CHAPTER 1 INTRODUCTION

1.1 Outline of the Study

(1) Background to the Study

In Bogotá Plain, with a population of 7 million, the capital city of Colombia, Bogotá D.C., and its neighboring cities are located. The population in the plain is estimated to increase to 9 million in 2015 because of migration from local towns and rural areas as well as natural increase. Public water supply in the metropolitan area depends on surface water sources. Quantity and quality of the public water supply at present reach to sufficient level.

New stable water sources, however, will be necessary to correspond to future population increase and industrial development. Further, alternative water sources for emergency supply have to be urgently developed to avoid social disorder caused by breakdown of water supply facilities at times of natural and social disasters, and to survive during abnormal dry year (or El Niño). Water resources development using surface water will incur higher costs in facility construction as well as in operation and maintenance because the sources will be located in more remote areas due to limited availability of the surface water near the city.

Groundwater development in Bogotá Plain up to the present has been depending on aquifers in comparatively shallow the Quaternary Aquifers. The Groundwater in the Quaternary Aquifers have been fully exploited by now mainly for floriculture and manufacturing industry and further development would be very difficult, on one hand. On the other hand, the promising aquifer in comparatively deep, namely the Cretaceous Aquifer, has yet to be developed. Large interests in the potential of this aquifer are paid as long term and stable water sources.

Bogotá D.C through EAAB formulated a "Groundwater Investigation Plan" and started a study on the Assessment of hydrogeological potential of deep aquifers in Bogota city in 1999. The results obtained so far are still limited due to insufficient data/information and technical capability. A groundwater development plan should be formulated after confirmation of the potential of deep aquifers for stable water supply.

Against the background described above, the Government of the Republic of Colombia requested to the Government of Japan to conduct a "Study on Sustainable Groundwater Development in Bogotá Plain" (herein after referred to as the "Study"). In response to the request, Japan International Cooperation Agency (hereinafter referred to as "JICA") dispatched a preparatory study team, and a scope of work was agreed and signed between the authorities concerned of Colombia and the preparatory study team in July 2000. In accordance with the agreed scope of work, JICA dispatched a team for the Study (hereinafter referred to as the "Study Team") in December 2000, and the Study actually commenced. After Phase-1 stage of the Study (December 2000 – March 2001) was completed, the result of the Study was already reported as a "Progress Report". The result of the Phase I and II studies were described in a "Interim Report". This "Final Report" presents the sequence of the whole study including Phase I, II and III.

(2) Objectives of the Study

The objectives of the Study, targeting the whole area of the Bogotá Plain, are as given below:

- To evaluate potential of groundwater in Bogotá Plain
- To investigate the current situation of the environment related to groundwater
- To formulate a development plan of groundwater
- To conduct technical transfer programs for counterpart personnel in the course of the Study

(3) The Study Area

Targeted area of the Study is Bogotá Plain, where the capital city of Colombia, Bogotá D.C., and its neighboring cities of Cundinamarca department are located. According to GIS database prepared in the Study, the Study area is 4,268 km^2 including 31 municipalities.

(4) Scope and Contents of the Study

The Study has been implemented over three (3) phases.

Phase-1: General Comprehension of Present Conditions
<12/2000 – 03/2001>

The Team conducted field reconnaissance & surveys and preliminary analysis in order to clarify the present conditions of the Study, and to get necessary data for groundwater potential evaluation using such methods as geophysical survey and exploratory drilling.

Phase-2: Study on Groundwater Potential
<05/2001 – 02/2002>

The Team conducted a preliminary evaluation of groundwater potential with data collected and measured in Phase-1 and Phase-2. Effective and efficient evaluation will be pursued with more volume of and more precise data obtained using groundwater simulation and GIS (geographic information system).

Phase-3: Formulation of a Master Plan for Groundwater Development
<05/2002 – 01/2003>

Master Plan including well drilling plans, water supply plans and plan for operation & maintenance has been formulated for the Study Area, while groundwater potential being settled. The Team shall plan a sustainable projection in respects of construction funds and maintenance aspects, considering such conditions as financial situation, managing performance and financial procurement.

1.2 Study Organization

The organization of the study was established to implement effectively the Study and to ensure good communications and transfer of technology to the counterparts as shown in Figure-1.1. The counterpart, namely EAAB (Water Supply and Sewerage Company of Bogotá), established the Steering Committee consisting of the representatives from EAAB, CAR, DAMA, INGEOMINAS, IDEAM, ACCI, etc. The Technical Committee proposed by the Study Team was not established. Because, the Steering Committee has dealt with technical matters as well as steering matters of the Study. The members of the Study Team and the counterpart team are divided into three (3) work groups: Group-A (for Groundwater Resources Potential Study), Group-B (for Groundwater Development Plan) and Group-C (for Project Evaluation), according to their technical specialties.

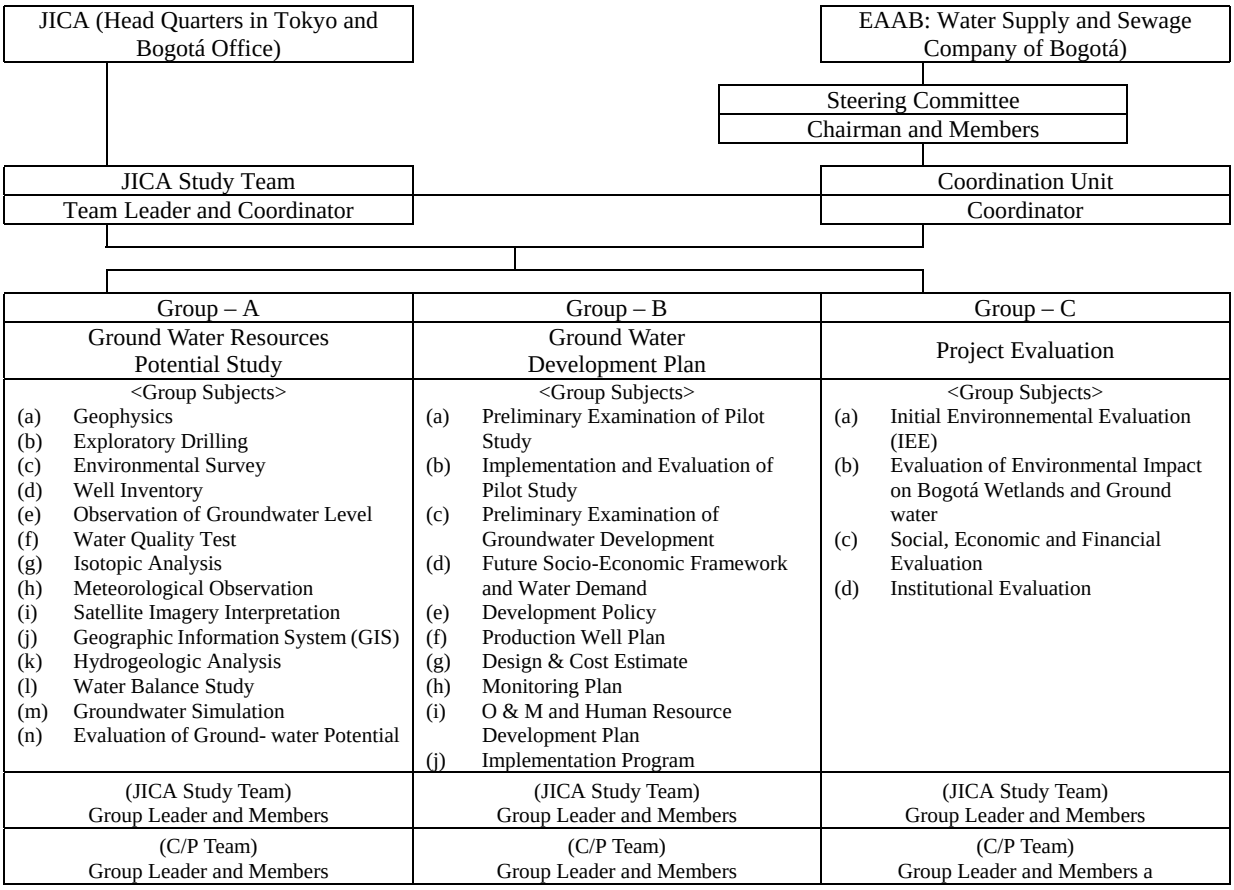

Figure-1.1 General Organization of the Study

1.3 Main Meeting

Main Meetings were held between the Study Team and Counterpart Organizations as shown in Table-1.1.

Table-1.1 Main Meetings

Meeting and Date	Main Subject and Discussion
Inception Report Meeting February 18, 19 of 2000	Main Subject：Comprehensive Study Schemes Discussion：Agreement with Study Schemes of JICA Study Team・Environmental survey on groundwater to be added to the・To use existing study results ・Water quality analysis to be based on Colombian Standards・Water contamination to be also studied in groundwater simulation Others。
Steering Committee Meeting （No.1/Phase 1） January 5, 2001	Main Subject：Organization of the Study Discussion： Technical events also to be discussed in the Steering Committee Meeting, accordingly no Technical Committee to be established Study Team and Counterpart Group to be divided into 3 working groups (A. groundwater potential, B. Groundwater development, C. project evaluation)・Aggressive participation to the study and sending experts to the working groups from respective counterpart organization to be expected
Steering Committee Meeting （No.2/ Phase 1） March 8, 2001	Main Subject：Exploratory drilling well plan and pilot study plan Discussion： The Study Team proposed 4 sites （Ciudad Bolivar、Vitelma, La Aguadora, Subachoque）for exploratory drilling well of EAAB in Phase 2 and also 4（Vitelma, La Aguadora、La Salle およびSubachoque）for pilot study.
Steering Committee Meeting （No.3/ Phase 1） March 15, 2001	Main Subject：Contents of Progress Report and Study Schemes in Phase -2 Discussion： Discussion about study result of Phase 1 by the Team Study schemes in Phase-2（to be prepared by EAAB for：exploratory well、pilot study, metrological station and observation of monitoring well set up in Phase 1）
Steering Committee Meeting （No.1/ Phase 2） June 28, 2001	Main Subject：Monthly Meeting Discussion： Introduction of new members・IDEAM and ASOCOLFLORES newly joined. Unified management of data related to groundwater・To hold Steering Committee Meeting on every last Thursday of the month

Meeting and Date	Main Subject and Discussion
Steering Committee Meeting (No.2/ Phase 2) July 25, 2001	Main Subject：Monthly Meeting Discussion：・IDEAMA and CAR have agreed with well database information exchange, and so the Study Team can confirm the progress making contact with them. ・To unify the groundwater data owned by organizations related to the groundwater management and to build them in the database of this Study To discuss more about administrative organization and structure on groundwater in Bogotá Plain ・ACCI will make a check signature on the minutes hereafter.
Steering Committee Meeting (No.3/ Phase 2) August 30, 2001	Main Subject：Monthly Meeting Discussion：・Administration system of groundwater・To establish 3 monitoring wells・To establish meteorological stations・The Study Team asked related organizations to provide data for well inventory study. ・The Study Team explained groundwater simulation（2 model：large area and study area）・Counterpart training
Steering Committee Meeting (No.4/ Phase 2) September 27, 2001	Main Subject：Monthly Meeting Discussion：・EAAB explained the reason for delay of exploratory drilling well. The necessity of exploratory drilling well in Subachoque basin was explained by EAAB. The location of 11 meteorological stations・Authorization is required for provision of information from INGEOMINAS・Water balance analysis requires hydrological data owned by CAR・Presentation of result on isotopic analysis
Steering Committee Meeting (No.5/ Phase 2) October 25, 2001	Main Subject：Monthly Meeting Discussion：・EAAB explained the development of Vitelma exploratory drilling well・Agreement on location of 11 meteorological stations・The Study Team explain the improvement of existing groundwater simulation model.・Work Shop concerning water balance and simulation will be held every Thursday.・Plan of CAR regarding groundwater recharge in Subachoque
Steering Committee Meeting (No.6/ Phase 2) November 29, 2001	Main Subject：Monthly Meeting Discussion：・EAAB explained the development of Vitelma exploratory drilling well・Area survey result revealed the exploratory area in Subachoque proposed by CAR would be unsuitable・Progress of well inventory study . EAAB proposed joint survey on wells. ・The Study Team requested to complete Vitelma exploratory drilling well soonest possible.
Steering Committee Meeting (No.7/ Phase 2) January 17, 2002	Main Subject：Monthly Meeting Discussion： The Study Team reported preliminary result of water balance and large area simulation・Progress of database preparation
Steering Committee Meeting (No.8/ Phase 2) February 19, and 20 of 2002	Main Subject：Monthly Meeting Subjects to be discussed in the coming Steering Committee Meeting：Final results of phase 2 by the study team. Counter part request training on visual modflow. CAR will submit the last results of the water level monitoring campaign. Study team will delivery the list of information required for phase 2 from all entities. EAAB will submit the progress report to the counterpart members and will finish all the drilling works at Vitelma site. Study team will submit the results of chemistry analysis of data of phases 1 and 2 on the Steering Commettee. ・Schemes in Phase-3 study
Steering Committee Meeting (No.1/ Phase 3) June 13 of 2002	Main Subject：Monthly Meeting Discussion： Study Team explained content of Phase-III.・EAAB explained progress of well inventory by Colombian side. EAAB explained progress of Vitelma drilling and result of pumping test.
Steering Committee Meeting (No.2/ Phase 3) July 25, and 20 of 2002	Main Subject：Monthly Meeting Discussion：Study Team explained integrated explanation on Water quality analysis and isotope analysis. Study Team proposed establishment of work group for planning of groundwater development/conservation of Eastern hills and groundwater conservation in western Bogota Plain.
Steering Committee Meeting (No.3/ Phase 3) October 10 of 2002	Main Subject：Monthly Meeting Discussion：Study Team explained progress on analysis of groundwater recharge. Hand over of groundwater simulation model and other analyzed results by Study Team to Colombian side. Study Team explained progress on formulation of groundwater development/conservation project. .
Steering Committee Meeting (No.4/ Phase 3) November 28 of 2002	Main Subject：Monthly Meeting Discussion：Study Team explained result of groundwater recharge analysis and groundwater flow of the Study Area. Study Team explained groundwater development and conservation project in Eastern Hills and conservation project in western Bogotá Plain.
Steering Committee Meeting (No.5/ Phase 3) January 16 of 2002	Main Subject：Draft Final Report Discussion：Discussions on Draft Final Report are to be made , and results of the discussions are to be summarized as Minutes of Meeting

1.4 Workshop

The Study Team opened workshops in Phase-I to Phase-III. The workshops were opened on each study item when necessary. In the workshop, the Study Team explained the contents and the progress of the Study. Active discussions occurred between the Study Team and Colombian side on the Study contents, analysis method and its result. The Colombian side also made presentations on the topics that were requested by the Study Team. Through the workshops above, technical transfer was carried out to Colombian side, and the Study Team obtained precious information on the study items from Colombian side. Especially, in the workshops, the results of the existing studies by the Colombian side and the interpretations for them were made clear by Colombian side. Moreover, problems in the implementation of the Study were made

clear and the precious proposals and opinions for the solution of them were proposed from Colombia side. The Study items were deeply examined by both the Study Team and Colombian side in the workshops. The topics of the workshop in all the Study period are shown in Table-1.2.

Table-1.2 Result of Workshop

Phase	No		Data	Topics of the Workshop
Phase-I	1	WS-1-1	Jan.09, 2001	- Exploratory Drilling
	2	WS-1-2	Jan.26,.2002	- Wetland of Bogotá Plain, - Wet land of Bogotá City - Duty of EAAB of management of wetland of Bogotá City
	3	WS-1-3	Feb.12, 2001	- Method of evaluation of groundwater potential - Hydrological Characteristics of Bogotá Plain - The result of the existing geophysical survey - Management of wetland by EAAB
	4	WS-1-4	Feb.14, 2001	- Integrated water resource management project - Management of groundwater resource by DAMA - Management of groundwater resource by CAR - Policy for institutional evaluation
	5	WS-1-5	Feb.19, 2001	- Land use plan of Bogotá City, - Water demand of Bogotá City - Land use plan of Bogotá Plain, - Water demand of Bogotá Plain
	6	WS-1-6	Mar.06, 2001	- Progress of exploratory drilling, - Drilling plan of Phase-II
	7	WS-1-7	Mar.06, 2001	- Plan of Pilot Study of Phase-II
	8	WS-1-8	Mar.06, 2001	- Proposed groundwater simulation - The existing groundwater simulation model
	9	WS-1-9	Mar.06, 2001	- Water quality analysis and isotope analysis - Water quality of Bogotá Plain, - Water quality of Bogotá City - The existing isotope analysis
Phase-II	1	WS-2-1	July.06, 2001	- Pilot Study, - Exploratory Drilling, - Water Quality, - GIS
	2	WS-2-2	July.19, 2001	- Artificial Recharge Pilot Study
	3	WS-2-3	Sep.21, 2001	- Groundwater Management
	4	WS-2-4	Oct.04, 2001	- Water Balance Study, - Groundwater Simulation
	5	WS-2-5	Oct.11, 2001	- Meteorological Observation, - Well Inventory Survey
	6	WS-2-6	Oct.18, 2001	- Water Balance Study, - Groundwater Simulation
	7	WS-2-7	Nov.08, 2001	-Water Balance Study, - Groundwater Simulation - Artificial Recharge Test
	8	WS-2-8	Nov.15, 2001	- Water Balance Study, - Groundwater Simulation
	9	WS-2-9	Nov.22, 2001	- Meteorological Analysis, - Hydrological Analysis - Groundwater Simulation
	10	WS-2-10	Dec.06, 2001	- CSMAT Exploration, - Water Balance Study - Hydrological Analysis
	11	WS-2-11	Dec.13, 2001	- Water Balance Study, - Groundwater Simulation
	12	WS-2-12	Dec.20, 2001	- Water Balance Study, - Hydrogeological Study
	13	WS-2-13	Jan.10, 2002	- Groundwater Potential, - Artificial Recharge Projection - Groundwater Simulation
	14	WS-2-14	Jan.17, 2002	- Groundwater Simulation
	15	WS-2-15	Jan.24, 2002	- Water Demand, - Groundwater Simulation
	16	WS-2-16	Jan.31, 2002	- GIS, - Water Quality, - Groundwater Simulation
	17	WS-2-17	Feb.07, 2002	- Groundwater Simulation
Phase-III	1	WS-3-1	Jun.20, 2002	- Land subsidence, -GIS
	2	WS-3-2	Jun.27, 2002	- Water balance analysis
	3	WS-3-3	Jul.4, 2002	- GIS, -Water balance analysis by CAR
	4	WS-3-4	Jul.11, 2002	- Water quality Analysis
	5	WS-3-5	Jul.23, 2002	- Water balance analysis
	6	WS-3-6	Aug.1, 2002	- Vitelma pumping test
	7	WS-3-7	Aug.8, 2002	- Water balance analysis, - Groundwater simulation
	8	WS-3-8	Aug.15, 2002	- Water balance analysis
	9	WS-3-9	Nov.15, 2002	- Water balance analysis, - Groundwater simulation
	10	WS-3-10	Nov.22, 2002	- Water balance analysis
	11	WS-3-11	Nov.14, 2002	- Water quality Analysis
	12	WS-3-12	Nov.22, 2002	- Water quality Analysis

1.5 Technical Transfer Seminars

Technical transfer seminar was opened twice during the Study period. The outline of the seminars is summarized in Table-1.3.

Table-1.3 Summary of Technical Seminar

No	Date	Place	Lecturer	Content
First	22nd, Feb. 2002	Hall of EAAB office in Calle 71.	Mr. Masatomo WATANABE	Progress of Study
			Mr. Carlos MOLAO	Groundwater of Bogotá Plain
			Mr. Sigifredo TENJO	Groundwater management of CAUCA Valley
Second	16th, Jan. 2003	Hall of EAAB training facilities in La Aguadora	Dr. Kenji JINNO	Groundwater development and conservation
			Mr. Masatomo WATANABE	Final result of the Study
			Mr. Hiroshi NAKAMURA	Investigation of groundwater
			Mr. Naoki HARA	Institution of groundwater management

(1) First Technical Transfer Seminar

Presentation by Study Team

The first technical transfer seminar was opened in February 2002, at the end of Phase-II of the Study. Mr. WATANABE, reader of the Study Team, made presentation on progress and interim result of the Study by Phase-II. The Content of the presentation was on all the Study progress especially on interim result of groundwater recharge and groundwater simulation. In addition to this, promising sites for new groundwater development and possibility of artificial recharge were proposed.

Presentation from Colombian side

There were two presentations from Colombian side. The first presentation was by Mr. Carlos MOLAO, a lecturer at Los Andes University, and the second was by Mr. Sigifredo TENJO, an engineer of CVC. Mr. Molano made presentation starting from on groundwater flow mechanism, then on groundwater flow and hydrogeology of Bogotá Plain, which include scientific topics. Mr. Sigifredo TENJO made presentation on project of groundwater development and management of CAUCA Department. This project is highly evaluated in Colombia as most successful one and was precious information for this Study.

Response to presentation by Study Team

To this seminar, there were many attendants form not only C/P organization of this Study, but also from various organizations such as Bogotá City, governmental organizations, universities and municipalities around Bogotá City. The contents of the presentation by the Study Team gave important new information to attendants. These were, ① the amount of current groundwater pumping in Bogotá Plain, ② groundwater recharge of the Study Area, ③ promising sites for groundwater development of Cretaceous aquifers, ④ groundwater conservation by artificial recharge.

①The current pumping rate in Bogotá Plain was partly investigated in the past by Colombian side. By this Study, the total amount of pumping was made clear for the first time. ②In the past, Colombia side estimated amount of groundwater recharge of the Study Area. However, newly estimated groundwater recharge by the Study was much higher than this and caused big interest of Colombian side in its method and result. ③The Study Team proposed Eastern Hills of Bogotá Plain as promising site for new groundwater development, where there was little groundwater development in the past. This idea was fresh to Colombia side. ④Artificial recharge has not yet conducted in the Study Area, and this plan attracted attendants' attention.

(2) Second Technical Seminar

The second technical seminar was held at the last stage of the Study, January 2003. From the Study Team, Mr.Watanabe (team leader and in charge of groundwater development), Mr.Nakamura (in charge of hydrogeology A), Mr. Hara (in charge of institution/human resource development) explained the result of this Study. Mr. Jinno, professor of Kyushu University of Japan, was invited to the seminar as special lecturer from Japan, who made presentation on groundwater use in Japan and subjects related to groundwater development and conservation.

Presentation by Professor Jinno

Professor Jinno, at first, introduced the current groundwater use in Japan and availability of groundwater. Then, he explained problems that were caused by extraction of groundwater: In Japan, 86% of the total water use depends on surface water, and 14% of the total water used depends on groundwater. Groundwater is evenly used for industry, water supply and irrigation. On the other hand, it is estimated that total volume of groundwater in current use is more than total volume of groundwater water recharge in Japan, which caused serious problems of groundwater environment such as land subsidence and sea-water intrusion. Against these problems, many studies and researches were carried out and regulations relating to groundwater disaster were formulated. In recent years, groundwater contamination was made known to the public, which caused serious social problems. As countermeasures of the problems, new regulations were formulated and methods for investigation and remediation against contaminated soil and groundwater were proposed and put into practice. What is most important for settling the problems of groundwater environment is: i) more realistic study to understand real situation, ii) collaboration with experts in different research area, iii) importance of key person to integrate each research.

Presentation from the Study Team

Mr.Watanabe, Team Leader of the Study, explained out line of the Study results: Potential for groundwater development was evaluated based on water balance of the Study Area. Also the current groundwater use in the Bogotá Plain was made clear. Base on the results above, it was concluded that groundwater could be developed corresponding to the potential of each area. This conclusion and predicted water demand led to proposal for 2 projects: i) groundwater development and conservation in Eastern Hills of Bogotá Plain, ii) groundwater conservation of area of high groundwater use in Bogotá Plain. Project evaluation concluded that these projects were feasible.

Mr. Nakamura, hydrogeologist of the Study Team, explained results of study on groundwater potential: Groundwater development potential was estimated by groundwater recharge, which was evaluated based on water balance analysis. In this analysis, groundwater recharge was calculated from precipitation, real evapo-transpiration and river discharge. The resulted value of groundwater recharge was 144mm/year. This value was clarified by groundwater simulation.

Mr. Hara, in charge of institution/human resource development of the Study, made presentation. In his presentation, at first historical changes in ownership of groundwater over the world, as well as concepts and trends of groundwater management after the shifts of the ownership to the public domain, were overviewed. Secondly, concepts of groundwater in Japan were outlined, where groundwater ownership still belongs to the private. Then, proposals for institutional improvement and human resource development were summarized.

Response to presentation

Professor Jinno of Kyushu University made presentation on current groundwater use and

problems of groundwater environment, which caused deep interests from attendants of the Seminar. The attendants of Colombian side made many questions showing their awareness that the same problems as occurred in Japan will also occur in Colombia in the near future. Especially, topics on land subsidence, groundwater contamination and current regulation against it brought about many questions to Dr.Jinno from Colombian side. In the presentation, Dr.Jinno suggested methodology of groundwater investigation desirable to be carried out in the near future in Colombia.

The Study Team made presentation on results of the Study. The Study Team appealed results of the Study to more people in the Seminar than in usual meetings that were held before by the Study Team to explain progress of the Study. In the presentation, resultant groundwater recharge of 144mm/year by the Study Team, which has important meaning in future groundwater development, brought about strong interests of Colombian side. Moreover, it seemed that necessity of two proposed projects on groundwater development and conservation was firmly accepted by Colombian side.