it should be pointed out that the people who should evacuate in an event of flood understand the meaning of the early warning system and

they take necessary actions are quite important. In this sense, unless the people understand the importance of the system and can make use of the system actually, any expensive equipment for the monitoring and early warning is meaningless.

Based on the purpose, the monitoring system of Soacha should be proceeded as following phases,

Monitoring and Data Gathering System

Phase 1 : Waterlevel measurement by affected people in May 2006 flood and rainfall measurement in the upstream by local residents

The Soacha river basin is defined as the most important monitoring area and the following station were setup.

List of Station to be monitored for Soacha (Short –Team)

Location	Monitoring item	Purpose of Monitoring	Equipment	Person in charge of Monitoring
San Jorge (ICA)	Hourly rainfall	To monitor the upstream local rainfall at representative position in the upper part of the catchment.	Rain gauge(tipping bucket), data logger with external display, solar panel, battery, cabinet and earth	Three times a day monitoring by security guard and reporting to Firefighter Station by radio
Fusunga	Waterlevel	In order to assure the accuracy of warning, waterlevel is monitored.	Staff gauge	Three times a day monitoring by people and reporting to Firefighter Station by radio. The person in charge is quite cooperative to the monitoring activity in entire basin.
City Prison	Rainfall and waterlevel	Monitoring rainfall and waterlevel in middle part of the basin and issuing of alert to downstream target area.	Staff gauge, waterlevel simple alarm device and simple rainfall gauge	Three times a day monitoring by security guard and reporting to Firefighter Station by radio
Ladrillera Santa Fe(brick factory)	waterlevel	Monitoring waterlevel at most downstream as long as the security is assured and issuing of alert to downstream target area.	Non-touch waterlevel sensor(ultrasonic), data logger with external display, solar panel, battery, cabinet and earth	Three times a day monitoring by security guard and reporting to Firefighter Station by radio

Llano Grande	Waterlevel	The affected people in May 2006 flood should start waterlevel monitoring.	Staff gauge	Three times a day monitoring by people and reporting to Firefighter Station by radio
Firefighter Station	10 minutes rainfall	As a Monitoring Centre of Soacha, the rainfall measurement should be started.	Rain gauge(tipping bucket), data logger with external display, solar panel, battery, cabinet and earth	Hourly monitoring by Firefighter
Firefighter Station	Web site monitoring for rainfall and waterlevel	All information from Monitoring station will be input into Data Base.	Desktop PC, Laptop PC and data download software	

In this phase, the following thins should established.

- Accumulation of waterlevel monitoring experience of the downstream people and rainfall monitoring experience of upstream people.
- Establishing of information transfer system between Firefighter station and monitoring stations and communities by radio, in order to let the Firefighter confirm the current status of the Basin.
- Accumulation of data regarding the short duration rainfall in the upstream and the waterlevel response in the downstream
- Downstream people's understanding on the phenomena of waterlevel response by upstream rainfall(understanding on false alert)

Phase 2 : Telemeterizing of San Jorge (rainfall) and automatic measuring of Ladrillera Santa Fe(waterlevel) and conducting of discharge measurement at Ladrillera Santa Fe

Data Analysis and Processing

By measuring of waterlevel at Ladrillera Santa Fe continuously, the data on response of waterlevel for the upstream rainfall will be accumulated, as well as discharge measurement (by floating during flood) will be conducted to confirm the runoff from the upstream and analyze effective rainfall, which could improve the warning criteria. The velocity measurement by float should be arranged by the people who monitored the staff gauge at Ladrillera Santa Fe in the Short Term.

After telemeterizing of San Jorge and Ladrillera Santa Fe, the Soacha monitoring system will be integrated into IDEAM system. An agreement between Soacha Municipality and IDEAM regarding future maintenance and data exchange has been discussed. The discussion should be continued after the study in order that the Soacha will receive technical support from IDEAM.

Warning Criteria and Susceptibility Map

The flood map in May 2006 flood was made by the Study Team based on the flood interview survey for the affected people in 2006 in the Soacha river.

The flood alert of the Study area was proposed to be daily rainfall 10 mm tentatively. This is based on the statistical analysis of rainfall and some kind of flood events in the study area from Soacha Municipality recent 10 years data. In Soacha Municipality, in recent 10 years, 101 flood events were reported to Municipality. The detailed phenomena of such flood was not recorded, however, it is a sum of various flood events such as overflow from ditch and inland flood based on people's information.

Among them, 56 events (55 %) happened at the time of daily rainfall 10 mm. It means that in Soacha Municipality, when the daily rainfall is 10 mm, some kind of flood would occur with possibility of 50 %, so that this rainfall should be set as alert tentatively.

The warning waterlevel and rainfall was tentative setup based on the actual waterlevel on May 2006 flood and monitoring and hydraulic analysis.

Information Transfer Plan

The Soacha Municipality is in charge of transfer of warning to communities based on the monitoring data. The firefighter station will collect all monitoring data and manage them, and provide information with CLOPAD for warning issue.

The updating of warning criteria will be done by Soacha Municipality receiving of support from IDEAM.

Evacuation Plan

The evacuation plan for the pilot project area was formulated based on the actual inundation in May 2006 flood. People should evacuate to their 2nd floor or community center outside of the inundation area.

Institutional Aspects

The proposed plan will be implemented basically by CLOPAD of Soacha Municipality. CREPAD of Cundinamarca Government which is the upper level organization of the Municipality, is in charge of Bogota river committee whose members are municipalities along the Bogota river. The monitoring data which will be accumulated in Soacha river and experience of community activities will be a model for other municipalities. In this sense, CLOPAD in Soacha Municipality and other municipalities and CREPAD should coordinate more and contribute to the activities of the committee.

4.5 Community-based Disaster Prevention Plan in Soacha

(1) General

Regarding community organizations of Soacha Municipality, quite a few international organizations have been studying, however, the study on disaster prevention activities was done first in this Study.

(2) Community Survey

According to the communities' awareness survey in the Study area, a lot of people are interested in participation to disaster prevention activities, however, they did have few training on disaster prevention.

(3) Focus Group

Based on the survey on communities' awareness, some barrios were selected in which they have experiences on past disasters (landslides and floods) and have high awareness on participation to disaster prevention activities, and also have leaders who can actually participate into the activities. Inviting of those communities leaders, focus group meetings were held and some barrios for the pilot project were selected.

(4) Community Workshop

In the course of the Study, a series of workshops were held to invite community's organizations called JAC and to formulate community based disaster prevention plan in the pilot project area.

(5) Community-based Disaster Prevention Plan

Main Component	Outline
Rainfall and waterlevel Monitoring System	Rainfall and waterlevel stations which were installed in Soacha river and Altos de Cazuca area and El Divino Niño area will be monitored by communities and related entities. The monitored data will be reported to Firefighter station by radio.
Information Transfer System	Communities will receive information (alert and warning, etc.) from Firefighter station through speaker system installed in JAC leader's houses.
Early Warning System	The proposed system is based on collaboration among upstream people and downstream people. The upstream people will participate in the rainfall and waterlevel monitoring. The person in charge of monitoring at each station will report the data to firefighter station. The Firefireghter station will inform communities by radio information (alert and warning) based on warning criteria.
Operation and Maintenance	The radio and speaker system necessary for information transfer will be maintained by communities. However, advanced equipment such as automatic rainfall gauge and waterlevel gauge will be maintained by Soacha Municipality with support from IDEAM.
Consideration of Lead time for early warning criteria	The necessary lead time for evacuation in communities including time for information transfer, preparation and moving) was assumed to 50 to 105 minutes according to communities' leaders, which will be revised in the course of the drill.
Evacuation Plan	The evacuation plan for the pilot project area was formulated based on the actual inundation in May 2006 flood. People should evacuate to their 2nd floor or community center outside of the inundation area.
Community Disaster Prevention map	In the course of repeated community's workshops, necessary information were compiled in maps for each barrio in the pilot project area.
Meeting Point and shelter for evacuation	In the community disaster prevention map, evacuation route and meeting points are indicated. At present, the capacity of evacuation center is not enough for emergency situation, and the Soacha Municipality and Communities should discuss to improve the situation.

5 Implementation of Pilot Projects

The pilot project was conducted in the study as the first step of the plan on monitoring and early warning system formulated for DPAE and Soacha Municipality.

5.1 Landslides in Bogota

Pilot Project for landslide in Bogota is to execute the monitoring works mentioned in Section 4.1. The monitoring equipments were in stalled in July 2007, and the monitoring works are still in progress.

Any significant movement has not been seen on all the monitoring at the moment. The results may show that the landslide has not been reached to the safe areas, and the residential areas may be still in safe status.

5.2 Flood in Bogota

The pilot project for flood in Bogota is the implementation of Phase I area proposed in section 4.2. DPAE already started to monitoring activities using installed equipment in the Study.

5.3 Landslides in Soacha

Pilot Project for landslide in Soacha Municipality is to execute the monitoring works mentioned in Section 4.3. The monitoring equipments were installed in July 2007, and the monitoring works are still in progress.

Reading of rain gauges has been done by school teachers and security guards. In the first stage of the monitoring, some mistake like the unit wrong can be seen in record sheets. Reliable monitoring can be done after workshop which held after one month monitoring.

Three landslide disasters were recorded in the period from 13th October to 15th October 2007 in Altos de Cazuca area. Rain continued intermittently from 6th October to 14th October 2007 in Altos de Cazuca area.

Precipitation monitoring was carried out for five months in 2007, still the precipitation data must be accumulated for longer periods to have information on rainfall.

5.4 Floods in Soacha

The pilot project for flood in Soacha is the implementation of Phase 1 proposed in section 4.4. This is the establishment of system that resident or security guard monitor the rainfall gauge and waterlevel staff gauge and report the data by radio to the firefighter station at least 3 times a day.

Also in the case of Sacha Municipality, for the seriously affected area in May 2006 of the Soacha river left bank between Autopista Sur (7+877) and upstream 9+000, information transfer system was established among 4 barrio leaders in those areas and one administrator of El Silo downstream of the Autopista Sur. The Firefighter station will inform those leaders by radio alert and warning about floods. In this Study, speaker system was installed in those barrio leaders house and handy radio receivers were provided for the communication with firefighter station. By this system, people in communities will take action based on the instruction of leaders who receive message from the firefighter station.

In the last phase of this Study, the drill for the information transfer between monitoring stations and the firefighter station, and for the process that the firefighter station sends message to community leaders based on the warning criteria and the leaders prompt proper action to their community people was conducted, receiving of support of the Municipality, Red Cross and Civil Defense.

6 Temporary Works in Soacha Municipality

6.1 Background

In the Territorial Ordering Plan (POT) Soacha Municipality, the municipality classifies the area of El Divino Niño area as a “Hazard Zone by Landslide”, and the municipality is going to implement a relocation program of houses which are located in the hazardous zone. At the preparatory stage of this study (September 2005), Soacha municipality requested the study and implement emergency measures of slope protection against the landslide in El Divino Niño area. As a result, the it was concluded that the relocation of houses is the only way to assure the safety of residents and any other measures are impractical even some measures have possibility to induce further dangerous situation.

The Study Team examined and decided in concrete form the Critical Zone in El Divino Niño area. The Critical Zone is signified by the criteria of; slope angle is not less than 30 degree and slope height is not less than 5m, and distance from the slope toe is within twice of height of slope. Since there are many houses to be relocated in the Critical Zone, the Critical Zone was classified into two zones; Emergency Zone (the area within 10m or 2 rows of houses from the toe of the slope) and the remaining. And the priority for the relocation of houses was given to the relocation program by the Municipality.

Although the relocation of houses in the Emergency Zone is implemented by Soacha municipality, there are many remaining houses facing critical situation in the Critical Zone. Therefore the Study Team planed to implement temporary works in the Emergency Zone after the relocation of houses to reduce the damages to remaining houses by small-scale slope failures and rockfalls.

6.2 Design of the Temporary Protection Wall in El Divino Niño

(1) General

From the background as mentioned above, the objectives of temporary works are 1) to reduce the damages to remaining houses in the Critical Zone by small-scale slope failures and rockfalls, 2) to inform that the Critical Zone is a risk zone to the neighbors, and 3) to be a symbol of a emergency measures to avoid new settlement in the risk zone.

(2) Area for the Temporary Works

The temporary works is installed in the area of 5,100m^2 (0.51ha) defined as the Emergency Zone; the area within 10m or 2 rows of houses from the toe of the slope.

(3) Temporary Works

The temporary works is consisted of four items, which are a) temporary gabion wall for rockfalls, b) drainage channel at the house side of the wall, c) conventional drainage channel at the top of slope and 4) hazardous sign board.

7 Recommendations

7.1 General

The Study Team proposed the above plan on monitoring and early warning system to DPAE and Soacha Municipality and desires the system on landslides and floods will be made use of by them in the future in order to enhance the safety of people and early warning system on flood will be improved. Therefore the Study Team would like to recommend the following.

7.2 Recommendations for DPAE (Landslide)

<u>Continuous of Monitoring Works</u>

The results of the monitoring works as the pilot project may show that the landslide has not been reached to the safe areas, and the residential areas may be still in safe status. However, the period of the monitoring is too short to judge the safety of the areas, the monitoring should be continued and accumulate the data to confirm the safety of the areas. When significant movement is found in the monitoring result, the following steps should be taken to make sure that the landslide reaches the place.

1. Increasing of frequency of the monitoring at the place where the movement was found. Frequency of the monitoring may be about once a week.
2. Conducting of visually observations around the place to find the landslide reaches the place. This observation survey is performed to examine the extent, direction of movement, and the mechanism of landslides in detail.
3. If it is concluded with the result of the monitoring and observations that the landslide affect the place, the phases should be reconsidered.

<u>Recommendation for Stabilization Works in Altos de Estancia</u>

DPAE is planning stabilization works in the Landslide, however the details are not confirmed yet at the moment. Generally stabilization works are classified into two major categories, works for reduction of driving forces and works for increase in resistance force. In a large scale landslide like the Landslide in Altos de Estancia, method for reduction of driving forces is given to priority, since cost effectiveness for a large scale landslide is normally better than method for increase in resistance force. As remarkable thing in Altos de Estancia, surface water which comes from inadequate drainage system in Phase III area flows into the Landslide area at all over the place of heads of the Landslide. Water flow into the Landslide makes many channels and pools in the Landslide. The most important and effective stabilization works for the Landslide is to reduce the groundwater level, and prevent water penetration into the ground especially from sewer and rainwater.

7.3 Recommendations for Soacha (Landslide)

It is recommendable to relocate from the Critical Zones as measures against slope disasters on steep slopes in abandoned quarries. The houses close to the steep slopes in abandoned quarries should be relocated to safe areas. However it may take a long time to relocate from Critical Zones because there are many steep slopes in abandoned quarries and houses in the Critical Zones. The following non-structural measures are recommended.

1. People in Critical Zones should be relocated. Priority of relocation should be given to the people in most danger in Critical Zones.
2. Until all the people in Critical Zones relocated, Soacha Municipality should take care of safety of people remaining in Critical Zones.
3. People remaining in Critical Zones should be informed that they are in Critical Zones and always are at risk even in fine weather.
4. In heavy rain, Soacha Municipality should be on the alert for people in Critical Zones
5. To obtain the basic information about alert level of rain fall, Soacha Municipality should collect rainfall data.

As it could take a long time to complete the plan, relocation from more dangerous area with the following steps is necessary.

1. Complete the relocation program from Emergency Zone in El Divino Niño area
2. Set up Emergency Zones in La Capilla area.
3. Proceed relocation program from Emergency Zones in La Capilla area following the process in El Divino Niño area.
4. Set up Critical Zones and Emergency Zones in El Arroyo area (Villa Esperanza area) where is surrounded by steep slopes formed by mining activities.
5. Proceed relocation program from Emergency Zone in El Arroyo area (Villa Esperanza area) in accordance with the process in El Divino Niño area.
6. Set up Critical Zones and Emergency Zones in other areas where steep slopes in abandoned quarries are exist, and proceed with the program of relocation from Emergency Zones.
7. After completion the relocation program from Emergency Zones, proceed relocation program from Critical Zones in El Divino Niño area, and continue the relocation program from Emergency Zones.

Precipitation monitoring and record of landslides which commenced in the pilot project of this study should be continued in order to collect and accumulate the basic information for analysis of the

relation between rainfall and occurrence of landslide and to study landslide disaster prevention measures. After the precipitation data accumulated and analyzed, automatic record type rain gauge is recommendable in Altos de Cazuca area in order to improve the resolution of precipitation monitoring.

7.4 Recommendations for DPAE (Flood)

The early warning criteria tentatively proposed by the Study Team are only estimations given the conditions derivate from scarcity of registers Such rainfall criteria and waterlevel should be updated to precise their reliability through the use of registered information by the community even after the Study; therefore those tentative criteria are not definitive values.

After the Study, DPAE will conduct the following activities, (a) Continuous monitoring, (b) Studies for early warning criteria using the monitored data, (c) Establishment of more reliable early warning plan, (d) Dissemination of the plan to the communities, based on the recommendation of the Study Team.

7.5 Recommendations for Soacha (Flood)

(1) Monitoring of Rainfall and Waterlevel

The activities carried out in this Study, such as monitoring of rainfall, waterlevel and riverbed elevation, information transfer/evacuation drill, etc. should be continued by the Soacha Municipality's initiative. Soacha Municipality and community will take necessary actions and/or measures if necessary things rise in the activities.

Equipment installed in Firefighter station, Llano Grande station, Ladrillera Santa Fe station, Prison station, Fusunga station and San Jorge station should be maintained by each station with the support of Soacha Municipality.

(2) Training on Information Transfer and Evacuation

The Soacha Municipality should organize to conduct continuous training of information transfer and evacuation.

(3) Dredging of Soacha river and Tibanica river

Management and maintenance of Soacha river and Tibanica river including dredging should be done by CAR, EAAB and Soacha Municipality.

7.6 Recommendations for Soacha (Community Disaster Prevention Activities)

(1) Role of Soacha Municipality

In the course of a series of community workshop held in the Study, Soacha Municipality recognized that the importance of its role as facilitator between CLOPAD and communities. It means Soacha Municipality should put a emphasize on making of supportive, inclusive and safe working environment for disaster prevention, rather than setting top down rules or limiting information sharing to a minimum. Soacha Municipality should confirm its role and maintain and develop the disaster prevention activities.

(2) Expanding to other communities

Through the repeated community workshops in the Study, an interchange between communities in the study area and disaster prevention related organizations proceeded a lot. Also the communities who participated in the monitoring and disaster prevention activities, especially the community leaders became interested in the Soacha river itself and hydrological data, as well as gained some confidence to hold a workshop by themselves. Soacha Municipality should expand the community disaster prevention activities to cooperate with the community leaders involved in the pilot project.

7.7 Recommendations for Soacha (Temporary Works)

The Study Team sincerely expresses fully respects for the Soacha Municipality's efforts on the relocation from landslide emergency zone.

Even after the temporary works are completed, the Study Team does not guarantee the safety of the remaining critical zone in El Divino Niño area. Therefore the Study Team recommended that relocation program should be continued by the Soacha Municipality.

The temporary works is implemented in the Emergency Zone after relocation program by the Municipality. In this situation, following recommendations are given.

(1) Manual for the Relocation Program

Until now the Municipality does not have any experiences of the relocation from the hazardous area, and the relocation in El Divino Niño area is defined as the first experience for the Municipality. The processes and methods for the municipal relocation program; for example 1) understanding of the risk in the hazardous area to the community through the seminars, 2) examination of the legal process and 3) solutions for the new settlement area, etc., are legally implemented. The results of the relocation works which the Municipality has examined and decided are very useful for other dangerous areas of the Municipality. In order to apply easily to other relocation program, the relocation manual which includes the experience and results of the relocation activities until now is required.

(2) Countermeasures including Temporary Works

In the period of this Study, several countermeasures have been executed by the Municipality according to the disasters. The countermeasures for the disasters require a suitable and adequate execution in short time. In order to correspond promptly to the disasters, it is recommended that the unified management system which organizes executed measures by the Municipality until now is prepared.

MAIN REPORT
TABLE OF CONTENTS

List of Tables

List of Figures

List of Photos

List of Abbreviations

ASE	Exclusive Service Areas (Áreas de Servicio Exclusivo)
AFRODES	Association of Displaced Afro-Colombians (Asociacion de Afrocolombianos Desplazados)
CAM	Municipal Committee of mutual Attendance for Prevention and Attention of Disasters (Comité Municipal de Atención Mutua para Prevención y Atención de Desastres)
CAR	Regional Autonomous Corporation (Corporación Autónoma Regional)
CBDM	Community Based Disaster Management (Manejo de Desastres Basado en la Comunidad)
CCTV	Closed-circuit Television (Cicuito Cerrado de Televisión)
CHF	Canadian Hunger Foundation (Fundación Canadiense para el Hambre)
CLE	Emergency Local Committee (Comité Local de Emergencia)
CLOPAD	Local Committee for the Prevention and Attention of Disasters (Comité Local para la Prevención y Atención de Desastres)
CODENSA	
CODHES	Advisory for Human Rights and Displacement (Consultoría para los derechos humanos y el desplazamiento)
CREPAD	Regional Committee for the Prevention and Attention of Disasters (Comité Regional para la Prevención y Atención de Desastres)
DABS	Administrative Department of Social Welfare (Departamento Administrativo de Bienestar Social)
DANE	National Administrative Department of Statistics (Departamento Administrativo Nacional de Estadísticas)
DAPD	Administrative Department for District Planning (Departamento Administrativo de Planeación Distrital)
DCP	Data Collection Platform (Plataforma Colectora de Datos)
DNPAD	National Office for the Attention of Disasters (Dirección Nacional para la Atención de Desastres)
DPAE	Direction for the Prevention and Attention of Emergency (Dirección para la Prevención y Atención de Emergencias)
DTM	Digital Terrain Model (Modelo Digital del Terreno)
EAAB-ESP	Company of Water Supply and Sewage Service of Bogotá (Empresa de Acueducto y Alcantarillado de Bogotá)
EDAN	Ecumenical Disability Advocates Network (Red de Defensores de la Discapacidad Ecuménica)
EFP(PEF)	Emergency Family Plan (Plan de Emergencia Familiar)
ETB	Company of Telecommunications of Bogotá (Empresa de Telecomunicaciones de Bogotá)
FOPAE	Fund for Prevention and Attention of Emergencies (Fondo para la Prevención y Atención de Emergencias)
FTP	File Transfer Protocol (Protocolo de Transferencia de Archivos)
GDP/PIB	Gross Domestic Product (Producto Interno Bruto)
GDS	Grid Development System (Sistema de Desarrollo de Grilla)
GIS/SIG	Geographic Information System (Sistema de Información Geográfica)
GMS	Geostational Meteorological Satellite (Satélite Meteorológico Geo- estacional)
GNP	National Gross Product (Producto Nacional Bruto)
GOC	Government of Colombia (Gobierno de Colombia)
GOES	Geostatinaly Operatinal Environment Satellite (Satélite Geoestacionario de Operación Ambiental)
GOJ	Government of Japan (Gobierno de Japón)
GPS	Global Positioning System (Sistema de Posicionamiento Global)
GSM	Global Scale Model (Modelo a Escala Global)
GST	Greenwich Standard Time (Hora Estándar Greenwich)
HECRAS	Hydrologic Engineering Center River Analysis System (Centro de Ingeniería Hidrológica Sistema de Análisis de Ríos)
ICA	Colombian Institute of Agriculture (Instituto Colombiano Agropecuario)
ICBF	Colombian Institute for Family Welfare (Instituto Colombiano de Bienestar Familiar)

ICS/SCI	Incident Command System (Sistema Comando de Incidentes)
ICT	Institute of Territorial Credit (Instituto de Crédito Territorial)
IDB	Inter-american Development Bank (Banco Inter-americano de Desarrollo)
IDEAM	Institute of Hydrology, Meteorology and Environmental Studies (Instituto de Hidrológica, Meteorología y Estudios Ambientales)
IDF	Intensity Duration Frequency (Frecuencia Duración de la Intensidad)
IDU	Institute of Urban Development (Instituto de Desarrollo Urbano)
IGAC	Geography Institute ¨Agustin Codazzi¨ (Instituto Geográfico Agustín Codazzi)
INGEOMINAS	Institute of Investigation and Geo-scientific, Mining-Environmental and Nuclear Information (Instituto de Investigación e Información Geocientífica, Minero Ambiental y Nuclear)
INM	National Institute of Meteorology (Instituto Nacional de Meteorología)
IOM/OIM	International Organization for Migration (Organisation Internationale pour les Migrations)
ITCZ	Inter-tropical Confluence Zone (Zona de Convergencia Intertropical)
JAC	Assembly of Community Actions (Junta de Acción Comunal)
JAL	Local Administrative Assembly (Junta Administradora Local)
JICA	Japan International Cooperation Agency (Agencia de Cooperación Internacional del Japón)
JMA	Japan Meteorological Agency (Agencia Meteorológica del Japón)
MAT	Multi-annual Average (Promedio Multi -Anual)
MAT	Multi-annual Average Temperatura (Temperatura Promedio Multi-anual)
MATPEL	Dangerous Material (Materiales Peligrosos)
MAVDT	Ministry of Environment, House and Land Development (Ministerio de Ambiente, Vivienda y Desarrollo Territorial))
MEWS	Monitoring and Early Warning System (Sistema de Monitoreo y Alerta Temprana
MHz	megahertz
MM5	Mesoscale Model 5 (Modelo a Meso Escala 5)
MSM	Meso Scale Model (Modelo a Meso Escala)
NASA	National Aeronautics and Space Administration (Administración del Espacio y Aeronáutica Nacional)
NGOs	Non-Governmental Organization (Organización No-Gobernamental)
NOAA	National Oceanic and Atmospheric Administration (Administración Atmósferica y Oceanica Nacional)
NWP	Numerical Weather Prediction (Predicción Numérica del Clima)
OCHA	United Nations Office for the Coordination of Humanitarian Affairs (Oficina para la Coordinación de Asuntos Humanitarios)
OFDA	Foreign Disaster Attendance (Oficina de Relaciones Exteriores de los EE.UU. de Asistencia para Desastres)
ONG	Non Government Organization (Organización No Gobernamental)
OPAD	Office for the Prevention and Attention of Emergency and Disasters of Cundinamarca (Oficina para la Prevención de Desastres y Emergencias de Cundinamarca)
P.M.U.	Unified Control Post (Puesto de Control Unificado)
PAHO/OPS	Pan-American Health Organization/Worldwide Health Organization (Organización Panamericana de la Salud/Organización Mundial de la Salud)
POT	Territorial Ordering Plan (Plan de Ordenamiento Territorial)
PRIMAT	First Response to Incidents with Dangerous Materials (Primera Respuesta en Incidentes con Materiales Peligrosos)
RTU	Remote Terminal Unit (Unidad Terminal Remota)
SDA	District Secretary of Environment (Secretaria Distrital Ambiental)
SEGOBDIS	District Secretariat of Government (Secretaria de Gobierno Distrital)
SIRE	Information System for Risk Management and Attention of Emergency (Sistema de Información para el Manejo y Atención de Emergencias)
SISBEN	Selection System of Beneficiaries for Social Programs (Sistema de Selección de Beneficiarios para Programas Sociales)
SMLM	Monthly minimum legal salary (Salario Minimo Legal Mensual)
SRTM	Shuttle Radar Topography Mission(Misión Topográfica Radar Shuttle)
SYNOP	Surface synoptic observations (Observaciones Sinópticas de la Superficie)
UBN	Unsatisfied Basic Necessities (Necesidades Básicas Insatisfechas)

UESP	Executive Unit of Public Services (Unidad Ejecutiva de Servicios Públicos)
UHF	Ultra High Frequency (Frecuencia Ultra Alta)
UN	United Nations (Naciones Unidas)
UNDP/PNUD	United Nations Development Programme (Programa de las Naciones Unidas para el Desarrollo)
UNHCR/ACNUR	United Nations High Commissioner for Refugees (Alto Comisionado de las Naciones Unidas para los Refugiados)
UNICEF	United Nations Children´s Fund (Fondo de las Naciones Unidas para la Infancia)
UNIFEM	United Nations Development Fund for Women (Fondo de Desarrollo de las Naciones Unidas para la Mujer)
UNV/VNU	United Nations Volunteers (Voluntarios de las Naciones Unidas)
UPS(SAI)	Uninterruptible Power Supply (Sistema de Alimentación Ininterrumpida)
UPZ	Unit of Zone Planning (Unidad de Planeamiento Zonal)
URL	Uniform Resource Locator (Localizador Uniforme de Recurso)
USA/EUA	United States of America (Estados Unidos de América)
USD	United States Dollar (Dolár de Estados Unidos)
USGS	United States Geological Survey (Levantamiento Geológico de Estados Unidos)
WMO	World Meteorological Organization (Organización Meteorológica Mundial)
ZMPA	Environmental Management and Reservation Zone (Zonas de Manejo y Preservación Ambiental)

PART 1

GENERAL

CHAPTER 1 INTRODUCTION

1.1 General

In response to the request of the Government of the Republic of Colombia (hereinafter referred to as " Government of Colombia" or “GOC”), the Government of Japan has agreed to conduct the Study on Monitoring and Early Warning System for Landslides and Floods in Selected Areas of the Capital District of Bogota and Soacha Municipality in the Republic of Colombia (hereinafter referred to as "the Study") in accordance with the relevant laws and regulations in force in Japan.

Accordingly, the Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of technical cooperation programs of the Government of Japan, undertook the Study, in close cooperation with the authorities concerned of the Republic of Colombia.

The final report contains all the Study results.

1.2 Background of the Study

Bogota city and its surrounding area are called Bogota Metropolitan Area of the Republic of Colombia. They cover the vast area of 1,949 km^2 with a population of 6.99 million in 2000. The area for this Study is located in the southern part of the Metropolitan area. The total area for the Study is about 84 km2, which is 4% of the Master Plan area.

The Study area includes a lot of landslide-prone areas in terms of topography and geology where the low-lying areas have suffered from flooding of the Tunjuelo River. In addition to such natural conditions, the population of Bogota city and Soacha city increased very rapidly in the 90’s due to the migration into those cities by national refugees. Because of a rapid increase of the population, slopes of landslide areas and flood-prone areas in the Tunjuelo river basin, which are supposed to be protected, were developed extensively, resulting in high vulnerability in terms of natural disasters such as landslide and floods. In responding to this situation, the organizations related to disaster prevention in Bogota and its surrounding area have implemented disaster prevention measures such as monitoring in major landslide areas, flood control projects for the Tunjuelo river, and a flood monitoring system. However, the implementation of structural measures for the entire area including tributaries will require a long time. For a priority in saving lives, monitoring and early warning system has been given priority.

Under these circumstances, the Government of Colombia requested the Government of Japan to implement a study on monitoring and early warning system for landslides and floods.

This Study made use of existing and valuable outputs made by the Colombian side, and also formulate a plan on monitoring and early warning system for landslide and flood for the areas in which disaster prevention measures have not yet been completed. Further, pilot project(s) for the selected areas shall be implemented in the course of the Study for a better preparation against disaster by governmental authorities as well as communities.

1.3 Objectives of the Study

The objectives of the Study in the Scope of Work are as follows:

- To prepare a Plan for monitoring and early warning system for the Study area in Tunjuelo middle river basin and the Soacha river basin, for landslides and floods.
- To establish, operate and maintain the monitoring and early warning system for the selected areas as pilot projects relying on the initiative of community people as much as possible.
- To transfer the technologies and knowledge to the Colombian personnel involved in the Study.

In accordance with the Scope of Work, the Inception Report was prepared in the preparatory work period in Japan (June 2006). When the Study Team mobilized in Bogota end of June 2006, the Study Team was planning to do some study items related with community aspects for both DPAE and Soacha. During the Inception Report discussion, DPAE strongly requested the Study Team to let DPAE handle with communities aspects such as community workshops, community survey, etc. The Study Team understood the request and decided to concentrate on the study for Soacha regarding the community aspects. While the study items for Soacha were not changed, the revised Inception Report was submitted by the Study Team on July 14, 2006.

1.4 Study Area

The study area covers part of the Capital District of Bogota and Soacha Municipality as shown in Figure 1-1.

With regard to flood disaster and landslide disaster, the Study covers the six (6) creek/river basins and three (3) specific areas as shown in Table 1-1. The term “flood disaster” covers “disaster caused by flood, and flash flood containing sediment such as debris flow”. The term “landslide disaster” covers “disaster caused by mass movement such as slow landslide, steep slope failure and rock fall”.

Table 1-1 Basic Features of Study Area

City	Monitoring and early Warning System for Floods			Monitoring and Early Warning System for Landslides
	Creek/River	Catchment Area (km^2)	Principal River Length (km)	
Bogota City	Chiguaza Creek	18.9	7.0	Altos de La Estancia (100 ha)
	Santa Librada Creek	5.5	5.0	
	Yomasa Creek	15.4	5.0	
	La Estrella-El Infierno Creek (Trompeta creek)	8.3	1.5	
Soacha City	Soacha River	44.3	13.0	Altos de Casuca and El Divino Niño (total 230 ha)
	Tibanica River	19.2	6.0	
Total No.	6 creeks/rivers			3 areas

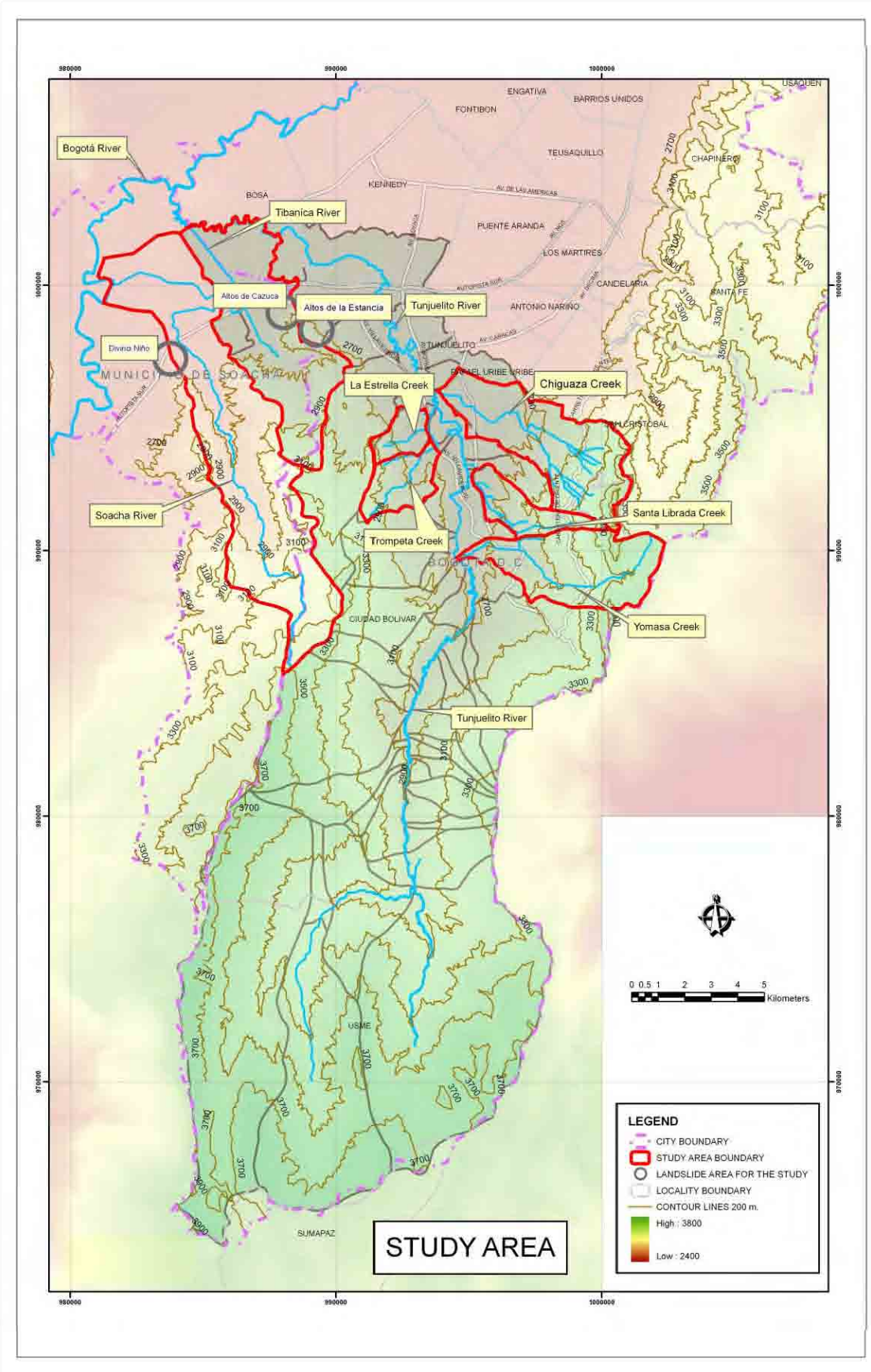


Figure 1-1 Study Area

1.5 Study Schedule

The Study was undertaken in three (3) Phases: Basic Study (Phase I), Formulation of the Plan for Monitoring and Early Warning System (Phase II), and Implementation of Pilot Project(s) (Phase III), for a period of 22 months starting from June 2006 and ending in March 2008. The workflow of the general approach of this Study is shown in Figure 1-2 and Figure 1-3

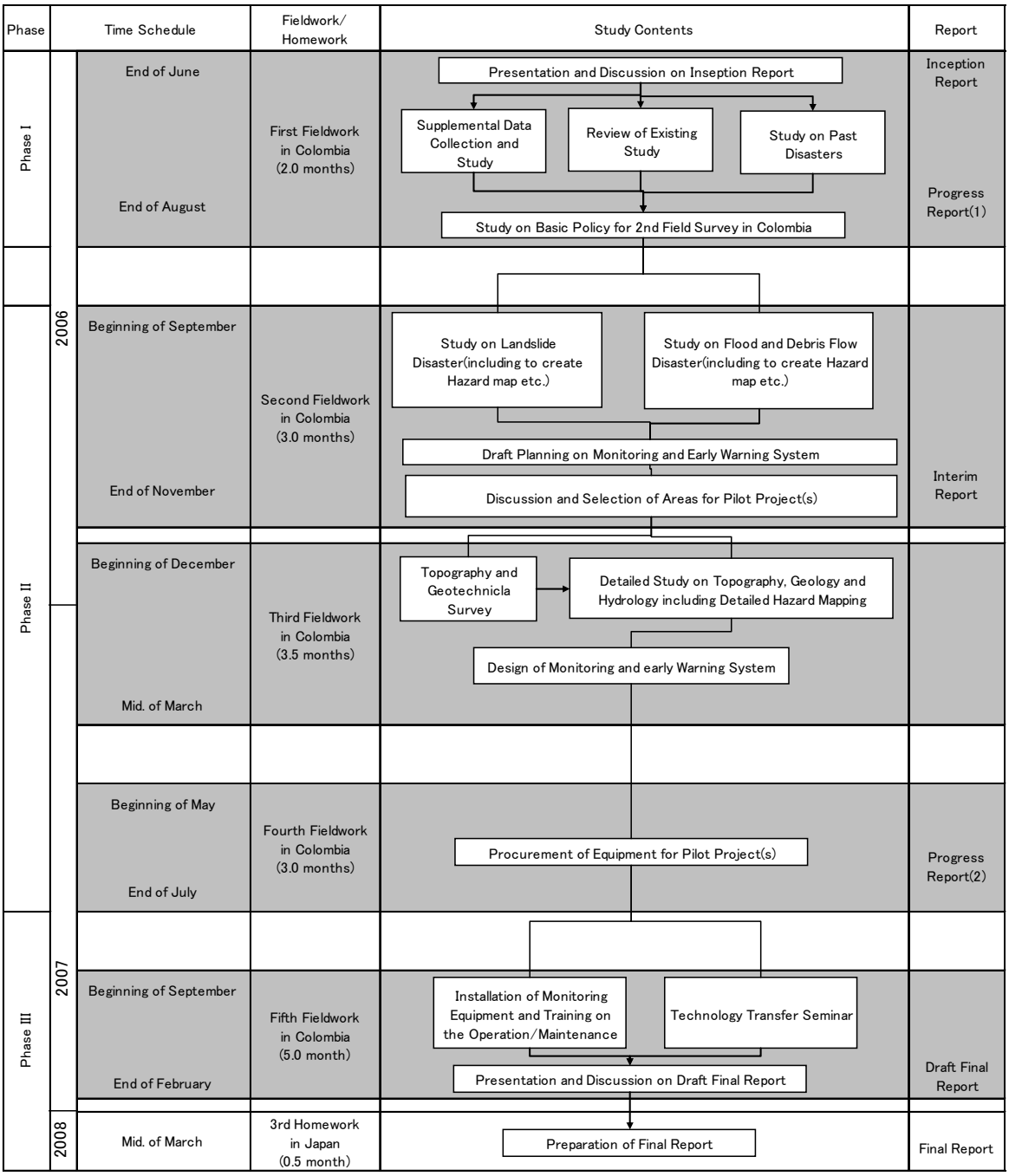


Figure 1-2 Flowchart of Work in Study Phases (Bogota)

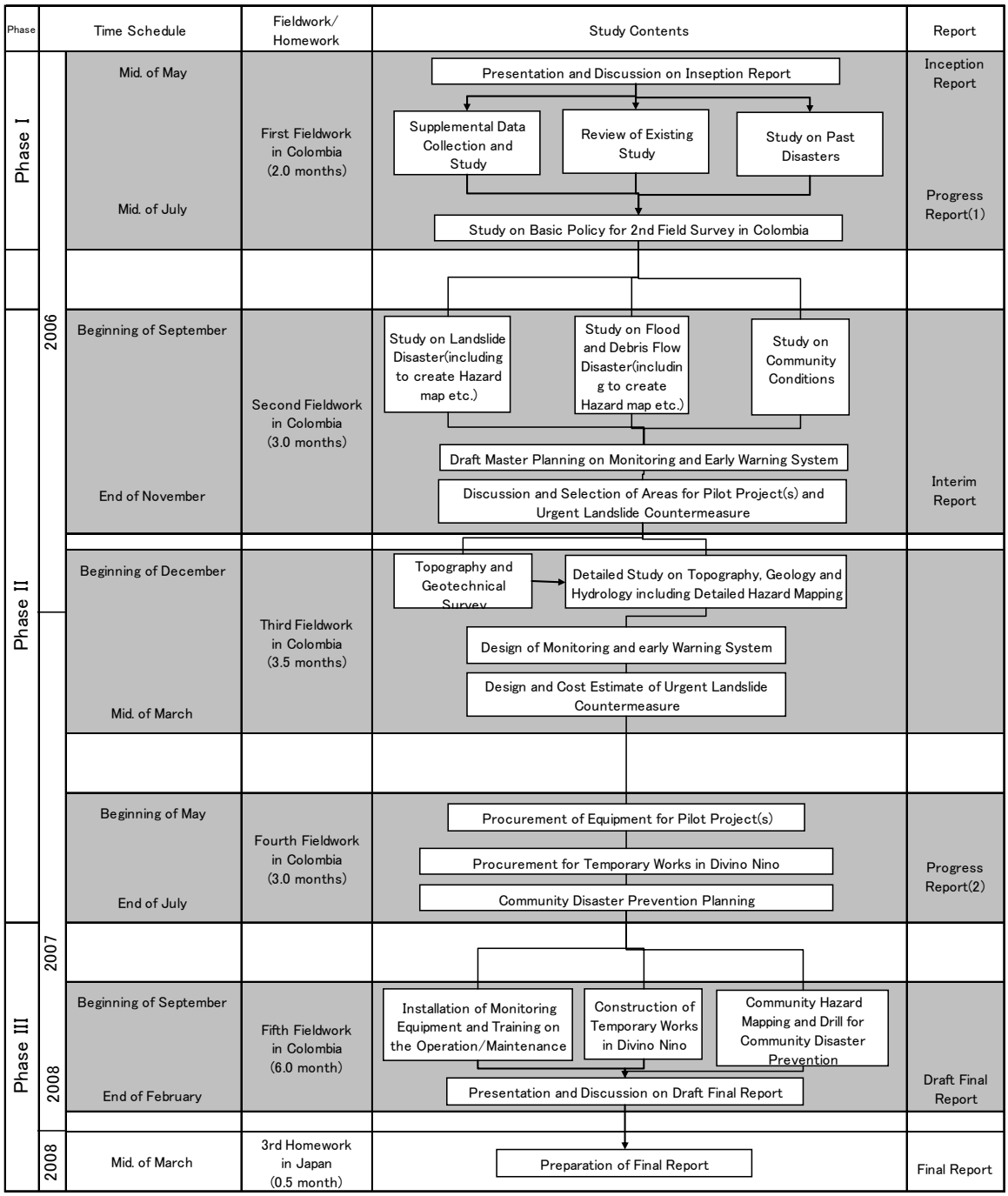


Figure 1-3 Flowchart of Work in Study Phases (Soacha)

1.6 Study Organization

1.6.1 Study Organization

The Study was undertaken in close cooperation between DPAE, Soacha Municipality and the Study Team with the support of the Cundinamarca Government (OPAD) and JICA Colombia. JICA Headquarter (see Figure 1-4) dispatched the Monitoring Team related to the Study in November 2006 and November 2007. The members of the Monitoring Team had a discussion with the DPAE and Soacha Municipality as well as the Study Team and gave technical advises to JICA.

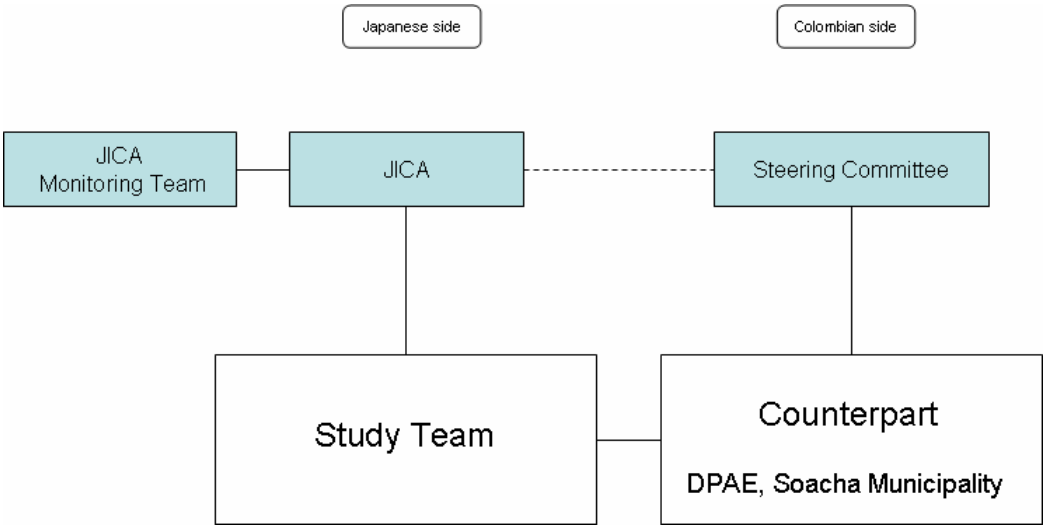


Figure 1-4 Organization for the Study

1.6.2 Counterpart

The Study was conducted through the close coordination between the Study Team and the counterpart of Colombian side. Since the Interim Report, there has been replacement of counterpart personnel in DPAE and Soacha City. The latest counterpart personnel for the Study were appointed by the DPAE and Soacha Municipality as shown in Table 1-2. and Table 1-3.

Table 1-2 List of Counterpart of DPAE

Name	Position	Area
Guillermo Ávila	General Coordinator of DPAE Counterpart	
Doris Suaza	Deputy General Coordinator of DPAE Counterpart	
Carolina Rogelis	Studies and Concepts Group. Research and Development Coordination	Flood
Jorge Rosas	Studies and Concepts Group. Research and Development Coordination	Flood
Diana Arévalo	Studies and Concepts Group. Research and Development Coordination	Landslide
Lucy Bohórquez	Rural and Slope Areas Group, Territorial Management Coordination	Landslide
Paola Sánchez	Expert on Community Participation	Community Participation
Ligia Cañón	Rural and Slope Areas Group, Territorial Management Coordination	Community Participation
Neida Alvarado	Studies and Concepts Group. Research and Development Coordination	Geography and Geological Analyses
Piedad Camargo	Studies and Concepts Group. Research and Development Coordination	Geography and Geological Analysis
Diana González	National and International Relations	Logistics

Table 1-3 List of Counterpart of Soacha Municipality

Name	Position	Area
Jose Ernest Martinez T.	City Mayor	City Mayor
Jesus Ochoa Sanchez	Former City Mayor	City Mayor
Jose Ernesto Morales Morales	Former Government Secretary	Administrative
Ligia Goyeneche	Government Secretary	Administrative
Ivan Demostenes Calderon Ulloa	General Coordinator of Soacha Counterpart	Expert on Administrative Law
Angela Piedad Alfonso Cruz	Lawyer	Legal Advisory
Olga Yaneth Infante Ramirez	Former Planning Secretary	Flood
Ismael Molina	Planning Secretary	Flood, Landslide
Manuel Puentes	Former Infrastructure Secretary	Flood, Landslide
Pastor Humberto Borda	Infrastructure Secretary	Flood, Landslide
Sandra Milena Vasquez Mancera	Civil Engineer	Landslide, Flood
Oscar Danilo Gomez Veloza	Housing and Treasury Secretary	Community
María Eugenia Casas Buenas	Civil Engineer	Landslide
Ramón Augusto Mendoza López	Former Planning Secretary	Flood
Sandra Bacca	Former Catastral Engineer	Geographical Analysis
Oscar Fernando Charry	Catastral Engineer	Geographical Analysis
Rodrigo Cumbe	Civil Engineer	Flood
Jorge E. Barragán	Geologist	Landslide
Sonia Marentes	Social Worker	Community Participation
Nelson Cifuentes	Civil Engineer	Landslide

1.7 Composition of the Report

This report presents all results of the technical studies achieved during the Study. The report consists of the following;

Summary
Main Report
Supporting Report
and Data Book 1,2 and 3.

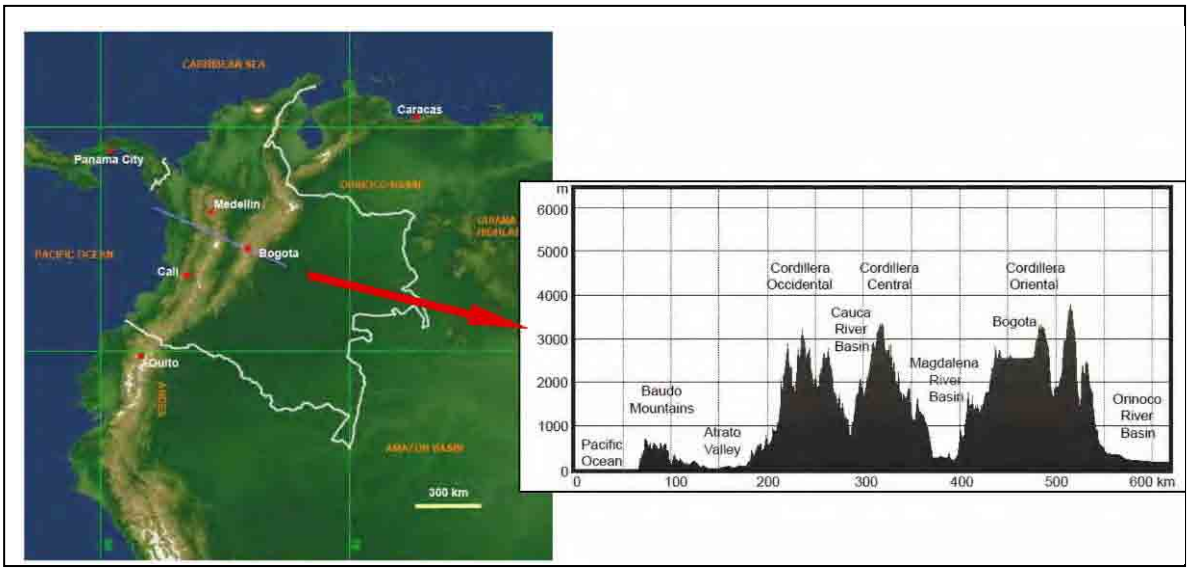
CHAPTER 2 NATURAL CONDITIONS

2.1 Topography and Geology

2.1.1 Topography of Colombia

The territorial area of Colombia is 1,138,910 km^2, ranging between latitude 4.2 degree south and 12.4 degrees north, and between longitude 66.9 degrees west and 78.8 degrees west. Colombia faces Pacific Ocean in west side, Caribbean Sea in north side, and is bordered on the northwest by Panama, on the east by Venezuela and Brazil, and on the southwest by Peru and Ecuador.

The northern Andes in Colombia curve in an arc from northeast to southwest. The arc consists of three main parallel ranges, known as the Cordillera Occidental (Western Cordillera), the Cordillera Central (Central Cordillera), and the Cordillera Oriental (Eastern Cordillera). There are plateaus and valleys between the each cordillera, see Figure 2-1, in which are the most densely populated parts of the country. In addition to three main ranges, there is a coastal mountain range on the Pacific coast of Colombia, the Baudó Mountains (Serranía de Baudó). Geologically, the Baudó Mountains represent an extension of the Isthmus of Panama. They are separated from the Cordillera Occidental by the Atrato valley where the Atrato River flows and Quibdó is located.



(*base data : NASA SRTM-30 and SRTM-3*)

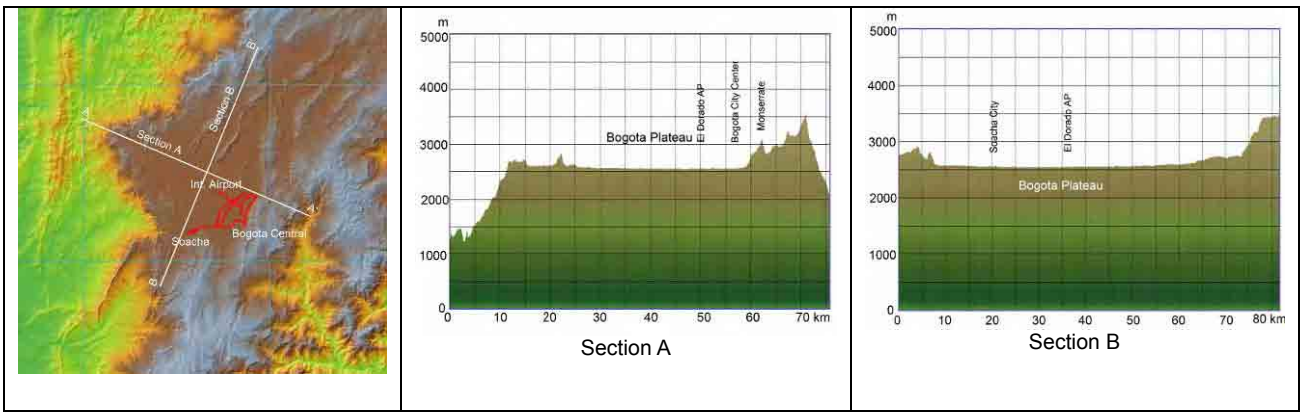
Figure 2-1 Topographic Map of Colombia and Cross Section of Andes Mountains

The rivers flowing toward the Pacific are short and small in volume because the rainfall on the western slopes of the mountains is limited. The streams to the east are long and supplied with an abundance of water from the trade winds, which deposit precipitation as they approach the mountains. These mountain streams are the source of the major headstreams of the three great river systems of South America: the Amazon, which flows through Peru and Brazil; the Orinoco of Colombia and Venezuela; and the Parana-Paraguay-Uruguay river system, which empties into the Rio de la Plata, a large marine estuary along the Atlantic coast between Uruguay and Argentina.

Bogota is located at an elevation of about 2640 m on a mountain-rimmed plateau high in the Cordillera Oriental of the Andes Mountains.

2.1.2 Topography of Bogota and Surroundings

Bogota is located on a flat plateau that is designated by Bogota Plateau or Sabana de Bogota, found approx. at 2,560 m above the sea level and the height of eastern mountainous area reaches 3,000 m or more, and beside the west side slope of the Cordillera Oriental as shown in Figure 2-2. Bogota Plateau (Sabana de Bogota) is extending about 40 km from northwest to southeast and 60 km from northeast to southwest as shown in Figure 2-1. The City is located in the area limited by the surrounding hills in the east and by Bogota River in the west.



(base data : NASA SRTM-3)

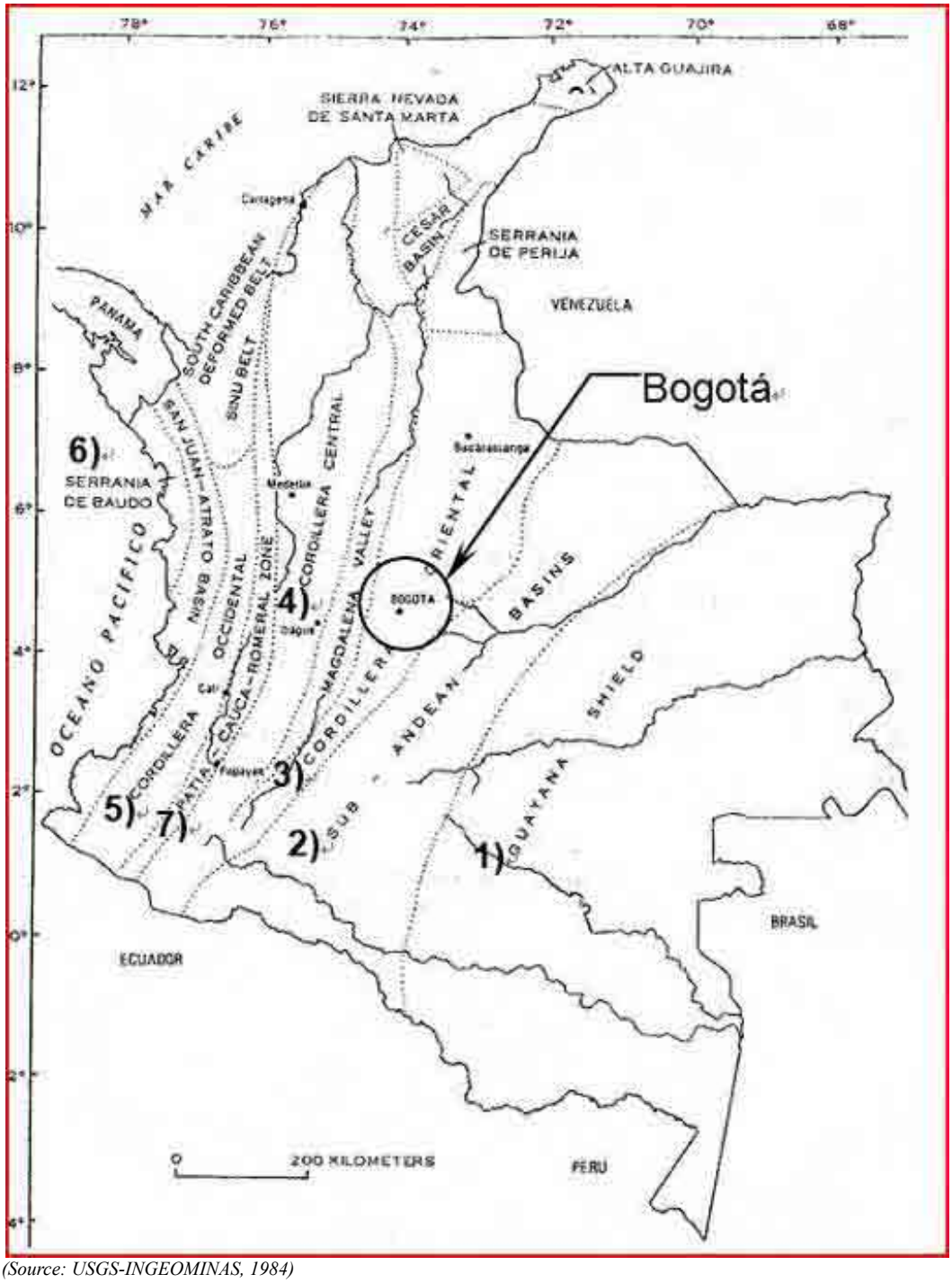
Figure 2-2 Topographical Cross Sections correspond to the lines in the Figure

2.1.3 Geology of Colombia

Colombia is generally classified into two measure geological areas, Orogeny and Shield. The south-eastern part of Colombia is flat land of the Shield area which is the oldest and most stable structural element of the continent. It comprises a Precambrian (before 570 million years ago) complex of igneous and metamorphic rocks. In most places the shield is overlaid by sedimentary rocks, mostly of Paleozoic age (570 million to 225 million years ago). The north-western part of Colombia is the Orogenic area where is active area of folding, faulting, and uplift of the Earth's crust to form the Andes Mountain ranges, often accompanied by volcanic and seismic activity. The Orogenic area in Colombia is the northern end of the Andean range formed by collision of eastward subjecting Nazca plate with a moving rate of 70 mm / year. Colombia is distinguished into nine areas harmonizing furthermore with the topographic classifications, and the areas correspond with geological features as shown Figure 2-3.

<u>The Shield Area</u>
1) Guayama Shield
2) Sub-Andean Basins

<u>The Orogenic Area</u>
3) Cordillera Oriental, Serrania de Perija
4) Cordillera Central
5) Cordillera Occidental
6) Serrania de Baudo
7) Patia-Cauca-Romeral
8) Mountain and sedimentary basin in Guajira Peninsula
9) Inland basin between mountains

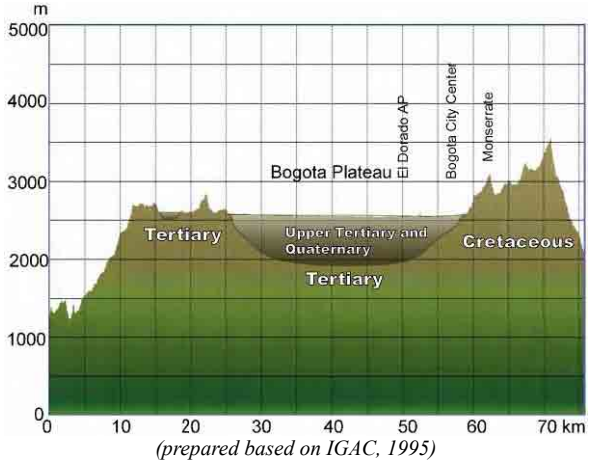


(Source: USGS-INGEOMINAS, 1984)

Figure 2-3 Topographic Classification in Colombia

2.1.4 Geology of Bogota and Surroundings

The geology in the area and its environment distributes sandstone, siltstone and claystone of Cretaceous to Tertiary in mountainous area. Quaternary sediment of lake origin spreads in Bogota Plateau (Sabana de Bogota), while the mountains area in the east and south of Bogota Plateau is mostly composed of Cretaceous or Tertiary origin sediment rock. They are made mostly of sandstone or siltstone. Thickness of the Quaternary sediment in Bogota Plateau is over 500 m as shown in Figure 2-4.



(prepared based on IGAC, 1995)

Figure 2-4 Sediment in Sabana de Bogota (Bogota Plateau, Section A)

Condition of Study Area

Landslides in Bogota ; Landslides in Bogota are generally distributed at steep slopes in the eastern part of the Bogota. Many landslides are located along Bogota Fault which runs along the eastern rim of Bogota Plateau.

Landslides in Soacha; There are large scale quarries, from which sand and stone as material for bricks and construction is extracted, along Soacha River. Many of the open quarries are abandoned, and there are many residential houses in the abandoned quarries. Most of the landslide disasters have occurred along excavated steep slopes in the abandons quarries.

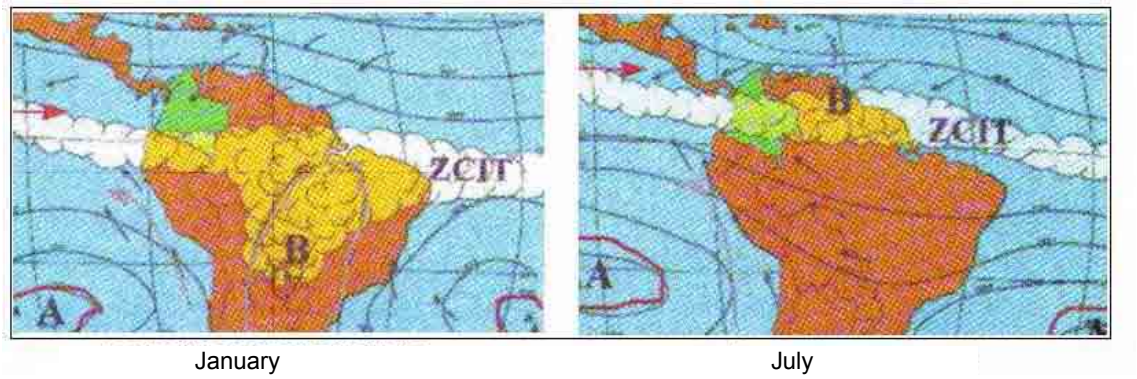
Rivers; The total area of the river basin in Bogota and Soacha is 41.8 km^2 that consist of Chiguaza River (18.7 km^2), Santa Librada River, (15.4 km^2), Yomasa River (5.5 km^2), La Estrella-Trompeta River (2.2 km^2) and is 40 km^2 that consist of Soacha River (30 km^2), Tibanica River, (10 km^2), respectively.

2.2 Meteorology and Hydrology

2.2.1 General Description in Cundinamarca including the Study Area[1, 2]

Colombia is located in the equatorial zone and presents an inverse relationship between clouds cover and sun brightness, registering a high cloud covering with high rainfall. The climate is affected by the relief, whose more important effect is the temperature conditioning. In the west cordillera that influences Cundinamarca, the variation of the temperature is 0.63°C for each 100 meters in their west flank (Sabana de Bogota and Bogota's east hills), this variation is known as "Thermal Floors" or "Pisos Térmicos" in Spanish. According with this, Savanna of Bogota corresponds to the cold thermal floor among 2000-3000m (height above sea level) and its temperatures is among 12-18°C.

In Colombia, the rainfall values varied due to interaction between equatorial zone and Andes cordillera. Colombia is included in the Inter tropical Convergence Zone (ITCZ), for this reason, the trade winds from northeast and southeast to get into the territory, generating the rains for convective phenomena. The ITCZ is displacing in latitudinal sense, and is located at the south in the first months of the year, and in the northern extreme of the country during July - August, with intermediate position during the rest of the year. Displacement of ITCZ is shown in Figure 2-5.



(Source: "Fig25,ESTUDIO DE LA CARACTERIZACIÓN CLIMÁTICA DE BOGOTA Y CUENCA ALTA DEL RIO TUNJUELO", FOPAE - IDEAM, 2006)

Figure 2-5 Displacement of ITCZ

The ITCZ displacement generate two (2) types of temporary rain fluctuation, registering in Cundinamarca the bimodal pattern, that is to say, two (2) wet or rainy periods alternated with two (2) dry periods. The varied relief is conditioning for the rainfall regime, because it serve as an obstacle for the air currents and it originates high rainfall volumes when the winds collide with the cordillera, and the air masses ascend and are condensed. The forced ascent for the air masses due to the relief, produce an orographic rain type that are characteristic for the Andean zone. In some sectors will be produced some temporary droughts in the interior area caused by masses of air that ascend by windward and they descend for leeward, warming and drying off (Phenomena of Fohen).

The inter-Andean valleys, such as the cordilleras above the 2,000 meters, present different annual rainfall amount (≈ 1,500 - 3,000 mm/year) with a bimodal regime of two (2) dry periods alternating with two (2) high rainfall periods.

In general, the relative humidity varies from high to low through the year. In the middle Magdalena valley including Cundinamarca, the relative humidity is contrasting the values below 60% during the first months of the year and from July to September with the values of about 80 % in other period. On the other hand, the relative humidity in Sabana de Bogota is almost constant in 76-85% through the year. The example of monthly humidity in San Jorge station located in Soacha is shown in Table 2-1.

[1] IGAC, 2002, Atlas de Colombia
[2] IDEAM, 2000, Proyecto red de alertas hidrometeorológicas para inundaciones y fenómenos de remoción en masa

Table 2-1 Monthly Humidity in San Jorge (GJA) Station (IDEAM)

Station	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
SAN JORGE (GJA) (IDEAM)	%	81	81	82	84	83	82	82	82	82	83	84	82	82

(Source: "Tabla 2,ESTUDIO DE LA CARACTERIZACIÓN CLIMÁTICA DE BOGOTA Y CUENCA ALTA DEL RIO TUNJUELO", FOPAE - IDEAM, 2006)

The average temperature in Bogota (*Multi-Annual Average Temperature, MAT*) is registered in Table 2-2, and monthly temperature in San Jorge station is shown in Table 2-3.

Table 2-2 Multi-Annual Average Temperature in Bogota

Item(unit)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MAT (°C)	12.8	13.3	13.0	13.0	13.4	12.8	12.6	12.9	13.0	12.8	12.8	12.8	12.9

Table 2-3 Monthly Temperature in San Jorge (GJA) Station (IDEAM)

Station	**Item(unit)**	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
SAN JORGE (GJA) (IDEAM)	Average(°C)	11.5	11.6	11.8	11.9	11.9	11.6	11.1	11.3	11.5	11.5	11.7	11.6	11.6
	Maximum(°C)	20.8	20.6	20.2	19.4	20.2	19.4	19.4	19.0	20.0	19.4	19.6	20.0	20.8
	Minimum(°C)	0.5	0.2	0.2	2.0	0.7	0.5	0.0	3.8	0.5	0.7	3.2	1.0	0.0
	Average Maximum(°C)	16.5	16.7	16.6	16.0	16.2	15.6	15.0	15.4	15.8	16.0	16.0	16.2	16.0
	Average Minimum	6.3	6.9	7.3	7.7	7.5	7.3	7.2	7.1	6.9	7.1	7.2	6.8	7.1

(Source: "Tabla 3, ESTUDIO DE LA CARACTERIZACIÓN CLIMÁTICA DE BOGOTA Y CUENCA ALTA DEL RIO TUNJUELO", FOPAE - IDEAM, 2006)

The historical winds mean values registers 8-10.7 m/s with NE-SW direction and 10.8-13.8 m/s with E-W direction. The calm period of the wind is 21% of the year.

2.2.2 Meteorological/Hydrological Stations in and around the Study Area

Quite a few meteorological and hydrological stations are found nowadays or existed in and around the Study Area, which are/were monitored and operated by DPAE, EAAB, CAR, IDEAM and other organizations. Some of the stations are telemeter stations, but most of the stations are conventional. Figure 2-6 shows the location map of meteorological and hydrological stations managed by DPAE, EAAB, CAR and IDEAM in and around the Study Area, and Table 2-4 shows the list and conditions of the stations.

Meteorological and hydrological data for the Study are collected from within the stations shown in Table 2-4. The list of collected data is shown in Table 2-5 to 2-8.

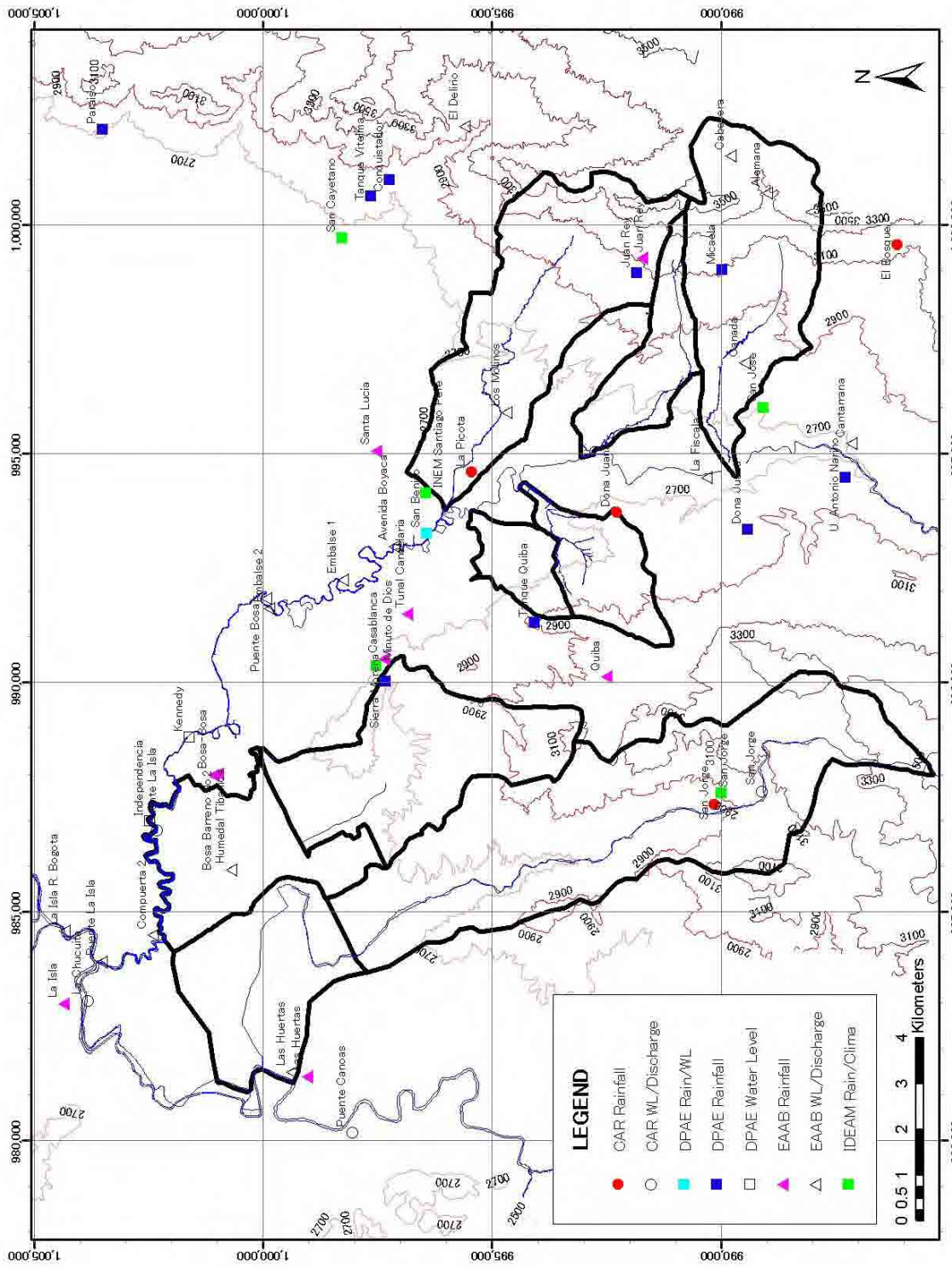


Figure 2-6 Location Map of Meteorological/Hydrological Stations in and around the Study Area

Table 2-4 List of Meteorological/Hydrological Stations in and around the Study Area

ENTITY	CODE 1	CODE 2	TIPO	NAME	SUBCUENCA	DEPTO.	MUNICIPI	COORD	Elevation	INST DATE	SUSP DATE	Status in Oct. 2006	Telemeter	TYPE	Present Situation/Remarks
DPAE			PG,LG	San Benito	Tunjuelito	BOGO	BOGOTA	043351N740817W	2590	200010			Telemeter (Radio)	DPAE Rain/WL	
DPAE			PG	Sierra Morena	Tunjuelo	BOGO	BOGOTA	043430N741014W	3078	200010			Telemeter (Radio)	DPAE Rainfall	
DPAE			PG	Tanque Quiba (Quiba-Mirador)	Tunjuelo	BOGO	BOGOTA	043235N740921W	3078	200010			Telemeter (Radio)	DPAE Rainfall	
DPAE			PG	Conquistador (Escuela de Logistica)	San Cristobal	BOGO	BOGOTA	043428N740435W	2780	200010			Telemeter (Radio)	DPAE Rainfall	Out of study area
DPAE			PG	Juan Rey	Q. Chiguaza	BOGO	BOGOTA	043108N740520W	3160	200010		No Function	Telemeter (Radio)	DPAE Rainfall	
DPAE			PG	Tanque Vitelma	San Cristobal	BOGO	BOGOTA	043431N740418W	3078	200010			Telemeter (Radio)	DPAE Rainfall	Out of study area
DPAE			PG	Micaela (Santa Maria Micaela)	Q. Yomasa	BOGO	BOGOTA	043021N740511W	2900	200010			Telemeter (Radio)	DPAE Rainfall	
DPAE			PG	Dona Juana	Tunjuelo	BOGO	BOGOTA	043002N740815W	3078	200010			Telemeter (Radio)	DPAE Rainfall	
DPAE			PG	Paraiso II	Rosales	BOGO	BOGOTA	043742N740331W	2820	200010		No Function	Telemeter (Radio)	DPAE Rainfall	Out of study area
DPAE			PG	U. Antonio Narino (Nariano USME)		BOGO	BOGOTA	042854N740331W	2820	200010			Telemeter (Radio)	DPAE Rainfall	Out of study area
DPAE			LG	Kennedy	Tunjuelo	BOGO	BOGOTA	043650N741053W	2577	200303			Telemeter (Radio)	DPAE Water Level	
DPAE			LG	Independencia	Tunjuelo	BOGO	BOGOTA	043719N741154W	2576	200010			Telemeter (Radio)	DPAE Water Level	
EAAB	P-042	2120057	PG	Santa Lucia	Tunjuelo	BOGO	BOGOTA	043410N740701W	2618	195607				EAAB Rainfall	
EAAB	P-051	2120154	PG	Bosa Barreno No.2	Tunjuelo	BOGO	BOGOTA	043646N741106W	2578	-				EAAB Rainfall	
EAAB	PS-91	2120154	PG	Bosa-Bosa	Bosa	BOGO	BOGOTA	0436N7412W	2640	195705	195812			EAAB Rainfall	
EAAB	P-081	2120204	PG	Juan Rey	Q. Chiguaza	BOGO	BOGOTA	0431N7405W	2985	199008				EAAB Rainfall	
EAAB	P-090	2120205	PG	Quiba	Bogota	BOGO	BOGOTA	0432N7410W	3000	199001				EAAB Rainfall	
EAAB	P-092	2120211	PG	Las Huertas	Bogota	CUND	SOACHA	0435N7414W	2572	196811			Telemeter (GSM)	EAAB Rainfall	
EAAB	P-083	2120209	PG	La Isla	Bogota	BOGO	BOGOTA	0438N7413W	2537	196510				EAAB Rainfall	
EAAB	P-045	2120059	PM	Tunal Candelaria	Tunjuelo	BOGO	BOGOTA	0434N7409W	2599	195704				EAAB Rainfall	
EAAB	P-031	2120197	PM	Casablanca	Tunjuelo	BOGO	BOGOTA	0434N7410W	2665	197605				EAAB Rainfall	
EAAB	L-192		L	Puente La Isla	Tunjuelo	BOGO	BOGOTA	-	-	-				EAAB WL/Discharge	
EAAB	L-036	2120701	LG	Puente Bosa	Tunjuelo	BOGO	BOGOTA	0436N7412W	2550	192607			Telemeter (GSM)	EAAB WL/Discharge	
EAAB	L-005	2120806	LG	Las Huertas	Bogota	CUND	SOACHA	0435N7414W	2572	196811			Telemeter (GSM)	EAAB WL/Discharge	One of the main station in EAAB.
EAAB	L-004	2020802	LG	La Isla R. Bogota	Bogota	BOGO	BOGOTA	0438N7413W	2537	196510			Telemeter (GSM)	EAAB WL/Discharge	
EAAB	L-026	2120705	LM	El Delirio	San Cristobal	BOGO	BOGOTA	0433N7404W	2890	192701				EAAB WL/Discharge	
EAAB	L-033	2120750	LM	Cantarrana	Tunjuelo	BOGO	BOGOTA	0430N7407W	2643	195508				EAAB WL/Discharge	
EAAB	L-058	2120858	LM	La Fiscala	Tunjuelo	BOGO	BOGOTA	0430N7408W	2460	198811				EAAB WL/Discharge	
EAAB	L-070	2120904	LM	Embalse 1	Tunjuelito	BOGO	BOGOTA	0435N7409W	2586	199009				EAAB WL/Discharge	
EAAB	L-071	2120905	LM	Embalse 2	Tunjuelito	BOGO	BOGOTA	0435N7409W	2583	199009				EAAB WL/Discharge	
EAAB	L-034	2120943	LM	Humedal Tibanica (Compuesta 1)	Tunjuelo	BOGO	BOGOTA	0437N7413W	2600	198603		No Function		EAAB WL/Discharge	
EAAB	L-035	2120944	LM	Compuerta 2	Tunjuelo	BOGO	BOGOTA	0437N7437W	2600	198701		No Function		EAAB WL/Discharge	
EAAB	L-039	2120945	LM	Alemana	Q. Yomasa	BOGO	BOGOTA	0429N7404W	3300	198501		No Function		EAAB WL/Discharge	It was stolen march 2000.
EAAB	L-111	2120956	LM	Los Molinos	Q. Chiguaza	BOGO	BOGOTA	0433N7407W	2800	199001		No Function		EAAB WL/Discharge	
EAAB	L-038	2120957	LM	Cabecera	Q. Yomasa	BOGO	BOGOTA	0430N7404W	3360	198507		No Function		EAAB WL/Discharge	
EAAB	L-094		LM	Canada	Q. Yomasa	BOGO	BOGOTA	-	-	-				EAAB WL/Discharge	
EAAB	L-060	2120836	LM	Avenida Boyaca	Tunjuelito	BOGO	BOGOTA	0434N7409W	2630	198811				EAAB WL/Discharge	1 year ago, some equipment was stolen, since then the station has been operated as "LM".
CAR		2120630	CP	Dona Juana	Tunjuelito	BOGO	BOGOTA	0430N7410W	2700	198903				CAR Rainfall	
CAR		2120085	PG	El Bosque	Tunjuelito	BOGO	BOGOTA	042820N740458W	2880	196212				CAR Rainfall	One of the main station in CAR.
CAR		2120156	PG	La Picota	Q. Chiguaza	BOGO	BOGOTA	0434N7408W	2580	198006				CAR Rainfall	
CAR		2120172	PG	San Jorge	Soacha	CUND	SOACHA	0431N7412W	2890	196004				CAR Rainfall	
CAR		2120755	LM	San Jorge	Soacha	CUND	SOACHA	0430N7411W	2952	196004				CAR WL/Discharge	
CAR		2120771	LM	Puente La Isla	Tunjuelo	BOGO	BOGOTA	0437N7412W	2569	196402	196712	No Function		CAR WL/Discharge	
CAR		2120772	LM	La Chucuita	Bogota	BOGO	BOGOTA	0438N7414W	2538	196402	196612	No Function		CAR WL/Discharge	
CAR		2120829	LM	Puente Canoas	Bogota	CUND	SOACHA	0431N7415W	2550	195809				CAR WL/Discharge	It was replaced by Las Huertas (EAAB).
IDEAM		2120664	CO	San Jose	Tunjuelito	BOGO	BOGOTA	0430N7407W	2700	200111				IDEAM Rain/Clima	
IDEAM		2120665	CO	San Cayetano	Tunjuelito	BOGO	BOGOTA	0435N7405W	3100	200111				IDEAM Rain/Clima	
IDEAM		2120666	CO	INEM Santiago Pere	Tunjuelito	BOGO	BOGOTA	0434N7408W	2565	200111				IDEAM Rain/Clima	
IDEAM		2120572	CO	San Jorge	Soacha	CUND	SOACHA	0431N7412W	2900	196004				IDEAM Rain/Clima	
IDEAM			CO	Minuto de Dios (Sierra Morena)	Tunjuelo	BOGO	BOGOTA	043436N741003W	-	-			Telemeter (GOES)	IDEAM Rain/Clima	

Table 2-5 Collected Hydrological Data from DPAE

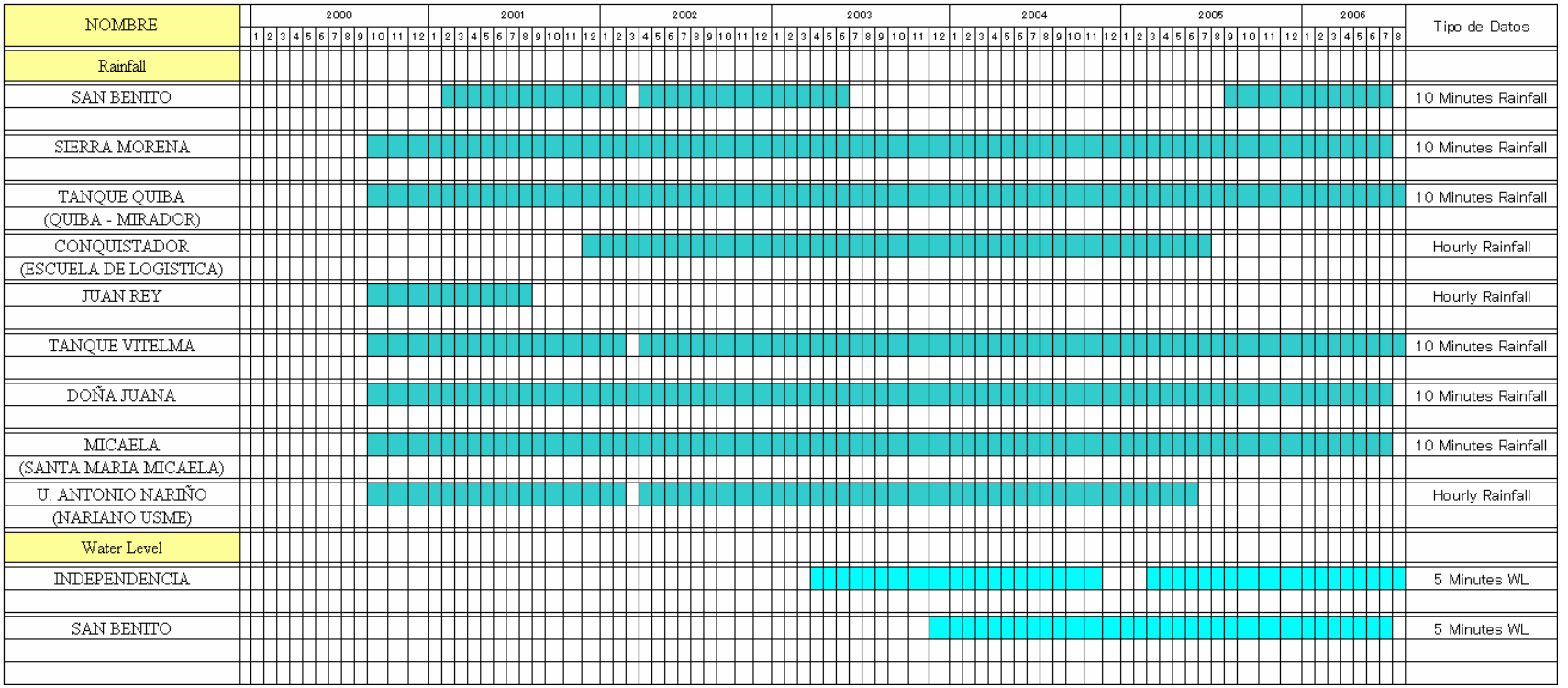


Table 2-6 Collected Hydrological Data from EAAB

NOMBRE	Code	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	Tipo de Datos
Rainfall																																																																				
JUAN REY	P-081																																																		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Daily Rainfall (Diaria)
LAS HUERTAS	P-092																																																		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Daily Rainfall (Diaria)
BOSA BARRENO No.2	P-051		■	■	■			■	■	■	■	■	■	■	■	■	■	■	■	■									■		■	■	■	■		■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Daily Rainfall (Diaria (24Hrs))
Waterlevel/Discharge																																																																			
AVENIDA BOYACA	L-060																																																	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Daily Discharge (Diaria)
AVENIDA BOYACA	L-060																																																	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		Daily Water Level (Diaria)
LA FISCALA	L-053																																																	■	■	■												■	■			Daily Discharge (Diaria)
ALEMANA	L-039																																													■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■							Daily Discharge (Diaria)
CABECERA	L-033																																													■	■	■	■	■	■	■																Monthly Discharge (Mensual)
CANADA	L-094																																																											■	■	■	■	■	■	■	■	■	Monthly Discharge (Mensual)
CANADA	L-094																																																											■	■	■	■	■	■	■		Daily Discharge (Diaria)
LAS HUERTAS	L-005																																	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Daily Discharge (Diaria)
LAS HUERTAS	L-005																																									■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		Daily Water Level (Diaria)
LAS HUERTAS	L-005																																																																■	■	Hourly Water Level (Hourly)
PUENTE BOSA	L-035																										■	■			■	■	■	■	■	■	■	■	■	■								■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		Daily Water Level (Diaria)
PUENTE LA ISLA	L-192																																																											■	■	■	■	■	■			Daily Water Level (Diaria)
LA ISLA	L-004																															■	■	■							■											■		■		■	■	■	■	■	■	■	■	■	■			Daily Water Level (Diaria)
LA ISLA	L-004																									■	■																																						■	■	Hourly Water Level (Hourly)

Table 2-7 Collected Hydrological Data from CAR

NOMBRE	Code	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	Tipo de Datos
Rainfall																																												
LA PICOTA	2120156																■							■	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		Daily Rainfall
																																												(Diaria)
DONA JUANA	2120630																											■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		Daily Rainfall
																																												(Diaria)
SAN JORGE GJA	2120172		■	■	■	■	■	■	■	■	■	■	■	■	■		■							■				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		Daily Rainfall
																																												(Diaria)
EL BOSQUE	2120085		■	■	■	■	■	■	■	■	■	■	■	■	■		■							■	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		Daily Rainfall
																																												(Diaria)
Waterlevel/Discharge																																												
SAN JORGE GJA	2120755		■	■	■	■	■	■	■	■	■	■	■	■	■	■												■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		Daily Discharge
																																												(Diaria)

Table 2-8 Collected Hydrological Data from IDEAM

NOMBRE	Code	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	Tipo de Datos
Rainfall																			
SAN JOSE	2120664													■	■		■	■	Daily Rainfall
																			(Diaria)
SAN CAYETANO	2120665													■	■	■			Daily Rainfall
																			(Diaria)
INEM ANTIAGO	2120666													■	■	■	■		Daily Rainfall
																			(Diaria)
SAN JORGE GJA	2120572							■	■	■	■	■	■	■	■	■	■	■	Daily Rainfall
																			(Diaria)
MINUTO DE DIOS	-																	■	Hourly Rainfall
(SIERRA MORENA)																			(10 minutes)

2.2.3 Characteristic of Rainfall in and around the Study Area

(1) Annual Rainfall

The Annual Rainfall Distribution in the area in 2003 is shown in Figure 2-7. The annual rainfall amount in the Study Area varies by the area from 470 mm to 1040 mm in 2003. Its spatial distribution has a similar tendency for which the rainfall amount is high in the eastern hilly area in Bogota and southern mountain area in Soacha, and it is low in the lowland area such as along the Rio Tunjuelo and near the confluence of Tunjuelo river and Bogota river.

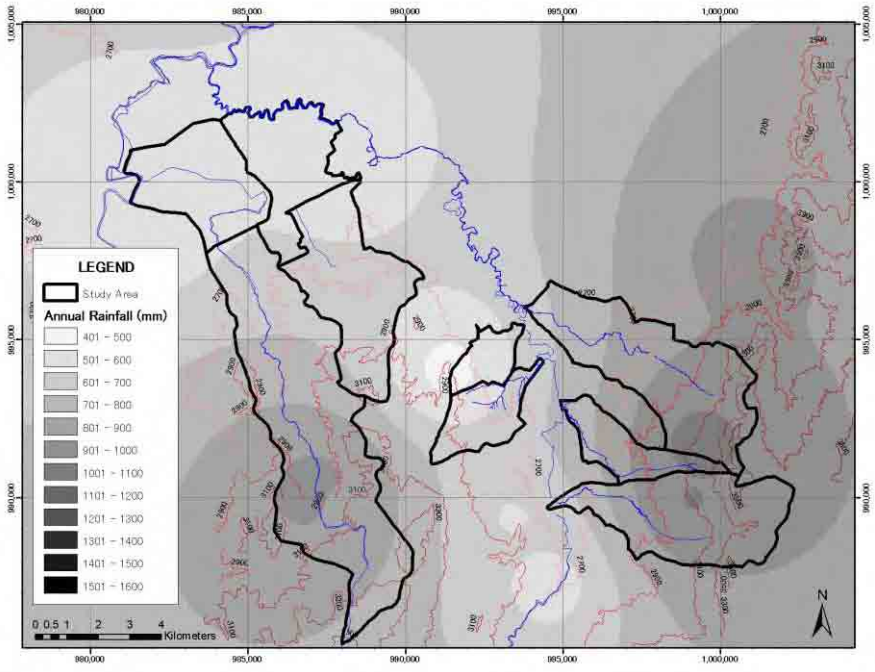


Figure 2-7 Annual Rainfall Distribution (2003)

(2) Monthly Rainfall

The monthly rainfall variations in several stations in the Study Area is shown in Figure 2-8 As described in "(1) General Description in Cundinamarca including the Study Area" in this Chapter, there are two (2) rainy season from March to May and from September to November in the Study Area. As for the characteristic of the Study Area, the rainfall amount is comparatively high in the eastern hilly area in Bogota and southern mountain area in Soacha through the year, and especially the rainfall amount in July is also high in these areas apart from the two (2) rainy seasons as registered by the Micaela station located in eastern and southern hilly area in the Study Area. This trend is also observed in other years such as 2002, 2004 and 2005.

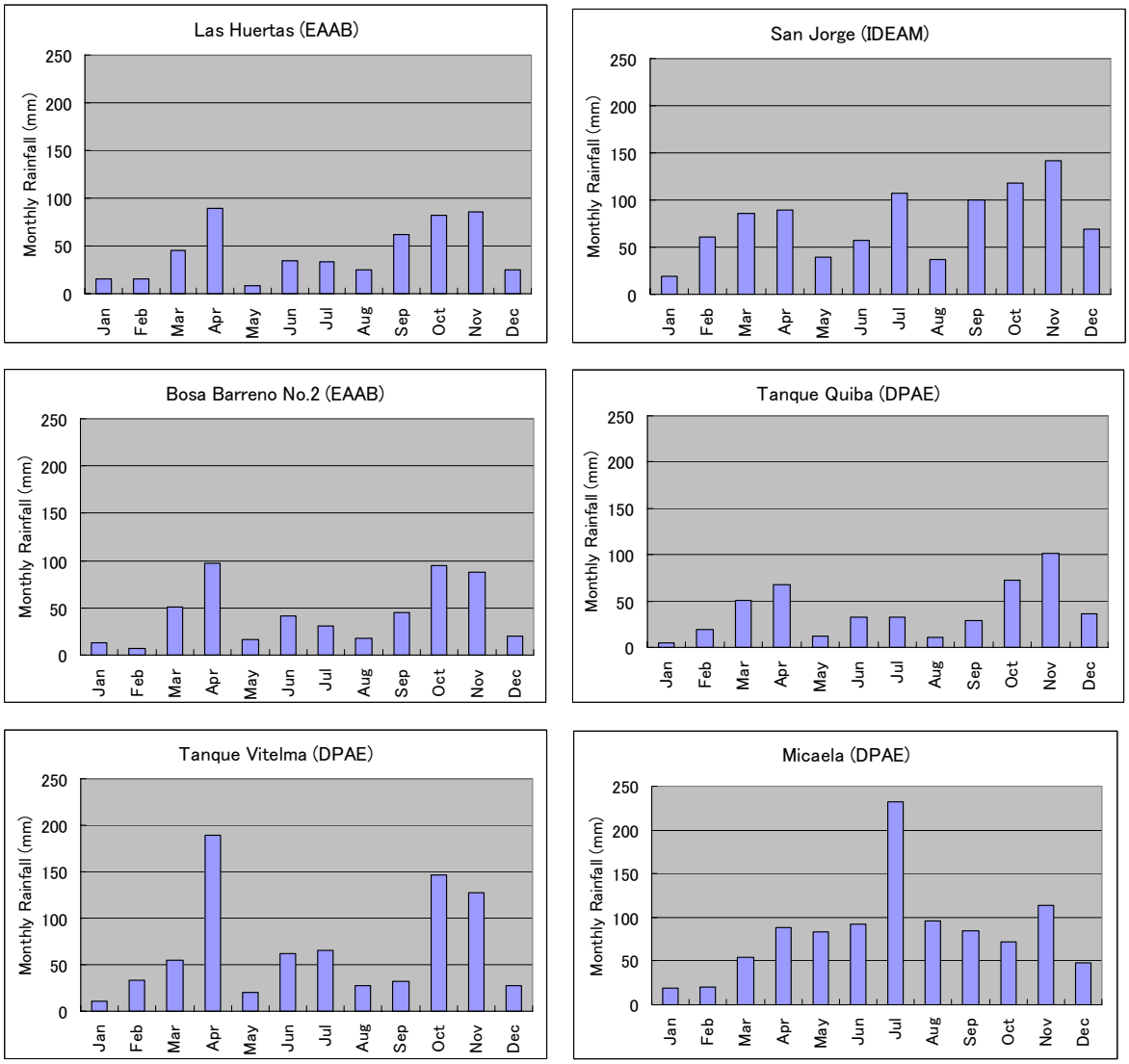


Figure 2-8 Monthly Rainfall Variation in 2003

(3) Number of Rainy Days in Month

Table 2-9 shows the number of rainy days in month in 2003, when rainfall amount more than 0.1 mm was recorded, in the same stations as Figure 2-8. High numbers of Rainy days are recorded in April, July, October and November in all stations. The monthly variation among the stations is almost similar except Micaela station. The highest number of rainy days of 29 days is recorded in May in the Micaela station.

Table 2-9 Number of Rainy Days in 2003(unit: days)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Las Huertas (EAAB)	1	6	14	16	6	11	19	13	13	19	20	9	147
San Jorge (IDEAM)	1	8	11	16	11	13	13	10	8	17	15	5	128
Bosa Barreno No.2 (EAAB)	1	8	13	14	7	12	15	11	14	19	21	7	142
Tanque Quiba (DPAE)	1	11	13	17	11	12	15	9	8	18	19	8	142
Tanque Vitelma (DPAE)	3	12	14	21	19	20	23	20	18	24	27	13	214
Micaela (DPAE)	2	11	15	21	29	21	26	24	21	21	20	15	226

(4) Daily Rainfall

Figure 2-9 and 2-10 show the monthly maximum daily rainfall in DPAE stations from October 2000 to August 2006. Figure 2-9 shows the value of eastern side of Tunjuelo river, and Figure 2-10 shows the value of western side. As a general trend, daily rainfall is bigger in eastern side than western side. In eastern side, daily rainfall is heavy in June and July as well as rainy season, although the daily rainfall in western side tends to be heavy in rainy season. Maximum value of 54.2 mm is recorded in May 3, 2005 in Tanque Vitelma station located in eastern side.

Table 2-10 shows the probable daily rainfall amount with several return periods in 5 (five) stations. It was analyzed through the Gumbel method using collected data in this Study.

Table 2-10 Probable Daily Rainfall (unit :mm)

Station	Return Period (year)					
	3	5	10	25	50	100
Las Huertas (EAAB)	29.19	32.03	35.60	40.12	43.47	46.79
San Jorge (IDEAM)	35.38	38.74	42.96	48.30	52.26	56.19
Bosa Barreno No.2 (EAAB)	33.56	37.23	41.83	47.65	51.97	56.25
Juan Rey (EAAB)	47.74	52.98	59.56	67.88	74.06	80.18
La Picota (CAR)	35.91	40.33	45.89	52.91	58.11	63.28

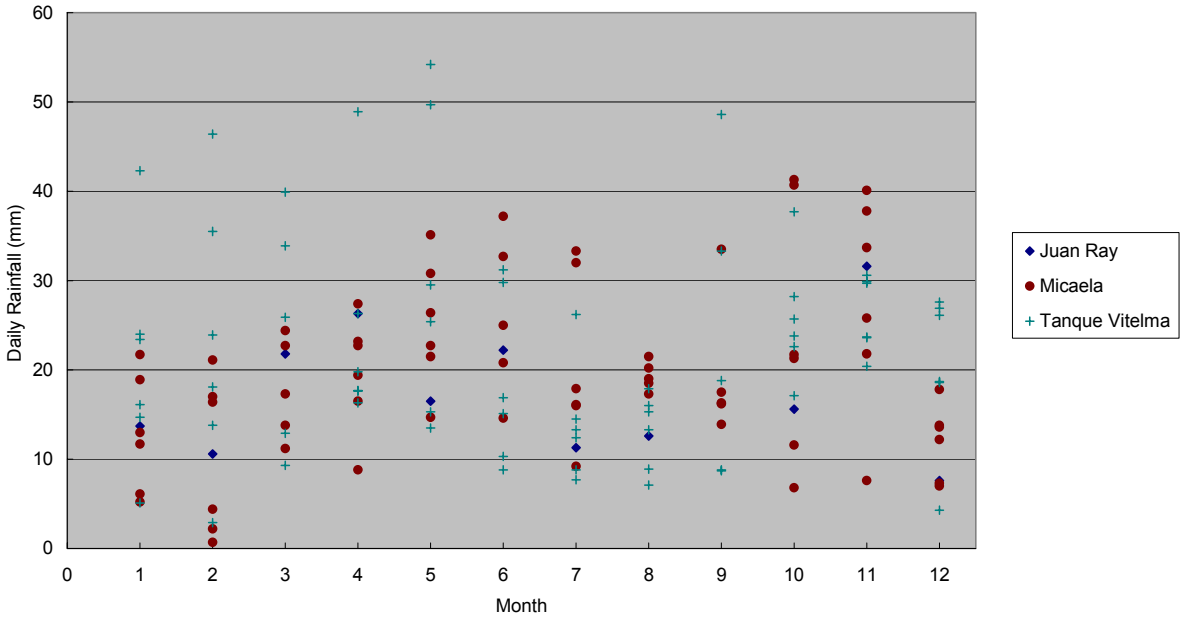


Figure 2-9 Maximum Daily Rainfall in DPAE Stations in Eastern Side of Rio Tunjuelo from 2000 to 2006

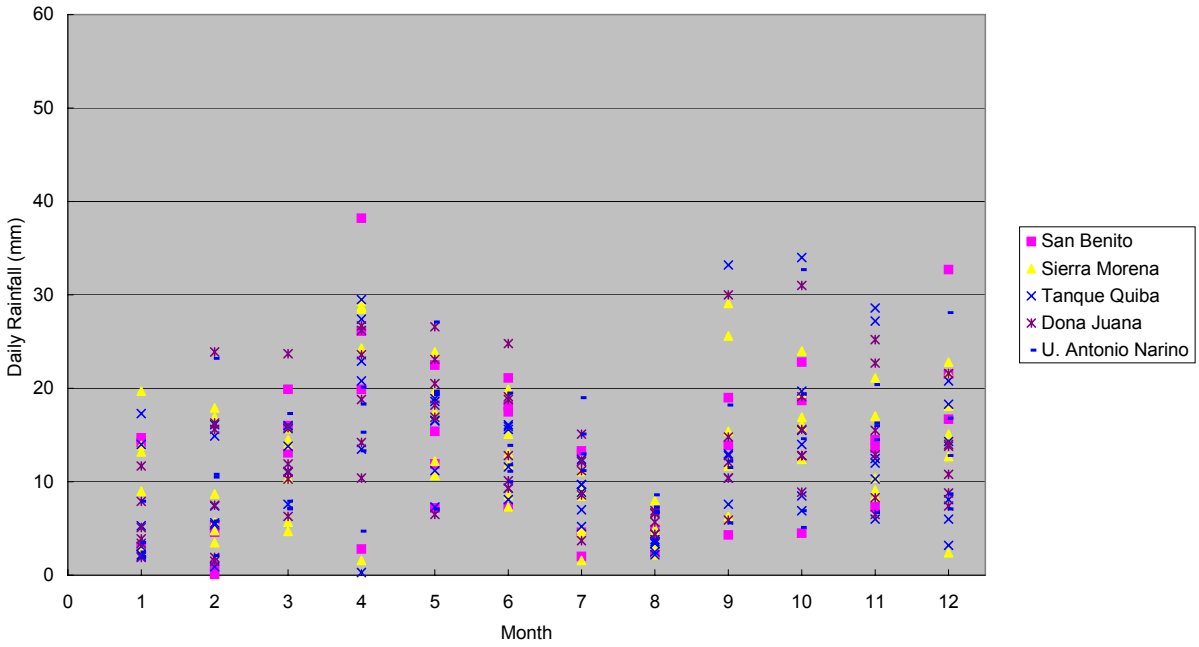


Figure 2-10 Maximum Daily Rainfall in DPAE Stations in Western Side of Rio Tunjuelo from 2000 to 2006

(5) Hourly Rainfall

Figure 2-11 and 2-12 show the monthly maximum hourly rainfall in DPAE stations from October 2000 to August 2006. Figure 2-11 shows the value of eastern side of Rio Tunjuelo, and Figure 2-12 shows the value of western side. Hourly rainfall is bigger in eastern side than western side as is the case with daily rainfall. In both side, the value of maximum hourly rainfall is heavy in rainy season. Hourly rainfall of eastern side in June and July is comparatively low unlike with the tendency of the daily rainfall. It shows that rainfall intensity of eastern side in June and July is not strong whereas rainfall duration is long. Maximum value of 42.1 mm is recorded in September 25, 2005 in Tanque Vitelma stations.

Figure 2-13 shows the zoning of rainfall pattern by EAAB, 1995, with Study Area. Almost all the Study Area is included in zone of Z4, Z5 and Z7. The rainfall pattern varies by the zone. The rainfall intensities in several return periods in each zone by EAAB, 1995 are shown in Table 2-11.

Figure 2-14 shows the relation between daily rainfall and hourly rainfall in DPAE stations in 2000-2006. The daily rainfall has a maximum value for each month from 2000 to 2006, and the hourly rainfall has also the maximum value for each month from 2000 to 2006. From the figure, we can see that the percentage of hourly rainfall amount to the daily rainfall amount is about 40-60%, which means the heavy rainfall finishes in short time. Figures 2-15and 2-16 shows rainfall distribution, in 1:00-24:00 for Tanque Quiba and Micaela stations, respectively. These 10 examples in each figure are top 10 of high daily rainfall amount from October 2000 to August 2006 in Tanque Quiba station, and from October 2000 to July 2006 in Micaela station. In Tanque Quiba station, rainfall distribution can classify two (2) patterns. One is comparatively moderate curve such as 2002/4/25 and 2003/4/12 and 2002, and other is very steep curve such as 2005/9/25 and 2006/4/30, which highest hourly rainfall almost equals daily rainfall amount. In Micaela station, the rainfall distribution can include also two (2) patterns. One is a very moderate curve such as 2001/11/12 and 2002/6/22, and the other is comparatively steep curve such as 2003/9/27 and 2005/10/23.

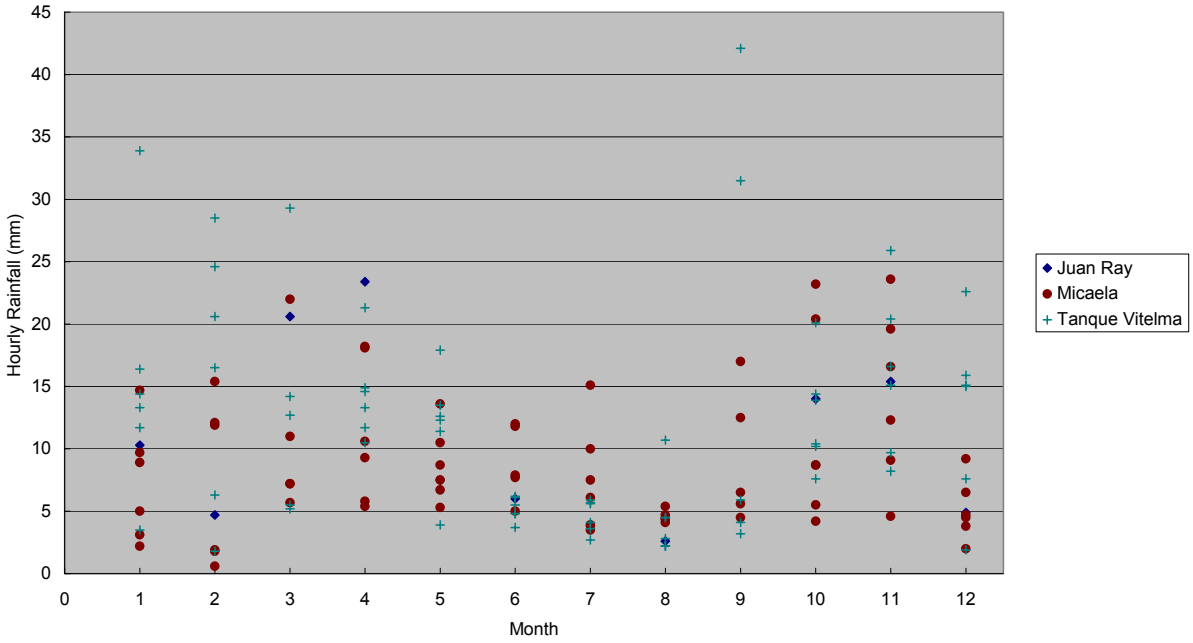


Figure 2-11 Maximum Hourly Rainfall in DPAE Stations in Eastern Side of Rio Tunjuelo from 2000 to 2006

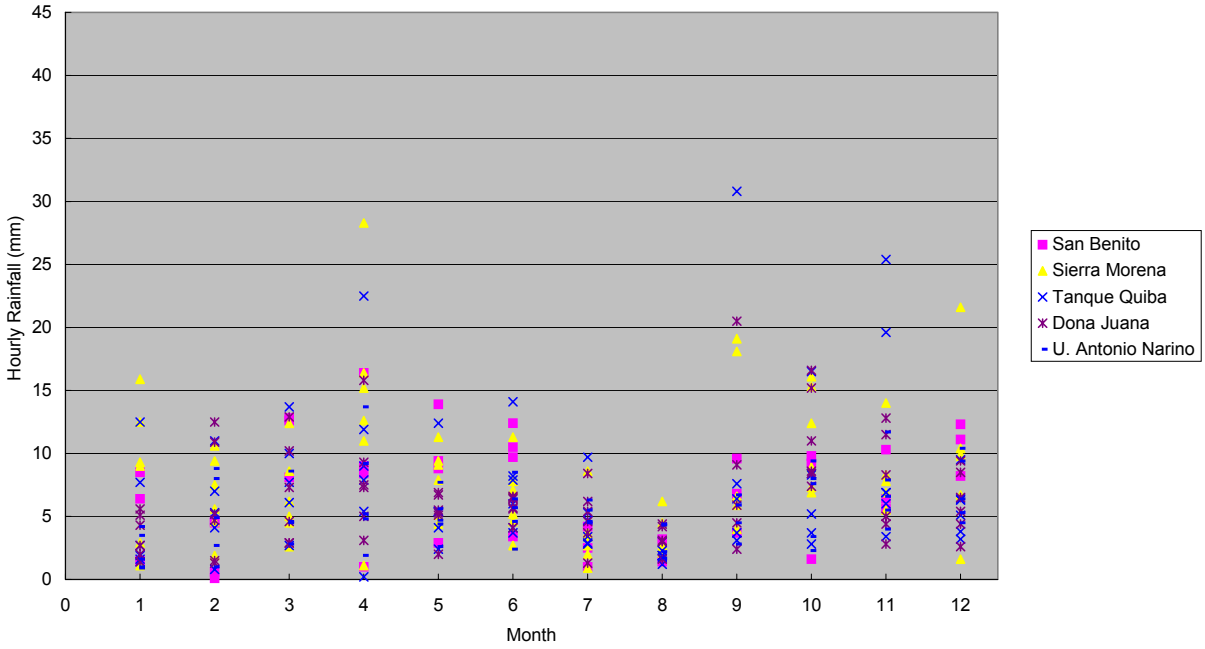
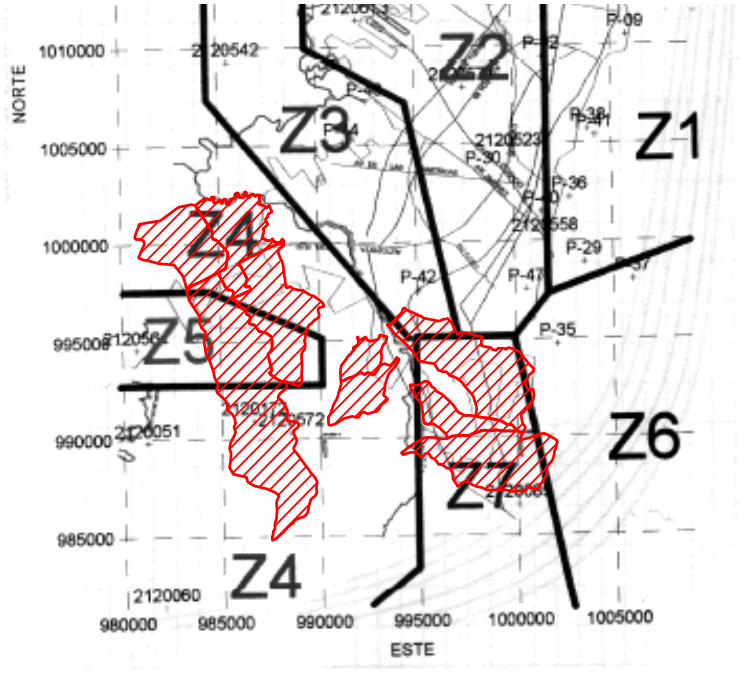


Figure 2-12 Maximum Hourly Rainfall in DPAE Stations in Western Side of Rio Tunjuelo from 2000 to 2006



(Source: "ESTUDIO PARA EL ANALYSIS Y CARACTERIZACION DE TORMENTAS EN LA SABANA DE BOGOTA", EAAB, November 1995)

Figure 2-13 Zoning of Rainfall Pattern

Table 2-11 Rainfall Intensity in each Zone

Zone 4 (Z4)						
Duration (min.)	3 years	5 years	10 years	25 year	50 years	100 years
15	48.72	57.42	68.38	82.21	92.49	102.67
30	34.47	39.91	46.74	55.40	61.82	68.19
60	22.09	25.34	29.43	34.59	38.43	42.23
120	12.68	14.55	16.95	19.92	22.15	24.35
360	4.85	5.50	6.37	7.47	8.27	9.06
Zone 5 (Z5)						
Duration (min.)	3 years	5 years	10 years	25 year	50 years	100 years
15	39.30	44.10	50.10	57.70	63.40	69.00
30	27.80	31.60	36.30	42.30	46.70	51.10
60	17.50	19.90	23.00	27.00	29.90	32.80
120	10.10	11.80	13.80	16.40	18.30	20.20
360	3.70	4.30	5.10	6.00	6.80	7.50
Zone 7 (Z7)						
Duration (min.)	3 years	5 years	10 years	25 year	50 years	100 years
15	42.35	53.25	66.90	84.15	96.95	109.65
30	28.60	34.45	41.85	51.15	58.10	64.95
60	17.40	20.10	23.50	27.75	30.95	34.05
120	11.25	13.45	16.30	19.80	22.40	25.00
360	5.35	6.55	8.00	9.95	11.35	12.75

(Source: "ESTUDIO PARA EL ANALYSIS Y CARACTERIZACION DE TORMENTAS EN LA SABANA DE BOGOTA", EAAB, November 1995)

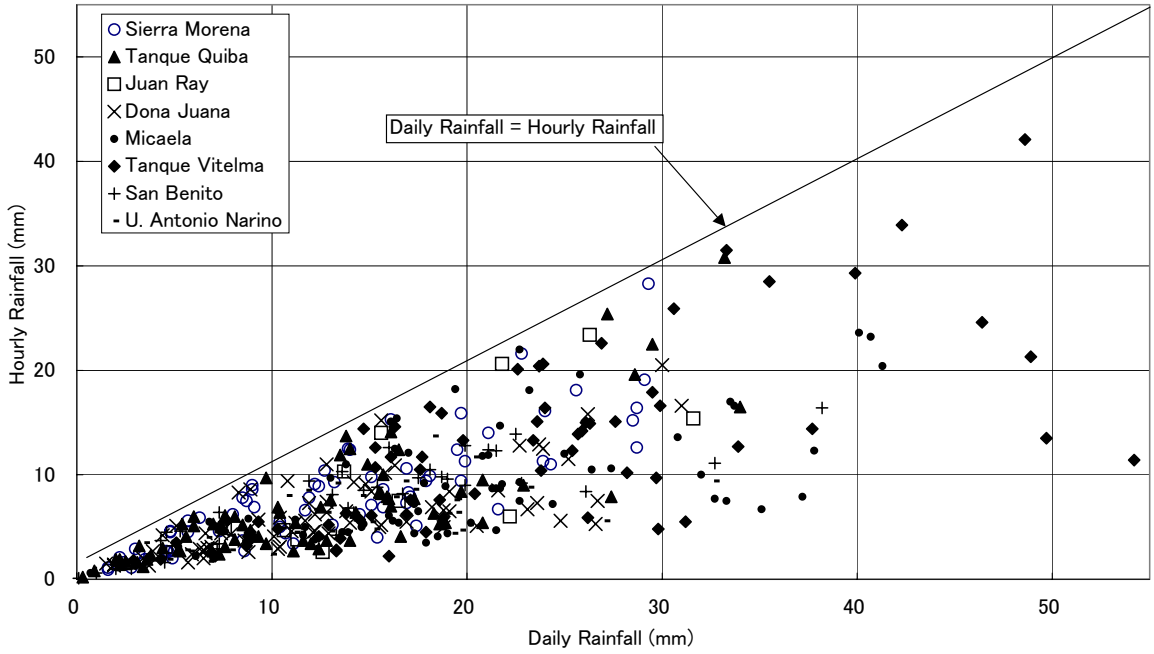


Figure 2-14 Relation between Daily Rainfall and Hourly Rainfall in DPAE Stations in 2000-2006

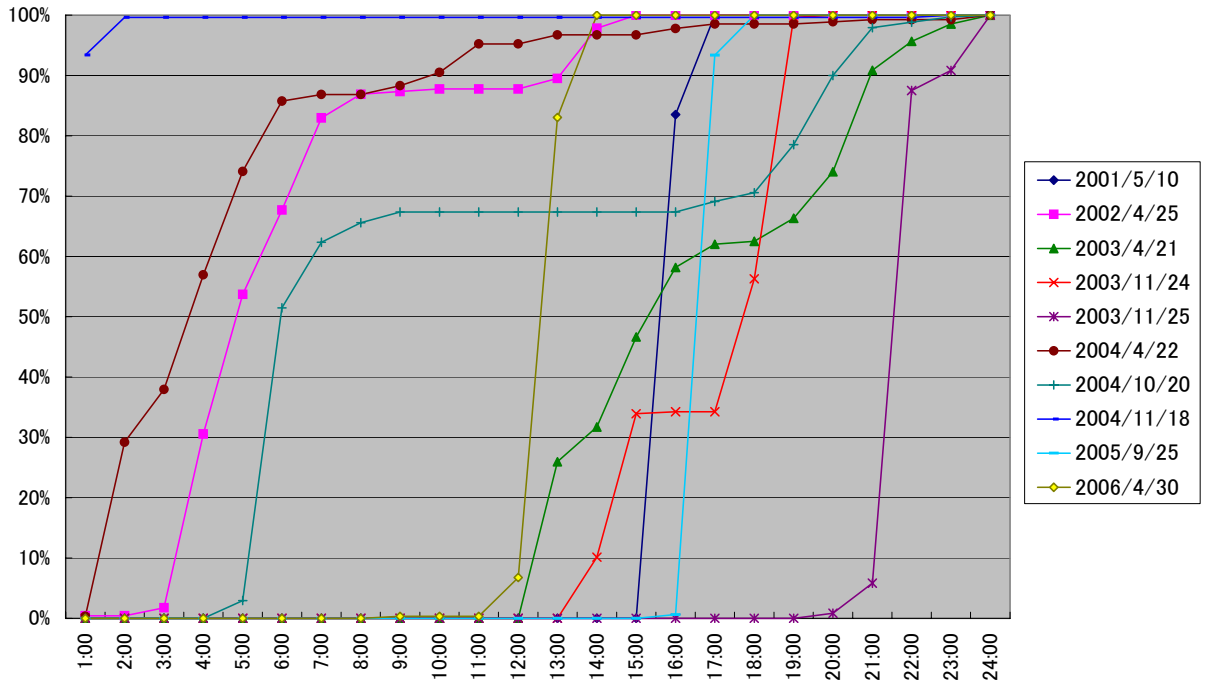


Figure 2-15 Rainfall Distribution in 1:00-24:00 in Tanque Quiba Station

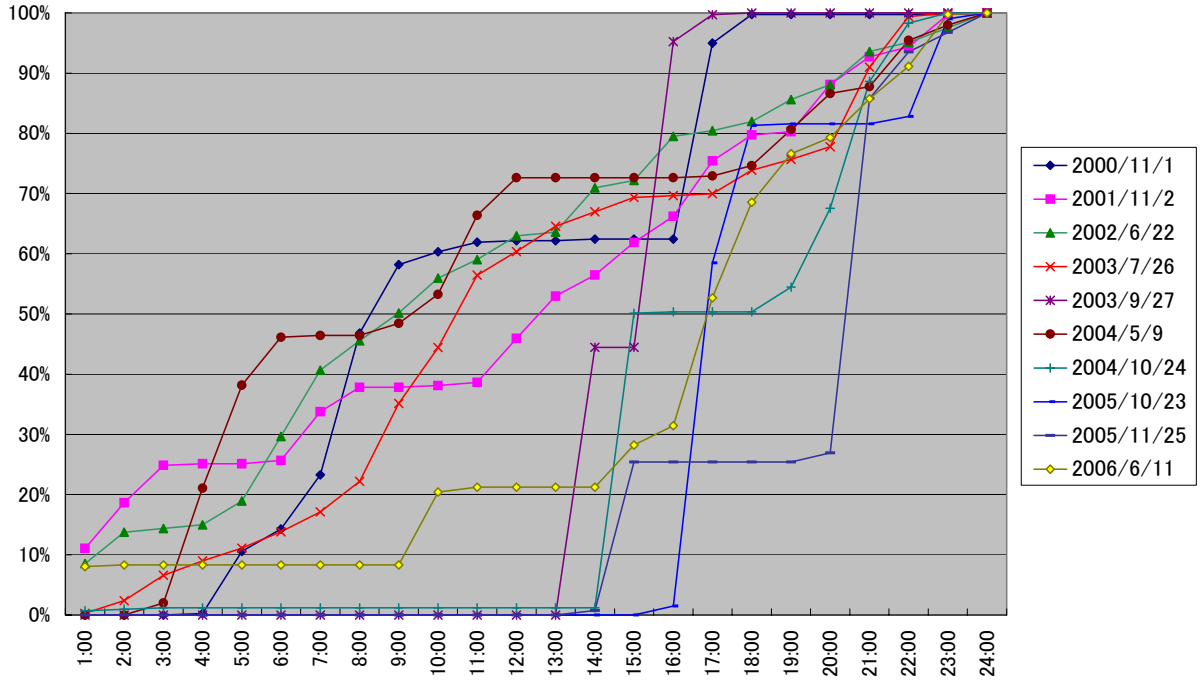


Figure 2-16 Rainfall Distribution in 1:00-24:00 in Micaela Station

2.2.4 Correlation of Rainfall Stations

(1) Correlation of Rainfall Stations in and around the Study Area

In order to examine the correlation of stations and the rainfall pattern in and around the Study area, the correlation coefficient of each station is calculated using the monthly rainfall data from 2000 to 2006 and daily rainfall data in 2003. It can be said that if the correlation coefficient is high between two (2) stations, the rainfall pattern is similar in relevant area. Figure 2-17 and 2-18 show the result of correlation calculation of monthly rainfall and daily rainfall in and around the Study Area, respectively. The values on the lines between stations designate the square value of correlation coefficient of each station.

The correlation of the stations, particularly of daily rainfall, is summarized as follows:

- The correlation is high in each stations located in lowland area such as along the Rio Tunjuelo and northern area of Soacha
- The correlation is comparatively high in the stations of Juan Rey, Micaela, Dona Juana (DPAE) and U. Antonio Narino, which are located in southeastern part of the Study Area
- The correlation is comparatively high in the stations of Tanque Vitelma, San Benito and La Picota, which are located northeastern part of the Study Area
- The correlation of comparatively low in east - west direction

(2) Correlation of DPAE Rainfall Stations

Figures 2-19 and 2-20 shows the result of correlation calculation of monthly rainfall data from 2000 to 2006 and daily rainfall data in 2003 only in the DPAE rainfall stations. However, the data of Juan Rey station of EAAB are used for analysis instead of Juan Rey station of DPAE because operating period of Juan Rey of DPAE is very short. The numerical characters in the figures designate the square value of correlation coefficient of each station.

The correlation of the DPAE rainfall stations, particularly of daily rainfall, is summarized as follows:

- The correlation is extremely high in the stations located along the Rio Tunjuelo in north - south direction
- The correlation is high or comparatively high in the stations located in western side of the Rio Tunjuelo
- The correlation of comparatively high in east - west direction except Sierra Morena - Tanque Quiba, Tanque Quiba - Juan Rey, and Tanque Quiba - Micaela station

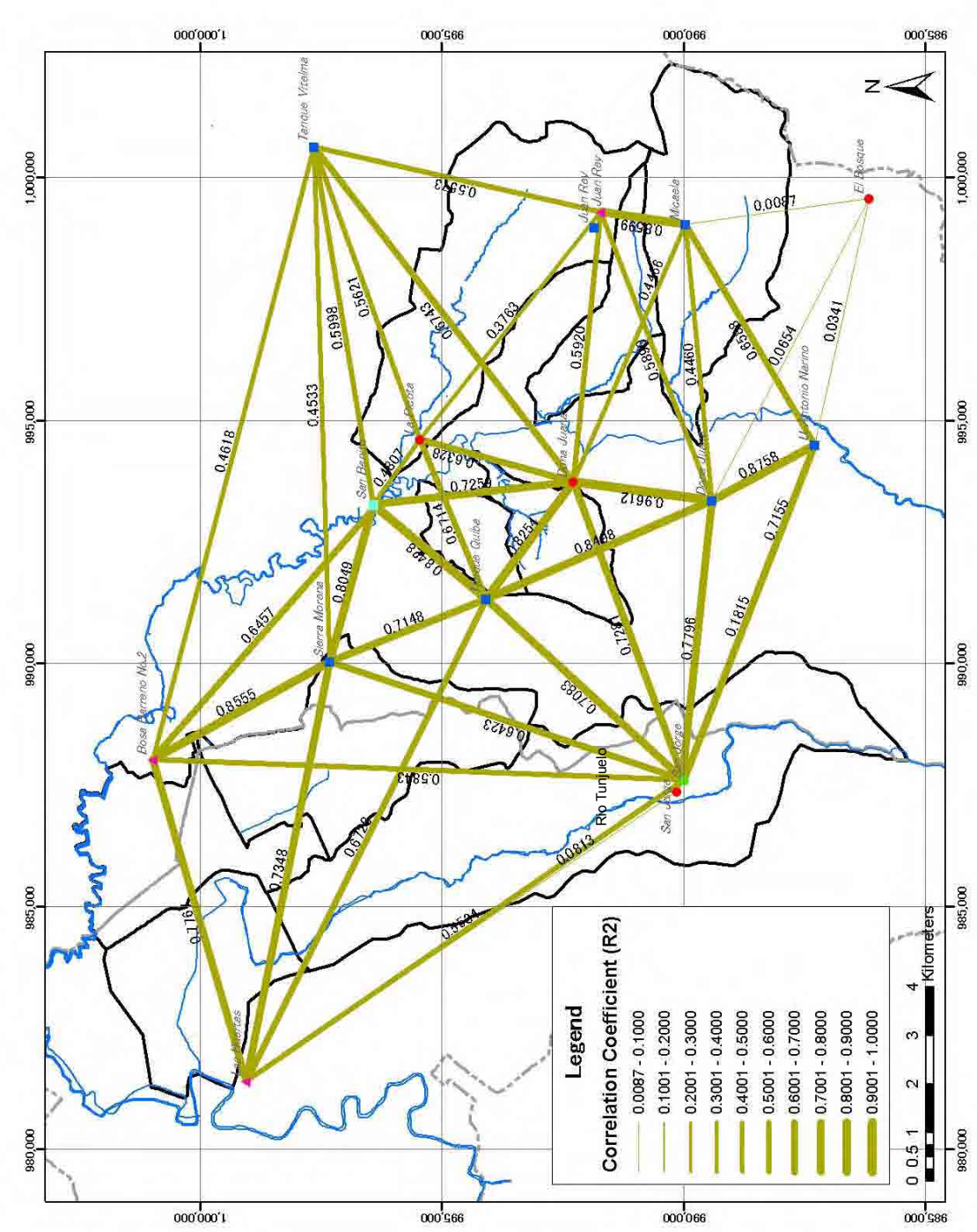


Figure 2-17 Correlation of Monthly Rainfall (2000 - 2006)

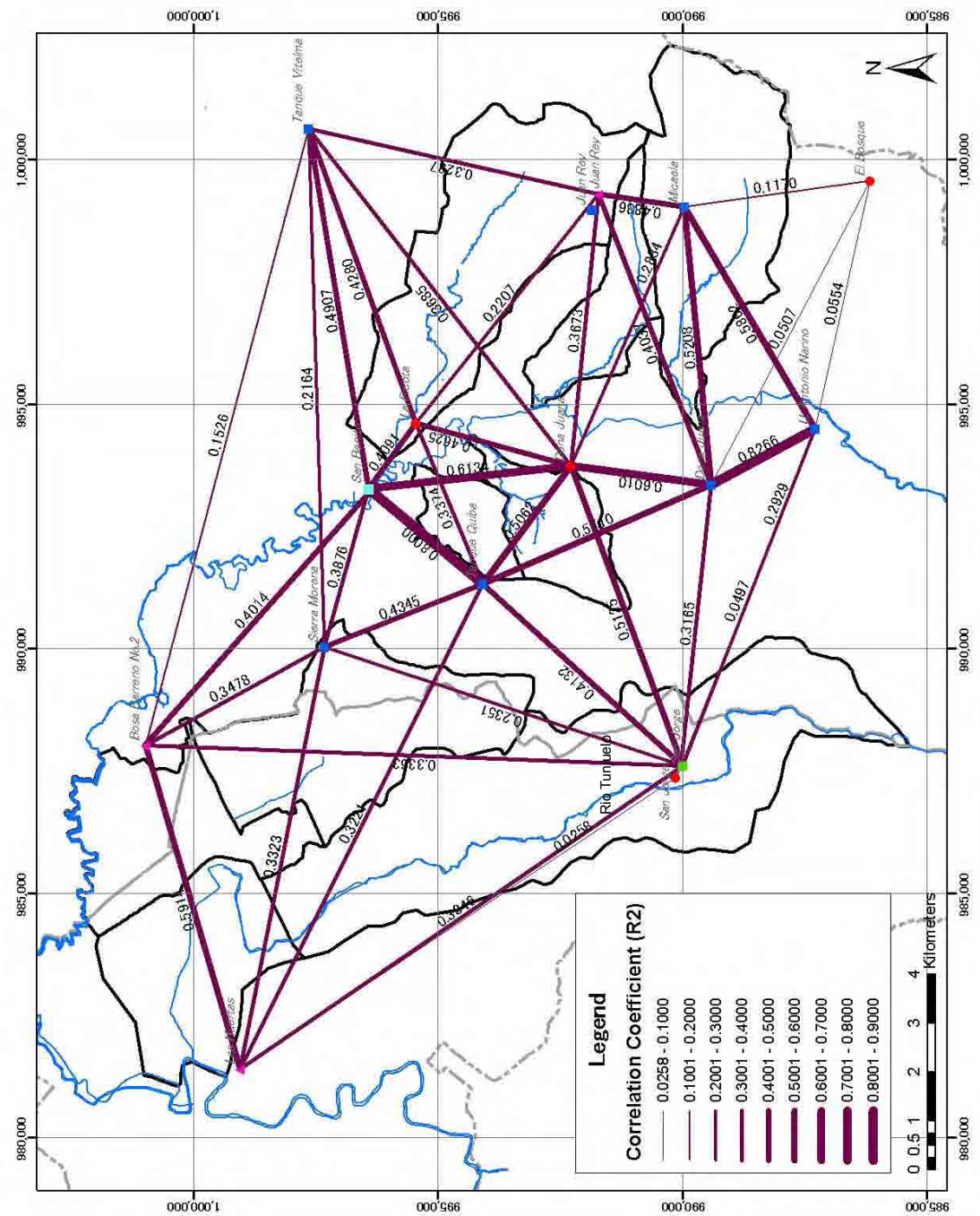


Figure 2-18 Correlation of Daily Rainfall (2003)

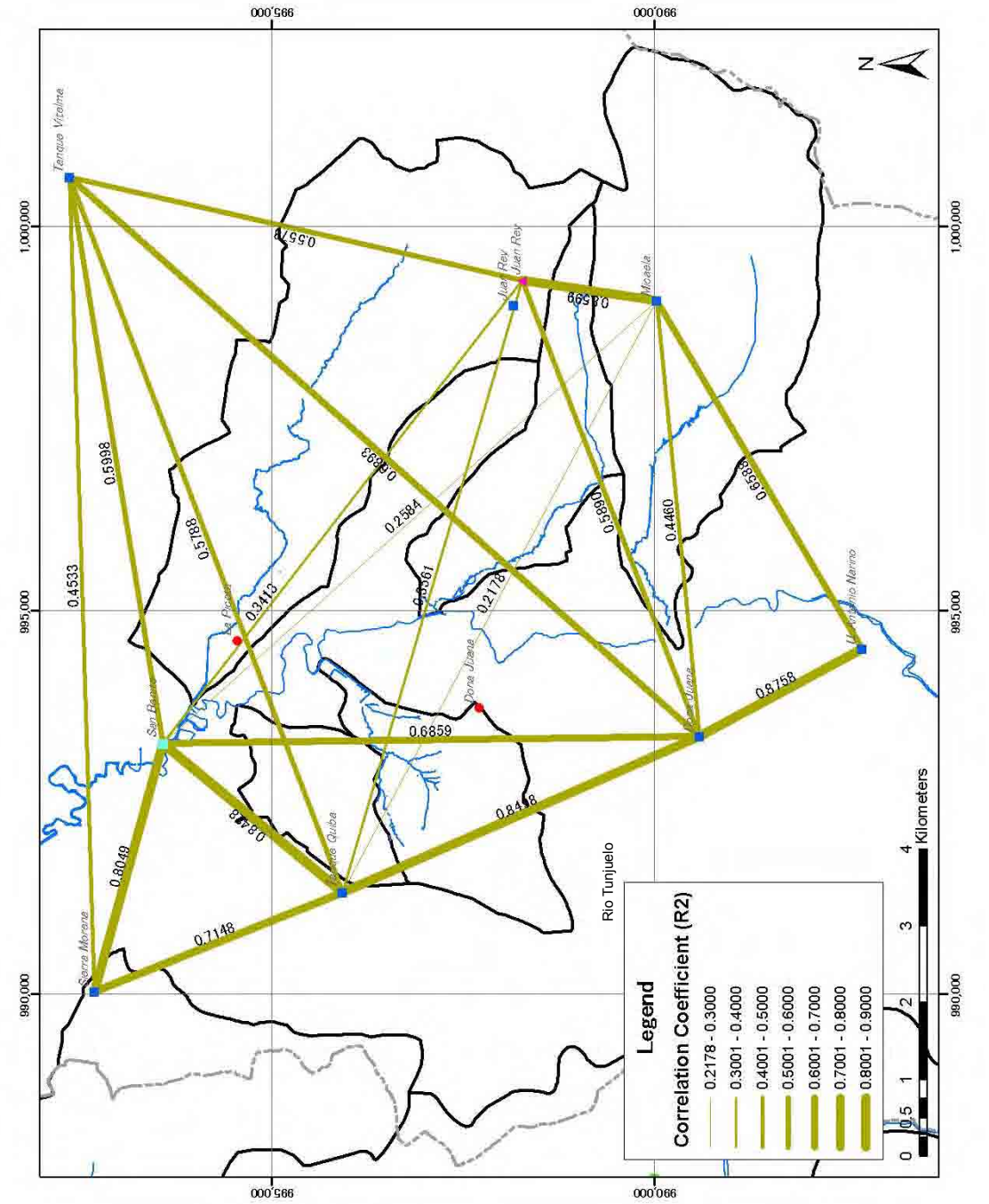


Figure 2-19 Correlation of Monthly Rainfall in DPAE Stations (2000 - 2006)

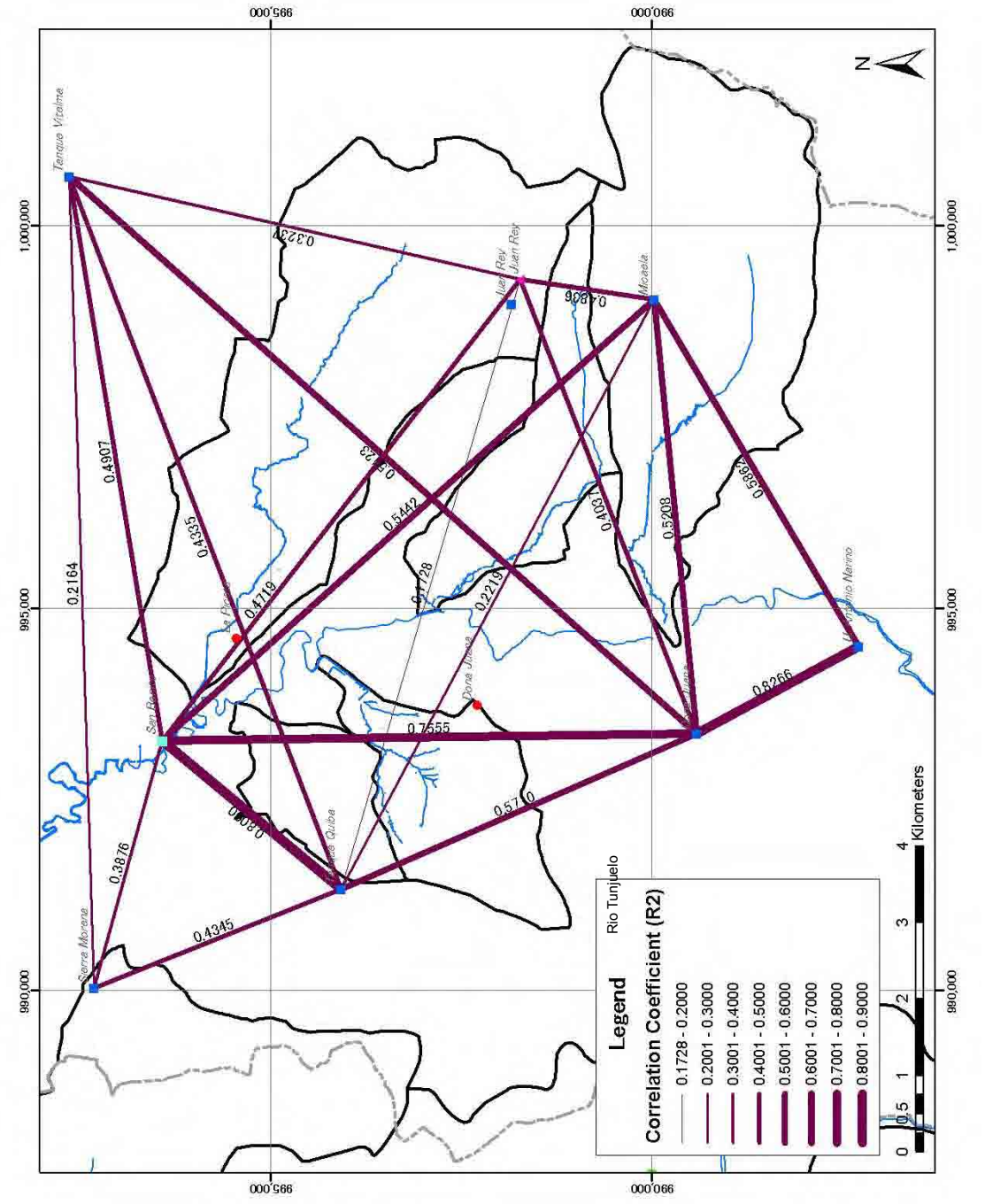


Figure 2-20 Correlation of Daily Rainfall in DPAE Stations (2003)