Japan International Cooperation Agency
The City of Bogotá

The Study on Disaster Prevention in the Bogotá Metropolitan Area in the Republic of Colombia

GIS Map

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Pacific Consultants International
OYO Corporation

CONTENTS OF MAPS

1. EXISTING CONDITIONS

1.1 Satellite Image

This satellite color composite, geo-corrected image, is prepared by JICA Study Team based on the original image provided by DPAE with the following characteristics:

- Image type: SPOT X
- SCENE ID 26463409802281518241X/7 TB0500L
- Pixel Size: 20m
- Number of Lines: 3960
- Number of Columns: 5400
- Image Type: Band Interleaved by Lines (BIL)
- Image acquired Date: 28 02 1998

This raw image was color-enhanced by applying linear stretching. Then it was geo-referenced using 18 control points (enough for the scale of 1:100,000) evenly distributed in the study area. The geo-referenced bands were used to make a color composite using standard 24 bit RGB (band1, band2, and band3), subjecting each band to histogram equalization. This color composition was made to enhance the exiting land use/land cover. Finally, the color composite image was geo-corrected to offset the distortion due to earth-rotation during image acquisition.

This image almost completely covers the study area and nicely depicts the land use/ land cover at the time of acquisition. Also, the landscape of the study area is represented almost to the detail. The intense red color shows the abundance of native vegetation cover, red depicts agricultural lands while the gray to grayish green color represents the urban zone; black color is for the shadow or area without vegetation and the intense black for the water bodies.

This processed image has been completely integrated with the other GIS layers and can be used for the regional visualization. Moreover, all the results generated in GIS system can be interactively displayed over this image to better understand these results.

1.2 Study Area

The study area composed of Bogotá City and the eight municipalities of Chia, Cota, Facatativa, Funza, La Calera, Madrid, Mosquera, and Soacha encompass a total area of 194,797 ha. The total area of Bogotá with 19 localities is 85,832 ha and the eight municipalities in Cundinamarca make up 108,965. The Bogotá Metropolitan Area, as the study area is called, covers 194,797 ha in total. .

1.3 Topography

Topographic map shows the natural conditions of the study area. It also includes administrative boundary as well as urban-rural boundary. Most of the urbanized area of the Bogotá Metropolitan Area has developed on high elevation area between 2,600 to 2,800 meters.

The study team digitized topographic maps of 1:25,000 scale, which is made by the Geographic Institute Agustin Codazzi of Colombia. The administrative boundaries are determined based on the existing Territorial Ordering Plan, which is prepared by Bogotá City as well as by each municipality.

1.4 Slope Gradient

The study team carried out slope analysis by contour data with a 50-meter interval. The slope is classified into seven categories based on FAO classification. The map shows Bogotá City is situated on very flat area of less than 3% gradient and surrounded by steep slope area, especially the eastern edge of the City is facing toward the steep mountainous area. The southern part of Bogotá City finds many steep slope areas from 7 to 50% gradient. In Cundinamarca, La Calera is located in the steep slope area.

1.5 Geology

Based on aerial photos, existing geological map, topographical map, compilation of existing boring, and site visits, geological map for the study area with a scale of 1/50,000 is made. Thick Quaternary lake deposit exists in the central part of the study area, while Cretaceous and lower Tertiary sediment rocks are dominant in the eastern and southern mountainous area.

1.6 Zoning System

The microzoning system was established in the Study Area by observing two factors:

- The possibility of aggregating data from the existing spatial division; and
- The homogeneous behavior of a seismic event.

Based on the above, the microzoning system was established as follows:

Summary of Microzoning System

Area	Rural	Urban
Bogotá	Village Boundary	Cadastral Barrio
Eight Municipalities	Village Boundary	Urbanized area of IGAC cadastral data divided in DANE Sector

The number of microzones in the Study Area is shown as follows:

Summary of Microzones

Area	Number of Microzones
Bogotá	950
Eight Municipalities	110
Total	1,060

In each microzone, collected data are distributed and a database for microzones is established. The databases are used as a unit of analysis.

1.7 Estrato Classification

The estrato is the index of the urban residential variables that are classified into six, from class one (lowest) to class six (highest). This classification was first done in 1995 through the "Stratification program," planned and guided by the National Department of Planning (DNP), and directly executed by DAPD and other related municipalities. After 1996, each municipality of the administration has been obligated to keep updating the data of the stratification project, and some revision has been made in Bogotá City. The map shows the estrato distribution of the study area. It should be noted that the estrato system is a little bit different from that of Bogotá and the eight municipalities. In this study, estrato is used as an index of socio-economic level.

1.8 Population Distribution

The population data for Bogotá are established based on the projection of the population for locality for the year 2000. The population of census 1993 by locality of Bogotá is projected for the year 2000 by the planning department of Bogotá. In the present study, these data are used.

For the eight municipalities, DANE data was obtained for rural and urban areas. The total population was distributed in these microzones based on the number of residents living in each housing unit, a factor estimated previously for each municipality.

Based on the above method, the population obtained is as follows.

Summary of Population

Area	Population
Bogotá	6,378,928
Eight Municipalities	606,581
Total	6,985,509

1.9 Population Density

Population density is high in southeastern part of Bogotá City, such as Ciudad Bolivar, Kennedy, San Cristobal, and Rafael Uribe. Low density areas are located in the northeastern part of the city, such as Suba, Fontibon and Teusaquillo.

Compared with that of Bogotá City, the eight municipalities have relatively low density.

1.10 Building Distribution (Total)

In this study, the building inventory database was prepared based on 2000 cadastral data. In Bogotá City, cadastral data are collected at the Bogotá cadastral office, while Cundinamarca data are prepared by IGAC office, which is the agency responsible for cadastral data collection in Cundinamarca.

Total number of buildings is approximately 956 thousand in the study area, yet more than 76 thousand buildings have no information on structure. Then, a building damage estimation done by the study shows damage on some 880 thousand buildings.

1.11 Building Distribution (Masonry)

More than 81% of buildings are classified as masonry structure building, which is mainly distributed in the low estrato. Those buildings are found in southern part of Bogotá City.

1.12 Building Distribution (RC Frame)

RC frame structure shares only 5.6% in the study area and many of them are found in the high estrato, especially in northern part of Bogotá City.

1.13 Infrastructure (Road and Bridges)

All the roads in Bogotá City area are under the jurisdiction of Bogotá City. The Urban Development Institute (IDU) under Bogotá City is responsible for the construction and the maintenance of these city roads. National roads outside of Bogotá City are under the jurisdiction of the Ministry of Transport. The Instituto Nacional de Vias (INVIAS) under the ministry is responsible for the construction and maintenance of these national roads. The eight municipalities have responsibility of roads inside their municipal boundaries. Cundinamarca Prefecture has responsibility for the roads connecting to national roads and municipality roads.

During the Study a bridge site survey has been carried out in Bogotá City and in the eight municipalities for confirmation of IDU bridge inventory. The number of bridges by type is shown as follows:

Number of Bridges by Type

	Pedestrian bridges	Vehicular bridges			Total
		Flyover	River	Sub-Total	
Bogotá	146	108	69	177	323
Eight Municipalities	19	6	11	17	36
Total	**165**	**114**	**80**	**134**	**359**

The location and structure of the bridge data collected from IDU have been clarified through the field investigation. It is found that the bridge inventory is accurate, except some bridge locations.

1.14 Lifeline (Water)

EAAB is responsible for water supply, sewage and drainage services to Bogotá City. With regard to the eight municipalities, a public company in each municipality services water supply from wells and rivers, and manages their resources and supply facilities. However, EAAB supplies water to them to cover the shortage of water supply in each municipality.

The distribution system is divided into matrix networks of tunnels, or of big iron pipelines with diameters between 60 and 78 inches, which conduct the water from the sources to the purifying plants, and then to the main distribution networks with diameters between 12 and 36 inches. Detailed distribution network is composed of pipelines less than 12” in diameter. According to EAAB, water for distribution is supplied through a 6,500 km long pipeline utilizing 65 operation stations composed of 31 pumping stations, 25 storage tanks and 9 control stations.

1.15 Lifeline (Natural Gas)

Around Bogotá there are two city gates: The first one is near a municipality called Cogua that is located North-west of the city, while the second one is located in Usme. The principal pipelines from the city gates to Bogotá and the distribution networks are controlled by Natural Gas Company.

The current extension of the primary and distribution network covers about 90% of the urban area in Bogotá City. For the capital city, the network attends to 751,734 users (houses or apartments) and is in capacity to attend to a total of 1,140,080 users; the respective numbers for Soacha are 91,122 and 306,556, and for Chia, 4,160 and 21,042.

1.16 Lifeline (Electricity)

The electricity supply in the study area is provided by several electricity supply companies such as EMGESA, EEB, CODENSA, AMBAS and ISA. The generation and transmission network is not an isolated one, but is connected to the national electrical system through the National Transmission System.

The distribution of electric lines in and around Bogotá City is composed of 230 kV by EEB, 115 kV and 57.5 kV by CODENSA. The high voltage lines of 230 kV are located outside Bogotá City bordered by Toroca, Noroeste, La Mesa, El Paraíso, Muna, Fusagasugá, Usme, Circo and Embalse San Rafael. At each boundary, there are eight main substations for transforming 230 kV into 115 kV.

The distribution of electricity for houses in Bogotá City and the eight municipalities of Cundinamarca are maintained by CODENSA. Facatativa is served by CODENSA and AMBAS. CODENSA is generally in charge of expansion, maintenance and repair of the distribution network less than 115 kV, and the facilities related with distribution such as sub-stations, posts, electrical transformers, etc.

1.17 Lifeline (Telecommunication) CAPITEL

CAPITEL has a cable telephone network and mobile telephone network. The information of both networks is provided by well-organized GIS database, which contains mobile radio station, overhead cable network, underground cable network and telephone poles. The share of overhead cable is 58% and that of under ground cable is 42%. The total number of poles is 54,970 and the number of radio stations is 98.

1.18 Lifeline (Telecommunication) ETB

ETB has 37 local control centers and 4,500 cabinets in Bogotá City. The average length of main cables per cabinet is approximately 42,000m, and the average length of local cables per cabinet is about 2,410m. The shares of overhead cable by type are as follows: main cables, 1%, local cables, 49%. Total number of poles is about 120,000.

1.19 Public Facility (Emergency Operation Center, Commanding Center, Emergency Goods Storage Center)

This map shows the distribution of the commanding centers, local mayor office of Bogotá, and emergency good storage center. The commanding centers include mayor’s office, health secretary, DPAE, OPAD, and Cundinamarca government. Other public facilities, such as civil defense, fire fighting station, national army, police station, and headquarters of ministries are located on the map.

1.20 Health Facility (Hospital, Red Cross)

Distribution of public and private hospitals, and Red Cross, is located on this map. Level I, II, and III for each public and private hospitals is identified.

1.21 Schools (Primary, Secondary and Tertiary)

Schools will act as evacuation facilities in a case of emergency. This map presents the distribution of the public and private schools for municipality, and primary-secondary, and superior public schools in the Bogotá city.

1.22 Open Space

The information on open space is collected from the District Institution of Sports and Recreation (IDRD). IDRD has responsibility for the maintenance and rehabilitation of the parks. The parks in the Study Area have six classifications based on the size of the park: metropolitan, urban, regional, barrio parks, pocket parks and zonal parks.

1.23 Distribution of Industrial Facilities

There were 1,800 industrial facilities surveyed in Bogotá City in 1999, while in the eight municipalities in Cundinamarca, 400 industrial facilities were surveyed in 2001. Industrial facilities are concentrated on eight localities, Puente Aranda, Fontibon, Kennedy, Engativa, Barrios Unidos, Usaquen, Los Martires and Suba. Industrial facilities may cause secondary disaster such as fire outbreak and explosion.

2. ANALYSIS OF EARTHQUAKE

2.1 Geotechnical Zoning

Based on aerial photos, geological map, topographical map, compilation of existing boring, and site visits, geotechnical classification map with a scale of 1/50,000 for the study area is made. The dominant geotechnical classification in each micro zone is attributed as geotechnical zone. Geotechnical zoning map is used to evaluate the ground motion amplification factor due to scenario earthquakes later on.

2.2 Peak Ground Acceleration (La Cajita Fault Model)

Peak ground acceleration is maximum amplitude of ground motion due to the earthquake measured in terms of acceleration. It indicates the intensity of ground motion and is used to estimate damages to buildings and various urban infrastructures later in the study.

The fault used to estimate peak ground acceleration is selected, with the following criteria, from listed faults in former study. 1) Fault having highest probability of occurrence, 2) Fault having maximum probable magnitude, and 3) Fault whose distance from Bogotá satisfies the distance specified in former study. As a scenario earthquake for case-1 (near), La Cajita fault is selected, which locates in the southern part of the study area, and has maximum probable magnitude of 6.4. The activity rate of the fault is evaluated as moderate, including an active segment of 5 km in length.

In this map, peak ground acceleration for La Cajita fault is calculated using attenuation at bedrock, and amplification factor for each geotechnical zone calculated by seismic record obtained during Loma Prieta earthquake at Coralitos. As a result, higher peak ground acceleration is estimated in the southern part of the study area, which is close to the fault, with a maximum value of 0.908g.

2.3 Peak Ground Acceleration (Guayuriba Fault Model)

Guayuriba fault is selected for case-2 (regional) scenario earthquake, from a listed fault within the radius of 200km from Bogotá, with the same criteria as used in La Cajita fault model. The fault belongs to Servita-Santa Maria fault system, and locates 60km southeast from Bogotá with maximum probable magnitude of 7.0, and is evaluated as active in former study.

The seismic record synthesized using the record at El Rosal by 1995 Tauramena earthquake is used for calculation of amplification factor within surface geology. The peak ground acceleration over 0.3g is estimated in southeastern part due to the closer distance to the fault, and in the central part of the Bogotá due to the amplification by lake deposit.

2.4 Peak Ground Acceleration (Subduction Model)

The case-3 scenario refers to a distant earthquake, generated in the subduction zone along the Pacific coast, whose distance is 400km from Bogotá, with a magnitude of 8.3. For the calculation of amplification factor in surface geology, an earthquake record obtained at Ciudad Universitaria of the 1985 Michoacan earthquake is used. Peak ground acceleration from 0.1g to 0.2 g is estimated in the central part of the study area due to the amplification of lake deposit.

2.5 Seismic Intensity Distribution (La Cajita Fault Model)

Modified Mercalli seismic intensity (MMI) is calculated for the purpose of damage estimation, from peak ground acceleration using empirical equation proposed by Trifnac & Brady. For La Cajita fault model scenario earthquake, the southern part of the study area close to the fault would suffer MMI ranging from IX to X. While estimated MMI is VII in most part of the study area, some zones would suffer MMI VIII due to the amplification by surface geology.

2.6 Seismic Intensity Distribution (Guayuriba Fault Model)

For Guayuriba fault model scenario earthquake, MMI in most part of Bogotá and northwestern part of the study area is estimated to be MMI VIII, due to the amplification by lake deposit. MMI for the rest of the study area is estimated to be VII, while northwestern end of the study area is in MMI V, and southeastern area closer to the fault is in MMI IX.

2.7 Seismic Intensity Distribution (Subduction Model)

For Subduction model scenario earthquake, MMI VII is estimated in the center of Bogotá and northwestern part of the study area, due to the amplification by lake deposit. MMI for mountainous area in the suburb of the study area is expected to be V.

2.8 Evaluation of Liquefaction (Guayuriba Fault Model)

Liquefaction phenomena during earthquake would occur in loose sandy ground with high ground water level. In this study, liquefiable area from geotechnical point of view is revised using newly obtained boring data in Bogotá. Then, these geotechnical information and seismic intensity data are used to delineate liquefiable area for each case of scenario earthquake. Delineated liquefiable area is used to evaluate seismic risks to water pipelines, gas pipelines, bridges, and industrial facilities in this study. For Guayuriba fault model scenario earthquake, probable liquefiable area is estimated in the southern part of Bogotá, where sandy soil originated from Tunjuelito River exists.

3. HAZARD MAP

3.1 Distribution of Weak Buildings (Masonry in Estrato 1 and 2)

Building inventory is established from data provided by the cadastral office in Bogotá and IGAC. Structural types of buildings are classified into six types, and then number of buildings by each type is counted in each microzone. In this map, distribution of masonry buildings in the microzone of estrato 1 and 2, structure type 2 as defined in this study, is shown. Type 2 buildings share 42.3% of the total buildings, and are one of the most vulnerable structure types.

3.2 Building Damage Ratio, La Cajita Fault Model (Total)

Damage ratio for each type of building is defined using damage statistics in the 1999 Quindio earthquake and site observation of buildings in Bogotá. The number and ratio of heavily damaged buildings are estimated using damage ratio and seismic intensity for each microzone.

This map shows the estimated building damage to all types of structures for La Cajita fault model scenario earthquake. Building damage ratio over 50% is estimated in the southern part of the study area, which is close to the fault. In total, 45.4% of the buildings, or 399,811 buildings, are estimated as heavily damaged.

3.3 Building Damage Ratio, La Cajita Fault Model (Masonry)

This map shows the estimated damage to masonry structures, structure type 2, 3, and 4 as defined in this study, for La Cajita fault model scenario earthquake. With respect to masonry structures, 48.4% of the buildings, or 358,325 buildings, are estimated as heavily damaged.

3.4 Building Damage Ratio, La Cajita Fault Model (RC Frame)

This map shows the estimated damage to reinforced concrete frame structures, structure type 5 and 6 as defined in this study, for La Cajita Fault Model scenario earthquake. With respect to masonry structures, 0.04% of the buildings, or 37 buildings, are estimated as heavily damaged.

3.5 Building Damage Ratio, Guayuriba Fault Model (Total)

This map shows the estimated damage to all types of structures for Guayuriba fault model scenario earthquakes. Most of the microzones in the study area would suffer damage ratio of 20% or higher. In total, 48.0% of the buildings, or 422,715 buildings, are estimated as heavily damaged.

3.6 Building Damage Ratio, Guayuriba Fault Model (Masonry)

This map shows the estimated damage to masonry structures, structure type 2, 3, and 4 as defined in this study, for Guayuriba fault model scenario earthquake. With respect to masonry structures, 51.3% of the buildings, or 380,020 buildings, are estimated as heavily damaged.

3.7 Building Damage Ratio, Guayuriba Fault Model (RC Frame)

This map shows the estimated damage to reinforced concrete frame structures, structure type 5 and 6 as defined in this study, for Guayuriba fault model scenario earthquake. No damage to RC frame structures is expected for this case.

3.8 Building Damage Ratio, Subduction Model (Total)

This map shows the estimated damage to all types of structures for Subduction model scenario earthquake. In total, 7.0% of the buildings, or 61,876 buildings, are estimated as heavily damaged.

3.9 Building Damage Ratio, Subduction Model (Masonry)

This map shows the estimated damage to masonry structures, structure type 2, 3, and 4 as defined in this study, for Subduction model scenario earthquake. With respect to masonry structures, 6.9% of the buildings, or 50,981 buildings, are estimated as heavily damaged.

3.10 Building Damage Ratio, Subduction Model (RC Frame)

This map shows the estimated damage to reinforced concrete frame structures, structure type 5 and 6 as defined in this study, for Subduction model scenario earthquake. No damage to RC frame structures is expected for this case.

3.11 Human Casualty (Death) Ratio (Guayuriba Fault Model)

Population database is constructed from census data projected for the year 2000 for Bogotá, and housing units adjusted by POT for Cundinamarca. Human casualty such as number of deaths and injured persons in each locality and municipality is estimated using relationship between heavily damaged buildings and casualty established from damage statistics for municipalities due to the 1999 Quindio earthquake. For Guayuriba fault model scenario earthquake, total number of deaths amounts to 41,380, which is 0.6% of total population.

3.12 Damage of Bridges (Guayuriba Fault Model)

There are 194 vehicular bridges and 165 pedestrian bridges according to the list of bridges provided by IDU and site survey by the study team. A statistical estimation method commonly used in Japan, including material, structure, ground type, seismic intensity, and liquefaction effect, is used to evaluate damages to vehicular bridges, since damage data for bridges in Colombia was not available. Seismic risk of pedestrian bridges is evaluated only with respect to liquefaction potential area. For Guayuriba fault model scenario earthquake, 58 vehicular bridges are evaluated as at high risk.

3.13 Damage of Lifeline (Water), La Cajita Fault Model

Water pipeline GIS database for the whole study area is provided by EAAB. The database includes information on service network pipe diameter, and pipe material, excluding pipelines to individual buildings. Basic damage ratio for water pipeline is defined from the situation report during the 1999 Quindio earthquake, and from Japanese experiences. Then, factors such as peak ground acceleration, pipe material, diameter, ground type, and liquefaction effect are taken into account to modify basic damage ratio. Number of damaged points, and number of damaged points in unit length is estimated for three cases of scenario earthquakes. For Guayuriba fault model scenario earthquake, 1,545 damaged points in total is estimated out of 6,790 km pipeline length, which amounts to 0.23 damaged points/km.

3.14 Damage of Lifeline (Electricity), La Cajita Fault Model

Network cable distribution, including overhead and underground cable for 11kV intermediate voltage for the study area, is provided by CODENSA. Damage to the electricity pole is estimated using the 1999 Quindio earthquake report and experience of earthquake in Kobe, assuming the strength of electric pole is the same as that in Japan. Length of disruptions and its ratio against total length is calculated for three cases of scenario earthquake. For Guayuriba fault model scenario earthquake, total damaged cable length amounts to 1.001km out of 5,765 km cable length, which amounts to damage ratio of 0.02%.

3.15 Damage of Lifeline (Telecommunication), La Cajita Fault Model

Secondary cable distribution between main station and user for the whole study area, excluding cables to individual buildings, is provided by two companies, ETB and CAPITEL. For the damage estimation of overhead and underground telecommunications cables, same procedure is applied as that of the electric power supply cables. For Guayuriba fault model scenario earthquake, total damaged cable length amounts to 2.189 km out of 11,700 km cable length, which amounts to damage ratio of 0.02 %.

3.16 Damage of Lifeline (Natural Gas), La Cajita Fault Model

Gas network pipeline for low-pressure distribution excluding pipelines to individual buildings is provided by Natural Gas Company for Bogotá, Chia and Soacha. Basic damage ratio as defined for water pipeline is used, while factors such as peak ground acceleration, pipe material, pipe diameter, ground type, liquefaction effect are taken into account to modify basic damage ratio. Number of damaged points and number of damaged points in unit length are calculated for three cases of scenario earthquakes. For Guayuriba fault model scenario earthquake, 139 damaged points in total is estimated out of 8,790 km pipeline length, which amounts to 0.02 damaged points/km.

3.17 Landslide Hazard

Uniform inventory of slope disaster in the study area is constructed using historical document, aero photos, latest satellite image, and site observation. In total, 423 sites are delineated in the study area. Slope disaster sites are evaluated and categorized into three grades according to the urgency and effects in case of ordinary time. As a result, from the viewpoint of human life protection, 94 sites are evaluated as grade-1 that requires structural measures or relocation of inhabitants. Sixty-eight (68) sites are evaluated as grade-2 that requires structural measures or non-structural measures. For the rest of 261 sites that are evaluated as grade-3, only non-structural measures are required.

3.18 Flooding Hazard

Flood Risk Map has basically been prepared by compiling the existing flood risk map prepared by each city. Since the existing flood risk map for the eight municipalities showing the inundation-prone areas and/or low-lying areas along rivers was made without any hydrological studies, the risk area has been modified and classified based on topographic and urbanized condition which was confirmed by field investigation during this Study, while the flood risk map of Bogotá City was prepared based on the hydrological studies. To prepare the complete flood risk map for the Study Area, it is necessary to conduct hydrological study targeted to the whole Rio Bogotá upstream basin.

3.19 Risk of Fire Breakout in the Industrial Facilities

The study team constructed a uniform inventory of industrial facilities in the study area, including 1,974 facilities in total. The facilities are classified into eight types according to the fire breakout ratio defined by Japanese experience to evaluate seismic risk for three scenario earthquakes. For Guayuriba fault model scenario earthquake, three localities in Bogotá are evaluated to be at high risk.

4. DEGREE OF REGIONAL DANGER FOR DISASTER

4.1 Degree of Regional Risk for Earthquake

This analysis was made to know which part of the Study Area is vulnerable to earthquake. Following conditions were applied:

- Because the expected damage to the Study Area is largest, result of Guayuriba fault was applied.
- Targeted area included in the analysis is the urbanized are of Bogotá, and urbanized area of the eight municipalities.
- Degree of risks for building, human casualties, and evacuation are used as variables.
- Result shown in the map is relative evaluation.

Higher risk is shown in darker red, which is spread mainly in the southern part of Bogotá, and northern part of Bogotá.

4.2 Degree of Danger for Building (Earthquake)

This map shows the relative evaluation of building vulnerability within the area. Areas in the southern part have more vulnerability of buildings comparing to other parts of the Study Area.

This was evaluated with the result data of damage estimation.

4.3 Degree of Danger for Human Casualty (Earthquake)

This map describes the relative evaluation of human casualty. The evaluation is based on the population density data.

The result is similar to the vulnerability of buildings, showing higher risk in the southern part of Bogotá and partially in the northern part of Bogotá.

4.4 Degree of Danger for Evacuation (Earthquake)

This shows the difficulty of evacuation of the area. It is analyzed with the rate of useful open space and road. These data were collected through the infrastructure and open space related agencies.

As shown in the map, there is lack of open spaces along the peripherals of Bogotá City. One of the causes for this is a matter of geography, where rough or untreated land cannot be used as a safe open space.

4.5 Degree of Regional Risk for Landslide

This analysis was made to know which part of the Study Area is vulnerable to landslide. Following conditions were applied:

- Analyzed area is the urbanized area of Bogotá, and urbanized area of the eight municipalities.
- Risk area identified by DPAE was used.
- Additional information which was obtained throughout the Study, as the high risk points of landslide, flows, and falls, were integrated into the map for further understanding.
- Result shown in the map is relative evaluation.

As a result, high risk area for landslide is highly related to the geographic condition. Mountainous area is at higher risk as shown in the map.

4.6 Degree of Regional Risk for Flood

This analysis was made to know which part of the Study Area is vulnerable to flood. Following conditions were applied:

- Existing hazard maps for Bogotá City and some municipalities of Cundinamarca were used for the basic data.
- Analyzed area is the urbanized area of Bogotá, and urbanized area of the eight municipalities.
- Two variables of degree of danger for buildings, and human vulnerability are used for this analysis.
- Result shown in the map is relative evaluation.

This result is also co-related with the geographic condition; however, area with high density and flood returning period make for high vulnerability.

4.7 Degree of Risk for Industrial Facilities

This analysis was made to know which part of the Study Area is vulnerable to fire outbreaks in industrial facilities. Following conditions were applied:

- Result of fire outbreak rate by Guayuriba fault earthquake was applied, because the expected damage to the Study Area is largest.
- Analyzed area is the urbanized area of Bogotá, and urbanized area of the eight municipalities.
- Degree of danger for fire outbreak ratio was used as variable.
- Result shown in the map is relative evaluation.

Area of higher risk is located in the central part of the City, where identified as the industrial zone.

4.8 Identification of Vulnerable Area

Based on the result of 4-1 Degree of Regional Risk for Earthquake, vulnerable areas by the urban planning zone (UPZ) were identified.

Following UPZs are identified as the vulnerable areas.

Identified Vulnerable Area

Locality	UPZ		ha
Bosa	84	Bosa Occidental	717.45
	85	Bosa Central	402.24
Ciudad Bolivar*	65	Arborizadora*	326.97
	66	San Francisco	182.34
	69	Ismael Perdomo	554.89
Kennedy	48	Timiza	431.38
	80	Corabastos	187.51
	81	Gran Britalia	179.41
	82	Patio Bonito	314.21
Rafael Uribe	54	Marruecos	358.6
	55	Diana Turbay*	182.12
San Cristobal	33	Sosiego*	235.49
	50	La Gloria*	385.88
	51	Los Libertadores	389.08
Santa Fe	95	Las Cruces	98.48
Suba	23	Casa Blanca Suba	419.92
Usme	52	La Flora	206.88
	56	Danubio*	268.11
	57	Gran Yomasa	530.24
	58	Comuneros	483.22
	59	Alfonso Lopez	233.54

Note: Area with * shows higher vulnerability

5. DISASTER MANAGEMENT PLAN

5.1 Disaster Management Centers

The study team identifies public buildings that could be used as disaster management centers. Important public buildings are distributed in the study area. However, some need improvement because they are of masonry structure. Priority should be given to those buildings for reinforcement.

5.2 Evacuation Place (Regional)

The study team identifies regional evacuation places, 50 in Bogotá City and 11 in Cundinamarca, in the study area. The public land is the first priority, but some of the localities cannot find public open space. Then the study team selects private land for proposed regional evacuation place. The private land, however, is not appropriate for the regional evacuation place in the long run. The governments should identify another land for the evacuation place.

5.3 Emergency Road Network

The study team identifies primary and secondary emergency road network in the Study Area. The primary road network has connected important emergency commanding centers at local and regional level. The secondary network covers the important emergency response organizational buildings and facilities.

The primary emergency road network is almost the same as primary road network in the Study Area. The secondary emergency road network is primary road as well as secondary road network in the Study Area. The emergency road network covers the whole study area and connects important buildings and facilities.

The study team identifies regional food supply corridor, which connects other regions and the Study Area. Five national roads are identified for this purpose: Via Melgar, Via Sasaima, Autopista Medellin, Via a Tunja and Via Villavicencio.

Bogotá City has depended on the food and logistic supply from outside regions and the roads connecting to these regions are the most important ones for this purpose. Therefore, the regional food supply corridor has the same importance as emergency road network.

5.4 Emergency Water Tanks

The emergency tanks are arranged at localities where water supply capacity is short for emergency situations. Thus emergency water tank is not allocated in Chapinero, Santa Fe, San Cristobal and Usme which have enough supply capacity for emergency.

Emergency water tank volume is provided to supply almost of target volume, which is decided on condition that inhabitants endure one week after disaster with a minimum water consumption of 3 liters/day/person. It means water supply system should be recovered somewhat at least one week after disaster.

Sewerage pipeline is also recommended installed nearby or in the regional evacuation place to ensure a minimum sanitary life for evacuated people. Necessary valves, pipe installation and faucet should be provided for the sewerage pipeline.