# CHAPTER 3 SOCIO ECONOMY AND CITY DEVELOPMENT

## 3.1 General

The Study Area is a part of the Bogota D.C. (D.C. for "Distrito Capital", capital district) and Soacha City. The area is located in the center of the country, on the eastern "Bogota Sabana", about 2,600 meters above sea level. The political-administrative system in Colombia is divided into four territorial entities: prefecture, district, municipality and territory inhabited by natives. Each territorial entity is given autonomy within limits defined the laws of the country's constitution.

The following sections summarize the existing socio-economic conditions of Bogota and Soacha especially related to the Study area and items.

## 3.2 Bogota

### 3.2.1 Administrative System

(1) General

Bogota is the capital of the Republic of Colombia as well as the Cundinamarca Department, and also acting as the center of economy and cultural activity of the country. The city has large territorial extension with a total of 177.598 Has with a population of more than 7 million[1], and about 27% of the total territory are occupied by urban and suburban areas.

The Main Mayor and the District Council – both elected by popular vote – are responsible for the city administration. Bogota city is divided into 20 localities and the each locality is governed by a JAL (Local Administrative Board) and a Local Mayor appointed by the Main Mayor from three candidates proposed by the JAL.

Administratively, Bogota is divided in four main administrative sectors[2:] namely Central Sector (Sector Central), Decentralized Sector (Sector Descentralizado), Localities (Sector Localities) and Special Regimen (Régimen Especial).

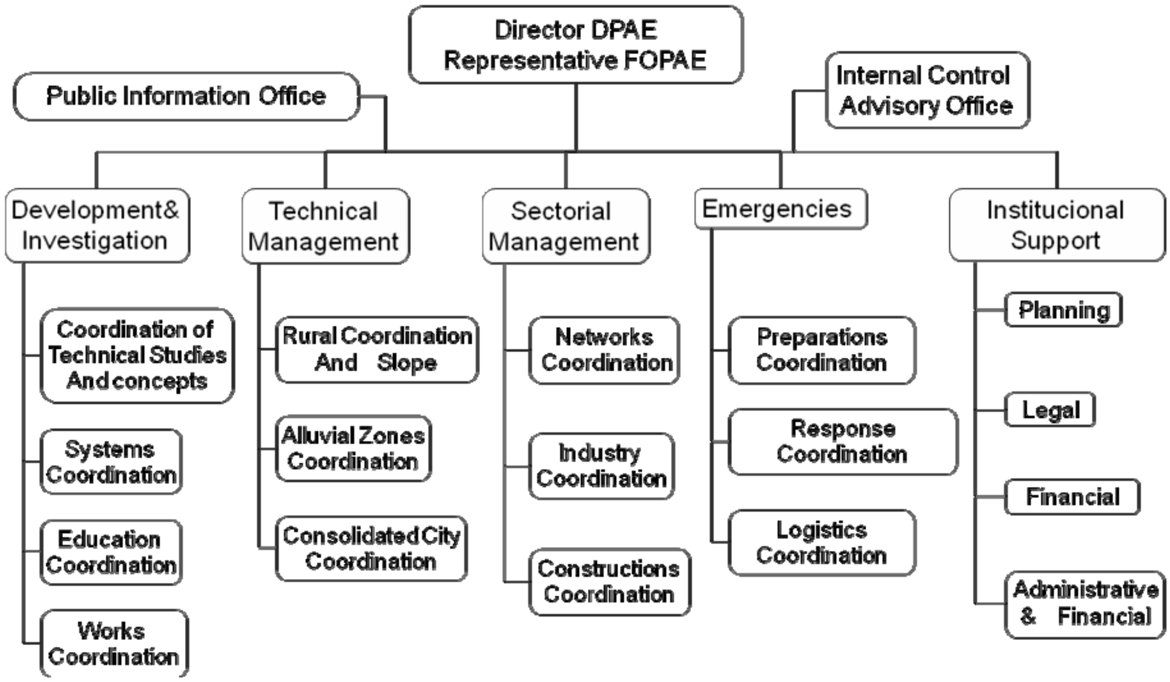
(2) DPAE: Disaster Management Administration

According to the city's regulation, five (5) percent of the city's annual budget is allocated to the disaster management investment and activities. FOPAE (Fondo de Prevención y Atención de Emergencias; Fund for Prevention and Emergencies response) is the authorization body for implementing this budget. FOPAE was established as a public entity (Establecimiento Público) belonging to the Decentralized Sector.

DPAE (Dirección de Prevención y Atención de Emergencias) is responsible for planning and implementing the disaster management activities within the city area as the legal representative of FOPAE.

DPAE has five Sub-directions namely Sub-direction of Territorial Management (Gestión Territorial), Sectorial Management (Gestión Sectorial), Emergencies (Emergencias), Research and Development (Investigación y Desarrollo), and Institutional Support (Apoyo Institucional) and several units under the sub-directions to implement the activities with more than 100 staffs. Figure 3-1 shows the organization Chart of DPAE.

1: Taken from DANE http://www.dane.gov.co/files/investigaciones/poblacion/inf_geo/Pob20062007.xls
2: Source (organigrama general del distrito. http://www.bogota.gov.co/portel/libreria/php/frame_detalle.php?h_id=468




*Source (DPAE)*

Figure 3-1 Organization Chart of DPAE

### 3.2.2 Socio-Economic Condition: Bogota

(1) Population and Urban Expansion

Bogota is experiencing a continuous population increase from its first census in 1775 with about sixteen thousand to 6.8 million in 2005. In its early days, the population growth speed was relatively slow and the city started to grow faster in the twentieth century. The city currently hosts 16.42% of the nation's population.

Since its metropolitan characteristics, the city is receiving a large number of immigrants and its results rapid population increase with a rate of 72.9% from 1993 to 2005. With the continuous population growth, the urban area of the city is also expanding, while the city area had 900 hectares in 1900, today it has 30,000 hectares3.

Many of the immigrants tend to settle in the south-western part of the city (e.g. Ciudad Bolivar: the sixth locality with high population density, and Bosa with the highest rate of growth, and where is known to be a high risk because its slope landform and border hill condition). Under the unstable conditions for their livelihood, the immigrants have settled in fringe area of the city and developed and expanded unplanned settlements with low quality buildings, lack of public infrastructure, transport integration and social services. Consequently, the expansion of unplanned urban areas took place with high population density towards the south has been observed.

(2) General Economy

The economy in Bogota is growing constantly with an Internal Gross Income (Producto Interno Bruto, PIB) for 2005 of USD 22,204 millions.

The economy crisis Colombia suffered in 1999 created a harsh situation with low revenue, an economic contraction, and the rate of unemployment above 18% and weakened to a low position.

3: Alvarez G. Ana Maria. Urban Practices in Bogota. 40th ISOCARP Congress 2004. http://www

While a slow recovery is taking place, the country is still shows high rates of unemployment. People with unstable monthly income ($44,660 pesos in Ciudad Bolivar) demonstrate a slow improvement.

According to the survey conducted by DANE in 2003, approximately 3 million residents in Bogota were working with 14.67% of the unemployed rate which is significantly high compared with the national figure of 12.3%.

(3) Strata: Classification of Urban Residential Area

The Strata (Estrato) is the index of urban residential area and is classified into six, from Strata 1 (lowest) to Strata 6 (highest), as shown in Table 3-1.

Table 3-1 Classification of Strata

| Population Strata | Description | Per capita income |
|---|---|---|
| Strata 1 | Low low | - 1 LMMW |
| Strata 2 | Low | 1-3 LMMW |
| Strata 3 | Low Middle | 3-5 LMMW |
| Strata 4 | Middle | 5-8 LMMW |
| Strata 5 | Middle High | 8-16 LMMW |
| Strata 6 | High | 16 + |

**Legal Monthly Minimum Wage (LMMW: Salario Mínimo Legal Mensual. At Oct 2006: 1 LMMW equals 408,000 pesos, approximately US$ 175 monthly.*

The unit of socio economic stratification is the household, and households are applied different public service bills. Since, low Strata sectors (1 to 3) are economically more vulnerable, these families have a discount in the amount of the bill, paying below the actual cost of the service, which is balanced out by those strata that have the capacity to contribute more.

Approximately 30% of the households in the Study Area earn below a minimum wage (aprox. $175 USD monthly) and 70% have an average monthly income between $175 and $525 USD.

### 3.2.3 Socio-Economic Conditions: Study Area

(1) Population of Study Area

This Study concerns six localities of Rafael Uribe, San Cristobal, Usme, Ciudad Bolivar, Bosa and Tunjuelito. The characteristics of the localities are summarized in Table 3-2.

Table 3-2 Population and Its Characteristics of the Localities

| Locality | Area | No Barrios | No Inhabitants | Men | Women | Professional Level |
|---|---|---|---|---|---|---|
| Rafael Uribe | 1,310 Ha | 116 | 385,391 | 48,1% | 51,2% | 6.5% |
| San Cristobal | 4,816 Ha | 211 | 460,414 | 48.2% | 51.8% | 5.0% |
| Usme | 21,556 Ha | 220 | 267,423 | 48.9% | 51.1% | 2.3% |
| Ciudad Bolivar | 12,998Ha | 252 | 658,477 | 48,8% | 51,2% | 3.2% |
| Bosa | 2,392Ha | 330 | 475,694 | 48.8% | 51.2% | 3.7% |
| Tunjuelito | 1,028 Ha | 30 | 204,367 | 48.2% | 51.8% | 8.4% |

*(Source :DANE. General Census 2005)*

(2) Employment in the Study Area

According to the information of Administrative Department of Planning Labor Force, economic activities in the six localities related to the Study are mainly commerce, restaurants, and hotels followed by the domestic services. Also, the manufactory industry that concentrates no qualified labor which reports revenues of around four hundred eighty thousand pesos.

Due to this low income, the families are unable to cover their basic needs. The lack of permanent and stable jobs increase the poverty rates forcing people to a poor consumption of food, clothing and recreation.

Table 3-3 shows the employment of the six localities in the Study Area. Rafael Uribe has the highest rate of unemployment almost 4 points above the national average, and followed by Ciudad Bolivar and San Cristobal where more than 30 thousand people have no permanent income.

Table 3-3 Employed and Unemployed People by Localities

| Locality | Employed Population | Un-employed Population | Total | Unemployment Rate (%) |
|---|---|---|---|---|
| Bosa | 225,873 | 36,886 | 262,759 | 14.04 |
| Ciudad Bolivar | 244,599 | 44,660 | 289,259 | 15.44 |
| Rafael Uribe | 183,359 | 34,402 | 217,761 | 15.80 |
| San Cristobal | 179,254 | 30,782 | 210,036 | 14.66 |
| Tunjuelito | 91,794 | 14,204 | 105,998 | 13.40 |
| Usme | 103,601 | 15,945 | 119,546 | 13.34 |
| Total | 1,028,480 | 176,879 | 1.205.359 | 14.67 |

*(Source: DANE census 2003.)*

(3) Living Conditions and Public Services

Majority of the population related to the Study Area is socio-economically located under strata 1 and 2. The people in lowest condition are concentrated in Ciudad Bolivar (almost all population in Strata 1 and 2) and Usme (about three quarters of population in Strata 1 and 2). A high value of UBNM (Unsatisfied Basic Needs Methodology) ranging from 90% in Useme to 33% in Tunjuelito also shows the socio-economically harsh conditions of people living in the area.

EAAB (Empresa de Acueducto y Alcantarillado de Bogota), the official company to supply potable water and sanitary services, provides a relatively high percentage of coverage of water and sewerage as shown in Table 3-4.

Table 3-4 Percentage of Service Coverage

| Locality | Aqueduct | Sanitary Sewerage system |
|---|---|---|
| USME | 91.6 | 92.3 |
| SAN CRISTOBAL | 99.7 | 90.1 |
| TUNJUELITO | 100.0 | 99.7 |
| RAFAEL URIBE | n/d | n/d |
| BOSA | 97.6 | 65.3 |
| CIUDAD BOLIVAR | n/d | n/d |
| Total Bogota | 98.0 | 90.1 |

Regarding the waste management services in the study area, the service is delivered by three private companies with valid legal concessions for seven years. The service providers cover most of the localities related to the Study, however, some areas have problem to provide services due to a number of physical limitations in site. In some sites, improper waste disposal (e.g. informal a deposit of waste, waste is thrown to open spaces and slopes, burn or bury the trash) has been found.

In addition, some Localities related to the Study such as Rafael Uribe, San Cristobal, Bosa, and Tunjuelito are suffering from an insufficient capacity as local towns to supply community needs of education, public services and infrastructure due to rapid growth of population.

(4) Disaster Hazard

<u>Landslide Disaster Hazard Areas</u>

In the city of Bogota, landslide hazard areas can be found in Ciudad Bolívar, San Cristobal, Rafael Uribe, Santa Fe, Usme, Chapinero, Usaquén y Suba. Table 3-5 shows the landslide hazard areas in localities[4] related to the Study. The Localities with greater total areas in hazard of landslide are Ciudad Bolivar and San Cristobal.

Table 3-5 Number Blocks of Landslide Hazard Areas

| Locality (UPZ) | High Hazard | Middle Hazard | Low Hazard |
|---|---|---|---|
| Usme (La Flora, Danubio, Gran Yomasa, Los Comuneros, Alfonso Lopez, Parque EntreNubes) | 187 | 716 | 2,257 |
| San Cristobal (La Gloria, Los Libertadores) | 224 | 1,162 | 85 |
| Rafael Uribe (Marruecos, Diana Turbay) | 177 | 820 | 35 |
| Ciudad Bolivar (El Mochuelo, Lucero, El Tesoro) | 237 | 1,480 | 343 |
| Total | 825 | 4,178 | 2,720 |

Flood Hazard areas

The localities of Usme, Tunjuelito, Rafael Uribe, and Ciudad Bolívar have hazard areas of flood disasters. Tunjuelito has the largest area (Table 3-6).

Table 3-6 Summary of Flood Hazard Areas (unit: ha)

| Locality (UPZ) | High Hazard | Middle Hazard | Low Hazard |
|---|---|---|---|
| Usme (Gran Yomasa, Los Comuneros,Parque EntreNubes) | 10.34 | 9.28 | 8.64 |
| Tunjuelito (Tunjuelito) | 60.00 | 90.90 | 58.80 |
| Rafael Uribe (Marruecos, Diana Turbay) | 18.20 | 3.60 | 11.90 |
| Ciudad Bolivar (El Mochuelo, Lucero, El Tesoro) | 22.70 | 15.00 | 40.40 |
| Total | 111.24 | 118.78 | 119.74 |

### 3.2.4 Land Use and Urban Planning

(1) Land Use and Urban Planning of Bogota

Bogota has the Metropolitan Territorial Plans namely POT (Plan de Ordenamiento Territorial) which conceptually integrates the best both diverse and land uses in expanding cities. The POT set in place in 2000, constitutes a major step on the organization of the city growth, its spatial distribution of land uses.

The objectives of the POT, according to its fundamental law (388/97), are 1) mitigate and compensate the regional impacts of the economic trends, 2) optimal use of space, 3) prospective vision of development, 4) harmonize social and economic goals, and 5) restore and protect natural resources[5].

The POT established the categories of Urban Land, Rural Land, Protection Land and Expansion Land for Bogota DC. These follow the rationale guiding the entire POT, which seeks to adjust the "real" city with the planning instruments, in order to provide some control over the current uses, and to allow for planned adjustments towards compact growth.

Based on the category presented in the POT, the land of the city is classified as shown in Table 3-7.

Table 3-7 Bogota, Rural Urban, Protected and Expansion Lands (in hectares, 2002)

| Rural Land | | | Urban Land | | | Expansion Land | | | BOGOTA |
|---|---|---|---|---|---|---|---|---|---|
| Rural | Protected | Total | Urban | Protected | Total | Expansion | Protected | Total | Total |
| 48,029 | 73,445 | 121,474 | 34,219 | 4219 | 38,438 | 2,557.70 | 1106 | 3,664 | 163,575 |

*(Source:http://www.segobdis.gov.co/)*

4 Recorriendo Cd Bolivar, San Cristobal, Rafael Uribe, Santa Fe, Usme, Chapinero, Usaquén y Suba(2004)
5: Perez Preciado,Alfonso. Bogotá y Cundinamarca Expansión Urbana y Sostenibilidad. Corporación Autonoma Regional de Cundinamarca. Santa Fe de Bogotá. 2000. Pg 18.

The Urban Land is subdivided into UPZs (Unidades de Planeación Zonal: Units of Zonal Planning). The UPZ is a unit of urban planning according to the homogenous characteristics of neighboring areas composed of a number of Barrios.

The Rural Land is divided to the Rural Planning Units (Unidades de Planeamiento Rural -UPR) which is a foundation of the rural planning to address the ecological management, the uses and occupation of rural land and the activities in the urban border.

The Protected Areas composed of natural (ecological) areas, urban parks, not avoidable high hazard areas, areas in which some future uses are foreseen and the alluvium valley of Bogota River.

The Expansion Areas are those areas defined and selected for current or future urban use. Typically the expansion area would be in the process of applying or included in the Barrio Improvement.

(2) Land Category, Localities and UPZ containing the Study Area

The Study Area is located under six distinct Localities: San Cristobal, Usme, Tunjuelito, Bosa, Rafael Uribe and Ciudad Bolivar. Table 3-8 shows the area of localities by land use categories.

Table 3-8 Extension and Type of Soil of the 6 Localities of the Study

| LOCALITIES | Total | RURAL AREA | | | URBAN AREA | | | EXPANSION | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (Ha.) | Rural | Protected | Total | Urban | Protected | Total | Expansion | Protected | Total |
| San Cristobal | 4,816 | | 3,187 | 3,187 | 1,425 | 204 | 1,629 | - | - | - |
| Usme | 21,556 | 9,239 | 9,068 | 18,307 | 1,496 | 568 | 2,064 | 882 | 303 | 1,185 |
| Tunjuelito | 1,028 | | - | - | 752 | 276 | 1,028 | - | - | - |
| Bosa | 2,392 | - | - | - | 1,699 | 230 | 1,929 | 229 | 234 | 463 |
| Rafael Uribe | 1,310 | - | - | - | 1,221 | 89 | 1,310 | - | - | - |
| Ciudad Bolivar | 12,998 | 5,574 | 3,982 | 9,556 | 2,645 | 593 | 3,238 | 194 | 11 | 205 |
| Total of Six | 44,100 | 14,813 | 16,237 | 31,050 | 9,238 | 1,960 | 11,198 | 1,305 | 548 | 1,853 |
| BOGOTA | 163,575 | 48,029 | 73,445 | 121,474 | 34,219 | 4,219 | 38,438 | 2,558 | 1,106 | 3,664 |

A Locality is further divided to smaller planning units of UPZ, and the UPZ is composed of a number of Barrios these can be fully incorporated into the urban structure and form, or can be recent settlements of migrants that have not been able to consolidate their location into the city structure.

The UPZ classified into three types from 1 (lowest) to 3 (highest) and has a relation to the strata. All UPZ related to the Study, except El Mochuelo in Ciudad Bolivar, are classified as UPZ Type 1: Incomplete Residential Urbanizations.

Figure 3-2 shows the number and area of Legal Barrios in six Localities (Usme, Tunjuelito, Ciudad Bolivar, Rafael Uribe, Bosa and San Cristobal). A total area of 3,745 has represents 57.6 % of legalized barrios extension of Bogota (6499 has.).

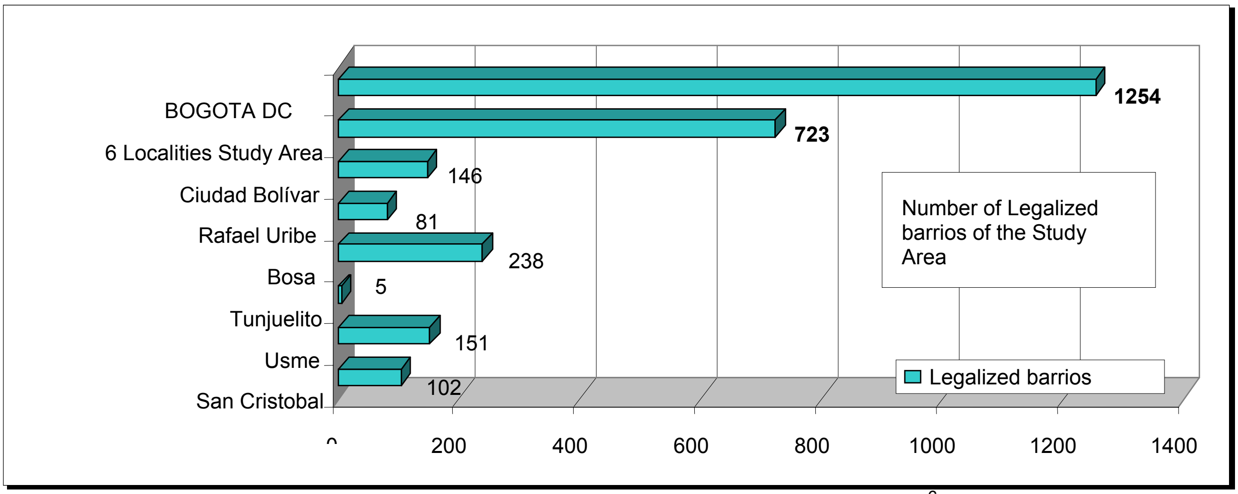



Figure 3-2 Number of Legalized Barrios in Six Localities[6]

### 3.2.5 Citizen Participation

In Bogota, various citizen participation mechanisms have been established to achieve different interests in the community. In 1993, the Local Administrative Board (JAL) was created to enlarge the participation mechanisms[7]. The Community Action Board (JAC) is another sphere of community organization existing since the last 50 years, and currently 1,753 JACs are working for their community[8,9].

Table 3-9 shows a number of community organizations established in the Localities related to the Study. Only in three Localities of Usme, Rafael Uribe and Bosa have a total of 137 Community Centers. These community centers are usually constructed through collective work of the community, which suggests an important community activity.

Table 3-9 Number of JAC, Community Councils and Community Centers

| Locality | Number of JAC | Community Councils | Total | Community Centers |
|---|---|---|---|---|
| Usme | 172 | 4 | 176 | 51 |
| San Cristobal | 111 | 8 | 119 | n/d |
| Tunjuelito | 18 | 1 | 19 | n/d |
| Rafael Uribe | 101 | 4 | 105 | 63 |
| Bosa | 162 | 12 | 174 | 23 |
| Ciudad Bolivar | 222 | 17 | 239 | n/d |

During the Study period, rainfall and water level gauges are installed to help community based flood monitoring activity. Table 3-10 shows the name of Barrios that relate to the activity and JAC is the organization in charge of monitoring activity.

Table 3-10 JAC Organizations Participating to Flood Monitoring[10]

| Barrio Name | Locality Name | Activity related to the Study |
|---|---|---|
| Molinos II Sector | Rafael Uribe | Water level monitoring (Molinos) |
| Moralba Suroriental | San Cristobal | Rainfall monitoring (Colegio Moralba) |
| San Jacinto | San Cristobal | Water level monitoring (La Gloria) |

6: Departamento Administrativo de Planeación. Recorriendo Usme. Diagnóstico Físico y Socioeconómico de las localidades de Bogotá D.C. Alcaldía Mayor de Bogotá. D.C. 2004. Calculations for the year 2002
7: http://www.bogota.gov.co/portel/libreria.
8: http://www.participacionbogota.gov.co
9: Decreto 2350 20/08/2003 by president Alvaro Uribe
10: http://www.participacionbogota.gov.co/jac_dignatarios_upz

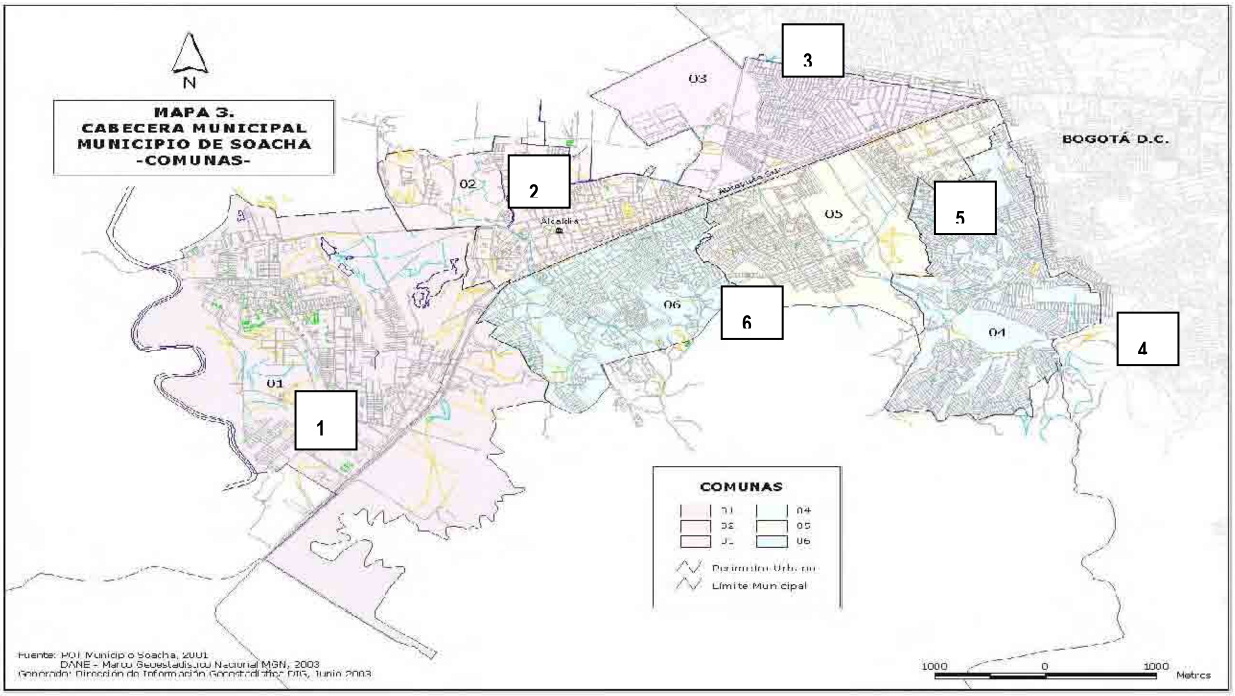
## 3.3 Soacha

### 3.3.1 Administrative System

(1) General

The Soacha Municipality is located 18 km southeast of Bogota. The city has two defined areas, namely urban area with 19 $km^2$ of territorial extension with 98% of the total population of the city, and rural area with 165 $km^2$ territorial expansion.

The urban areas are divided administratively in 6 communes with 348 neighborhoods[11] (Figure 3-3). On the other hand, the rural area is divided into two jurisdictions with 15 rural villages called veredas, and each one has its Corregidor, or supervisor designated by the mayor of Soacha (Table 3-11).




*(Source: http://www.alcaldiasoacha.gov.co/infoNoticia.asp?IdNot=131)*

Figure 3-3 Urban Communes of Soacha

Table 3-11 Rural Areas of Soacha

| Jurisdiction No. 1 | Jurisdiction No. 2 |
|---|---|
| Romeral | El Charquito |
| Alto del Cabra | Alto de la Cruz |
| Hungría | San Francisco |
| San Jorge | Cascajal |
| Fusungá | Canoas |
| Panamá | Bosatama |
| Chacua Primavera | |
| Tinzuque Primavera | |
| San Francisco | |

*(Source: http://www.alcaldiasoacha.gov.co/infoNoticia.asp?IdNot=131)*

[11]: Source: File of Alcaldia de Soacha(Power point presentation)partially printed

The administrative structure is constituted by a Municipal Mayor elected through popular vote, with three control headquarters (Internal Control, Disciplinarian Control, Legal Advise) and eight secretaries (General, Government, Planning, Treasure, Social Development, Education, Health and Infrastructure). The Mayor is the highest authority, and main administrator of the local budget and resources.

(2) Disaster Managment Adiministration

CLOPAD (Local Committee for Disaster Attention and Prevention) is responsible for disaster management activities at the municipal level. The members of CLOPAD include the Municipal Departments, Firefighters, Civil Defense, Volunteers, and International agencies.

As the CLOPAD is a relatively new organization and has a low budget for disaster prevention activities and lacks an exclusive staff, it has been inactive, and consequently, the people living in the municipality are lacking information about the hazards of their neighborhood and do not know how to cope with eventual emergencies.

### 3.3.2 Socio-Economic Condition

(1) Population

According to the Experimental Census 2003, Soacha is in the position fourteenth among 1,100 most populated municipalities with about 360 thousands inhabitants in 2003[12] (See Table 3-12).

Table 3-12 Experimental Census of Soacha 2003

| Area | Men | Women | Total | Total Houses |
|---|---|---|---|---|
| URBAN | | | | |
| Commune 1 | 38,511 | 40,818 | 79,329 | 19,638 |
| Commune 2 | 19,708 | 21,292 | 41,000 | 10,636 |
| Commune 3 | 24,816 | 26,095 | 50,911 | 12,987 |
| Commune 4 | 31,053 | 32,192 | 63,245 | 15,892 |
| Commune 5 | 27,882 | 30,811 | 58,693 | 17,127 |
| Commune 6 | 31,544 | 33,859 | 65,403 | 15,980 |
| Total | 173,514 | 185,067 | 358,581 | 92,260 |
| RURAL | | | | |
| Inhabit Center | 669 | 664 | 1,333 | 364 |
| Dispersal Rural | 1,641 | 1,464 | 3,105 | 1,017 |
| Special places for accommodation | 287 | 72 | 359 | |
| Total | 2,597 | 2,200 | 4,797 | 1381 |

*(Source: DANE, 2003 (Information compiled by Alcaldía de Soacha))*

The table shows that;

- most of the city's population was concentrated to the urban area of 19 $km^2$ of urbanized area,
- the city has a tendency of female population's prevalence which is same as nation's tendency, and
- concentration of family members is the same level as the national average of 3.9 people by household.

According to the information, which is prepared based on the DANE Experimental Census, the city experienced a high evolution in population in urban area. From 1985 to 1993, the population was growing at the rate of 5.9 %/annum with an increase of 6.3%/annum from 1993 to 2003.

---

12: Press statement, DANE, June 13 2003

Two river basins of Soacha River and Tibanica River are the target river basins for the Study on flood monitoring, and these river basins are located in Commune 2, 3, 4, 5 and 6 and the rural area of Bosatama, Panama, Fusunga, and San Jorge. The Study Areas for landslide's disasters are Altos de Cazuca in Commune 4 and Divino Niño in Commune 6 (Table 3-13, Barrio name details are presented in Annex S4-2-1, in supporting report.)

Table 3-13 Communes Related to the Study

| Commune/ Rural Area | Popuation | Disaster | Area | Remarks |
|---|---|---|---|---|
| Commune 2 | 41,000 | Flood | Soacha River | |
| Commune 3 | 50,991 | Flood | Tibanica River | |
| Commune 4 | 63,245 | Flood | Tibanica River | |
| | | Landslide | Alots de Cazuca | |
| Commune 5 | 58,693 | Flood | Tibanica River | |
| Commune 6 | 65,403 | Flood | Soacha River | |
| | | Landslide | Divino Niñp | |
| Corregimiento No.1 | 4,222 | Flood | Soacha River | Panama, Fusunga, San Jorge |
| Corregimiento No.2 | | Flood | Tibanica River | Bosatama |

*(Source: Soacha Municipality, compiled by the Study Team)*

(2) Economy in Soacha

Soacha significantly contributes in the regional economy. The GDP in Soacha exceeds 1.3 trillion ($1.3*10^{12}$) pesos in 2002 price and it shares 11.8% of the GDP of Cundinamarca Department.

Soacha is traditionally a mining town; estimations of 113 open sky exploitation mines[13], and the materials extracted are used for bricks, decorative stones, sand and other construction materials. This activity supports the local economy however it becomes a main cause of adverse effect of environment in the area, while industrial business contributes economic development of the municipality.

Soacha's main economic activity changed in the last decades moving from agriculture to services and industry activities. According to a survey carried out by the municipality in 2004, approximately 102 companies settled in Soacha, and 5,551 employees[14] providing jobs for non residents (61.08%) with higher education levels such as technical and professional careers were hired. Accordingly few opportunities were left to the locals with low skills which kept the informal and low qualified tasks.

Commercial activity in Soacha is relatively active compare to other municipalities in Cundinamarca with its economic share of 39%[15]. However, this commercial activity does not offer a wide range of employment opportunities or solutions to unemployment because in most cases these small businesses are attended by immediate family members.

In spite of its economic activity, Soacha remains a municipality with low budget, because of lower employment opportunities and an increasing rate of non-qualified and underemployed population. The city promotes its economic activities by helping the working population, to reduce their daily commuting distance and costs to Bogota in search for low pay jobs as domestics, street vendors, construction workers, security guards, or recycling workers.

(3) Socio-Economic Conditions

Since the Soacha Municipality continuously receives a large number of immigrants (Figure 3-4) from all over the country, it can be said that the socio-economic are affected by the presence of these immigrants.

[13] Planeacion Municipal, given by Ivan calderon, Ivan, Excel file, consolidado_SrIvan_Soacha.xls
[14] Source (http://www.alcaldiasoacha.gov.co/infoNoticia.asp?IdNot=131)
[15] Source: Alcaldía de Soacha website: (http://www.alcaldiasoacha.gov.co/infoNoticia.asp?IdNot=131)

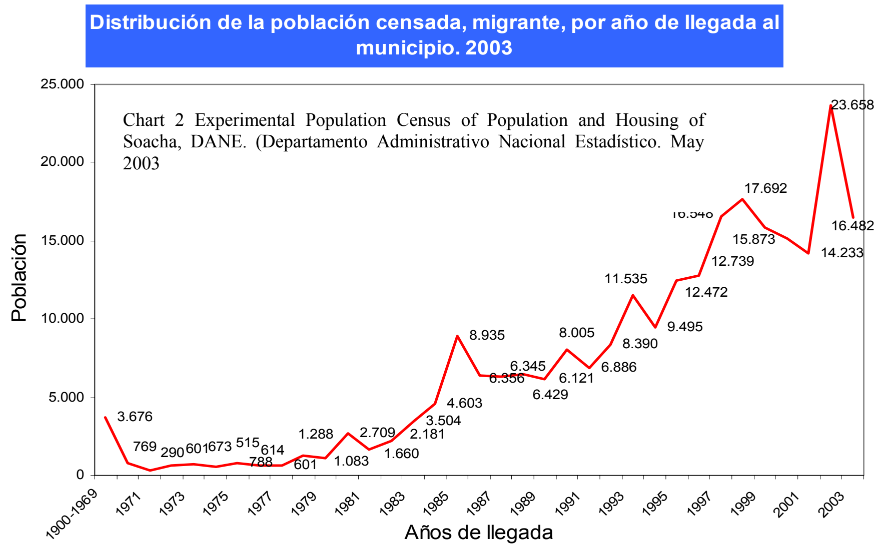



Figure 3-4 Immigrants to Soacha by Arrival Year

It is well known that the communities of displaced people and families are enjoying minimal infrastructure and deficient public services, including access to health. Their settlements are sometimes classified as informal settlements lacking of legal status or titles for their land. These undocumented “barrios” are living mainly in Communes 4 and 6[16].

Table 3-14 shows the comparison of living conditions between displaced people and people living in Strata 1 which is the lowest economic Strata[17]. The people living in Strata 1 have higher rate of housing ownership and better housing quality, however, either groups or people, they share insufficient access to proper aqueduct and drainage systems. The new comers have to build their houses with the cheapest most available low quality of materials.

Table 3-14 Socio Economic Indicator 2002

| Variable | Displaced people | Strata 1 |
|---|---|---|
| Percentage of houses owned by residents | 47.2 | 76.3 |
| Percentage of houses with permanent material walls. | 47.9 | 64.5 |
| Percentage of houses with disposable material walls. | 52 | 35.5 |
| Percentage of houses with aqueduct | 1.5 | 1.5 |
| Percentage of houses with sewage system | 13.4 | 14.1 |
| Percentage of houses with electrical energy | 95 | 97.7 |

*(Source: Organización Panamericana de la Salud/Instituto Nacional de Salud. 2002. Study of the epidemiological profile of displaced population and strata 1 non displaced in 4 cities of Colombia. Electronic version: http://www.disaster-info.net.co)*

In Soacha, those most exposed to harsh conditions are children, youth, elders and people with physical disabilities. The Social Development of the municipality has a list of local organizations classified by types which are working for the social activities in the municipality. According to the list, 57 organizations out of 217 currently devote the activities to physical disabilities, and another 32 groups are formed by -or working with- elders.

This shows that despite many people do not know each other, they come from different locations, altitudes, cultures and identity backgrounds, they know about mutual relations for self help, a key basis for identity reconstruction and collective problem solving.

[16] Garzón, Clara Stella. *Diagnóstico de Género de la Población de Soacha, con énfasis en las Mujeres Desplazadas*. Fondo de Desarrollo de las Naciones Unidas para la Mujer. UNIFEM. Colombia. 2005. www.acnur.org/biblioteca/pdf/4088.pdf.
[17] People under Strata 1 and Strata 2 earn below $300 a day.

(4) Public Services and Education

The municipality has a relatively high coverage of public services except Commune 4 where it suffers from lack of basic services with low coverage of 25% of electricity, water supply, and sewage system (Table 3-15).

According to the statistics of the Secretary of Eduction of Soacha Municipality, 165 schools are located within the municipality to provide education to the citizen. Most of the students are receiving traditional education in academic schools and barely a small percentage of total population can frequent the university.

Table 3-15 Public Services of Soacha Municipality

| Areas | Total Houses | Houses with Electricity, Water and Sewage | % | Houses with Telephone | % | Houses with GAS supply | % |
|---|---|---|---|---|---|---|---|
| Total | 84,318 | 66,664 | 79.06 | 65,063 | 77.16 | 52,199 | 61.91 |
| Commune 1 | 17,933 | 16,214 | 90.41 | 14,577 | 81.29 | 13,584 | 75.75 |
| Commune 2 | 9,782 | 9,144 | 93.48 | 8,014 | 81.93 | 685 | 70.03 |
| Commune 3 | 11,886 | 9,743 | 81.97 | 9,667 | 81.33 | 919 | 77.32 |
| Commune 4 | 14,063 | 3,569 | 25.38 | 8,077 | 57.43 | 305 | 21.69 |
| Commune 5 | 15,004 | 14,651 | 97.65 | 13,034 | 86.87 | 12,529 | 83.50 |
| Commune 6 | 14,159 | 13,159 | 92.94 | 11,612 | 82.01 | 9,738 | 68.78 |
| Rural Populated Center | 277 | 184 | 66.43 | 4 | 1.44 | 0 | 0.00 |
| Rural Dispersal | 714 | 0 | 0.00 | 78 | 10.92 | 3 | 0.42 |

*(Source: Emergency Plan of Soacha Municipality. Project Support to the mobilization of the Volunteers in attention and Response to the Emergency Declared in Soacha September 8th 2006.)*

### 3.3.3 Urban Planning

(1) Urban Expansion

With the permanent arrival of immigrants into the municipality, housing areas must be expanded. The land suitable for life has already been occupied and consequently only available spaces for immigrants under hardship conditions are the surroundings of the mining areas (quarries).

Management of closure processes of quarries are lack of strict compliance. The land recovery plans have been difficult to enforce. Many old mining areas are just left as it is, and becoming target areas for new informal settlements. As shown on the following photos, the uncontrolled urban expansion with poor infrastructures can be observed in many places within the municipal territory, and this situation creates unfavorable living conditions (poor infrastructure such as lack of road, water supply and sewerage, facing hazards, etc.).

Photo 3-1 Typical Pattern of Urban Expansion


Photo 3-2  Homes Built in the Foothills Old Mine and Facing Landslide Hazards


Photo 3-3  Neighborhoods Growth over Rural Hills

Photo 3-3 shows the case of Altos de Cazucá, an entire hill has been covered with many barrios in which more than 60,000 people live without any plan in terms of urban development.

In the informal development areas (non zoned area), no public works are allowed and due to this, investments in infrastructures has been thus delayed. Sloppy roads and rain runoff as well as sewerage overflow can be seen anywhere in and around the informal development areas.

There is growing concern about the pollution coming from other types of industries located in the urban center such as chemical industries, natural gas, textiles and gasoline stations, leading the authorities to increase controls over air quality and finding strategies to improve management for the drainage systems.

Other recent processes lead Soacha's communities and decision makers to face unforeseen challenges of development. The expansion of the public transportation system, with the construction of a new transect of the Transmilenio into Soacha's territory. The increase of individual's mobility will generate greater density patterns in the urban cluster, and spin-off new commercial and service activities.

(2) Territorial Ordering Plan (POT)

In order to regulate the uncontrolled urban expansion and normalize the land use by integrating the urban development and social, environmental and disaster management aspects, the POT 2000 Zoning Plan was established. However, it has been disrupted by the urban expansion, continuous migration and industrial growth. Areas that were once designated as open space, such as slopes and hills, old mines and rural lands have already been heavily populated and became hazardous areas for inhabitants.

To overcome the difficulties of the present situation the Soacha municipality is updating the POT 2000. At present there are four (4) phases and among them, the first phase (Validation) was recently finished, while the Second Phase (Assessment) is focusing on current conflicting topics, like transportation, connectivity, population and urban growth. The third and fourth phases are "Formulation and socialize", submission to Municipality Board, CAR and Territory Board for approval new POT.

The current analysis of the POT is looking at the hazard prone areas and activities, stressing the need to emphasize upon the development of policies to protect environmental resources and its enforcement.

(3) Barrio Area

Table 3-16 shows number of barrios in each Commune by legal status. As shown in the table, most of the illegal barrios can be found in Commune 4 where by displaced persons are mainly settled down, and Commune 6 with a high percentage of illegal settlements inhabited mainly by Soacha natives [18] and also by displaced people, that live for paying rent or paying a new house in illegal cheaper lands.

Table 3-16 Legality Condition of Barrios at Soacha Municipality

| COMMUNE | LEGAL | % | ILEGAL | % | TOTAL |
|---|---|---|---|---|---|
| Commune 1 | 31 | 79.5 | 8 | 20.5 | 39 |
| Commune 2 | 29 | 62.5 | 19 | 37.5 | 48 |
| Commune 3 | 29 | 100 | 0 | 0 | 29 |
| Commune 4 | 10 | 25.6 | 27 | 74.4 | 37 |
| Commune 5 | 96 | 100 | 0 | 0 | 96 |
| Commune 6 | 28 | 43.1 | 37 | 56.9 | 65 |
| Total | 223 | | 91 | | 314 |

*(Source: Soacha Municiaplity)*

For the legalization process in barrio areas, three independent processes need to occur; the legalization of the land, of the building or house and the legalization of the barrio as urban settlement. According to Decree 564 in 2006, any land ownership is not required for the process.

### 3.3.4 Citizen Participation

The office of community participation of the Soacha Municipality is in charge of supervising social organizations (e.g. JAL, JAC, etc.), while the Cundinamarca Government used to be in charge of this function before the new policies of decentralization in the nineties came into effect.

In Soacha as in Bogota, the “Ediles” are citizens elected by popular vote and they belong to JAL (Local Administrative Board) which are receiving supervision from Soacha Municipality. All six Communes in the urban area and two Jurisdictions in the rural area have JAL organization.

JAC is organized by community level and they are also directly supervised by the municipality, however, they can not be provided funds from the municipality. The activities of JAC are various, and JAC of Florida II which is located in the Study Area has shown positive achievements.

[18] Ramírez, Juan Carlos-Muñoz Jorge. *Así son los hogares en Soacha* . DANE. Bogotá, Abril 2004

The JAC of Florida II was constituted in 1986, and currently has now a total of 93 members. Nine (9) Board directors (originally 17 directors) are working actively. The Board of Directors; President, vice-president, Secretary and Treasurer and representatives composing commissions such as, Sports, Safety, and Health commissions are elected through neighborhood meeting held every four years.

As mentioned, since JACs can not be provided any funds from the municipality, the JAC of Florida II has planned and implemented fundraising events and activities, such as town fairs, voluntarily created by the community itself, and this JAC has being achieved several activities. In addition, this JAL is trying to work together with JAL even Ediles, Presidents of JAC, and Municipal Councils rarely work together.

### 3.3.5 Institutional Aspects on Disaster Management

(1) Legal Framework

Table 3-17 shows the legal situation for disaster management. This chronological review proves that the historical change of disaster management concept from the emergency response approach during the early eighties, to total risk reduction approach including institutional strengthening and land use regulations.

Table 3-17 Legal Situation for Disaster Management

| LAW/ DECREE | DESCRIPTION |
|---|---|
| 1982. Law-Decree 3489 | Ruled the Title VIII of the Law 09, 1979 and the Law-Decree 2341 de 1971 regarding to disasters. |
| | Classified the emergency situations. Organizes the National Committee of Emergencies. Creates the Emergencies Operations Center. Establishes the functions for the Regional and Local Committees. |
| | The planning is mentioned only as task, designated to Civil Defense, Art 20. |
| 1984. Decree 1547 | Created the National Fund of Calamities. Funds for catastrophes and similar situations. |
| 1989. Decree 919 | Organized The National System for the Prevention and Attention to Disasters. |
| | Art. 6. Establishes Regional and Local Committees for the Disasters Prevention in each one of the Municipalities, Departments, jurisdiction and Commissaries and Local Committees for Bogota. |
| 1989. Law 9 | Urban Reform Law explicitly frames local planning. |
| | Art. 4. Defines Hazard Zones. |
| 1997. Law 400 | Established criteria and minimum requirements for the new buildings and community recovery after an earthquake, forces by nature or use, with the purpose of increasing their resistance, decreasing the loss of human lives, and defending the State patrimony of State and citizens. |
| 1998. Presidential Decree No. 93 | National Plan for the Prevention and Disasters Attention. |
| | Guided the State and civil society towards prevention and hazards mitigation actions and the sustainable development of communities facing natural and anthropic events. |
| | Art. 3. Objectives of the National Plan for the Disasters Hazard reduction and disasters prevention. Effective response and rapid recovery of affected zones. |
| | Art. 5. General principles guiding actions of the territorial and national entities. |
| | Art. 6. General Strategies of the Plan for the Prevention and Disasters Attention. Knowledge of the natural and anthropic origin of hazards. Incorporation of prevention and hazards reduction in the land use sphere. Strength institutional development. Dissemination of prevention and disasters mitigation topics. |
| 2004 Decree 810 | Legal Disaster Management Soacha CLOPAD was created by Decree 810 in 2004 and modified by Decree 1065 in 2005. |
| 2005. Decree 1065. August 31st | |

*(Source: Document of the Base line SCI .Local Committer for the Attention and Disasters Prevention. CLOPAD. 2006. pp. 5-7.)*

(2) Local Disaster Management Capacity

1) CLOPAD and Soacha Municipality

Soacha Municipality establishes its local disaster prevention structure (CLOPAD) in 2005. It is composed of a range of existing local institutions related to disaster management such as firefighters or hospitals as well as Municipal Departments such as Infrastructure Department or Planning Department. Each institution has a specific function to avoid a duplication of tasks. Table 3-18 shows the inventory list of CLOPAD that is presented in the Base Line Document prepared in 2006.

Table 3-18 Inventory List of CLOPAD Resources

| Entity | Staff Number | Existing Resources |
|---|---|---|
| GOVERMENT ORGANIZATIONS | | |
| FIREFIGHTERS | 7 | Pumping machines, handy radios and base, rescue equipments, elements against fire, tools for manual removal and maintenance equipments, portable bed, vests, tapes, fire extinguisher, hydraulic jack, axes, lamps, hoses, special personal protection equipment for firefighters, pulleys, pistols, warning adds, drill and 3 vehicles of extinction and 1 rescue car. |
| CIVIL DEFENSE | 56 | First aid kits type vest and box type, folding and rigid portable beds, immobilization necks, rescue equipments, fire extinguishers, communications equipment, helmets, ropes, chemical and water fire extinguishers, gloves, lanterns, equipments and tools for manual removal, handy radios and base transceivers. |
| POLICE | 213 | n/d |
| ARMY | 180 | n/d |
| TOTAL STAFF | 456 | |
| OTHER INSTITUTIONS | | Police stations: Centro, Compartir, El Chicó, San Mateo, La Despensa, Leon XIII, Military Base Indumil, Base Military Ciudadela Sucre, District 59 Army, CT.I Soacha, transit and circulation, DNPAD, DPAE, CREPAD, Police stations 1st,2nd, 3rd, 4th, 5th and 6th. Police Inspections Corregimientos No1 and No 2 and Health local management, E.S.E Municipal Health, Soacha Hospital and Education Secretary. |
| PRIVATE ENTITIES, PERSONAL SUPPORT (SECURITY BRIGADES , OPERATING GROUPS) | | |
| CODENSA | 10 | n/d |
| EAAB | 10 | n/d |
| SERVIGENERALES | 15 | n/d |
| SOCILUZ | 30 | n/d |
| TOTAL STAFF | 65 | n/d |
| HEALTH STAFF (DOCTORS, NURSES, OTHERS) | 116 | n/d |
| HUMAN TALENT HOSPITAL MARIO GAITAN YANGUAS | 49 professionals<br>10 nurses<br>62 auxiliary nurses<br>3 watchmen<br>5 drivers<br>4 radio operators<br>5 RX technicians. | 124 beds, 1 operating room , 1 revival room 1 lab , 1 images scanner, ultrasound 4 hours, 1 room of respiratory therapy, 1 land phone, 1 radio, urgencies network (dentist network), 3 ambulances of low complexity, 1 van, 1 car, electrical plant capacity 150A, 1 oxygen central, 1 morgue capacity level 3. |
| EMPRESAS DE SALUD DE SOACHA | 5 doctors<br>5 auxiliary nurses<br>2 health promoters<br>1 chief nurse | 18 metallic foldable beds, 15 gynecological foldable beds, 1 foldable bed, 1 wood foldable bed with immobilization. |
| OF ALCALDIA SOACHA | 50 | 3 trucks, 1 backhoe,1 charger,1 motoniveladora,1 water tank car for water transportation, y 4 firefighters machines |
| OF CLOPAD | | 40 fixed first aid kits, 4 rigid foldable beds, 3 foldable beds brand Miller, 1 campaign foldable bed 1 immobilization vest 1 batteries lantern, and two megaphones. |
| TOTAL HUMAN RESOURCES | 708 | |

*(Source: Base Line Document SCI CLOPAD 2006. PP 36-42)*

The followings should remain as lessons learned during the emergency in May 2006.

- It is necessary to consolidate the plans and protocols, and to establish a routine for their upgrading.
- It is necessary to improve at least one road in the high hazard area as an infrastructure of emergency operation.
- It is necessary to have an office and warehouse for CLOPAD to ensure the logistic support for emergency operation.
- Stable funds for disaster prevention, response and permanent resettlement are required.
- Training at all levels from government to community is necessary to enhance the capacity to cope with disasters.

The direction of the municipality has lead towards working among agencies. A collaboration among institutions and NGOs has been established since 2004. Currently, Red Cross Cundinamarca, OPS/OMS and the National University, Center for Disaster Prevention (CEPREVE)[19], PAHO/WHO and UNDP are carrying out programs.

PAHO/WHO has been actively developing the local capacity. The UNDP is conducting a local program with a local planning process with components such as construction capacity, leadership, training and implementation of some communitarian projects, however, the efforts are concentrating just in Commune 4.

2) Firefighters

Firefighter is one of main actors in disaster management especially emergency response. Firefighter's department of the Soacha Municipality is in operation around the clock. However, staff and equipment are very limited even for the daily operation.

Firefighter's department of has an extensive training curriculum for any volunteer willing to serve, ranging from practical emergency skills such as use of manual ladders, electricity basics or vehicle rescue to planning principles, firefighter's legislation or management. More specialized topics add close to 90 extra training hours, in order to be a Fire-fighter 2, which learn skills like applied hydraulics or advanced rope maneuvers. The curriculum of the firefighter training is presented in the Annex S4-2-4 in Supporting Report.

(3) Community Awareness and Response

Before the Study started in 2006, as the communities in the Study Area were facing frequent disaster events, the awareness on the disasters were relatively high even CLOPAD did not actively working. According to the results of the Community Survey done by the Study Team, the population has received little knowledge and training on disaster activities. Nevertheless, their willingness to learn and collaborate is honorable.

However, in the course of the Study, CLOPAD has been working actively with Red Cross and other international organizations such as UN and JICA, as a result the CLOPAD and communities' capacity and experiences have been enriched.

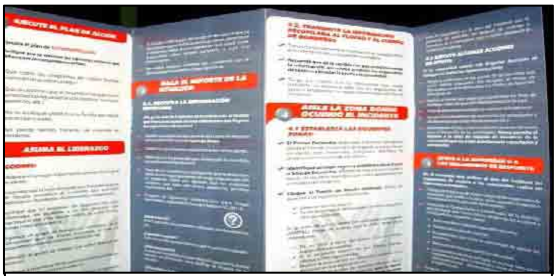
CLOPAD prepared a "Municipal Emergency Plan" with the support of UN Volunteers. These documents cover the resource inventory with contact details as well as a broader contact list and the drafts of three types of Protocols -First Respondent, Rescue Organisms and Business, and it was distributed by the municipality during middle of 2007.

---

[19] Need Assessment. Altos de Cazucá, Municipio de Soacha. OCHA. Junio de 2006.

www.colombiassh.org/imagenes_nuevas/documentos/Need_Assesment_Soacha_14.06.06.pdf

The protocol for the first respondent covers community's protocol as first responder of disaster event (See Annex S4-2-6 in Supporting Report).



The protocol for Community First Respondent contains five steps: 1. Execute the Action Plan 2. Engage leadership 3. Make situational report 4. Isolate incident zone 5. Support the response authorities.


Photo 3-4 Protocol for Community as First Respondent

"Family Emergency Plan" has been produced by the municipality with the support of the UN System (OPS/OMS, OCHA, UNICEF, UNDP and UNV). This guide aims to be a tool for families to be prepared for any hazardous event, and it includes generic preparation measures for different hazards: flood, fire, strong winds, earthquakes, excessive cold and hot temperatures, and droughts, radioactive and chemical pollution. To be highlighted are the recommendations before and during flood emergencies are included. These cover communication suggestions, mobility precautions, hygiene measures, and mutual support recommendations.

Family Emergency Plan also shows the list of minimum emergency kits recommended by CLOPAD and the instruction for Evacuation.

These materials are very useful and continuous improvement especially with careful review of the wording used in these documents to be meaningful for the target groups is required.

In December 2007, Soacha Municipality and Red Cross prepared a report called "Strengthening of risk management capacity in Soacha Municipality". Soacha Municipality and Red Cross hold a series of workshop containing CLOPAD officers, educative institutions and communities since August 2007. In the workshops for educative institutions, there were 630 people participated from school. In the workshops for communities, 213 people participated from 6 communes. In the course of there workshops, Communities and educative institutions increased their awareness for disaster prevention activities and recognized the importance of collaboration between them.

CHAPTER 4 RAINFALL AND DISASTERS

# 4.1 Analyses for Target Basins in Bogota

## 4.1.1 General Characteristic of Disasters and Selection of Disaster Events for Analyses

### (1) Landslide

Figure 4-1 shows the frequency of landslide events in five (5) localities including target basins in Bogota. Landslides frequently occur in latter month of first rainy season from March to May. The frequency shown in the figure includes all events categorized in “Fenómeno de Remoción en Masa (Landslide)” in disaster records of DPAE from January 2002 to July 2006, which concerns various phenomena such as slope failure, rockfall, earth flow, etc., and it is presumed that their causes vary from rainfall to accidental impacts. Many landslide events may occur by accidental impacts regardless of rainfall. In order to confine the cause of landslides through natural condition from mainly rainfall as much as possible, the analysis is targeting at only the date when a number of landslides were recorded in the same basin on the same date since it is difficult to specify the causes of landslides from the information of the database. Selected events are shown in Table 4-1.

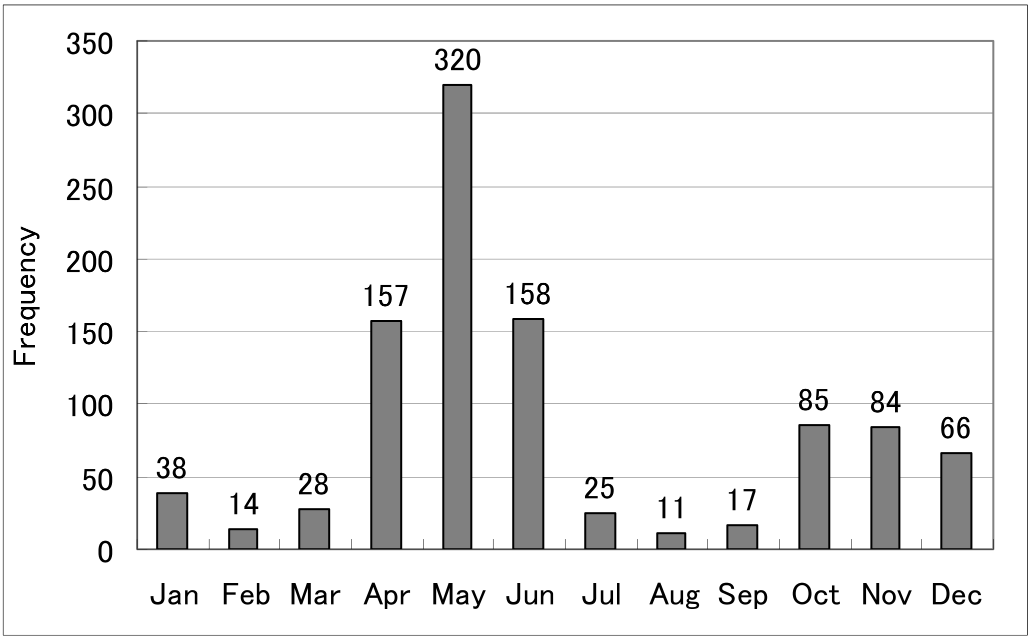



Figure 4-1 Frequency of Landslide Events (2002 Jan. - 2006 Jul)
in Tunjuelito, Rafael Uribe, San Cristobal, Ciudad Bolivar and USME Localities

Table 4-1 Selected Landslide Events for Analysis in Target Basins in Bogota

| Date | Chiguaza | Yomasa | Santa Librada | Estrella &Trompeta |
|---|---|---|---|---|
| 2004/11/16 | | | | Quiba, Bellavista Lucero Alto |
| 2004/11/17 | San Agustin (2), Los Libertadores, La Picota | Monte Blanco (2) | | El Tesoro, Quiba, Bellavista Lucero Alto |
| 2005/5/4 | Canada o Guira, Diana Turbay Cultivos, Las Guacamayas, Arrayanes, | | | |
| 2005/5/5 | Altamira, El Playon | | | |
| 2005/10/26 | Moralba, Diana Turbay Cultivos | | | |
| 2005/11/16 | Los Alpes, Nueba Delly | | | |
| 2005/12/6 | Diana Turbay, Cerros de Oriente, Santa Rita Sur Oriental | | | |
| 2006/1/14 | | | | Estrella del Sur, Sumapaz |
| 2006/3/27 | Diana Turbay, El Playon | | | |
| 2006/4/6 | Cerros de Oriente, Altamira (2) | | | |
| 2006/4/12 | Los Alpes, Arrayanes | | | |
| 2006/4/14 | El Playon (2) | | | |
| 2006/4/17 | Diana Turbay Cultivos (2), Quindio | | | |
| 2006/5/4 | Palermo Sur, Cerros de Oriente | | | |
| 2006/5/5 | | Marichuela, La Cabana | | |
| 2006/5/6 | Guiparma, Canada o Guira, Diana Turbay | | | Lucero del Sur, Estrella del Sur |
| 2006/5/8 | Los Libertadores, Arrayanes | | | Mexico, Quiba, Bellavista Lucero Alto |
| 2006/5/9 | Diana Turbay Cultivos, Los Alpes (2) | | | |
| 2006/5/10 | Canada o Guira, Moralba | | | |
| 2006/5/10 | | | | Billavista Lucero Alto, Estrella del Sur |
| 2006/5/11 | | | | El Tesoro (2) |
| 2006/5/12 | Canada o Guira, La Gloria Occidental | | | |
| 2006/5/19 | Los Molinos, Las Guacamayas | | | |
| 2006/5/30 | Atenas, El Playon | | | |
| 2006/6/12 | | | | Quiba, Naciones Unidas |

(2) Inundation

In the Study Area in Bogota, inundation phenomena are categorized in following three (3) types: 1) High water and overflow of creeks, 2) overflow of drainage system, and 3) backwater through sewerage. In the Study area, the sewerage is connected directly to the creeks, therefore an inundation due to the backwater through the sewer pipes may occur even though the water level of the creek does not exceed the bank height. At the same time, an inundation occurs due to lack of drainage because the storm sewerage system is not laid down or does not have enough capacity in some barrios.

Figure 4-2 shows the frequency of inundation events in five (5) localities including target basins in Bogota. Inundations frequently occur in two (2) rainy seasons especially in the second rainy season from October to December. The frequency shown in the figure includes all the events categorized in "Inundación (Inundation)" in disaster records of DPAE from October 2001 to June 2006, which concerns not only high water and overflow of the creek but also overflow of drainage system and backwater through the sewerage as described above.

Distinction of the type of inundation is extremely difficult due to the insufficient information, whereas the main target of the analysis is the inundation by high water and overflow of the creeks. Table 4-2 and Figure 4-3 summarize the inundation events in target basins, which can recognize as much as possible to be caused by high water and overflow of the creeks out of the records of DPAE. Table 4-1-2 shows the inundation events to be caused by high water and overflow of the creeks, which are the results of the on-going study by IDEAM for DPAE. Both DPAE records and IDEAM study results don't include the enough information to comprehend the magnitude of inundation, such as inundation depth, inundated area and damage, therefore it is able to analyze only the relation between rainfall amount and occurrence of inundation. The inundation events as shown in Table 4-2 and Table 4-3 are used for the analysis of relation between rainfall and inundation.

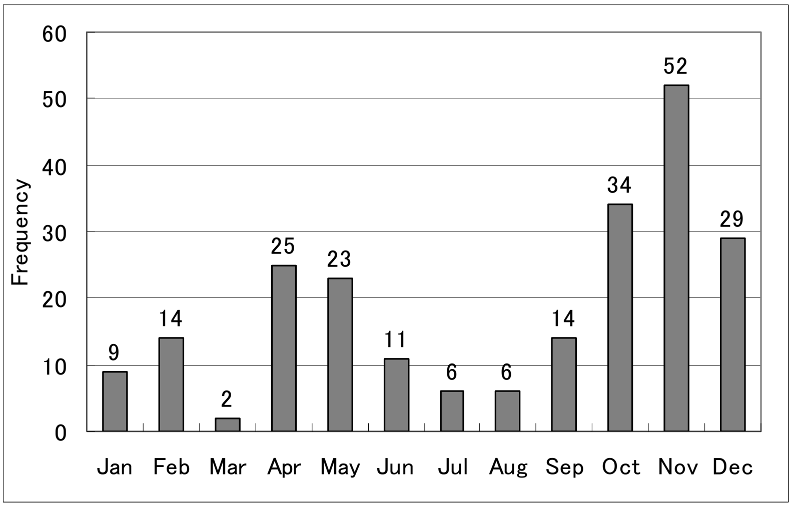



Figure 4-2 Frequency of Inundation Events (2001 Aug. - 2006 Jun.)
in Tunjuelito, Rafael Uribe, San Cristobal, Ciudad Bolivar and USME Localities

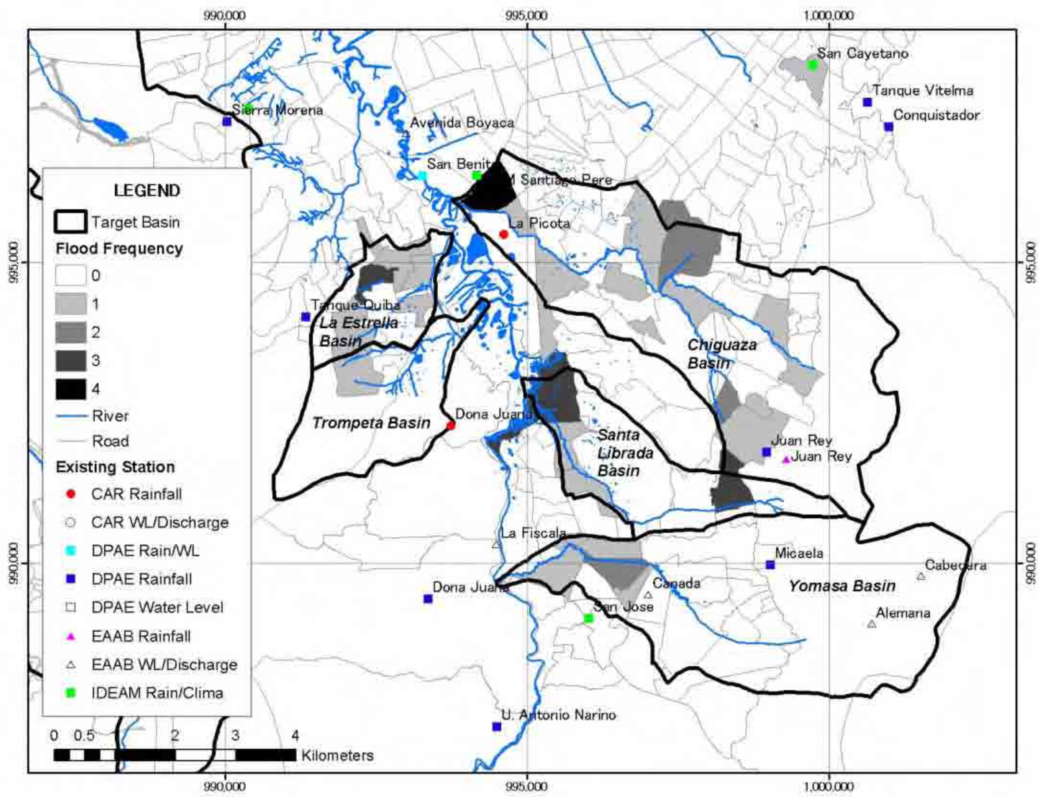



Figure 4-3 Inundation Frequency in Target Basin in Bogota

Table 4-2 Inundation Record by DPAE in Target Basins in Bogota

| Date | Chiguaza | Yomasa | Santa Librada | Estrella & Trompeta |
|---|---|---|---|---|
| 2002/1/20 | Abraham Lincon | | | |
| 2002/2/10 | Guacamayas | | | |
| 2002/2/11 | Sasn matin de loba | | | |
| 2002/4/28 | | | | La Alameda |
| 2002/5/28 | | | Santa Marta | |
| 2002/5/29 | Nueva Delly | | | |
| 2002/5/31 | Tunjuelito | | | |
| 2002/6/4 | | | | Bellavista Lucero Alto |
| 2002/6/9 | La Belleza | | | |
| 2002/6/24 | Tunjuelito | | | |
| 2002/10/29 | | Charala | | |
| 2002/12/20 | | Chuniza | | |
| 2003/10/5 | | | | Naciones Unidas |
| 2003/10/26 | Cerros del Oriente - El Rosal, San Martin, Las Gaviotas | | | La Estrella |
| 2003/11/23 | | | Yomasa, Santa Marta | |
| 2003/11/25 | | | | Lucero |
| 2003/11/26 | La Belleza | | | |
| 2003/11/30 | Guacamayas, Villas del Diamante | | Santa Librada | |
| 2003/12/1 | | | | Tesorito |
| 2003/12/3 | | | | Buenos Aires |
| 2003/12/4 | | | | Lucero Bajo |
| 2004/2/25 | Tunjuelito | | | |
| 2004/4/22 | | | | La Estrella |
| 2004/5/20 | | | | El Tesoro |
| 2004/7/31 | San Benito | | | |
| 2004/10/1 | Tunjuelito | | | |
| 2004/10/20 | | | | Bellavista Lucero Alto |
| 2004/10/24 | Juan Rey (La Paz) | | | |
| 2004/10/25 | | | | Arabia |
| 2004/11/9 | Arboleda Sur | | | |
| 2004/11/15 | | La Reforma | | |
| 2005/1/29 | | | Santa Librada | |
| 2005/5/5 | Diana Turbay Arrayanes | | | |
| 2005/5/23 | | Tihuaque | Tihuaque | |
| 2005/9/25 | | | La Aurora | Bellavista Lucero Alto, Sotavento |
| 2005/9/29 | Abraham Lincon | | | |
| 2005/12/5 | Diana Turbay Cultivos, Altamira, San Martin Sur | | | |
| 2005/12/7 | Canada o Guira | | | |
| 2006/5/10 | | Gran Yomasa, Monte Blanco | | Sumapaz |
| 2006/5/11 | La Picota | | | |

Table 4-3 Inundation Record in 2000 - 2005 by IDEAM Study in Target Basins in Bogota

| Date | Chiguaza | Yomasa | Santa Librada | Estrella & Trompeta |
|---|---|---|---|---|
| 2002/1/20 | Abraham Lincon | | | |
| 2002/2/10 | Guacamayas | | | |
| 2002/2/11 | Sasn matin de loba | | | |
| 2002/4/28 | | | | La Alameda |
| 2002/5/28 | | | Santa Marta | |
| 2002/5/29 | Nueva Delly | | | |
| 2002/5/31 | Tunjuelito | | | |
| 2002/6/4 | | | | Bellavista Lucero Alto |
| 2002/6/9 | La Belleza | | | |
| 2002/6/24 | Tunjuelito | | | |
| 2002/10/29 | | Charala | | |
| 2002/12/20 | | Chuniza | | |
| 2003/10/5 | | | | Naciones Unidas |
| 2003/10/26 | Cerros del Oriente - El Rosal, San Martin, Las Gaviotas | | | La Estrella |
| 2003/11/23 | | | Yomasa, Santa Marta | |
| 2003/11/25 | | | | Lucero |
| 2003/11/26 | La Belleza | | | |
| 2003/11/30 | Guacamayas, Villas del Diamante | | Santa Librada | |
| 2003/12/1 | | | | Tesorito |
| 2003/12/3 | | | | Buenos Aires |
| 2003/12/4 | | | | Lucero Bajo |
| 2004/2/25 | Tunjuelito | | | |
| 2004/4/22 | | | | La Estrella |
| 2004/5/20 | | | | El Tesoro |
| 2004/7/31 | San Benito | | | |
| 2004/10/1 | Tunjuelito | | | |
| 2004/10/20 | | | | Bellavista Lucero Alto |
| 2004/10/24 | Juan Rey (La Paz) | | | |
| 2004/10/25 | | | | Arabia |
| 2004/11/9 | Arboleda Sur | | | |
| 2004/11/15 | | La Reforma | | |
| 2005/1/29 | | | Santa Librada | Paraiso Quiba |
| 2005/5/5 | Diana Turbay Arrayanes | | | |
| 2005/5/23 | | Tihuaque | Tihuaque | |
| 2005/9/25 | | | La Aurora | Bellavista Lucero Alto, Sotavento |
| 2005/9/29 | Abraham Lincon | | | |
| 2005/12/5 | Diana Turbay Cultivos, Altamira, San Martin Sur | | | |
| 2005/12/7 | Canada o Guira | | | |
| 2006/5/10 | | Gran Yomasa, Monte Blanco | | Sumapaz |
| 2006/5/11 | La Picota | | | |

### 4.1.2 Analysis for Relation between Rainfall and Selected Disaster Events

(1) Rainfall Stations for Analyses

The relation between rainfall and disaster is analyzed using collected daily and hourly rainfall data, and selected disaster records.

The stations using the rainfall data for the analyses are La Picota station (CAR) for Chiguaza basin, Juan Rey station (EAAB) for Chiguaza and Santa Librada basins, Micaela station (DPAE) for Santa

Librada and Yomasa basins, and Tanque Quiba station (DPAE) for La Estrella and Trompeta basins, which are selected in consideration of their locations. The selected stations for the analyses are shown in Figure 4-4.

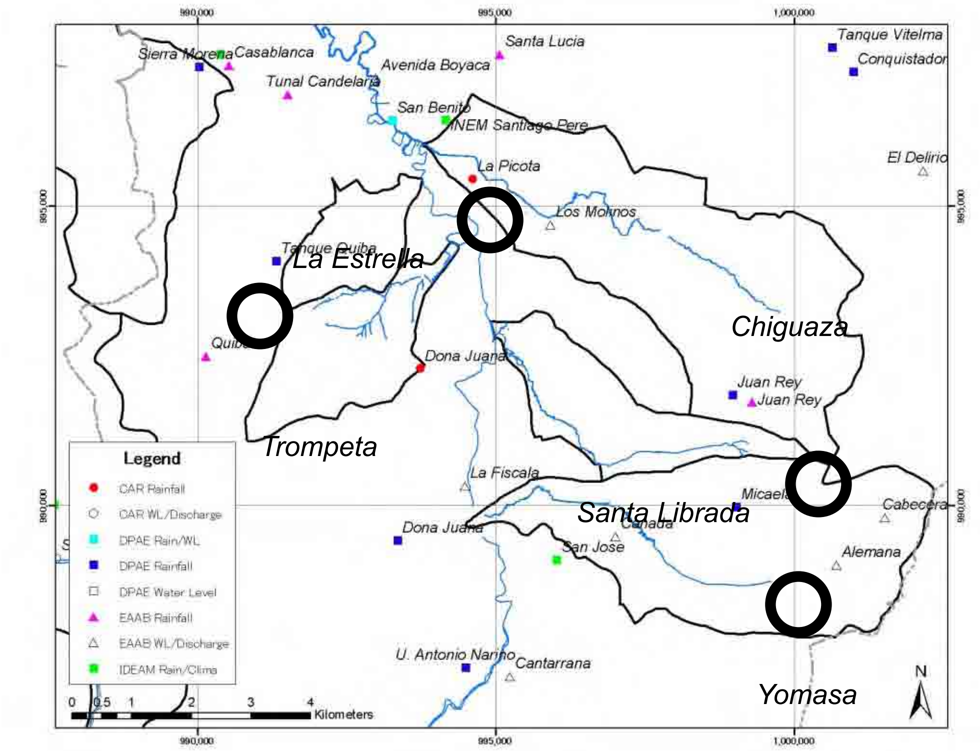



Figure 4-4 Selected Stations for Analysis

(2) Analyses for Landslide

Table 4-4 summarized the daily rainfall amount in the day when a number of landslides occurred in each basin on the same date.

Table 4-4 Daily Rainfall of the Day of Landslides Occurrence

| Basin/Station | No. of Days when a Number of Landslides Occurred from 2002 to 2006 | Daily Rainfall (mm) | | | | |
|---|---|---|---|---|---|---|
| | | < 5 | < 10 | < 15 | < 20 | < 25 |
| Chiguaza Basin (Juan Rey (EAAB)) | 18<br>100%(18/18) | 8<br>44%(8/18) | 14<br>78%(14/18) | 17<br>94%(17/18) | 17<br>94%(17/18) | 18<br>100%(18/18) |
| Yomasa Basin (Micaela (DPAE)) | 2<br>100% | 0<br>0% | 0<br>0% | 1<br>50% | 2<br>100% | 2<br>100% |
| Santa Librada | 0 | - | - | - | - | - |
| La Estrella Basin (Tanque Quiba (DPAE)) | 8<br>100% | 5<br>63% | 6<br>75% | 6<br>75% | 8<br>100% | 8<br>100% |
| Trompeta Basin (Tanque Quiba (DPAE)) | 3<br>100% | 3<br>100% | 3<br>100% | 3<br>100% | 3<br>100% | 3<br>100% |
| Total | 31<br>100% | 16<br>52% | 23<br>74% | 27<br>87% | 30<br>97% | 31<br>100% |

More than 50% of landslides occurred less than 5 mm of daily rainfall. It is difficult to understand the characteristics of rainfall in landslides occurrence using only daily rainfall of the day of the landslides occurrence. Thus, antecedent rainfall is investigated for the analysis. Figure 4-5 shows the various type of rainfall amount of Juan Rey (EAAB) station in landslides occurrence in Chiguaza basin and the average values in Juan Rey (EAAB) station for comparison. The upper values with box in each category are the rainfall amount in landslides occurrence. Accumulative rainfall is a total rainfall amount up until the calculated day (the day of landslides occurrence), which was calculated adding the entire daily rainfall amount after the day when the daily rainfall was zero (0) previously. For example, when the daily rainfall was zero (0) before 2 days of the calculated day, accumulative rainfall is total rainfall amount of the previous day and the calculated day.

From the following figure, the obvious differences of the tendency are not seen in the cases of occurrence day and daily rainfall (average), and occurrence day & previous day and 2 days rainfall (average). On the other hand, differences can be clearly found in case of accumulative rainfall, and can be recognized in 3 days and 4 days rainfall. DPAE already sets and uses the 3 days rainfall for the criteria in the current monitoring system. Therefore, analyses are undertaken using accumulative rainfall and 3 days rainfall (rainfall of occurrence day and previous 2 days).

The relation between landslide events and three (3) days or accumulative rainfall is summarized in Tabl 4-5. In the table, the percentage of "Landslide" rows constitutes the rate of the number of days with the designated rainfall amount when landslides occurred, and the percentage of "Average" rows is the rate of the number of days with the designated rainfall amount in the period of 2001-2006.

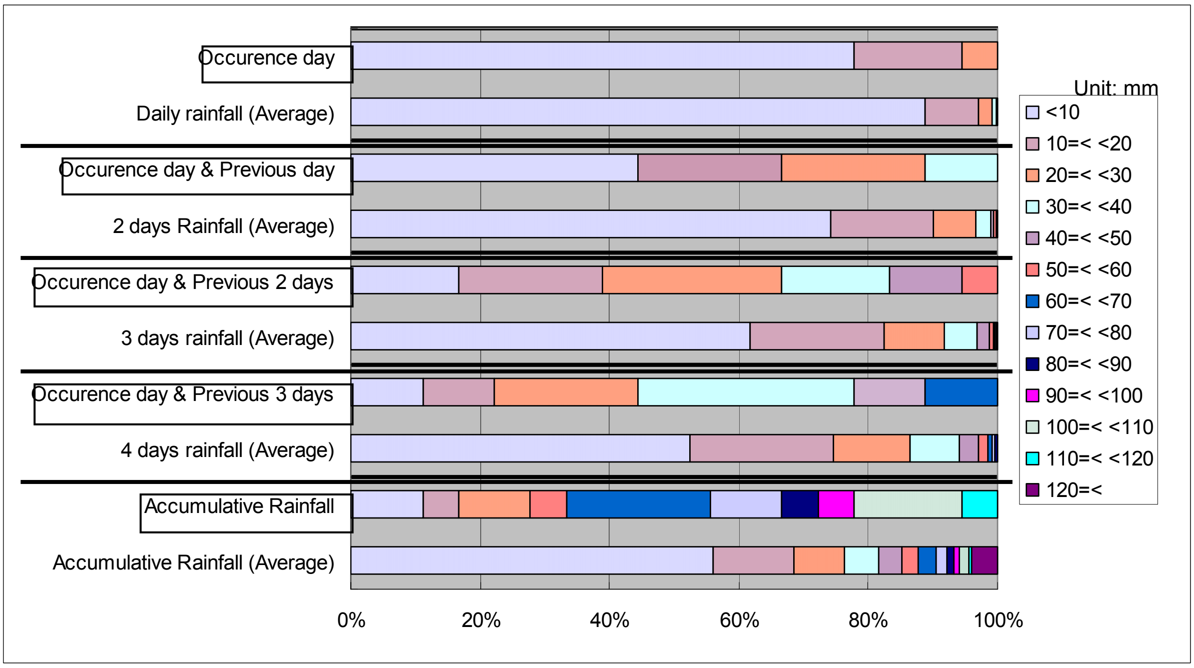



Figure 4-5 Various Rainfall Amount in Landslides Occurrence and Average Values in Juan Rey Station (EAAB)

Table 4-5 Summary of Relation between Rainfall and Landslide Events

| Basin | Rainfall | | Rainfall (mm) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | <10 | <20 | <30 | <40 | <50 | <60 | <70 | <80 | <90 | <100 | <110 | <120 | 120=< |
| Chiguaza (Juan Rey) | 3 days Rainfall | Landslide | 17% | 39% | 67% | 83% | 94% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | Average | 62% | 83% | 92% | 97% | 99% | 99% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | Accum. Rainfall | Landslide | 11% | 17% | 28% | 28% | 28% | 33% | 56% | 67% | 72% | 78% | 94% | 100% | 100% |
| | | Average | 56% | 68% | 76% | 82% | 85% | 88% | 91% | 92% | 93% | 94% | 96% | 96% | 100% |
| Yomasa (Micaela) | 3 days Rainfall | Landslide | 0% | 0% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | Average | 63% | 83% | 93% | 97% | 99% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | Accum. Rainfall | Landslide | 0% | 0% | 0% | 0% | 50% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | Average | 54% | 66% | 75% | 80% | 84% | 88% | 89% | 91% | 92% | 93% | 94% | 95% | 100% |
| La Estrella (Tanque Quiba) | 3 days Rainfall | Landslide | 13% | 25% | 75% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | Average | 86% | 95% | 98% | 99% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | Accum. Rainfall | Landslide | 13% | 13% | 25% | 50% | 75% | 75% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | Average | 84% | 91% | 95% | 97% | 98% | 99% | 99% | 100% | 100% | 100% | 100% | 100% | 100% |
| Trompeta (Tanque Quiba) | 3 days Rainfall | Landslide | 0% | 0% | 67% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | Average | 86% | 95% | 98% | 99% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | Accum. Rainfall | Landslide | 0% | 0% | 33% | 33% | 67% | 67% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | Average | 84% | 91% | 95% | 97% | 98% | 99% | 99% | 100% | 100% | 100% | 100% | 100% | 100% |

Either of three (3) days rainfall and accumulative rainfall is considered to be able to use as the threshold for general warning. However, for those relevant days are quite frequent using them independently, investigation of their combination is attempted.

The classification of thresholds is set to three and is determined using the rate of occurrence of past landslides. Since there are a lot of pattern of the combination of three (3) days rainfall and accumulative rainfall, which satisfy a certain rate of occurrence, three (3) days rainfall and accumulative rainfall are combined by the following way: 1) three (3) days rainfall is temporarily fixed as a base, and 2) combination pattern is adjusted by accumulative rainfall. This is because three (3) days rainfall is regarded to be easy to handle in actual operation than accumulative rainfall that needs the longer time for data collection.

Table 4-6 shows the example of the combination of three (3) days rainfall and accumulative rainfall as a threshold, and probable annual frequency. This is nothing but the example. On the occasion that actual threshold is going to be determined, more detailed and careful investigation should be conducted. For example, it should be carefully investigated whether two (2) kinds of rainfall amounts shall be used independently or in combination. Whatever, grasping and recording the exact phenomena and conditions of disasters are absolutely necessary.

Table 4-6 Example of Thresholds for General Warning of Landslide

| Criteria / Basin/Station | Occurrence probability More than 70% | Occurrence probability Less than 50% | Occurrence probability Less than 30% |
|---|---|---|---|
| Chiguaza Basin Juan Rey (EAAB) | 3days Rain > 10mm & Accum. Rain > 20 mm | 3days Rain > 20mm & Accum. Rain > 50 mm | 3days Rain > 30mm & Accum. Rain > 70 mm |
| Probable Annual Frequency (days) | 94 | 28 | 12 |
| Yomasa Basin Micaela (DPAE) | 3days Rain > 30mm & Accum. Rain > 40 mm | 3days Rain > 30mm & Accum. Rain > 50 mm | 3days Rain > 40mm & Accum. Rain > 50 mm |
| Probable Annual Frequency (days) | 21 | 17 | 9 |
| La Estrella Basin Tanque Quiba (DPAE) | 3days Rain > 20mm & Accum. Rain > 20 mm | 3days Rain > 20mm & Accum. Rain > 40 mm | 3days Rain > 20mm & Accum. Rain > 50 mm |
| Probable Annual Frequency (days) | 18 | 6 | 4 |
| Trompeta Basin Tanque Quiba (DPAE) | 3days Rain > 20mm & Accum. Rain > 20 mm | 3days Rain > 20mm & Accum. Rain > 50 mm | 3days Rain > 30mm & Accum. Rain > 50 mm |
| Probable Annual Frequency (days) | 18 | 4 | 2 |

(3) Analyses for Inundation

Since catchment areas of Target Rivers are small and their principal river lengths are short, for example, catchment area of Chiguaza river that is largest river among the Target Rivers is about 19 $km^2$ and its river length is about 7 km, their concentration time is regarded as a short time. In addition, rainfall data collected from the related organizations is only daily rainfall except DPAE's data. Therefore, analyses are conducted mainly using daily rainfall of the day when inundation occurred.

1) Analysis for Relation between Annual Top 10 of Rainfall and Inundation Events

For a better understanding of the rainfall characteristic in inundation, the relation between annual top 10 of rainfall and inundation events is analyzed. The analysis is done by the following procedure:

1. To select the annual top 10 of rainfall in each year in selected stations from 2000 to 2006
2. To check whether inundations occurred or not in the day when annual top 10 of rainfall was recorded

The results of analysis are shown in Table 4-7 for daily rainfall and Table 4-8 for hourly rainfall, respectively. In the Table 4-7 and Table 4-8, "No. of Days when Inundation Occurred from 2001 to 2006" literally shows all the number of the day when inundation occurred in each basin from 2001 to 2006, and the values of each row show the number of inundation events in each basin, which occurred when the top 10 of daily rainfall was recorded in each station.

Table 4-7 Summary of Relation between Annual Top 10 of Daily Rainfall and Inundation Events

| Station / Basin | *No. of Days when Inundation Occurred from 2001 to 2006* | La Picota (CAR) | Juan Rey (EAAB) | Micaela (DPAE) | Tanque Quiba (DPAE) |
|---|---|---|---|---|---|
| Chiguaza | *38* | 8 | 6 | - | - |
| Yomasa | *9* | - | - | 3 | - |
| Santa Librada | *11* | - | 6 | 5 | - |
| La Estrella | *15* | - | - | - | 9 |
| Trompeta | *7* | - | - | - | 5 |

Table 4-8 Summary of Relation between Annual Top 10 of Hourly Rainfall and Inundation Events

| Station / Basin | *No. of Days when Inundation Occurred from 2001 to 2006* | Micaela (DPAE) | Tanque Quiba (DPAE) |
|---|---|---|---|
| Yomasa | *9* | 4 | - |
| Santa Librada | *11* | 5 | - |
| La Estrella | *15* | - | 5 |
| Trompeta | *7* | - | 3 |

From the above results, it can be said that the relation between occurrence of past inundations and heavy rainfall are comparatively high in Santa Librada, La Estrella and Trompeta basins, whereas its relation is comparatively low in Chiguaza and Yomasa basins. However, it can be hardly said that heavy rainfall is directly related to inundation.

The following reasons or possibilities can be considered as the above explanation:

i) Since catchment areas of Santa Librada, La Estrella and Trompeta basins are less than 6 $km^2$, the nearby rainfall stations can represent the rainfall in all the basins. On the other hand, nearby stations in Chiguaza and Yomasa basins cannot able to represent the rainfall in the basins because their basins have comparatively large catchment areas of about 19 $km^2$ and 15 $km^2$, respectively.

ii) The spatial rainfall pattern in the Study Area may be extremely local.

2) Relation between Rainfall and Inundation Events

Figure 4-6 shows the daily rainfall in all the day when inundation occurred in Chiguaza basin from 2001 to 2006.

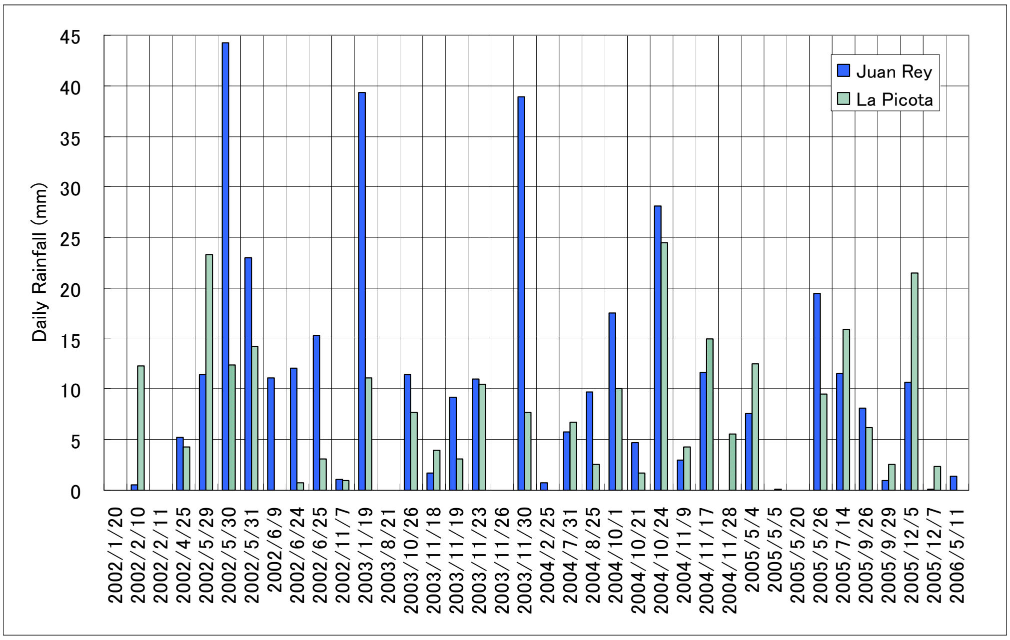
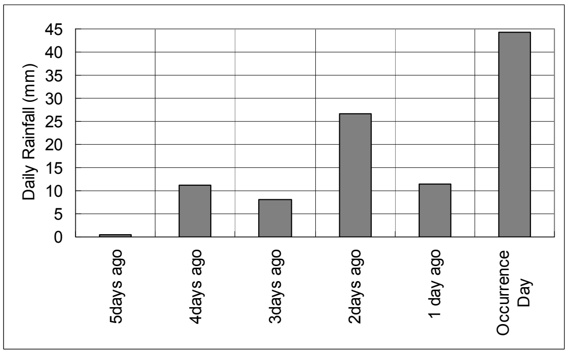



Figure 4-6 Relation between Daily Rainfall in Juan Rey (EAAB) and La Picota (CAR) Stations and Inundation Events in Chiguaza Basin

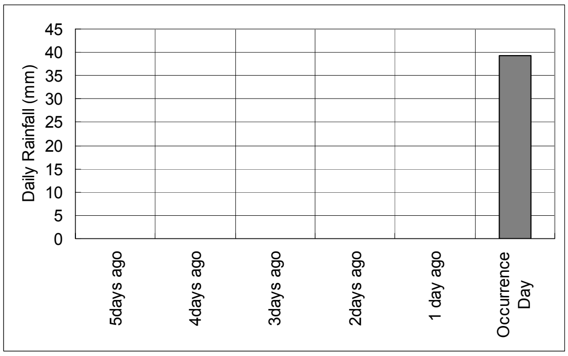
In the above figure, inundations occasionally occurred when the rainfall amount is very small or in no rainfall. The following reasons may be considered:

- Accuracy of rainfall data and inundation records
- Time lag between the occurrence time in the records and the actual occurrence time.
  For example, in case that inundation occurred at midnight, the occurrence date may have been recorded in the following day of actual inundation occurrence. Then, rainfall that caused inundation and rainfall used for the analysis are mismatched. In case of 2003/11/24 and 2004/2/20 in Yomasa basin, daily rainfall amounts of the previous day are more than 10 mm.
- Distance of rainfall station and actual rainfall area (local rainfall).
  In other words, it is the case that covered area of specified rainfall station could not include the rainfall area/inundated area in the basin. For example, in case of 2002/12/20 in Yomasa basin, daily rainfall amount of Micaela station is quite small; however, rainfall amount of Tanque Quiba station is about 30 mm.
- Influence of other factors.
  Inundation in the Study Area may have occurred due to not only rainfall but also the influence of human activities or some surrounding environmental problems

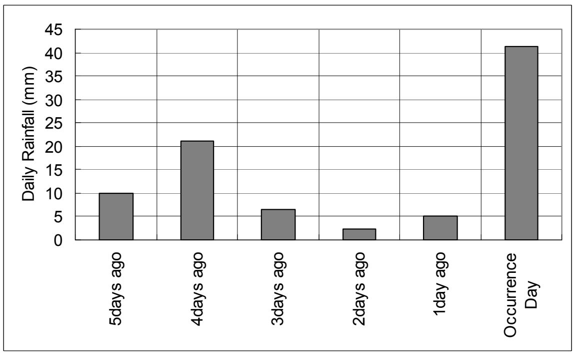
In addition to the above possibilities, the antecedent rainfall may influence the occurrence of inundation. Figure 4-7 shows the antecedent rainfall when inundation occurred. From the figures, the influence of antecedent rainfall to the inundation is not clear.



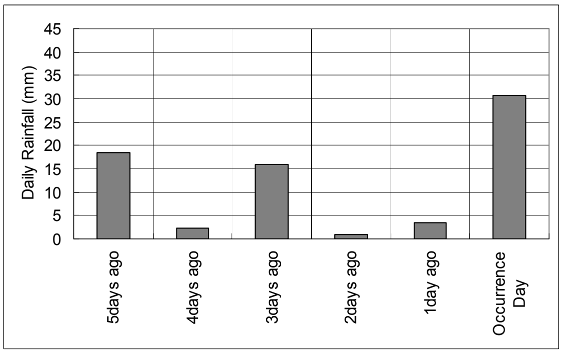

2002/5/30 in Juan Rey Station (EAAB)



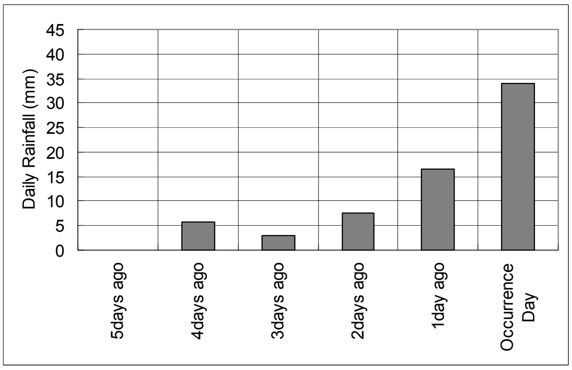

2003/1/19 in Juan Rey Station (EAAB)



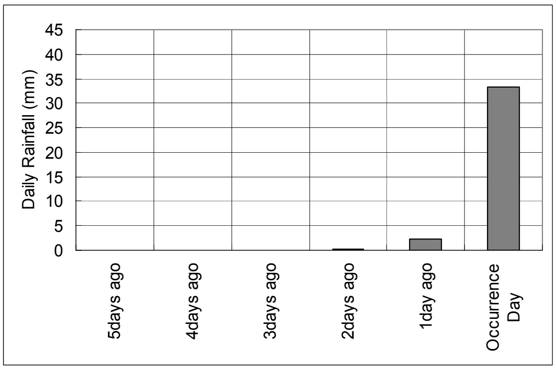

2004/10/24 in Micaela Station (DPAE)




2006/5/10 in Micaela Station (DPAE)




200410/20 in Tanque Quiba Station (DPAE)




2005/9/25 in Tanque Quiba Station (DPAE)

Figure 4-7 Antecedent Rainfall when Inundation Occurred

From the above analyses, inundation in the Study Area may happen by the influence of the some factors other than rainfall and may be difficult to explain from only rainfall. In addition, rainfall station and rainfall data in the Study Area are limited, few water level data exist in limited basin, and relation of rainfall and water level is impossible to know. Although the conditions are quite hard as described above, the determination of threshold is attempted by using only rainfall.

Daily rainfall amounts in past inundations are summarized in Table 4-9.

Table 4-9 Summary of Relation between Daily Rainfall and Inundation Events

| Basin/Station | No. of Days when Inundation Occurred from 2001 to 2006 | Daily Rainfall (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | < 5 | <10 | <15 | <20 | <25 | <30 | <35 | <40 | 40=< |
| Chiguaza<br>La Picota (CAR) or Juan Rey (EAAB) | *38*<br>*100%* | 14<br>37% | 20<br>53% | 26<br>68% | 31<br>82% | 34<br>89% | 35<br>92% | 35<br>92% | 37<br>97% | 38<br>100% |
| Yomasa<br>Micaela (DPAE) | *9*<br>*100%* | 3<br>33% | 3<br>33% | 4<br>44% | 5<br>56% | 8<br>89% | 8<br>89% | 9<br>100% | 9<br>100% | 9<br>100% |
| Santa Librada<br>Juan Rey (EAAB) or Micaela (DPAE) | *11*<br>*100%* | 0<br>0% | 0<br>0% | 3<br>27% | 3<br>27% | 5<br>45% | 7<br>64% | 8<br>73% | 10<br>91% | 11<br>100% |
| La Estrella<br>Tanque Quiba (DPAE) | *15*<br>*100%* | 4<br>27% | 5<br>33% | 7<br>47% | 10<br>67% | 12<br>80% | 13<br>87% | 15<br>100% | 15<br>100% | 15<br>100% |
| Trompeta<br>Tanque Quiba (DPAE) | *7*<br>*100%* | 1<br>14% | 2<br>29% | 2<br>29% | 4<br>57% | 5<br>71% | 5<br>71% | 7<br>100% | 7<br>100% | 7<br>100% |

Table 4-10 shows the threshold of daily rainfall amount in each target basins, which is set using the rate of occurrence of past inundations as shown in the above table. The thresholds are classified into three. Since inundation record doesn't include the scale of the inundation and the damage, the relation between rainfall amount and the scale of inundation is not obvious, and it cannot be said that inundation with low rate of occurrence is severe inundation. However, in general, severe inundation occurs in heavy rainfall and the rate of occurrence of severe inundation is low. Based on the above assumption, thresholds were classified using rainfall amount. "Probable Annual Frequency" in the table means "how many times per year the relevant rainfall amount will be observed".

These thresholds are for daily rainfall. According to the former analysis, rainfall tends to concentrate in a short time when inundation occurs; therefore these thresholds are regarded to serve as a reference for determining the threshold of hourly rainfall.

Table 4-10 Thresholds of Daily Rainfall for Inundation

| Criteria / Basin/Station | Inundation Occurrence probability More than 70% | Inundation Occurrence probability Less than 50% | Inundation Occurrence probability Less than 30% |
|---|---|---|---|
| Chiguaza Basin | | | |
| La Picota (CAR) | 5 mm | 10 mm | 20 mm |
| Probable Annual Frequency | 37 days | 15 days | 3 days |
| Juan Rey (EAAB) | 5 mm | 10 mm | 20 mm |
| Probable Annual Frequency | 85 days | 41 days | 11 days |
| Yomasa Basin | | | |
| Micaela (DPAE) | 5 mm | 20 mm | 25 mm |
| Probable Annual Frequency | 81 days | 9 days | 3 days |
| Santa Librada Basin | | | |
| Juan Rey (EAAB) | 20 mm | 30 mm | 35 mm |
| Probable Annual Frequency | 11 days | 3 days | 1 day |
| Micaela (DPAE) | 20 mm | 30 mm | 35 mm |
| Probable Annual Frequency | 9 days | 2 days | 1 day |
| La Estrella Basin | | | |
| Tanque Quiba (DPAE) | 5 mm | 20 mm | 25 mm |
| Probable Annual Frequency | 36 days | 2 days | 1 day |
| Trompeta Basin | | | |
| Tanque Quiba (DPAE) | 5 mm | 20 mm | 25 mm |
| Probable Annual Frequency | 36 days | 2 days | 1 day |

For the reference, values to have converted frequency of rainfall into the number of the days during a year (365 days) in each station are shown in Table 4-11. For example, daily rainfall of more than 10mm may occur 14 times per year in Tanque Quiba (DPAE) station.

Table 4-11 Average Number of Days of Daily Rainfall Amount per Year

Unit: Number of days

| Station | Daily Rainfall (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0≦ | 5≦ | 10≦ | 15≦ | 20≦ | 25≦ | 30≦ | 35≦ | 40≦ |
| La Picota (CAR) | 365 days | 37 | 15 | 8 | 3 | 1 | 1 | 0 | 0 |
| Juan Rey (EAAB) | 365 | 85 | 41 | 21 | 11 | 5 | 3 | 1 | 1 |
| Micaela (DPAE) | 365 | 81 | 40 | 21 | 9 | 3 | 2 | 1 | 1 |
| Tanque Quiba (DPAE) | 365 | 36 | 14 | 7 | 2 | 1 | 0 | 0 | 0 |

*(Remarks: Data Period is 2001-2006)*

## 4.2 Analyses for Soacha

### 4.2.1 Disaster Events for the Analyses in Soacha

For the analyses of the relation between hydrological conditions, mainly rainfall, and disasters in Soacha, disaster records from the fire station (Bomberos) from May 1996 to April of 2006 for inundation and from May 1998 to June 2006 excluding 2004 for landslide are used. The disaster records by the fire station do not include enough information to understand the magnitude of disaster, such as inundation depth, inundated area and the damage to the people and houses; therefore it can analyze only the relation between hydrological conditions and occurrence of disasters.

Figure 4-9 shows the number of inundation events in each barrio in Soacha urban area, and Table 4- 14 shows the list of inundation events in Soacha urban area. Figure 4-8 shows the number of landslide events in each barrio, and Table 4-12 and Table 4- 13 show the list of all landslide events and the list of selected landslide events for analysis, respectively. The landslide events for the analysis are selected in the same way as the landslide analysis of Bogota.

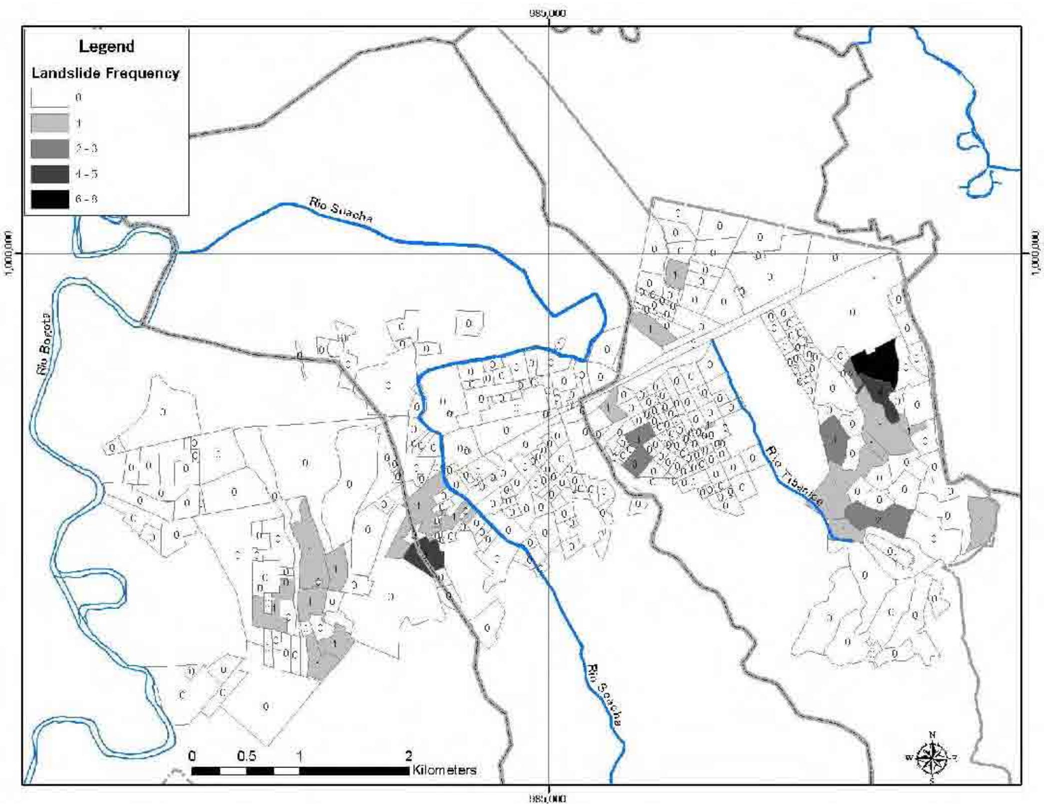



Figure 4-8 Number of Landslide Events in Barrio in Soacha Urban Area

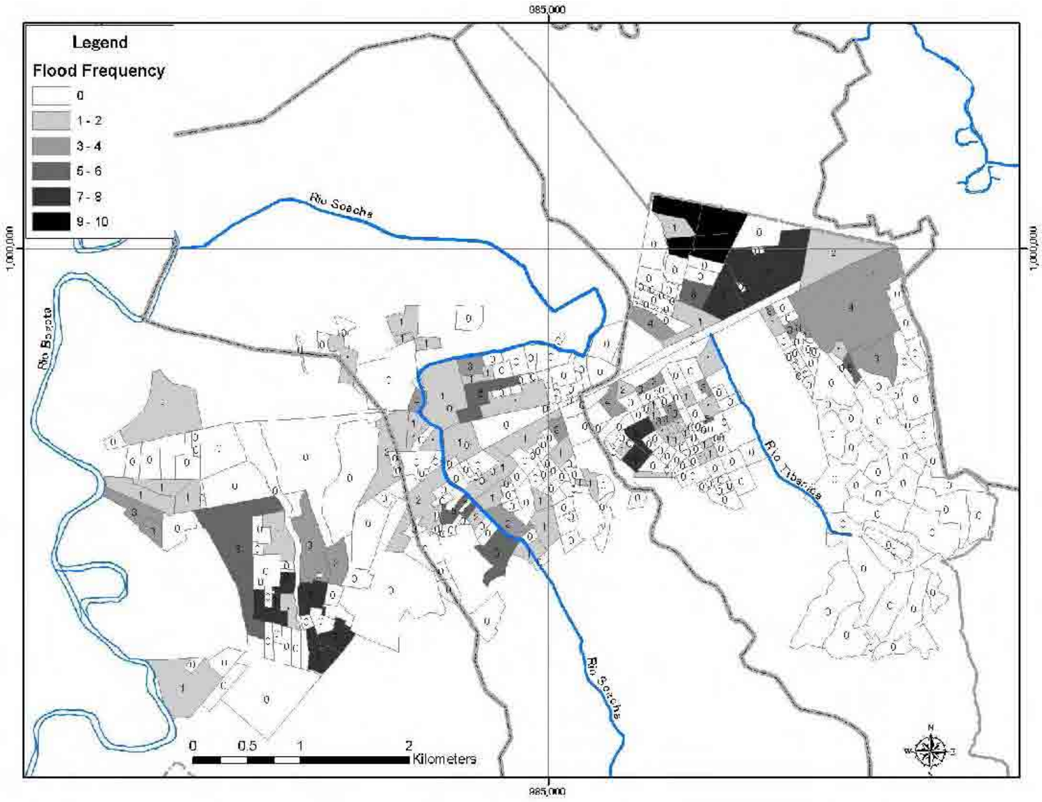



Figure 4-9 Number of Inundation Events in Barrio in Soacha Urban Area

Table 4-12 Landslide Records in Soacha Urban Area

| Date | Barrio Name | No. of Wounded | No. of Dead |
|---|---|---|---|
| 1998/5/6 | Divino Nino | 0 | 0 |
| 1998/7/19 | S. Mateo | 0 | 0 |
| 1998/9/15 | S. Mateo | 0 | 0 |
| 1998/12/17 | Km 12 via mesitas | 0 | 0 |
| 1999/3/17 | La capilla | 0 | 0 |
| 1999/5/17 | La florida | 0 | 0 |
| 1999/6/1 | La capilla | 0 | 0 |
| 1999/11/1 | | 0 | 0 |
| 2000/2/10 | Villa Esperanza Barreno | 0 | 0 |
| 2000/2/29 | Divino nino | 0 | 0 |
| 2000/11/1 | LOMA LINDA | 0 | 0 |
| 2000/11/8 | LOMA LINDA, LA CAPILLA | 0 | 0 |
| 2000/11/9 | LOMA LINDA | 0 | 0 |
| 2002/4/27 | OSAS SAN MATEO | 0 | 0 |
| 2002/4/30 | LA CAPILLA | 0 | 0 |
| 2002/5/30 | VILLA ESPERANZA | 0 | 0 |
| 2002/6/3 | LA CAPILLA | 0 | 0 |
| 2002/6/2 | EL ARROYO | 0 | 0 |
| 2002/6/6 | LA CAPILLA, TERRANIOVA, DIVINO NINO, LA CAPILLA, VILLA SANDRA | 0 | 0 |
| 2002/6/7 | DIVINO NINO | 0 | 0 |
| 2003/1/19 | 2003 | 0 | 0 |
| 2003/4/15 | 2003 | 0 | 0 |
| 2005/10/31 | CAZUCA | 0 | 0 |
| 2005/11/1 | CIUDADELA SUCRE | 0 | 0 |
| 2005/11/11 | V. MERCEDES | 0 | 0 |
| 2005/11/24 | CAZUCA | 0 | 0 |
| 2005/11/28 | V . SANDRA | 0 | 0 |
| 2005/12/20 | V. SANDRA | 0 | 0 |
| 2006/1/9 | CAPILLA | 0 | 0 |
| 2006/6/24 | EL PROGRESO | 0 | 0 |
| 2006/4/10 | EL PROGRESO | 0 | 0 |
| 2006/5/5 | LOMA LINDA, SANTA ANA, Divino nino | 0 | 0 |
| 2006/5/21 | SANTA MARIA | 0 | 0 |
| 2006/6/10 | V. ESPERANZA | 0 | 0 |
| 2006/6/11 | OLIVARES, DUCALES | 0 | 0 |
| 2006/6/15 | EL BARRENO | 0 | 0 |
| 2006/6/24 | LOS ROBLES | 0 | 0 |

Table 4- 13 Selected Landslide Events for Analysis in Soacha

| Date | Barrio Name | No. of Wounded | No. of Dead |
|---|---|---|---|
| 2000/11/8 | LOMA LINDA, LA CAPILLA | 0 | 0 |
| 2002/6/6 | LA CAPILLA, TERRANIOVA, DIVINO NINO, LA CAPILLA, VILLA SANDRA | 0 | 0 |
| 2006/5/5 | LOMA LINDA, SANTA ANA, DIVINO NINO | 0 | 0 |
| 2006/6/11 | OLIVARES, DUCALES | 0 | 0 |

## Table 4- 14 Inundation Records in Soacha Urban Area

| Date | Barrio Name | No. of Wounded | No. of Dead |
|---|---|---|---|
| 1996/5/17 | C. Latina | 0 | 0 |
| 1996/5/20 | Satelite | 0 | |
| 1996/5/23 | OLIVOS | 0 | 0 |
| 1996/6/29 | S.MARCOS | 0 | 0 |
| 1997/6/4 | El Sol, Cazuca Inc. | 0 | 0 |
| 1997/11/4 | Lnconl | 0 | 0 |
| 1997/11/11 | Portalegre | 0 | 0 |
| 1997/12/2 | Casa linda | 0 | 0 |
| 1998/4/3 | El Praiso | 0 | 0 |
| 1998/4/30 | Cumbres S.M | 0 | 0 |
| 1998/5/2 | Rincon Santafe Cra.7-11 Soacha | 0 | 0 |
| 1998/5/3 | El Praiso | 0 | 0 |
| 1990/5/4 | Cazuca Ind. | 0 | 0 |
| 1998/5/5 | Clivos | 0 | 0 |
| 1998/5/8 | Cien Familias, El paraiso | 0 | 0 |
| 1998/9/16 | Cazuca | 0 | 0 |
| 1998/10/16 | Cazuca | 0 | 0 |
| 1998/10/17 | S. Mateo iglesia | 0 | 0 |
| 1999/1/2 | Comercial Tequendama | 0 | 0 |
| 1999/1/3 | Leon 13 | 0 | 0 |
| 1999/2/23 | 12 de octubre | 0 | 0 |
| 1999/3/17 | La despensa | 0 | 0 |
| 1999/3/18 | San mateo | 0 | 0 |
| 1999/3/28 | La capilla | 0 | 0 |
| 1999/4/5 | Cien Familias, La florida | 0 | 0 |
| 1999/4/12 | San mateo | 0 | 0 |
| 1999/6/17 | Santana Tropiabastos | 0 | 0 |
| 1999/7/23 | Capilla de cazuca | 0 | 0 |
| 1999/10/30 | Quintas de Santana, Compartir | 0 | 0 |
| 1999/11/1 | La huerta (Indumil), Quintas de la Laguna, Quintas de Santana | 0 | 0 |
| 1999/11/2 | La Capilla | 0 | 0 |
| 2000/3/24 | OLIVOS | 0 | 0 |
| 2000/4/23 | Centro | 0 | 0 |
| 2000/11/7 | Santa Maria del rincon, Nuevo Colon | | |
| 2000/11/21 | SANTA ANA | 0 | 0 |
| 2000/11/26 | COMPARTIR | 0 | 0 |
| 2001/3/19 | SAN NICOLAS | 0 | 0 |
| 2001/5/9 | VEREDITA | 0 | 0 |
| 2001/5/10 | EL ROSAL | 0 | 0 |
| 2001/5/31 | BOSATAMA | 0 | 0 |
| 2001/6/2 | FLORIDA | 0 | 0 |
| 2001/6/6 | SANTILLANA, RICAURTE, Leon 13, CIUDADELA SUCRE, LA UNION, ACACIAS, QUINTANARES | 0 | 0 |
| 2001/7/7 | COMPARTIR | 0 | 0 |
| 2001/11/2 | RICAURTE | 0 | 0 |
| 2001/11/3 | EL SOL | 0 | 0 |
| 2001/12/2 | DUCALES, Mirador de S.Ignacio | 0 | 0 |
| 2001/12/24 | Mirador de S.Ignacio, EL CHICO | 0 | 0 |
| 2002/5/14 | SAN CARLOS | 0 | 0 |
| 2002/5/24 | COMPARTIR | 0 | 0 |
| 2002/5/31 | BOSATAMA | 0 | 0 |
| 2002/6/7 | LLANO GRANDE, EUGENIO DIAZ | 0 | 0 |
| 2002/8/11 | Mirador de S.Ignacio | 0 | 0 |
| 2002/11/7 | OLIVOS, Leon 13 | 0 | 0 |
| 2002/11/9 | OLIVOS, QUINTANARES, Altico, 12 DE MARZO, Ricaurte, Sta.Ma. Rincon, SAN MATEO | 0 | 0 |
| 2002/11/10 | Portalegre | 0 | 0 |
| 2002/11/13 | Santa Elena | 0 | 0 |
| 2002/11/16 | Altico | 0 | 0 |
| 2002/11/24 | SANTA ANA | 0 | 0 |
| 2002/12/5 | SANTA ANA | 0 | 0 |
| 2002/12/17 | LOS CRISTALES | 0 | 0 |
| 2003/1/3 | OLIVOS, QUINTANARES, UBATE, Portalegre, ACACIAS, Ducales, Leon 13 | 0 | 0 |
| 2003/1/20 | OLIVOS | 0 | 0 |
| 2003/3/21 | Compartir | 0 | 0 |
| 2003/4/3 | COBEC | 0 | 0 |
| 2003/4/15 | SANTA ANA, Leon 13, Terragrande, San Mateo | 0 | 0 |
| 2004/10/19 | CIUDADELA SUCRE | 0 | 0 |
| 2004/10/20 | LA MARIA | 0 | 0 |
| 2004/10/25 | FANALCA S.A | 0 | 0 |
| 2004/10/27 | ECOOPSOS | 0 | 0 |
| 2004/10/30 | EL SILO | 0 | 0 |
| 2004/10/31 | ALMACEN FRAGUA | 0 | 0 |
| 2004/11/3 | UNISUR | 0 | 0 |
| 2004/11/8 | UNISUR | 0 | 0 |
| 2004/11/14 | TROPIABASTOS | 0 | 0 |
| 2004/11/16 | EL SILO | 0 | 0 |
| 2004/11/18 | EL SILO | 0 | 0 |
| 2004/11/24 | SANTA ANA | 0 | 0 |
| 2004/11/28 | DUCALES | 0 | 0 |
| 2005/1/5 | EL SOL | 0 | 0 |
| 2005/2/12 | EL SILO Y SAN IGNACIO, FLORIDA, R.SANTA M. | 0 | 0 |
| 2005/4/23 | OLIVOS, Leon 13 | 0 | 0 |
| 2005/5/2 | EL DORADO, DANUBIO | 0 | 0 |
| 2005/5/15 | CENTRO, SAN CARLOS, CAZUCA IND. | 0 | 0 |
| 2005/5/17 | S.MATEO | 0 | 0 |
| 2005/5/18 | CENTRO | 0 | 0 |
| 2005/5/22 | QUINTAS DE LA LAGUNA | 0 | 0 |
| 2005/5/23 | CAZUCA | 0 | 0 |
| 2005/5/25 | OLIVOS 1 | 0 | 0 |
| 2005/5/29 | CIUDADELA SUCRE | 0 | 0 |
| 2005/8/3 | LAS VEGAS | 0 | 0 |
| 2005/8/22 | CENTRO | 0 | 0 |
| 2005/10/21 | DESPENSA, CAZUCA, OLIVOS, VILLA SOFIA | 0 | 0 |
| 2005/10/23 | SANTA ANA, SANTA MARIA DEL RIN. | 0 | 0 |
| 2005/11/10 | SAN MATEO | 1 | 0 |
| 2005/11/23 | CAZUCA, CAZUCA IND. | 0 | 0 |
| 2006/1/10 | ALMACEN ALCALDIA | 0 | 0 |
| 2006/3/8 | TABACAL | 0 | 0 |
| 2006/3/26 | FLORIDA | 0 | 0 |
| 2006/4/5 | CENTRO | 0 | 0 |
| 2006/4/12 | SAN MATEO | 0 | 0 |
| 2006/4/13 | CIUDADELA SUCRE | 0 | 0 |

### 4.2.2 Analysis for Relation between Hydrological Conditions and Selected Disaster Events

(1) Hydrological Stations for Analysis

The relation between hydrological conditions, mainly rainfall, and disasters in Soacha is analyzed using collected daily rainfall data, water level data and disaster records.

The stations using the rainfall data for the analyses are Las Huertas station (EAAB), Bosa Barreno No.2 station (EAAB), Sierra Morena station (DPAE), and San Jorge station (IDEAM). And the stations using the water level data are Las Huertas station (EAAB) and Independencia station (DPAE). The selected stations for the analyses are shown in Figure 4-10.

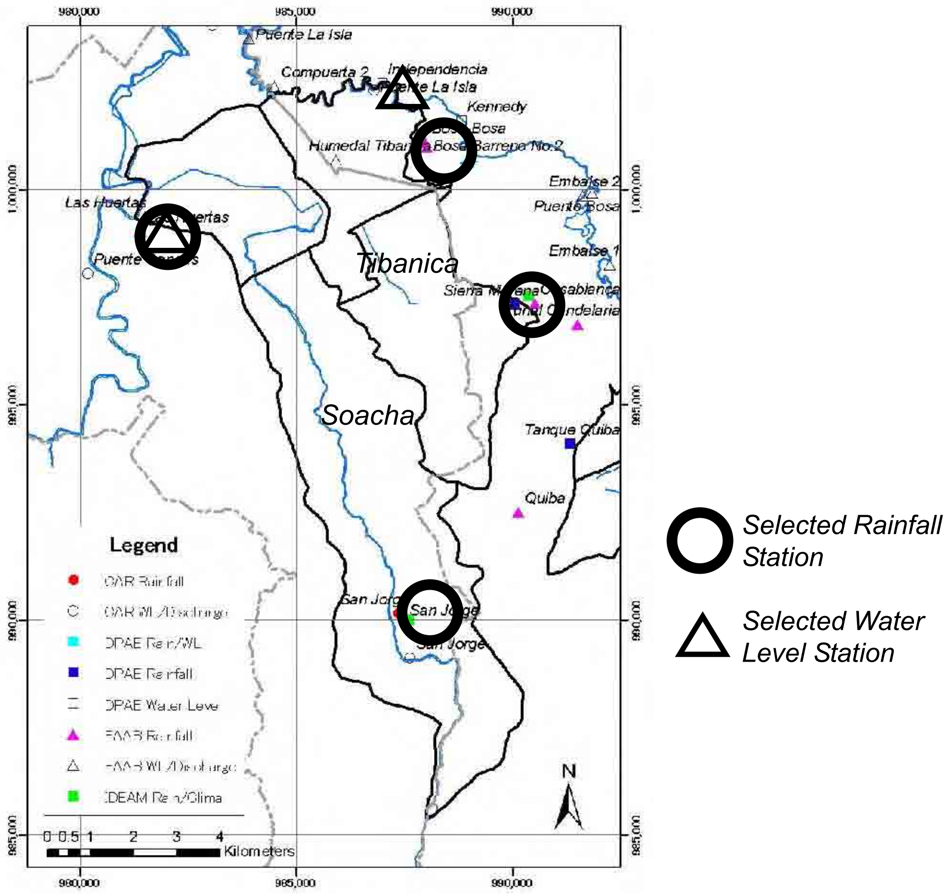



Figure 4-10 Selected Stations for Analyses

(2) Analyses for Landslide

The same analysis as for landslide in Soacha is undertaken for the selected landslide events as shown in Table 4-15. Rainfall amount using the analysis is the maximum value of three (3) stations of Las Huertas (EAAB), Bosa Barreno No.2 (EAAB) and Sierra Morena (DPAE).

Figure 4-11 shows the daily rainfall, 3 days rainfall and accumulative rainfall in the day when a number of landslides occurred on the same date. Each rainfall value is the maximum value of the three stations described above.

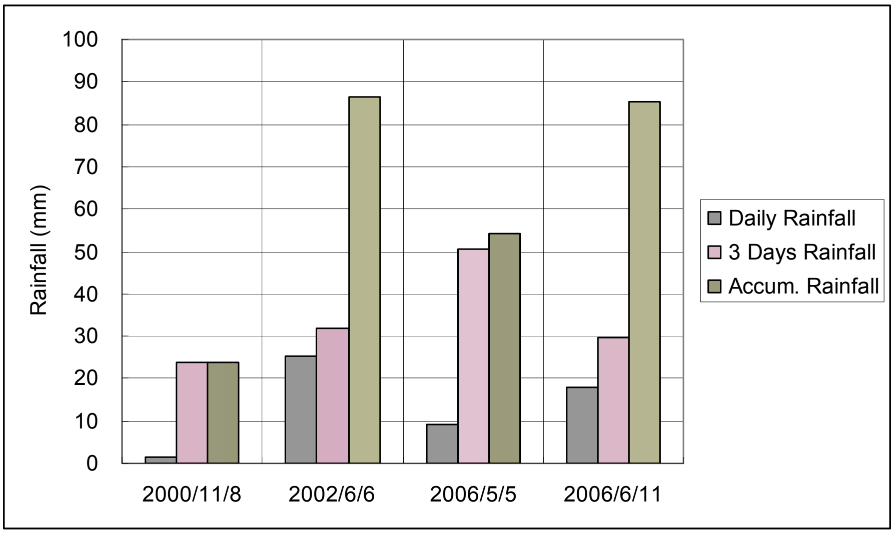



Figure 4-11 Daily, 3 days and Accumulative Rainfall when Landslides Occurred

The relation between landslide events and three (3) days or accumulative rainfall is summarized in Table 4-15. In the table, the percentage of "Landslide" rows is the rate of the number of days with the designated rainfall amount as landslide occurrence, and the percentage of "Average" rows is the rate of the number of days with the designated rainfall amount in the period of 1996-2006.

Table 4-15 Summary of Relation between Rainfall and Landslide Events

| Area | Rainfall | | Rainfall (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | <10 | <20 | <30 | <40 | <50 | <60 | <70 | <80 | <90 |
| Soacha Urban Area | 3 days Rainfall | Occurrence of Landslide | 0% | 0% | 50% | 75% | 75% | 100% | 100% | 100% | 100% |
| | | Average in 1996-2006 | 78% | 92% | 97% | 99% | 100% | 100% | 100% | 100% | 100% |
| | Accum. Rainfall | Occurrence of Landslide | 0% | 0% | 25% | 25% | 25% | 50% | 50% | 50% | 100% |
| | | Average in 1996-2006 | 71% | 84% | 91% | 94% | 97% | 98% | 99% | 99% | 100% |

By the use of the above results, the combination of three (3) days rainfall and accumulative rainfall as an example of threshold is examined in the same way as the analysis for landslide in Bogota. The result is shown in Table 4-16. This is nothing but the example. More detailed and careful investigation and accumulation of exact disaster records are vitally important and necessary in order to determine the thresholds.

Table 4-16 Example of Threshold for General Warning of Landslide

| Criteria / Area/Station | Occurrence probability More than 70% | Occurrence probability Less than 50% | Occurrence probability Less than 30% |
|---|---|---|---|
| Soacha Urban Area Las Huertas (EAAB), Bosa Barreno No.2 (EAAB) & Sierra Morena (DPAE) | 3days Rain > 20mm & Accum. Rain > 50 mm | 3days Rain > 30mm & Accum. Rain > 50 mm | 3days Rain > 40mm & Accum. Rain > 50 mm |
| Probable Annual Frequency (days) | 7 | 4 | 2 |

(3) Analysis for Inundation

Table 4-17 show the daily rainfall amount of four (4) selected stations in all the days when inundation occurred (101 days, 150 inundation events) from May 1996 to April 2006. For example, 57% of the inundation events occurred when the daily rainfall at Las Huertas was less than 5 mm. And Table 4-18 show the water level in Las Huertas (EAAB) and Independencia (DPAE) stations when inundation occurred in Soacha. The difference of waterlevel means that the difference between the instant waterlevel at inundation event in Soacha and the average waterlevel on record of station. When the difference is large, the waterlevel at Bogota river is high. More than 50% of inundation events occurred when daily rainfall amount was less than 10mm and difference of water level for average value was lower than 0.2 m.

Table 4-17 Summary of Relation between Daily Rainfall and Inundation Events

| Daily Rainfall (mm) | San Jorge (IDEAM) | Las Huertas (EAAB) | Bosa Barreno No.2 (EAAB) | Sierra Morena (DPAE) | Max of 4 stations |
|---|---|---|---|---|---|
| 0-5 | 65% | 57% | 58% | 49% | 34% |
| 5-10 | 8% | 23% | 19% | 24% | 22% |
| 10-15 | 9% | 11% | 9% | 7% | 15% |
| 15-20 | 8% | 5% | 4% | 9% | 10% |
| 20-25 | 7% | 2% | 7% | 7% | 11% |
| 25-30 | 1% | 1% | 2% | 3% | 5% |
| 30-35 | 0% | 1% | 0% | 0% | 1% |
| 35-40 | 2% | 0% | 1% | 0% | 3% |

Table 4-18 Differences between Average Water Level and Water Levels in Inundations

Unit of differences: m

| WL Station | <-0.4 | <-0.2 | <0 | <0.2 | <0.4 | <0.6 | <0.8 | <1.0 | <1.2 | <1.4 | <1.6 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Las Huertas (EAAB) | 1% | 9% | 30% | 54% | 71% | 85% | 91% | 96% | 100% | 100% | 100% |
| Independencia (DPAE) | 3% | 18% | 32% | 53% | 62% | 76% | 91% | 91% | 94% | 97% | 100% |

Soacha urban area is divided into six (6) communes as shown in Figure 4-10. The relation between inundation events in each commune and daily rainfall in four (4) stations are shown in Figure 4-13.

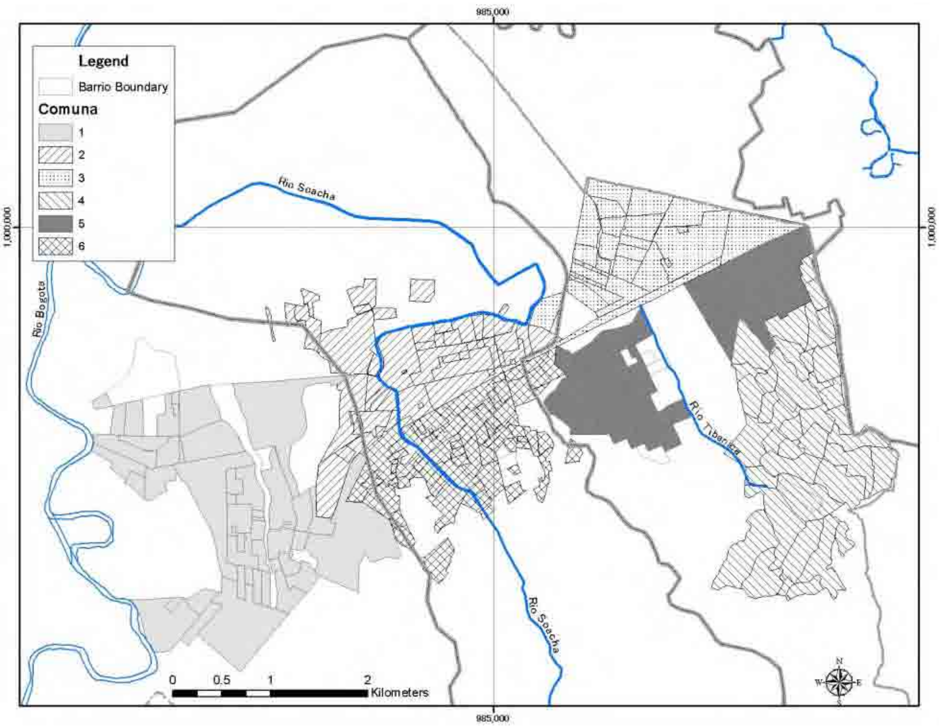


Figure 4-12 Commune in Soacha

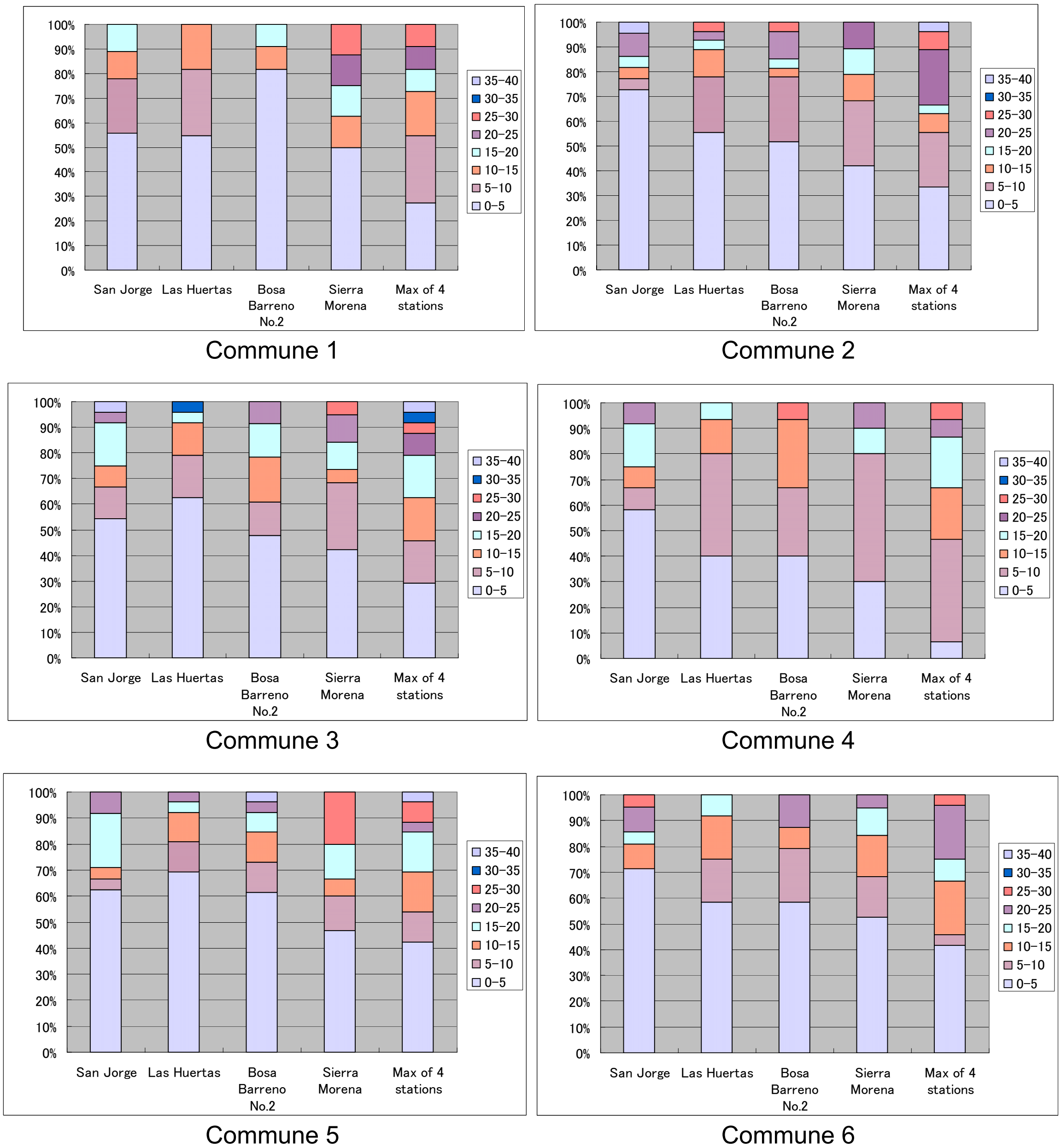



Figure 4-13 Daily Rainfall in Inundation Events in Each Commune

From the above figures, the strong correlation of commune/area and rainfall of each station cannot be found. Therefore, investigation of threshold value in Soacha is conducted using the maximum among the selected four (4) stations.

Table 4-19 summarizes the relation between past inundation events and maximum value among the four (4) selected stations.

Table 4-19 Summary of Relation between Daily Rainfall and Inundation Events

| Area/Station | No. of Days Inundation Occurred from 1996 to 2006 | Daily Rainfall (mm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | < 5 | < 10 | < 15 | < 20 | < 25 | < 30 | < 35 | < 40 |
| Soacha Urban Area (Las Huertas (EAAB), Bosa Barreno No.2 (EAAB), Sierra Morena (DPAE) & San Jorge (IDEAM)) | 101<br>100% | 34<br>34% | 56<br>55% | 71<br>70% | 81<br>80% | 92<br>91% | 97<br>96% | 98<br>97% | 101<br>100% |

The thresholds for inundation in Soacha, which is investigated using the above results, are shown in Table 4-20. Values to have converted frequency of rainfall into the number of the days during a year (365 days) in each station are shown in Table 4-21.

Table 4-20 Thresholds for Inundation in Soacha

| Criteria / Area/Station | Occurrence probability More than 70% | Occurrence probability Less than 50% | Occurrence probability Less than 30% |
|---|---|---|---|
| Soacha Urban Area<br>Las Huertas (EAAB), Bosa Barreno No.2 (EAAB) & Sierra Morena (DPAE) | 5 mm | 10 mm | 15 mm |
| Probable Annual Frequency (days) | 81 | 40 | 20 |

Table 4-21 Average Number of Days of Daily Rainfall Amount per Year

Unit: Number of days

| Station | Daily Rainfall (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0≦ | 5≦ | 10≦ | 15≦ | 20≦ | 25≦ | 30≦ | 35≦ | 40≦ |
| San Jorge (IDEAM) | 365 | 52 | 26 | 12 | 6 | 3 | 1 | 1 | 0 |
| Las Huertas (EAAB) | 365 | 33 | 13 | 6 | 3 | 1 | 1 | 0 | 0 |
| Bosa Barreno No.2 (EAAB) | 365 | 38 | 16 | 8 | 4 | 2 | 1 | 0 | 0 |
| Sierra Morena (DPAE)[1] | 365 | 37 | 16 | 8 | 3 | 1 | 0 | 0 | 0 |
| Max of 4 stations | 365 | 81 | 40 | 20 | 10 | 4 | 2 | 1 | 0 |

*(Remarks: Data period is 2000 – 2006 except Sierra Morena (2000-2006))*

# PART 2

# MONITORING AND EARLY WARNING PLANNING FOR SELECTED AREA IN BOGOTA

CHAPTER 5 LANDSLIDE IN BOGOTA

## 5.1 Outline of 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, at the north of the Bolivar City. 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 100ha. 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 areas, 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 as shown in Figure 5-1. The figure shows that there were no residential houses in Phase I areas, but still there were a lot of houses in Phase II area in the Year 2007.

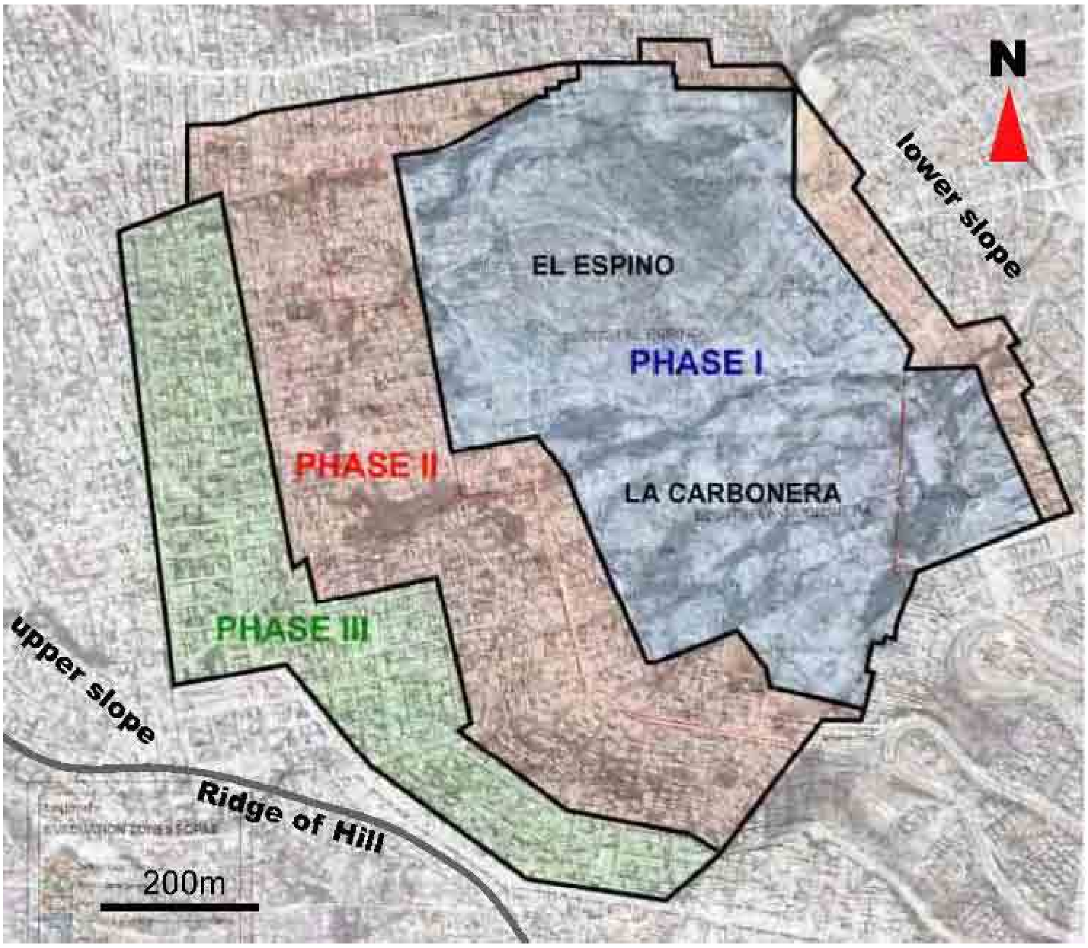



Figure 5-1 Phases in Altos de Estancia
(Combination of aero photo and topographic map)

(1) Topography

The slope direction in the area is to north east and the moving direction of the Landslide in the aggregate is from south west to north east. Average angle of the slope is about 15 - 20 degrees and mostly the slope angle is mostly less than 30 degrees. Steep slopes (over 30 degrees) in the area shape outlines of the active landslide masses. Alternations of low angles and high angles of slopes can bee seen, as it is sometimes common with large scale landslide. It may show there are some sub landslide masses in the main landslide mass.

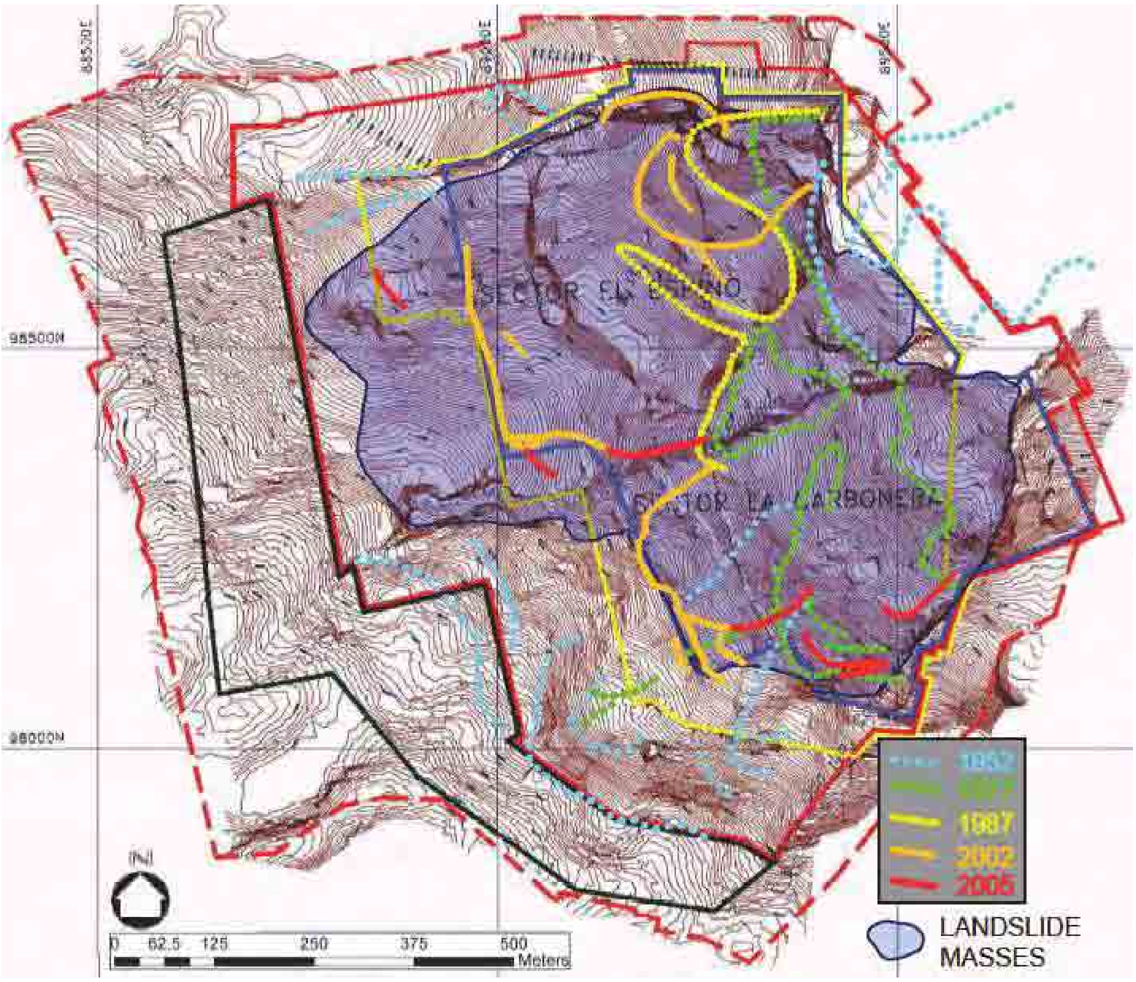
(2) Geology

The reference studies show the presence of two lithostratigraphic units in the area, Sandstone's Member of Guadalupe Formation (Ksglt) and Guaduas Formation (KTg). These members of sandstone which belong to the age of Cretaceous and Tertiary are dipping almost toward east. Therefore the geological structure is "daylight structure" in the slope of the Landslide.

## 5.2 Existing Studies

### 5.2.1 Past Disasters (Historical Information on Landslide)

The feature of the Landslide came in view clearly in 1977. In spite of the occurrence of landslide, however, the quarries in the area had been exploited until the 90's, and this situation could have resulted in a serious pass. According to Figure 5-2 which shows the development of the cracks, we can observe cracks on the upper to lower slopes in 1952. The cracks in 1952 might not be formed by the landslide activities, but existed before the Landslide occurred. These cracks might be seen easily in the slopes since there were few human activities on the slope in the 50's and before that period. After 1977, the cracks shown in Figure 5-2 tended to invade upward from lower parts of slopes. The crack's upward invasions means the Landslide grew upward.

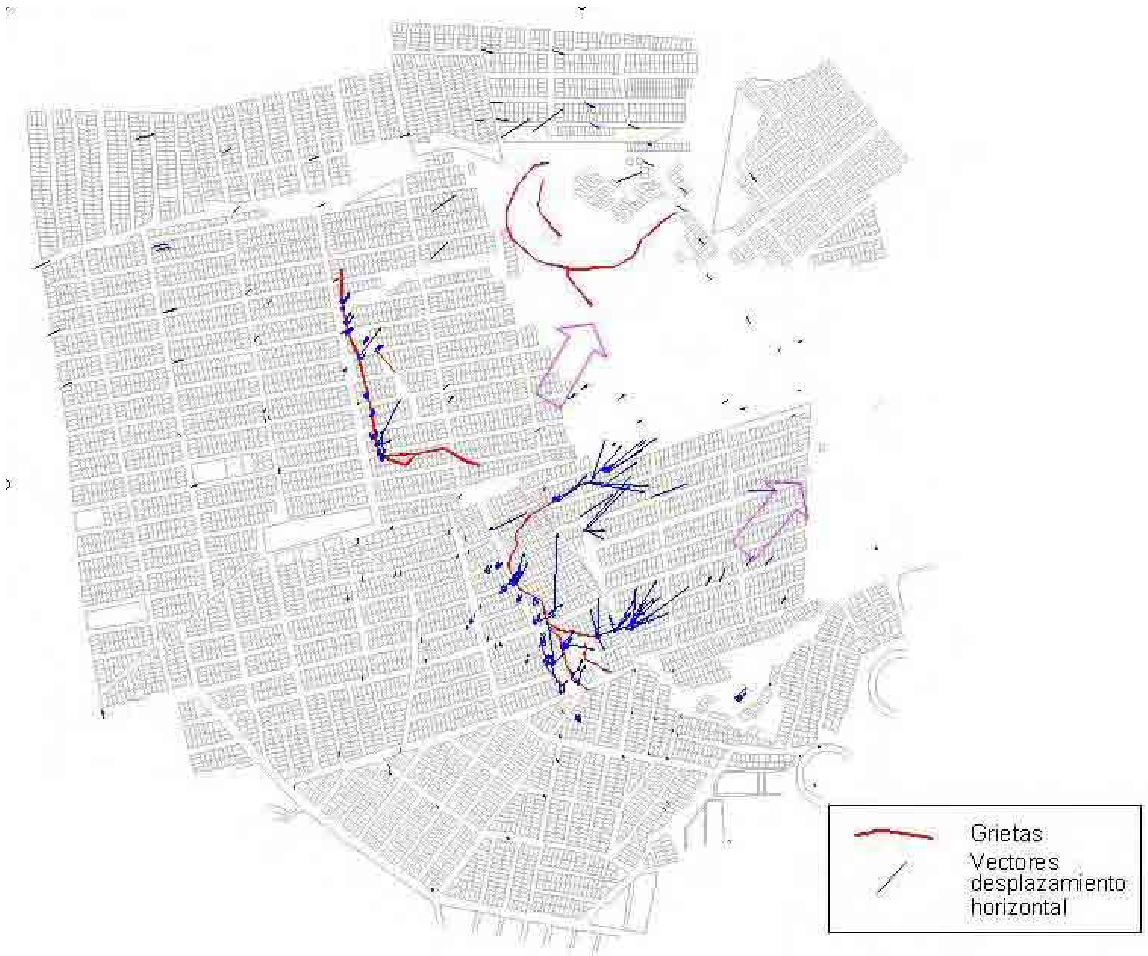



*Vectores de desplazamiento, (Modified from Monitoreo y seguimiento de los deslizamientos activos que afectan el sector Altos de la Estancia, localidad de Ciudad Bolívar, Bogotá D.C.".INGENIERIA Y GEORIESGOS, 2004 by Yokoo this study)*

Figure 5-2 Development of Cracks in the Landslide

### 5.2.2 Existing Investigations and Monitoring

The Landslide has been studied for a long period of time and many reports are available regarding this subject. The most complete and comprehensive study is the report written in 2004, which compiled the result of the studies made in the past. Monitoring works on the Landslide have been executed and reported since 1999. The latest monitoring study in 2005 concluded that the maximum displacement was up to 90 mm during the period of monitoring. In La Carbonera, two inclinometers show sliding surfaces at the depth of 7-8 m at INCGC-1and and at the depths of 9 m and 18 m at INCGC-3. At INCGC-3, total magnitude of the movement in three month was 50 mm (17 mm/month). Figure 5-3 shows the directions of topographic control points differential. Most of the directions cross the contour lines at right angles. The directions are shown lightly toward to north east.




*(Vectores de desplazamiento (Modified from Monitoreo y seguimiento de los deslizamientos activos que afectan el sector Altos de la Estancia, localidad de Ciudad Bolívar, Bogotá D.C.".INGENIERIA Y GEORIESGOS, 2004 by Yokoo this study))*

Figure 5-3 Directions of Topographic Control Points

## 5.3 Surveys Results

There are no residential people in Phase I area in the Landslide, and the relocation program in Phase II area is on progress. Therefore no serious danger would be encountered that threatens the lives of people in the Landslide. However, a small community is found , living near the Landslide, in Phase III area and outside of Phase I area and Phase II area. The Landslide could affect the surrounding community through the expansion. Hereinafter, the places outside Phase I area and II area are designated by "the residential area" The residential area includes Phase III area.

A site survey was carried out at three sectors where the parts of the Landslide may approach the residential areas as shown in Figure 5-4. Any abnormalities such as cracks or deformations on the ground or structures are not found at three sectors in the residential areas except for Espino 1. At Espino 1, some cracks were found in a house outside of the landslide near the uplift which was made through compression at toe of landslide recently.

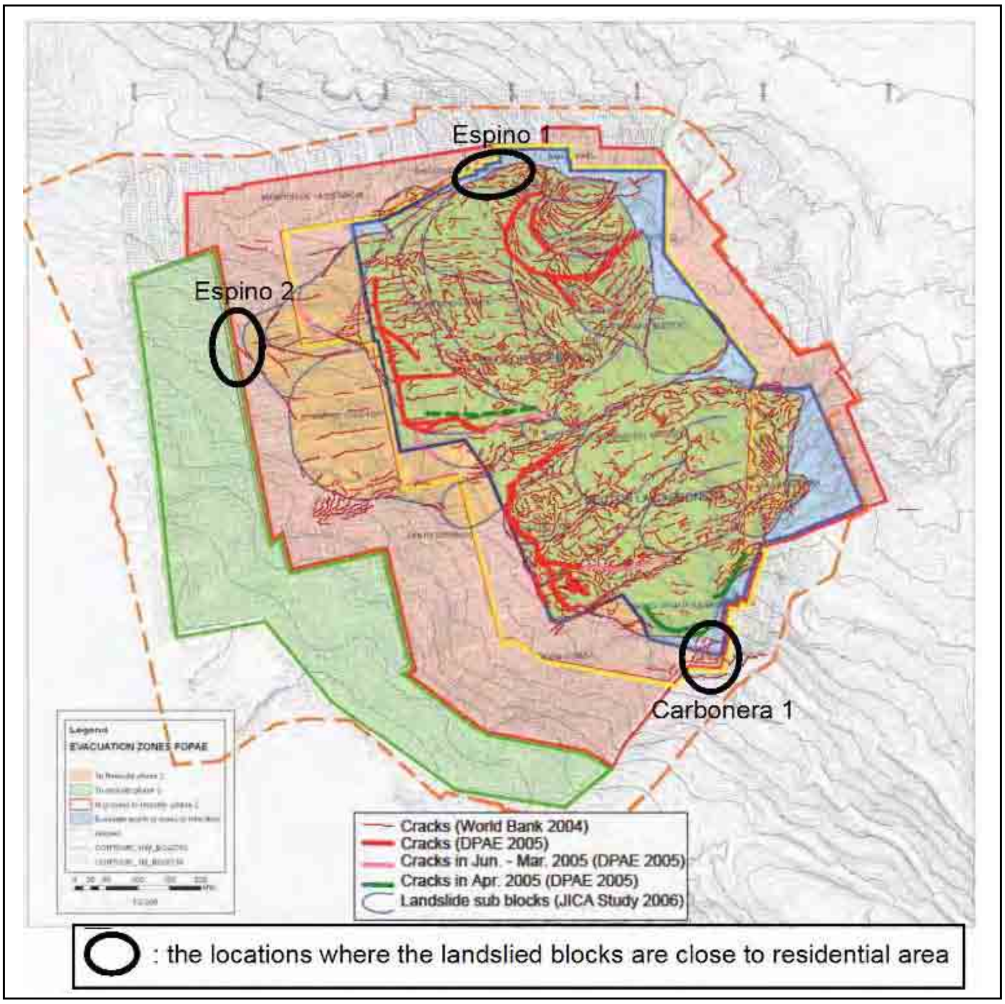



Figure 5-4 Locations for Site Survey

The uplift at Espino 1 probably rose through compression at the toe of the landslide as shown in Figure 5-5. The house which got cracks is close to the uplift, and the force of the landslide which lift the ground, could damage on the house. If the influence of the landslide on the house in the residential area is confirmed, the Landslide area (Phase I and II areas) should be reconsidered and be expanded.

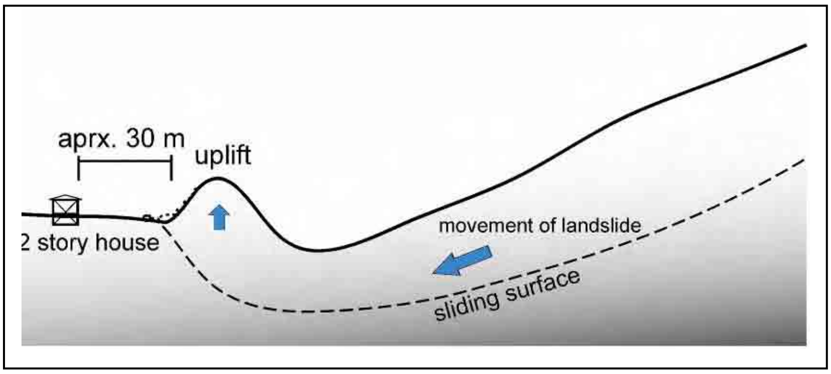



Figure 5-5 Supposed Mechanism of the Uplift

As remarkable thing in the survey, surface water, which comes from sewer, flows into the Landslide area at all over the place. Water makes many channels and pools in the Landslide. It is easily understand that the water flow has a great influence on the Landslide.

The results achieved through these surveys are summarized as follows.

a. Any abnormality could not be found in the residential areas (outside Phase I and II areas) deemed safety area and it would be out of the relocation program.

b. There is no danger of threatening residents' lives in the Landslide because the relocation program is progressing and nobody lives in hazardous area in the Landslide. An any Early warning system for the residents is not required.

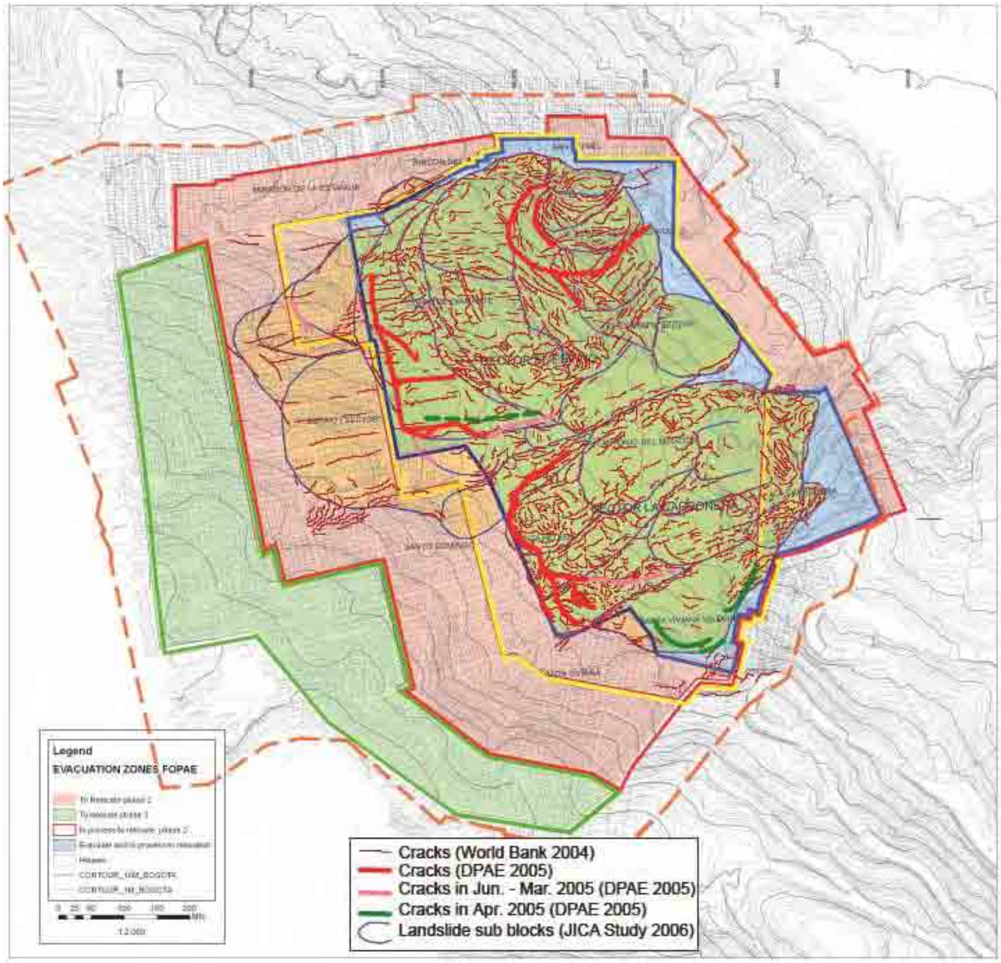
c. The Landslide has expanded upwards and its expansion would continue. There is no guarantee that the residential area will be safe in future, thus it is necessary to monitor the safety the residential area.

d. There is an abnormality in a house near the uplift in Espino 1. If the abnormality in that house depends for the Landslide activity, the area of the Landslide should be reconsidered.

e. The drainage system in Phase III is inadequate. For the stability of the Landslide, it is necessary to maintain the drainage system in Phase III to prevent the water flowing into the Landslide.

## 5.4 Hazard Map

DPAE proceeded with the area division in three areas namely Phase I area, Phase II area and Phase III area, based on available information and especially on data from the study of INGEOMINAS (2003) in order to relocate the population of all areas (Figure 5-1). A map has been issued to public as Hazard Map. Almost all of the inhabitants in Phase I area actually have been relocated, and their relocation in Phase II area is progressing. The Phase III area, deemed a stable area and being outside relocation plan, corresponds to the high slope part.




(*Modified from Monitoreo y seguimiento de los deslizamientos activos que afectan el sector Altos de la Estancia, localidad de Ciudad Bolívar, Bogotá D.C.".INGENIERIA Y GEORIESGOS, 2004 byJICA Study Team in this study*)

Figure 5-6 Ground Surface Cracks and Landslide Blocks in the Landslide

## 5.5 Monitoring Plan

### 5.5.1 Outline of Monitoring Works

The early warning systems using the automatic monitoring devices are not required in the Landslide in terms of saving human loss in the area, because of an 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.

The instrumentation and monitoring could be applied as follows, for the conditions of this Landslide.

a. Safety of the residential area; this confirms the Landslide activity is not approaching the residential areas. This monitoring should be continued as far as the people are living there along the rim of the Landslide.

b. Monitoring on specific cracks and deformation on structures and the ground; this concerns the monitoring works on cracks or deformations on the ground or structures when they are found. This monitoring should be applied whenever cracks or deformation are found on the ground and structure.

c. Safety of construction works; this concerns the monitoring works to prevent accidents under construction. Accident could occur on both workers and residents surroundings. This monitoring should be applied on each construction works during their progress.

d. Verification of effectiveness of stabilization works; it is necessary to confirm the effect of stabilization woks at completion of the construction works.

### 5.5.2 Monitoring for Safety of the Residential Area

The residential areas deemed safe with the authoritative assurance based upon the past study should be monitored to check any change of the conditions of the areas as far as the people are living there. The stability of the slope should be confirmed, especially during the stabilization works. In order to prognosticate any imminent landslide danger in the residential areas surroundings as early as possible, and to take the appropriate administrative measures, the most important step to undertake would be an observation survey carried out by engineers periodically. This would allow finding abnormality on the ground or houses in the residential areas that are close to the Landslide and observing the condition of the Landslide. Then, collecting information from the residential people who are sensitive to the change of surroundings would be required. To collect information from them, the followings are recommendable;

to exchange information with community leaders
to held meeting with community people periodically
to visit and interview the residential people in the area

The point of interview is asking any abnormality around the house. To avoid the confusion of landslide activity with overflow, question should be more plainly, such as cracks on the ground or the house, tilting of the house and so on. If any abnormalities are reported, the engineers should visit the place and ascertain the situation.

The problem of theft and delinquency should be considered in the area when the instruments for monitoring are provided. For a large scale landslide, the survey points monitoring should be as simple and easy to handle as possible. The survey points should be installed along the boundary between the Landslide area and the residential areas. If the movement is found on a point, one should assume that the Landslide approaches the residential area, and engineers should carry out an observation survey around the point, and the frequency of the monitoring should be raised.

Tiltmeter and GPS can be used for the monitoring of the ground movement. By monitoring the ground movement using these instruments along the Landslide and the residential areas as shown in Figure 5-7, we can estimate whether the Landslide is approaching. Tiltmeter and GPS should be installed in secure places such as private sections and premises.

The extensometer is useful at the toe of landslide to monitor the expansion of landslides. Generally, extensometer requires wire to monitor the distance, therefore it is not recommendable for this area. The laser distance meter should be used for the area since no wire is required between the residential houses and the Landslide.

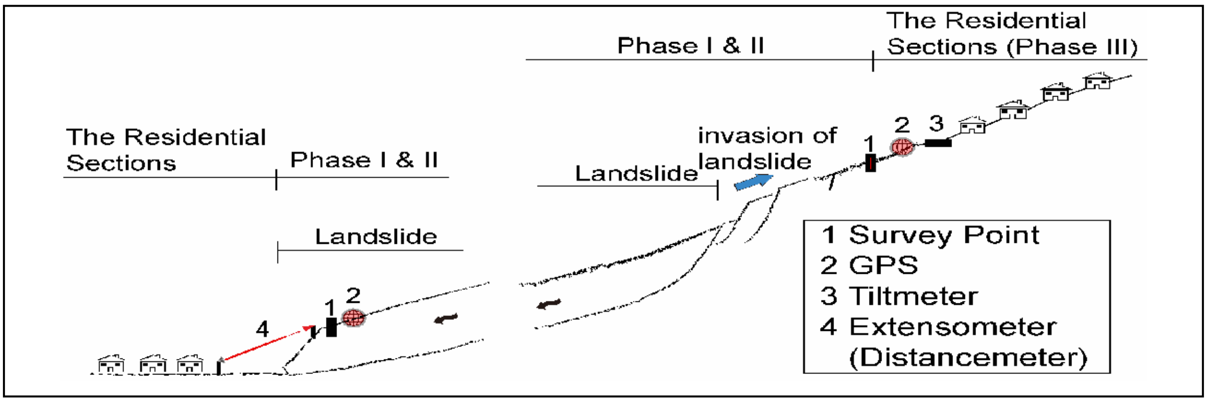



Figure 5-7 Example of Instrumentation along the Landslide and the Residential Area

At the area where the Landslide approaches, an intensive monitoring should be carried out. Figure 5-8 shows four places where the landslide blocks close to the residential area by growth of the Landslide. The place "A" may be closer to the imminent landslide danger since the landslide has grown upward. At the places "B" and "C", the locations should be watched since cracks can be seen outside of the landslide mass. The place "D" could be in danger in the future since the location is found at the toe of the landslide and it is oriented in the direction of the landslide movement. A priority should be given to the locations A, B, C and D for monitoring over other areas, even there is no clear evidence of a critical situation at the moment.

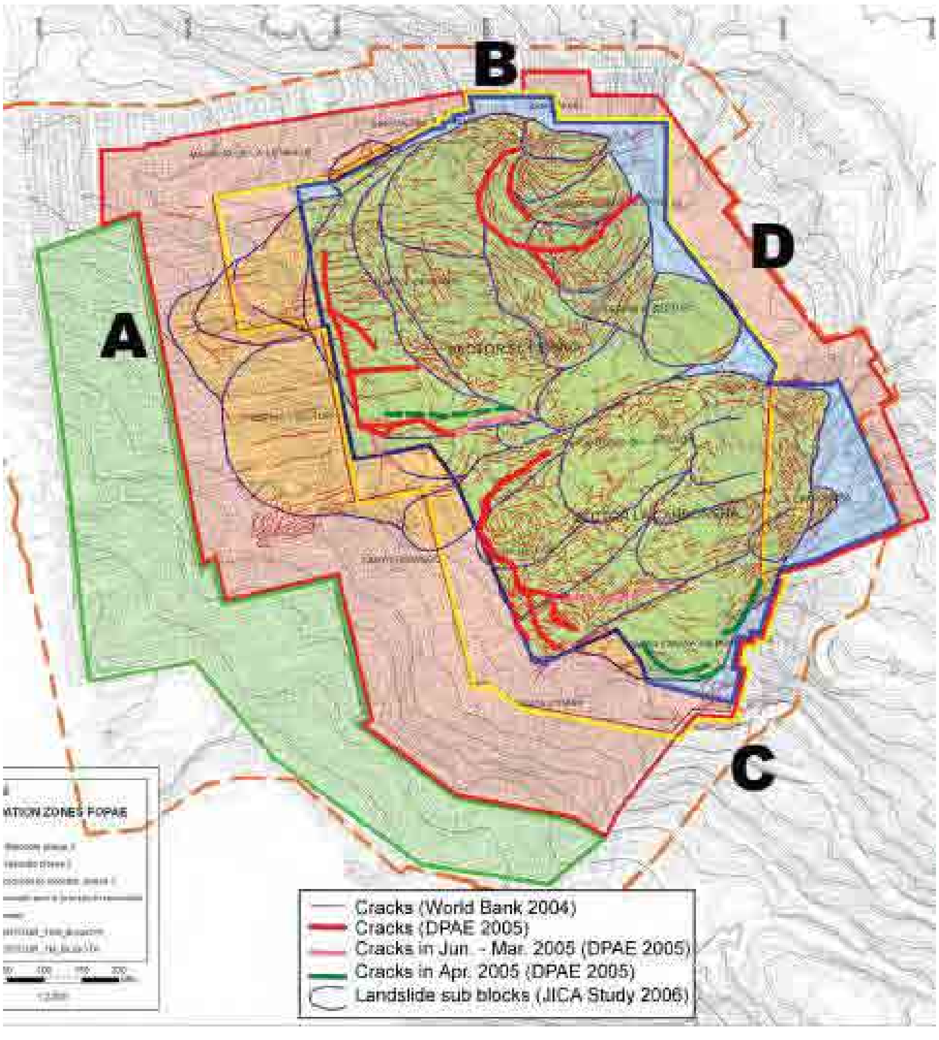



Figure 5-8 Four Places Where the Landslide Blocks Closes to the Residential Area

### 5.5.3 Monitoring for Specific Cracks and Deformation on Structures and the Ground

When new cracks or deformation on the ground or structures are found, they should be monitored simply and easily. In case of crack on the ground, monitoring should be using simple crack gauge. If there is a big difference in level between the both sides, an extensometer will be useful. A verification should be made to know whether the crack is still opening or ceasing through monitoring.

The followings are explanation of Simple ground crack gauge and extensometers.

(1) Simple Ground Crack Gauge

One of the simplest methods to determine landslide movement is a simple ground crack gauge. For the installation of the crack gauge, drive the stakes across a tension crack along the direction of slide movement. Then attach horizontal board to the stakes, and saw through the board. Any movement across the tension crack can be determined by measuring the space between the sawed portions of the board.

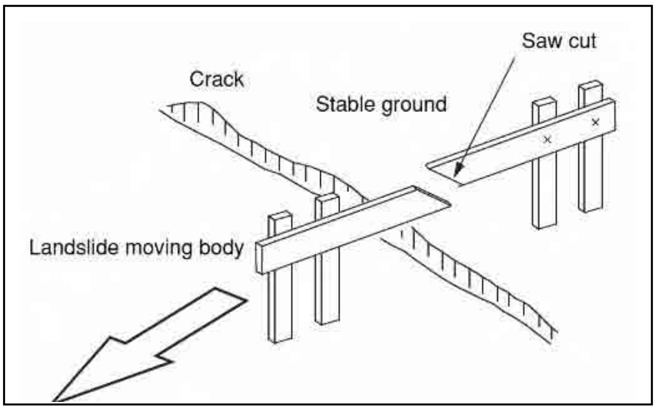



Figure 5-9 Simple Ground Crack Gauge

(2) Extensometer

The extensometer is used to measure the relative movement by comparing the extension of two points. The extensometers are generally installed across the main scarp, at transverse cracks and transverse ridges near the toe or front portion of the slide and parallel to the suspected slide direction. The measurements should be accurate to within 0.2 mm and the magnitude of the movement and daily rainfall data should be recorded to establish the relationship between the measurable movement and the precipitation rate.

(3) Simple Crack Gauge and Tiltmeter on Structures

When a new deformation is found in a house, the latter should be monitored. The crack in a house can be monitored simply by marker pen and ruler or by simple gauge. For the monitoring on a deformed house, a tiltmeter is also useful.

(4) Alert

The establishment of an alert system in the study area has been proposed in 2005 by DPAE as shown in Table 5-1. However, for the basic concept of the automatic monitoring on a landslide, the detection of differential movement can activate the alert (for instance, the increase of velocity of movement or inclination of the ground, or new movement may occur in the stable place.

Table 5-1 Proposed Index of Alert

| Item | Unit | Factor of Weighting | Category of Alert | | | |
|---|---|---|---|---|---|---|
| | | | Low | Medium | High | Critical |
| Altimetry | mm/day | 0.25 | < 1.6 | 1.6 – 3.3 | 3.3 – 5.0 | > 5.0 |
| Inclinometer | mm/month | 0.15 | < 2.0 | 2.0 – 5.0 | 5.0 – 10 | > 10 |
| Structural control | - | 0.3 | 0.25<br>CGR (< 1.5) | 0.5<br>CGR (1.5 – 2.0) | 0.75<br>CGR (2.0 – 2.4) | 1.0<br>CGR (> 2.4) |
| Location of house with movement | - | 0.3 | 0.25<br>(> 50m) | 0.5<br>(50 – 30m) | 0.75<br>(30 – 10m) | 1.0<br>(10 - 0m) |
| Index of alert | | 1.0 | < 1 | 1 – 2.3 | 2.3 – 4.1 | > 4.1 |

*(Source: Monitoreo y seguimiento a los deslizamientos activos que afectan el sector Altos de La Estancia de la localidad de Ciudad Bogota, 2005)*

### 5.5.4 Monitoring for Verification of Effectiveness of Stabilization Works

The instruments used for the stabilization works in the verification of effectiveness of the works should be selected. DPAE is planning the stabilization works in the Landslide; however the details are not confirmed yet.

The stabilization works are classified into two main categories, namely works for reducing the driving forces and those for increasing the resistance force. In the case of a large scale landslide such as the Landslide, a priority is given to the method for reducing the driving forces, since the cost effectiveness for a large scale landslide is normally a better choice than for the method in increasing the resistance force. The only natural character of a slope that can be changed economically, and on a scale large enough to improve slope stability, is groundwater, because it can be drained by gravity. The alternatives to drainage are expensive regarding of a slope to reduce the gravity induced shear stresses with it, or equally expensive support measures to increase the resistance of the slope to these stresses. Hence the drainage of groundwater is a common component of slope design. The first thing we have to do as measure for the Landslide is to reduce the groundwater level, and prevent water penetration into the ground especially from sewer and rainwater.

(1) Common Monitoring

The monitoring of the ground movement monitoring should be necessary to confirm the effectiveness of the stabilization works, a factor that is important to stop or mitigate the landslide activities. Monitoring should be continued before and after the execution of the stabilization works. It is also necessary to continue in this manner in the future following the completion of the construction works in order to monitor any resumption of the landslide.

(2) Monitoring for Water Control Works

To confirm the effectiveness of the water control works, the ground water monitoring is necessary through the use of water standpipes and piezometers. Rain gauge monitoring in or around the Landslide should be applied.

(3) Monitoring for Works for Increasing the Resistance Force, Piling and Anchoring

The individual or contiguous piles are common for the increase of the resistance force. Monitoring of deformation of piles should be applied if the pile works are employed in the stabilization works. The ground inclinometer close to the pile and behind it can measure the movement of the pile. A strain gauge pasted on a steel pile or on reinforcement bars of a bored pile can monitor the movement of the pile. The depth of ground inclinometer should be deeper than the pile. If the monitoring shows a great movement of the pile, the latter might be at risk against the Landslide force.

Anchors are also common as increase in resistance force. The anchor can control by monitoring the tension force by means of a load cell at the anchor head.

### 5.5.5 Safety of Construction Works

Most of the construction works of stabilization follow, digging and watering, therefore they could trigger a resumption of the landslide. The frequency of monitoring should be raised during the construction period.

A small landslide occurring near the construction site may endanger the workers on the construction site. To protect them and the site, the construction site should be always monitored by the engineers or workers. If a crack is found, it should be verified using a simple crack gauge or an extensometer. In case the crack is opening, the construction works should be stopped and the area should be checked carefully.

### 5.5.6 Time Schedule

DPAE has commenced designing work of stabilization works in the landslide. Figure 5-10 shows monitoring plan and time schedule based on DPAE's preliminary time schedule of stabilization works.

Most of the construction works of stabilization accompany digging and watering, therefore the construction works could trigger activation of the landslide. The frequency of monitoring should be raised under construction period.

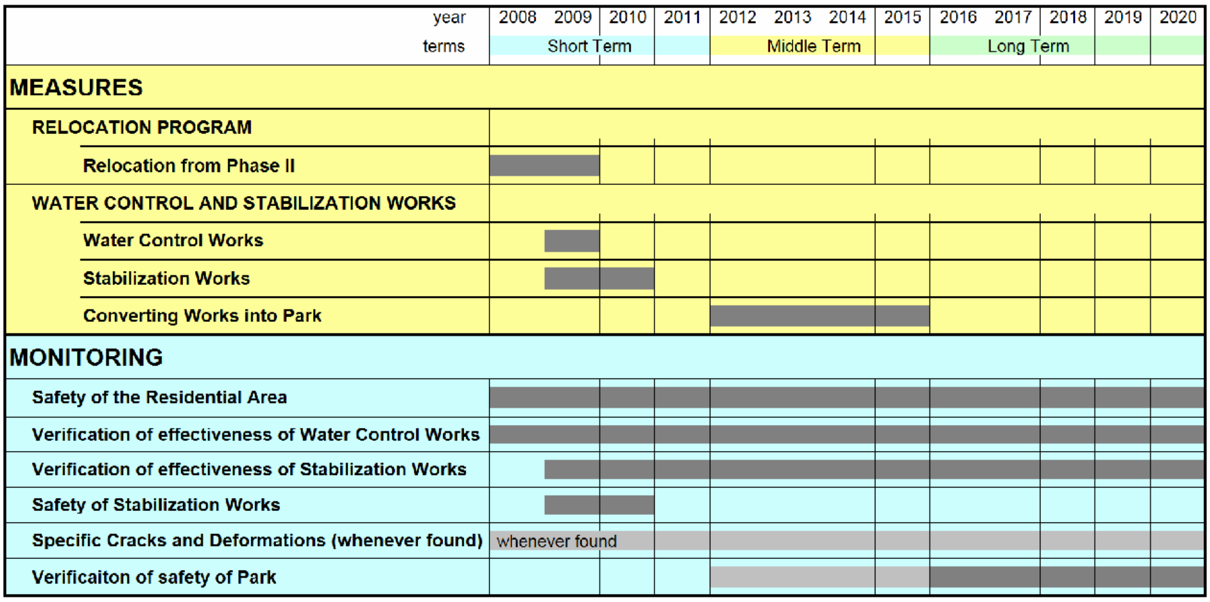



Figure 5-10 Time Schedule of Monitoring by 2020

## 5.6 Pilot Project

The purpose of the monitoring is to verify the residential areas as for its safety. This concerns only the object area of the monitoring of the residential area (Phase III area and the areas out of the landslide area). Any landslide monitoring is not proposed in Phase I area and II area, since there are no houses to be protected in the areas of Phases I and II areas. The locations of monitoring are 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). 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. With reference to “c” above, some cracks and deformations of a house in safe area were found recently. These deformations may show that the landslide has been reached to the safe areas.

### 5.6.1 Monitoring Equipment

The following five kinds of monitoring works concern the items mentioned hereinafter.

a. Survey Points
b. Crack Gauges
c. Level Survey
d. Tiltmeter
e. Laser Distance Meter

The extent of the monitoring is shown in Table 5-2.

Table 5-2 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 | 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 |

### 5.6.2 Installation Points of Monitoring Equipment

(1) Survey Points

The survey points were installed along the boundary between the residential area and the Landslide in order to confirm whether the safe areas are still safe. The details of the each point are described as followings.

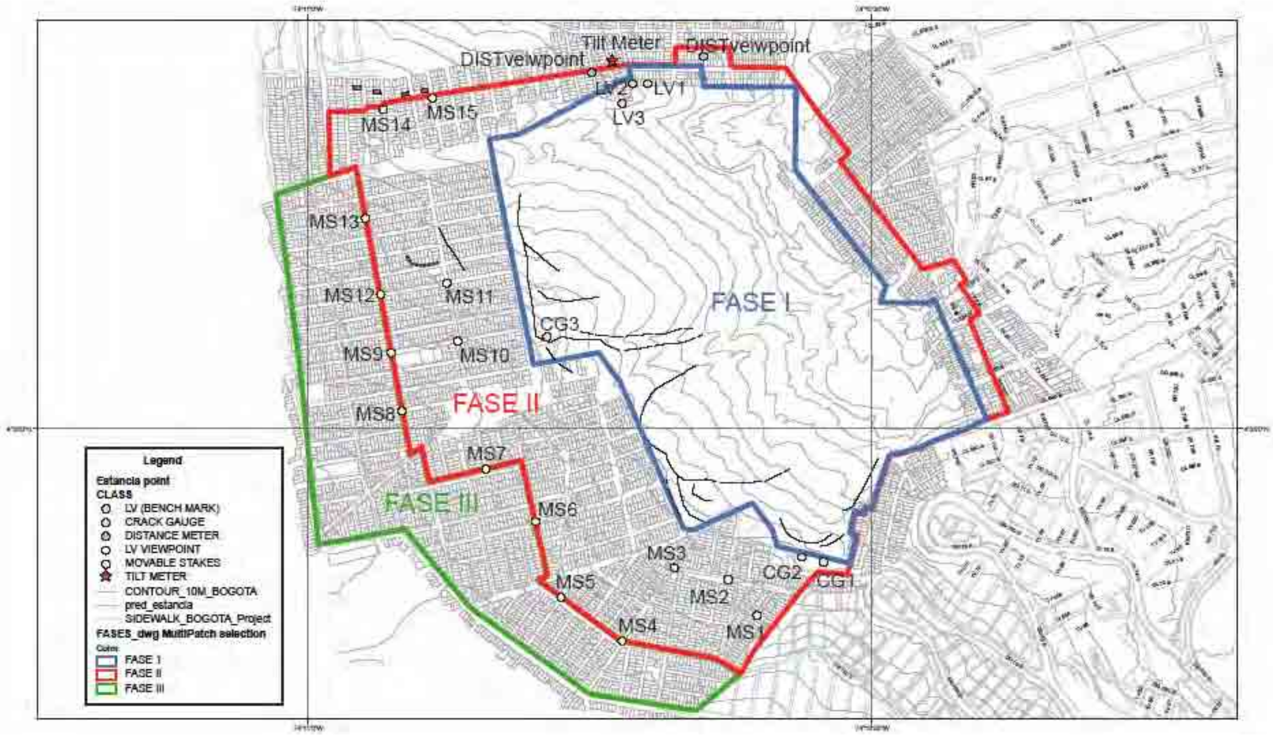



Figure 5-11 Location of Survey Points and Other Monitoring Equipments

In case any movement on some survey points is 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. If the influence of the landslide on the area is found out, it is necessary to reconsider the area of Phase III. A total of 15 numbers of the survey points were installed, and 5 numbers of fix points are installed as bench marks. Actually the survey points made of concrete with brass points were installed to avoid their removal.

(2) Crack Gauges

The movement of the cracks monitored by the 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. Sign boards are installed at the crack gauges to explain the meaning of the monitoring to the residential people around.

Crack gauges installed on the site are quite bigger and stronger than those found in Japan since they might be destroyed as shown in Figure S8-1-4 in Supporting Report. However some of them were destroyed by people after their installation on the site, and they were substituted with stakes.

(3) Monitoring for the House

In the house which is object of the monitoring, some cracks were found by residents of the house in October 2006. The house locates at the boundary between evacuation area and safe area and at the place close to the uplift formed by the landslide movement.

The following equipments were installed in and around the house to monitor 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

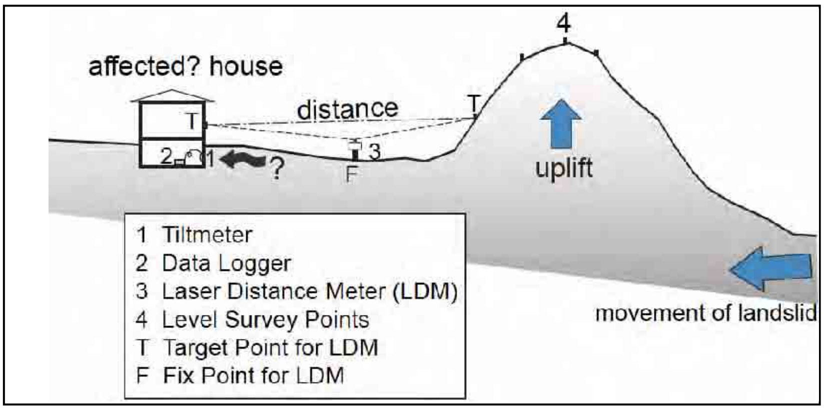



Figure 5-12 Monitoring Equipments for the House

For the monitoring of distance between the house and the uplift, laser distance meter is employed. The distance is not monitored directory using laser distance meter, but monitored indirectly using laser distance meter which on the fix point, and three numbers of target points installed one at the house and two on the uplift.

(4) Level Survey

The level survey is undertaken to monitor the rising of the uplift. The results are analyzed with another monitoring such as the distance meter and the tiltmeter.

(5) Distance Meter

In case the distance between the house and the uplift is short, the landslide may get closer to the house, and the extension of Phase II area should be discussed. One portable laser distance meter is employed for the monitoring, and its specification is as follows;

Maximum distance to measure: 100 m or farther,
Measuring accuracy: ±1.5 mm (up to 30 m in distance),
Tilt sensor accuracy to laser beam: ±0.15°, to the housing: ±0.3°

Two (2) numbers of target plates for the laser distance meter were installed on the uplift ground

(6) Tiltmeter

If the tiltmeter installed in the house show the house is tilting, the landslide may influence on the house. The influence of the landslide should be analyzed comparing with the result with the distance meter. If we find the landslide is imminent to the house, the house should be object of relocation.

To monitor the tilting of the house, one automatic tiltmeter is installed with data logger on the wall of the basement in the house. Specifications of the tiltmeters are as follows;

Standard Range: ±10° or more precisely,
Sensitivity: ±10 arc seconds or more precisely, and
A single channel type data logger was employed to collect the tiltmeter data. Specifications of the tiltmeters are as follows;

Available to change any measurement interval (selectable every 1 sec, 1 min, 1 hr, 1 day),
Data memory: more than 1,000 data

### 5.6.3 Results

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. 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.