3.9 Meteorological Observation

The Study Team installed eleven meteorological stations for the purpose of meteorological observation of the Study Area.

(1) Sites for Installation of Meteorological Stations

Meteorological observation stations were installed in eleven sites as shown in Figure-3.11. These sites were selected after discussions among the Study Team, EAAB, CAR, IDEAM, and INGEOMINAS. Eleven sites were finally installed in hills and mountains in the Study Area, where meteorological data has not obtained fully until the present day. Installed meteorological stations by the Study Team are connected to the existing meteorological observation network, and observed result is shared by all the relating organizations. In the selection of the sites for the installation, it was examined that sites should have not only importance in meteorological observation but also security against theft and destruction.

1) Tomine	2) Suesca	3) Casa Loma	4) EL tablazo
5) El Vino	6) Cruz verde (Bojaca)	7) Paramo de Guerrero	8) Siecha
9) Aguas claras (Muna)	10) Dona Juana	11) Manjui (Chia)	

(2) Items for meteorological observation and Instruments

Items to be observed are listed below.

1) Wind speed and direction	2) Precipitation	3) Humidity	4) Temperature
5) Sunshine Hour	6) Evaporation	7) Solar Radiation	

(3) Meteorological Observation

Installation of meteorological stations was completed at the end of February 2002, and then observation stared. The result of observation was used efficiently for climate analysis in the Study.

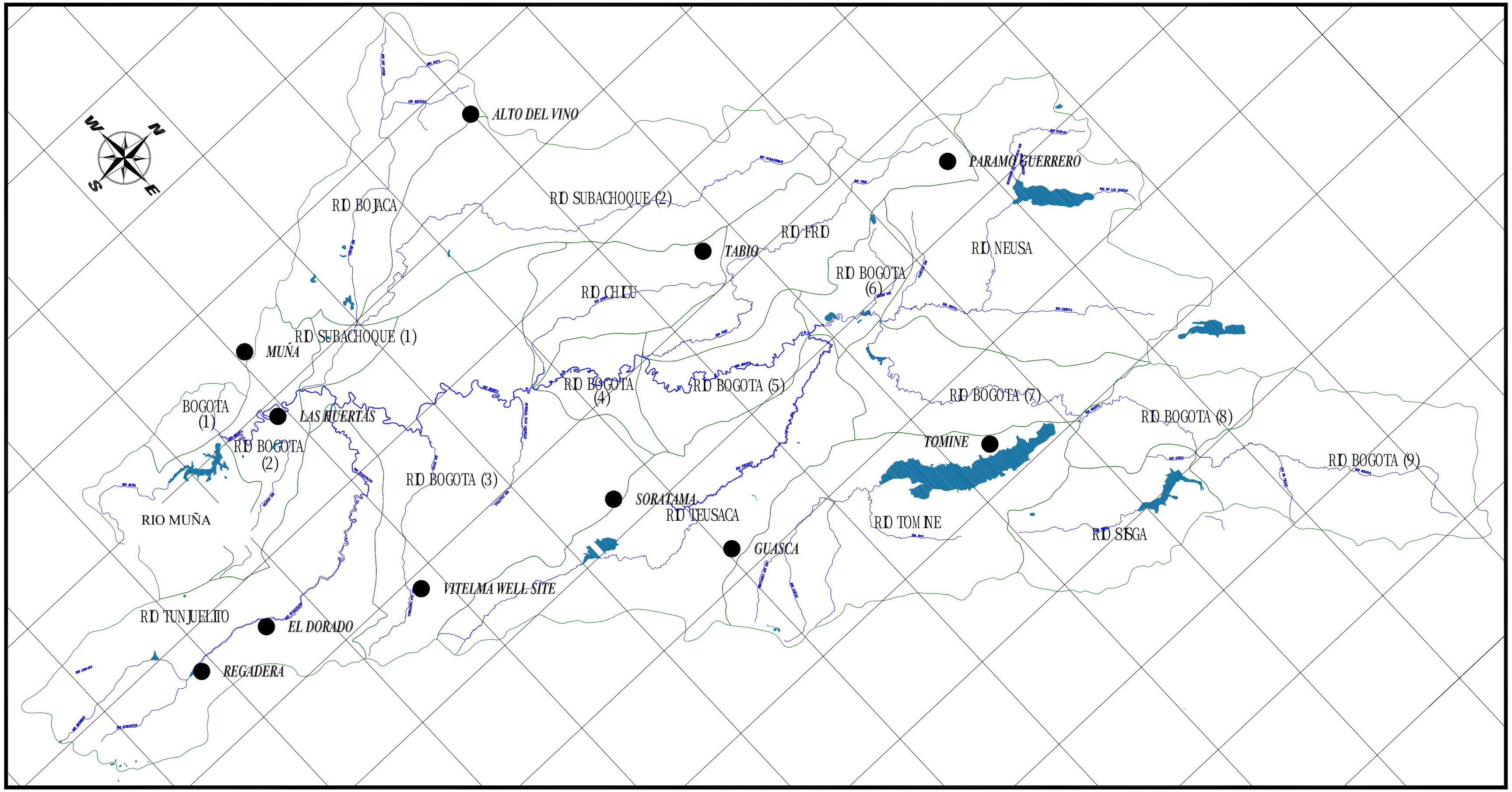

Figure-3.11 Sites for Installation of Meteorological Stations

3.10 Pilot Study

Pilot Study for artificial recharge was implemented by actually injecting water into wells to clarify its possibility and problem, and to obtain basic information to formulate a plan of artificial recharge project.

(1) Selection of Pilot Study Site

JICA Study Team proposed four sites for Pilot Study for artificial recharge.

① Vitelma
② La Aguadora
③ La Salle
④ Subachoque

The target of artificial recharge in site ①～③ is Cretaceous Formation and Quaternary in site ④. Pilot Study for artificial recharge into Cretaceous Formation was examined in this Study. From the proposed sites of ①～③, ①Vitelma site was finally selected for site for Pilot Study. The reasons are listed below:

- San Cristobal River flows near Vitelma site, where it enough water is supplied during the Pilot Study period.
- There is a settling pond of EAAB in Vitelma site. Therefore, it is easy to obtain clean water for Pilot Study.
- Vitelma site is located at the altitude of 2,800m. It seems no possibility of flowing well and suitable for Pilot Study.

(2) Method of Pilot Study

Procedure of the Pilot Study (artificial recharge test) is as follows.

EAAB drilled two wells in Vitelma site, one well for artificial recharge and the other for observation. Geological condition of wells are described in Table-3.13

Table-3.13 Geological condition of Vitelma Well

Well	Depth	Diameter	S.W.L.	Geology	Depth	Rock face
Recharge well	300m	8 inch	GL-6.63m	Colluvial	0-22	Gravel, sand, silt
				Labor ·	22-1	Sandstone dominant alternation
				Chipaque	180-	Shale
Monitoring well	240m	4 inch	GL-6.84m	Colluvial	0-36	Gravel, sand, silt
				Labor ·	36-1	Sandstone dominant alternation
				Chipaque	188-	Shale

Note) S.W.L. of monitoring well is from ground level of recharge well.

According to the pumping test in Vitelma wells, specific capacity of recharge well is 62m^2/day, which shows high production capacity of this well. The distance between two wells is 120m and the influence on the monitoring well was observed within 15 minutes after pumping stated. This result shows that response between wells of Cretaceous aquifer is vary fast because of highly confined state of Cretaceous aquifer. Therefore, it is expected that the effect of artificial recharge will travel fast toward surrounding wells.

(3) Procedure of Pilot Study

Procedure of Pilot Study is shown in Figure-3.12.

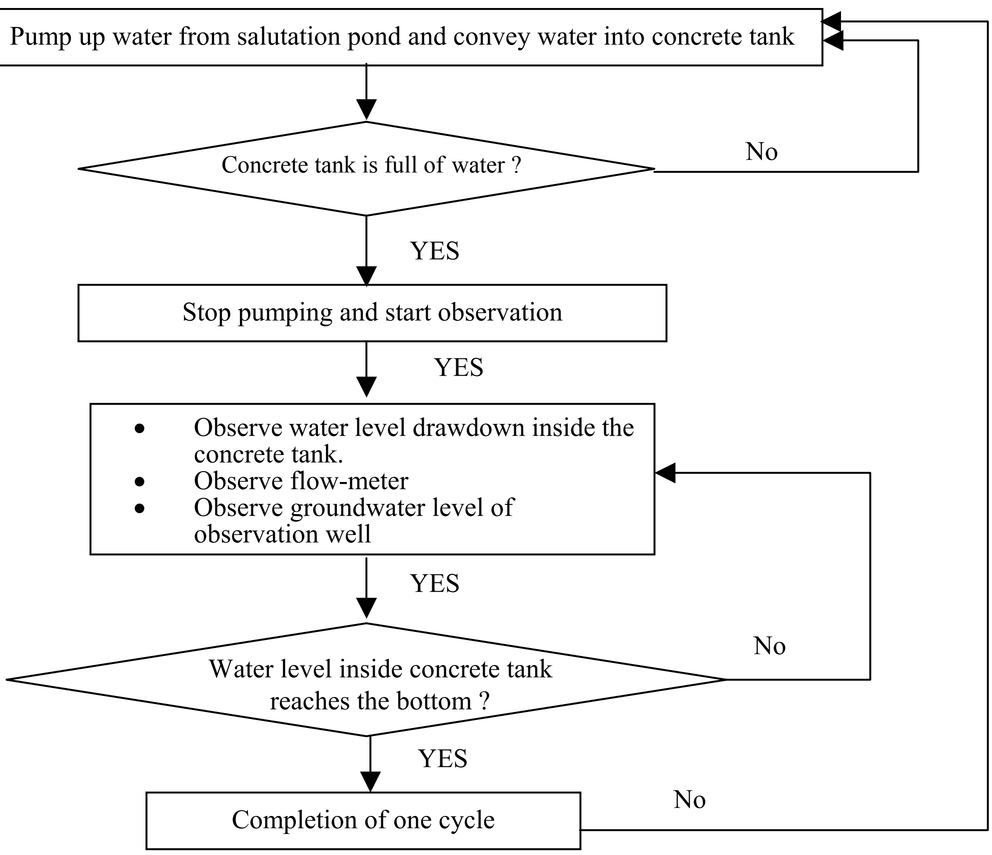

Figure-3.12 Observation Cycle of Pilot Study

(4) Result of Pilot Study

One example of the result of the Pilot Study is shown in Figure-3.13. Figure-3.13 shows fluctuation of groundwater level inside recharge well during water injection, from16th to 26th of Nov. 2002. This result is summarized in Table-3.14.

Table-3.14 Result of Artificial Recharge

Injection rate	Pressure head of injection	Specific injection	Specific capacity in Pumping Test
864 m^3/day	8.41 m	103 m^2/day	69 m^2/day (pumping rate1,296 m^3/day)

Efficiency of artificial recharge is judged from specific injection (=injection rate/increased groundwater level in well). Specific injection has almost the same meaning of specific capacity. The former shows the capacity of injection and the latter shows capacity of pumping. Specific injection will decrease as injection rate increases. Specific injection of 103m^2/day in Table-3.14 is for the injection rate of 864m^2/day. From the Pilot Study, it was proved that the value of specific injection is more than that of specific capacity of the pumping test.

It is expected that efficiency of artificial recharge will decrease with continues injection. Injection rate is so far gradually decreasing from 1,300 to 864m^3/day. It is due to clogging of aquifer surrounding recharge well. However, injection rate will recover by pumping.

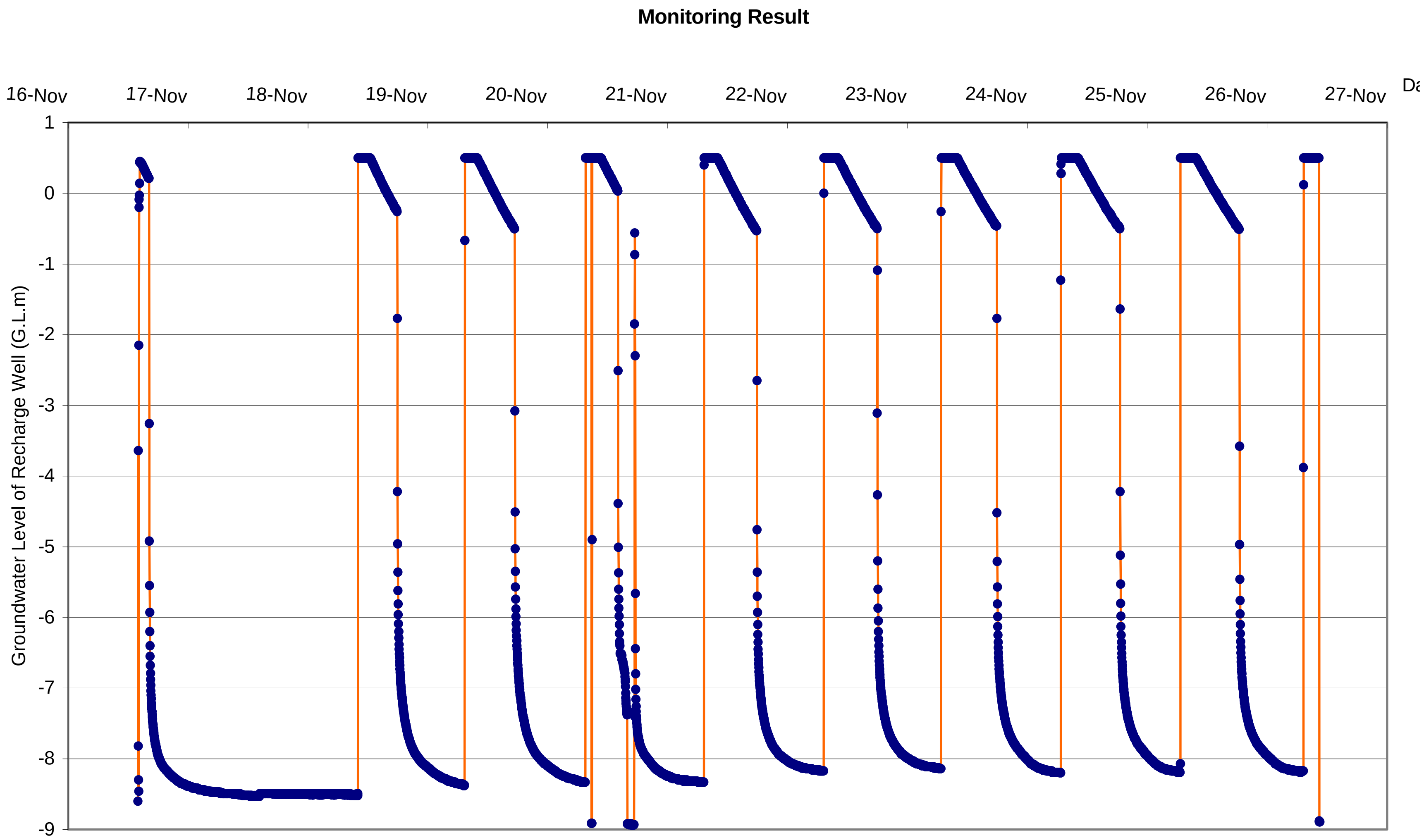

Figure-3.13 Result of Pilot Study

3.11 Reparation of GIS Database

The JICA study introduced GIS system to support construction of database for the survey results in order to unified management of groundwater information. There were some dispersed situations among agencies about GIS and database relating to the groundwater development in Colombia. Each organization has developed system indipendently with holding many dificulties for the data sharing.

Production of database in the study also was influenced with these situations. Therefore, it was hard to collect data resource especially digital data.

GIS system includes equipments such as ArcView 3.2 (ESRI corporation), Personnel computer, input devices and output devices and the networking. See Figure-3.14. GIS database was defined about data specification of GIS data as shown in Table-3.15. Items of GIS database are shown in Table-3.16.

(1) Base map

Base maps were compiled to thematic maps that were able to produce from topographic map by using digital topographic map (1:100,000) from IGAC. Necessary location maps and other were produced drawing files of AutoCAD. See Figue-3.15.

(2) Satellite image data

Satellite image data were arranged to be able to treat thematic maps in the system. These data include color composite image, land cover map and other thematic maps to support geological interpretation. To recover the area covered by thick clouds in the data of phase1 and to produce the thematic map for hydrogeology interpretation, ESPACIO MAPAS was purchased (Figure-3.16). Edge enhanced image as in Figure-3.17 was produced for geological interpretation. This satellite image of LANDSAT5-TM in 1995 was supported by IGAC.

(3) Existing well inventory data

Results of the inventory was compiled to database for GIS. Those of INGEOMINAS were imported to ArcView directly.

(4) Meteorological database and hydrological database

Monthly average data of meteorological data and hydrological data of the total of 158 gages belonging to EAAB, IDEAM, CAR, and EEEB were edited and compiled for GIS database. Items of the first data are precipitation, temperature, humidity, evaporation, solar radiation and the second is mean discharge m^3/sec.

(5) Topographic and geological database

Thematic maps of elevation, topography, geology and hydrogeology were produced based on the existing data resources and the results of survey. As a result, thematic map was produced for GIS database. Elevation map was contour map of 100 meters and DEM (Digital elevation Model) from topographic maps. River stream and river basin were interpreted by the study and land form map was compiled from existing map and geological map in Figure-3.18 were delineated about geological unit and linear structure of geology by the study with reference of that of INGEOMINAS. Parameters of hydro geological characteristics to examine due to the groundwater simulation according to the well inventory data were linked to the geological unit in Figure-3.19.

(6) Land use map and land use planning map

Thematic maps to show the present status and the feature land use were produced to compile POT among municipalities in Figure-3.21.

(7) Administrative boundary map and relevant statistic data

Administrative boundary used for latest national census survey by DANE in 1993 and administrative boundary in 2000 (Figure-3.20) were produced to GIS data. .Results of the census of DANE was used as properties of these maps which contain the data of population and water demand. Sector map of Bogotá city used for the water demand study in EAAB was also added in the database.

(8) Water demand map

Simulation map of water demand in 2015 was produced by the direct link between data and administrative boundary based on the result of water demand analysis for evaluating and simulating the administrative boundary unit.

(9) Water supply facility map and sewerage facility map

Data of EAAB and POT in municipalities were edited and unified. Thematic maps in main pipe line and drainage, facilities relating to tank, pumping station and others were produced (Figure-3.22).

(10) Environmental conservation map

Thematic map of environment conservation map was produced to show natural environment, ecology, and protection and conservation of wetland by data of POT and CAR.

(11) Hazard zones and historical map

Hazard zones and historical map were produced by the editing of POT among municipalities about hazard zone map and risk map relating natural disaster of erosion, earthquake, mass movement, inundation and others. Legends of POT data was arranged and unified from different items among municipalities. See Figure-3.23

(12) Observation data and Visualization map of the observation data

Observation data of water quality and pumping test were produced as GIS data of wells. To produce maps from the results of water quality analysis, well inventory and geophysics exploratory survey, following thematic maps were produced:

water quality map processed by visualization of water quality map in Figure-3.24 with the interpolation calculation module from well data, well depth distribution map in Figure-3.25 processed by query and overlay from data of well inventory and thematic map of result of CSAMT exploratory in Figure-3.26 to display data on ArcView.

In the process of database production it became obvious that there were some issues about data situation at the present as follows:

- Difficulties for the use of digital data, arrangement and unification of existing well data with dispersion,
- Differences of accuracy and quality among data
- Closed information of data specification
- Delay for digitalization
- Existence of different map projection

Especially problems about map projection made various kinds of data affect. Therefore, it is hard to share a common consensus. Through the process of database production in the study, it is expected that participants recognize necessities of data preparation again and these will be accelerated to the feature. It is also necessary to establish a guideline in the procedure of production and data specification for database.

As the technology transfer of GIS in the study, the follow carried out operation and management of ArcView and management of database.

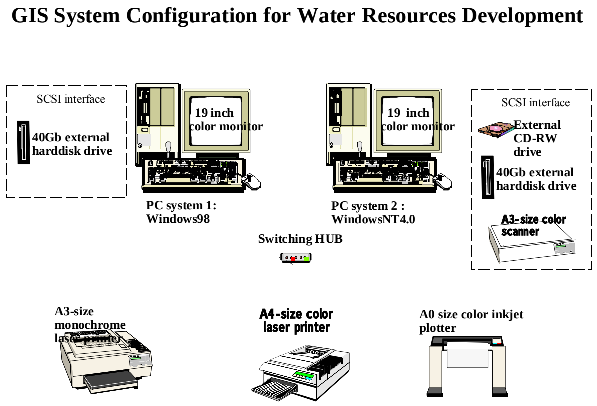

Figure-3.14 System Configuration of GIS equipment

Table-3.15 Definition of GIS data

Definition of database	Contents
Range of map coordinate of X (EAST)	940,000 m - 1,070,000m
Range of map coordinate of Y (NORTH)	960,000 m - 1,080,000m
Origin of GRID CELL : (X, Y)	X = 940,000 m, Y = 1,080,000m
Resolution of DEM and GRID CELL	100m, 250m, 500m
Map projection	Gauss conformed
ESFEROID:	International
ZONE ORIGEN GEOGRAPHICAL COORDINATES:	LATITUD; NORTH 4 ° 35 ' 56.57"
	LONGITUDE; WEST 74° 04 ' 51.30 "
PLAIN COORDINATES;	1'000.000 METRERS NORTH;
	1'000.000 METRERS EAST;
VERTICAL DATUM:	MEAN LEVEL OF THE OCEAN IN BUENAVENTURA
HORIZONATAL DATUM:	BOGOTA

Table-3.16 List of GIS database

Database item	Contents of database
(a)Base map	Compilation map of topographic map of 1:100,000 topographic map from IGAC including contour line, road, administrative boundary, river, settlement, annotation of topographic map etc.
	A series of AutoCAD files about the survey activity
(b)Satellite image database	Color composite image, Land cover map, Normalized Vegetation Index map, Edge enhancement map for geological interpretation.
(c)Well inventory database (Result of survey)	Results of existing wells inventory
(d)Meteorology and hydrology database(Observation data)	Monthly data at the meteorological observation station: Precipitation, Temperature, Humidity, Evaporation, Solar Radiation. Monthly data at the hydrological observation station: Mean discharge(m3/sec), Flood discharge hour(hours)
(e)Topographic and geological Database	Contour map
	DEM(100meter, 250meter, 500 meter)
	River stream map
	River basin map
	Land form map
	Geological map
	Hydro geological map
(f)Land use map	Land cover map from satellite image data
	Present land use map, land use planning map
(g)Administrative boundary map and relevant statistic data (Statistic data)	Administrative boundary map of municipality in 1993, 2000, Sector map of Bogotá City
	National census survey data in 1993 and the other statistic data related to data analysis of water demand analysis.
(h)Water demand map	
(i)Water supply facilities and sewerage facilities	Water supply network and water supply facilities
	Sewerage network, drainage, and sewerage facilities
(j)Environmental conservation map	Protection area and Conservation area for ecological protection and protection for development
(k)Hazard zones and historical map	Inundation, soil erosion, landslide, zoning map of seismic hazard and etc.
(l)Observation data and Visualization map of observation data	Well map for water quality, Well map for pumping test
	Water quality of wells distribution map
	Well depth distribution map
	CSAMT exploratory map(Observation data)

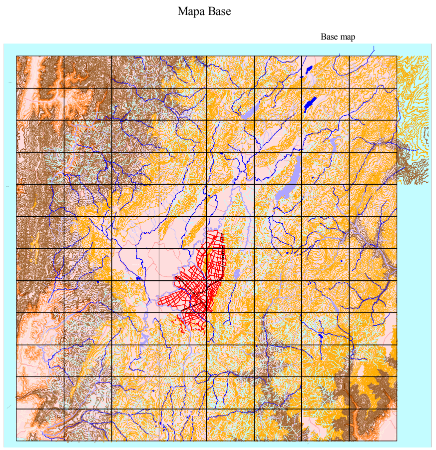

Figure-3.15 Base map in the study

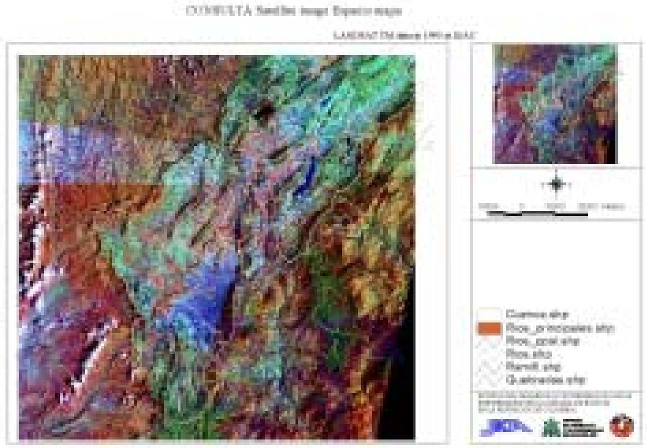

Figure-3.16 Spatial Map of LANDSAT5 from IGAC in 1995

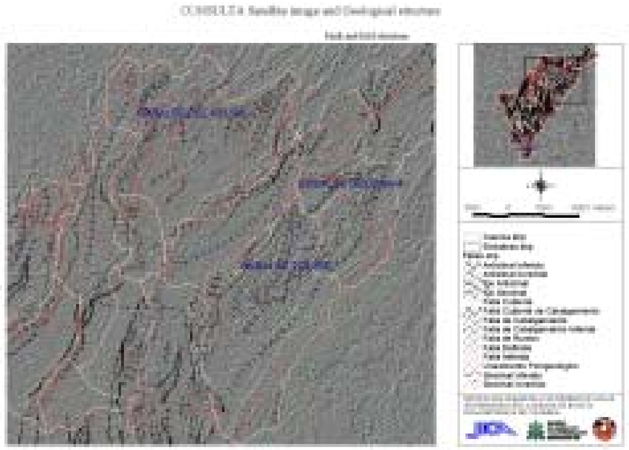

Figure-3.17 Edge enhance image of NW direction

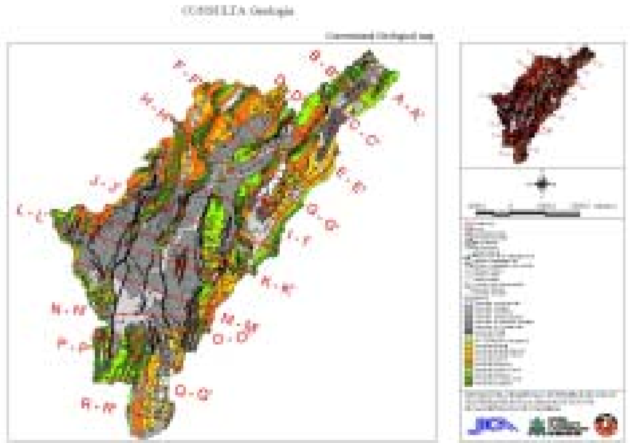

Figure-3.18 Conventional geological map in the study

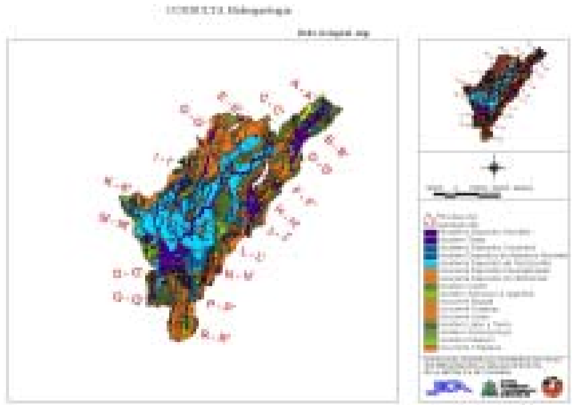

Figure-3.19 Hydro geological map

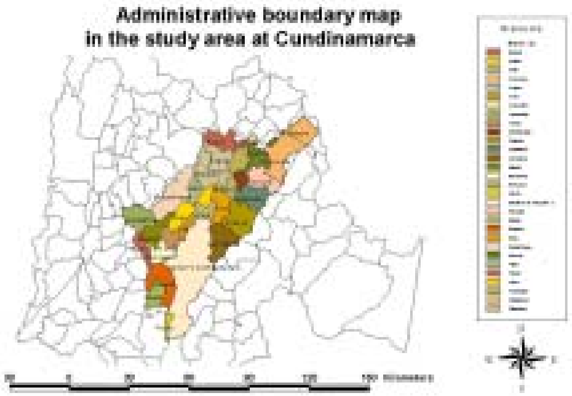

Figure-3.20 Administrative boundary map of DANE2000

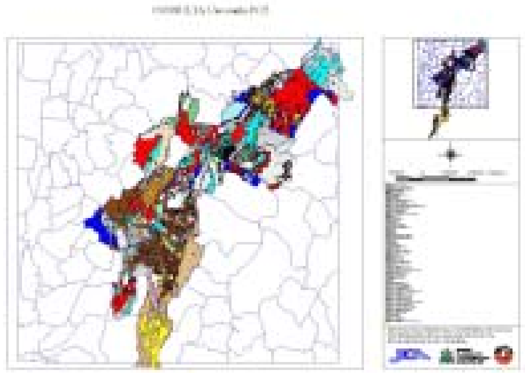

Figure-3.21 Compiled land use and land use planning map in POT

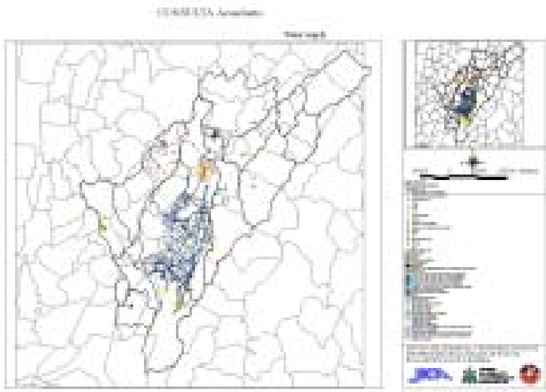

Figure-3.22 Compiled water supply map of POT

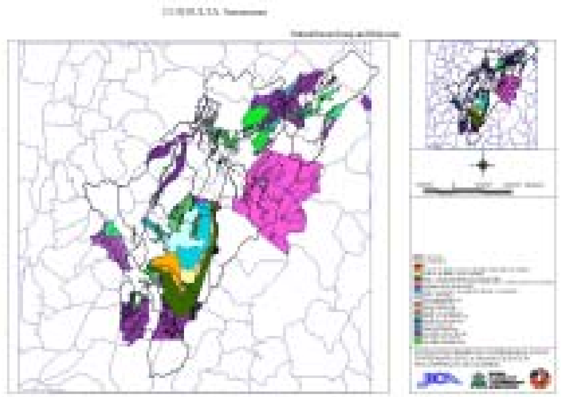

Figure-3.23 Natural hazard map and risk map

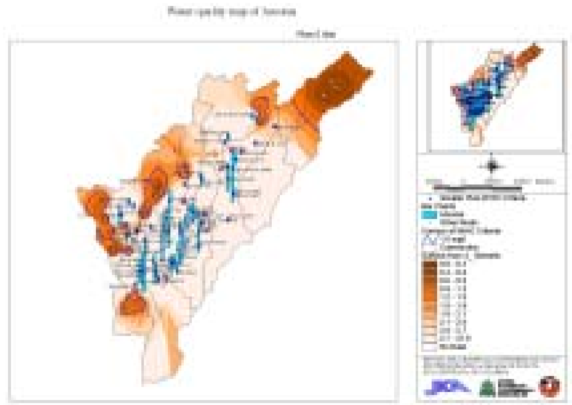

Figure-3.24 Example of water quality map of Ammonia

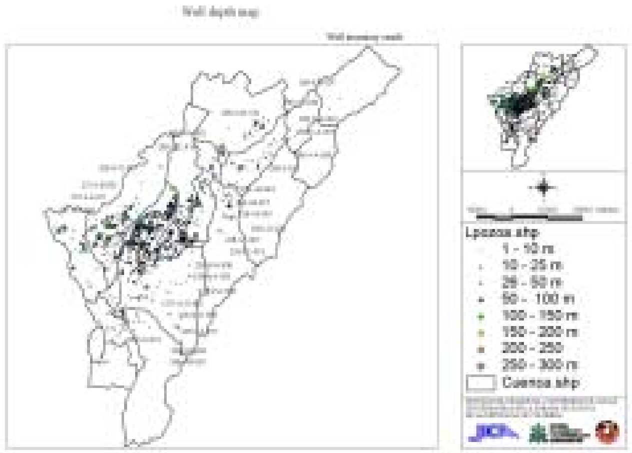

Figure-3.25 Example of well depth map

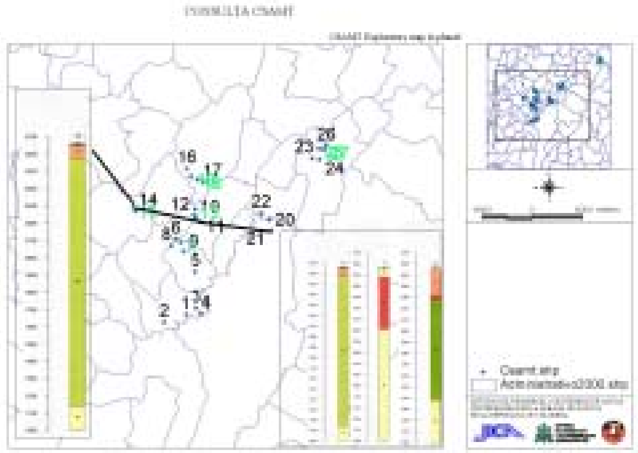

Figure-3.26 CSAMT Geophysics explorer map