BOGOTÁ WATER SUPPLY
AND SEWAGE COMPANY
(ACUEDUCTO)

STUDY ON SUSTAINABLE WATER SUPPLY FOR BOGOTÁ CITY AND SURROUNDING AREA BASED ON THE INTEGRATED WATER RESOURCES MANAGEMENT IN THE REPUBLIC OF COLOMBIA

FINAL REPORT
MAIN REPORT

March 2009

JAPAN INTERNATIONAL COOPERATION AGENCY

YACHIYO ENGINEERING CO., LTD.

<u>Exchange Rate</u>

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Average between May to November 2008

PREFACE

In response to a request from the Government of the Republic of Colombia, the Government of Japan decided to conduct a study on the Study on Sustainable Water Supply for Bogotá City and Surrounding Area Based on the Integrated Water Resources Management, in Republic of Colombia, and entrusted the study to the Japan International Cooperation Agency.

JICA selected and dispatched a study team headed by Mr. Hiroshi Nakamura of Yachiyo Engineering Co., Ltd. to Colombia, three times between November 2006 and January 2009.

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

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

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

March 2009

Mr. Ariyuki Matsumoto
Vice President
Japan International Cooperation Agency

March 2009

Mr. Ariyuki Matsumoto,
Vice President
Japan International Cooperation Agency

Dear Mr. Matsumoto

LETTER OF TRANSMITTAL

We are pleased to submit to you the final report of the Study on Sustainable Water Supply for Bogotá City and Surrounding Area Based on the Integrated Water Resources Management in the Republic of Colombia. The report took into account of the advices and suggestions of your Agency. Also included are comments made by Bogotá Water Supply and Sewerage Company.

Water is conveyed to Bogotá city from the dam reservoir 40km away through mountain tunnel. However, it is pointed out from before that water supply will be suspended by collapse of the tunnel when natural disaster such as a large earthquake happed, which will give serious impact on water supply of Bogotá city. Bogotá city has faced this problem for a long period time. As one of measures against the problem, groundwater resources around Bogotá city are paid attention with high expectation.

This report consists of Master Plan and Feasibility Study for emergency water supply by use of the groundwater for Bogotá city and surrounding area, targeting the year of 2020. In view of the urgent necessity for implementation of projects of emergency water supply, we recommend that Government of Colombia will implement urgently the projects proposed in the Feasibility Study. Emergency response in water supply will be improved greatly by use of the results of this Report.

We wish to take this opportunity to express our sincere gratitude to your Agency and the Ministry of Foreign Affairs. We also wish to express our deep gratitude to the Bogotá Water Supply and Sewerage Company and the relating organizations for close cooperation and assistance extended to us during our investigation and study.

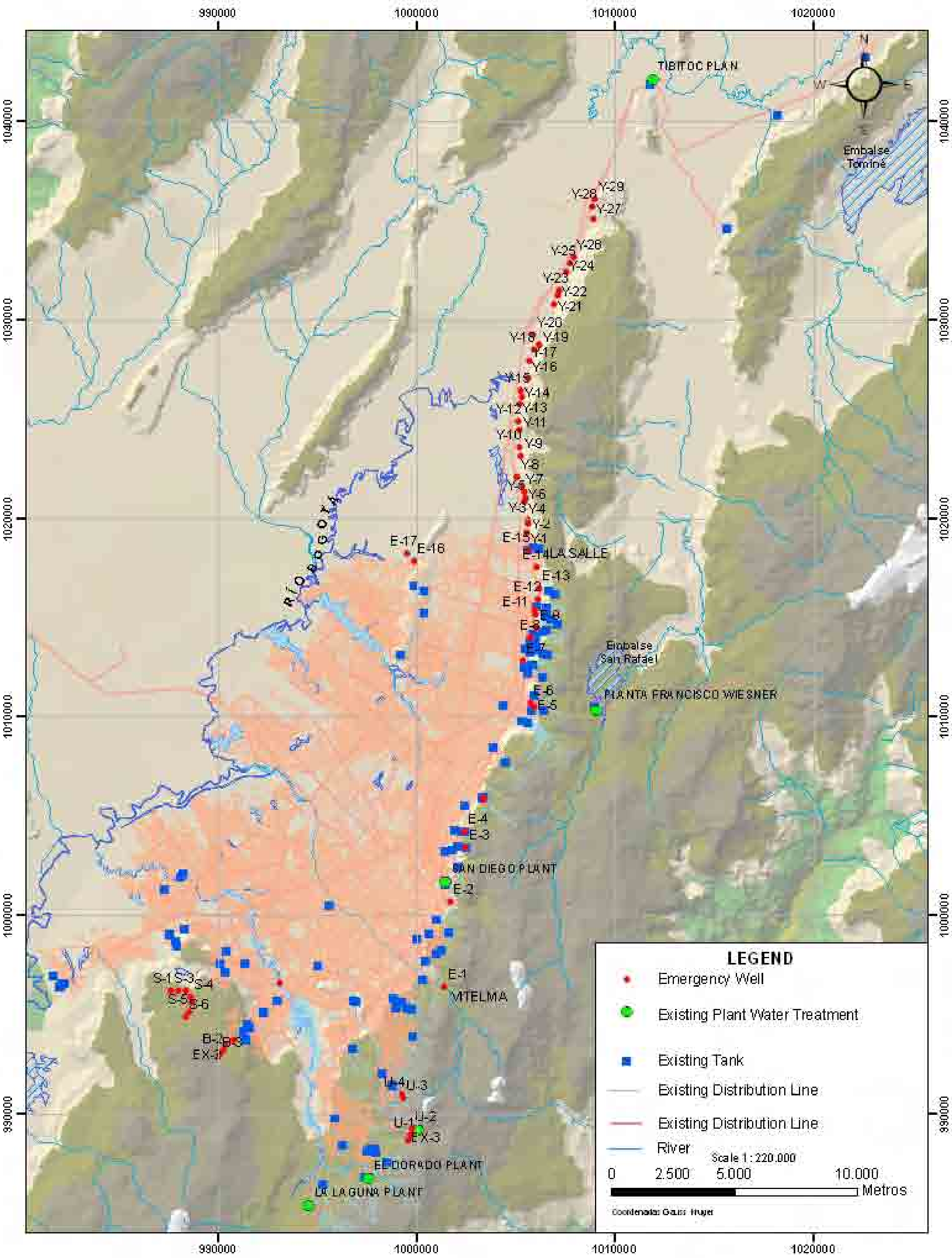
Very truly yours,

中村 浩

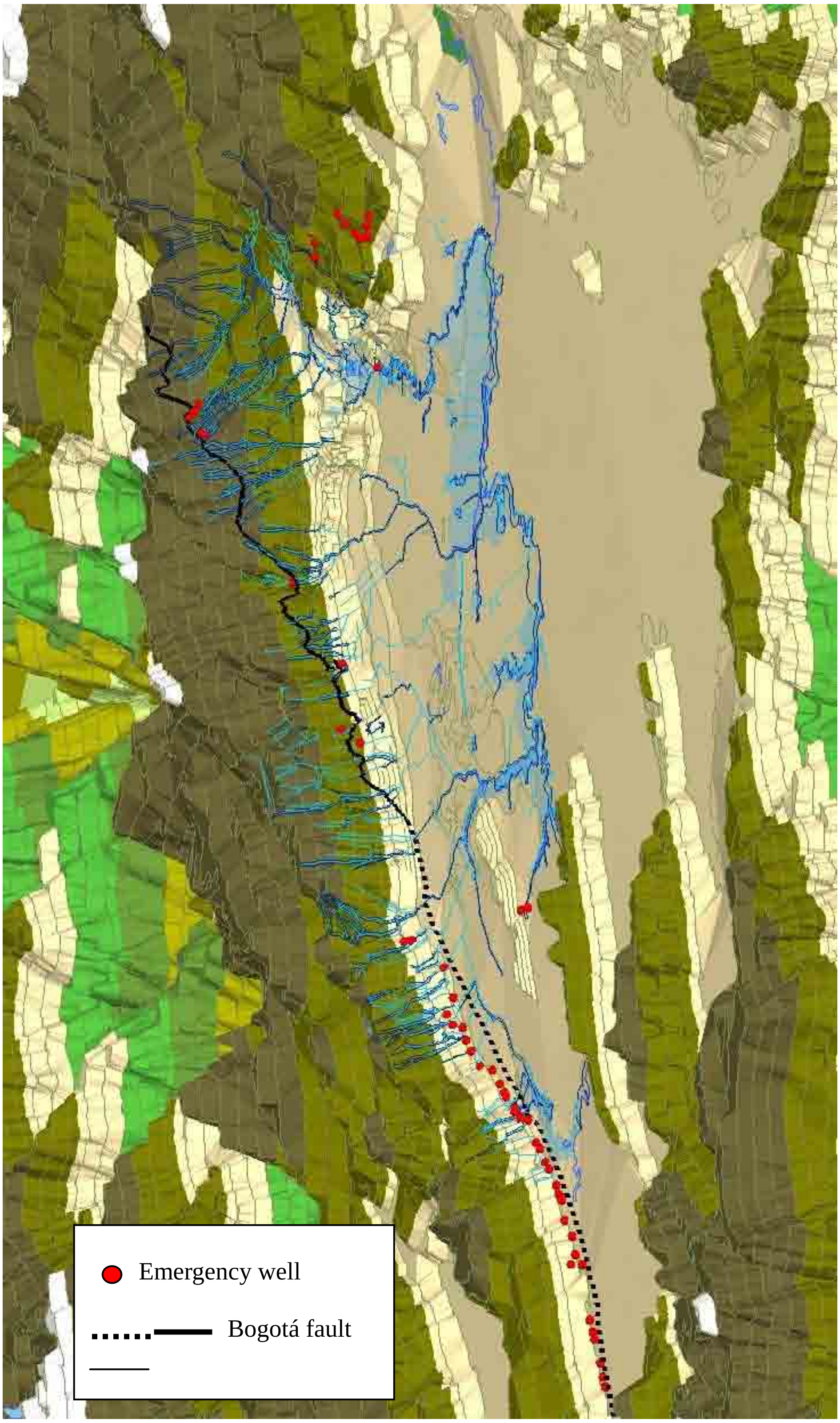
Hiroshi Nakamura
Team Leader
The Study on Study on Sustainable Water Supply for Bogotá City and Surrounding Area Based on the Integrated Water Resources Management in the Republic of Colombia

	
Codito area in Eastern Hills. Residential area is distributed in the slope.	Soacha area in Southern Hills. Residential area is distributed in the slope.
	
Proposed drilling site of the Eastern project, near E-12 well point.	Proposed drilling site of Southern project, neat B-3 drilling point.
	
Proposed drilling site of Yerbabuena project, near Y-18 drilling point.	Drilling work by JICA in Ciudad Bolivar, which is candidate for future pilot project.

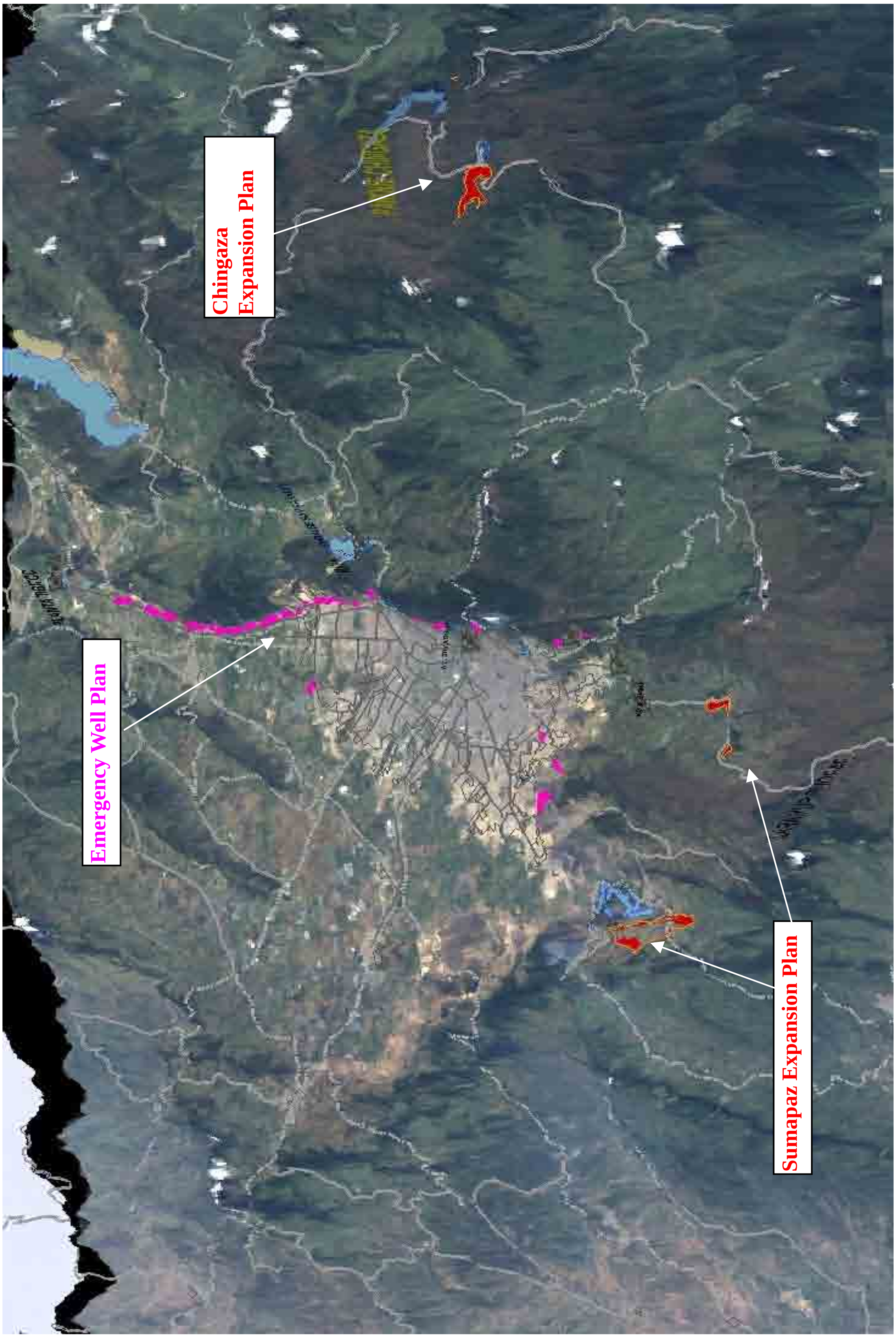
	
Drilling work by Acueducto in La Aguadora, which is candidate for future pilot project.	Site for Pilot Project in Vitelma, which will be implemented form April 2009 by Acueducto.
	
Site for Pilot Project in La Salle, which will be implemented form April 2009 by Acueducto.	Water treatment facility for groundwater in Tocancipa. Proposed facilities for water treatment in this JICA Study is more compact than this.
	
Mountain fire happens every year in Eastern Hills of Bogta. Groundwater in Easter hill can be used for fire-fighting.	Landscape of Eastern Hills. Steep slope consists of the Cretaceous rock, and gentle slope consists of the Tertiary rock. Boundary between them is Bogotá fault.



Study Area <● **Emergency well** >



Emergency Wells and Bogotá Fault


Chingaza Expansion Plan
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THE STUDY ON SUSTAINABLE WATER SUPPLY FOR BOGOTÁ CITY AND SURROUNDING AREA BASED ON THE INTEGRATED WATER RESOURCES MANAGEMENT, COLOMBIA

FINAL REPORT - MAIN REPORT

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List of Abbreviations

Abbreviation	Spanish	English	Japanese
Acueducto	Empresa de Acueducto y Alcantarillado de Bogotá	Bogotá Water Supply and Sewerage Company	ボゴタ上下水道公社
AWWA	Asociación Americana de Acueductos	American Water Works Association	米国水道協会
ACCIÓN SOCIAL	Agencia Presidencial para la Acción Social y la Cooperación Internacional	Presidential Agency for the Social Action and International Cooperation	コロンビア社会開発・国際協力庁
a.s.l.	Sobre el nivel del mar	Above sea level	海抜
ASOCOLFLORES	Asociación Colombiana de Exportadores de Flores	Colombian Flower Exporters Association	コロンビア花卉輸出業者組合
B/C	Relación Beneficio-Costo	Benefit-Cost Ratio	便益対費用比
BOD	Demanda Bioquímica de Oxígeno	Biochemical Oxygen Demand	生化学的酸素要求量
CAR	Corporacion Autónoma Regional de Cundinamarca	Regional Autonomous Corporation of Cundinamarca	クンディナマルカ地域公社
COD	Demanda Química de Oxígeno	Chemical Oxygen Demand	化学的酸素要求量
CORPOGUAVIO	Corporación Autónoma Regional del Guavio	Regional Autonomous Corporation of Guavio	グアビオ地域自治公社
CORPOORINOQUIA	Corporación Autónoma Regional del Orinoco	Regional Autonomous Corporation of Orinoco	オリノキア地域自治公社
CPI	Indice de Precio al Consumidor	Consumer Price Index	消費者物価指数
DANE	Departamento Administrativo Nacional de Estadística	National Administrative Department of Statistics	国立統計局
D.C.	Distrito Capital	Capital District	首都圏
DPAE	Dirección de Prevención y Atención de Emergencias	Prevention and Attention Emergencies Direction	ボゴタ首都圏都市防災局
DEM	Modelo Digital de Elevación	Digital Elevation Model	数値標高モデル
EEEB	Empresa de Energía Eléctrica de Bogotá	Bogotá Electric Power Company	ボゴタ電力会社
EIA	Estudio de Impacto Ambiental	Environmental Impact Assessment	環境影響評価
EIRR	Tasa Interna de Retorno Económico	Economic Internal Rate of Return	経済的内部収益率
EMGESA	Empresa de Generadora de Energía S.A.	Electric Power Generation Company	発電会社
FAO	Organización de las Naciones Unidas para la Agricultura y la Alimentación	Food and Agriculture Organization of the United Nations	国際連合食糧農業機関
FC	Capacidad de Campo	Filed Capacity	圃場容水量
FIRR	Tasa Interna de Retorno Financiero	Financial Internal Rate of Return	財務的内部収益率
F/S	Estudio de Factibilidad	Feasibility Study	フィージビリティスタディ
FY	Año Fiscal	Fiscal Year	会計年度
GDP	PIB (Producto Interno Bruto)	Gross Domestic Product	国内総生産
GIS	Sistema de Información Geográfica	Geographic Information System	地図情報システム

Abbreviation	Spanish	English	Japanese
GL	Nivel de Terreno	Ground Level	地盤高
GOBERNACION DE CUNDINAMARCA	Gobernación de Cundinamarca	Cundinamarca Government	クンデイナマルカ県庁
GPS	Sistema de Posicionamiento Global	Global Positioning System	全地球測位システム
GRDP	Producto Interno Bruto Regional	Gross Regional Domestic Product	域内総生産
IDB	Banco Interamericano de Desarrollo	Inter-American Development Bank	米州開発銀行
IDEAM	Instituto de Hidrología, Meteorología y Estudios Ambientales	Institute of Hydrology, Meteorology and Environmental Studies	水文気象環境調査庁
IEC	Comisión electrotecnica internacional	International Electrotechnical Committee	国際電気技術委員会
IEE	Examinación Ambiental Inicial	Initial Environmental Examination	初期環境評価
IGAC	Instituto Geográfico "Agustín Codazzi"	"Agustín Codazzi" Geographic Institute	国土地理院
INGEOMINAS	Instituto de Investigación e Información Geocientífica, Minera Ambiental y Nuclear	Institute of Geoscientific, Mining Environmental, Nuclear Research and Information	国立地質科学鉱山環境核調査情報研究所
ISO	Organización Internacional para la Estandarización	International Organization for Standardization	国際標準化機構
IVA	Impuesto al Valor Agregado	Value Added Tax	付加価値税
JBIC	Banco de Cooperación Internacional del Japón	Japan Bank for International Cooperation	日本国際量録
JICA	Agencia de Cooperación Internacional del Japón	Japan International Cooperation Agency	日本国際協力機構
Kc	Coeficiente de Cultivo	Crop Coefficient	収穫率
NGO	Organización No Gubernamental	Non-governmental Organization	非政府組織
MAVDT	Ministerio de Ambiente Vivienda y Desarrollo Territorial	Ministry of Environment, Housing and Land Use Development	環境・住宅・土地開発省
M/P	Plan Maestro	Master Plan	マスタープラン
DO	Oxigeno Disuelto	Dissolved oxygen	溶存酸素
PML	Evaluación por pérdida Máxima Probable	Evaluation for Probable Maximum Loss	予想最高損害額評価
POMCA	Plan de Ordenamiento y Manejo de Cuencas	Settlement and Management Plan of Basins	流域管理計画
POMCO	Plan de Ordenamiento y Manejo de la cuenca de los Cerros Orientales	Settlement and Management of the Eastern Hills Basin	東部山地帯流域管理計画
POT	Plan de Ordenamiento Territorial	Territory Settlement Plan	土地利用計画
SCADA System	Control supervisor y Adquisición de Datos	Supervisory Control and Data Acquisition System	監視制御データ収集システム
SDA	Secretaría Distrital de Ambiente	District Secretary of Environment	ボゴタ首都圏地区環境局
SDP	Secretaria Distrital de Planeación	District Secretary of Planning	ボゴタ首都圏都市計画局
SISBEN	Sistema de Seleccion de Beneficiarios para programas	System of Selection of Beneficiates	社会保障年金制度

Abbreviation	Spanish	English	Japanese
	sociales	for social programs	
S/W	Alcance del Trabajo	Scope of Work	実施細則
TEM	Método de Tiempo de Dominio Electromagnético	Time Domain Electro-magnetic Method	時間領域電磁探査法
UAESPNN	Unidad Administrativa Especial de Sistema de Parques Nacionales Naturales	Special Administrative Unit of National Natural Parks System	国立自然公園システム特別管理ユニット
UAESP	Unidad Ejectiva Servicios Público	Executive Unit of Public Services	ボゴタ首都圏地区公共事業局
WB	Banco Mundial	World Bank	世界銀行
WHO	Organización Mundial de la Salud	World Health Organization	世界保健機構
WMO	Organización Metereológica Mundial	World Meteorological Organization	世界気象機関
WTP	Planta de Tratamiento de Agua	Water Treatment Plant	浄水場
WWTP	Planta de Tratamiento de Aguas Residuales	Waste Water Treatment Plant	下水処理場

SYNOPSIS

The Study on Sustainable Water Supply for Bogotá City and Surrounding Area Based on the Integrated Water Resources Management in Republic of Colombia

Study Period: November 2007 ― March 2009
Recipient Agency: Bogotá Water Supply and Sewerage Company

1. Background of Study

Population of Bogotá city and surrounding area (Bogotá urban area and 10 surrounding municipalities), is 7.6 Million in year of 2005, which is political and economic center of Colombia, where 20% of total population is concentrated with high population growth rate. EAAB (Acueducto) is in charge of water supply for Bogotá city and surrounding 10 municipalities. Acueducto satisfies every requirement in water supply, such as unit consumption rate, water quality, water supply ratio, with stable financial condition. However, currently Acueducto faces vulnerability in emergency water supply. Measures against emergency in water supply are now under preparation, with both soft and hard aspects. Adding above measures, it is pointed out that groundwater should be developed around Bogotá city for emergency water sources, in case water pipelines are damaged by occurrence of large earthquake. Responding to requirement of Colombian side, this study was commenced to solve the problem.

2. Purpose of Study

Purpose of this Study is as follows:

a) Master Plan for emergency water supply by use of groundwater will be formulated, with target year of 2020.

b) Feasibility Study will be implemented for high priority project proposed in the Master Plan Study.

3. Outline of Master Plan for Emergency Water Supply by Use of Groundwater

(1) Existing Plan for Expansion of Water Supply System by Acueducto and its Problem

Responding to increase in water demand of Bogotá city in the future, Acueducto has plan of new development of water resources in Chingaza area. This project is expected to have high financial efficiency, and Acueducto intends to place more weight in Chingaza system for the future. On the other hand, water of Chingaza system will be conveyed from the reservoir in remote area to Bogotá city though single mountain tunnel with 40km length. Thus, there is high risk of interruption of water conveyance by tunnel collapse. Damage by water supply interruption of Chingaza system will be more serious, because importance of Chingaza system will be higher in the future.

(2) Strategy of Master Plan

Water conveyance from Chingaza water sources is vulnerable to natural disaster. Consequently, it was proposed to formulate the plan for emergency water supply by use of groundwater near Bogotá city. Based on above strategy, Master Plan for emergency water supply was formulated in this Study.

(3) Scenario of Emergency Water Supply

Two scenarios were prepared for emergency water supply as listed below:

Table-1 Scenario of Emergency Water Supply

Scenario	Emergency Water Supply
Senario-1	Pipelines for water supply are seriously damaged throughout Bogotá city just after earthquake, and groundwater near Bogotá city is only source for water supply.
Senario-2	Water conveyance from Chigaza system is stopped for a long period of time due to collapse of tunnel, and the other alternative sources for water supply are restored including groundwater.

(Source：JICA Study Team)

Senasrio-1 and scenario-2 are most serious situation in water supply, and measure against 2 scenarios is main target of this Master Plan. Beside 2 scenarios, water shortage by draught and water supply interruption by maintenance works of the facilities are included into the emergency.

(4) Water Demand for Emergency Water Supply

Water demand in emergency water supply by groundwater was planned as shown below:

Table-2 Water demand for Emergency Water Supply by Groundwater

Scenario		Period for recovery	Groundwater demand		Note
			year	Demand (m^3/s)	
Senario-1	Damage of pipelines within Bogotá city	60 days	2007	1.18	Unit water consumption of 15ℓ/person/day is target of Acueducto
			2020	1.68	
Senario-2	Damage to water conveyance tunnel from Chingaza	9 month	2007	2.20	Shortage in water supply by the recovered water system will be supplemented by groundwater
			2020	6.10	

(Source：JICA Study Team)

(5) Groundwater Development

Sixty two (62) wells were proposed for emergency water supply. Aquifer of the wells is the Cretaceous sandstone along the Eastern and Southern hills, which was proved to have high groundwater productivity.

(6) Optimum Yield of Emergency Wells

Optimum yield from sixty two (62) emergency wells were evaluated based on water balance analysis and groundwater simulation. As a result of the analysis, draw-down of groundwater level by pumping from emergency wells was forecasted for the Cretaceous and Quaternary aquifer. Based on this analysis, yield of 1.44m^3/s from sixty wells (62) wells was finally proposed as optimum yield.

(7) Project Plan and Project Cost

Entire project consists of three projects as listed in Table-3. Total amount of 1.44m^3/s will be pumped up for water supply from sixty two (62) wells. Purpose of groundwater development is emergency water supply, and water supply from groundwater is only for case of emergency, period of which will be less than 9 months.

Table-3 Emergency Water Supply by Use of Groundwater（Master Plan）

Project		No. of Wells	Groundwater development (m^3/s)	Project Cost (Col$ Million)
a)	Eastern Project	29	0.67	Col$46,310
b)	Southern Project	16	0.38	Col$33,500
c)	Yerbabuena Project	17	0.39	Col$28,800
Total		62	1.44	Col$108,610

(Source: JICA Study Team)

(8) Organization for Emergency Water Supply by Groundwater

By organizational reform of Acueducto in 2007, sustainable groundwater development and its use were added to responsibility of water supply division, which takes main part of water supply in Acueducto. Moreover, it was proposed to establish new unit within Master System Department, in charge of emergency water supply by use of groundwater.

(9) Project Evaluation

Initial Environmental Evaluation (IEE)

Initial Environmental Evaluation was implemented by the Study Team. As result of the IEE, it was concluded that proposed project in Master Plan will not cause serious impact on social and natural environmental. Therefore, proposed project is classified into "B" rank of JICA categories.

Economic Evaluation

Proposed project is for emergency water supply. For such a project, economic evaluation by monetary base is difficult. . Consequently, proposed project was evaluated by following 4 view points, and was concluded to be economically highly efficient: i) scattering of emergency wells can reduce risk of interruption of water supply in emergency, ii) cost for groundwater development is cheaper than that for surface water development, iii) emergency well can be located near Bogotá city that has high water demand in case of emergency, iv) groundwater development can postpone projects for Chingaza expansion, of which implementation is planned after year of 2021.

Financial Evaluation

Proposed project is for emergency water supply. From such a project, financial profit can not be expected. Total project cost was estimated Col$108,610 Million, which occupy only 7.2% of long term investment plan of Acueducto. It is concluded that Acueducto can afford the capital and interest for entire proposed project, even though the entire budget for the projects are procured within Colombia. Business profit of Acueducto is steadily increasing every year, and additional budget for the proposed project will give only small impact to financial condition of Acueducto

Social Evaluation

Social profit expected from the proposed project is as follows: a) Increase in population that can be supplied water in case of emergency, b) water for fire fighting, c) increase in employment for facilities construction of the project

4. Feasibility Study of High Priority Project

Master Plan for Emergency Water Supply by Use of Groundwater was approved by Colombia side. Following the Master Plan, feasibility Study was implemented for high priority projects proposed in Master Plan. Priority was given to each project as shown below:

Priority	Project		
i)	Pilot Project	→	Prior project
ii)	Eastern project	→	1st Period Project
iii)	Southern project	→	2nd Period Project
iv)	Yerbabuena project	→	3rd Period project

Feasibility Study was implemented for entire projects, considering that each project is important for water supply in emergencies.

4.1 Outline of Project

Projects proposed in Master Plan were reviewed in Feasibility Study, and content of the projects was finally decided as follows:

(1) Prior Project: Pilot Project for Groundwater Use

Pilot project has important purpose to resolve technical problem of emergency water supply by groundwater. Pilot project should be implemented at 8 sites within Bogota urban area, prior to the other projects. Pilot project, as sample facilities for emergency water supply, will promote implementation of proposed projects throughout Bogotá city.

(2) 1st Period Project: Eastern Project

In Eastern Project, facilities for emergency water supply was planned to be constructed in the Eastern hills. The centre of Bogotá city is near the Eastern hills, from which groundwater of wells can be quickly delivered to the city centre. Easy access form Eastern hills to the city centre make Eastern Project as main project of emergency water supply. Number pf emergency well is thirty three (33), and planned yield is 685,000m^3/day, which can provided water to 4,565,000 persons with unit consumption rate of 15ℓ/person/day.

(3) 2nd Period Project: Southern Project

In Southern Project, facilities for emergency water supply was planned to be constructed in the Southern hills. The epicentre of large earth quake is assumed in the Southern hills, where there are many houses on the slope of the hills. Damage by earthquake, including damage to water supply facilities, is expected more serious than other area of Bogotá city. Number pf emergency well is fourteen (14), and planned yield is 13,100m^3/day, which can provide water to 872,000 persons with unit consumption rate of 15ℓ/person/day.

(4) 3rd Period Project: Yerbabuena Project

Yernabuena area is located to the north of Bogotá city, in Chia and Sopo municipalities. In case of emergency, groundwater from wells in Yerbabuena area can be delivered by water wagons or be conveyed through pipelines to Bogotá city and the surrounding area. Yerbabuena area is located relatively far from the center of Bogotá urban area, so that priority of Yerbabuena Project is lower than the other projects, though groundwater development potential of this area is high. Number pf emergency well is seventeen (17), and planned yield is 34,000m^3/day, which can provide water to 2,266,000 persons with unit consumption rate of 15ℓ/person/day.

4.2 Project Cost

Total cost for proposed three projects (Eastern, Southern and Yerbabuena Project) was estimated 122,300 million pesos. Average annual cost for the projects implementation was estimated 15,400 million peso, under assumption that construction works for the entire projects will be completed in 7 years.

Table-4 Project for Emergency Water Supply by Use of Groundwater（Feasibility Study）

Project		No. of Wells	Groundwater development (m^3/s)	Project Cost (Col$ Million)
a)	Eastern Project	33	0.79	Col$67,500
b)	Southern Project	14	0.15	Col$23,000
c)	Yerbabuena Project	17	0.39	Col$32,800
Total		64	1.33	Col$123,300

Note) Number of well and yield, which was proposed in M/P, were reviewed and modified in F/S.

4.3 Project Evaluation

(1) Technical Evaluation

- Location and number of facilities for emergency water supply were planned, taking into account of relating conditions, such as hydrogeology, land use and accessibility in emergency. Amount of water to be produced from emergency wells can meet water demand of Bogota urban area in emergency.

- From result of water balance analysis, planned pumping rate from emergency wells were concluded to be optimum. Groundwater use by private wells will not be interrupted by draw-down of groundwater level, which will be caused by pumping from emergency wells during less than 9 month. It was also concluded that land subsidence will not take place by the pumping.
- Water quality of groundwater of the Cretaceous sandstone, which is aquifer for emergency wells, is excellent. It needs only chlorination and simple water treatment to remove iron and manganese. Water treatment facilities were planed to satisfy water quality standard of Colombia.
- Point water supply in emergency can be efficiently implemented by water wagons or usual trucks with water tank. For water tanks to be loaded on trucks, light plastic tanks are effective.
- Proposed facilities for emergency water supply meet design criteria of Colombia, and can be constructed by Colombian engineering technology.

(2) Social Environmental Consideration.

Initial Environmental Examination (IEE) was implemented for the proposed projects based on JICA Guideline for Social Environmental Consideration. According to the result of the examination, it was judged that proposed projects would not give serious impact to social environment of the project area, and the projects were classified into JICA Category B.

(3) Economic Evaluation

Purpose of the proposed project is to secure water supply in emergency. As for emergency water supply, it is difficult to implement economic evaluation of the project on monetary base. Consequently, appropriateness of the proposed project was proved by three advantages of the projects below:

a) Dispersion of risk of water source failure
b) Lower water resource development cost
c) Development of water sources near water consumption area

(4) Financial Evaluation

Total cost of the proposed project is 123,300 million pesos. Judging from financial condition, Acueducto can afford the entire debt payment, even under condition that entire cost will be loaned from domestic banks. The incremental cost of interest and depreciation generated by the proposed projects do not affect seriously the expected profit of Acueducto.

(5) Social Evaluation

The project is expected to generate several social benefits to the project areas as shown below:

a) Increase of served population in emergency, b) Water supply to forest fire fighting, c) Increase of employment opportunity.

4.4 Pilot Project

The Pilot Project has evolved into an elaborated process by stages, which could decrease the costs of the Feasibility Study. The operation manual which involves mobile treatment and operation solutions must be taken to account based in the fact that the simultaneousness of the catastrophic events does not occur in foreseeable places, but in random ones. Therefore, the result of using different scenarios alternatives will reduce costs and would only require the construction of the 64 wells in different times.

PART 1 INTRODUCTION

CHAPTER 1 OUTLINE OF STUDY

(1) Background of Study

The Population of Bogotá Metropolitan Area (Bogotá Capital District and 10 neighboring cities) has reached to 7,600,000 inhabitants by 2005, which is the center of the politics and economy of Colombia where 20% of population of the country concentrates. The population growth rate was 2.3% in the past 10 years during 1993-2003, exceeding country average growth rate of 1.8%, which reflects inflows of internally displaced persons.

Bogotá Water Supply and Sewage Company (Acueducto) takes responsibility for water supply in Bogotá D.C. Acueducto has been expanding its water supply areas to neighboring 10 cities with the expansion of "Bogotá urban area (distrito urbano)", which is defined in Plan of Land Use Regulation of Bogotá D.C. Although unaccounted rate for water is as high as around 36%, Acueducto satisfies basic management standards, such as the gap between water supply and demand, water quality, ratio of service coverage and financial situation.

However, Acueducto faces the problem of water supply in emergency cases. Natural disasters frequently occur in the Bogotá Metropolitan Area. Acueducto mainly carries out the urgent measures with assumption of earthquakes. They perform physical countermeasures, such as anti-earthquake reinforcement of water tanks, and countermeasures of software, such as strengthening of coordination with relating organizations and preparation of manuals. In addition, it is necessary to secure groundwater as water sources when pipeline for water supply are suspended by natural disaster. Technical assistance by the Government of Japan was requested necessary to solve these problems.

(2) Objective of Study

Implementing agency of this Study is Bogotá Water Supply and Sewage Company (Acueducto), and purpose of this Study is as follows:

a) Formulate an emergency water supply master plan for Bogotá Metropolitan area, using groundwater and develop it completely for the year 2020.

b) To implement Feasibility Study on high priority projects selected in the Master Plan

(3) Study Area

Study Area: Bogotá plain, Chingaza river basin, Sumapaz River basin (Bogotá D.C. and 10 neighboring cities)

Land Area: About 4,305 km^2

Population of Study Area: 7,600,000 (2005)

(4) Scope of Study and Major Outputs

This Study will be implemented in two phases. Major outputs of each phase are shown in Table-1.1-1.

Table-1.1- 1 A Scope of Study and Main Output

Phase	Content
Phase-1: Formulation of Master Plan (M/P)	[1st year] 1) Analysis of current situation and possibility of groundwater use for water supply
	[2nd year] 2) Exploratory drilling 3) Formulation of Master Plan and selection of priority projects
Phase- : Feasibility Study for priority projects (F/S)	[3rd year] 4) Formulation of implementation plan of high priority project 5) Promotion of understanding on M/P (water supply plan by groundwater) for Colombian side

CHAPTER 2 SUMMARY OF THE STUDY

2.1. Summary of the Study Organization and Operation

2.1.1. General Condition of the Study Area

(1) Current Situation of the Study Area

(a) Socio-economic Condition

The 2005 census population of the study area totaled 7.6 million inhabitants, an increase of 2.2 million since the previous census of 1993. The annual growth rate during the two censuses was 2.9%, which slowed slightly down from the 3.0% during the same of 1985 and 1993.

- The 2005 census population of Bogotá D.C. increased in (by) 1.9 million or by an annual rate of 2.7% since 1993.
- The 2005 census population of the 10 municipalities of the Cundinamarca Department increased in (by) 0.4 million since the 1993 census. The growth rate was remarkably high in Mosquera, Chía and Tocancipá.

(b) Institution for Water Resources Management

Water Resources Management

Decree-Law No. 2811 of 1974, Decree No. 1541 of 1978 and Article 23 of Law 99 from 1993 provide legal frame for water resources management District Secretary of Environment (SDA), Regional Autonomous Corporation of Cundinamarca (CAR) and Special Administrative Unit of Natural Park System (UAESPNN) give concessions for water use in respective jurisdictions. Currently, a total of 19.02 m^3/s of water concession is given to Water Supply and Sewerage Company of Bogotá (Acueducto), while Acueducto produces 14.5 m^3/s of potable water.

Organization for Water Supply

Water Supply and Sewerage Company of Bogotá (Acueducto) is a public company, without any private capital, in charge of water supply and sewerage services in Bogotá D.C. Acueducto also supplies water to some surrounding 10 cities, such as Cajicá, Sopó, Chía, Tocancipá, La Calera, Gachancipá, Soacha, Funza, Mosquera, Madrid, under contracts with each of the municipalities. Acueducto employs 1,765 persons as of November 2007.

(c) Natural Condition

Climate

Bogotá River Basin has an average annual precipitation of 825 mm. The precipitation is uniformly distributed throughout a year, and it shows a bi-modal pattern with peaks around April to May and October to November. Its climate is classified under the annual precipitation Pattern (f) of Koeppen division. The arid boundary (annual evaporation) of Bogotá River Basin is calculated to be 406 mm. Since this is less than a half of the annual precipitation of Bogotá River Basin. Bogotá River Basin is, then, classified into the Humid Climate (C), although the basin has relatively small precipitation within Colombia.

Hydrology

The Bogotá River Basin has an area of 4,396 km^2. The conventional division of the river basin has been examined and redefined based on the DEM data. The basin was finally divided into 16 sub-basins. The average annual flow volume at the terminal of the river stream system in the basin is of 1.07×10^9 m^3, and the Coefficient of Variation is calculated to be 0.24 to 1.04. The monthly river discharge is relatively stable throughout the year.

This data are affected by waste water effluent from Bogotá city, which could be around 80% to 90% from the city water consumption and a 70% from water coming from Guatiquía River (Orinoco

Basin).

(2) Water Resources of the Study Area

(a) Surface Water

Surface water is the most important water resource in the Bogotá River Basin, been used in many sectors. Due to the basin's topographic characteristics, every water resources originate in precipitation. The amount of precipitation was found to have a close relation with the altitude. Annual precipitation of Bogotá River Basin is 825 mm, but it is lower in the plain and higher in the mountains. The specific discharge values for each sub-basin were calculated using the data from the gauging stations, and their distribution by sub-basins was analyzed in relation with distribution of precipitation.

(b) Groundwater

Groundwater is an important source of water in the Bogotá River Basin, and its consumption in 2000 was 0.32 million m^3/day (14% of the total water use volume of 2.672 million m^3/day). The only major recognized source of recharge to groundwater is the infiltration by precipitation. CAR, INGEOMINAS, and the Previous JICA Study Team (2003) employed the water balance method, and estimated the amount of recharge from precipitation to groundwater, and reported the values of 36 mm/year, 8 mm/year, and 145 mm/year respectively. These differences are because: 1) JICA Study Team performed estimation with daily average data while CAR and INGEOMINAS used monthly average data, 2) the method used to calculate evapotranspiration potential by JICA Study Team was with data from observed evaporation pan while CAR and INGEOMINAS calculated it with theoretical methods like Penman.

All these studies used the water balance method to calculate the groundwater recharge values. The estimated values showed large differences due to significant variation in the estimated values of evapotranspiration. In this JICA study, the FAO's "Crop Evapotranspiration-Guidelines for computing crop water requirement" was employed to calculate evapotranspiration. The calculated values ranged from 383 to 499 mm/year at 15 observation points within Bogotá River Basin with its average of 442 mm/year. The average groundwater recharge amount over the entire basin was calculated to be 132 mm/year.

Other estimation methods were also studied for comparison. The outcome of these several different analyses suggests the following. The groundwater recharge by precipitation in Bogotá River Basin is abundant and the estimated recharge values of more than 100 mm/year are considered realistic.

(c) Water quality

Water Quality of Bogotá River

In relation to the Bogotá River water pollution aspect, there are three (3) areas clearly classified by its characteristics. The first area is between the headwaters and Villa Pinzón, where water quality of Bogotá River is good. The second area is between Villa Pinzón and Chocontá. In this area, there are many small leather industries. These industrial wastes are discharged into the Bogotá River without treatment, polluting it immensely. The third area is the middle reach of the Bogotá River including the Bogotá Metropolitan Area. When Bogotá River passes though the town area, the water quality becomes worse dramatically. The water quality contamination is caused by the sewage from Bogotá urban area (domestic and industrial waste). Furthermore, it is confirmed by water quality analysis that there is large amount of the chemical material and heavy metal discharged from Tunjuelo River. In Chingaza and Sumapaz River Basin, according to the results of water quality analysis, the water quality is very good.

Groundwater quality of the existing well

In Quaternary Aquifer, Turbidity, NH_4, H_2S, Ba and Coliform are detected in high concentration. In view point of groundwater contamination in area of industrial activity, no apparent impact on water quality has been detected as a result of industrial activity. Although analyzed concentration of the groundwater form Cretaceous Aquifer exceeds water quality standards in Mn, Fe and coloration, these are minimal in degree compared to groundwater from Quaternary Aquifer. A major difference in water quality between Cretaceous and Quaternary Aquifer is the fact that almost no NH_4 is detected from Cretaceous Aquifer. It can accordingly be concluded that there is clear difference in the water quality between the Cretaceous and Quaternary layers.

Supplementary Water Quality Analysis

The rivers and wells for supplementary water quality analysis were selected based on the data base of the existing monitoring by SDA and CAR. Fifteen sampling point from rivers and twenty sampling wells with Quaternary and Cretaceous Aquifer were selected to analyze water quality. Water quality of the sampling points was confirmed as being essentially identical to those obtained by Acueducto analysis. Water quality of groundwater from the sampling wells has exceeded, at most of sampling points, the standard for water quality in the items of Fe, Mn and NH_4 throughout the Study area. It is clear that Fe and Mn in groundwater have originated from geology of the area. Concentration of Mn in the Quaternary Aquifer is much higher than that in the Cretaceous Aquifer. Overall water quality of Cretaceous Aquifer is good, though it shows a little high concentration in Fe and Mn.

(3) Water Use and Water Resources Management

(a) Existing Water Facilities

There are three main water supply systems for Bogotá City. That is Chingaza System, Tibitóc System and South System. Each system has water sources and purification plant. Chingaza System has Chuza Reservoir and Wiesner Plant. Tibitóc System has Tibitóc Plant. The Southern System has La Regadera Reservoir and El Dorado Plant. Amount of water supply is 10.0 m^3/s by Chingaza System, 4 m^3/s by Tibitóc System, 0.5 m^3/s by Southern System, with total water supply of 14.5 m^3/s for Bogotá city area in 2006. Full capacity of the existing purification plants is 30.2 m^3/s. On the other hand, amount of water with confirmed concession is 19.0 m^3/s, and amount of water with development potential is 22.0 m^3/s. Full capacity of the existing facilities exceeds amount of water with concession and development potential.

(b) Water Consumption

The numbers of user's account in Bogotá, Soacha and Gachancipá were 1,569,000 in 2006. The remarkable increase was seen in Estrato-1 and Estrato-2 compared with 2002. Total consumption of 2006 was 22,698,000 m^3/month (8.75 m^3/s). The unit consumption of the residential sector is estimated at 100 liter/day/capita in 2006. Amount of the block water supply to 8 municipalities of Cundinamarca was 1,364,000 m^3/month (0.53 m^3/s) in 2006. The remarkable increase was seen in Chía and Mosquera.

Water Tariff

The tariff consists of both the basic tariff and the tariff by consumption. The basic tariff was drastically cut in July 2004; to the contrary, the tariff by consumption was raised. Afterwards, both the basic tariff and the tariff by consumption have been revised only when the accumulative consumer price index has exceeded 3%.

(c) Facilities for Sewage Drainage and Treatment

The covering rate of sewage drainage in Bogotá City area is around 85%-90%. However, it does not mean that all the collector sewage is being treated. The most of the collector sewage water is discharged into the river without treatment. El Salitre WWTP is the only one in Bogotá City area. However, the treatment type is still primary level. Acueducto has been undertaking and executing the projects to complete both the sewage drainage and treatment system now. All of solid wastes of Bogotá City area and some of neighborhood municipalities are handled in Doña-Juana Waste Disposal Plant. The plant is planned with modern design, and its operation is satisfactory. In the area outside of Bogotá City, CAR directly executes the construction of WWTP and control of the management and maintenance. However, the operation rate is not satisfactory, because there is not enough sewage drainage networks and maintenance fund.

(d) Water Resources Management

Water resources management is implemented by CAR and SDP in the Study Area. CAR and SDA manage water resources in quantity by restricting and controlling concession for water use. They also manage water resources in quality by monitoring of water quality on observation network. SDA is in charge of water resources management in Bogotá D.C. and has given concessions for use of more than 400 wells in Bogotá City area. Owners of the wells are registered to SDP and have to monitor groundwater level of their wells to report it to SDA. On the other hand, CAR is in charge of water resources management in Bogotá Plain out of Bogotá city.

(e) Monitoring of Water Quality

Water quality of Bogotá River, which is monitored in Bogotá City area, is inspected by SDA and Acueducto. Outside of the city area it is under competency of CAR. Acueducto has quite a sophisticated laboratory for water quality analysis. Acueducto laboratory conducts the water quality analysis of drinking water, river water, treated sewage water, and domestic and industrial waste water. CAR inspects water quality of rivers and wells. CAR utilizes results of water quality analysis, not only for water quality management, but also for authorization of water concession and environmental license.

(f) Ecosystem and natural Environment

In Colombia, the Bogotá River basin is the most economically diversified area. In agriculture, product of flower crops occupies 80% of its national product. On the other hand, the breeding of cattle and the dairy industry are the economic basis of this area. Water resources are used for multisector, agriculture, livestock, industry, mining, water supply and sewerage and electric generation. Areas in the eastern hill with elevations above 2,700-2,750 m comprise forest reserve (*Proteccion Forestal*) as designated by the CAR. Tree felling and building within this area is strictly restricted.

Urbanization has proceeded within the Bogotá City area outside the forest protection area. There are accordingly no natural forests and rare and endangered wildlife species within this urban area. On the other hand, there is no forest protection area in the southern hill. The area for proposed project of groundwater development in the eastern hill comprises vacant land and grazing land. This area will require no human resettlement. Also, area for the groundwater development in the southern hill lays livestock grazing land outside densely populated area. Although there is no forest protection area, permission and water concession for well drilling must be obtained from CAR or SDA.

(g) Artificial Groundwater Recharge

Pilot study for artificial recharge was performed in Vitelma silting pond site of Acueducto in the previous JICA Study. As a result of the Pilot Study, it was concluded that 2,000 m^3/day of water can be injected though one recharge well. Water for artificial recharge can be taken from San Cristóbal River for Vitelma Area. Artificial Groundwater recharge can be studied in bigger scale with real studies in other locations.

In recent years, importance of conservation of natural environment of the Eastern Hills has been emphasized, and relating regulation has been issued. Artificial groundwater recharge is useful for conservation of groundwater resources of the Eastern Hills. Water leakage from San-Rafael Reservoir has the same effect as groundwater recharge to Cretaceous Aquifer. According to the result of water balance analysis by daily data (1998-2001) of the San-Rafael Reservoir, water leakage from the reservoir was estimated be 3 m^3/s in average.

2.1.2. Identification of Issues in Current Water Supply

(1) Security of Water Supply in Emergency

Acueducto is responsible for water supply and has to prepare plan for disaster prevention and emergency response in water supply. According to the past JICA Study (2002), water pipe will be damaged at 3,753 points in Bogotá Metropolitan Area by La Cajita earthquake with seismic center in the Southern Hills. In addition to it, there is possibility that huge earthquake with seismic center between Bogotá and Chuza Reservoir will give damage to water conveyance tunnel. Acueducto has performed diagnosis on resistance of facilities against earthquake. Based on result of the diagnosis, reinforcement work is now under implementation. For this purpose, Acueducto is performing preventive works against collapsing of tunnel that conveys water from Chuza to Bogotá. Moreover, Acueducto has completed centralized automatic control center of water supply facilities. In addition to above measures, Acueducto is now under consideration of possibility of emergency water supply by use of groundwater.

(2) Water Supply in Residential Area of Low income Group at High Altitude

Actual conditions of water use in the residential areas of low-income group at the high altitude were studied through the following two surveys: 1) social activities of Acueducto and 2) Socio-economic survey. Acueducto has a policy and strategy to work together with the community for the execution of the water supply project. The interview survey and questionnaire survey was carried out in the 15 areas of the Eastern and Southern hills. These 15 areas are located over 2,750 m and are not provided with water by Acueducto. The coverage ratio of public services is very low: water supply 14%, sewerage 23.3%, gas 1%, and telephone 25%Derechos de Concesión de Agua

(3) Water Right

Acueducto withdraws water of Bogotá River in Tibitóc Plant with concession from CAR. In recent year, the concession has been decreasing. In the past Acueducto had concession of 10.0 m^3/s until 2000. Then, it was gradually reduced to 8 m^3/s in 2001, to 6 m^3/s in 2002 and to 4.8 m^3/s in 2003. This tendency will continue in the future. Water distributed from Tibitóc is important in case of emergency when water supply of Chingaza System is suspended. Alternative water sources for Tibitóc Plant are necessary.

2.1.3. Potential for Water Resources Development

(1) Surface Water

The surface water demand at present already exceeds the total available amount of water resource. Construction of nine dams and retention ponds in the upstream (northern part) of Bogotá River Basin and one dam outside of it, especially water conveyance project from Chuza Reservoir, somehow alleviated the problem. However, with the current trend of economic and population growth, the balance of water supply and demand is anticipated to fail in near future. In order to tackle this future problem, Acueducto has a plan to introduce more water from outside the basin, by expanding the capacity of Chingaza system and by development of water resources of Sumapaz region, which are located to the east and south of Bogotá River Basin respectively.

Expansion Plan of Chingaza System

The plan consists of several components of facilities expansion: it is mainly consists of i) augmenting the capacity of existing collection facilities in the north and south of Chuza Reservoir, ii) construction of Playa Reservoir and augmenting the capacity of collection facilities in south of Playa Reservoir. According to water balance analysis, the available amount of water to be supplied by this expansion project is calculated to be 8.5 m^3/s.

Development Plan of Sumapaz System

Sumapaz System development plan in the southern area aims to augment water supply capacity by effective utilization of the water in Sumapaz River Basin. Construction of a dam, water collection facilities, water channels and purification plant are planned. According to water balance analysis, the available amount of water to be collected after implementation of the project is estimated to be 12.95 m^3/s.

(2) Groundwater

(a) Aquifer

JICA Study Team collected the geological and topographical data of Study Area. JICA Study Team carried out field survey for comprehending the geological features in Study Area (the Eastern and Southern Hills). JICA Study Team reviewed the existing geological map by field survey and the interpretation of aerial photograph. JICA Study Team has distinguished area of the Cretaceous Formation from those of the Tertiary and the Quaternary in the Study Area. Furthermore, JICA Study Team proposed the location of promising well sites from hydrogeological view point. The proposed wells are 62 points in total (including 53 new production wells, 5 exploratory wells, 4 existing production wells). Moreover, observation well (1 point) and optional wells (8 points) is additionally proposed.

(b) Geophysical Survey

Geophysical survey in TEM method was carried out in the Bogotá Plain at 64 points in total. Purpose of the TEM survey is to know vertical and lateral distribution of main aquifer, Guadalupe Group in Eastern Hills and Southern Hills. According to TEM result, sandstone of Guadalupe Group shows extremely high resistivity more than 1,000 ohm-m in Eastern Hills and Southern Hills. The high resistively formation is thick in central part of Southern Hills. Formation with high resistivity is distributed with the same thickness in the high altitude area in the Eastern Hills. Geological situation in the south of Eastern Hills could be carefully examined, because shallower part shows high resistively in the area, but it’s resistively value is less than 1,000 ohm-m. Therefore geophysical and geological investigation shall be reinforced with other methods and Studies more in detail to develop groundwater in the south of Eastern Hills. Some promising areas for drilling wells for water supply are recommended taking into consideration of other information from geological and hydrogeology survey including data of the existing wells.

(c) Groundwater Development Potential

Since direct measurement of groundwater recharge has just started, and the data is not yet available. The FAO method was employed in this JICA study to estimate evapotranspiration. The evapotranspiration values were re-calculated using newly chosen parameters and the same pan evaporation data used in the previous JICA Study. The distribution of evapotranspiration within the basin was estimated. This result was, then, combined with the results from the hydrologic analysis to estimate groundwater recharge by the water balance method. Groundwater recharge of Bogotá Plain is analyzed 132 mm/year in average. In formulation of groundwater development plan, the evaluated value of 132 mm/year should be taken into account for planning the total amount of water from wells.

(d) Groundwater Simulation

The groundwater flow in the Cretaceous Aquifer distributed in the Eastern and Southern Hills of Bogotá City was mainly analyzed by simulation based on the results from the previous JICA Study. The effect of pumping, from the planned 62 deep wells, on the groundwater in the surrounding aquifers (the Cretaceous and Quaternary) was evaluated. The simulation model adopted the structure and other conditions of the model created in the previous JICA Study with some minor alterations in grids and in model parameters and boundary conditions. The model was calibrated by adjusting the hydraulic conductivity of each layer. The final outcome of the calibration under steady state condition was used as initial conditions for the transient simulation.

(e) Exploratory Drilling

Sites for five exploratory wells and one observation well were selected in this Study. Of these six wells, two exploratory wells (EX-2 and EX-3) and one observation well (EX-4) were drilled within this Study period. Both EX-2 (Ciudad Bolivar) and Ex-3 (Usme) are located in the southern hill, where Cretaceous rocks are distributed. From the beginning, EX-2 encountered thick Cretaceous rocks with high groundwater productivity. On the other hand, EX-3 well is located on Cretaceous sandstone just near Bogotá faults and encountered Cretaceous rocks at the beginning. However, EX-3 encountered Tertiary rocks deep in the ground. This is because that Bogotá fault is reverse fault. Due to the low permeability of Tertiary rocks, EX-3 resulted in low groundwater productivity. From this result, it can be concluded that production wells should be located distant from Bogotá faults to same extent.

2.1.4. Issues in Existing Master Plan of Water Supply

(1) Existing Master Plan

Acueducto formulated Water Supply M/P in 1995, which predicted necessity of development of new water sources by 2005 and proposed projects of expansion of Chingaza System. On the other hand, after "Crisis of Chingaza", water supply to Bogotá City was controlled, and consumption rate became lower than expected. As a result, water consumption was 14.5 m^3/s in 2005, which was much lower than 25 m^3/s that was predicted in 1995. In 2005 Acueducto revised old M/P and the beginning of the proposed projects were postponed until after 2029. Acueducto is going to review the old M/P again in 2008 and will newly set the year for beginning of the proposed projects, based on the latest water demand prediction (Aspectos en el Plan Maestro Existente desde el Punto de Vista del Plan Maestro de Recursos Hídricos Integrados).

(2) Issues in Existing Master Plan in view point of Integrated Water Resources Master Plan

Issues in the existing Master Plan are summarized in view pint of 4 items: quantity, quality, water right and risk management.

- As for quantity management, Acueducto has measure to control water consumption after "Crisis of Chingaza" in 1997, which has resulted in considerable, reduces in water consumption and postponement of new water resource development.
- As for water quality management, CAR and SDA is in charge of it. Acueducto is continuously monitoring water quality of water sources to provide safe drinking water.
- As for water right distribution, concession at Tibitóc Plant is now under pending in court. This situation has influence on strategies of future water supply of Acueducto.
- As for risk management, Acueducto is preparing for prevention measures against natural disaster to water supply. Acueducto has a plan for expansion of Chingaza System. This system is vulnerable to natural disaster due to 40 km-long mountain tunnel for water conveyance. Expansion of Chingaza System will cause higher risk in stability of water supply. Acueducto is conducting many measures to overcome vulnerability above.

(3) Recommendation for the Existing Master Plan

The projects for expansion of Chingaza System have high efficiency in financial aspect. Therefore, future expansion of water sources should be implemented following this plan. However, there is a high vulnerability in Chingaza System due to long water conveyance to Bogotá by single mountain tunnel of 40 km length, which is subject to collapse by the natural disaster. Consequently, expansion of Chingaza System in the near future will cause higher damage to water supply to Bogotá city, when interruption of water conveyance happens by natural disaster. To overcome this risk, as many measures as possible should be prepared: a) use of water stored in San-Rafael Reservoir, b) increase of water production in Tibitóc Plan, c) re-operation of closed water purification plant for emergency, d) development of alternative water sources such as groundwater near Bogotá City.

2.1.5. Water Supply Master Plan for Bogotá City Area by Use of Groundwater

(1) Basic Policy of Plan

Water resources expansion of Chingaza area should be promoted for sustainable water supply for the future. On the other hand, Chingaza System is vulnerable to natural disaster. Therefore, construction of emergency water supply facilities by use of groundwater around Bogotá City is proposed. These facilities need regular operation for maintenance. If water supply by use of groundwater is cheaper than existing water supply in operation cost, groundwater should be used not only for emergency but also for usual water supply. Based on the background mentioned above, this Study is going to formulate Master Plan for emergency water supply to Bogotá city by use of groundwater.

(2) Water Supply Plan in Case of Emergency

Emergency case in water supply means suspension of water supply due to outbreak of large earthquake and serious draught. Assumed damage in case of emergency are: i) Damage to the water pipe network within Bogotá City, ii) damage to the water conveyance tunnels from Chingaza. Measures for it are: a) preparation for a seismic disaster by reinforcement of facilities, b) emergency water supply by alternative water sources. Immediate (up to 60 days) after the disaster, when water distribution network is damaged and out of order, groundwater from emergency wells can be delivered by water wagons. On the other hand, in case of damage to water conveyance tunnel from Chingaza, water supply interruption will continue for a long period of time (for maximum 9 month). To overcome shortage of water supply caused by interruption of Chingaza System, entire alternative water sources should be used to keep water supply same as usual. Alternative water sources for emergency water supply are: i) increase of water intake at Tibitóc Plant, ii) use of storage water of San-Rafael Reservoir, iii) re-operation of closed water purification plant, vi) groundwater development of Eastern and Southern Hill.

(3) Water Demand Projection by Groundwater

The groundwater demand in emergencies is estimated separately in two scenarios as below:

- Scenario 1: Damage to distribution networks of Bogotá City.
- Scenario 2: Damage to conveyance tunnels from Chingaza.

Table-1.2- 1 Groundwater Demand in Emergencies

Scenario	Period until Restoration	Base for estimate			Groundwater Demand
<Scenario 1> Damage to Distribution Networks	60 days	Per person/day (a)		Population of Bogotá City (b)	= (a) x (b)
		Year 2007	15 liter [1]	6.8 million [2]	1.18 m^3/s
		Year 2020		9.7 million [3]	1.68 m^3/s
<Scenario 2> Damage to conveyance tunnels from Chingaza	9 months	Total demand (c)		Full supply from other plants (d)	= (c) – (d)
		Year 2007	14.5 m^3/s	Tibitoc (10.5 m^3/s), Southern (0.5 m^3/s) and others (1.3 m^3/s)	2.2 m^3/s
		Year 2020	18.4 m^3/s [4]		6.1 m^3/s

Note: 1) Expected volume of Acueducto, 2) Estimate from 2005 census population, 3) "*Proyecciones de la poblacion*, 2003" of Humberto Molina, 4) Master Plan of Acueducto 2005.

(Source: JICA Study Team)

(4) Water Supply Plan in Case of Emergency

(a) Production Wells

The Cretaceous sandstone in the Eastern and Southern Hills has high groundwater development potential. Total number of 62 emergency wells is planned in the area. The sites of proposed wells are classified into three areas: i) Eastern Hills, ii) Yerba Buena Area, iii) Southern Hills. In the Eastern Hills, well sites are planned along major faults and fold axises. In Yerba Buena Area, well sites are planned along foot of hills. In Southern Hill, well sites are planned along major faults and fold axises. In selection of well site, many factors were carefully examined: a) geology, b) wells distance, c) availability of lands for facilities, d) environmental restriction. Especially, it is precautionary planned that wells site should be scattered covering entire Eastern and Southern Hills, which will promote emergency water supply.

(b) Optimum Yield from Wells

Optimum yield from 62 wells were examined by groundwater simulation. For this analysis, 6 alternatives for the total yield from 62 well (1.0, 2.0, 3.0, 4.0, 5.0, 6.0 m^3/s) were given to the model. Transient simulation was conducted to evaluate drawdown of groundwater level of Cretaceous and Quaternary Aquifer by pumping from 62 wells with 6 alternative yields for 9 month period. The results of the simulation suggest the following:

- The average drawdown in the Cretaceous Aquifer is around 5 m, and the drawdown of this degree is considered not to hinder operation of pumping wells.
- Pumping from newly planned 62 wells has little effect on the water table of the Quaternary sediment layers.
- Up to a few meters of residual drawdown will remain in the Cretaceous aquifer long after the pumping is stopped.

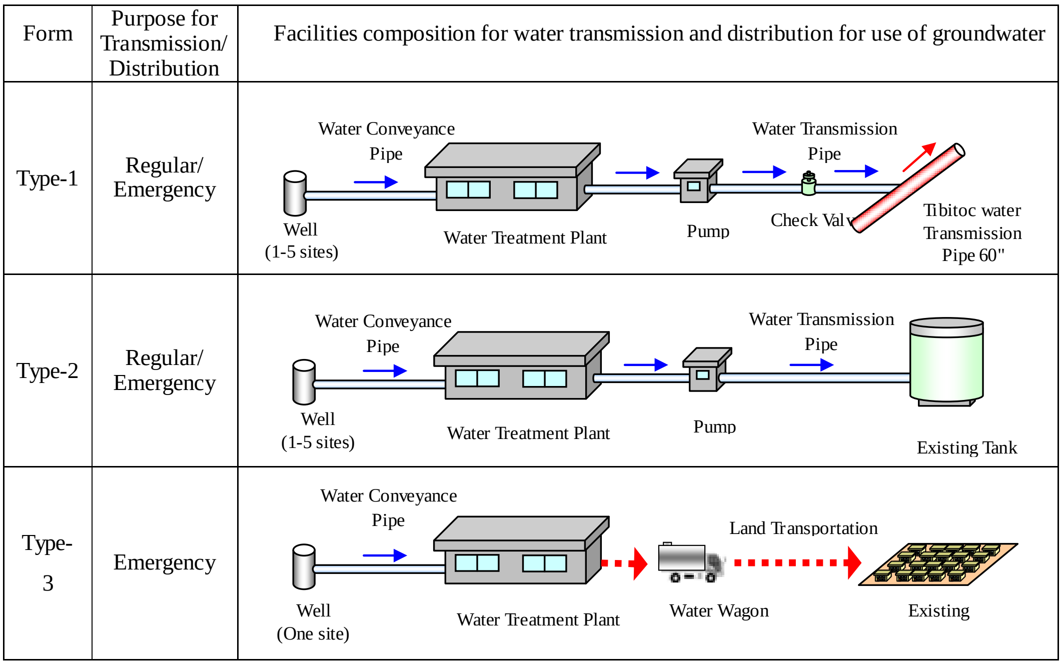
Based on the result of the simulation, the planned yield of 1.5 m^3/s was finally selected as optimum yield.

(c) Purification Facilities

Optimum water treatment facilities, which are composed of water treatment system and sludge treatment system, are planed depending on the purpose of water use and water quality of groundwater. Three alternatives for water treatment system, i) the combination of chlorination and mixing with clean water, ii) the pressure filter system to remove Fe and Mn and iii) the conventional system composed of mixing, coagulation, sedimentation and filtration, was examined. Then, pressure filter system was finally selected for optimum water treatment based on the raw water quality of groundwater. Sludge treatment systems for drainage from water treatment system should be planed only when the conventional system is adopted because of cost effectiveness.

(d) Water Distribution Facilities

Regarding the construction of the water transmission and distribution facilities to utilize the groundwater in the emergency case, optimum plan was formulated basically based upon the following conditions. As the composition of the water transmission and distribution facilities, three (3) types are proposed as shown in Figure-1.2-1.



(Source: JICA Study Team)

Figure-1.2- 1 Composition of water transmission and distribution facilities for the utilization of the groundwater

(5) Management of Yield from Wells

Total yield from wells is proposed as 62 wells × 2,000 m^3/day = 1.44 m^3/s. However, it is necessary to increase yield from wells when more water is requested urgently in case of emergency. In this case, there is a possibility of large lowering of groundwater level by well interference, which is accompanied with increased yield. To avoid serious lowering of groundwater level by well interference, yields from wells should be controlled. For this, yield from wells should be allocated smaller in the center of well field, and then will be allocated gradually larger toward the end of well filed. Such a pattern of yield management is desirable.

(6) Land Subsidence

There is possibility of land subsidence due to pumping from Cretaceous aquifer. Tertiary strata overlie Cretaceous strata, and then Quaternary strata overlie Tertiary strata. There is a possibility of elastic compression of Cretaceous and Tertiary strata, and moreover, there is a possibility of consolidation of Quaternary strata by pumping from Cretaceous aquifer. Model for land subsidence was created, and lowering of groundwater level estimated by groundwater simulation was given to the model. As a result of the calculation by this model, amount of land subsidence after 9 month pumping was estimated as around 1 cm, which is small and negligible. This is because, a) pumping period is limited for 9 month at the longest, b) intermediate Tertiary strata between Quaternary and Cretaceous strata will prevent land subsidence of soft Quaternary strata.

(7) Pilot Project for Groundwater Use

Pilot Project for groundwater use is proposed by Acueducto to investigate technical problem of the project. Purpose of this project is: a) to know and solve technical problems in construction, operation and management of emergency water supply facilities by use of 'groundwater, b) to estimate cost of construction, operation and maintenance for the above facilities. The pilot project should be implemented in Vitelma sedimentation pond of Acueducto, where pilot project for artificial recharge was implemented in the previous JICA Study (2002). The existing well in the site can be connected to a newly planned facility for water treatment. Then, treated groundwater from the facility will be sent to the existing pipeline.

(8) Monitoring Plan

Operation and maintenance is necessary for sustainable use of wells at best condition. For this purpose, monitoring of groundwater level and groundwater quality of wells is indispensable. Moreover, monitoring to inspect the impact by pumping, to natural condition such as land subsidence, is also necessary. Therefore, two type of monitoring is proposed: a) monitoring to control water production from wells, b) monitoring to inspect impact to natural environment caused by pumping. For the first propose, dynamic groundwater level, well yield and water quality of production wells should be monitored. For the second purpose, static groundwater level of the Quaternary observation wells and ground elevation of them should be monitored. Groundwater level should be monitored by automatic recorder.

(9) Institution and Operation/Maintenance

<u>Operation and Maintenance for Water Supply in Case of Emergency by Groundwater</u>

Operation of emergency water supply is to be gradually developed after a disaster, according to the development of rehabilitation of facilities for water treatment, transmission and distribution facilities.

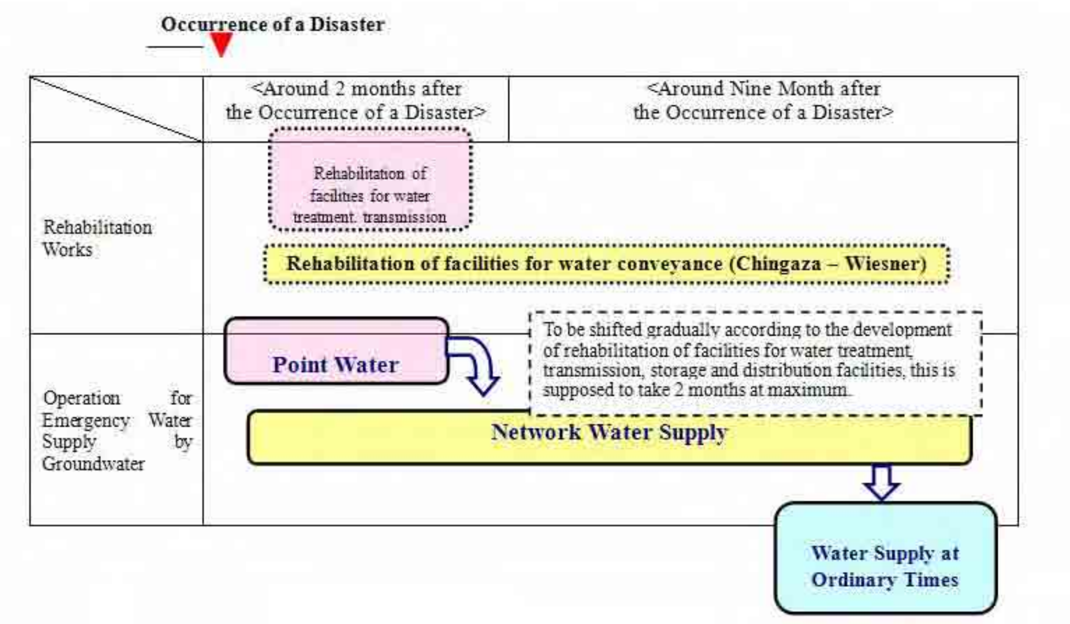


Figure-1.2- 2 Operation for Emergency Water Supply by Groundwater

Organization to Manage Water Supply by Groundwater

For management of groundwater supply, establishment of a new unit is recommended within Corporate Management Office of Mater System of Acueducto. Responsibility of the unit is: i) to manage emergency and ordinary water supply by groundwater, ii) to enhance preparedness of emergency water supply by groundwater, and iii) to conduct well monitoring.

(10) Implementation Program

The entire project consists of three projects: i) Southern Area Project (16 wells), ii) Eastern Area Project (29 wells) and iii) Yerba Buena Area Project (17 wells). Total amount of 1.37 m^3/s of water will be provided from 59 emergency wells. Purpose of groundwater development of this project is for emergency water supply that will be supplied, in principle, for emergency period (10 day to 9 months). For this purpose, it is desirable to start the construction works of this project as soon as possible for earlier completion. It is proposed that entire projects should be completed for three years after four years preparation including this JICA Study.

(11) Design and Cost Estimate

Well facilities of this Study are designed following Colombian Standards, which are based on USA's Standards. The facilities consist of wells, conveyance pipelines, water treatment plants and transmission pipes. Wells and water treatment plants are accompanied by power receiving facility, emergency generator and building for the equipment. Standard specification of well is 300 m in depth, 8 inch (0-150 m in depth) and 6 inch (150-300 m in depth) in diameter. Capacity of submergible pump is 2,000 m^3/day with 190 m pump head, by 440V and 45kW motor. Construction works and cost is proposed in Table-1.2-2.

Table-1.2- 2 Works and costs of construction

	Phase-1	Phase-2	Phase-3	Total
Area	Southern	Yerba Buena	Eastern hill	-
Number of wells	16	17	29	63
Cost	Col$ 28.800 millions.	Col$ 33.500 millions.	Col$ 46.310 millions.	Col$ 108.610 millions.

(Source: JICA Study Team)

(12) Initial Environmental Examination (IEE)

The IEE was carried out to assess possible adverse impacts and to recommend mitigation measures for such impacts. Screening at the IEE level was followed by assessment for the above impacts by the proposed projects, taking into account institutional requirement of Colombia for environmental impact assessment (EIA). The proposed project will have minor environmental impacts compared to large scale development works. The proposed projects are estimated to be "JICA category B", which means that they may not cause significant adverse impact on the surrounding environment and society compared to case of "JICA category A". On the other hand, according to requirement of Environmental License, EIA, Permission and Concession of Colombia, it is considered that the proposed project will not cause significant adverse impact on surrounding environment. Therefore, the proposed projects are estimated as "JICA category B". However, drawdown of groundwater level and land subsidence by the proposed projects should be analyzed further in the feasibility study stage.

(13) Economic Evaluation

The evaluation is carried out in this Master Plan from the viewpoint of comparative advantages that groundwater development has because economic evaluation for emergency is hardly worked out in monetary basis.

Diversification of Risks

The production amount of 62 wells is planned 1.435 m^3/s. At present, the production capacity of the Weisner plant is 13.5 m^3/s. Accordingly, the groundwater development shall diversify the risks arithmetically by 10.6% (=1.435 /13.5).

Lower Development Cost

Groundwater development cost is US$ 37.7 million/m^3/s. Meanwhile, Acueducto has planned eight (8) water supply expansion projects in the "Plan de Expansión de Abastecimiento de Agua, 2005" to develop 32.23 m^3/s of surface water with average unit cost of US$ 70.6 million/m^3/s. In terms of development cost per m^3, the groundwater is obviously evaluated lower by US$ 32.9 million than surface water in Bogotá D.C.

Well Location closer to Demand Area

Development of 62 wells is planned near the residential areas, which enables to make a quick delivery and distribution of water to citizens. This quick delivery reduces the transportation costs as well as saving the time.

Postpone of Investment for foreseeable Shortage of Water in 2022

The production amount of 62 wells is planned 1.435 m^3/s. This enables to postpone the implementation of expansion projects planned in the "Plan de Expansión de Abastecimiento de Agua, Acueducto, 2005" for 3 years.

(14) Financial Analysis

(a) Actual Financial Condition of Acueducto

Acueducto acquired a high credit rate of "AAA" from credit rating company (BRC Investors Services) for the corporate bond issued to securitize loans from WB and domestic banks in October 2006.

Profitability

"Profit and Loss Statement" of Acueducto from FY 2003 to 2006 clearly indicates that Acueducto has performed excellent operation results every year.

Financial Safety and Stability

"Balance Sheet" of Acueducto from FY 2003 to September 2007 reveals continuous financial safety and soundness of Acueducto.

Cash Flow

Cash flow projection of Acueducto represents that operation activities generates positive net cash flow and helps a good cash flow balance every year 'Corte de Costos Financieros por Secularización'.

Financial Cost Cut by Securitization

Acueducto launched Col$ 250 billion of corporate bond in October 2006 to reduce the interest payment and exposure of foreign exchange risks by repaying in advance the outstanding loan from domestic bank and World Bank. As a result, the interest rate has fallen from 12.3% to 9.8% at initial stage.

(b) Financial Evaluation of Project

Development Cost

Groundwater development cost is estimated at Col$ 108,610 million in 3 years. Average annual development cost is Col$ 36,300 million. According to the "*Plan Financiero Plurianual* 2008-2017" of Acueducto in October 2007, Col$ 5,000,000 million of investment is planned over the 10 years. Annual investment amounts to Col$ 500,000 million on average. Annual groundwater development cost of Col$ 36,300 million represents 7.3% of it.

Funding

The development cost is assumed to be funded by domestic bank with following condition.

- Term of Loan: 12 years, Grace Period: 3 years, Interest Rate: 12%.

This loan condition is considered rather conservative compared to actual loan condition of Acueducto. Acueducto plans to formulate a new master plan in 2008 by revising the Master Plan 2005. According to the Financial Department, the appropriate funding measures are to be studied including own funds, when investment decision is finally made on groundwater development.

Ability of Debt Payment

The annual maximum debt payment is Col$ 23,900 million and Col$ 17,800 million on annual average. Acueducto considers affording the debt above, judging from the sufficient level of cash flow balance and high level of "ability to pay".

Profitability Analysis

Profit and Loss projection of Acueducto presents that operation revenue grows every year, and net income results in positive also every year. The incremental cost including interest and depreciation by the groundwater development is Col$ 19 billion in 2014 and Col$ 18 billion in 2017. These costs are very small and do not affect seriously the projected profit of Acueducto.

Investment Cost Recovery

Acueducto cannot generate the additional operational income from this project and recover the development cost theoretically during the period when the water supply capacity surpasses the water demand. Meanwhile, Acueducto could recover the development cost, if incorporating it into the tariff according to the existing formula, although the tariff change largely depends on the top management decision.

(15) Social- Analysis

The project is expected to generate several social benefits to the project areas as follows.

Increase of Served Population in Emergencies

Two methods of water supply in emergencies are considered in this Master Plan: one is point water supply and another is network water supply. The served population by both methods is estimated respectively as below.

- 8,300,000 inhabitants can be served by the use of point supply (unit consumption is 15ℓ/person/day).
- 706,000 inhabitants can be served by the use of network supply (unit consumption is 100ℓ/person/day).

Water Supply to Forest Fire Fighting

Forest fires occur at Eastern and Southern Hills every year especially during the dry season from January to February. The project plans to construct tanks and distribution pipes which enable to take water for fire fighting operation.

Increase of Employment Opportunity

In implementation of the project, the construction works would offer a new labor opportunity. And, the consumption by the workers would stimulate the business activities of the region.

2.2. Summary of Feasibility Study

(1) Priority Project

Feasibility Study was implemented for high priority project, which were proposed in Master Plan Study for emergency water supply. Priority given to the projects is: i) Pilot Project, ⅱ)Eastern Project ⅲ)Southern Project, ⅳ)YerbaBuena Project. Colombian side requested implementation of Feasibility Study for Pilot Project and 1st Period Project, which are most important and urgent. However, the entire project is urgently necessary, and size of each project is compact. Therefore, it was agreed between Colombian side and JICA Study Team that 2nd Period Project and 3rd Period project also would be included in Feasibility Study.

(2) Action Plan

Action Plan was proposed for promotion of the projects proposed in Master Plan Study. Activities of Action plan are: a)Agreement on Master Plan for emergency water supply, b) Selection of high priority project, c) Implementation of Feasibility Study, d) Approval of result of Feasibility Study, e) Implementation of Pilot Project, f) Technology development and study for groundwater development, g) Decision on investment and budget procurement by Acueducto。 At the end of this Study, items a)-d) and f) were completed or are on going. Item e) Pilot Project is being prepared for implementation in 2009.

(3) Pilot Project

Pilot Project for groundwater use was approved as 1st priority project. Pilot project should be implemented before the other projects. Technical problems in design and construction of facilities for emergency water supply can be resolved by implementation of the Pilot Project. Facilities for emergency water supply will be constructed one after another following result of the Pilot Project. 9 existing wells within Bogotá city can be used for the project. After examination of priority of each project site, La Salle site and Vitelma site were selected for the highest priority sites. Acueducto will implement the Pilot Project, at first, in above 2 sites in 2009.

(4) First Period Project

Eastern Project was agreed as 1st Period Project. Eastern hills are located near the city centre of Bogotá. So it efficient to provide water to the entire Bogotá city in case of emergency from wells in the Easter hill. High accessibility from Eastern hill to Bogotá city gave high priority to Eastern Project. A total number of 33 wells are proposed, with total production rate of 68,256 m^3/day, which can provide water to 4,550,400 people, under condition of unit consumption of 15ℓ/person/day.

(5) Second Period Project

The Southern Project was selected as the second period project. Area of the Southern Project is located in the southern part of Bogotá city, near the assumed epicenter of serious earthquake, where there are many houses on the hill slope. Serious disaster and big damage to water pipeline are expected by an earthquake. Total number of 14 wells are proposed, with total production rate of 12,960 m^3/day, which can provide water to 864,000 people, under condition of unit consumption of 15ℓ/person/day.

(6) Third Period Project

The Yerbabuena Project was agreed as the third period project. Yerbabuena area is located in Chia and Sopo municipalities, to the north of Bogotá city. Groundwater from wells in Yerbabuena area can be brought to Bogotá city and surrounding municipalities, by water tracks and pipelines, in case of emergency. On the hand, Yerbabuena area is far from the center of Bogotá city. Therefore, it was given the low priority. Total number of 17 wells are proposed, with total production rate of 34,000m^3/day, which can provide water to 2,266,000 people, under condition of unit consumption of 15ℓ/person/day

(7) General facilities Plan

Plan for Water Treatment Facility

Water treatment plan was planned following water quality standard of Colombia. The result of the groundwater quality is good on the inspection well in the planned area, and the concentration of Fe and Mn exceeds slightly for the drinking water standard. In this plan, in order to use the remaining pressure of the well pump effectively as water supply pressure and to shorten reaction time, a pressure filtrate system is adopted. Three (3) type of facilities are planned for the water treatment process, (1) chlorine, (2) chlorine + pressure filtrate and (3) chlorine + aeration + pressure filtrate, according to water quality.

Plan for Water Supply Facility

The methodology for water supply are three depending on the damage in the water supply system, (1) water wagon, (2) existing water tank and (3) existing water distribution line. The water treatment facilities should be able to supply water in case of emergency using the three methods.

(8) Optimum Yield

Groundwater drawdown was simulated by using groundwater model. As the result of 9 months continuous withdrawal, groundwater drawdown would get maximum of less than 6m in Cretaceous Stratum and less than 3m in Quaternary sediments. No adverse affection could be predicted by this level of groundwater head drawdown. Groundwater balance was calculated by identifying the recharge area and using the recharge rate from the result of hydrological analysis It has been made clear that the annual groundwater recharge is less than 9 month pumping amount; however, its deficit can be completely recovered within 2 years.

Therefore, from both viewpoints of groundwater balance and avoidance of adverse affect to environment and groundwater use, the Eastern project is feasible in the condition of 9 month pumping with more than 2 years interval for appropriate aquifer recuperation.

(9) Groundwater Organization

Emergency water supply, must be performed by Acueducto employees. For the regular monitoring plan of groundwater resources, it is recommended new employees to be hired.

It is recommended to strengthen the Committee for Prevention and Attentions of Emergencies. The committee will consist of a Directive Committee and an Operative Committee. The Directive committee will conduct information exchanges and general coordination with external organizations. Operative Committee will implement emergency water supply (pumping and water treatment). Zone group, which will be in charge of emergency water supply for each zone, will be established within the Committee. Moreover, the establishment of Groundwater Division in Acueducto is proposed in the Directorate of Water Supply of the Corporate Management Office of Master System. This division is in charge of: i) monitoring, development and conservation of groundwater resources, and ii) water supply in emergency with other divisions.

(10) Environmental and Social Consideration

Based on the discussion results with Acueducto, priority projects for the emergency water supply were decided. In the Feasibility Study, screening at the IEE level was conducted again by analyzing assessment results, considering a) the environmental and social impacts caused by the proposed and b) the environmental requirements of the Governments of Colombia. In addition, the mitigation measures were recommended for such impacts as might be caused by the proposed projects. As a result of final screening, it was concluded that the proposed projects might not cause significant adverse impact on surrounding environment and society. Therefore, the proposed projects were classified into Category B of JICA Guideline. Regarding expected environmental and social impacts by the project, the following items are listed for formulation of mitigation measures.

a) Land Acquisition

b) Obtaining drilling permits

c) Traffic management

d) Water pollution (treatment of drilling mud)

e) Noise and vibration

f) Lowering of the groundwater level

g) Land subsidence

(11) Design and Cost Estimate

Design

The basic design principle in the master plan shall be to comply with the techniques and technical levels actually adopted in Acueducto. Moreover, economic factors such as initial investment, operation and maintenance costs shall be considered in the design. Furthermore, equipment and materials were selected from items procurable in Columbia with a view to enabling the long-term sustainable operation, maintenance and after-service of the equipment. Since the water quality analysis results from the test well showed the quality of groundwater to be good, pressure filtration water purification facilities shall be adopted in the project. Moreover, the minimum necessary electricity house and perimeter security fencing around facilities shall be installed, while access roads to the facilities and inside the facilities shall be provided to facilitate passage by water trucks and large vehicles, etc.

Cost Estimate

Total cost for the Project was estimated as shown below:

Phase-I	67.540 (million. Col$)	35.32 (mil. US$)	3,732 (mil. yen)
Phase-II	23.000 (million. Col$)	12.03 (mil. US$)	1,271 (mil. yen)
Phase-III	32.630 (million. Col$)	17.06 (mil. US$)	1,803 (mil. yen)
Total	123.170 (million. Col$)	64.41 (mil. US$)	6,804 (mil. yen)

(12) Project Implementation Schedule

Taking into account of target year of 2020, project implementation schedule was proposed as shown below:

a) Pilot Project : 2009 - 2011 (Total 9 wells)

b) 1st period Project (Eastern Project) : 2012 - 2016 (Total 53 wells)

c) 2nd Period Project (Southern Project) : 2017 - 2018 (Total 12 wells)

d) 3rd period Project (Yrebabuena Project) : 2019 - 2020 (Total 17 wells)

Drilling of total 91 wells is proposed for 9 years. Average drilling rate is almost 10 wells/year, which seems enough feasible for implementation.

(13) Financial Plan

Year-wise Development Cost

Groundwater development cost is estimated at Col$ 123,300 million in total over the period of 7 years. The annual development cost amounts to Col$ 15,400 million on average.

Funding

The development cost is to be funded from the following 3 sources independently or compound:

a) Acueducto own funds,

b) Domestic bank loan

c) International donor's soft loan

According to the Financial Department, the appropriate funding measures are to be studied including Acueducto own funds at the time of this investment decision on groundwater development.

(14) Economic Evaluation

The evaluation is carried out in this Master Plan from the viewpoint of the following 3 comparative advantages that groundwater development has because economic evaluation for emergency is hardly worked out in monetary basis.

1) Diversification of Risks, 2) Lower Development Cost, and 3) Well Location closer to Demand Area

(15) Financial Analysis

(a) Updated Financial Condition of Acueducto

Profitability

"Profit and Loss Statement" of Acueducto from FY 2004 to 2008 clearly indicates that Acueducto has continuously performed excellent financial results every year.

Safety

"Balance Sheet" of Acueducto from FY 2004 to September 2008 reveals continuous financial safety and soundness of Acueducto.

Cash Flow

Operation activities continuously generate positive net cash flow and help Acueducto to retain a good cash flow balance every year.

(b) Financial Evaluation

Funding of Development Cost

Col$ 123,300 million of the groundwater development cost is assumed to be loaned by the domestic bank with the following same condition.

a) Term of loan: 12 years, b)grace period: 3 years, and c) interest rate: 13.5%

Ability of Debt Payment

Acueducto must consider paying the debt of the described funding judging from the cash flow balance. The debt payment will be an annual average of Col$ 12,800 million.

Profitability

The incremental cost of interest and depreciation generated by the groundwater development is Col$ 3,100 million in 2013 and Col$ 19,100 billion in 2020. It is obvious that these costs are not so large and do not affect seriously the projected profit of Acueducto.

(16) Social Evaluation

The project is expected to generate several social benefits to the project areas as follows.

1) Increase of Served Population in Emergencies

Two methods of water supply in emergencies are considered in this Feasibility Study: one is point water supply and another is network water supply. The served population by both methods is estimated respectively as below.

7,700,000 inhabitants can be served by the use of point supply

600,000 inhabitants can be served by the use of network supply

2) Water Supply to Forest Fire Fighting

Forest fires occur at eastern and southern hills every year especially during the dry season from January to February. The project plans to construct tanks and distribution pipes which enable to take water for fire fighting operation.

CHAPTER 3 STUDY ORGANIZATION AND OPERATION

3.1. Study Organization

Mutual discussions between the Study Team and the counterpart, namely Acueducto (the Water Supply and Sewerage Company), concluded the study organization as follows:

- Acueducto shall establish the Steering Committee consisting of the representatives from Acueducto, MAVDT, CAR, SDA, SDP, DPAE, INGEOMINAS, IDEAM, Cundinamarca Government, ACCIÓN SOCIAL.
- JICA Study Team has held monthly meetings with the Steering Committee to collect information, to exchange opinions and to steer the Study.

3.2. Main Meeting

The following main meetings were held for the study between the Study Team and the counterpart organizations.

Table-1.3- 1 History of Steering Committee Meeting

No.	Date	Content
1	1st December, 2006	Content of the Inception Report was discussed between Colombian side and JICA Study Team.
2	11th January, 2007	Study organization and content of the Study was discussed between Colombian side and JICA Study Team.
3	15th February, 2007	Content of the Report on Study Progress was discussed between Colombian side and JICA Study Team.
4	4th July, 2007	Continuity of this Study was discussed. Definition and necessity of emergency water supply was discussed between Colombian side and JICA Study Team.
5	23rd November, 2007	Progress of the Study was discussed between Colombian side and JICA Study Team. Comment was made from the Colombian sides to the previous JICA Report, and it was agreed that the comments should be taken in to account in the next JICA report.
6	28th December, 2007	Discussion was made on 4 items, which are criteria of continuity of this Study between Colombian side and JICA Study Team.
7	7th July, 2008	Progress of M/P Study was explained and discussed between Colombian side and JICA Study Team.
8	14th May, 2008	Discussion was made on content of Interim Report between Colombian side and JICA Study Team.
9	3rd September, 2008	Content of F/S and priority Project was discussed between Colombian side and JICA Study Team.
10	4th October, 2008	Progress of F/S was explained by the Study Team and discussion was made between Colombian side and JICA Study Team.

(Source:JICA Study Team)

3.3. Workshop

The following workshops have been held covering all aspects of the Study. Presenter from JICA Study Team has contributed to the workshop program as shown below.

Table-1.3- 2 Content of Workshop

No.	Date	Topics	Content	Speaker
WS1-1	11th January, 2007	Content of study for analysis of water resources development potential	Hydrological analysis	Lei
			Geological and topographic survey	Inoue
WS1-2	2nd,February, 2007	Geophysical Survey and Result of the Previous JICA Study	Geophysical Survey	Fujita
			The Result of the Previous Study	Nakamura
WS1-3	8th February, 2008	Environmental Issue and Result of the Previous JICA Study	Water Purification for Lakes and Marches	Ueda
			The Result of the Previous Study	Nakamura
WS1-4	7th February, 2007	Field Technical Transfer for TEM Survey	TEM Field Measurement with TEM-FAST48HPC	Fujita
WS1-5	16th February, 2007	Analysis of TEM Data	Procedures to process and analyze TEM Data	Fujita
WS2-1	2nd October, 2007	Surface water resources development potential	Water balance analysis for surface water	Lei
WS2-2	17th October, 2007	Groundwater resources development potential	Water balance analysis for groundwater	Lei
WS2-3	26th October, 2007	Water resources development potential	Water development Potential in the Study Area	Lei
WS2-4	23rd December, 2007	Environmental consideration and example of water resources development of Japan	Environmental consideration	Ueda
			Example of water resources development of Japan	Nakamura
WS2-5	3rd December, 2007	Groundwater simulation	Introduction of groundwater simulation	Yasuda
WS2-6	4th December, 2007	Master Plan of Emergency Water Supply by Use of Groundwater	Summary of the Project.	Nakamura
			Groundwater development potential and Design of Water Supply facilities.	Nakamura
			Plan for Pilot project for groundwater development.	Nakamura
			Lowering of groundwater level by groundwater development.	Yasuda
			Organization, operation and maintenance of the facilities for emergency water supply.	Hara
			Cost Estimate	Fujii
			Financial and Economic Evaluation	Osakabe
			Social situation of the hills area	Elsa
			Exploratory well.	Ikeda
WS2-7	22nd January,2008	Pilot project for groundwater use	Water treatment for pilot project of groundwater use Topic:	Nakamura
WS3-1	17th September , 2008	Groundwater Simulation	Groundwater Simulation	Nakamura
WS3-2	24th September , 2008	Result of groundwater level Monitoring by Automatic Recorders	Result of groundwater level Monitoring by Automatic Recorders	Nakamura
WS3-3	1st September , 2008	Pumping Test	Pumping Test	Nakamura
WS3-4	3rd October, 2008	Design and Cost Estimate of Feasibility Study	Design and Cost Estimate of Feasibility Study	Fujii
WS3-5	8th October , 2008	Operation method of Visual Modflow	Operation method of Visual Modflow	Nakamura
WS3-6	15th October , 2008	Geophysical Survey and Groundwater Study	Geophysical Survey and Groundwater Study	Nakamura
WS3-6	22nd October, 2008	Groundwater simulation	Theory and application of groundwater simulation	Lei
WS3-7	29th October, 2008	Groundwater simulation		Lei
WS3-8	31st October, 2008	Groundwater simulation		Lei
WS3-9	7th October, 2008	Analysis for groundwater potential	Result of groundwater simulation	Lei

3.4. Seminar

First Technical Transfer Seminar

The First Technical transfer seminar was held on 13th of May, 2008. Presentation was made by the Study Team and relating organizations. Content of the seminar is summarized in Table-1.3-3.

Table-1.3- 3 Content of Technical Transfer Seminar

Time	Presentation	Lecturer	Organization
8:00 - 8:15	Opening speech	Mr.Kazunori HAYASHI	JICA Colombia Office
8:20 - 9:00	Water Resources Management by CAR	Mr.Alfredo Molina	CAR
9:05 - 10:20	Groundwater resources and Emergency water Supply	Mr. Hiroshi NAKAMURA	JICA Study Team
10:50 - 11:30	Forest Protection Area in Eastern Hills	MS. Myriam Amparo Andrade	CAR
11:35 - 12:15	Proposal for Emergency Water Supply	Mr. Guillermo Escobar	DPAE
13:25 - 14:05	Current situation of Groundwater in Bogotá	Mr. Ismael Martinez	SDA
14:10 - 14:50	Long term Water Demands of Bogotá	Mr. Nestor Raul Garcia	Acueducto
14:50 - 15:00	Closing speech	Mr. Alberto Groot	Acueducto

Topics on water resources development and management in Bogotá D.C. were presented by CAR and JICA Study Team. Regulation on water resource development was explained by CAR, and emergency water supply was explained by DPAE and JICA Study Team. SDA made presentation on current groundwater environment of Bogotá City. Acueducto made presentation on history of water demands of Bogotá and future demand.

Attendants of the seminar had common recognition on necessity of emergency water supply in Bogotá city. Active discussion was made among the attendants, how to develop groundwater for emergency water supply. There is the forest protection area in Eastern Hill, where activity for economic development is regulated. Groundwater resource development is also regulated in the forest protection area. The attendants discussed whether it is correct or not to regulate groundwater development for emergency water supply.

Second technical transfer seminar

The second technical transfer seminar was held on the 21st of January, 2009. Presentations shown in Table -1.3-4 was made by the Study Team and relating organizations.

Table-1.3-4 Content of 2nd Technical Transfer Seminar

Time	Presentation	Lecturer	Organization
8:30 - 8:35	Opening Seminar	Mr.Kiyoshi YOSHIMOTO	JICA Colombia Office
8:35 - 8:45	Opening Speech	Mr. Alberto Groot	Acueducto
8:45 - 10:00	Sustainable Water Supply for Bogotá City and Surrounding Area based on the Integrated Water resources Management	Mr. Hiroshi NAKAMURA	JICA Study Team
10:00 - 10:30	Use and Conservation of Groundwater in Bogotá	Mr. Oscar Osorio	SDA
10:45 - 11:05	Protection Hills of Bogotá, Proposal for modification and adjustment of the PMA	Mrs. Miriam Amparo Andrade	CAR
11:05 - 11:25	Hydrogeology in the Eastern Hills of Bogotá	Mr. Romulo Camacho	CAR
11:25 - 12:00	Water Supply in Emergency for Bogotá	Mr. Guillermo Escobar	DPAE
12:00-12:30	WTP for Groundwater and Emergencies	Mr. Alvaro Sanjinez	VALREX
13:30-14:30	Site Visit to Aguadora Well		
14:30-15:00	Water Supply Plan of Groundwater in Emergency for Bogotá	Mr. Alberto Groot	Acueducto
15:00-15:30	Potable Water Quality in cases of Emergencies.	Mr. Jorge Arboleda	HIDROSAN
15:30-15:45	Close	Mr. Alberto Groot	Acueducto

The final result of this JICA Study was presented by the JICA Study Team in the seminar. Necessity on emergency water supply and current issues on this topic were made clear by presentation of the seminar. Attendants of the seminar have fully understood importance of emergency water supply. Media also attended the seminar, and they introduced result of this JICA Study by the broadcast, which was expected causing wide interest on this JICA Study from many people. Furthermore, Acuedcuto implemented pumping test on the day of the seminar at the exploratory wells, which were drilled near the seminar hall. Scene of pumping test was broadcasted and appealed to many people.

SDA made presentation on the use and conservation of groundwater inside Bogotá city. CAR explained about the regulations on the eastern hills of Bogotá and explained about the proposal for modifying and adjusting the environmental management plan. Also CAR did a technical presentation regarding hydrogeology in the Eastern Hills of Bogotá. DPAE explained about the water supply in emergency for Bogotá City. A presentation on water treatment plants for emergencies was presented by VALREX. Acueducto with JICA Study explained about the plan for water supply by groundwater in cases of emergency for Bogotá city. Water Quality in cases of emergency was discussed by HIDROSAN providing guidelines for emergency cases.

PART 2 MASTER PLAN STUDY

CHAPTER 1 GENERAL CONDITION OF THE STUDY AREA

1.1. Current Situation of the Study Area

1.1.1. Socio-economic Conditions

(1) Study Area

The Study Area is comprised of both the Bogotá District Capital (Bogotá D.C.; 1,605 km^2) and 10 municipalities of the Cundinamarca Department (1,173 km^2).

Bogotá D.C. is divided into 20 localities. The Study Area includes 19 urban localities of Bogotá D.C.

The Cundinamarca Department is divided into 15 provinces (*provincias*), and these provinces are divided into 116 municipalities (*municipios*). The Study Area extends to 4 provinces and 10 municipalities of the Department. Out of the 10 municipalities, Soacha was created recently in 1997.

The total area of the Study Area is of 1,785.7 km^2 which corresponds to 64% of the total land area of Bogotá D.C. and the 10 municipalities of the Cundinamarca Department that are 2,778 km^2 as shown in Table-2.1-1.

Table-2.1- 1 Total Study Area

Administrative Division			Total Land Area (km^2) 1)	Study Area 2)	
Department	Province	Municipality		Land Area (km^2)	Ratio (%)
Bogotá D.C.			1,605	769.0	48%
Cundinamarca	S.C.	1. Cajicá	53	53.0	100%
	S.C.	2. Chía	76	76.0	100%
	S.O.	3. Funza	71	71.0	100%
	S.C.	4. Gachancipá	44	44.0	100%
	Guavio	5. La Calera	340	184.8	54%
	S.O.	6. Madrid	120	120.0	100%
	S.O.	7. Mosquera	107	107.0	100%
	Soacha	8. Soacha	187	185.9	100%
	S.C.	9. Sopó	103	103.0	100%
	S.C.	10. Tocancipá	72	72.0	100%
	Subtotal		1,173	1,016.7	87%
Total			2,778	1,785.7	64%

Note: S.C.: Sabana Centro, S.O.: Sabana Occidental.

Source: 1) IGAC, 2) Final Report of "The Study on Sustainable Groundwater Development for Bogotá Plain in the Republic of Colombia, February 2003", JICA.

(2) Population

Table-2.1-2 shows the census population and the adjusted population of Colombia and the Study Area.

<COLOMBIA>

The census population of year 2005 was 41.5 million inhabitants. The population increased by 8.4 million over the 12 year period from the previous census year of 1993. The annual growth rate between the censuses of 1993 and 2005 was 1.9%, which slowed down from 2.2% between the censuses of 1985 and 1993.

Table-2.1- 2 Actual Population and its Growth of the Study Area

Region		Population (1,000 persons)					Growth of Census Population		House Hold Size (Adjusted Population)
		Census				Adjusted			
		1973 1)	1985 1)	1993 1)	2005 2)	2005 2)	85-93	93-05	
Bogotá D.C.		2,571.5	3,982.9	4,945.4	6,778.7	6,840.1	2.7%	2.7%	4.0
Cundinamarca	1. Cajicá	12.4	20.7	29.5	44.7	45.4	4.5%	3.5%	4.2
	2. Chía	20.6	37.0	45.7	97.4	97.9	2.7%	6.5%	4.1
	3. Funza	17.6	27.2	37.8	60.6	61.4	4.2%	4.0%	5.0
	4. Gachancipá	2.6	3.4	5.5	10.8	10.9	6.4%	5.8%	5.4
	5. La Calera	11.8	15.3	17.9	23.3	23.8	1.9%	2.2%	3.6
	6. Madrid	18.1	27.0	39.2	61.6	62.4	4.8%	3.8%	6.3
	7. Mosquera	7.7	12.3	20.4	63.6	63.2	6.5%	9.9%	4.8
	8. Soacha	37.8	109.1	230.3	398.3	402.0	9.8%	4.7%	4.3
	9. Sopó	5.9	8.3	11.4	21.0	21.2	4.1%	5.2%	4.2
	10. Tocancipá	4.5	6.7	11.2	24.0	24.1	6.6%	6.6%	4.8
	Subtotal	139.0	267.0	448.9	805.3	812.3	6.7%	5.0%	4.4
	(% of the Dept.)	(12%)	(19%)	(27%)	(36%)	(36%)	-	-	-
Total of the Study Area		2,710.5	4,249.9	5,394.3	7,584.0	7,652.4	3.0%	2.9%	4.0
Colombia		20,666.9	27,853.4	33,109.8	41,468.4	42,888.6	2.2%	2.0%	4.3

Note: DANE announces the two types of population: census (*censada*) population and adjusted (*reconciliada*) population where error and omission are corrected. Source: 1) *Colombia Estadística* 1998-2000, DANE, 2001, and *Anuario Estadístico* 1997-1998, Cundinamarca, 2) Website of DANE.

<THE STUDY AREA>

The census population of year 2005 totaled 7.6 million inhabitants, an increase of 2.2 million from the previous census of 1993. The annual growth rate between the censuses of 1993 and 2005 was 2.9%, which also slightly slowed down from 3.0% between the censuses of 1985 and 1993.

- The census population of Bogotá D.C. in 2005 increased by 1.9 million or by 2.7% per annum compared with that in 1993.
- The census population of the 10 municipalities of the Cundinamarca Department increased by 0.4 million compared with the 1993 census. The population growth of this area shrunk to 5.0% from the previous rate of 6.7%; however the growth is remarkably high, especially in Mosquera, Chía and Tocancipá.

The population density (persons/km^2) of Bogotá D.C. and the 10 municipalities, of the Cundinamarca Department, in the Study Area in 2005 was 8,800 and 790 respectively.

(3) Gross Regional Domestic Product

Table-2.1-3 shows the gross domestic product (GDP) of Colombia and the gross regional domestic product (GRDP) of Bogotá D.C. and the Cundinamarca Department.

GDP of Colombia grew by 7% in 2006 and reached at Col$ 382 billion (10^{12}).

GRDP of the Bogotá D.C. in 2006 grew by 7.3% and reached at Col$94 billion that accounted for 24.5%of GDP of Colombia; while that of the Cundinamarca Department in 2006 was Col$20 billion that was 5.3% of GDP.

GRDP as well as GDP have turned to the positive growth since 2000 in spite of the sharp negative growth due to the economic stagnancy in 1999.

Table-2.1- 3 GDP & GRDP (at Constant Price of 2005)

Item	Region	2002	2003	2004	2005	2006 1)
GDP & GRDP (Col$ billion)	Colombia	309,186	323,446	338,531	357,898	382,818
	Bogotá D.C.	74,561	78,100	81,160	87,567	93,971
	Cundinamarca Dept.	15,760	17,763	17,728	18,595	20,244
Share to GDP Colombia	Colombia	100.0%	100.0%	100.0%	100.0%	100.0%
	Bogotá D.C.	24.1%	24.1%	24.3%	24.5%	24.5%
	Cundinamarca Dept.	5.1%	5.5%	5.2%	5.2%	5.3%
Annual Growth	Colombia	2.5%	4.6%	4.7%	5.7%	7.0%
	Bogotá D.C.	4.1%	4.7%	5.2%	6.6%	7.3%
	Cundinamarca Dept.	-2.1%	12. 7%	-0.2%	4.9%	8.9%

Note: 1) A preliminary figure for year 2006
Source: DANE (unities)

Table-2.1-4 indicates GDP and GRDP per capita.

Table-2.1- 4 GDP and GRDP per Capita (at Constant Price of 2005)

Item	Region	2002	2003	2004	2005	2006 1)	US$ 2)
Per Capita (Col$.000)	Colombia	7,494	7,742	8,004	8,359	8,819	3,740
	Bogotá D.C.	11,435	11,784	12,201	12,802	13,530	5,740
	Cundinamarca Dept.	6,422	6,217	6,310	6,269	6,566	3,700
Ratio to Colombia	Colombia	1.0	1.0	1.0	1.0	1.0	-
	Bogotá D.C.	1.4	1.4	1.4	1.4	1.4	-
	Cundinamarca Dept.	1.1	1.1	1.1	1.0	1.0	-
Real Growth	Colombia	1.2%	3.3%	3.4%	4.4%	5.5%	-
	Bogotá D.C.	2.4%	3.1%	3.5%	4.9%	5.7%	-
	Cundinamarca Dept.	-4.0%	10.6%	-2.0%	3.1%	7.0%	-

Note: 1) a preliminary figure for year 2006. 2) Average Exchange Rate (Col$/US$) in 2006: 2,358 (Refer to the Table-1.6).
Source: DANE (unities)

GRDP per capita of the Bogotá D.C. was US$ 5,740 in 2006 that is larger by 53% than GDP per capita of Colombia. Meanwhile, GRDP per capita of the Cundinamarca Department was US$ 3,700 in 2006 that is almost as same as GDP per capita of Colombia.

(4) Economic Activities

Table-2.1-5 shows the distribution and the growth of GRDP by the economic sector.

<BOGOTÁ D.C.>

The service sector is a predominant economic activity in Bogotá D.C., which accounted for 77% of GRDP in 2006 especially; commercial/hotel/restaurant, real estate and financial sectors are remarkable in the city.

The industrial sector also plays a big role in the economic activity in the Bogotá D.C., representing by 23% of GRDP in 2006. Textile/garment, food/beverage and petroleum/chemical are the three largest industries of the Bogotá D.C.

Table-2.1- 5 Distribution and Growth by Economic Sector

Item	Sector	2002	2003	2004	2005	2006 1)
Contribution to GRDP at Factor Cost	Bogotá D.C.	100.0%	100.0%	100.0%	100.0%	100.0%
	Agriculture	0.0%	0.0%	0.2%	0.2%	0.1%
	Mining	0.2%	0.2%	0.3%	0.3%	0.2%
	Industry	22.1%	22.5%	22.5%	22.7%	22.8%
	Services	77.7%	77.3%	77.0%	76.8%	76.9%
	Cundinamarca Dept.	100.0%	100.0%	100.0%	100.0%	100.0%
	Agriculture	24.1%	24.1%	22.0%	22.1%	20.6%
	Mining	1.8%	1.5%	1.5%	1.4%	1.5%
	Industry	28.1%	29.2%	28.9%	29.8%	31.0%
	Services	46.0%	45.2%	47.6%	46.7%	46.8%
Real Growth of GRDP	Bogotá D.C.					
	Agriculture	-6.1%	457.6%	10839.9%	12.5%	-18.6%
	Mining	21.2%	15.0%	14.8%	18.5%	-29.3%
	Industry	5.1%	6.1%	5.8%	7.1%	7.5%
	Services	3.4%	4.2%	5.1%	6.4%	6.6%
	Cundinamarca Dept.					
	Agriculture	-0.6%	11.5%	-10.9%	5.5%	1.0%
	Mining	6.8%	-7.9%	-4.8%	1.9%	11.6%
	Industry	-12.0%	15.7%	-3.3%	8.4%	12.2%
	Services	2.8%	9.6%	3.1%	2.7%	8.8%

Note: 1) a preliminary figure for year 2006

Source: DANE

<CUNDINAMARCA DEPARTMENT>

The agriculture is an important sector of the Department, accounting for 21% of the GRDP of the Department. The main agriculture products of the Study Area are such transitory crops as tomato, carrot, and pea. Also the floriculture is a very important economic sector of the Study Area.

The industry sector accounted for 31% of the GRDP in 2006. The most remarkable industries in the Department are 1) Food and Beverage, 2) Ceramic & Glass, and 3) Cement.

1) Consumer Price Index and Exchange Rate

The consumer price index (CPI) of Colombia during eight years was shown in Table-1.6. CPI of the years of 1990's recorded more than 15% every year. It fell sharply to 9% in 1999. CPI fell continuously from 1999 and recorded a historical low level of 4.5% in 2006 during these last 15 years. However, CPI has soared in 2008 due to a hike in global commodities prices.

Table-2.1- 6 Consumer Price Index and Exchange Rate

Items	2001	2002	2003	2004	2005	2006	2007	2008
Consumer Price Index in Colombia								
(%)	7.7	7.0	6.5	5.5	4.9	4.5	5.7	7.9 1)
Exchange Rate (Average of monthly average rate)								
(Col$/US$)	2,299.8	2,508.0	2,877.5	2,626.2	2,320.8	2,358.0	2,078	1,900 2)

Note: 1) Annual rate as of October, 2) Average until October

Source: 1) DANE, 2) Central Bank of Colombia.

Colombian peso has been devaluated in 2002 and 2003 due to the South American financial crisis. However, it has been stabilized since 2004 or even restored to the year 2000 level in 2007. In October 2008, the average exchange rate Colombian peso against US dollar quoted at 2,290.

1.1.2. Institution for Water Supply and Water Resources Management

(1) Current Legislation on Water Resources Management

The 1991 Constitution of the Republic vests the ownership of subsoil, natural and renewable resources on the state. Major decrees, laws, resolutions related to water resources management are as follows.

<Decree-Law No. 2811 of 1974-National Code of Renewable Natural Resources and Environmental Protection>

Decree-Law 2811 of December 18, 1974, named as "National Code of Renewable Natural Resources and Environment Protection", is the fundamental law of water resources management. All water resources in any condition and any location within the territory of the Republic are recognized as renewable natural resource. In the Code, renewable natural resources are deemed as common property of the nation, and the state shall participate in their preservation and management as social interests. Conservation, improvement and rational use of them shall be made with maximum social participation to assure harmonic development for the benefits of health and well-being of the present and future nation.

<Decree No. 1541 of 1978 and Accord of CAR No. 10 of 1989>

Decree No. 1541 of 1978, gives provisions on non-marine water based on the National Code of Renewable Natural Resources and Environmental Protection. The Decree defines types of domains, such as public or private, of non-marine water as well as riverbeds. Main part of the decree is destined for manners and procedure for giving rights to use non-marine water and watercourses to individual persons, including juridical ones. Accord of Regional Autonomous Corporation of Cundinamarca (CAR) (No. 10 of 1989) gives the same provisions for the jurisdiction of the corporation, i.e., the river basins of Bogotá, Ubaté and Suárez, etc.

<Law No. 99 of 1993>

Law No. 99 of 1993 institutes organizations for public administration of environmental protection and conservation as well as renewable natural resources management, such as Ministry of Environment, National Council of Environment, Institute of Hydrology, Meteorology and Environmental Study (IDEAM), Regional Autonomous Corporations. The Law also provides duties and jurisdictions of the relevant organizations. The Law stipulates that Regional Autonomous Corporations, with financial independence and their own properties, administer environment and renewable natural resources according to the laws and polices of the Ministry.

Study Area, the Upper Bogotá River Basin, falls under the territory of CAR. Besides, parts of Chingaza River Basin and Sumapaz River Basin belong to jurisdiction of CORPOGUAVIO and CORPOORINOQUIA. In case an ecosystem or a water basin extends to territories of two or more regional autonomous corporations, there will be a joint commission for coordinated management. In case of a large urban center with a population of one million or more, environmental authority of the local government of the area takes same functions as the regional autonomous corporation of the area within the urban zone. The provision is applied in the Study Area, and SDA take the duties of environmental and renewable natural resources management in its jurisdiction.

<Law No. 373 of 1997>

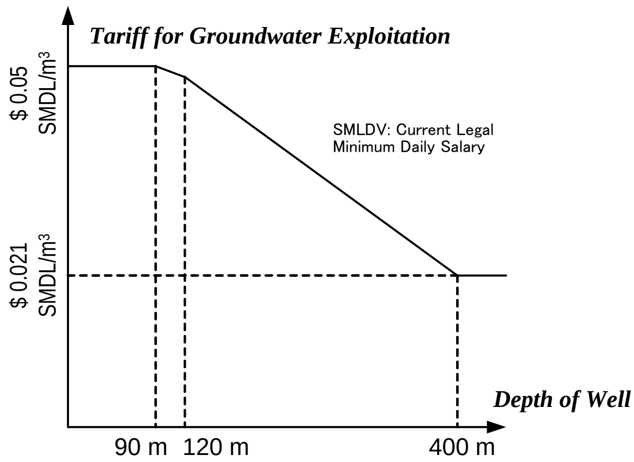
Law No. 373 of 1997 provides programs for efficient use and saving of water. All municipalities shall elaborate five-year program in cooperation with entities of water supply, sewerage, irrigation, electrical generation etc., to be approved by respective regional autonomous corporation and to be submitted to the Ministry of Environment.

<Accord of CAR No. 8 of 2000>

Accord of CAR No. 8 of 2000, determines water right charge. Basic charges by municipality are calculated taking account of factors on i) aridity, ii) unsatisfied basic necessity, as socio-economic conditions, and iii) availability of water resources. Pressure on water resource potential, i.e. Percentage of granted volume to half of mean discharge in dry seasons in case surface water and recharge in case of groundwater is also a factor for the calculation. For groundwater the charge is lower when the depth of the well is deeper.

<Resolutions of DAMA (previous name of SDA) on Groundwater Management>

Resolution No. 250 of DAMA, 1997, determines formula to calculate rate for abstraction of groundwater. The resolution gives higher rate for shallow borehole less than a depth of 90 m, 120 m and 400 m. The tariff for a cubic meter of water is constant for wells with depth up to 90 m. From the depth of 90 m, the tariff starts to decrease. From the depth of 120 m up to 400 m, the tariff decreases a little more sharply as shown in Figure-2.1-1:



Source: Resolution No. 250 of DAMA, 1997

Figure-2.1- 1 Tariff for Groundwater in Bogotá D.C

The resolution No. 251 of DAMA, 1997 gives obligation of registration of wells located in the urban zones of the Capital District to SDA.

<Legislation on Water Basin Management>

Decree No. 1604 of 2002 stipulates members of a Joint Commission and its functions based on Law No. 99 of 1993. The members include directors, or their delegates, of regional autonomous corporations and the environmental authorities of the large urban center. Functions of the Joint Commission are to coordinate activities on i) formulation of regulation and management plan of the water basin, ii) to approve the plan, iii) to set up mechanism for the implementation of the plan, and iv) to implement programs of economic instruments. The Decree allows the commission to establish a technical commission for the support to carry out its functions.

Decree No. 1729 of the same year gives provisions of concept, objectives, compositions, implementation, and financing for the implementation of Regulation and Management Plan of Water Basin (POMCA). The plan has a) diagnostic, b) prospective, c) formulation, d) implementation, and e) monitoring and evaluation phases. Law No. 388 of 1997 on land regulation plan introduced the concept of water basin management.

(2) Legislation on Prevention and Attention of Emergencies

Decree No. 332 of 2004 of Bogotá D.C. organizes regime and system for prevention and attention of emergencies in Bogotá D.C. The Decree defines situations of emergencies of the district, activities for prevention and mitigation of the risks including District Plan for Prevention and Attention of Emergencies, District System for Prevention and Attention of Emergencies and provides other relevant dispositions. According to the Decree, an organization headed by the Mayor of Bogotá D.C. manages the system with the members as follows.

1) Mayor of Bogotá D.C.

2) District Committee for the Prevention and Attention of Emergencies.

3) Secretariat of the Government.

4) Fund of Prevention and Attention of Emergencies of Bogotá.

5) Directorate of Prevention and Attention of Emergencies of the District.

6) District Inter-institutional Commissions.

7) Local Mayors.
8) Local Emergency Committees.
9) Fire Brigade, Red Cross and Civil Defense.
10) Secretariats, Administrative Departments and district decentralized entities when their competencies and functions have relations with activities of prevention and attention of disasters, calamities and emergencies of the district.
11) National and regional public and private entities when their competencies and functions have relations with activities of prevention and attention of disasters, calamities and emergencies of the district and have dependences or executing functions in the territory of the Capital District..

The District Committee for the Prevention and Attention of Emergencies is presided by the Mayor of the District and has members of secretaries and directors of departments of the district government, commanders of the police, military and fire brigade, president of the Red Cross of Bogotá and Cundinamarca Section, director of Civil Defense of Bogotá Section and managers of executive units of public services and of companies of public utility services operating in the district.

There are five inter-institutional commissions under the Committee, namely Commissions of i) Planning, ii) Environment and Housing, iii) Infrastructure, Mobility, and Public Utility Services, iv) Social Management, Education and Public Participation, and v) Operation. As the company for collective water supply in Bogotá D.C., Water Supply and Sewerage Company of Bogotá (Acueducto) has to be involved in activities of the Committee and Commissions of Environment and Housing and of Infrastructure, Mobility, and Public Utility Services.

Decree No. 423 of 2006 of Bogotá D.C. provides policies, general objectives, lines of actions, scenarios, programs of the District Plan for Prevention and Attention of Emergencies. The Decree set up seven general objectives of the Plan, as shown in the below table (Table-1.7). The Decree also identifies territorial scenarios; 1) rural and natural areas, 2) hillside areas, 3) alluvial areas, and 4) consolidated city areas, and sector scenarios; a) construction, b) network (of public utility services, c) industry, and d) mass of people (such as religious, political or sports events, trade fairs, theatres). The scenario related to water supply is the network scenario, which includes networks of i) water supply and sewerage system, ii) electricity distribution, iii) supply of natural gas, iv) distribution of other types of hydrocarbon, v) communications, vi) roads and mass transit and vii) collection and disposal of wastes. The Decree also defines expected results for each scenario corresponding to each of the seven general objectives. The expected results for the scenario of the networks are given in the table below (Table-2.1-7).

Table-2.1- 7 Expected Results for the Management of Networks

General Objective	Expected Results
Safe Location	*Land planning instruments (*Plan de Ordenamiento Territorial* (POT) and master plans, among others) are strengthened with the component of public risk in networks (including establishment of vulnerability maps)
Safe Construction	*Update of technical norms for risk reduction in networks *Reduction of the functional vulnerability of the public services, transportation and mobility networks
Safe Operation	*Reduction of the functional vulnerability of the public services, transportation and mobility networks *Establishment of contingency plans implemented for all public services systems, transportation and mobility systems
Including of Risk Management in Culture	*Incorporation of management practices on risk management into formal education sector *Increase in of the self-protection behavior in the community *Strengthening of risk management within institutional and corporate culture
Visibility and responsibility	*Strengthening of District System for Prevention and Attention of Emergencies (SDPAE) *Public, private and community sectors must be, technically and economically, responsible for their own activities with regards to risk generation, especially with public service companies and companies from infrastructure and mobility sector *Strengthening of social control around inadequate home installation of public services networks
Integrated Attention of Emergencies	*Strengthening of high organizational capacity, logistics, communications and training for emergencies operations *Strengthening of regulatory framework, information system and coordination at regional, national and international levels for emergencies attention *Increase in capacity of the citizen on preparation, self-protection and recovery in emergency situations
Resilience in Front of the Disaster	*Incorporation of city planning system with the policies, organization, structure and regulatory framework for the recovery processes after disasters of the city *Implementation of strategy for reducing fiscal vulnerability of the District in natural disasters *Implementation of contingency plan for rehabilitation of networks after the events

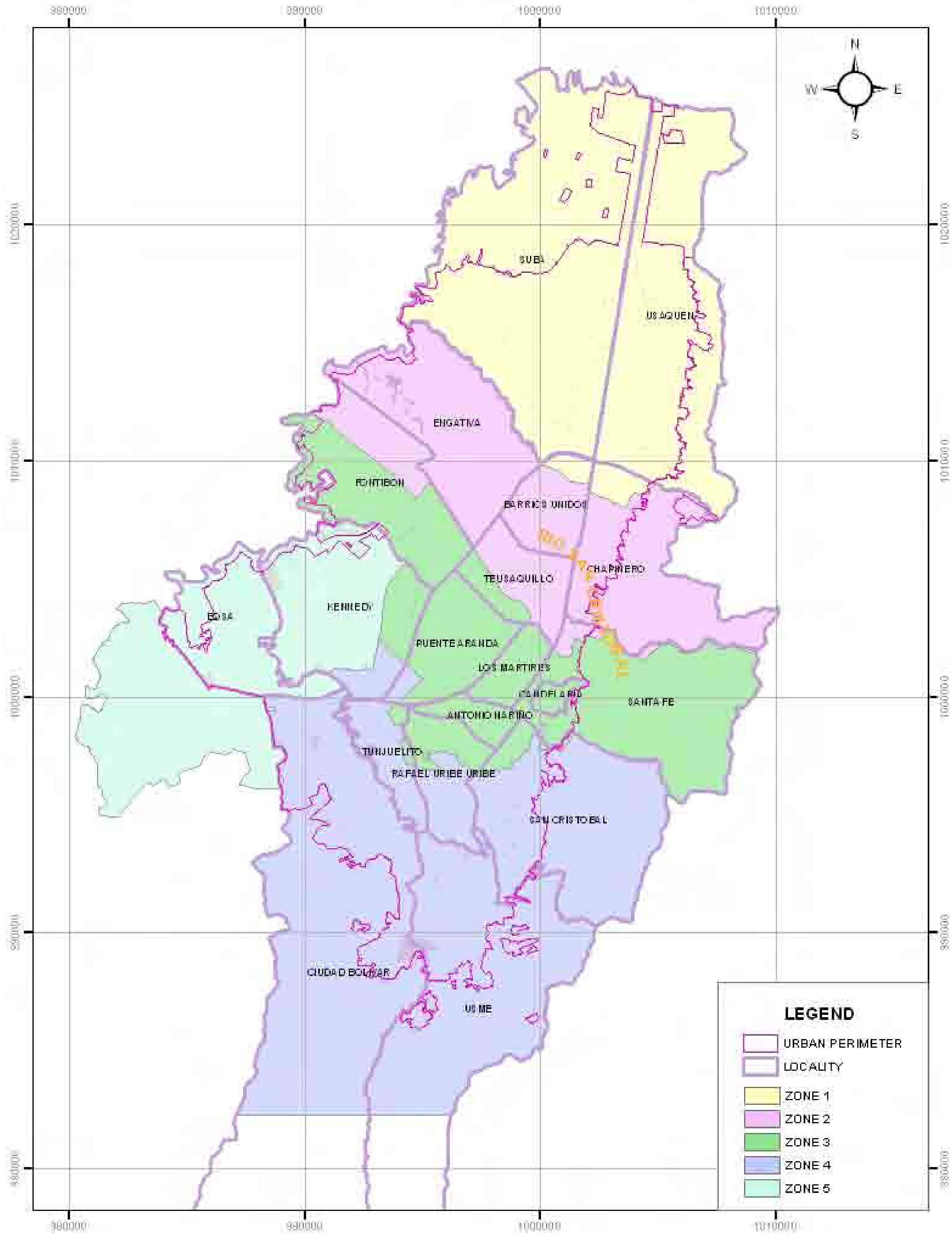
Source: Decree No. 423 of 2006.

(3) Organizations for Water Use and Water Resources Management

Organizations that have relation to water use and water resources management are as follows:

<Acueducto>

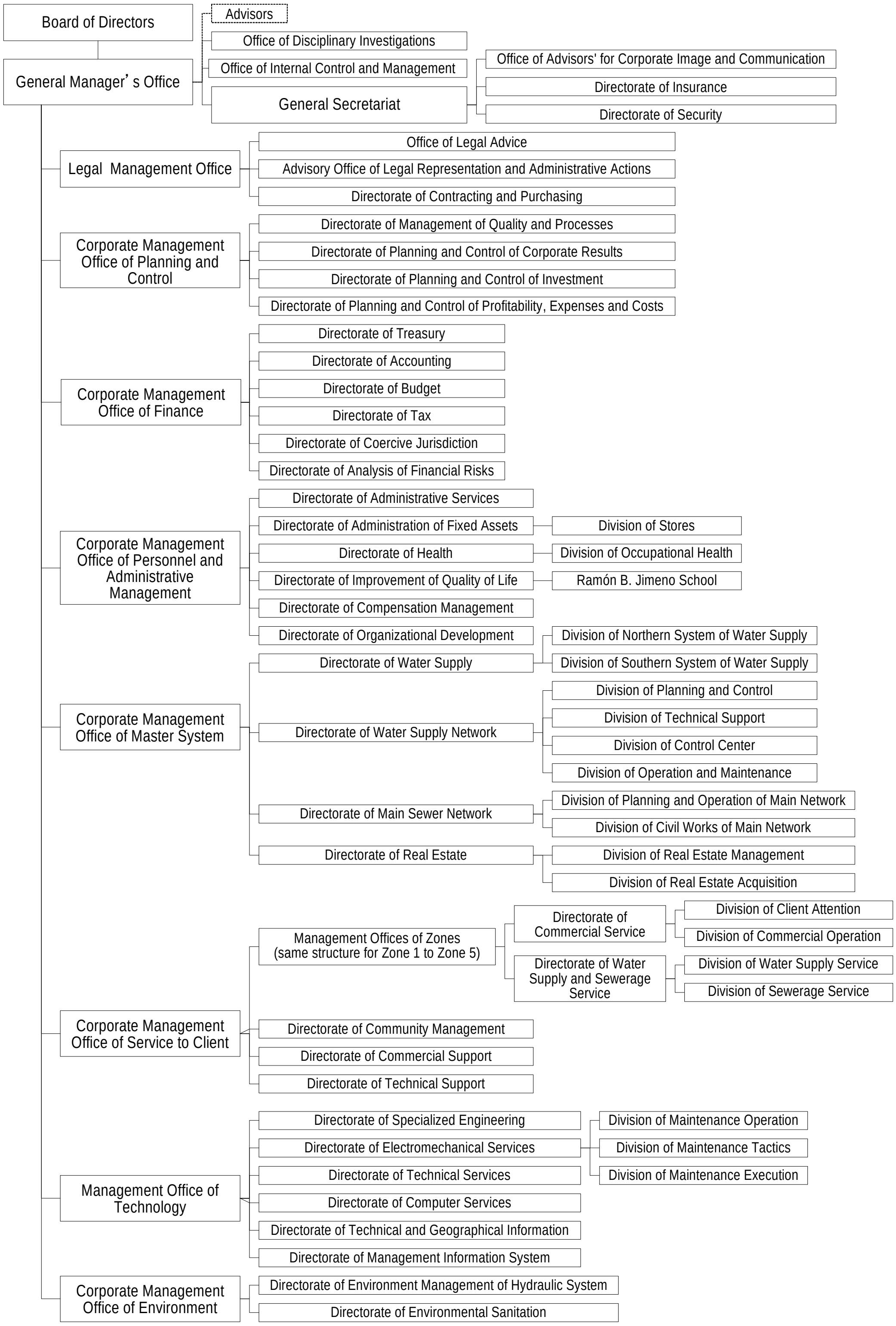
Water Supply and Sewerage Company of Bogotá (Acueducto) is a public company, without any private capital, in charge of water supply and sewerage services in Bogotá D.C. Acueducto also supplies water to some surrounding 10 cities, such as Cajicá, Sopó, Chía, Tocancipá, La Calera, Gachancipá, Soacha, Funza, Mosquera, Madrid, under contracts with each of the municipalities. Acueducto is also engaged in environmental activities, such as implementation of wetlands conservation projects, which are formulated by SDA. Acueducto employs 1,765 persons as of November 2007. At present, water sources for Acueducto are mostly of surface water.



Source: Acueducto

Figure-2.1- 2 Jurisdiction of Zone Offices of Acueducto

Organization structure of Acueducto is illustrated in the figure below (Figure-2.1-3). Core organization for provision of the water supply and sewerage services is the Corporate Management Office of Mater System, while the Corporate Management Office of Service to Clients implements customer attention. Number of the staff of these two Corporate Management Offices by directorate and division are given in the Table-2.1-8.



Source: Acueducto

Figure-2.1- 3 Organization Structure of Acueducto

Table-2.1- 8 Number of Employees in the Two Corporative Management Offices (1)

Directorate and Divisions	Number of Employees
Corporate Management Office of Master System	2
Directorate of Water Supply	39
Division of Northern System of Water Supply	69
Division of Southern System of Water Supply	43
Directorate of Water Supply Network	5
Division of Planning and Control	4
Division of Technical Support	8
Division of Control Center	67
Division of Operation and Maintenance	3
Directorate of Main Sewer Network	7
Division of Planning and Operation of Main Network	8
Division of Civil Works of Main Network	3
Directorate of Real Estate	12
Division of Real Estate Management	4
Division of Real Estate Acquisition	5
Total Corporate Management Office of Master System	279
Corporate Management Office of Service to Client	9
Directorate of Community Management	29
Directorate of Commercial Support	11
Directorate of Technical Support	21
Total of Administration Center	70
Management Offices of Zone 1	5
Directorate of Commercial Service Zone 1	8
Division of Client Attention Zone 1	7
Division of Commercial Operation Zone 1	11
Directorate of Water Supply and Sewerage Service Zone 1	11
Division of Water Supply Service Zone 1	11
Division of Sewerage Service Zone 1	56
Management Offices of Zone 3	109
Management Offices of Zone 2	5
Directorate of Commercial Service Zone 2	2
Division of Client Attention Zone 2	7
Division of Commercial Operation Zone 2	12
Directorate of Water Supply and Sewerage Service Zone 2	7
Division of Water Supply Service Zone 2	61
Division of Sewerage Service Zone 2	61
Total of Management Office Zone 2	155
Management Offices of Zone 3	5
Directorate of Commercial Service Zone 3	4
Division of Client Attention Zone 3	10
Division of Commercial Operation Zone 3	13
Directorate of Water Supply and Sewerage Service Zone 3	9
Division of Water Supply Service Zone 3	64
Division of Sewerage Service Zone 3	67
Total of Management Office Zone 3	172
Management Offices of Zone 4	5
Directorate of Commercial Service Zone 4	vacant
Division of Client Attention Zone 4	7
Division of Commercial Operation Zone 4	15
Directorate of Water Supply and Sewerage Service Zone 4	7
Division of Water Supply Service Zone 4	13
Division of Sewerage Service Zone 4	67
Total of Management Office Zone 4	114

Source: Acueducto

Table-2.1-8(2) Number of Employees in the Two Corporative Management Offices (2)

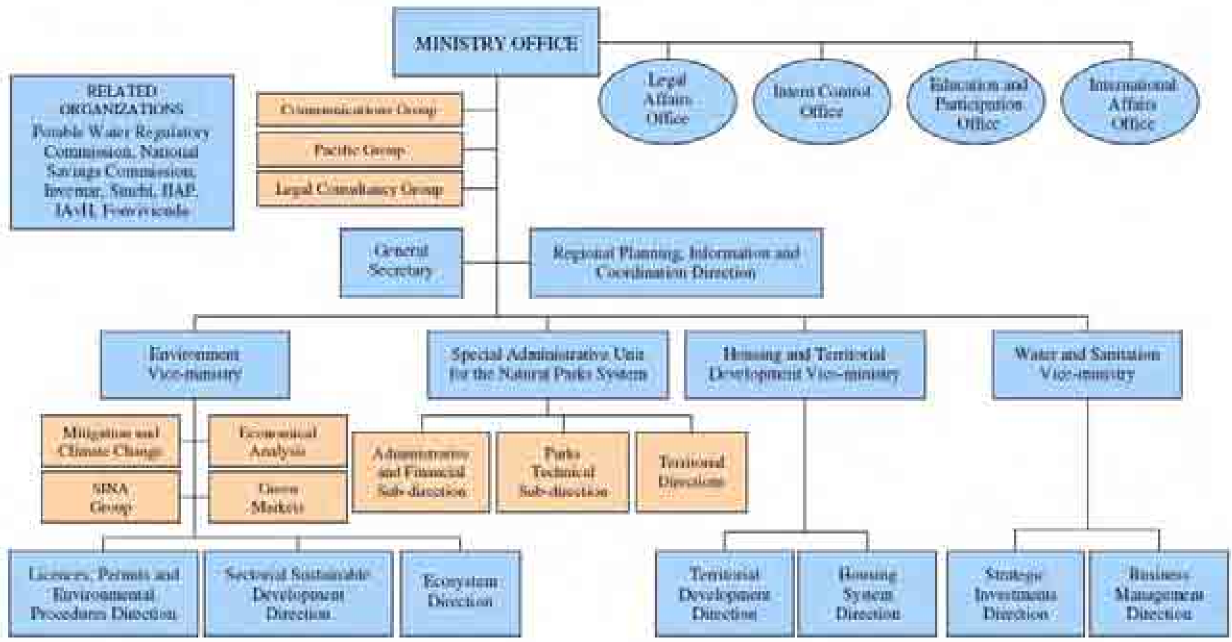
Directorate and Divisions	Number of Employees
Management Offices of Zone 5	5
Directorate of Commercial Service Zone 5	1
Division of Client Attention Zone 5	7
Division of Commercial Operation Zone 5	13
Directorate of Water Supply and Sewerage Service Zone 5	10
Division of Water Supply Service Zone 5	12
Division of Sewerage Service Zone 5	71
Total of Management Office Zone 5	119
Total of Corporate Management Office of Client Service	739

Source: Acueducto

Acueducto implements customer attention through five Management Office of Zones. The office for Zone 1 is located in Usaquén and that for Zone 4 in Santa Lucia, while other offices (Zone 2, 3 and 5) are located in the same place as the Headquarters Office of Acueducto.

<Ministry of Environment, Housing and Land Use Development>

Ministry of Environment, Housing and Land Use Development is in charge of management of environment and renewable natural resources, such as water resources. The ministry formulates policies of the matters at national level, while regional entities, such as CAR or SDA are in charge of policy formulation and implementation for the management for their jurisdictions. Special Administrative Unit of Natural Park System gives concession for water use located in the National Natural Park.

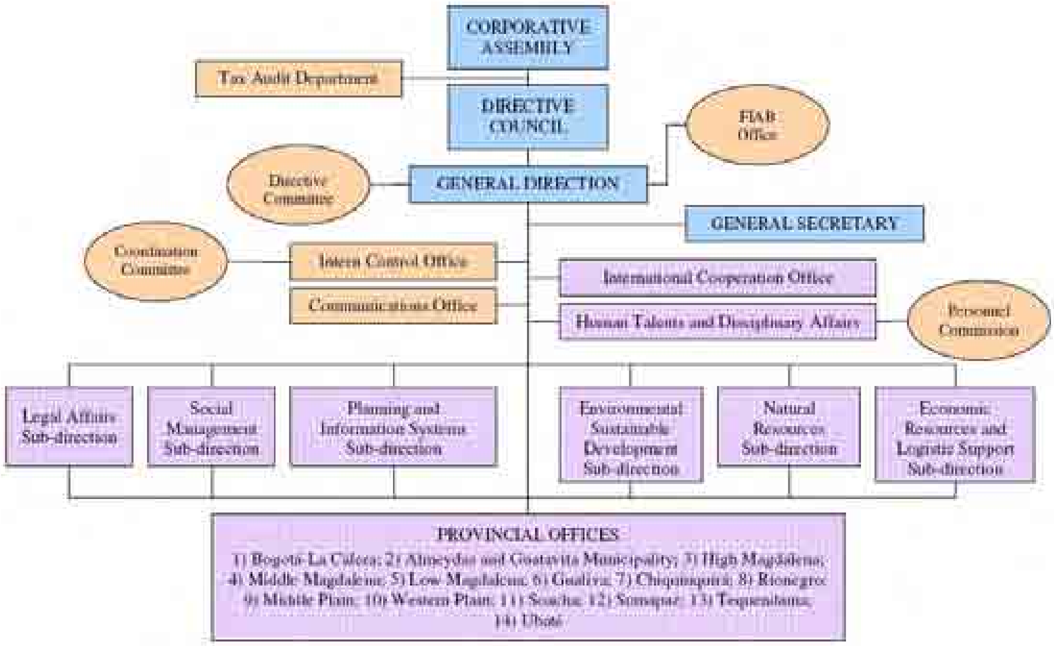


Source: MAVDT

Figure-2.1- 4 MAVDT Organization

<CAR>

CAR takes main role in environmental conservation and management of the renewable natural resources, including water resources. CAR was originally established as a water basin management entity and changed its name as the present one by the Law No. 99 of 1993. Its territory has also been changed from areas of basins to areas of administrative units. Organization chart is shown in Figure-2.1-5. Sub-directorate of Management of Shared Environment implements inventory of natural resources and Sub-directorate of Management of Shared Environment examines use of natural water resources. General Secretariat and Legal Support deals environmental license and permission.



Source: CAR

Figure-2.1- 5 CAR Organization

<SDA>

SDA is one of the Administrative Technical Departments of the Government of Bogotá District (*Alcaldía Mayor*) in charge of managing the environment and renewable natural resources within the urban perimeter of Bogotá D.C. In fact, however, SDA grants water rights of groundwater but not of surface water due to the scarce availability of it in the area with bad water quality (Figure-2.1-6).

<IDEAM>

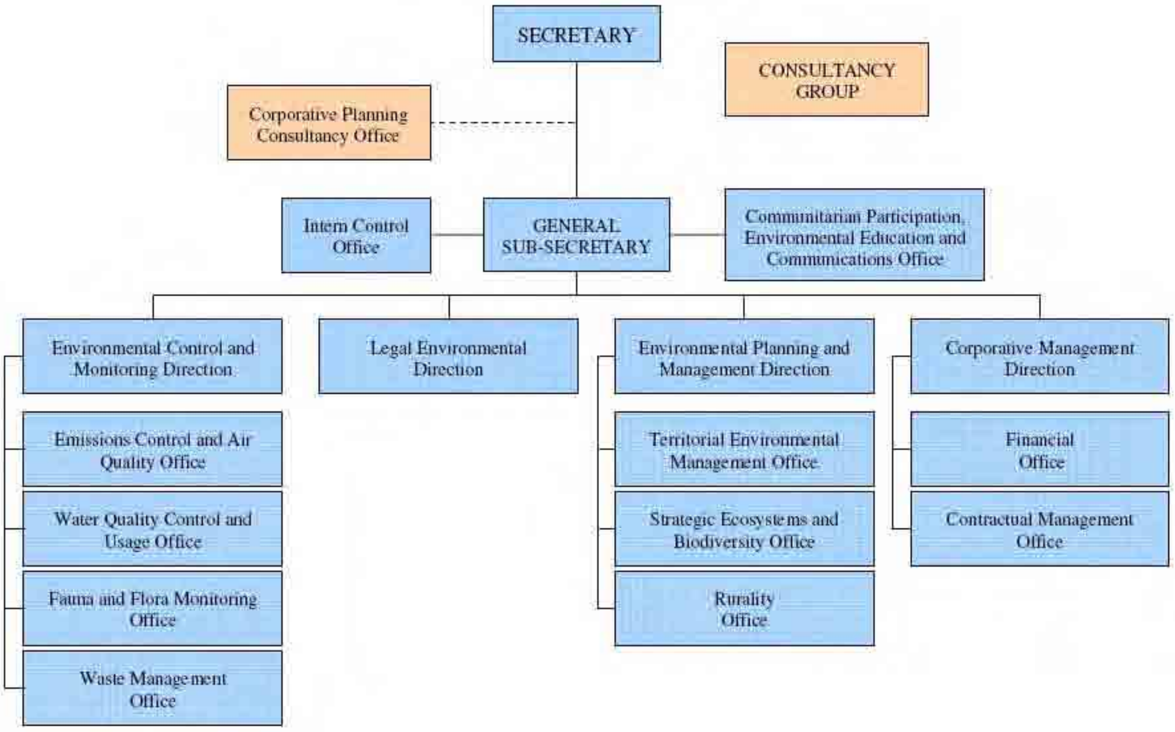
IDEAM is in charge of hydrological, meteorological and environmental investigations, researches and studies for the policy formulation by the Ministry of Environment.

<INGEOMINAS>

INGEOMINAS is a technical center of geology or any matters related underground, including groundwater.

<CORPOGUAVIO>

Corporación Autónoma Regional del Guavio has jurisdiction area in upper-stream area of Guavio River basin. CORPOGUAVIO has almost same function as CAR, which is in charge of formulation of policy and plan, implementation of project and program. They have authorization to give environmental license and concession for water right in their jurisdiction area.



Source: SDA

Figure-2.1- 6 Organization of SDA

<CORPOORINOQUIA>

Corporación Autónoma Regional de la Orinoquía has jurisdiction area in upper-stream area of Orinoco River Basin. CORPOORINOQUIA has almost same function as CAR and CORPOGUAVIO, which is in charge of formulation of policy and plan, and implementation of project and program. They have authorization to give environmental license and concession for water right in their jurisdiction area.

1.1.3. Natural Condition

(1) Meteorology

1) Climatic Division

Formation of water resources in a region is closely related to climatic division of the region. It is commonly known that under a humid and rainy climate, the water resources are generally abundant and that on the other hand, under dry and arid climate, the recharge to surface and groundwater is small. In order to determine the climatic zone of a region, the Koeppen division, the global standard, is most commonly employed. This classification is based on the examination of the temperature and precipitation data of a region to be evaluated.

(a) Distinction of Precipitation Pattern

Bogotá River Basin has an over 30 mm minimum monthly precipitation (35.6 mm) and the ratio between the values of the wettest and driest months is 2.47 (= 97.6 / 35.6), being much smaller than 10 (see Figure-2.1-7). Thus its climate is classified under the annual precipitation Pattern (f).

Source: JICA Study Team

Figure-2.1- 7 Variation of monthly precipitation in Bogotá River Basin

(b) Arid Boundary Calculation

In determining the climatic zone, it is most important to distinguish between dry and wet climates. To do this, the arid boundary "r" is calculated using the following formula:

$$r = 20 \times (t + x)$$

The "r" is the Arid Boundary which is defined as the amount of water evaporated from a given region in one year. If the precipitation is larger than this value, the surplus water is stored in the terrain, making it a wet region. On the contrary, if the precipitation is smaller than the arid boundary value, the region is classified as dry. In the formula "t" is the annual average temperature, "x" is the factor determined based on the precipitation pattern. In the case of Bogotá River Basin, the value is seven (x = 7). Since the annual average temperature in Bogotá River Basin is 13.3°C (see Figure-1.8), the arid boundary is calculated as follows:

$$r = 20 \times (13.3 + 7) = 406\ mm$$

(c) Climatic Classification

Based on the analysis of the meteorological data collected from the 60 stations, the annual average precipitation in Bogotá River Basin is calculated to be 825 mm. This is more than 200% of the calculated arid boundary value "r". Bogotá River Basin is, then, classified under the Humid Climate (C).

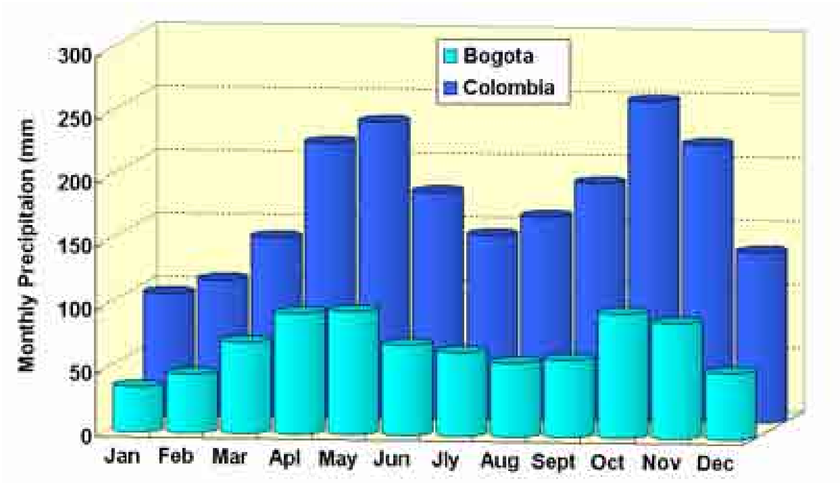
2) Monthly Variation of Annual Precipitation

In Bogotá River Basin, the precipitation is rather uniformly distributed throughout a year and the difference between the minimum and maximum monthly precipitation is small. January is the month with the smallest precipitation and the precipitation shows a bi-modal pattern. The first peak is around April and May, the second October and November. When the precipitation pattern of Bogotá River Basin and that of the average across the country are compared, the following two differences are recognized.

Source: Science Data Book (NAOJ edition) Maruzén

Figure-2.1- 8 Monthly Temperature in Bogotá River Basin

One is that although Bogotá River Basin belongs to wet climate, the average amount of precipitation within the basin is less than half of the average across the country. The average precipitation data used for this comparison was calculated from the data sets for 246 stations across the country archived in the WMO (World Meteorological Organization) database. The precipitation in Bogotá River Basin is placed in the 241st in the 246 series of data sets in descending order of precipitation. This indicates that Bogotá River Basin is an area with small precipitation within Colombia (see Figure-2.1-9). Another is that in spite of smaller total annual precipitation, the general precipitation pattern is quite similar to that of the national average, which implies that the seasonal wind affects the precipitation pattern in Bogotá River Basin as it does in Colombia as a whole.



Source: Science Data Book (NAOJ edition) Maruzén

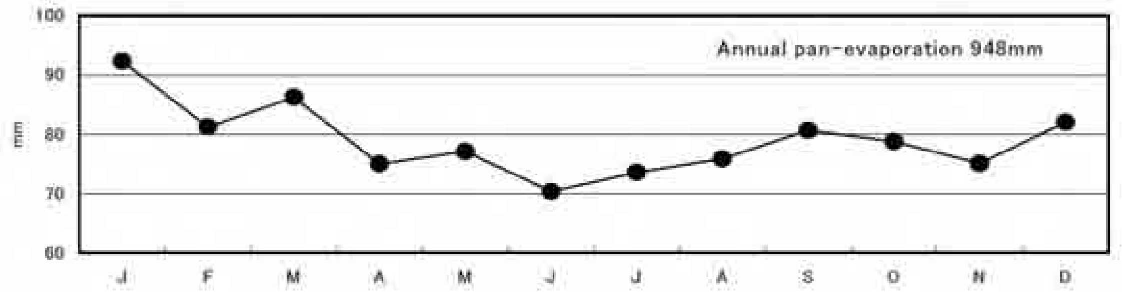
Figure-2.1- 9 Comparison of Precipitation Patterns between Bogotá River Basin and whole Colombia

3) Temperature

The monthly average temperature of the Study Area shows small variation, falling between 13°C and 14°C.

4) Evaporation

The seasonal fluctuation pattern of pan evaporation, as can be seen in Figure-2.1-10, shows the highest peak in January and hits the bottom around May to July. This pattern of pan evaporation is similar to those of solar radiation and sunlight hours. This is because these two factors have much stronger influence over pan evaporation than temperature. The evaporation in the Study Area is measured with a class-A pan (120 cm in diameter, depth 20 cm).



Source: Quoted from the previous study by JICA

Figure-2.1- 10 Monthly Evaporation Variation at a Representative Guaymaral Station, located in the middle of Bogotá River Basin

(2) Topography and Geology

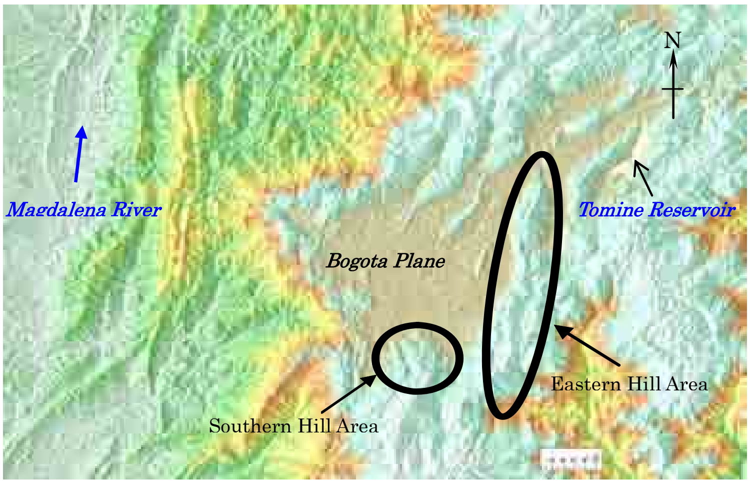
Study Area is located in a basin spreading out in the top of the western slope of East Mountain Range, which traverses from south to north in the eastern part of the Colombian country. This basin is called Bogotá Plain, of which bottom has elevation of 2,500-2,600 m, and the geographical surface of the basin is almost flat.

On the other hand, the basin is surrounded by a mountain range and a hill. The eastern and northern side of the basin forms the steep slopes, which make main ridge of the East Mountain Range. As for the southern and the western slope, the mountains and hills district with gentle slope face the plain. The west side of these mountains and hills makes the western slope of the East Mountain Range, and goes down to the Magdalena River in the steep inclination (Figure-2.1-11). Lineament having NNE-SSW or NE-SW direction which reflected geological structure is remarkable around Bogotá Plain.

Study Area consists of two places. One of them is the mountain that traverses from south to north in the eastern side of Bogotá Plain (It is named as "Eastern Hill Area"). Other one is the hill that spreads out in the southern part of Bogotá Plain (It is named as the “Southern Hill Area”).

The geological map of Bogotá Plain which contains Study Area is shown in Figure-2.1-12. The Bogotá Plain is composed of sedimentary rocks and sediments of Cretaceous-Quaternary, and igneous rocks are not distributed. The upper formations than the Chipaque Formation of Cretaceous are found in the Study Area.

The comprehensive geological structure of Bogotá Plain is characterized by the repetition of anticline and syncline having axis of NNE-SSW or NE-SW direction. The large-scale fault is mainly longitudinal one along the geological structure such as above mentioned. But, the geological structure in the Southern Hill area is irregular partly by a fault of NW-SE direction. The geological characters of Cretaceous-Quaternary in the Study Area are summarized as follows.



Source: JICA Study Team

Figure-2.1- 11 Geographic feature of Bogotá Plain (by SRTM data)

1) Cretaceous

The Cretaceous in the Study Area are divided into four formations as Chipaque Formation, Dura Formation, Plaeners Formation and Labor-Tierna Formation from the bottom part. All of them are marine sediments in origin, and the rock salt of Zipaquirá in the northern part of Bogotá Plain formed in the Cretaceous sea.

<Chipaque Formation>

Chipaque Formation consists mostly of clay stone with occasional thin beds of sandstone, mudstone and siliceous mudstone. Thickness of the formation is about 1,000 m. It can be evaluated as the impermeable basement in the Study Area from hydrogeological view point.

<Dura Formation>

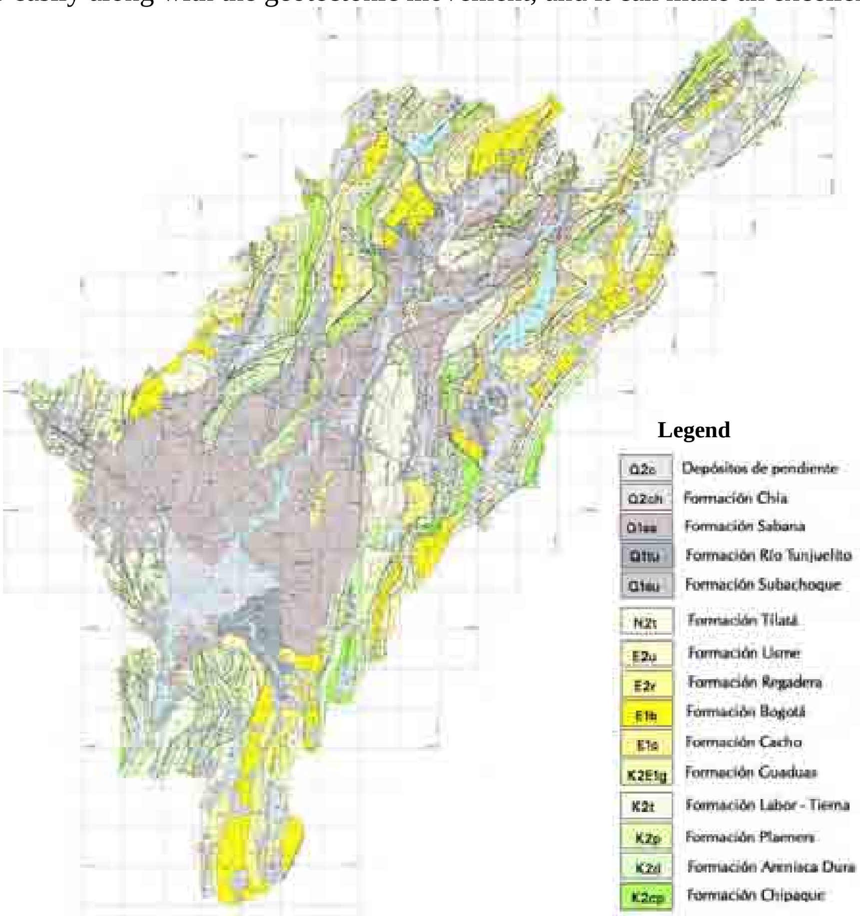
Dura Formation is represented by thick-bedded to massive sandstone with small amounts of intercalated mudstone and chart. Thickness of the formation is about 320 m. Because it consists mostly of sandstone, many cracks can develop easily along with the geotectonic movement, and it can make an excellent aquifer.

<Plaeners Formation>

Plaeners Formation consists mostly of mudstone with occasional thin beds of chart and sandstone. Thickness of the formation is about 100 m. Because it consists generally of fine grain sediments, it is evaluated as the impermeable layer.

<Labor-Tierna Formation>

Labor-Tierna Formation consists mostly of sandstone with very small amounts of intercalated mudstone. Thickness of formation is about 100 m. Because it consists mostly of sandstone, many cracks develop easily along with the geotectonic movement, and it can make an excellent aquifer.



Source: INGEOMINAS

Figure-2.1- 12 Geological Map of Study Area

2) Tertiary

The Tertiary in the Study Area is divided to five formations as Guaduas Formation, Cacho Formation, Bogotá Formation, Regadera Formation and Usme Formation from the bottom part. The Tertiary is distributed in the foot of the mountains that consist of Cretaceous, and gentle slope is formed in the Tertiary area. Usme formation as the top of Tertiary is distributed only in the Tunjuelo River Basin in the southern end of the Study Area. The strata after Usme Formation are continental sediments because orogenic movement began in the middle Paleocene. It is thought that Cretaceous was covered widely by the marine Guaduas Formation at the beginning. But the later the Guaduas Formation was eroded by the glacier. The Cretaceous are exposed directly in most of the summit of mountains in the Study Area now.

3) Quaternary

The Quaternary in the Study Area consist of the Tilatá Formation of Pleistocene and the Alluvium of Holocene. The Quaternary forms the plain in the Study Area. The Cretaceous and the Tertiary were eroded widely by glacier in the Pleistocene. And now, the thick glacial sediments accumulate in Bogotá Plain.

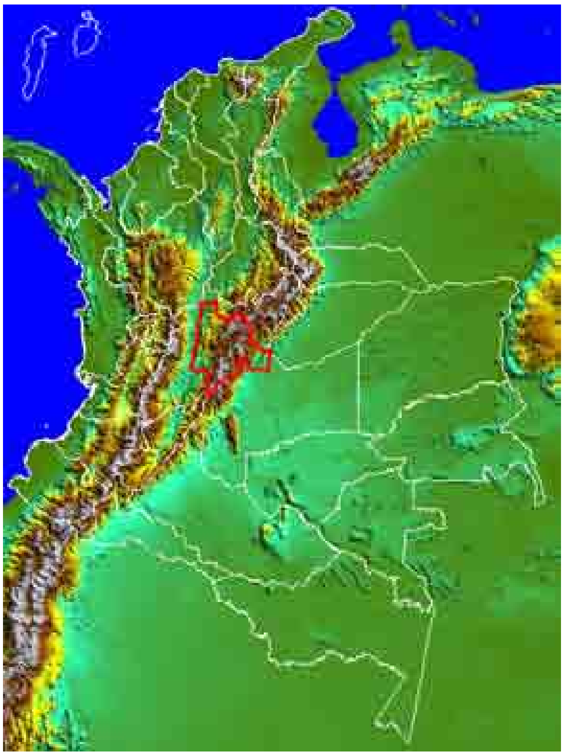
(3) Hydrology

1) River System

The Study Area is the River Basin of Bogotá D.C. and the principal river is the Bogotá River. The basin is located within Cundinamarca Region which lies in the center of Colombia. It also is situated at the top part of the Andes Mountains forming a hydrographic basin. The surrounding areas of the basin are mountainous and serve as catchments for the Bogotá River Basin. Alluvial sediment is widely distributed in the center of the basin where the urban area of Bogotá lies. The area of the basin is 4,396 km^2 and it has an elongated shape extending in NE-SW direction as shown in Figure-2.1-13 to Figure-2.1-15.

Source: JICA Study Team

Figure-2.1- 13 Location of Cundinamarca Region



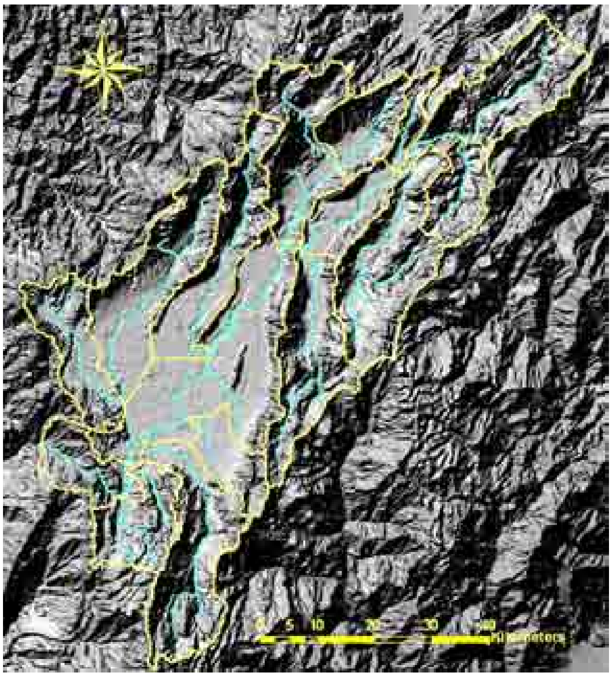
Source: JICA Study Team

Figure-2.1- 14 Topography of Colombia

Source: US-NASA

Figure-2.1- 15 Location and Topography of Bogotá River Basin

The Bogotá River main stream originates in the north-eastern part of the basin and flows southwest. The river eventually flows out of the basin in the southwest from the point where Tequendama waterfall is located. The main stream has many tributaries across the basin. The conventional division of the river basin has been examined and redefined based on the DEM data (90 m mesh SRTM DEM, US-NASA). As a result, Bogotá River Basin has been divided into a total of 16 parts consisting of one basin of the main river stream and 15 others for the primary sub-basins as illustrated in Figure-2.1-16 and Figure-2.1-17.



Source: US-NASA

Figure-2.1- 16 Distinguished sub-divisions of Bogotá River Basin Based on DEM Data

Source: US-NASA

Figure-2.1- 17 Redefined Division of Bogotá

2) Basic Characteristics of the River Regime

(a) Average Flow Volume

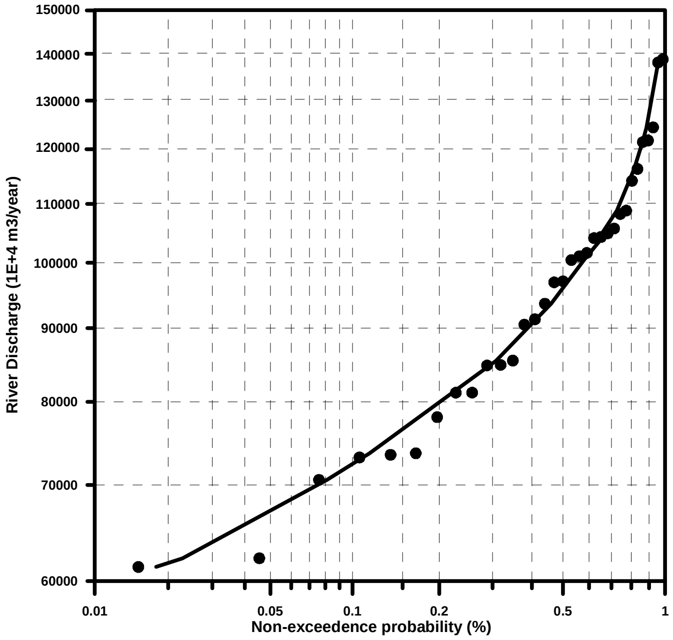
The hydrological analysis revealed that the average flow volume at the terminal of the river stream in Bogotá River Basin (south-western exit) is 1.07 x 10^9 m^3 (approximately 33.9 m^3/sec).

(b) Annual Fluctuation of Flow

For the main stream and its primary tributaries, CORRs (Coefficient of River Regime), in other words the ratio of annual maximum flow and minimum flow, fall between 2.16 and 11.05. With the length of the observation period considered, CV (Coefficient of Variation) is calculated to be 0.24 to 1.04.

(c) Probability of Flow Fluctuation

The river flow observation station, Las Huertas, located closest to the outlet of Bogotá River Basin covers a catchment area of 4,257 km^2. This accounts for over 96 % of the total area of Bogotá River Basin. Therefore, the flow record from this station is considered representative of the whole Bogotá River Basin. Figure-2.1-18 shows probability distribution plot of annual river discharge for this station.



Note: The dots represent values calculated by the Hazen method, and the curved line is a log Normal fitting

Source: JICA Study Team

Figure-2.1- 18 Probability Distribution of River Discharge at Las Huertas Station

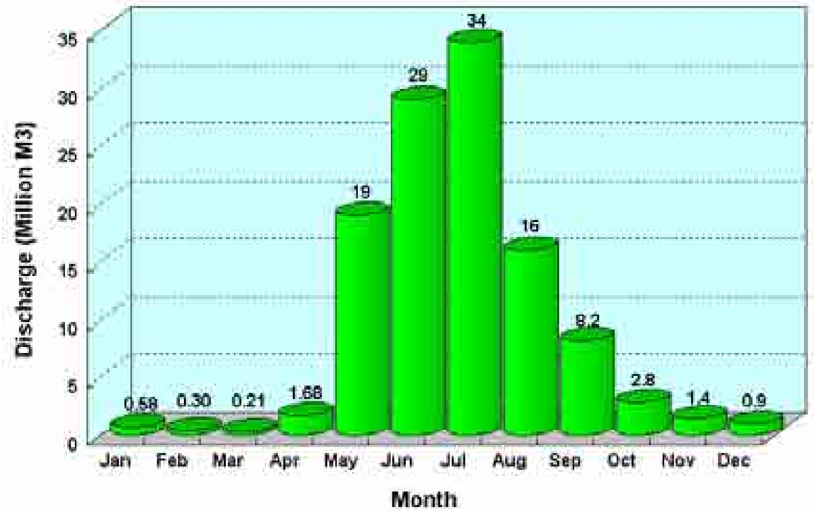
(d) Annual Flow Variation

Reflecting the annual precipitation pattern discussed earlier, the monthly river discharge is relatively stable throughout the year. The averaged monthly discharge variation pattern for the 37 rivers analyzed in this study is shown in Figure-2.1-19. The discharge pattern shows two peaks in May and November, which is comparable to the bimodal distribution of monthly precipitation. However, the ratio of monthly maximum to minimum discharges is as small as 2 while that of precipitation is about 3.

Source: JICA Study Team

Figure-2.1- 19 Variation of Monthly Average River Discharge for 37 Rivers in Bogotá River Basin

For a comparison purpose, an example of monthly river discharge for an arid region is presented in Figure-2.1-20. The river is the one in extremely arid Turpan Basin located in north-western China.



Source: JICA Study Team

Figure-2.1- 20 Example of Monthly River Discharge Variation in Turpan Basin

In arid regions, recharge from groundwater to river flow is limited and the river flows are sustained mainly by direct runoff due to rainfall. For this reason, most of river flow concentrates during the rainy season. In this example, the ratio between the largest monthly discharge during the rainy season and the smallest monthly discharge during the dry season is more than 150.

(4) Hydrogeology

1) Aquifer Classification

Each stratum distributed in the Study Area is characterized by the geological age and the rock facies, and it is classified as shown in Table-2.1-9 by the hydrogeologic character.

Table-2.1- 9 Study Area Aquifer Classification

Age		Stratigraphy	Rock Facies	Mode	General Permeability
Quaternary	Holocene	Alluvium	Clay, silt, sand, gravel	Porous media	High-Low
	Pleistocene	Terraza Formation	Clay, sandy clay, sand		Middle-Low
		Sabana Formation	Clay, sandy clay, sand		Middle-low
		Tilatá Formation	Sand and gravel, silt, clay (consolidated)		High
Tertiary	Oligocene	Usme Formation	Claystone	Porous-fissured media	Low
	Eocene	Regadera Formation	Sandstone, conglomerate, claystone	Fissured media	Low
		Bogotá Formation	Claystone, siltstone, sandstone		Middle-Low
	Paleocene	Cacho Formation	Sandstone, conglomerate		High
		Guaduas Formation	Claystone, shale		Middle-Low
Cretaceous		Guadalupe Group	Sandstone, siltstone, shale		High-low
		Chipaque Formation	Shale, sandstone		Low

Source: JICA Study Team

(a) Characteristics of Aquifer

Aquifers in the Study Area are classified into 3 types as shown below:

i) Quaternary Aquifer.

ii) Tertiary Aquifer.

iii) Cretaceous Aquifer.

Aquifers above consist of alternation of permeable and impermeable formations. Therefore, aquifers are limited to permeable formations of them.

Quaternary Aquifer

Groundwater currently pumped up by wells in the Study Area is stored in sand and gravel layers of Sabana Formation. Quaternary Aquifer consists of sand and gravel layers, which distribute irregularly in different depth with poor continuity.

Tertiary Aquifer

In the Study Area, Tertiary mainly consists of clayey sediments. Only small sand and gravel strata locally included in clayey strata can form aquifer. Tertiary is difficult for large scale groundwater development because the aquifer is too small.

Cretaceous Aquifer

Cretaceous system consists of Guadalupe Group (Labor-Tierna Formation, Plaeners Formation, Arenisca Dura Formation) and Chipaque Formation in the Study Area. Guadalupe Group forms excellent aquifer including Sand Formation. On the other hand, Chipaque Formation mainly consists of shale, and it can not be expected as an aquifer.

(b) Hydrogeological Structure

Hydrogeological structure of the Study Area is strongly dominated by complicated geological structure, and distribution and continuity of aquifers are influenced by faults and folding. It seems that Quaternary, Tertiary and Cretaceous Aquifer form confined aquifers. Superficial aquifer of the Quaternary seems to form small-unconfined aquifer.

Groundwater is also confined in Tertiary and Cretaceous Aquifers. The static groundwater level of Quaternary, Tertiary and Cretaceous is between GL-20 m to GL-50 m. Though depth of these aquifers is different, static groundwater levels of these aquifers are similar. This suggests that there is hydrogeological connection among three aquifers.

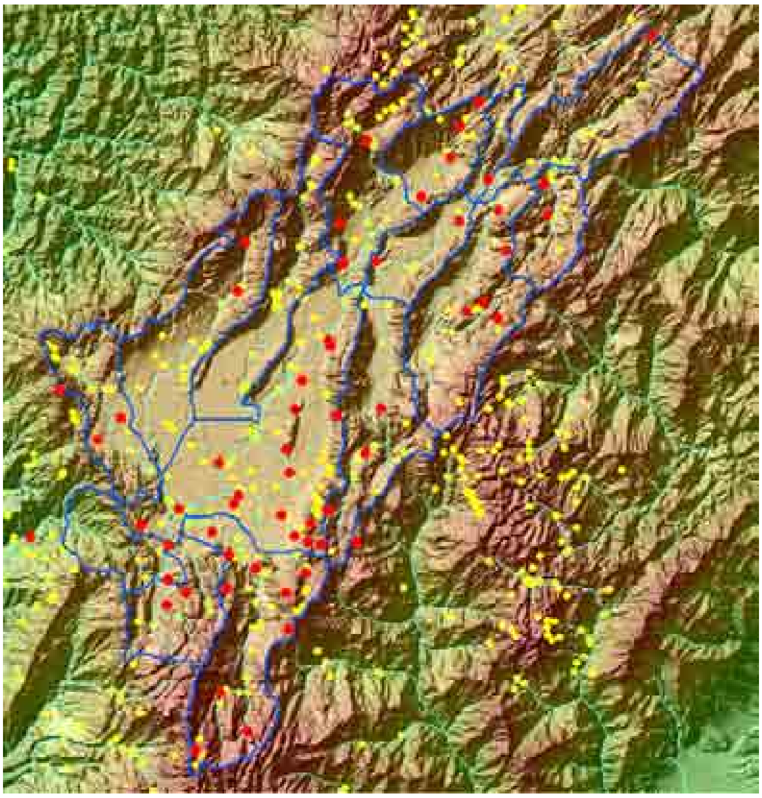
1.2. Water Resources in the Study Area

1.2.1. Surface Water

Surface water is the most important water resources in Bogotá River Basin and is used in many sectors. Due to the topographic characteristics of the basin, there are no inflows of both surface and groundwater from other basins, unless water is artificially transferred across watersheds. Therefore, precipitation is the only source of replenishing the water resources in Bogotá River Basin. Some direct precipitation is also artificially stored and used for flower culture and other purposes.

(1) Analysis of Precipitation in Bogotá River Basin

In this Study, daily precipitation data for a total of 60 observation stations were acquired from CAR, Acueducto, IDEAM and other relevant institutions. The collected data consist of those collected in the previous JICA study and also some new sets of data obtained in this study. The location of the observation stations from which data were collected is shown in Figure-2.1-21.



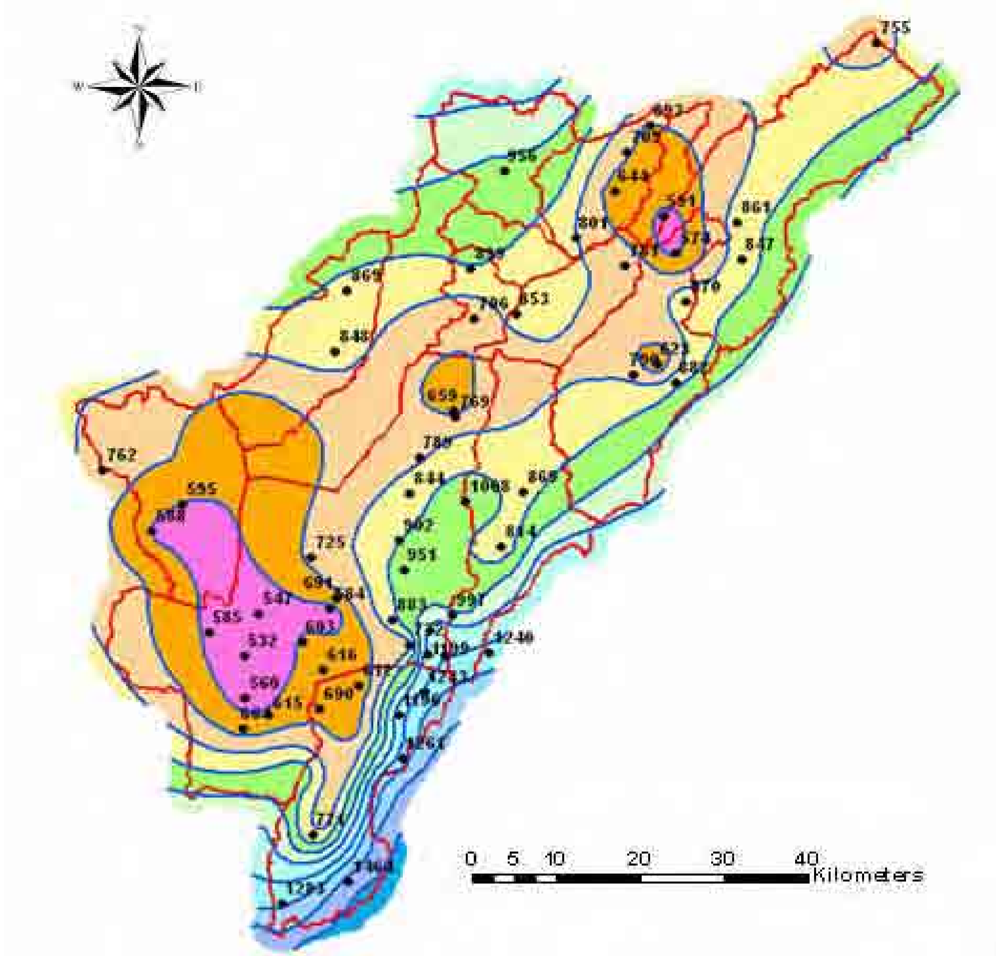
Note: The yellow circles represent stations managed by relevant institutions and red circles represent stations from which data has been newly collected. The locations are after Geo database of Acueducto and the geographic data is based on US-NASA 90m-mesh data

Figure-2.1- 21 Location of Observation Stations

The precipitation data was corrected and interpolated for errors and losses before analysis and the average annual precipitation in Bogotá River Basin was calculated to be 825 mm.

(2) Rainfall Distribution in Bogotá River Basin

Based on the precipitation data collected from the 60 observation stations for rainfall analysis, the average annual precipitation was found to show a large fluctuation ranging from 532 mm to 1,464 mm. The precipitation was also found to have a close relation with altitude: surrounding mountainous areas have large precipitation and the central plain of the Bogotá River Basin has smaller precipitation. The distribution of precipitation in the basin is shown in Figure-2.1-22.



Source: JICA Study Team

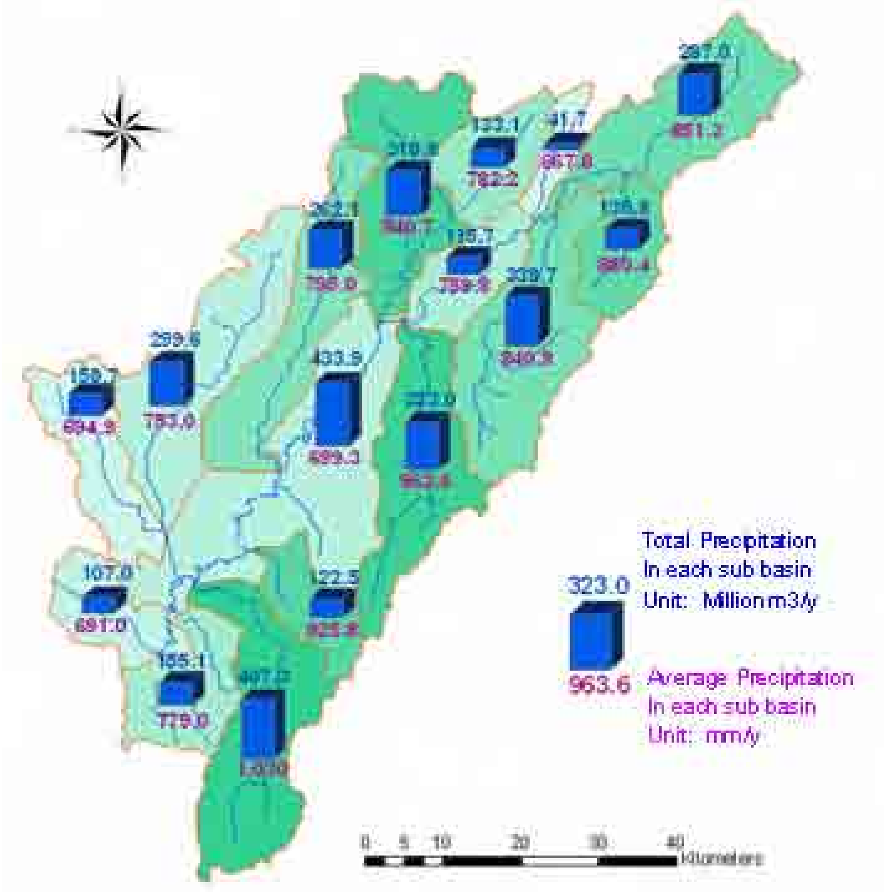
Figure-2.1- 22 Distribution of Precipitation in Bogotá River Basin (unit: mm/year)

(3) River Discharge Analysis for Bogotá River Basin

A set of daily discharge data for 37 river gauging stations obtained from CAR and Acueducto was used for river discharge analysis. Figure-2.1-24 shows the location of the gauging stations. As was done in precipitation analysis, the data was first checked for any lack of measurement or incorrect records and such errors were either interpolated or corrected before used for the analysis.

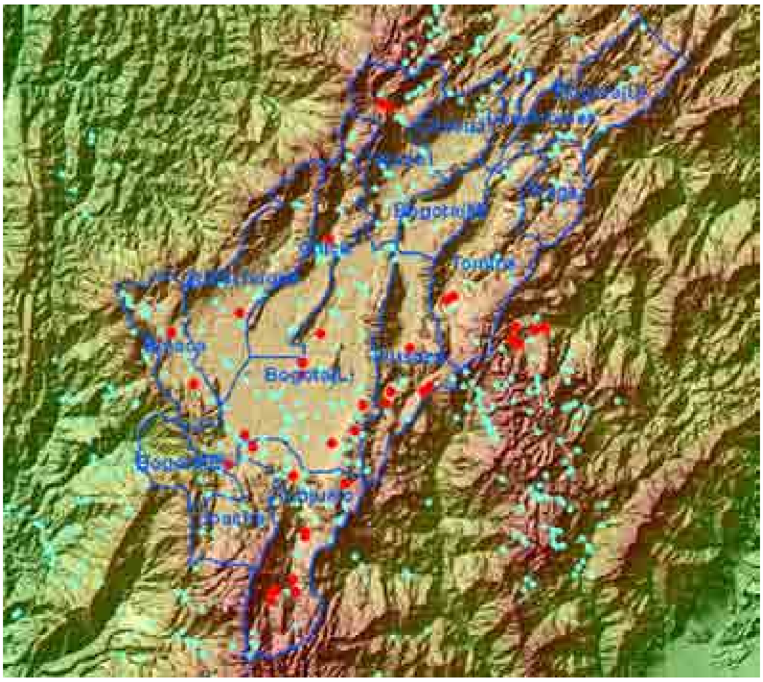
(4) Surface Water Resources in Bogotá River Basin

The specific discharge values for each sub-basin were calculated using the data from the gauging stations and their distribution by sub-basin was mapped out. The specific discharge values for the sub-basins that are not covered by any gauging stations were then estimated based on this map. Table-2.1-10 presents river discharge values along with precipitation values for all sub-basins in Bogotá River Basin.



Source: JICA Study Team

Figure-2.1- 23 Precipitation Distribution for Each Sub-basin in Bogotá River Basin



Note: Blue circles represent stations managed by relevant institutions and red circles represent stations from which data was newly obtained

Figure-2.1- 24 Location of Gauging Stations

Table-2.1- 10 Summary of Surface Water Resources in Bogotá River Basin

NAME	Method	Area	Discahrge	T_Disch.	Precip.	R_pcntg	D_runoff
Los Arboles	Estimation	62.7	11.5	11.5	667.6	27.5	155.4
Checua	Estimation	170.1	29.3	30.5	782.2	22.0	179.5
Neusa	Observation	68.5	23.3	65.7	940.7	21.1	198.7
	Estimation	261.9	42.4				
Chicu	Observation	142.9	35.8	53.7	795.0	20.5	162.8
	Estimation	186.8	17.9				
Subachoque	Observation	214.4	20.3	39.5	753.0	13.2	99.2
	Estimation	183.5	19.2				
Bojaca	Observation	93.5	24.0	42.1	684.9	27.9	191.3
	Estimation	126.6	18.1				
Sub Total		**1,511**	**241.7**		**793.0**	**20.2**	**160.0**
Bogota(U)	Estimation	337.1	98.4	98.4	851.3	34.3	247.0
Bogota(M)	Estimation	152.3	22.2	22.2	759.8	19.2	123.2
Bogota(L)	Observation	7.4	2.9	88.5	699.3	20.4	142.7
	Estimation	613.1	85.6				
Bogota(E)	Estimation	154.8	43.4	43.4	691.3	40.6	214.6
Sub Total		**1,265**	**252.4**		**792.1**	**25.2**	**199.6**
Sisga	Estimation	154.3	48.3	48.3	880.4	35.6	265.0
Tomine	Observation	94.7	76.0	150.7	840.9	44.4	373.1
	Estimation	309.3	74.7				
Teusaca	Observation	160.9	82.5	109.8	963.6	34.0	327.6
	Estimation	174.3	27.3				
Fucha	Observation	25.6	22.4	37.3	925.8	30.5	281.9
	Estimation	106.7	14.9				
Tunjuelo	Observation	383.7	168.8	170.4	1,030	41.8	431.0
	Estimation	11.8	1.6				
Soacah	Estimation	199.2	59.2	59.2	778.7	38.2	226.5
Sub Total		**1,620**	**575.8**		**915.5**	**38.8**	**355.4**
Total		**4,396**	**1,070**		**825**	**29.5**	**243.4**

Source: JICA Study Team
Note:Area : Square kilometer (km^2)
Discharge: Observed discharge and estimated discharge for the area where the discharge could not be obtained from observation result. (Unit: Million m3)
T_Discharge: The combination observed and estimated discharges for each basin.
R_pcntg: The ratio in percentage of runoff to precipitation
D_runoff: depth of runoff. Average depth in mm/year

1.2.2. Groundwater

Groundwater is an important source of water in Bogotá River Basin although its domestic consumption is small. The amount of groundwater used in year 2000 was 0.32 million m^3/day. This accounts for 14% of the total water use volume of 2.672 million m^3/day across the whole Bogotá River Basin. In detail, majority of the groundwater (about 90%) was used for agricultural irrigation and the domestic use accounts for only less than 5 %.

When groundwater is developed, it is important to plan the consumption amount in careful consideration of possible recharge amount. Otherwise, improper use of groundwater can cause excessive drawdown of groundwater table and other negative consequences. In fact, the problem of water level drawdown due to excessive pumping is reported in some parts of Bogotá River Basin.

Since there is no recharge form other basins to the groundwater in Bogotá River Basin, the only sources of recharge are as follows: 1) infiltration of precipitation, 2) Infiltration of the water used in various sectors of industry (mainly agriculture), 3) Infiltration of river water where the river stages are higher than the groundwater table. As for item 2, the water use amount within the basin for year 2000 is known to be 30.95 m^3/sec. However, for reasons of absence of data for estimating infiltration amount from this used amount, no discussion has ever been made concerning the contribution of this infiltration of used water to groundwater recharge.

CAR, INGEOMINAS, and JICA study team analyzed and estimated the amount of recharge from precipitation to groundwater in the past and reported the values of 36 mm/year (CAR)、8 mm/year (INGEOMINAS), and 145 mm/year (JICA, 2003) respectively. All these three studies employed the water balance method to calculate the groundwater recharge values. In this method, groundwater recharge is calculated by subtracting river discharge and evapotranspiration from precipitation. Out of these three parameters, the estimated values of evapotranspiration showed large differences and this led to the significant variation in the final estimated values of groundwater recharge.

In estimating evapotranspiration, many parameters such as field capacity, wilting point, depth of plant roots, growth period of plants, and a coefficient for calculation of potential evapotranspiration from pan evaporation data, are required. Thus, if there is any difference in any of these parameters, the calculation results will generally be different as well. Furthermore, calculation units (daily or monthly etc.) can also affect the results.

No methods other than the water balance method has ever been used to estimate groundwater recharge in the Study Area. Therefore in this study, the same method was adopted as the principal tool to calculate groundwater recharge amount for easier comparison of the calculation process and the results.

However, as mentioned previously, a large error may be expected depending on the choice of values for each input parameters. Therefore, in this study, some other methods were concurrently employed to estimate groundwater recharge. The methods employed and their results are summarized below.

(1) Water Balance Method

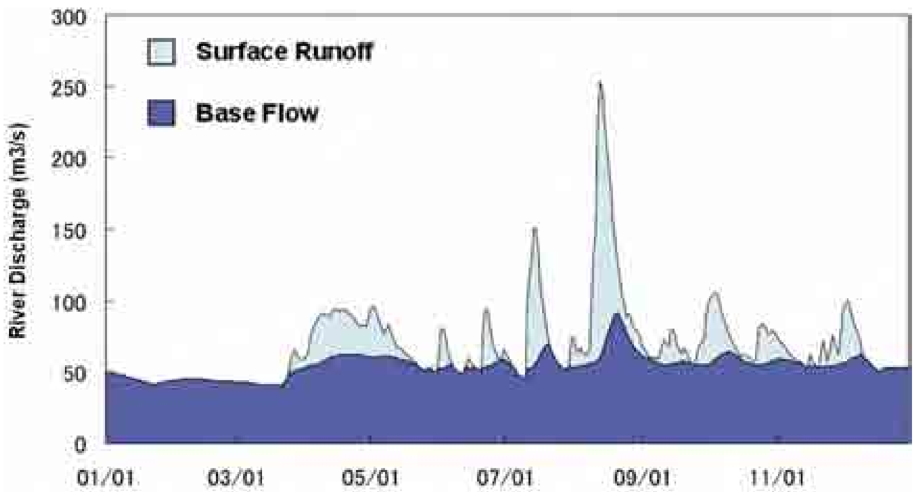
As did the related institutions, JICA Study Team followed the FAO's "Crop Evapotranspiration-Guidelines for computing crop water requirement" in order to calculate evapotranspiration using the pan evaporation data from 15 observation stations in Bogotá River Basin. The calculated values ranged from 383 to 499 mm/year with its average being 442 mm/year. With this result, the average groundwater recharge amount over the entire basin was calculated to be 132 mm/year.

(2) Climatic Division Method

If we follow the Koeppen climatic division described in the section of Meteorology of this Report, the average annual evapotranspiration is 406 mm. This result is about 10% less than the value estimated with the water balance method. Thus, if this method is adopted, the groundwater recharge amount is calculated to be 168 mm; 36 mm more than that estimated from the water balance method.

(3) River Discharge Method

As discussed in previous sections, the fluctuation of river discharge in Bogotá River Basin is small. The reason that the rivers do not dry up even after a series of dry days is that the groundwater is recharging the river streams. As shown in the example in Japan (Figure-2.1-25), most of the river discharge under the wet climate consists of the base flow, which is the groundwater eventually flowing into rivers. The amount of groundwater recharge can not be estimated with this method. However, without sufficient recharge to groundwater, the river flows in Bogotá River Basin can never be maintained. This indicates that the groundwater recharge within the basin is sufficiently large.



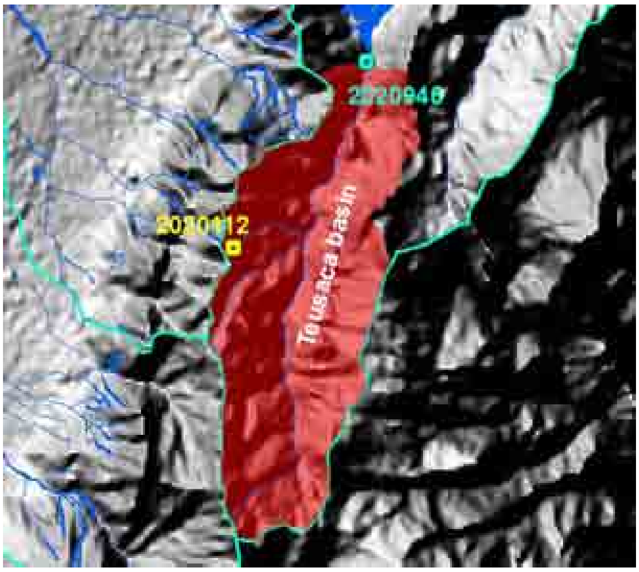
Data Source:Research on Hydrological Cycle and Groundwater Condition in Kushiro Mire, Keisuke Kudo and Makoto Nakatsugawa, Hokkaido, Japan, 2005

Figure-2.1- 25 Example of River Discharge Analysis

(4) Tank Model Method

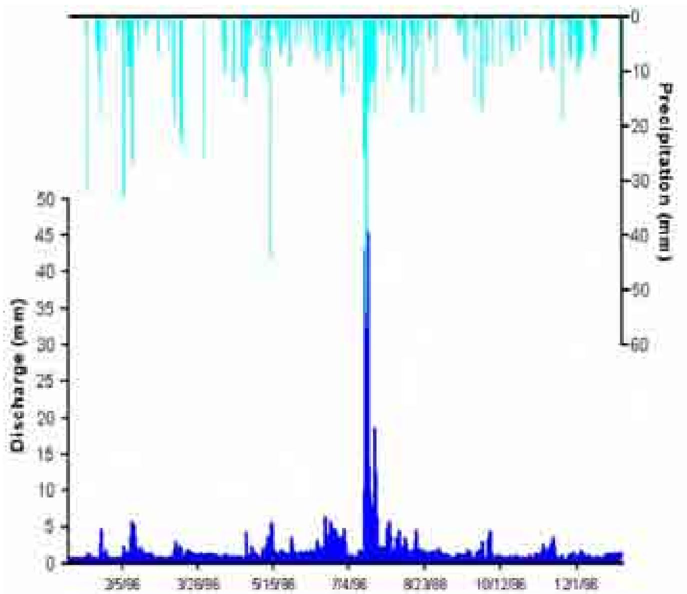
The river discharge gauging station (2120946) and the weather station (2120112) in the upper reach of Teusacá River sub-basin are taken for example (see Figure-2.1-26 for location) of Tank Model Method. The distribution patterns of river discharge and precipitation are similar to each other as can be seen from Figure-2.1-27. Thus a tank model consisting of 'two tanks in one series' was created to simulate runoff of rainwater. The results are shown in Figure-2.1-28. From this method, the direct runoff was calculated to be 138 mm, the base flow 515 mm, evapotranspiration 573 mm, and the infiltration into deep groundwater system 112 mm.

The outcome of these several different analyses suggests the following: The groundwater recharge by precipitation in Bogotá River Basin is abundant. Although the lack of direct measurement record of infiltration (recharge) necessitated the use of indirect estimation methods that will inevitably accompany some error, the estimated recharge values of more than 100 mm/year are considered realistic Figure-2.1-28.



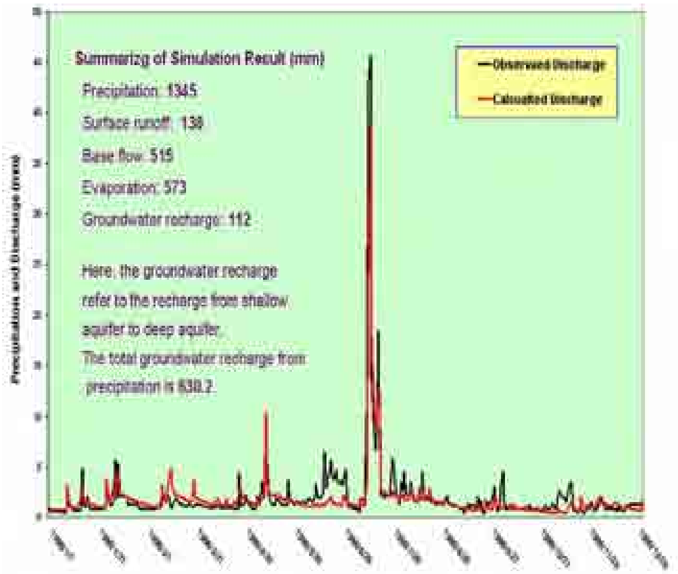
Source: JICA Study Team

Figure-2.1- 26 Location of River Gauging Station 2120946 and Weather Station 2120112 and the Relevant River Basin



Source: JICA Study Team

Figure-2.1- 27 Correlation of Discharge and Precipitation Data at the Two Stations



Source: JICA Study Team

Figure-2.1- 28 Results of Runoff Analysis by the Tank Model

1.2.3. Water Quality Survey

(1) Water quality in the Study Area

1) Bogotá River

From the standpoint of pollution, water quality in the Bogotá River Basin can be divided into four sectors ranging from upstream to downstream. Details on water quality are described in the Supporting Report.

Sector from source to Villapinzón

The water quality of this section is very good, with a BOD lower than 2 mg/ℓ.

Sector from Villapinzón Chocontá

This sector extends from Villapinzón to Chocontá. There are a total of 171 tanneries within the sector. Effluents from these factories are discharged untreated into the Bogotá River significantly compromising water quality. Further downstream, however, the influx of discharge from numerous tributaries into the Bogotá River has an auto-cleaning effect serving to improve water quality. At the junction with the Frío River, which marks the boundary between the upper reaches and the lower reaches of the Bogotá River, average river discharge is 13 m^3/s. From Villapinzón to the Juan Amarillo in the north of Bogotá urban area, river water is used mainly for cropping and animal husbandry. Agricultural discharge then flows directly into the Bogotá River. Although official water quality standards have been set for agricultural effluents, in actuality neither water quality monitoring or pertinent regulations are being enforced at present.

Middle reaches of the Bogotá River (urban Bogotá area)

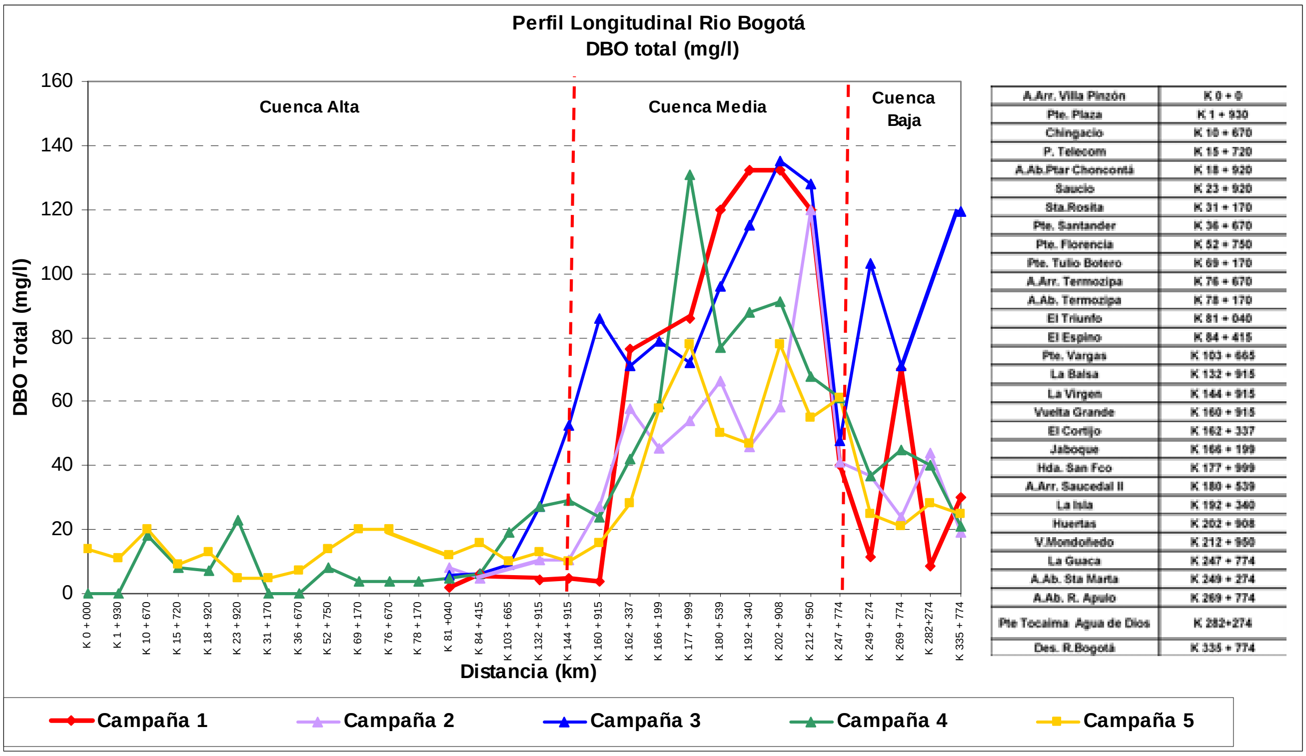
This sector comprises Bogotá urban area. As the Bogotá River passes though the urban area, water quality worsens dramatically. The domestic waste of the entire population of Bogotá, which is 6.4 million, is discharged into the Bogotá River. Main rivers flowing Bogotá urban area are the Salitre River, Fucha River and Tunjuelo River. The only Wastewater Treatment Plant within the Bogotá Metropolitan, the Salitre WWTP area is located at junction of Bogotá River and Salitre River. This plant carries out only primary treatment and organic treatment is not carried out. It results in a low BOD elimination rate. Untreated sewage water is discharged into the Bogotá River through Fucha River and Tunjuelo River. At the junction with the Salitre River, BOD of Bogotá River averages 120 mg/ℓ. At the junctures with the Fucha River and Tunjuelo River, this is 130 mg/ℓ and 140 mg/ℓ respectively. Dissolved oxygen (OD) is recorded at zero.

Water quality survey results indicate an extremely large influx of chemical and heavy metal content. Water quality contamination is caused by Bogotá urban area sewage (domestic and industrial waste). At the confluence with the Tunjuelo River, Bogotá River is significantly contaminated displaying a blackish-gray color and exuding an offensive odor. Total river discharge from the Bogotá urban area is around 21 m³/s, which accounts for about two-thirds of the total average discharge from the entire Bogotá Plain of 37 m³/s. Accordingly, sewage discharge from Bogotá urban area has a major impact on water quality of the Bogotá River. Furthermore, discharge from the urban area indicates an extremely high level of bacteriological contamination.

Sector from Subachoque River to Magadalena River

This sector covers the lower Bogotá River Basin extending from the junction with the Subachoque River and to that with the Magdalena River. From urban area up to Tequendama falls, auto-purification of river discharge cannot be expected due to low flow velocity. However, in the sector from Tequendama Falls to the junction with the Magdalena River, BOD is 18-34 mg/ℓ and OD is 2-7 mg/ℓ indicating a recovery in water quality.

As described above, water quality in urban area (mid reaches of the Bogotá River) exhibits degradation. Responding to above situation, Acueducto and CAR have already formulated plans for sewage infrastructure improvement and are now at the stage of moving to implement these projects. Funding to expand the Salitre WWTP has been procured, and construction is scheduled to commence from 2008. Also, sewage interceptor construction is currently in progress. Although the Canoa WWTP is still under planning, it is anticipated that its construction will significantly improve water quality of the Bogotá River.



Source: Acueducto, Annual Report, 2005-2006

Figure-2.1- 29 BOD_5 in the Bogotá River

Chingaza and Sumapaz River Basin

Water quality test results for the Chingaza River Basin are as follows.

Table-2.1- 11 Water quality analysis for the Chingaza Basin

Item	Water quality	Remarks
Hardness	50 mg/ℓ	Colombia potable water standard: 160 mg/ℓ; Japanese standard 300 mg/ℓ
Turbidity	1.25 NT or less	WHO potable water standard: 5 NTU
PH	6.3-7.6	Neutral
Alkalinity	5-17 mg of $CaCO_3$/ℓ	Colombia potable water standard: 100 mg/ℓ
Magnesium	0.2-0.9 mg/ℓ	Colombia potable water standard: 60 mg/ℓ
Manganese	0.02-0.08	Colombia potable water standard: 0.15 mg/ℓ
Iron	0.2-1.1 mg/ℓ	Colombia potable water standard: 0.5 mg/ℓ
Total bacillus coli	50-500	Ministry of Agriculture water quality control value: 1,000
Electro-conductivity	30-60	Colombia potable water standard: 1,500 µS/cm
Total dissolved substances	30-115 mg/ℓ	Colombia potable water standard: 1,000 mg/ℓ

Source: Acueducto, Annual Report, 2005-2006

On the basis of the above results, it is concluded that river water is a safe source of potable water.

(2) Groundwater Quality

Groundwater quality assessment is based on data collected during the previous JICA study as well as the latest monitoring data for INGEOMINAS wells.

1) Quaternary Aquifer

Turbidity, NH_4, H_2S, Ba and bacillus *Coli* are present in high concentration in groundwater from Quaternary Aquifer. In the case of groundwater in zones of industrial activity, no apparent impact on water quality has been detected as a result of industrial contamination. Likewise, no agro-chemical contamination is detected in groundwater in zones of agricultural activity. However, numerous wells exhibit water quality that exceeds Colombian standards in coloration, turbidity, bacillus *Coli*, ammonia, pH, Fe and Mn. Furthermore, although there is no water quality stipulations in Colombia standard, Ba, H_2S values exceed WHO water quality standards (guideline). Accordingly, it is concluded that drinking untreated groundwater from Quaternary Aquifer poses a significant health risk.

2) Cretaceous Aquifer

Although values exceeding standards in H_2S, Mn, Fe and coloration are observed in groundwater from Cretaceous Aquifer, these are minimal in degree compared to groundwater from Quaternary Aquifer. A major difference with the Quaternary Aquifer is the fact that almost no NH_4 is detected in groundwater from Cretaceous Aquifer. It can accordingly be concluded that there is a difference in the groundwater quality between the Cretaceous and Quaternary Aquifer.

3) Study of Test Results

Coloration

In addition to odor and taste, coloration has an impact on the perception of water quality. A high degree of coloration effectively limits the degree to which water can be used. Water source standard (assuming antiseptic chlorination) is 20 TCU. In this regard, nearly 80% of groundwater exceeds the average coloration criterion. Compared to groundwater from the Cretaceous Aquifer, that from the Quaternary layer has a much higher degree of coloration.

Ammonium nitrogen

Ammonium-nitrogen is detected throughout the Study Area in high concentrations. Water quality standard in this regard is 1.0 mg/ℓ; however, 70% of samples taken in the area exceed this level. Specifically, this averages 4.9 mg/ℓ in Quaternary Aquifer and 1.1 mg/ℓ in Cretaceous Aquifer.

Hydrogen Sulphide

Hydrogen sulphide is distributed at the same high concentration throughout the Study Area. Almost all wells exhibit a value in excess of the WHO reference value (guideline) of 0.03 mg/ℓ.

Fe and Mn

Detected Fe concentrations exceed the water quality standard of 0.3 mg/ℓ. The water quality standard for Mn is 0.15 mg/ℓ; however, detected concentrations of Mn showed a range of values from 0.1-0.7 mg/ℓ with a tendency to exceed the water quality standard.

(3) Supplementary water quality survey

1) Survey sites

Groundwater and surface water in the Study Area was sampled, and water quality of the sampled water was analyzed. The sampling was done covering the entire Bogotá Metropolitan Area. The previous JICA study revealed an insufficiency of groundwater quality data with regard to the Eastern and Southern Hill of the Bogotá Metropolitan area. For this survey, 20 existing well sites and 15 river sites were selected for water sampling.

2) Number of water quality tests

Sampling for water quality testing is divided into two phases. The goal of this testing is to identify long-term changes in water quality. In addition, by identifying groundwater quality in existing wells located in Cretaceous Aquifer distributed over the Eastern and Southern Hills, a sanitizing method can be determined to treat this water to be potable. In this regard, water quality testing is as follows:

- Phase 1: January 2007 - March 2007
- Phase 2: August 2007 - December 2007

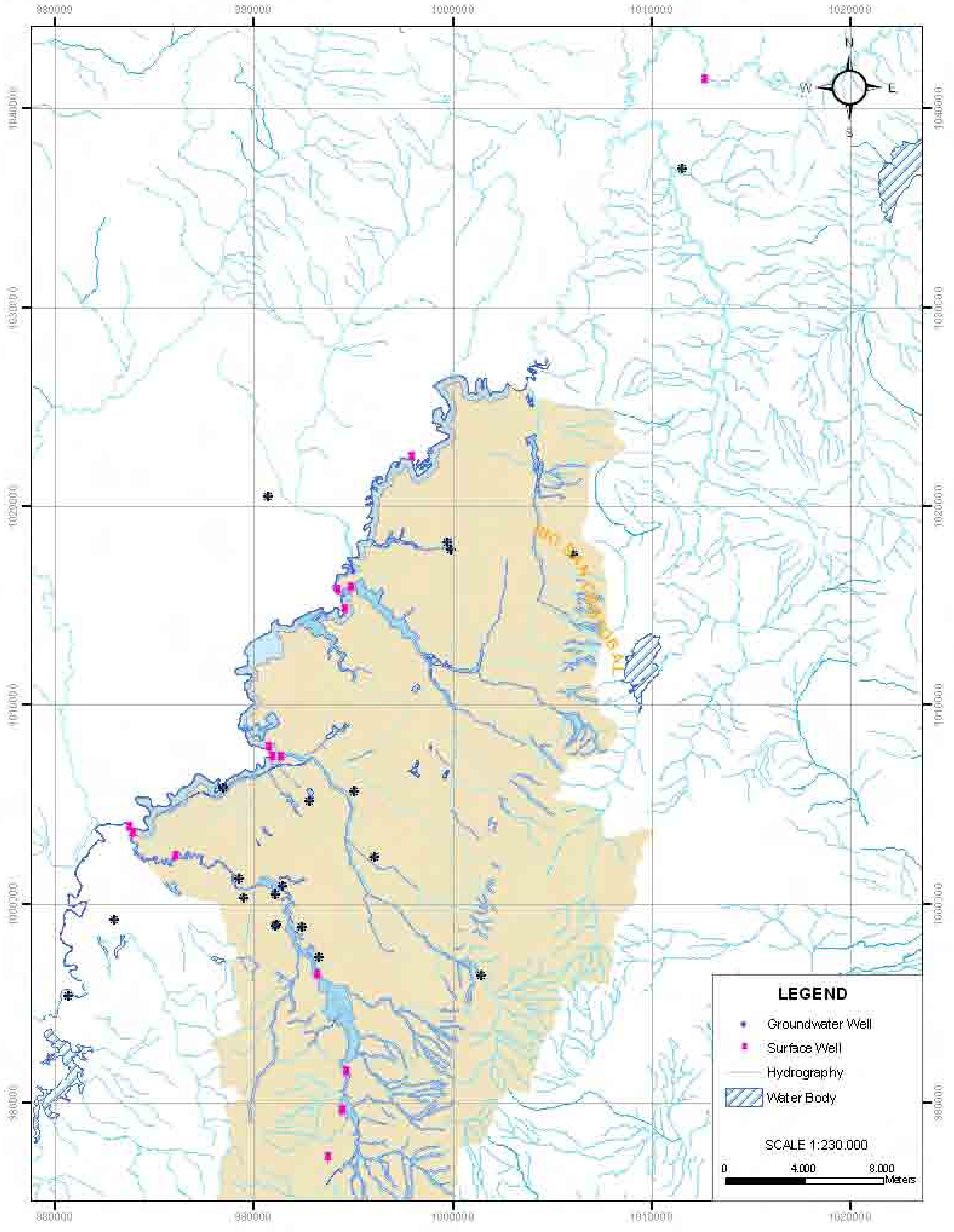
Groundwater quality is linked to factors including topographical well location, target aquifer and production amount.

3) Sampling sites

Representative aquifers, rivers and wells are selected.

- Wells and rivers for sampling are selected in the Bogotá River surrounding area. The status of groundwater contamination and the effect of river pollution on groundwater are then identified.
- To the possible extent, samples are taken from wells in Cretaceous Aquifer within the Bogotá Metropolitan area.
- Samples are also taken from Quaternary wells for comparison of groundwater quality with Cretaceous wells.
- Sampling wells are selected to enable an analyzing groundwater flow direction though change in water quality along the flow-direction.
- On the basis of water quality testing results, study and proposal is made with regard to the necessity for chlorination treatment to render groundwater safe for potable water supply.

Sampling sites are indicated in Figure-2.1-30. Names of sampled rivers and well sites are set out in Table-2.1-12 and Table-2.1-13, respectively.



Source: JICA Study Team

Figure-2.1- 30 Sampling Well Sites

4) Results of supplementary water quality testing

Results of river and well water quality testing are indicated in Table-1.12 for the river and Table-1.13 for the wells. The results of supplemental water testing were compared with water quality standards by the Colombian government.

(a) Rivers

Supplemental water quality results were confirmed as being essentially similar to those obtained by Acueducto testing. In the case of the Bogotá River, Cr+6 (hexavalent chromium) has been detected around Tibitóc due to inflow of tannery effluents in the upper reach. Other items are generally satisfactory. Cr^{+6} is not detected immediate upper reach of the urban area. Although some items are slightly above standards for wastewater, actual overall river discharge pollution is within at an allowable level. Nevertheless, water quality degrades dramatically as river passes through the urban area. For example, although turbidity value is 6-50 NTU at the upper reach of urban area, this value rises to 200 NTU at lower reach of the urban area. Dissolved oxygen (OD) value is zero because wastewater is released untreated from Bogotá urban area into the rivers. The Juan Amarillo River flows in the northern part of Bogotá urban area (residential district) and exhibits a high turbidity value of 50 NTU. Nevertheless, the presence of other contaminants is within standard values for wastewater. On the other hand, the Tunjuelo River flows in the southernmost part of the urban area and exhibits turbidity values of 200 in its middle reaches. This zone has a heavy presence of industrial establishments including tanneries, metal processing plants and food processing plants. Cr+6 values are a high 0.1-0.3 mg/ℓ. NH4 values are also high, which is attributed to the anaerobic characteristic of river sedimentation.

(b) Wells

A large number of the wells exceed the standard value for the items of Fe, Mn and NH_4 throughout the Study Area. For Fe, although 0.3 mg/ℓ is set as the water standard, almost all sampled wells in the Study Area exhibited a value of 0.2-6.5 mg/ℓ. For Mn, 0.20 mg/ℓ is set as water standard; several wells exhibited a value of 0.05-0.99 mg/ℓ. It is clear that the high concentration of Fe and Mn is related to the geological condition of the area. By the comparison in geological condition, the concentration of Mn in the Quaternary groundwater is much higher than that in the Cretaceous groundwater. Overall, groundwater quality is good in the Eastern Hills (Cretaceous Aquifer) even though it exhibits a little high concentration of Fe and Mn. For methods of treating Fe and Mn, air-oxidation, oxidation-reduction and absorption are proposed.

NH_4 value is high, but this is not considered due to river pollution. Moreover, hydrogen sulphide (H_2S) was detected in the groundwater. However, it can not be by groundwater contamination, because amount of hydrogen sulphide (H_2S) from the surface water to the groundwater is considered less than the concentration of sulphur in groundwater. Groundwater contamination is detected at considerable distant place from contaminated rivers. In general, for H_2S, there are almost no specific guidelines or standards for potable water. On the other hand, NH_4 must be studied in the future.

Also, Ba (barium) has been detected in high concentrations throughout the Study Area. Ba has been categorized as the item requiring further study, though toxicity of Ba to human being is not clearly evaluated so far, and allowable concentration of Ba in treated water remains unclear. Cr^{+6} have been detected from Quaternary wells in the vicinity of the Tunjuelo River, indicating that contamination from the river has infiltrated into Quaternary Aquifers.

Table-2.1- 12 Results of river water quality testing (River water)

No.	River	pH	TEM AMB	TEM AGUA	Conductivity	OD mg/l	Turbidity	Zn mg/l	Ba mg/l	Cr^{+6} mg/l	CN mg/l	F mg/l	Ag mg/l
1	Bogotá Cierre						×		×	×			
2	Bogotá Cortijo						×		×				
3	Bogotá after bridge discharge. Metallic						×		×	×			
4	Bogotá Lisboa									×			
5	Bogotá Bridge. Cundinamarca						×		×	×			
6	Bogotá Bridge. La Virgen												
7	Bogotá San Bernardino						×		×				
8	Bogotá Tibitóc						×		×	×			
9	Fucha con Alameda						×		×	×			
10	Tunjuelo 100 m down Yomasa						×						
11	Tunjuelo San Benito						×		×	×			
12	Tunjuelo Usme						×						
13	Tunjuelo Isla Pontón San José						×		×				
14	Quibba						×						
15	Juan Amarillo						×						
No	River	Mn mg/l	Cu mg/l	Fe mg/l	Hardnes $CaCO_3$ mg/l	SO_4 mg/l	S mg/l	NO_3 mg/l	Mo mg/l	NH_4 mg/l	Fenol mg/l	NO_2 mg/l	Mn mg/l
1	Bogotá Cierre												
2	Bogotá Cortijo	×		×						×			×
3	Bogotá después de la descarga Pte. Metálico									×			
4	Bogotá Lisboa			×						×			
5	Bogotá Pte. Cundinamarca												
6	Bogotá Pte. La Virgen									×			
7	Bogotá San Bernardino			×						×			
8	Bogotá Tibitóc			×						×			
9	Fucha con Alameda												
10	Tunjuelo 100 m abajo de Yomasa							×		×			
11	Tunjuelo San Benito			×						×			
12	Tunjuelo Usme			×									
13	Tunjuelo Isla Pontón San José			×						×			
14	Quibba			×				×					
15	Juan Amarillo												

Note: with those items marked where values are in excess of standard values

Source: JICA Study Team

Table-2.1- 13 Results of well water quality testing(Groundwater)

No.	Well	pH	TEM AGUA	Conductividad	OD mg/l	Turbidad NTU	Zn mg/l	Ba mg/l	Cr^{+6} mg/l	CN mg/l	F mg/l	Ag mg/l	Mn mg/l
1	Bavaria							×	×				
2	Carboquímica							×	×				
3	Dersa												×
4	Districarnazas Luna								×				×
5	Frigorifico Guadalupe					×		×					×
6	Gaseosas Colombiana 2							×					
7	Gibraltar					×		×	×				
8	Gm Colmotores					×		×					×
9	Indumil							×	×				×
10	Jardines Apogeo					×		×					
11	La Diana					×							
12	La Salle							×					
13	Manufacturas Eliot					×			×				
14	Mariscal Sucre					×							
15	Parque Tunal												
16	Petco												×
17	Quintas de Santa Ana												×
18	Siberia					×							×
19	Suba					×							×
20	Vitelma					×							×

No	Well	Cu mg/l	Fe mg/l	$CaCO_3$ Dureza mg/l	SO_4 mg/l	NO_3 mg/l	Mo mg/l	NH_4 mg/l	Fenol mg/l	NO_2 mg/l	Al mg/l	B mg/l	Cl mg/l
1	Bavaria		×					×					
2	Carboquímica		×										
3	Dersa	×	×					×					
4	Districarnazas Luna		×										
5	Frigorifico Guadalupe		×					×					
6	Gaseosas Colombiana 2		×		×								
7	Gibraltar		×					×					
8	Gm Colmotores		×										
9	Indumil		×										
10	Jardines Apogeo		×										
11	La Diana		×					×					
12	La Salle												
13	Manufacturas Eliot							×					
14	Mariscal Sucre												
15	Parque Tunal		×										
16	Petco		×										
17	Quintas de Santa Ana		×										
18	Siberia		×					×					
19	Suba		×										
20	Vitelma		×										

Note: with those items marked where values are in excess of standard values
Source: JICA Study Team

1.3. Water Use and Management of Water Resources

1.3.1. Existing Water Supply Facilities

(1) Outline of Water Supply System of Bogotá

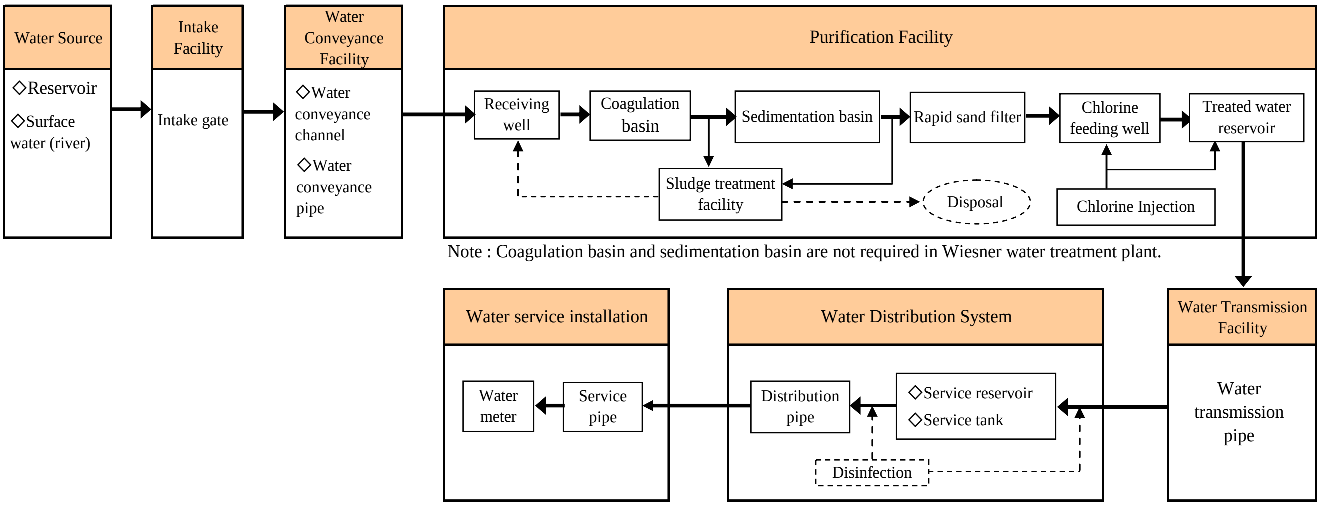
Acueducto is responsible for water supply and sewerage services in the capital district and surrounding 11 cities. Coverage ratio of water supply has reached to about 100%.

Acueducto is well-organized and has been conducting proper operation and maintenance with a high level of technology. Central control center is controlling all the main facilities to which SCADA (Supervisory Control and Data Acquisition) system is applied. In the center, continuous monitoring is being done for production water volume and water quality at Water Treatment Plants, and also a remote control of pump facilities and main valves are conducted.

In general, water supply facilities are categorized and defined as follows:

- Water resource: source for Water Supply System.
- Intake facility: Facility to take raw water from the water source.
- Water conveyance facility: Facility to convey the raw water from the intake facility to Water Treatment Plant (WTP).
- Purification facility: Facility to purify the raw water conveyed from the source.
- Water transmission facility: Facility to transfer the treated water from WTP to service reservoir.
- Water distribution facility: Facility necessary for distributing water such as service reservoir, elevated tank, distribution pipeline, pumping station, etc.
- Water service installation: Service pipes branched from the water distribution pipe for supplying water to the customers and water supply equipment to be connected with the pipes.

In general, overall system flow of water supply facilities managed by Acueducto is as shown in Figure-2.1-31:



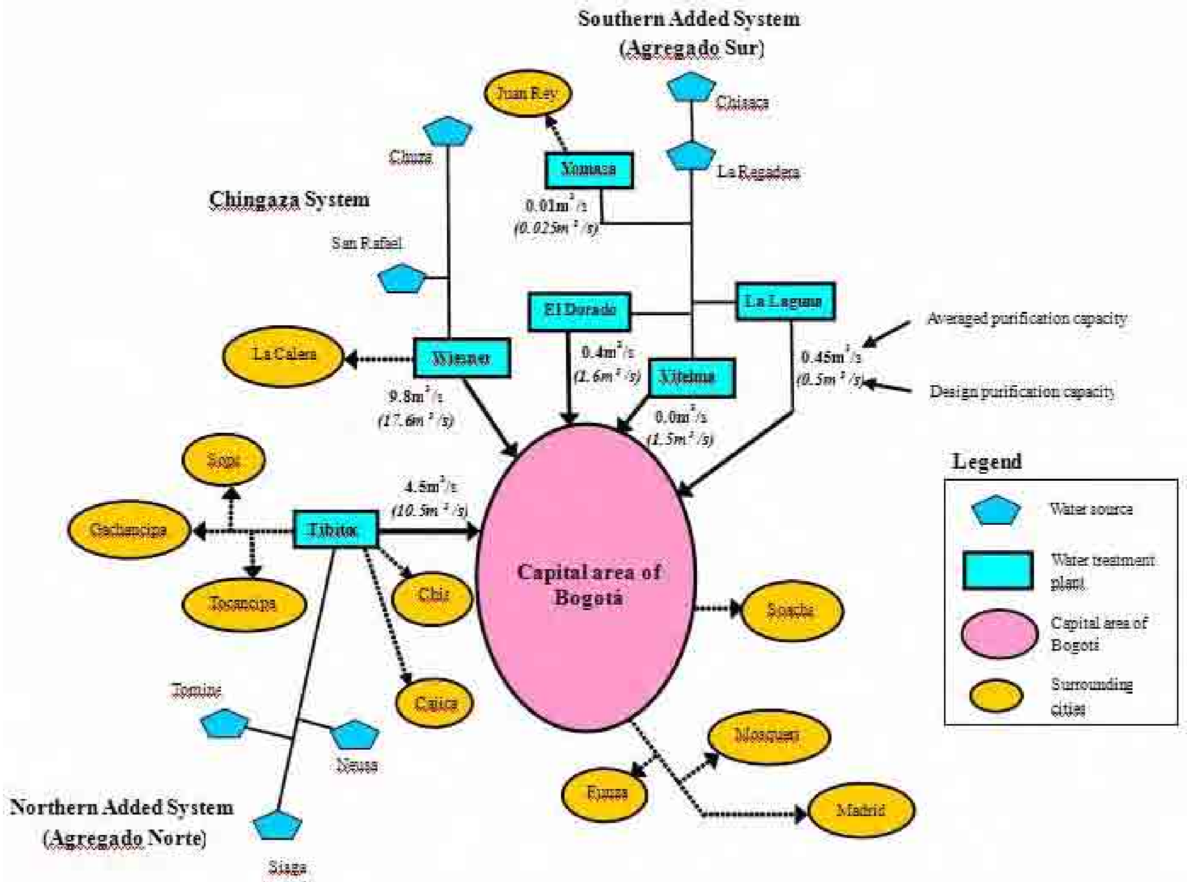
Source: Prepared by JICA Study Team based on data from Acueducto

Figure-2.1- 31 Overall System Flow of Water Supply Facilities in Capital Area of Bogotá

Water sources for Water Supply System of Acueducto are divided into the following:

- Chingaza System.
- Northern added System (*Agregado Norte*).
- Southern added System (*Agregado Sur*).

There are seven (7) Water Treatment Plants where the raw water is conveyed from the above water sources. However, among these plants, five (5) plants are in normal operation and two plants out of the five plants are operated alternatively. The conceptual drawing for Water Supply System of Bogotá and the surrounding cities are as shown in Figure-2.1-32.



Source: Acueducto

Figure-2.1- 32 Conceptual Drawing for Water Supply System of Bogotá and Surrounding Cities

Vitelma WTP started its operation from August 1938 and stopped in 2003. This plant remains kept in good condition even today by the proper maintenance and is ready for continuous operation in emergency cases. It is under study that this plant is converted into national historical and artistic monument like a water museum.

San Diego WTP, the operation of which started from 1943, is now out of operation

(2) Summary of Water Supply and Sewerage Management by Acueducto

Current situation (as of October 2007) of water supply and sewerage management by Acueducto is as shown in Table-2.1-14. According to the summary, the following are featured:

- Although the development of Water Supply System and Sewage Discharging System is almost completed, Wastewater Treatment System has not yet been developed. Therefore, there are serious concerns about water pollution from the disposal of untreated sewage into public water bodies such as Bogotá River.
- Facility utilization ratio is as low as 63% to the daily maximum water distribution volume.
- Total capacity of service reservoirs is more than 8-hour volume of the daily maximum water distribution volume which is sufficient against hourly fluctuation of water consumption and emergency cases.
- Since unaccounted-for water ratio is as high as about 37% (or as low as revenue water ratio is 63%), countermeasures against real losses and apparent losses are needed.

Table-2.1- 14 Summary of Water Supply and Sewerage Management by Acueducto (As of October 2007)

Item	Figures
[General]	
Service population	7,210,000
Surrounding cities supplied by Acueducto	11 cities
Service ratio (or Coverage ratio)	99.51%
Sewage collection ratio	98.86%
Sewage treatment ratio	30%
Number of staff	1,833
[Water Supply]	
Number of Water Treatment Plant	7 nos. (2 WTPs are out of service)
Purification capacity	30.23 m^3/s (2,611,440 m^3/day)
Averaged purification volume	14.65 m^3/s (1,265,760 m^3/day)
Capacity of service reservoir	571,600 m^3
Number of well	Nil (not used)
Water Transmission main	770 km
Water distribution network	8,318 km
Number of house connection	1,650,406 nos.
Meter installation ratio to the customers	98.5%
Unaccounted-for water ratio	36.76%

Source: Acueducto

(3) Water Source and Water Conveyance System

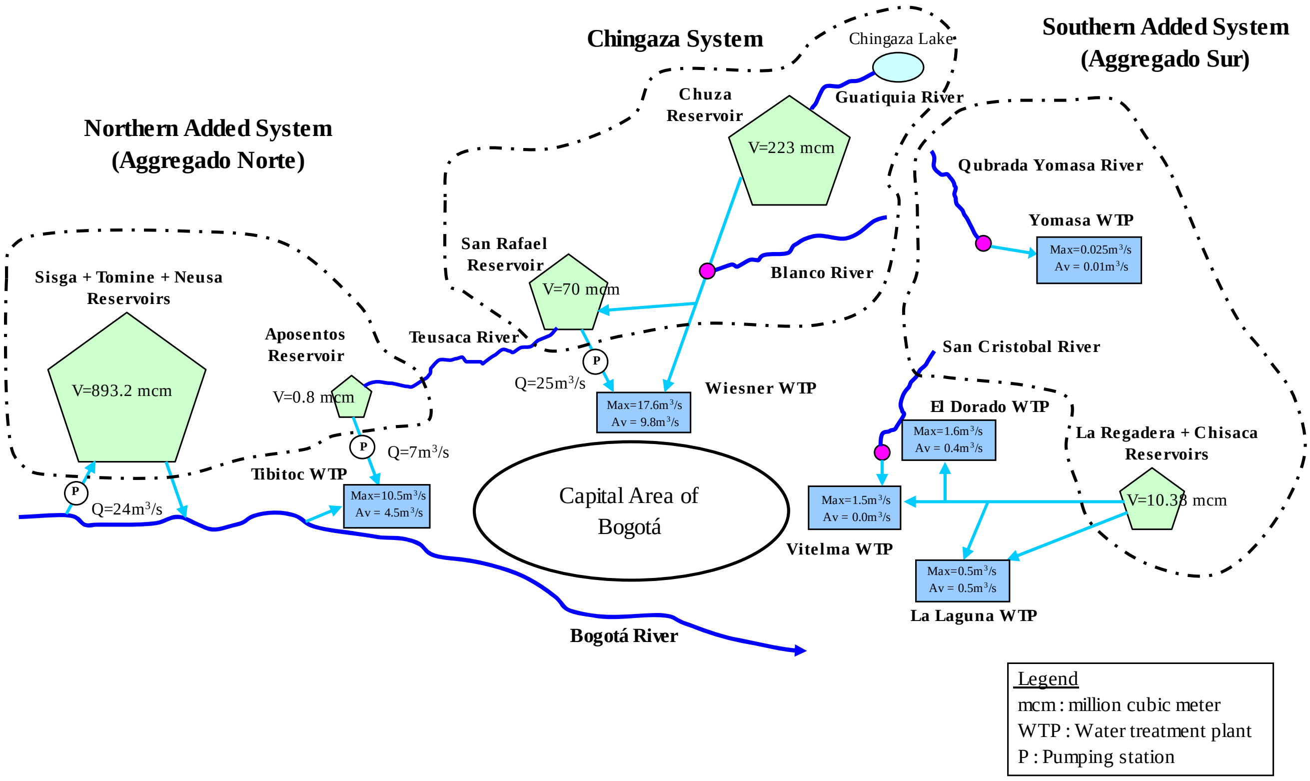
As mentioned before, there are three (3) water sources for Water Supply System of Bogotá Capital Area: Chingaza, Northern added System and Southern added System. Capacity of each reservoir is as shown in Table-2.1-15.

Table-2.1- 15 Water Sources for Water Supply System of Bogotá Capital Area

Water Source	Reservoir	Effective Storage Volume (MCM)	Remarks
Chingaza System	Chuza	223.0	Source of Wiesner WTP, property of Acueducto
	San Rafael	70.0	Source of Wiesner WTP, property of Acueducto
Northern Added System (Agregado Norte)	Sisga	101.2	Source of Tibitóc WTP, property of CAR
	Tominé	691.0	Source of Tibitóc WTP, property of Bogotá Electric Power Company
	Neusa	101.0	Source of Tibitóc WTP, property of CAR
Northern Added System	Aposentos	0.8	Source of Tibitóc WTP in emergency case. Available water flow of Teusacá River is utilized.
Southern Added System (Agregado Sur)	Chisacá	6.7	Source of El Dorado WTP, property of Acueducto
	La Regadera	3.7	Source of El Dorado WTP, property of Acueducto

Source: Acueducto

Conceptual drawing for water conveyance system from each water source to the main water treatment plants are as shown in Figure-2.1-33



Source: Acueducto

Figure-2.1- 33 Conceptual Drawing for Water Conveyance System in Water Supply System of Bogotá City Area

(4) Water Purification System

Allocated volume under the water right for each water source, the related water treatment plants and their design/current production volume are as shown in Table-2.1-16.

Table-2.1- 16 Water Sources and Production Volume of Water Treatment Plants

Water Treatment Plant (WTP)	Water Source	Operation started	Design Purification Capacity (m^3/s)	Averaged Purification Volume (m^3/s)
Tibitoc	Northern added system	1959	10.50	4.50
Wiesner	Chingaza system	1996	17.60	9.80
El Dorado	Southern added system	2001	1.60	0.40
La Laguna	Southern added system	1985	0.50	0.50
Vitelma	Southern added system	1938	1.50	0.00
San Diego	Southern added system	1943	0.21	0.00
Yomasa	Southern added system	2003	0.02	0.01
Total	-	-	31.94	14.71

Note: El Dorado WTP and La Laguna WTP has the same water source. Usually, El Dorado WTP is operated. However, La Laguna WTP will be operated in case of some accident or periodical maintenance in El Dorado WTP.

Source: Acueducto

Features for the main Water Treatment Plants are summarized as in Table-2.1-17.

Table-2.1- 17 Features for the Main Water Treatment Plants in Bogotá (1)

Item	Tibitóc WTP	Wiesner WTP	El Dorado WTP	Yomasa WTP
Design Purification Capacity (m^3/s)	10.5	17.6	1.6	0.025
Averaged Purification Volume (m^3/s)	4.5	9.8	0.4	0.010
Water Source	Bogotá River, the sources of which are Sisga, Tominé, Neusa and Aposentos reservoirs	Chuza and San Rafael Reservoirs	La Regadera Reservoir	Yomasa River
Main purification facility	Raw water reservoir + Receiving well + Coagulation basin + Chemical sedimentation basin + Rapid sand filter	Receiving well + Rapid sand filter (Coagulation basin and chemical sedimentation basin are not required)	Receiving well + Coagulation basin + Chemical sedimentation basin (with inclined plates) + Rapid sand filter	Compact unit (all-in-one with coagulation, sedimentation and filtration)
Place where water is transmitted.	Casablanca service reservoir by 2.0 m pipeline 109 avenue where water from Wiesner WTP joins Surrounding 10 cities	Water from Wiesner WTP covers almost all the distribution area with approx. 70% of the whole distribution volume of Bogotá	El Dorado zone and La Laguna zone	Juan Rey district
Remarks	Turbidity of raw water is high (10-80 NTU). Calcium carbonate is used as pH control chemicals. Aluminum sulphate, polymer or iron chloride is used as coagulant. Anthracite + sand + gravel are used as filter media. O&M is executed by private company under the contact with Acueducto.	Since turbidity of raw water is low (approx. 2.5 NTU) Calcium carbonate is used as pH control chemicals. Cationic polymer is used as coagulant. Anthracite + sand are used as filter media.	Sludge treatment system consists of drainage basin, thickening tank and sludge drying bed (with roof).	This plant is located at 3,250 msn and supplies water to Juan Rey district that is separated from Bogotá Water Supply System.

Source: Prepared by JICA Study Team based on data from Acueducto

(5) Water Transmission and Distribution System

Water Transmission and Distribution System in Bogotá is divided into three (3) primary systems as follows:

- Wiesner System.
- Tibitóc System.
- El Dorado System.

Conceptual drawings for each primary system are as shown in Figure-2.1-34. As shown in the figure, Wiesner System and Tibitóc System is inter-connected and thereby water supply can be manipulated in case of accidents or emergency. El Dorado System is separated from other two primary systems and it covers Southern hilly area.

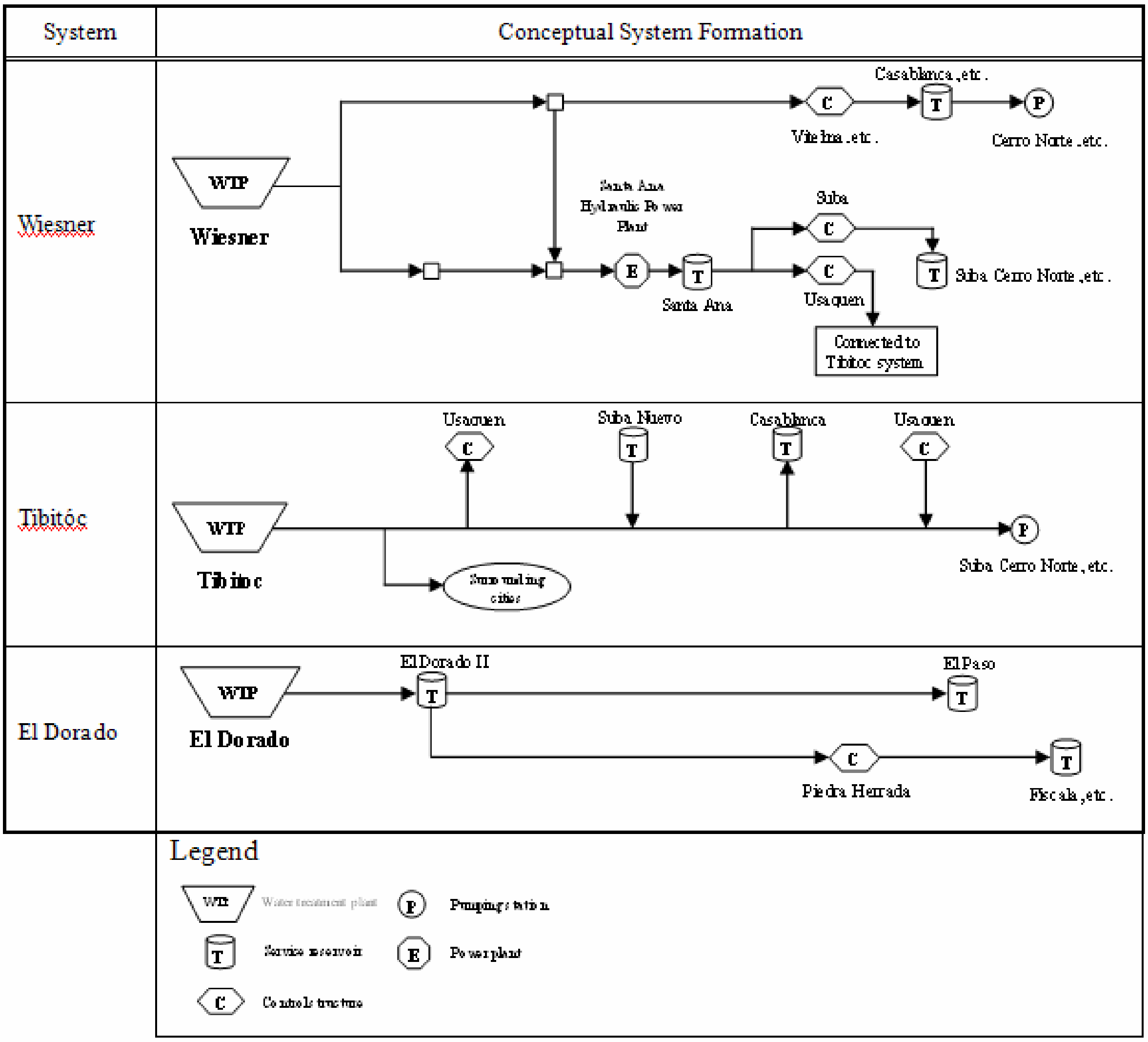
Wiesner System is considered as the most important system in Bogotá, accounting for approx. 70% of the total water distribution volume in the capital city. Tibitóc System covers approx. 30% and El Dorado System accounts for less than 1%.

Flow of the whole Water Transmission and Distribution System in Bogotá is shown in Figure-2.1-35.

(6) System for Controlling Water Supply and Sewerage Facilities

Water supply and sewerage facilities managed by Acueducto are all monitored and/or controlled by SCADA System at the central control center located west of Bogotá city.

In the central control room of the center, there are eight (8) screens which enable the operator to monitor and control eight different facilities at the same time. Monitoring is being done by one operator permanently stationed in three shifts (6:00 am to 2:00 pm, 2:00 pm to 10:00 pm, 10:00 pm to 6:00 am) (see Figure-2.1-36).



Source: Prepared by JICA Study Team based on data from Acueducto

Figure-2.1- 34 Conceptual System Formation of Primary Water Transmission and Distribution Systems in Bogotá

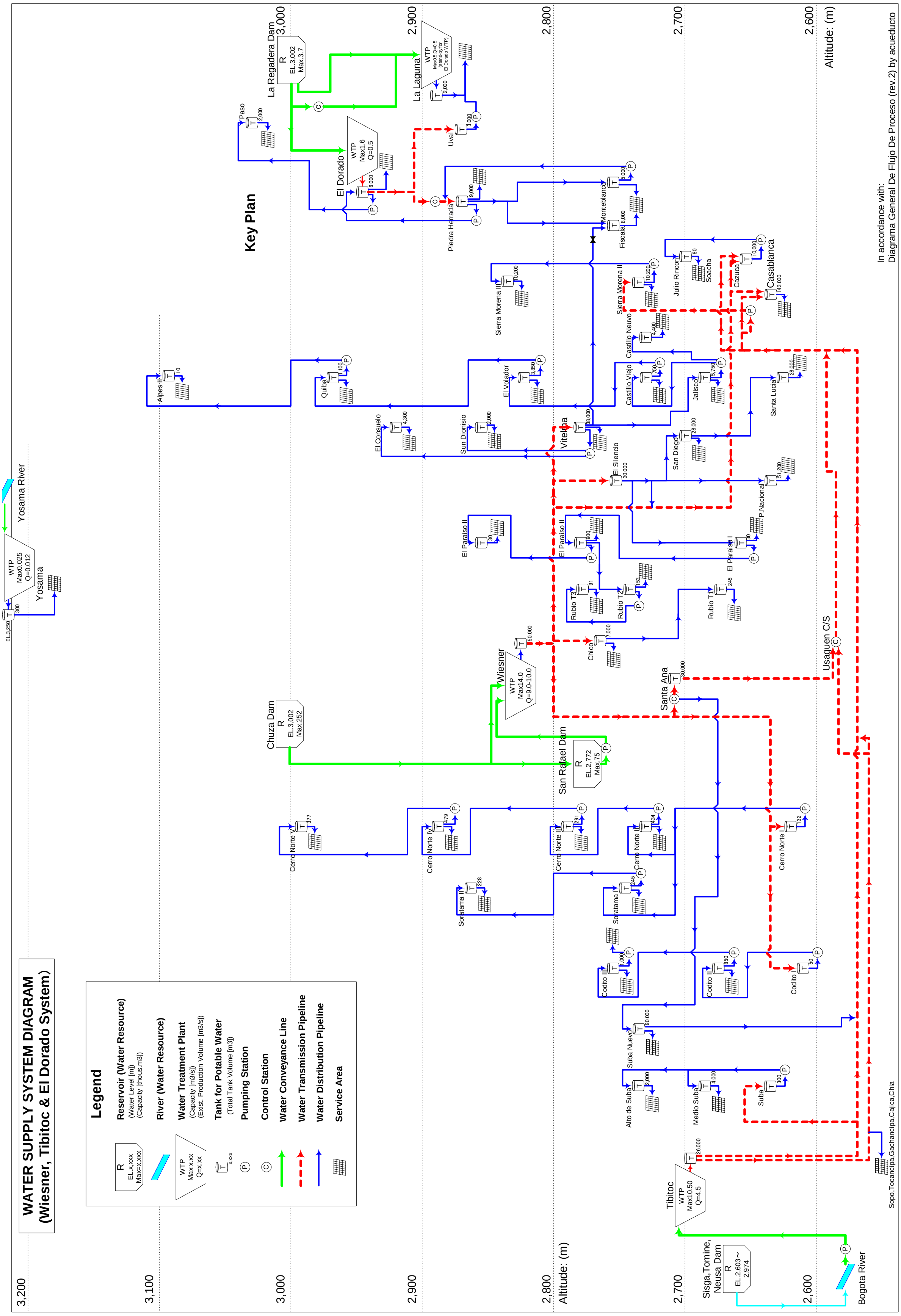


Figure-2.1- 35 Flow of the Whole Water Transmission and Distribution System in Bogotá

Figure-2.1- 36 Picture of Central Control Room at Central Control Center

Facilities under monitoring and controlling are as shown in Table-2.1-18.

Table-2.1- 18 Facilities Monitored and Controlled by Central Control Center

Facility	Quantity	Remarks
Water Treatment Plant	6	Monitoring
Hydraulic power plant (Santa Ana)	1	Monitoring
Distribution pumping station	64	Monitoring & control
Service reservoir	56	Monitoring & control
Flow control structure	10	Monitoring & control
Pressure reducing station	6	Monitoring & control
Main pressure reducing valves	16	Monitoring & control

Source: Acueducto

Monitored items by the center are as follows:

Monitored items by Central Control Center

- Intake volume and transmission volume in WTP (Wiesner, Tibitóc, El Dorado)
- Water pressure of water transmission by pump (including primary pressure and secondary pressure)
- Water level at service reservoir
- Distribution water volume to each water supply district (zone)
- Main water quality parameters (Chlorine injection amount, pH, turbidity)

In the center, remote control as well as monitoring is applied to all the water supply and sewerage facilities under SCADA system. Controlled items are as follows:

Controlled items by Central Control Center

- Starting and stopping pumps
- Opening and closing valves

1.3.2. Water Consumption

(1) Actual Water Consumption of Bogotá, Soacha and Gachancipá

Acueducto supplies water directly to the users in Bogotá, Soacha and Gachancipá. Table-2.1-19 shows the number of user's account from 2004 until 2008. The table clearly reveals that Estrato 2 and Estrato 3 are the most remarkable for the increase of account among others.

Table-2.1- 19 Number of User's Account 3) (1,000)

Sector	Classi-fication 1)	2004		2005	2006	2007	2008 until Oct.		Increase 2)
Residential	Estrato 1	100.9	**8%**	108.3	112.8	112.3	116.4	**8%**	**15.4**
	Estrato 2	439.4	**33%**	456.9	474.9	484.9	493.3	**33%**	**54.0**
	Estrato 3	509.5	**38%**	527.9	535.5	543.9	555.9	**37%**	**46.4**
	Estrato 4	165.4	**12%**	173.3	182.9	190.0	198.2	**13%**	**32.8**
	Estrato 5	59.7	**5%**	62.5	65.5	67.6	70.2	**5%**	**10.5**
	Estrato 6	48.1	**4%**	51.4	53.9	56.0	58.4	**4%**	**10.3**
	Subtotal	1,323.0	**100%**	1,380.3	1,425.5	1,454.7	1,492.4	**100%**	**169.4**
Non-residential		133.4	-	137.5	148.3	171.6	176.0	-	**38.5**
Total		1,456.4	-	1,517.8	1,573.8	1,626.3	1,668.4	-	-

Note: 1) "Estrato" is an area classified with the definitions of the various social-economic levels by the authorities; Estrato 1 is classified as the lowest level area, but on the other hand Estrato 6 the highest level area. 2) An increase compared with that of 2004. 3) Average of the year.
Source: Acueducto (Gerencia Corporativa Servicio al Cliente)

Table-2.1-20 presents the water consumption (m^3/month) from 2004 until 2008. Total consumption of 2008 was 23,986,300m^3/month; that is, 9.25m^3/second.

Total consumption of 2008 increased by 1,789,000m^3/month compared with that of 2004, which was caused mainly by the increase of non-residential by 1,540,000m^3/month during the same period. It is also obvious that the consumption of Estrato 1 and 5 has been continuously increasing.

Table-2.1- 20 Consumption 2) (1,000 m^3/month)

Sector	Classi-fication	2004		2005	2006	2007	2008 until Oct.		Increase 1)
Residential	Estrato 1	1,225.0	**7%**	1,266.8	1,304.6	1,306.8	1,373.9	**8%**	**149**
	Estrato 2	5,736.8	**34%**	5,769.8	5,687.1	5,769.3	5,702.2	**33%**	**-35**
	Estrato 3	6,271.8	**37%**	6,301.5	6,152.5	6,171.4	6,085.1	**35%**	**-187**
	Estrato 4	2,090.6	**12%**	2,123.9	2,187.4	2,253.4	2,276.2	**13%**	**185**
	Estrato 5	894.0	**5%**	915.0	938.7	957.1	957.8	**6%**	**64**
	Estrato 6	850.2	**5%**	892.5	890,3	916.8	922.5	**5%**	**73**
	Subtotal	17,068.4	**100%**	17,269.4	17,160.6	17,374.8	17,317.7	**100%**	**249**
Non-residential		5,128.5	-	5,312.6	5,668.1	6,223.8	6,668.6	-	**1,540**
Total		22,196.9	-	22,582.0	22,828.7	23,598.6	23,986.3	-	**1,789**

Note: 1) Consumption of 2008 that increased or decreased compared with that of 2004. 2) Average of the year.
Source: JICA Study Team based on the data of Acueducto (*Gerencia Corporativa Servicio al Cliente*)

Table-2.1-21 presents the estimated unit water consumption, litter/day/capita, from 2004 until 2008.

For the calculation of the unit consumption, the JICA Study Team used tentatively 4.5 persons per household in the "Report of Work Results in March 2007" according to the study paper of Humberto Molina (2003). However, the result of the 2005 census revealed that 4.0 persons lived at a household in Bogotá D.C., Soacha and Gachancipá. Accordingly, the JICA Study Team revised the unit consumption by utilizing the census figure of 4.0 persons. Thus, average unit consumption of year 2008 was estimated at 97 litter/day/person as shown in Table-2.1-21.

Table-2.1- 21 Estimated Unit Consumption (litter/day/person)

Sector	Classification	2004	2005	2006	2007	2008
Residential	Estrato 1	101	97	96	97	98
	Estrato 2	109	105	100	99	96
	Estrato 3	103	99	96	95	91
	Estrato 4	105	102	100	99	96
	Estrato 5	125	122	119	118	114
	Estrato 6	147	145	138	136	132
	Average	108	104	100	100	97
Non-residential	liter/day/ establishment	1,281	1,288	1,274	1,209	1,263

Note: For the calculation of the unit consumption, census figure of 4.0 persons per household were applied for every year.
Source: JICA Study Team based on the data of Acueducto (*Gerencia Corporativa Servicio al Cliente*)

Table-2.1-22 shows the average water charge of the year to the users from 2004 until 2008. The average charge continuously rose in every estrato until 2004; however, due to the drastic tariff change in July 2004 – see (3) of this chapter -, the charge to Estrato 1 decreased from 2005, and that to Estrato 2 and Estrato 3 also from 2006.

Table-2.1- 22 Water Charge of the Year (Col$/m3)

Sector	Classification	2004	2005	2006	2007	2008
Residential	Estrato 1	823	816	734	740	812
	Estrato 2	1,277	1,415	1,408	1,436	1,581
	Estrato 3	2,067	2,306	2,251	2,176	2,317
	Estrato 4	2,210	2,316	2,329	2,339	2,584
	Estrato 5	3,186	3,223	3,609	3,633	4,074
	Estrato 6	3,672	3,464	3,876	3,853	4,341
	Average	1,868	2,009	2,025	2,012	2,195
Non-residential		2,258	2,393	2,442	2,603	2,717

Note: Water charge is an average of the year.
Source: JICA Study Team based on the data of Acueducto (*Gerencia Corporativa Servicio al Cliente*)

(2) Actual Water Supply to the Municipalities

Acueducto supplies the water in block to eight (8) municipalities of the Cundinamarca Department at present. Table-2.1-23 presents the block water supply amount to these municipalities from 2004 until 2008. The supply amount has been increasing, which is remarkable in Chía and Mosquera. The former is caused by the increasing population and the latter by the decreasing usage of groundwater.

The supply amount to these municipalities in 2008 increased by 386,000m^3/month compared with that in 2004.

Table-2.1- 23 Block Water Supply (1,000 m^3/month) and Water Charge [2])

Municipality Name	2004		2005	2006	2007	2008 until Oct.		Increase [1])
1. Chía	462.2	**40%**	545.1	604.4	652.6	703.2	**45%**	**241**
2. La Calera	43.2	**4%**	42.6	23.1	14.5	10.0	**1%**	**-33**
3. Tocancipá	80.3	**7%**	90.0	93.7	97.6	104.5	**7%**	**24**
4. Sopó	72.7	**6%**	71.6	80.5	86.9	89.0	**6%**	**16**
5. Cajicá	211.9	**18%**	207.6	213.8	229.4	220.6	**14%**	**9**
6. Funza	78.7	**7%**	79.8	87.4	88.5	91.7	**6%**	**13**
7. Mosquera	146.3	**13%**	185.3	224.6	206.6	215.2	**14%**	**69**
8. Madrid	59.1	**5%**	68.2	36.9	66.7	106.1	**7%**	**47**
Total	1,154.4	**100%**	1,290.2	1,364.4	1,442.8	1,540.3	**100%**	**386**
Water charge (Col$/m^3)	892	-	702	716	766	820	-	-

Note:1) Consumption of 2008 that increased or decreased compared with that of 2004. 2) Water charge is an average of the year.

Source:Block water – Acueducto (Gerencia Corporativa Servicio al Cliente), Water charge - JICA Study Team based on the data of Acueducto (Gerencia Corporativa Servicio al Cliente)

(3) Water Tariff

Table-2.1-24 shows the water tariff of Acueducto as of June 2004. The tariff consists of both the basic tariff and the tariff by consumption.

Table-2.1- 24 Water Tariff in June 2004 (Col$)

Sector	Classification	Basic Tariff	Tariff by Consumption (m^3/month)			
		(Fixed)	< 20 m^3	21 m^3-40 m^3	41 m^3 <	Others
Residential	Estrato 1	8,482.26	599.37			
	Estrato 2	11,037.39	925.08	1,970.35	2,066.58	-
	Estrato 3	18,366.26	1,558.79			
	Estrato 4	21,500.55	1,685.61			
	Estrato 5	55,352.37	2,033.47	2,364.42	2,479.90	-
	Estrato 6	78,911.38	2,273.66			
Non-residential	Industrial	22,828.38	-	-	-	2,364.42
	Commercial					
	Official	19,238.41	-	-	-	1,893.72

Source: Acueducto (Gerencia Corporativa Servicio al Cliente)

The basic tariff was drastically cut in July 2004: for example, 62% cut for Estrato 1 and 48% cut for Estrato 6; to the contrary, the tariff by consumption was raised. Afterwards, both the basic tariff and the tariff by consumption have been revised when the accumulative consumer price index exceeds 3%. Table-2.1-25 shows the tariff of October 2008 that was revised in July 2008.

Table-2.1- 25 Water Tariff in October 2008 (Col.$)

Sector	Classification	Basic Tariff	Tariff by Consumption (m^3/month)		
		(Fixed)	< 20m^3	21m^3 <	Others
Residential	Estrato 1	3,789.65	643.63		
	Estrato 2	7,579.36	1,287.27	2,145.45	
	Estrato 3	11,116.35	1,887.96		-
	Estrato 4	12,632.20	2,145.45		
	Estrato 5	28,296.17	3,218.15	3,218.15	
	Estrato 6	34,612.28	3,432.67	3,432.67	
Non-residential	Industrial	16,421.89			2,960.71
	Commercial	18,948.34	-	-	3,218.15
	Official	12,632.20			2,145.45

Source: Acueducto (Gerencia Corporativa Servicio al Cliente)

1.3.3. Facilities for Sewage Drainage and Treatment

(1) Present Status of Sewage Systems in Bogotá Urban Area

In the case of the Bogotá River Basin of the Study Area, wastewater treatment for urban area as stipulated under the Urban Maintenance Project (POT) falls within the jurisdiction of Acueducto. Remaining area is under the jurisdiction of CAR. The sewage service coverage in Bogotá urban area is 85-90%. However, the definition of sewage service coverage rate in Colombia is the number of persons availing of sewage service divided by the total population of the area. In other words, this is equivalent to the wastewater collection rate for sewers. On the other hand, not all collected sewage is subsequently treated. Main sewage pipeline and wastewater treatment facilities exist only within the Salitre System. Although sewage pipelines are under construction in some parts of Bogotá, sewage at present runs untreated into tributaries of the Bogotá River. Even in the case of the Salitre treatment plant, BOD elimination rate is around 65%. Outline of current Sewage System of Acueducto is summarized in Table-2.1-26.

Table-2.1- 26 Outline of Current Sewage System of Acueducto

Number of Wastewater Treatment Plant	1 no. (primary treatment only)
Sewage treatment capacity	4.0 m³/s（345,600 m³/day）
House connection for sewerage	2,200,000 nos.
Sewer trunk line	412 km
Sewer network	7,895 km
-Foul water network	5,638 km
-Rainwater network	2,257 km

The following three main tributaries within the Bogotá urban area as well as the Soacha area are under the sewage treatment jurisdiction of Acueducto. Specifically, the Soacha area was transferred to Acueducto control in 2005 and the agency has subsequently not yet completed a sewage pipe inventory

(a) Salitre System.

(b) Fucha System.

(c) Tunjuelo System.

(d) Soacha System.

Table-2.1-27 and Table-2.1-28 indicate the projected target population and sewage volume within the respective wastewater treatment sectors.

Table-2.1- 27 Projected Population (unit: persons)

Treatment sector	2000	2005	2010	2015	2020	Saturation value
Salitre	2,038,102	2,246,180	2,490.87	2,800,546	3,171,965	3,306,934
Fucha	2,287,190	2,611,238	2,767,524	2,933,240	3,153,876	3,496,275
Tunjuelo	2,117,618	2,448,870	2,775,736	3,047,517	3,298,957	3,422,820
Soacha	353,026	434.528	506,890	568,670	617,775	793,255
Total	6,795,936	7,740,816	8,541,019	9,349,973	10,242,572	11,019,284

Table-2.1- 28 Average sewage volume (unit: m³/s)

Treatment sector	2000	2005	2010	2015	2020	Saturation value
Salitre	5.9	6.4	7.1	7.8	8.5	10.8
Fucha	7.5	8.3	9.0	9.5	9.9	10.7
Tunjuelo + Soacha	5.7	6.4	7.2	7.8	8.2	8.3
Total	19.1	21.1	23.3	25.1	26.6	29.8

Source: Acueducto, Aspectos Técnicos Análisis del Saneamiento del Río Bogotá, May 2006

Sewage Systems are basically separate sewage systems. Because existing sub-main sewage pipelines are combined sewer types, rainwater gets mixed in with sewage. As a result, system design is such that in cases where discharge increases during periods of rain, discharge is subsequently diverted to rivers or regulating ponds by means of overflow facilities constructed along the sewage pipeline (intercepting sewer). Numerous instances of problems as a result of pipe connection method have be confirmed, including cases where sewage collector pipes are connected to rain drainage pipes and vice versa.

(2) Salitre Wastewater Treatment Plant

The Salitre Wastewater Treatment Plant (WWTP) is the only one in the Bogotá city area. The Bogotá D.C. (SDA) holds the ownership rights for the treatment plant. The SDA has subsequently consigned responsibility for operation, administration and maintenance of the plant to Acueducto. A general description of the Salitre WWPT is given below.

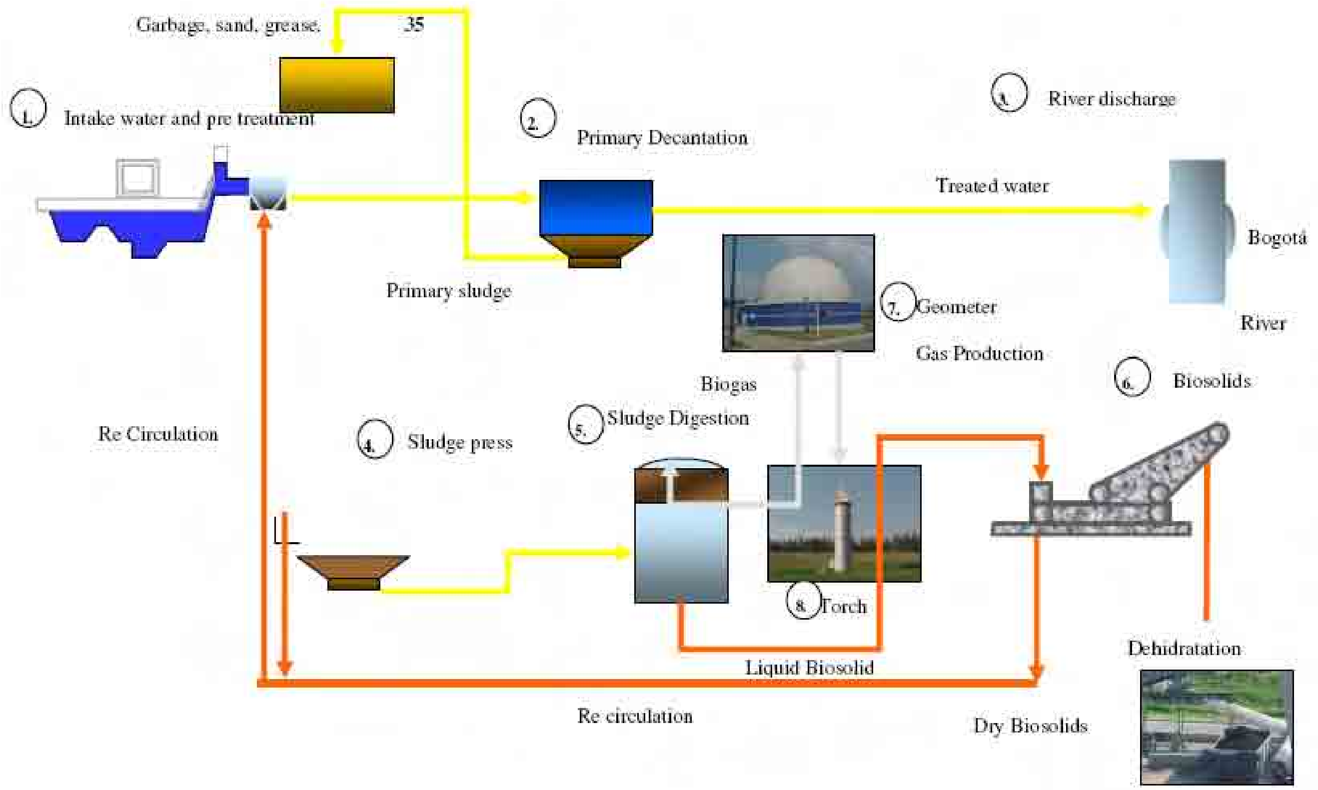
- Served population: 2.1 million

- Treatment method: First degree primary treatment (through chemically induced precipitation and basin sedimentation)
- Treatment capacity: $4 m^3/s$ on average; maximum of $9.94 m^3/s$
- Treatment efficiency: 40% BOD (biochemical oxygen demand) elimination (220 mg/ℓ → 130 mg/ℓ); TTS (total soluble solids) elimination of 60% (150 mg/ℓ→ 60 mg/ℓ)
- Sludge treatment: 135 tons/day by anaerobic treatment
- Biogas production: $15,000 m^3/day$

The Salitre Sewage Treatment Station operates 24 hours a day; its operational system is divided into three shifts with sixty-five employees. The monthly operational and maintenance cost is Col$ 1,200 million (around US$ 600,000 per month). This amount is paid to Acueducto by SDA.

Source: Acueducto

Figure-2.1- 37 Treatment flow at the Salitre WWTP

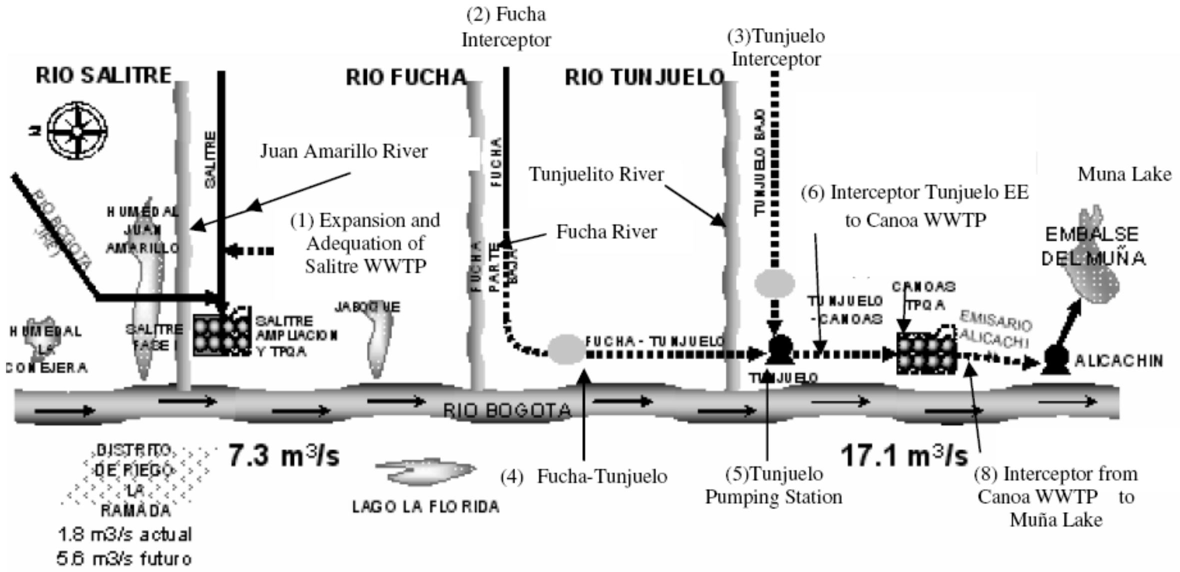


Source: Acueducto, Salitre WWTP

Figure-2.1- 38 Treatment flow at the Salitre WWTP

(3) Ongoing and Future Sewage Infrastructure Projects

In order to upgrade measures to cope with sewage from the Bogotá Metropolitan area, Acueducto is either currently executing, or planning for the future, the projects described below. Figure-2.1-39 gives an overview of the target area, and Table-2.1-29 gives an overview of projects as well as implementation status.



Source: Acueducto

Figure-2.1- 39 Overview of sewage infrastructure projects

(4) Doña Juana Waste Disposal Plant

Solid waste from the Bogotá Metropolitan area as well as neighboring municipalities is processed at the Doña Juana waste disposal plant. The plant was constructed by the Bogotá municipality, and began operation in 1998. Since 2000, plant operation and administration has been consigned to the private company, PROACTIVA. Bogotá municipal agency with jurisdiction over the plant is UAESP.

<u>Type of waste</u>

The plant processes (by landfill) 6,000 tons/day of general waste, 12 tons/day of medical waste, and 150 tons/day of sewage sludge. The plant does not handle industrial waste. Waste collection contractors are under different contract; and at present four contractors operate in their designated jurisdictions among the respective sectors. Specifically, these contractors both collect and transport waste. General waste material is not separated either in waste collection process nor in the disposal plant. Recycling of waste is not carried out.

<u>The disposal plant</u>

The disposal plant compound is divided into several zones by embankment, with a maximum landfill height of 32 m in 41 layers for each zone. Surface gradient has been designed for stability. Operation system has incorporated with ISO standards and facilities are both modern and streamlined. When one zone has been fully filled, disposal operations then shift to the next zone.

<u>Management flow</u>

Management flow is as follows: (a) zone delineation by embanking, (b) laying impermeable blanket, (c) constructing drainage channels, (d) finishing works, (e) bringing in and disposal of waste, (f) landfill and leveling (g) preliminary covering (plastic sheeting) to prevent fly infestation, foul odor, etc., (h) earth covering (mixture of sludge and soil), and (i) surface planting.

Table-2.1- 29 Overview of Sewage Infrastructure Projects and Status of Progress

No.	Facilities	Project overview	Estimated construction cost (million US $)	Progress
a)	Expansion of Salitre treatment plant	(1) Facility expansion from current primary treatment capacity of 4 m^3/s to 8 m^3/s. (2) Construction of secondary treatment facilities with a capacity of 8 m^3/s.	200 (CAR funding)	Construction scheduled for 2008~2010. Design and construction combined under a single turnkey contract. Owner of the existing facility is SDA; construction funding is to be provided by CAR. Facility is operated by Acueducto. Institutional agreement among the concerned agencies has not yet been finalized.
b)	Fucha interceptor	Sewage main line construction to connect collector pipeline to the Fucha sector.	(Acueducto funding)	Completed
c)	Tunjuelo interceptor	Sewage mainline construction to connect a collector pipeline to the Tunjuelo sector.	(Acueducto funding)	There are four sectors: of which the upstream 1st and 2nd sectors are completed. The 4th sector down river is currently under construction and construction for the 3rd sector is scheduled for completion in 2008~2009.
d)	Fucha-Tunjuelo interceptor	Connects the Fucha sewage system with Tunjuelo pump station.	70 (Acueducto funding)	Construction scheduled for early 2007 to 2009 (33 months).
e)	Tunjuelo pump station	Sewage from the Fucha and Tunjuelo sectors is conveyed to the Canoa WWTP. Capacity: 17.1 m^3/s.	90 (Acueducto funding)	Bidding procedures in 2007. Construction start at the end of 2007; completion planned in 2011.
f)	Tunjuelo interceptor	Conveyance pipe from Tunjuelo pumping station to Canoa WWTP.	100 (Acueducto funding)	Preparatory works for bidding in 2007. Basic design completed in fiscal 2007. Tendering in 2008. Contract is to include both detailed design and construction.
g)	Canoa WWTP	(1) Primary treatment facilities: 18 m^3/s capacity. (2) Secondary treatment facilities: 18 m^3/s capacity.	(1)350 (2)350 (CAR funding planned)	CAR project. Basic design scheduled for completion in 2007. Construction scheduled for 2009~2014. However, funding source has not yet been finalized.
h)	Canoa pumping station (conveyance from Canoa WWTP to Muña lake)	A pump station is to be constructed at the treatment plant, and discharge for hydropower generation is to be diverted to Muña lake.	50 (CAR funding)	CAR project. Muña lake environment restoration plan has been drafted.

Source: Acueducto presentation, 2007

Drainage

Drainage from the plant is carried out by a private Italian company under a turnkey contract. Drainage treatment facilities comprise chemical oxidation, bio-processing by OD method, and a final sedimentation basin. Water quality control for discharged effluents is under the jurisdiction of the SDA

(5) Sewage Infrastructure outside the Bogotá Metropolitan Area

Outside the Bogotá Metropolitan area, CAR directly carries out construction, operation, administration and maintenance of sewage infrastructure.

Project for water quality improvement by CAR

In 1991, CAR implemented the CAR-BID project for improved water quality in the Bogotá Plain. This project was funded with USD 55.6 million by the Inter-American Development Bank (IDB), enabling the construction of small-scale wastewater treatment plants at 27 locations in 24 municipalities. CAR oversees project facility design and construction. Authority for facility operation and maintenance then shifts to the respective municipality (*municipio*) after completion of construction. Treatment methods are varied. On average, treatment capacity is 50 ℓ/s. The sewage service area at present comprises only urban areas. In rural areas, sewage disposal is by on-site means including septic tanks, putrefaction tanks, drop toilets, outdoor deposition, etc.

Current problem in existing sewerage

Nevertheless the following problems affect the above types of facilities:

- Service area is small.
- Sewage pipelines and culverts are obsolete.
- Treatment plants are not only small scale in capacity, but are also inefficient.
- There are facilities that have problems in terms of technical design.
- Municipalities are not ready to incorporate sewage treatment facilities in light of the requisite operation and maintenance cost.

In light of the above issues, the municipality cannot bear cost as well as technical requirements in terms of facility maintenance. As a result, facilities have gone without operation. Accordingly as of October 2005, CAR has consigned operation and maintenance of sewage treatment facilities to the private sector (ESSERE Inc.). This operating entity is responsible for operation and maintenance of only sewage treatment facilities; i.e. construction and maintenance of sewage collection as well as main sewage pipes is under respective municipal jurisdiction. Pipeline systems consist of combined sewer types.

New project for water quality improvement

As of October 2006, a new funding agreement for US$ 5 million was signed with IDB. This funding will be directed at both expanding water service infrastructure and improving sewage facilities

1.3.4. Water Resource Management

Water resources management in Bogotá Plain is implemented by CAR and SDA in quantity and quality. Water user in Bogotá Plain must be registered to SDA and CAR. This registration system has important function for water resources management by SDA and CAR.

Water resources management by SDA

SDA is in charge of management of groundwater resources in Bogotá urban area. Every users of groundwater has to be registered to SDA. Currently, around 400 wells are registered to SDA. Owners of the registered wells have to pay for water use. Monitoring of registered well is conducted by SDA every month for management of groundwater resources. Items of the monitoring are as follows:

- Groundwater level of wells.
- Yield of well.

Water resources management by CAR

CAR is in charge of management of water resources in area listed below:

- Forest Protection Area of Bogotá D.C.
- Rural area of Bogotá D.C.
- Bogotá Plain out of Bogotá D.C.

CAR implements water resources management based on the result of analysis for water resources development potential on surface water and groundwater that was analyzed by CAR. Water resources management in quantity is implemented by restriction and control of water right. Therefore, every user of water resources in Bogotá Plain has to be registered to CAR. The water user can get concession for water use based on the development potential that was evaluated by CAR. CAR collects tariff of water right from the registered users. Number of registered user is as follows:

- Number of legislation for surface water use: 1,400.
- Number of legislation for groundwater use: 1,200.

It is said that real number of water users may be around 8,000 of surface water and 7,000 of groundwater. It means that there are many users without legislation. Method of monitoring by CAR is as follows:

Table-2.1- 30 Method of Monitoring by CAR

Water resources	Monitoring method
Surface water	There are 340 monitoring stations for surface water observation within Cundinamarca. Data for 30 years is accumulated.
Groundwater	Groundwater monitoring is conducted at around 300 registered wells on groundwater level and yield of the wells. Frequency of the monitoring is once to twice a year. Observation is by owner s of wells

Source: CAR

Maintenance of observation wells that were completed by previous JICA Study to continue monitoring

In the previous JICA Study (2000-2003), six (6) Quaternary observation wells and five (5) Cretaceous observation wells were completed. Automatic recorders for groundwater level monitoring were installed into 11 Quaternary wells. Acueducto is steadily continuing monitoring of there observation wells. Moreover, Acueducto intends to expand the monitoring system, adding new monitoring wells with new automatic recorders. To continue observation and maintenance of these wells are requested to Acueducto for the future.

1.3.5. Water quality management and monitoring system

Water quality of rivers flowing through and from the Bogotá Metropolitan area is managed and monitored by SDA and Acueducto. In the case of rivers and wells outside the urban area within the Bogotá Plain, water quality is managed and monitored by CAR

(1) Acueducto

Acueducto possesses a laboratory that carries out water quality analysis of drinking water, surface water, drainage water and soil analysis. It is amply equipped to carry out these analyses. Acueducto has established 155 locations for gathering drinking water samples. Samples are taken at 52 locations each day. Water quality test items encompasses 25 physical-chemical parameters, and two biological parameters. Water quality standards are in accordance with Regulation 475/1988 as promulgated by the Colombia Ministry of Health. Surface water samples are taken at 60-70 sites one time every four months. Sampling includes analysis for heavy metal content. The Salitre Wastewater Treatment Plant carries out water quality testing as well. The Municipal Environmental Agency (SDA) outsource water quality testing for urban area to the Acueducto laboratory. In addition, SDA and Acueducto jointly carry out water quality testing for effluents from almost all factories (approximately 800) within Bogotá urban area. Nevertheless, Acueducto only reports on test results to SDA: Acueducto has no authority with regard to enforcing water quality regulations. The Acueducto laboratory also accepts requests for water quality testing from private sector companies.

(2) SDA-Secretaria Distrital de Ambiente de Bogotá

The SDA performs water quality management for river discharge, factory wastewater, wells, groundwater and marshland. Specifically, effluents from 800 factory sites are tested, and rectification guidance is provided in cases where test results exceed acceptable level. Water quality testing itself is outsourced to Acueducto. SDA is empowered to fine or suspend operations in the case of a factory that fails to improve substandard effluent water quality

(3) CAR - Corporación Autónoma Regional

CAR carries out water quality management and monitoring in the entire Cundinamarca Department outside the Bogotá urban area. The agency carries out regular water quality testing of surface water, groundwater, domestic wastewater, industrial wastewater and discharge from waste treatment plants. CAR also has the authority to grant water rights and environmental licenses with regard to water resources management. In the course of water quality testing, CAR collects surface water samples at

280 locations four times per year and groundwater samples at 101 locations one time per year. Up to now, water quality analysis has been carried out for 4,500 wells. In addition to water management, CAR investigates the results of water quality testing when they evaluate granting water rights or environmental license. The CAR water quality testing laboratory analyzes samples for items including microbiology, physical-chemistry, radiation contamination, toxicity and hydrobiology.

1.3.6. Ecosystem and Natural Environment

(1) Bogotá River Basin

Economic development and environmental conservation

In Colombia, the Bogotá River Basin is the most economically diversified area. About the land use within the basin area, the flower crops are main production in the agriculture, which represents 80% of the total of the national production. On the other hand, the breeding of cattle and the dairy industry are the economic basis of this area. The hydraulic resources are used for many different purposes, agriculture, cattle-breeding, industries, mining, water supply, hydroelectricity, etc. However, there is a fact that economic development has been given higher priority than conservation of nature in the area.

Urbanization and water balance

In addition, rapid urbanization leads also to an increase in the water demand. The increase in the supply and demand of water due to the expansion of socio-economic activities causes restrictions in the use of the water resources in quantity aspect, which sometime makes disputes over the water right and is controlled by the water resources management. In the quality aspect, it must be considered that the Bogotá River receives the sewage of 6.4 million inhabitants from the Metropolitan area of Bogotá and 430 thousand inhabitants from the 26 municipalities that are located in the Bogotá River Basin. The pollution is extremely critical because of the erosion and the accumulation of soil, waste treatment and untreated sewage.

Bogotá Wetland

In relation to the wet lands within the urban area of Bogotá, there are only 13 remaining along the Bogotá River. However, dwellings are already encroaching upon these wet lands. The water quality was also found to be quite polluted and in risk conditions due to the houses invasion, factories construction and the flushing of domestic and industrial water. The Environmental Department of Acueducto and SDA are in charge of the environmental conservation of the 13 wet lands within the urban area of Bogotá. This is not related to the CAR plan for the wet lands recovery. CAR also is planning the recuperation of the wetlands.

(2) Ecosystem and Natural Environment Affected by Groundwater Development in the Eastern and Southern Hill

Forest protection area

The Eastern and Southern Hills are located at elevations of 2,600-3,000 m. Elevations in the Eastern above 2,700-2,750 m comprise forest reserve (*protección forestal*) as controlled by the CAR. Tree felling trees and building structure within this area is strictly controlled.

None of the Southern Hill has been designated as forest reserve. Urbanization has proceeded within the Bogotá Metropolitan area outside the forest reserve. There are accordingly no natural forests, or no rare and endangered wildlife species within this urban area.

Water resources

The catchment area of the Eastern Hill is small, characterized by the absence of any major rivers. Small mountain streams disappear during the dry season. Rivers in the area account for only about 1% of potable water source.

Impact by groundwater development

The target area in the Eastern Hill for groundwater development by the proposed project comprises vacant land and grazing land located between the urban area and the forest reserve. This area will require no human resettlement by the project. Also, the groundwater development area within the Southern Hill lies outside the belt of concentrated human habitation, and solely comprises livestock grazing land. There is neither natural forest nor lakes within this grazing land area. Although there is no designated forest reserve area within the Southern Hill, permission for exploratory drilling and water rights concession for the groundwater extraction must be obtained from the CAR.

(3) Ecosystem and natural environment affected by the Chingaza No. 2 Dam and the Sumapaz Diversion plan

The planned sites for Chingaza No. 2 Dam (Playa Dam) and Sumapaz diversion plan are located between elevations 3,000-4,000 m in the mountainous Páramo zone. Annual average temperatures within this area ranges 0-10°C, and the natural environment comprises low scrub, high altitude vegetation, peatland and wetland.

Flora

The plant ecology within the Colombian Páramo zone includes 57% of plant species found within all Páramo ecosystems worldwide. The Páramo ecosystem in general includes some 5,000 different plant varieties. Specifically in the case of Chingaza, approximately 2,000 different plant species are estimated to be present. Most general plant growth are mixed varieties of common sunflower (*Helianthus annuus*) referred to as "frailejones", as well as some 30 or more herbaceous varieties (arnica). These plant varieties have adapted to a climate of low air pressure, dryness due to weathering, as well as exposure to strong ultraviolet radiation.

Fauna

The Chingaza area is the site of habitats for some endangered species. Fauna includes eagles, condors, guinea fowl, Páramo goats, spectacled bears, deer, squirrels and other small rodents

The planned sites for the Chingaza dam No. 2 construction (La Playa Dam) and deviation plan of Sumapaz are located at a height between 3.000 y 4.000 m.o.s.l in mountain area. Annual average temperature in this area varies between 0 and 10°C and natural environment has small bushes, high altitude vegetation and wetlands.

Geology and water resources

From geological view point, the Chingaza area is characterized by distribution of glacier sediment formed during previous ice ages. Rainy season in the Páramo area extends from June to July. The area is extremely rich in water source due to the low annual level of evapotranspiration.

(4) Socio-environmental Impacts from Chingaza No. 2 Dam

Due to a decrease in water demand, the Optimization Plan for Existing Water Supply Facilities under the revised Master Plan of 2005 is given priority. The plan for Expansion of the Water Supply System is accordingly scheduled for construction from 2029 onwards. Under the plan for Expansion the Water Supply System, Chingaza No. 2 Dam (Playa Dam) and the Sumapaz diversion plan (Chisacá Dam and Muña Dam) will have the greatest impact on the natural environment.

Environmental license and concession

These projects are planned within national park, and require authorization from MAVDT in order to obtain an environmental license. Also with regard to water right concession within national park, authorization is necessary from UAESPNN. Furthermore, because the Chingaza System straddles several districts, it is necessary to obtain water right concessions from CORPOGUAVIO as well as CORPOORINOQUIA.

Impact to natural environment

Project impact on the natural environment will occur in the highland Paroma area, which is populated with rare plant and animal species. Specifically, dam construction will have a large impact on the natural environment. Nevertheless, due to the fact that the area is highland with little forest, there will be no large scale cutting of the forest.

Impact to social environment

In terms of social impact, the project area is uninhabited and therefore entails no resettlement of residents. Furthermore, Acueducto will not require land acquisition, as necessary land has already been appropriated for the Chingaza II project at the time of implementation of the Chingaza I project. Under the project, water will be conveyed to Chuza Dam that was constructed under the Chingaza I project. Additional conveyance pipeline (tunnel), access road, etc. from Chuza Dam to Bogotá is not necessary in light of the fact that such facilities have already been envisioned and constructed under the original Chingaza I project.

Environmental impact assessment

The Chingaza II project EIA (environmental impact assessment) was prepared in 2002. However, due to postponement of project implementation, the EIA report has not yet been submitted to MAVDT and other concerned agencies

1.3.7. Artificial Groundwater Recharge

Artificial groundwater recharge was proposed in the previous JICA Study in view point of groundwater conservation. According to the pilot study of the previous study, the Cretaceous Aquifer in the Eastern Hills showed high capacity of artificial recharge. Groundwater artificial recharge is effective for conservation of groundwater resources of the Eastern Hills

(1) Results of the previous JICA Study

Pilot Study for artificial recharge was conducted in site of the sedimentation pond of Acueducto in Vitelma.

Result of Pilot Study

Result of Pilot Study is as follows:

Table-2.1- 31 Result of Pilot Study

Well structure	Aquifer	Average injected flow	Water head of Injection	Specific injection (=Injected low/water head)	Specific capacity of pumping test
Well depth: 300 m	Labor-Tierna	864 m^3/day	8.41 m	103 m^2/day	69 m^2/day (Yield 1,296 m^3/day)
Diameter of well: 8 inch	Static water level -6.63 m				

Source: The Study on Sustainable Groundwater Development for Bogotá Plain in the Republic of Colombia, 2003

As shown in Table-2.1-31, result of the Pilot Study showed high capacity of the Cretaceous Aquifer for artificial recharge.

Use of facilities for Artificial Recharge

Facilities for artificial recharge still remain in the Vitelma site, which can be operated again in future for artificial recharge. If groundwater development for emergency water supply is realized, it is recommended to drill around 10 wells along San-Cristóbal River for artificial recharge. In case of emergency, groundwater will be pumped-up from emergency wells located along the Eastern and Southern Hills for short period of time (for 1 week to 9 months). After emergency pumping, lowered groundwater level should be recovered. Artificial recharge will accelerate recovery of groundwater level.

Perennial rivers in the Eastern Hills are limited to few rivers, such as San-Cristobal River, San-Francisco River and Yomasa River. Artificial recharge is available in upper part of above three rivers. On the other hand, most of the rivers basins including above three rivers in the Eastern Hills are located in forest protection area. Artificial groundwater recharge will contribute for conservation of groundwater resources of the Eastern Hills. It should be approved in the future by the environmental entities.

(2) Groundwater Recharge from San Rafael Reservoir

San-Rafael Dam is located over Cretaceous formation of the Eastern Hills. It is assumed that some amount of water of the reservoir is infiltrating into the Cretaceous Formation though bottom of the reservoir.

Water leakage from bottom of the reservoir was evaluated by daily-calculation during January 1998 to March 2001. This calculation is based on water balance analysis shown below:

$$G = (R - E) + (D_1 - D_2) + (I_1 - I_2) - \Delta DV$$

G: If G>0, it is outflow of water (= water leakage) from the reservoir.

If G<0, it is inflow of groundwater into the reservoir.

R: Precipitation into the reservoir.

E: Evaporation from the reservoir. It is evaluated from Pan-evaporation × 0.7.

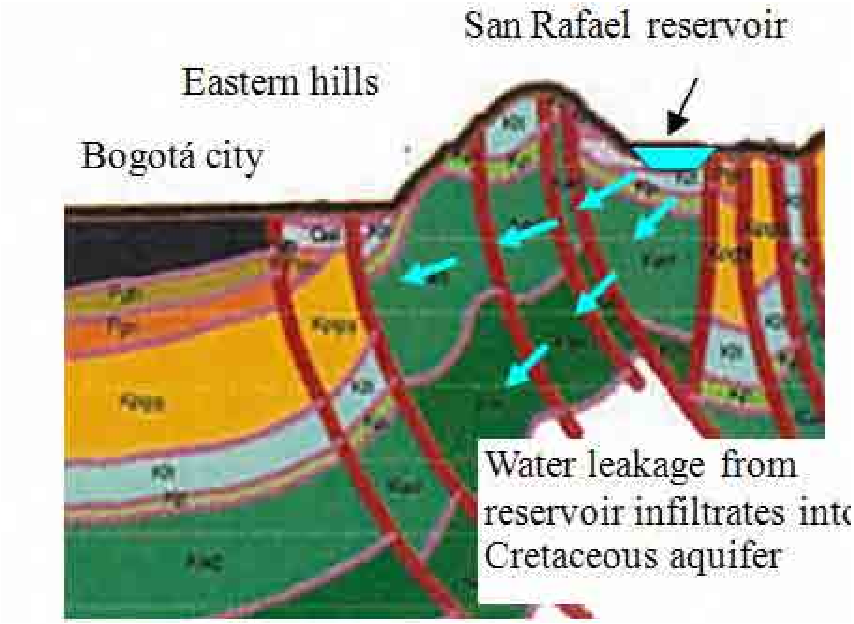
D_1: Inflow into then reservoir from Tominé River.

D_2: Outflow (= discharge) from the reservoir.

I_1: Inflow into the reservoir form Chingaza tunnel.

I_2: Outflow from the reservoir into Wiesner Plant.

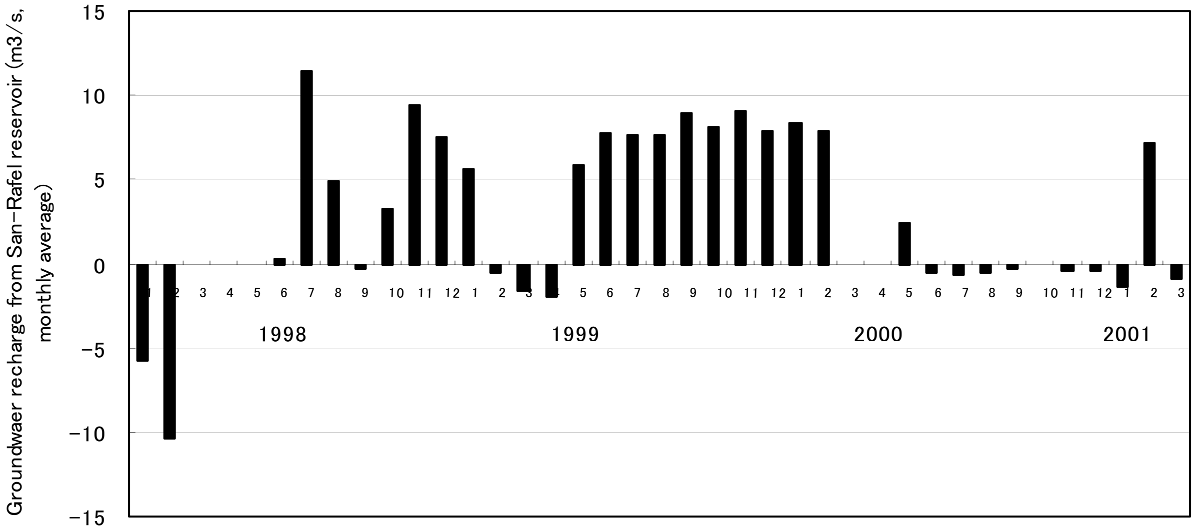
ΔDV: Change in storage capacity of the reservoir (it is calculated from water level of the reservoir).



Source: JICA Study Team

Figure-2.1- 40 Water leakage from San Rafael Reservoir

Result of calculation is as shown in Figure-2.1-41.



Note: Calculated result of "0" means no result due to luck of data.
Source: JICA Study Team analyzed based on Acueducto data

Figure-2.1- 41 Groundwater Recharge form San Rafael Reservoir (monthly average m^3/s)

According to the calculation result, monthly average of water leakage from San-Rafael Reservoir is 3.7 m^3/s. This amount of water is infiltrating into the Cretaceous Aquifer of the Eastern Hills, which will increase groundwater development potential on the area.

Above calculated 3.7m^3/s of groundwater infiltration is caused by water leakage from the reservoir. Such a leakage is an artificial phenomenon and considered unstable. Essentially, groundwater recharge means water infiltration into aquifer from rainfall (see CHAPTER 5). Consequently, the water leakage, from the reservoir, which was calculated above, should not be included into groundwater recharge from rainfall. On the other hand, in formulation of groundwater development in the Eastern hill, possibility of water leakage from the San-Rafael reservoir, which will act same as groundwater recharge, should be taken into account.

1.3.8. Groundwater Monitoring Result

(1) Groundwater Level Monitoring of Quaternary Aquifer by Automatic Recorder

It is said that groundwater level of Quaternary aquifer is continuously going down. Groundwater level automatic recorders were installed into 10 wells in Bogotá Plain during the previous JICA Study, in year of 2001. Acueducto is still continuing the monitoring of groundwater level by the automatic recorders until now. Sites for monitoring wells are summarized in Table-2.1-32.

Table-2.1- 32 Site of Monitoring Wells with Automatic Recorder

	Well. No	Coordinate		Depth of Well(m)	Aquifer
		E	N		
No.1	Gibraltar (Soacha)	988,439	1,005,845	198	Quaternary
No.2	Tisquesusa (Facatativa)	976,639	1,022,020	192	
No.3	Siberia (Tabio)	991,462	1,017,974	173	
No.4	Sopo (Sopo)	1,011,020	1,037,638	150	
No.5	Diana	1,013,170	1,038,429	188	
No.6	Choconta	1,049,874	1,067,343	123	
No.7	Suba	999,911	1,017,839	389	Cretaceous
No.8	Guadarrama	1,014,772	1,053,702	Unknown	Quaternary
No.9	Grasco	996,772	1,001,948	Unknown	
No.10	Santa Monica Flowers	977,203	1,014,760	Unknown	

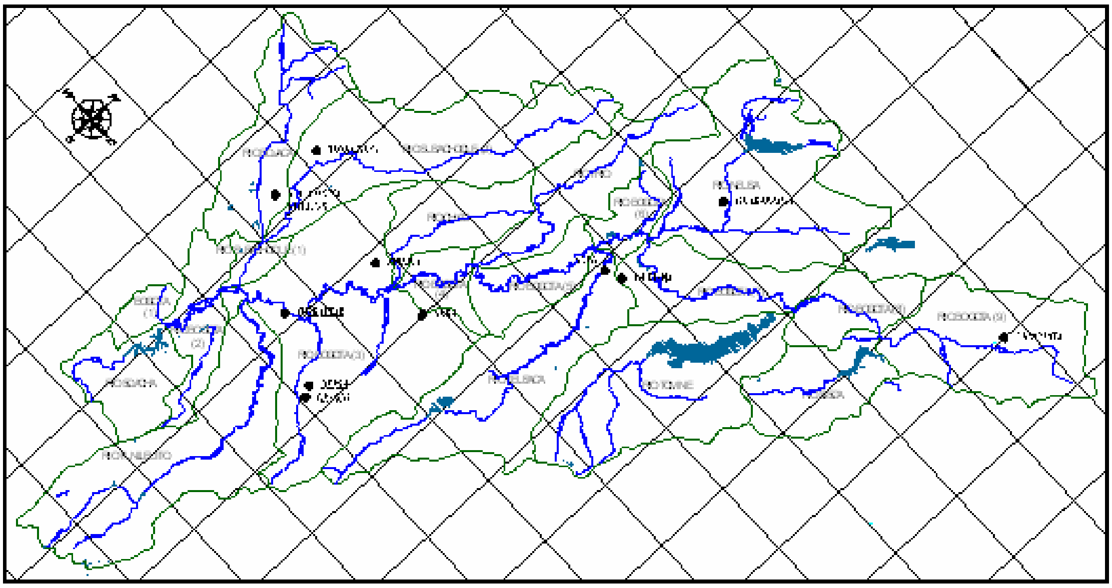


Figure-2.1- 42 Monitoring Site

(2) Result of Monitoring

Groundwater level was recorded by automatic recorders during 2001-2008 at 10 monitoring sites. Three (3) different fluctuation of groundwater level are found in long-term monitoring results. These are:

- **(a) Long-term trend**
- **(b) Seasonal fluctuation**
- **(c) Daily fluctuation**

To make clear of above 3 different fluctuations, adjustment as explained below was conducted for the observed data.

- Moving average of the observed data was calculated to make clear of long-term trend of the groundwater level. Duration of moving average is 1 yeasr/2=183 days.
- Seasonal fluctuation was calculated from relation below:
- Seasonal fluctuation = Observed data － Moving average of observed data
- In addition to calculation above, moving average of seasonal fluctuation was calculated to remove daily fluctuation.

Groundwater level after above adjustment is shown in Figure-2.1-43 to Figure-2.1-45 for three monitoring sites. From these results, matters below are understood.

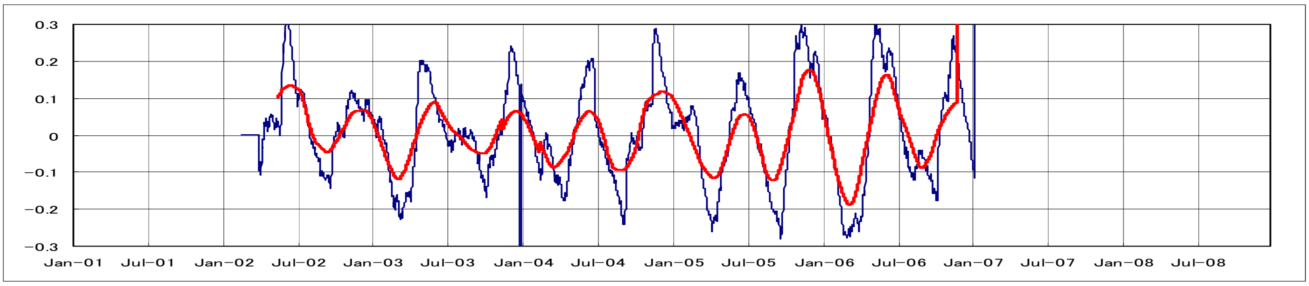
- Long-term trend of groundwater level seems to be constant, as a whole, and it is almost going up during 2001-2008. At least, it can be said that groundwater level is not going down.
- Periodic fluctuation with 6 month period is clear in groundwater level. This fluctuation is definitely related to seasonal periodicity of precipitation.

Two important conclusions below were resulted.

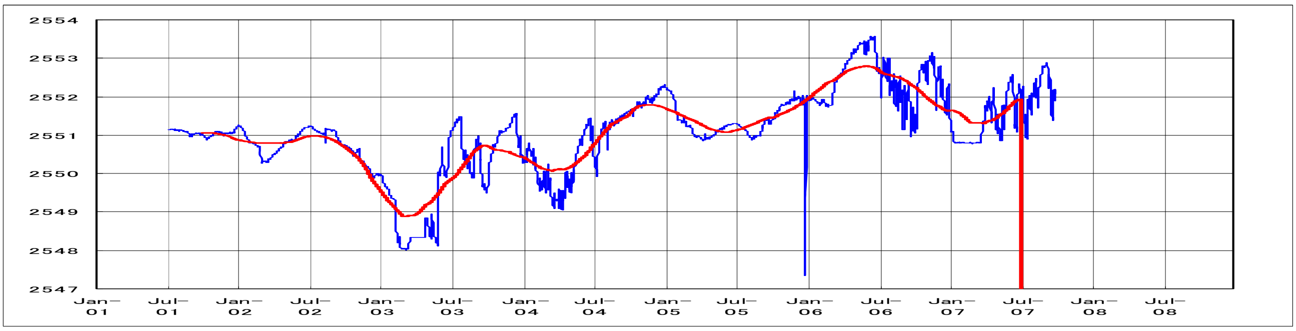
(Conclusion-1) Groundwater level of Quaternary is not going down for long period of time

(Conclusion-2) Groundwater level of Quaternary aquifer is clearly responding to rainfall. It means that Quaternary aquifer is receiving groundwater recharge from rainfall.

More than 7,000 wells were drilled in Quaternary aquifer of Bogotá Plain, where amount of 300,000m^3/day of groundwater is pumped up every day. However, groundwater level of Quaternary is not going down, responding to seasonal and daily rainfall. Quaternary aquifer is principally confined sate, but it is still receiving groundwater recharge from rainfall. Currently, groundwater recharge is much greater than pumping rate, and excessive groundwater (=groundwater recharge – pumping amount) is flowing within aquifer. Such a condition implies that there is more potential for groundwater development, as long as it is less than total groundwater recharge.

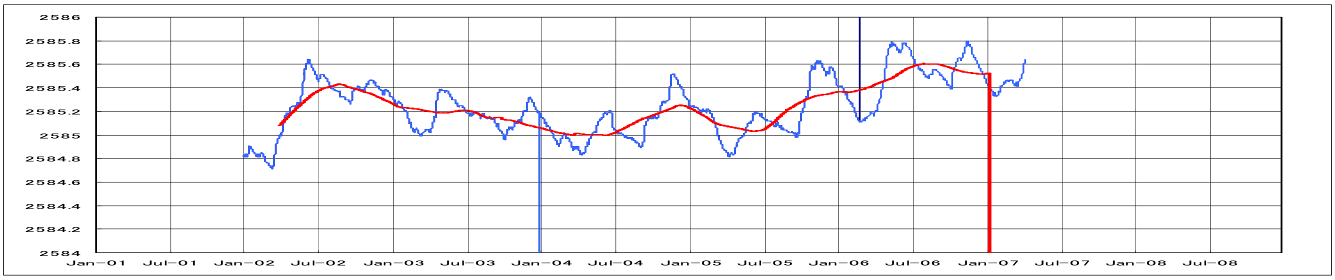


(a) Groundwater Level and Long-term Trend (Moving average)

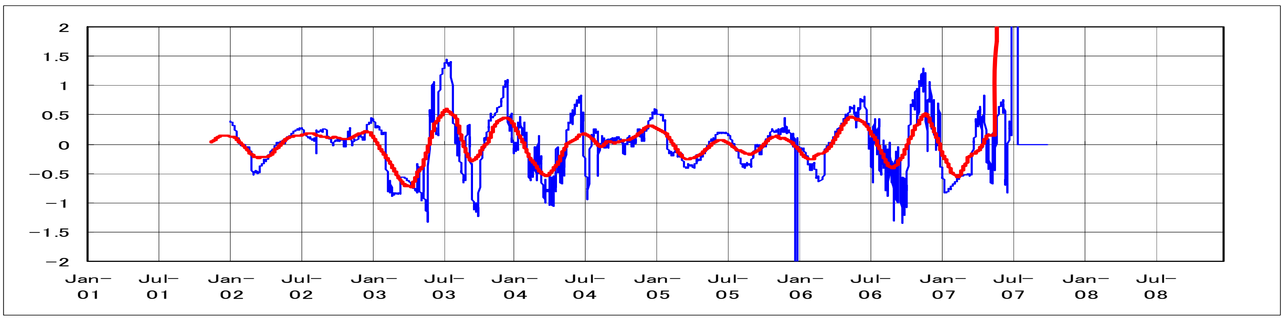


(b) Seasonal fluctuation of Groundwater level and its Trend (Moving average)

Figure-2.1- 43 GUADARRAMA Monitoring Site

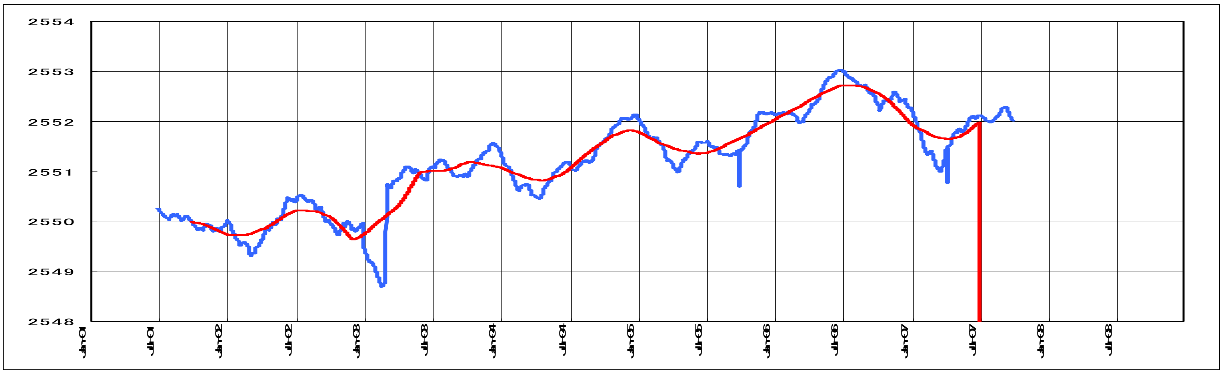


(a) Groundwater Level and Long-term Trend (Moving average)

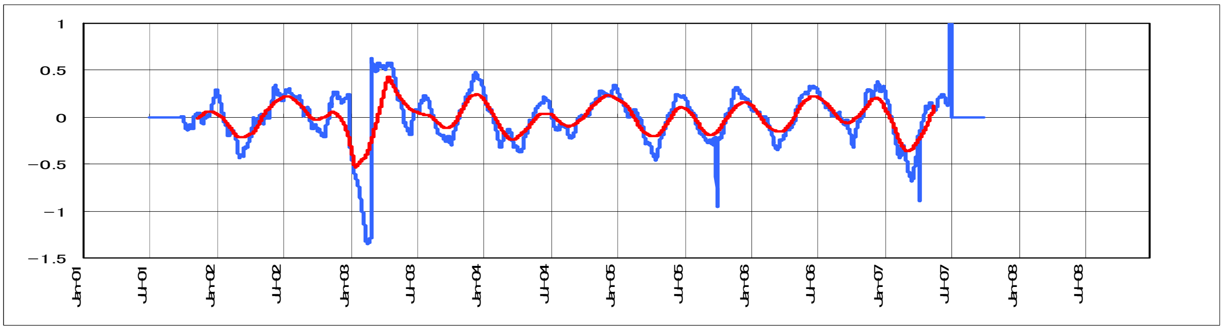


(b) Seasonal fluctuation of Groundwater level and its Trend (Moving average)

Figure-2.1- 44 LA DIANA Monitoring Site



(a) Groundwater Level and Long-term Trend (Moving average)



(b) Seasonal fluctuation of Groundwater level and its Trend (Moving average)

Figure-2.1- 45 SOPO Monitoring Site

CHAPTER 2 IDENTIFICATION OF ISSUES IN CURRENT WATER SUPPLY

2.1. Security of Water Supply in Emergency

The Mayor of Bogotá addressed through the Degree 332 of 2004 that public entities of Bogotá City has to establish an inter-institutional work for disaster prevention attention for emergency such as seismic events. In corresponding to this, the public entities of Bogotá have made clear of their vulnerability and formulated plan to mitigate it. They submitted the plan to DPAE in 2006. Following the background above, Acueducto has studied the components of risk in the water supply system such as water intake/conveyance/transmission/distribution, identifying seismic disaster as the emergency situation that can affect the normal operation for water supply to Bogotá City

(1) Institutional Framework in Case of Emergency

Bogotá city, Cundinamarca, Government of Colombia has committees as listed below, which will formulate disaster presentation measures for Bogotá Metropolitan Area.

- Bogotá D.C.: District Committee for Disaster and Attention.
- Cundinamarca: Regional Committee for Disaster presentation and Attention.
- Government of Colombia: National Committee for Disaster Presentation and Attention.

Under the committees above, the leading agencies and coordinating agencies in charge of formulation of disaster presentation measures are follows:

Table-2.2- 1 Leading Agency and Coordinating Agency

Responsible Entity	Bogotá Metropolitan Area		
	Bogotá	Cundinamarca	National
Leading Agency	District Secretary of Planning (SDP)	Government Secretary	Ministry of Interior
Coordinating Agency	DPAE	Government Secretary (OPAD)	DGPAD

Source: Acueducto.

In case of emergency, the agencies above will corporate each other. Acueducto, which is responsible for water supply, has to prepare plan of disaster prevention and emergency response for water supply. DPAE is in charge of coordination of the content of the plan.

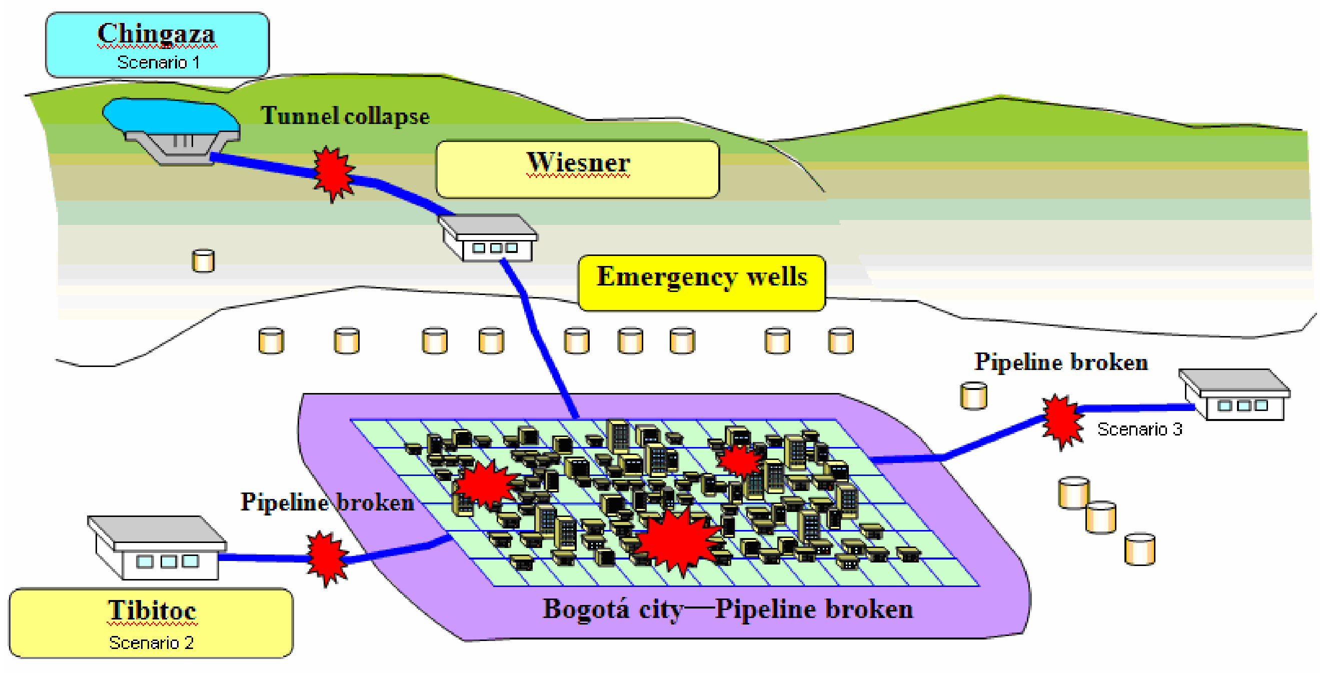
(2) Disaster Scenario by Earthquake

For formulation of Emergency Water Supply Plan, disaster scenarios are necessary. The disaster scenario for big earthquake was assessed by two reports below:

a) The Study on Disaster Prevention in Bogotá Metropolitan Area in the Republic of Colombia (JICA, 2002).

b) Evaluación por pérdida Máxima Probable (PML) por Terremoto para Infraestructura Indispensable de la Empresa de Acueducto y Alcantarillado de Bogotá (Acueducto, 2006).

Figure-2.2-1 explains the concept of different scenarios of emergency water supply. Possibility that the entire water supply system for Bogotá City is broken at the same time by one earthquake is assumed very low.



Not necessarily simultaneous
Source: JICA Study Team

Figure-2.2- 1 Possible Concepts of Emergency no simultaneously

<u>Disaster Scenario by "The Study on Disaster Prevention in Bogotá Metropolitan Area in the Republic of Colombia (JICA, 2002)"</u>

In this report, damage to water supply facilities of Bogotá Metropolitan Area was analyzed. However, area of water resources is out of analysis in this study. Disaster Scenario proposed by this Study was summarized as shown Table-2.2-2.

Table-2.2- 2 Disaster Scenario in Water Supply for Outbreak of Large Earthquake

Items		Earthquake Scenario Case-1 La Cajita Earthquake	Case-2 Duayuriba Earthquake	Case-3 Subduction Earthquake
Peak ground acceleration		Max Acceleration 0.908g	Max Acceleration 0.361g	Max Acceleration 0.125g
Estimated Damage of water pipelines	No. of damaged points	3,753 points	1,545 points	16 points
	No. of damaged points by diameter	(D : Diameter) D > 500 mm: 80 points D= 500-200 mm: 310 points D= 200-100 mm: 981 points D < 100 mm: 2,383 points	(D : Diameter) D > 500 mm: 32 points D = 500-200 mm: 150 points D = 200-100 mm: 456 points D < 100 mm: 907 points	(D : Diameter) D > 500 mm: 0 points D = 500-200 mm: 2 points D = 200-100 mm: 5 points D < 100 mm: 9 points
Area of serious damage		• Damage will be serious in the south of Bogotá city: Usme, Ciudad-Bolívar, San-Cristóbal and Soacha. • Damage of pipelines will be intense due to liquefaction in Kennedy.	• Damage will be spread in wide area of Bogotá city • Damage will be most serious in Tunjuelito.	• Damage will be negligible.
Preparedness		• Reinforcement of facilities for anti-seismic • Construction of water tank for emergency		—

Source: JICA Study: Study on Disaster Prevention for Bogotá Metropolitan Area, 2002.

Situation in outbreak of La Cajita Earthquake (Case-1) is predicted as below:

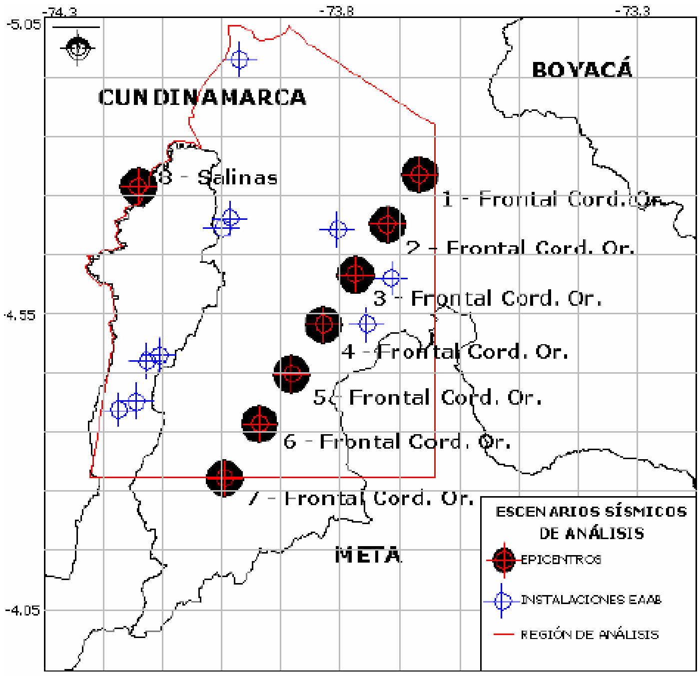
< Situation in outbreak of La Cajita Earthquake >

- Water supply will be suspended by damage of water pipeline due to earthquake. Emergency water supply will be implemented. However, it will be insufficient and water shortage will occur. Acueducto will begin recovery of damaged water pipeline. It will take long time to recover water supply, and water shortage will continue for long period.
- Ground acceleration will be big in the south of Bogotá City such as Usme, Ciudad-Bolívar, San-Cristóbal and Soacha city, where damage will be more serious. Liquefaction will occur in low plains of the south of Bogotá city due to earthquake, which cause serious damage to water pipelines.

Disaster Scenario according to "Evaluación por pérdida Máxima Probable (PML) por Terremoto para Infraestructura Indispensable de la Empresa de Acueducto y Alcantarillado de Bogotá (Acueducto, 2006)"

Damage to water intake and water conveyance system by big earthquake was analyzed by Acueducto in this report. Eight (8) seismic centers were assumed along a major fault line of the Eastern Range as shown in Figure-2.2-2. These seismic centers are located in the area of Chuza Reservoir of Chingaza System. This is a reason why the location of the active fault was assumed between Bogotá city and Chingaza area.

Different earthquakes simulations were performed in order to identify the power of the seismic waves and their effect under different assumed epicenters and magnitudes estimating the possible damages. The results of this simulation are in the above mentioned report.



Note:Eight (8) seismic centers were assumed along a major fault line extending NNE-SSW direction with constant distance. Scale of assumed earthquakes is 7.4 in magnitude with depth of 31 km.

Source: Acueducto, Evaluación por pérdida Máxima Probable (PML) por Terremoto para Infraestructura Indispensable de la Empresa de Acueducto y Alcantarillado de Bogotá (2006).

Figure-2.2- 2 Epicenter of Earthquake

Result of damage analysis by assumed earthquakes are summarized in Table-2.2-3. It is expected that damage by a big earthquake will spread to intake facilities, reservoir, and water conveyance and distribution system. Acueducto has already begun anti-seismic reinforcement work. However, it will take long time and large investment to complete it.

(3) Existing Preparedness for Disaster Prevention

Current preparedness for disaster prevention by Acueducto is as follows

(a) Emergency Response System of Acueducto

Emergency response system of Acueducto is as follows:

Reinforcement of facilities for anti-seismic

- Water supply facilities including tunnels/tanks/pipelines, which are located in dangerous area in case of earthquake, were selected. These facilities are under anti-seismic reinforcement works.
- Acueducto is conducting construction works to reinforce water conveyance tunnel. The inspection of tunnel and the construction works is conducted for 3 months every year by stopping water conveyance from Chuza Reservoir. During the construction work, water stored in San-Rafael Reservoir is used for source of water supply.
- Acueducto analyzed damage by big earthquake. It was anticipated that damage will be more serious in the area near boundary between mountain and plain. Acueducto has planned to install flexible joints in areas where that were identified especially dangerous.

Table-2.2- 3 Expected Damage

Facilities	Expected damage	
Tunnel	Tunnel collapse is expected where lining work of the tunnel is not completed.	• Guatiquía Tunnel. • Leticia Tunnel. • Palacio Blanco Tunnel. • Elfao Tunnel. • Siberia Tunnel. • Santa Barbara Tunnel. • Usaquén Tunnel.
Dam	Golillas Dam needs partial lining and re-enforcement for anti-seismic.	
Valve and intake gate	Valves and intake gates need reinforcement for anti-seismic.	
Pipeline	• There are structural problems in pipe-line between Tibitóc-Usaquén. • There are structural problems in pipe-line between Tibitóc-Casablanca.	
Tank	• There are small cracks on washing tank of Wiesner Plant, which may result in water leakage by earthquake. • There are structural problems in other tanks, which will lead to water leakage or inflow of dirty water into tanks in case of earthquake.	

Source: Acueducto, Evaluación por pérdida Máxima Probable (PML) por Terremoto para Infraestructura Indispensable de la Empresa de Acueducto y Alcantarillado de Bogotá (2006).

Security of Water in case of Emergency

- Water in San-Rafael Reservoir will be used for emergency water supply. San-Rafael Reservoir can store amount of water to be treated in Wiesner Plant for three (3) months.
- Maximum capacity of Tibitóc Plant is 10.5 m^3/s, though concession for water right is currently 4.8 m^3/s given to Tibitóc Plant. However, Acueducto can take more water to increase production rate of Tibitóc Plant, under permission from CAR, when water conveyance from Chingaza is suspended.

In case of emergency, closed plants, La-Laguna, Vitelma and San-Diego Treatment Plant, will be operated again.

(b) Immediate Response System of Acueducto

Acueducto is preparing for immediate response activities as mentioned below:

Manual for immediate response

A manual for emergency response has been prepared, which instructs activities to be performed for immediate response to disaster (see appendix-1).

Operation of Water Supply System in case of emergency

Acueducto has established centralized automatic operating system for water supply, the Central Control Center (see 3.3.1 of this Report). The Center can monitor condition of operation system time to time. Based on monitoring result, the Center will automatically control each facility. This system can be responsive in case of emergency by natural disaster, with function below:

- This system can immediately detect damage in water supply system by a big earthquake. It will give information of emergency response for water supply.
- If wells for emergency water supply are constructed in the Eastern and Southern Hills, the emergency wells can be controlled directly by the Center, according to information on damage in the water supply system.

(c) Alternative water sources in case of emergency

Groundwater is expected as one of alternative water sources in case of emergency. In "Study on Groundwater Development for Bogotá Plain" (JICA, 2003), groundwater development in the Eastern and Southern Hills was proposed for alternative water source in case of emergency. In this Study, groundwater development potential was analyzed as 4 m3/s for emergency water supply. Importance of groundwater in case of emergency was also proposed in M/P by Acueducto in 2005.

(d) Insurance of earthquake

Acueducto has insurance for damage by a big earthquake such as collapsing of water conveyance tunnel.

2.2. Water Supply in Residential Area of Low income Group at High Altitude

Actual conditions of Water Supply and use, in the residential areas of low-income group at the high altitude, were studied through the following two surveys: 1) Social activities of Acueducto and 2) Socio-economic survey.

(1) Social Activities of Acueducto

1) Policy and Strategy

Acueducto prepared a paper called "General Strategic Plan 2004-2008, updated in 2006, of Bogotá Water Supply and Sewerage Enterprise". The paper mentioned the following strategies.

i) Necessity of activities to make the community aware of the importance of joint work with Acueducto to implement the project.

ii) Search for the sustainable safe water resource for the community.

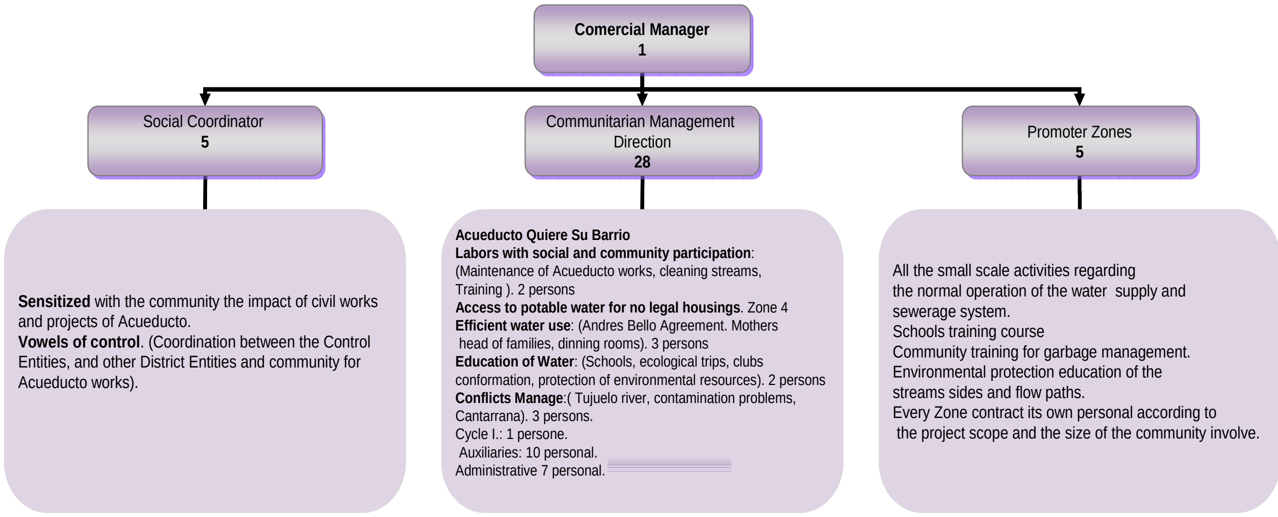
iii) Promotion of the community participation in Acueducto projects as the joint workers.

iv) Establishment of a good relationship with the community, to promote i) the proper management of the water resources and the infrastructure of water supply system and ii) the appropriate recovery of the natural streams and wetlands.

In order to fulfill the above policies, Acueducto structures a team as shown in Figure-2.2-3.

2) Responsible Division

Community Management Division is responsible for the social activities in Acueducto. In total, 43 staff including managers, directors, social workers and auxiliary persons works for the division. Two of them are advisors for the General Manager of Acueducto. They support the integration of guidelines and projects of Acueducto, for water supply to residential areas, currently without water service connection. They are replacing all the hoses used in the residential areas, which belong to "I-Cycle", taking into account of the legal matters.



NOTE: The small number in every block means the number of personnel assigned inside the enterprise

Source: JICA Study Team

Figure-2.2- 3 Organizational Scheme for Community Awareness

For communities' located up-warders, Acueducto wants to promote interactive programs of water supply through agreements with the residential areas by establishing a Community ESP (Enterprise of Public Services). This new small enterprise will receive and buy block water from Acueducto and distribute it to each residents of their neighbor. The subscription of a Border Agreement with the community, before the selling of block water starts, will allow for Acueducto to control water distribution, by estimation of the exact amount of water suitable per family, according to the Word Health Organization. This methodology is still being tested at Serrezuela Residential Area (Usaquén Locality) and was already developed 30 year ago. The methodology promotes a very active and organized community that will assume the responsibilities and the implementations explained above

3) Actual Activities and Focal Points

According to the strategy, Acueducto is focusing on the followings activities.

i) A program of cleaning and maintenance of channels and streams by the community members of the project area, whom Acueducto contracts.

ii) Giving a hygienic awareness, related to the water, to the mother-and-child families, through the system of "Madres Comunitarias", according the agreement among UESP, Andrés Bello Agreement and Acueducto.

iii) Educating the student of the District schools to preserve and conserve the water resources, accompanied with the ecological fieldtrips.

iv) Contracting the community members for cleaning and maintenance work during the implementation of the project of Cantarrana and Tunjuelo River.

4) Issues and Problems

The followings are the major problems that Acueducto is facing.

i) Community requirement to Acueducto for providing water for those areas with environmental restrictions.

ii) Low pressure of distribution tank system mainly in Ciudad Bolívar and Usme area, affected by the unaccounted water loses with the increasing illegal connections.

(2) Social Economic Survey

The socio-economic survey is composed of 1) interview survey with the community leaders and the communities itself, and 2) questionnaire survey to the households.

The process of the survey is as follows.

- Collecting the existing data and information.
- Contacting the members of the local action of joint committee - JAL (*Junta de Acción Local*) -, in some communities.
- Analyzing the priority areas and field trips for recognition of the priority areas.
- Selecting the areas.
- Designing the contents of field work and the schedule.
- Starting the field survey.

1) Survey Area

The Study Team selected finally 15 survey areas as shown in Table-2.2-4 according to the following criteria:

- The area located at Eastern and Southern Hills.
- The area of the low income community located at over 2,750 m.
- The area without water supply by Acueducto.

Caracolí
Ciudad Bolívar Locality

La Fiscala Fortuna
Usme Locality
Laureles

Table-2.2- 4 Survey Area

Locality	Name of Selected Area	No. of Questionnaires	Identified Problems
1. Usaquén	1. Altos de Serrezuela	6	No periodical car tank.
	2. Lomitas	10	Own water source
	3. Villas de la Capilla	16	No road access
	Subtotal	32	
3. Usme	1. Arrayanes	1	No water resource
	2. La Fiscala	19	Bad surface water quality
	3. La Fiscala II Fortuna	7	No roads, no water
	4. San Pedro	3	Contaminated drinking water taken from the small stream.
	5. Portal del Divino Nino	4	Hose, community and Acueducto
	6. Sierra Morena	11	Own water source, tank and hose
	7. Las Violetas	3	Car tank.
	8. Villa Rosita	6	Hose
	9. Villa Anita	7	Hose and tank
	10. Tihuaque	7	No road access.
	Subtotal	68	
4. San Cristóbal	1. Aguas Claras	9	Low quality of the drinking water taken from the stream.
	2. San Manuel	14	Low quality of the drinking water taken from the stream. Bad road access.
	3. La Cecilia	16	Hose. No road access.
	4. Villa Aurora	12	Surface water
	5. Ciudad Londres	11	Contaminated drinking water taken from the small stream.
	Subtotal	62	
5. Ciudad Bolívar	1. Bella Flor – Verbenal	25	Car tank. Low pressure from Acueducto
	2. Caracolí	16	Hose, tank and Acueducto
	3. Los Robles	1	Hose. Bad road
	4. Quiba – Verbenal Sur	2	No water source
	Subtotal	44	
Total	15 Areas	206	

Source: Acueducto and JICA Social Study.

2) Interview Survey

Interview survey has started on January 12 and is scheduled to be completed at the end of February. Until middle February, 13 interview surveys were carried out as shown in Table-2.2-5.

Table-2.2- 5 Interview Survey

	Group of Neighborhood, etc	Interview	Representatives	Date
1	Acueducto advisor	Acueducto	Ignacio Castro	12/01/07
2	Usaquén	A	Luis Villamil of JAL	13/01/07
3	El Mirador, Arauquita, Soratama and Lomitas	A, B	Community of Codito and Cerros Norte	16/01/07
4	Usme, San Cristóbal, Ciudad Bolívar Representatives	A	Representatives of Southern part of Bogotá	18/01/07
5	Verbenal Visita	A	Esperanza, community leader Alba Rocío Riaño	25/01/07
6	Verbenal Sur	A	Esperanza Gonzalez	27/01/07
7	Lomitas, Villas de La Capilla and Serrezuela	B	Jose Antonio Selma	01/02/07
8	El Divino Niño, Santa Viviana and Sierra Morena	A	Esperanza Vargas, Usme Community	29/01/07
9	Laureles, Aguas Claras and La Cecilia	A, B	José Gonzalo Alvarado, JAL of San Cristóbal, and Henry Fuentes, community leader	05/02/07
10	San Manuel, Villa Aurora and Ciudad Londres	A, B	Julia Blanco de Rodríguez, Rodrigo Garzón, and Gino Gonzáles	06/02/07
11	Villa Anita	A	Esperanza Vargas	06/02/07
12	La Fiscala Alta and La Fiscala Fortuna	A, B	Jorge Alberto Forigua-JAC, La Fiscala	11/02/07
13	Los Robles and Caracolí	A, B	Francisco Rodriguez, JAC of Los Robles and Blanca Myrian Cortés, community leader	12/02/07

Note: Interview A - Community leader, and Interview B - Community itself.

Source: JICA Study Team.

The contents of interview are summarized as follows.

- Number of households without the safe drinking water.
- Water source that they use.
- Number of families and average family size.
- Number of persons moved from the other area.

Number of persons living at the illegal area

3) Questionnaire Survey

The questionnaire survey of 200 households has been carried out in 15 areas as presented in Table-2.2-4 and will be completed at late February. The contents of questionnaire are summarized in Table-2.2-6.

Table-2.2- 6 Contents of Questionnaire Survey

Classification	Questionnaire Items
1. General	1. Number (sex and age of the house residents, insecurity, unemployment, other).
	2. Available public service.
	3. Accessibility to house.
	4. Reasons to live in the area.
2. Health	1. Frequent problems on public health.
	2. Availability medical service.
	3. Frequency of waterborne disease.
3. Income	1. Main economics activities of the residents.
	2. Main income sources of the residents.
	3. Total daily income of the residents.
	4. Monthly expenses of the residents by type.
	5. Daily food (breakfast, lunch, dinner, other).
4. Water Supply	1. Main drinkable water source.
	2. Distance to water source.
	3. Water transport system.
	4. Drinking water quality.
	5. Water treatment type.
	6. Water storage system.
	7. Domestic treatment of water before consumption.
	8. Service continuity.
	9. Cost of the initial connection to the house.
	10. Monthly cost of drinking water.
	11. Monthly cost of sewage service.
5. Sanitation	1. Available sanitation system.
	2. Frequency of cleaning water storage tank.

Source: JICA Study Team.

4) Analysis of Survey

The result of survey is summarized in Table-2.2-7. In the survey area, 1,057 persons live with an average of 5.2 persons per family. The coverage ratio of public services is very low: water supply 14%, sewerage 23.3%, gas 1%, and telephone 25%.

The inhabitants don't seem to be suffering from health problems. The reason is that most of them, 61%, are attended by SISBEN (*Sistema de Seleccion de Beneficiarios para Programas Sociales*) health system.

Regarding the monthly income, 70% of the households earn between Col$ 300,000-1,000,000. Regarding the monthly expenses, 60% of the households spend between Col$ 300,000-1,000,000.

Regarding the water supply, 32% of the households are supplied from the community-self supply system, and 25% are illegal intakes from Acueducto. And 24% of the households get water from local plastic tanks and springs that are prepared by Acueducto.

As to the water quality, 45% who get water legally or illegally from Acueducto answered well. On the other hand, 32% who are supplied from the community-self supply system answered badly: neighbors like Ciudad Londres, San Manuel, La Cecilia, Caracolí, Sierra Morena, Verbenal and La Fiscala Fortuna.

Table-2.2- 7 Summary of Survey Results

Classification	Questionnaire Items	Summary of Answers
1. General	1. Number (sex and age of the house residents, insecurity, unemployment, other).	Total survey population =1057 (kids= 555, adults:502)
	2. Available public service	Acueducto (NO= 85.92%, Yes= 14.08%). Sewerage (NO=76.70, YES=23.3%). Garbage collecting (NO=30.58,%, YES=69.42%), Gas (NO=98.95%, YES=1.07). Telephone (NO=75.24%, YES=24.76%)
	3. Road Access	Not Available: 23.30%. Available: 76.70%
	4. Reasons to live in the area	Owners=85.44% (Some of them are owners of the house some of them rent the house. Owners=80.10% and rent=19.90%). Time living there(1 to 5 years= 7.58%, 11 to 20 years= 19.42%, 6 to 10 years=25.75%, more than 20 years=11.17%, less than 1 year= 6.31%)
2. Health	1. Frequent problems on public health	NO= 84.47%, YES=15.55%
	2. Availability medical service	NO=11.65%, YES=88.55%. Main Health Service Center (Local Health Center=8.14%, Social Secure=8.14%, SISBEN=61.05%)
	3. Frequency of waterborne disease	Cardiovascular and rheumatic = 0.49%, infections and respiratory system=1.46%, skin infections=1.46%, infections=46.60%, eyes= 0.49%, digestive system= 5.85%, urine system=0.49%, others=3.88%.
3. Income	1. Main economics activities of the residents	Agriculture=1.46%, handyman=16.997%, Mechanic=12.62%, Commerce= 25.24%, house keeper=9.22%, other=29.61%.
	2. Total monthly income of the residents	Less than 50,000=1.94%, between 50,000 to 100,000=2.43%, between 300,000 to 500,000 =43.20%, between 500,000 to 1,000,000 =23.79%, more than 1,000,000 =6.31%. No fix income=0.49%. Not answer=2.43%.
	3. Monthly expenses of the residents by type	Less than 50.000=3.33%, between 50,000 to 100,000=5%, between 100,000 to 300,000= 31.67%, between 300,000 to 500,000=35.00%, between 500,000 to 1,000,000 =25%.
	4. Daily food (breakfast, lunch, dinner, other)	1 meal=4.37%, 2 meals=19.42%, 3 meals=68.93, 4 meals=0.97%, 1 to 2 meals=2.91%, 2 to 3 meals=1.46%., communitarian dinning rooms=0.49%.
4. Water Supply	1. Main drinkable water source	Big plastic tanks and springs =23.785% , Acueducto=8.7385%, Communal Water supply=32.52%, car tank=17.961%, Illegal=24.7571%, natural spring= 1.456%
	2. Distance to water source	Less than 1 hour=29.13%, between to 4 hours=17.96, more than 4 hours=1.94, immediately=21.36%, not answer=29.61%.
	3. Water transport system	Acueducto distribution= 0.97%, plastic container =28.64, hose=49.51%, pipeline =14.08%. pump=0.49%, others=6.31
	4. Drinking water quality	Good= 44.66%, middle=20.39%, bad=32.04%, not answer=2.91%.
	5. Water treatment type	Untreated= 89,81%, treated = 10,19%
	6. Water storage system	Concrete containers=8.74%, different containers materials=55.83%, plastic tank=16.50%.
	7. Domestic treatment of water before consumption	Filter=4.37%, boiling water=64.56%, unknown=3.88%, not treated=27.18%.
	8. Service continuity	Continuous=16.02%, intermittent=53.88%, regular=26.70%, night time=0.97%, unknown=2.43%.
	9. Cost of the initial connection to the house	No=52.91%, Yes=41.26% (from 85 persons that answer to this question, the average rank between $53,952 for 51 persons and $728,333 for 8 persons). Unknown=5.83%.
	10. Monthly cost of drinking water	No=48.06% (not payment because water comes from natural springs, or illegal connections), Yes=48.54% (Those supplied some how by Acueducto $25,000. Others correspond to gallons or containers per month, total $14,453. An atypical case of 4 families that are supply by communitarian water supply system, they pay $62,500 monthly). Unknown=3.40%.
	11. Monthly cost of sewage service	No=83.98% (to the natural springs or neighbor roads), Yes=7.77% (some are included in the cost of the water supply tariff it means $50,000, others pay to the community local management $25,000 and some other mention a payment of $2,000), Unknown=8.25%
5. Sanitation	1. Available sanitation system	Sewerage with civil work =79%, waste water to the soil or road= 17%, waste water to the streams=3%.
	2. Frequency of cleaning water storage tank	Every 1 day=13,00%, after 8 days=36,18%, after 20 days=0,66%, after 30 days=7,24%, after 60 days=1,32%, after 90 days=1,97%, after 180 days=1,32%, after 365 days=1,32%. Every time the water is collected=35,02%, Every time the tank is empty=1,97%.

Source: JICA Study Team November 2007.

5) Future Water –Supply for Low income Group at High Altitude Are

Social survey was carried out in the areas that have not yet received water supply by Acueducto.

Acueducto has responsibility of water supply for urban area, where water supply is almost 100%. On the other hand, public water supply by Acueducto is prohibited for areas out of the urban area. According to the regulation, settlement in such an area without public water supply is illegal. Policy of Acueducto for water supply for such areas is as follows:

- Water supply for illegal settlement will promote further illegal settlement. Therefore, Acueducto intends not to implement public water supply for such areas.
- On the other hand, Acueducto is implementing water supply by water wagons and temporary water supply pipelines for residence out of the urban area. However, this is just temporary water supply, for humanitarian reasons, completely different from ordinary water supply.
- There is a possibility that these areas will be included into urban area in the future, and will receive public water supply by Acueducto. However, Acueducto will not implement water supply more than temporary water supply that is currently conducted, as long as the areas are located out of the urban area.

It is estimated that around 40,000 people of illegal settlement does not receive public water supply by Acueducto. It is 0.6% of the total population of Bogotá urban area. Their unit water consumption rate is 7 liters/person/day, which is not enough but barely satisfies water demand for human survival. Condition of water supply for illegal settlement should be improved within the current legal framework.

On the other hand, high altitude area in the Eastern and Southern hills has high groundwater development potential. However, as mentioned above, Acueducto will not implement ordinary water supply for those areas. Therefore, residents, living at high altitude out of urban area, do not become target of water supply by new groundwater development proposed in this Study.

2.3. Water Right Granted to Acueducto

(1) Water Right

Water right belongs to Government of Colombia. Water use and exploration for water resources need a) concession for water use and b) permission, respectively.

Table-2.2- 8 Organization in Charge of Water Right for Water Intake of Acueducto

Organization	Concession and Permission	
CAR	Concession	• Water use of surface water and groundwater in rural area of Bogotá D.C. • Water use of surface water and groundwater in Bogotá Plain out of Bogotá D.C.
	Permission	• Exploratory of groundwater in rural area of Bogotá D.C. • Exploratory of groundwater in Bogotá plain out of Bogotá D.C.
SDA	Concession	• Concession for groundwater use in urban area of Bogotá D.C.
	Permission	• Permission for exploratory of groundwater in urban area of Bogotá D.C.
UAESPNN	Concession	Water use right of the Chuza Reservoir and the Playa River, which are main water sources of Chingaza System. (Proposed area for future water development in Sumapaz is located in natural Park)
CORPOGUAVIO	Concession	Water use right of Blanco River, which is a tributary of Chingaza System.
CORPOORINOQUIA	Concession	Water use of Blanco River, which is a tributary of Chingaza System.

Source: Acueducto.

Concession for water use that is currently given to Acueducto is shown in Table-2.2-9.

Table-2.2- 9 Concession given to Acueducto for Water Supply

Water Supply System (Treatment Plant)	Water source	Water Rate Concession (m^3/s)	Organization to Authorize	Date of issue	Effective Period (years)	Date of next renewal
Chingaza (Wiesner)	Guatiquía River (La Playa)	5.248	UAESPNN	2004/Aug./31	50	2054/Aug./31
	Chuza Reservoir	5.933				
	Leticia stream	0.300				
Chingaza (San-Rafael-Wiesner)	Teusacá River	0.900	CAR	1990/Sep./03	50	2040/Sep./3
Chingaza (Blanco-Wiesner)	El Mangón stream	0.839	UAESPNN	2004/Aug./31	50	2054/Sep./31
	Blanca stream	0.090	CORPO-ORINOQUIA	2002/Sep./03	10	2012/Sep./3
	Siberia stream	0.085				
	Siberia stream	0.006				
	Plumareña stream	0.023				
	Colorada stream	0.073				
	Colorada stream	0.103				
Yomasa	Yomasa stream	0.0183	CAR	2001/Jun./28	10	2011/Jun./27
El Dorado	Tunjuelo River	1.000		---	---	Under renewal
Tibitóc	Bogotá River	4.800		2003/Dec./12	1	Under negotiation

Note: Concessions under application or in process of granting are excluded
Source: Acueducto

Water concession in Table-2.10 shows approved ones only and does not include the pending ones. Moreover, water concessions, which have been nominally kept but practically difficult to be used, are also excluded in Table-2.2-10.

Table-2.2- 10 Concession for Water Use Right by System

Supply System	Organization to authorize	Water with concession (m^3/s)	
		Authorized/Applied	Current use
Chingaza	UAESPNN	12.32	9.5
	CAR	0.90	0.0
	Total	**13.22**	**9.5**
Tibitóc	CAR	4.80	4.5
South	CAR	1.00	0.5
Total		**19.02**	**14.5**

Source: Acueducto

Tariff of Water Right

Law 99 in 1993, each environmental authority can independently decide price of concession for water use. Acueducto paid Col$ 120-150/m^3 to CAR and Col$ 5/m^3 to the other environmental organizations. However, by Decree 155 in 2004, price of water use was changed. It is Col$ 0.56/m^3 in 2006 as the minimum price. Then, price will be raised year by year until 2017. Price of water right will be decided by negotiation between environmental organizations and water users considering water intake rate (m^3/s) and water quality

(2) POMCO

Relating for water resources development in the Eastern Hills, "Plan for management of river basin of the Eastern Hill" (POMCO) was completed in 2006. Outline of the content is as follows:

Purpose

Purpose of this plan is to preserve ecosystem of the Eastern Hills, which will contribute to keep natural environment and development of city in harmony. Conservation of aquifer is among objectives.

Activities prohibited in the Eastern Hills

All the activities are prohibited out of the urban area (stipulated in POT) of the Eastern Hills except for activities for environmental protection. Construction of new buildings and expansion of existing facilities are prohibited out of the urban area of the Eastern Hills. Geophysical survey for groundwater research in the area also needs permission from CAR.

Water resources development and use in the Eastern Hills

Water resources development and its use needs concession from CAR and SDA. Application for concession will be submitted to CAR and SDA though committee of water user in the Eastern Hills.

Effect by POMCO in water resources development in the Eastern Hills

POMCO puts emphasis on conservation of ecosystem out of urban area of the Eastern Hills. Therefore, water resources development should be implemented within the urban area of the Eastern Hills. On the other hand, water resources development is possible even out of the urban area in the Southern Hills.