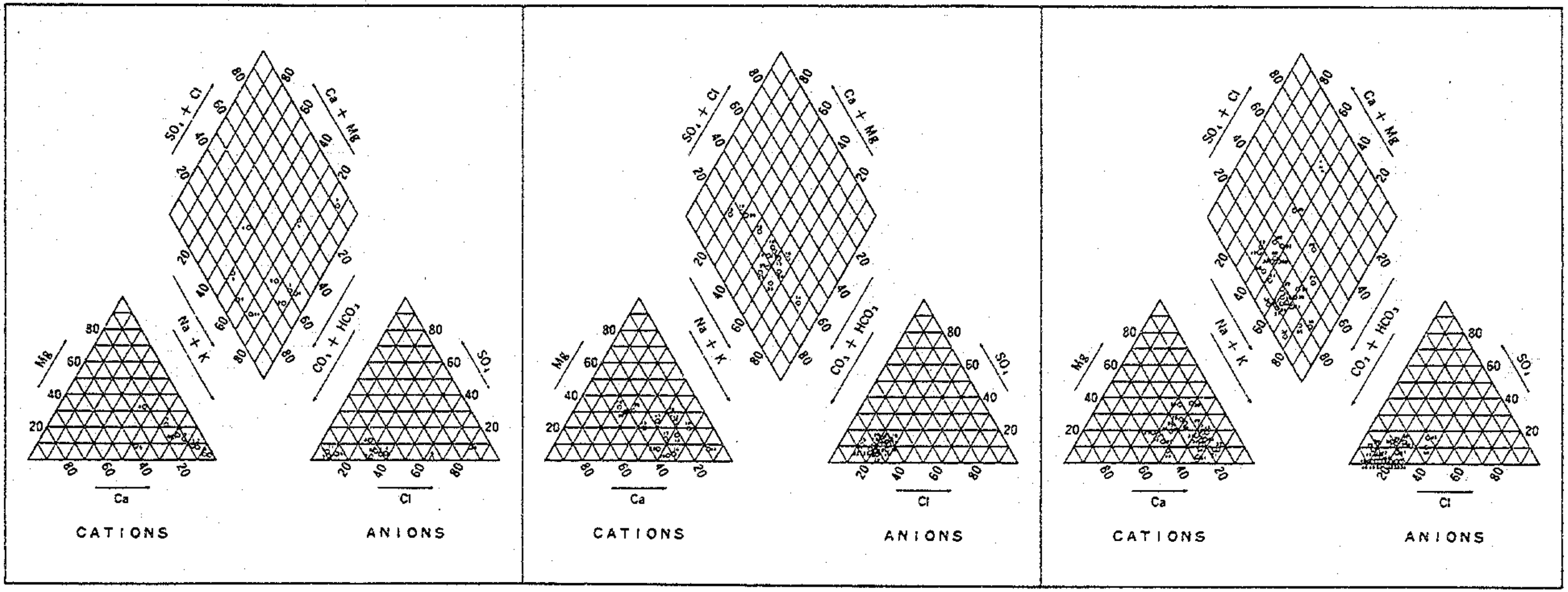
Trilinear Diagram (Diágrama Tri-lineal)



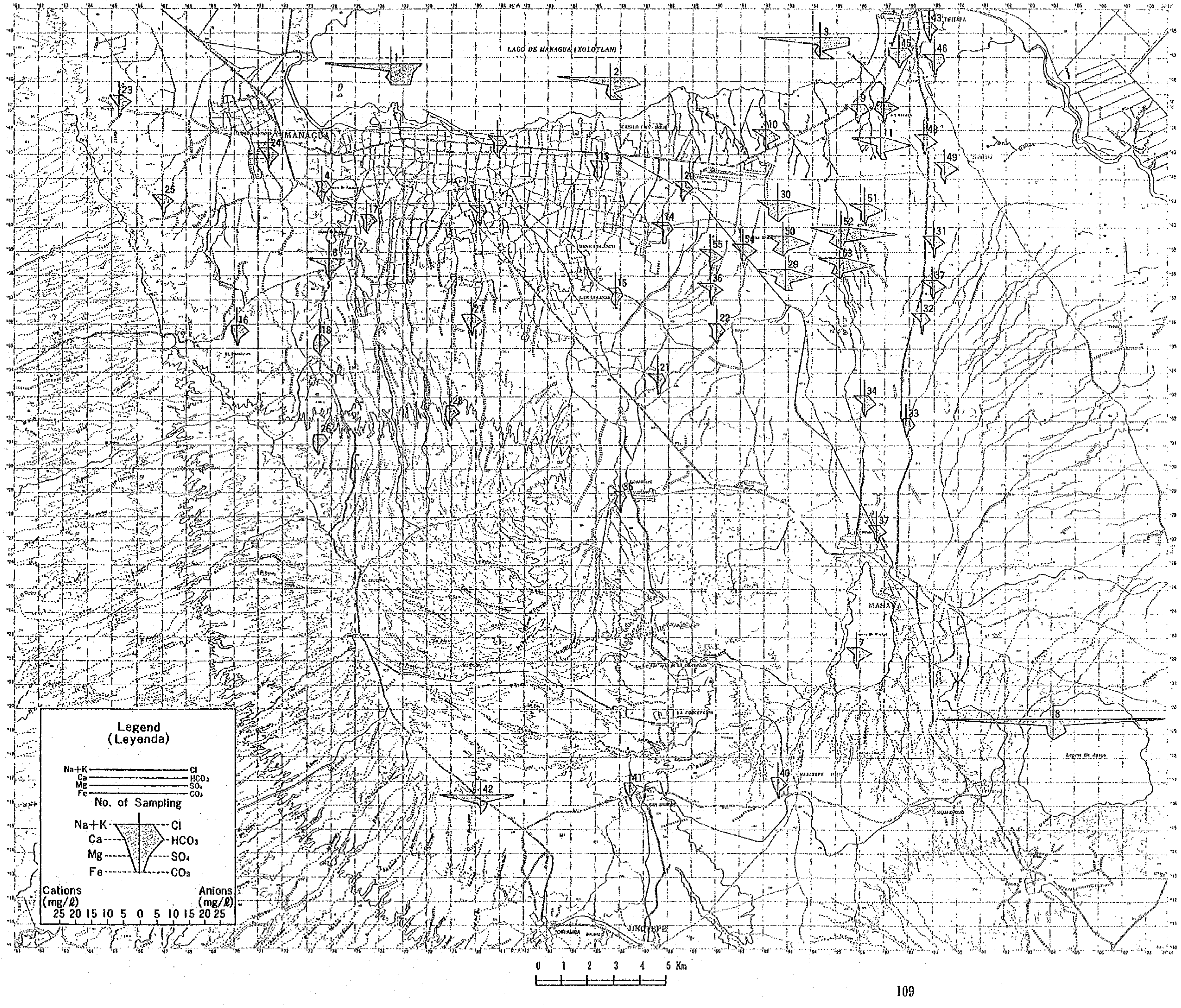
River, Spring, lakes
(Rios, Manantiales, Lagos)
河川、湧水、湖

Western & Central Hydrogeological Basin
(Cuenca Hidrogeológica Occidental y Central)
西部・中央地下水盆

Eastern Hydrogeological Basin
(Cuenca Hidrogeológica Oriental)
東部地下水盆

Fig. 4.7.1 Trilinar Diagram

Fig. 4.7.2
Stiff Pattern Diagram (Diágrama Patrón de Stiff)



4.8 Hydrogeological Features of the Study Area

4.8.1 Hydrogeological aspects

There are 3 principal water-bearing formations in the study area: Alluvial deposits with Quarternary pyroclastic materials; Masaya Group Volcanics; Middle Las Sierras Group. The El Salto formation and other Tertiary formations are regarded as hydrogeologically impermeable layers (aquitard or aquiclude).

(1) Alluvial deposits (Qal)

The alluvial deposits are mainly distributed in the Los Brasiles Valley between the Mateare fault scarp and the volcanic chain of Apoyeque, Asososca, Nejapa and Ticomo, and the surroundings of the Las Mercedes shore area.

Los Brasiles Valley is filled up with debris deposits mainly from the Mateare fault scarp, lake deposits composed of sand, silt and clay, and the Quarternary pyroclastic materials such as pumice and scoria. The principal aquifer in alluvial deposits is estimated to be found in coarse sand, pumice and scoria layers. The existing wells with a depth of around 120-150 meters produce 2,000-6,000 m^3/day by a drawdown of around 5 meters in the northwestern part of the valley.

The shore area of Lake Managua surrounding Las Mercedes is underlain by alluvial deposits and Quarternary pyroclastic materials. The alluvial deposits in this area are estimated to mainly contain fine sand, silty and clayey materials with lenticular or thin beds of coarse sand and gravel, while the Quarternary pyroclastic materials are presumably composed of volcanic ash and debris flow deposits from the Masaya Group Volcanic and the Las Sierras Group. From the above mentioned lithological characteristics, the alluvial deposits in the area show relatively low yielding capacity, and control the springs of groundwater from the Masaya Group Volcanics (Fig.4.1.4 and 4.8.1).

(2) Masaya Group Volcanics (QvM)

The principal aquifers of the Masaya Group Volcanics buried an old valley are basaltic-andesitic porous and auto-brecciated lava flows and permeable pyroclastic flows and pyroclastic fall deposits, and generally have a high yielding capacity. In this Study, two test wells were drilled in Veracruz (JI-2) and the eastern part of Sabana Grande (JI-3) for the hydrogeological investigation of the Masaya Group Volcanics condition in an underground valley.

However, the water-bearing formations of these well fields also characterize the Middle Las Sierras Group, as many drilled through the Masaya Group Volcanics penetrate the Middle Las Sierras Group. The main well fields in the area produce the following quantity of water.

Carlos Fonseca	(16 wells)	73,808 m^3/day	(4,613 m^3/day/well)
Sabana Grande	(5 wells)	14,913 m^3/day	(2,982 m^3/day/well)
Veracruz	(7 wells)	13,205 m^3/day	(1,886 m^3/day/well)
Total	(28 wells)	101,926 m^3/day	(3,641 m^3/day/well)

The total discharge quantity of many springs of groundwater from the Masaya Group Volcanics is about 1.3 m3/sec (112.320 m3/day, in February 1992). Besides, there is a large quantity of water as of underflows, forming many swamps.

(3) Middle Las Sierras Group (TQps(M))

The TQps(M) is distributed in all areas of the Managua groundwater basin. TQps(M) yields large quantity of groundwater from porous permeable layers such as pyroclastic flows and pyroclastic fall deposits of scoria with rock fragments, and weathered zones with fossil soils and fractured zones of basaltic-andesitic compact agglomerate with tuffbreccia and tuff. The existing wells of INAA drilled into TQps(M) are concentrated in the Managua central area and produce large quantities of groundwater from aquifers of TQps(M).

Wells (53)	179,788 m^3/day	(3,392 m3/day/well)
Lake Asososca	39,743 m^3/day	
Total	219,531 m^3/day	

Besides, the TQps(M) is known to be an aquifer of hot spring in the northeastern part of the Study area. There is a hot spring naturally flowing out from the outcrops of TQps(M) at the river side of Tipitapa.

4.8.2 Hydrogeological structure (Electric prospecting)

In this Study, 83 points of electric resistivity sounding were carried out to investigate hydrogeological structure of the Managua groundwater basin. This electric prospecting was composed of shallow prospecting of 100 - 215 meters with Wenner's electrode configuration (50 points) and deep prospecting of 400 - 750 meters with Schlumberger's electrode configuration (33 points).

The electric prospecting results were hydrogeologically analyzed and the outcome of the analysis were correlated with the apparent electric resistivity values and lithofacies, as shown in Table 4.8.1. The result of the correlation was used as a basis in the formulation of hydrogeological cross sections shown in Figures 4.1.5 to 4.1.9. The top elevation map of hydrogeologically impermeable basal layers underlying the Las Sierras Group shown in Figure 4.8.2 was prepared for water balance analysis, which should be based mainly on the results of electric prospecting and its geological and hydrogeological analyses.

4.8.3. Permeability of aquifer

In this Study, existing boreholes data containing discharge or pumping test records were collected as much as possible, and were analyzed and revaluated hydrogeologically by different aquifers and different geohydrolic sub-areas. As a result of this work, the iso-value line map of specific capacity shown in Figure 4.8.1 were prepared to evaluate permeability of aquifers in the study area.

The existing records of transmissivity resulting from proper pumping tests are limited to a few well fields. Therefore, transmissivity (T) was estimated from the existing records of specific capacity (Sc), by use of the next empirical equation.

$$T\ (m^2/day) = 1.22\ Sc\ (m^3/day/m)$$

Areal features of permeability of main aquifers in the Managua groundwater basin are summarized as follows:

(1) Alluvial deposits (Qal with pyroclastic sediments)

	T (m^2/day)	Sc (m^3/day/m)
Western sub-area (11 wells) (Los Brasiles Valley)	821	673.44
Eastern sub-area (7 wells) (Las Mercedes shore area)	215	184.00

(2) Masaya Group Volcanics (QvM) and Middle Las Sierras Group (TQps(M))

	T (m^2/day)	Sc (m^3/day/m)
Sabana Grande - Carlos Fonseca area (15 wells)	1,948	1,597.00
Veracruz area (4 wells)	1,794	1,466.00
Southwestern Veracruz area	340	279.00

(3) Middle Las Sierras Group (TQps(M))

	T (m^2/day)	Sc (m^3/day/m)
Managua Central sub-area (66 wells)	425	348.48
Western Sabana Grande area (8 wells)	443	363.00

The specific capacity values of existing wells in the Managua Central sub-area are variable ranging from 35 to 1,896 m3/day/m. As shown in Figure 4.8.1, a distribution of specific capacity value in the area is considered to be controled by the NE-SW fault system, and the high value zones of specific capacity are distributed along the fractured zones controled by NE-SW fault system. Although the relation between specific capacity and drilled depth in saturated zone of the Middle Las Sierras Group, no correlation can be seen as shown in Figure 4.8.4.

As mentioned in "Test Well Drilling and Pumping Test", although the test well JI-1 has revealed the existence of very high potential aquifer (Sc : 19,464 m^3/day/m) underlying the Middle Las Sierras Group, its extension has not been investigated. Therefore, the specific capacity value obtained from test well JI-1 is eliminated from the iso-value map of specific capacity (Fig. 4.8.1).

4.8.4 Groundwater occurrence and flow mechanism

The Managua groundwater basin is divided into the groundwater recharge area of the Sierras de Managua and the Sierras de Carazo, the groundwater storage and runoff area of the flat low plateau continued from the recharge area and the groundwater discharge area of Lake Managua, topographically and hydrologically. Besides, from the hydrogeological conditions such as a shape of top surface of basal layers (El Salto and Brito Formations) formed the base of groundwater basin, geological and lithological conditions in the groundwater basin, fault system and tension fractures as of volcanic chains and shape of groundwater table, the Managua groundwater basin can be divided into three groundwater sub-basin: the Western, the Managua Central and the Eastern sub-basins.

Figure 4.8.5 shows a groundwater flow mechanism in the Managua groundwater basin. This map was prepared based on the result of comprehensive analysis for topographical, hydrological and hydrogeological conditions mentioned above, and the result of analysis for flow rate and renewal of groundwater resulting from chemical component and tritium concentration (Fig. 4.7.2 and 4.8.8). As shown in Figure 4.8.5, the Eastern groundwater sub-basin has a big scale recharge area of groundwater with Masaya Caldera as of reservoir of surface water and groudwater and an underground old valley which is buried by good aquifers. Accordingly, it is evaluated to be a highest potential area for groundwater development in the Study area.

A shape of groundwater table is similar to that of the topography throughout of the Study area. In partially, it is, however, affected by the hydrogeological conditions such as a shape of top surface of basal layers, permeability of aquifers and fault systems, and pumping discharge of wells and Lake Asososca(Fig. 4.8.3).

Groundwater level of the basin is observed at the 250 - 120 meters below the ground surface in the recharge area of the Sierras de Managua and Carazo and at the less than 120 meters below the ground surface in the groundwater storage and runoff area. Groundwater occurs in unconfined water condition in general, and partially occurs as perched water and confined water conditions (Fig. 4.8.6).

According to the results of analysis for tritium concentration and continuous water levelling of Lake Masaya, groundwater flow rates in the recharge area which the groundwater level is deep below the ground surface are estimated to be 100 - 50 m/day in interflow domain and 0.8 - 0.6 m/day in base flow domain, respectively. On the other hand, groundwater flow rates in the storage and runoff area of the Eastern groundwater sub-basin are estimated to be 9.6 m/day in the fractured zone along NS fault system and 4.5 m/day in underground valley, respectively.

Table 4.8.1 CORRELATION BETWEEN RESISTIVITY AND LITHOFACIES IN THE STUDY AREA

INFORMATINO	LITHOFACIES	Grade humidity (ohm/m)			Remarks
		Dry	Capillary Wet	Saturate	
Alluvium Deposits with Quaternary Pyroclastic Materials	Clayey bed	45 - 90			
	Sandy bed	60 - 800		8 - 25	
	Gravelly bed		100 - 200	- 25	
	Pumice or Scoria		100 - 200	- 25	
Masaya Group Volcanics	Pyroclastic fall deposits (mainly Scoria)	170 - 880			
	Pyroclastic flow	90 - 120		25 - 50	
	Lava flow (Brecciated)	100 - 200		10 - 20	Affected by hydrothermal solution
	Lava flow (compact)		270 - 500	25 - 200	
Upper Las Sierras Group	Alternatione of pyroclastics	250 - 700			
Middle Las Sierras Group	Massive and compact agglomerate with tuffbreccia and tuff	110 - 400	40 - 60		
	Weathered tuffbreccia with fossil soil and pyroclastic plow			10 - 80	
El Salto Formation	Low consolidated tuffaceous sandstone and siltstone			1 - 25	Affected by hydrothermal solution
Brito Formation (?)	Sandstone and shale			57 - 456	

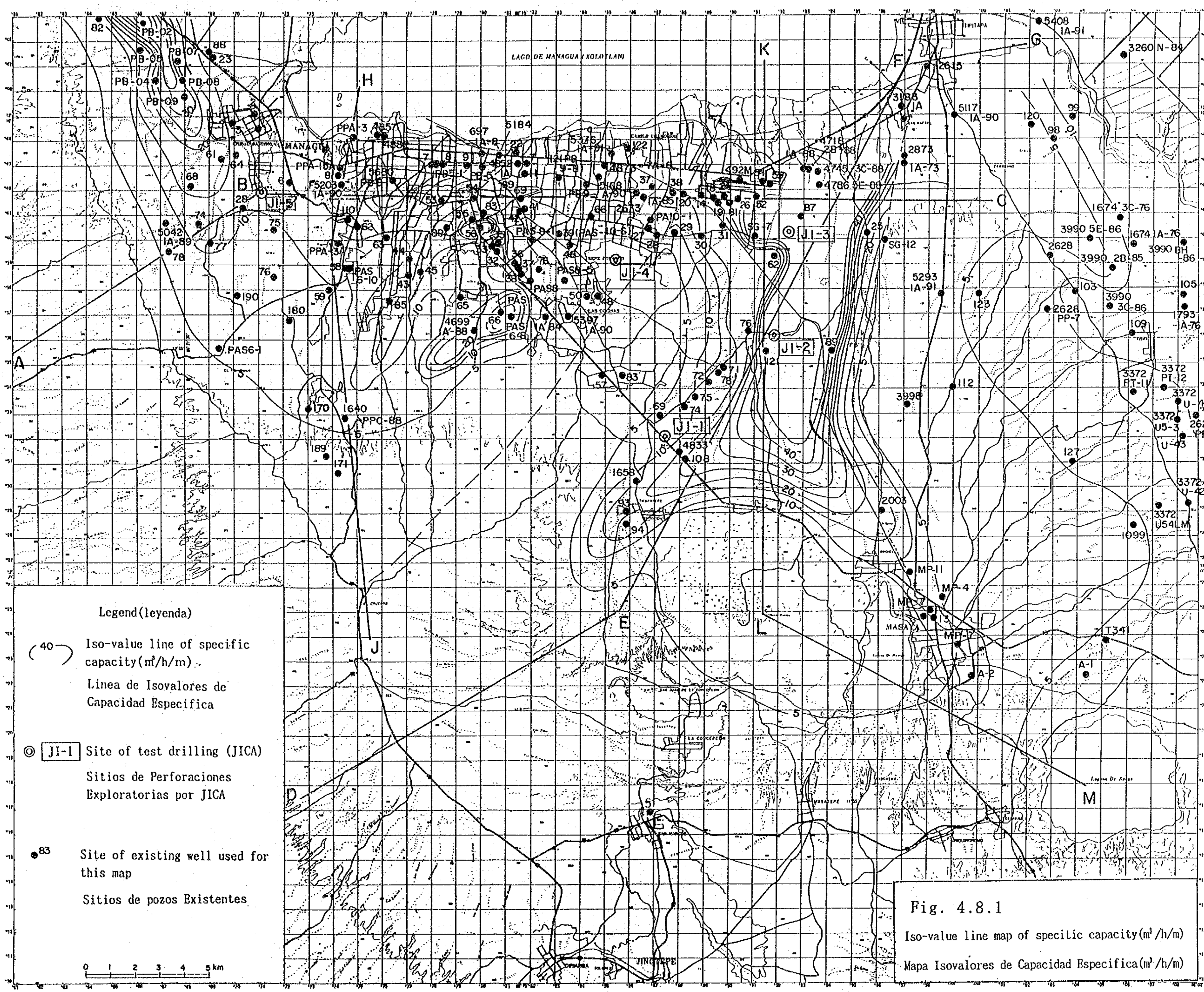


Fig. 4.8.1

Iso-value line map of specitic capacity (m³/h/m)

Mapa Isovalores de Capacidad Especifica (m³/h/m)

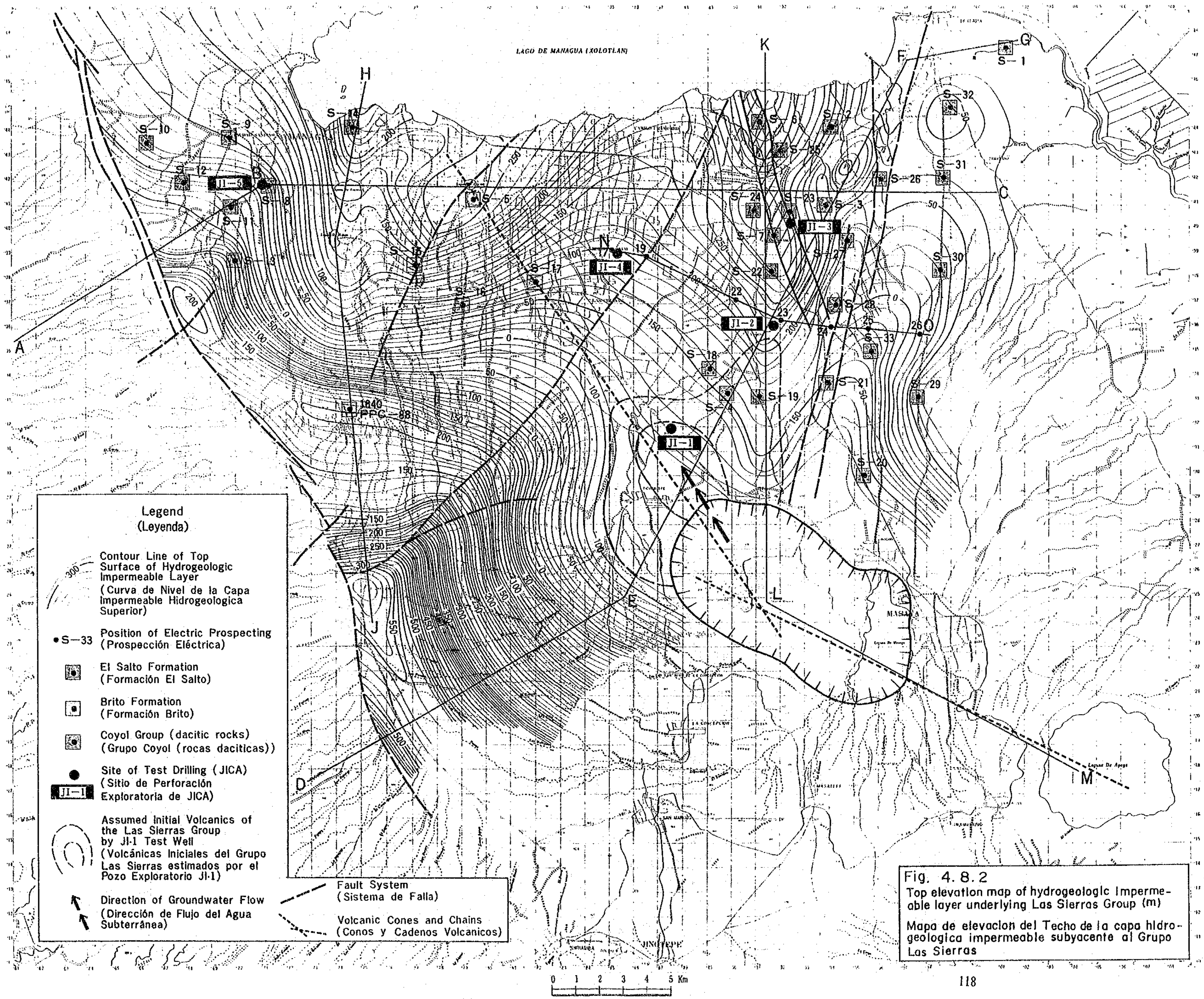


Fig. 4.8.2
Top elevation map of hydrogeologic impermeable layer underlying Las Sierras Group (m)
Mapa de elevacion del Techo de la capa hidrogeologica impermeable subyacente al Grupo Las Sierras

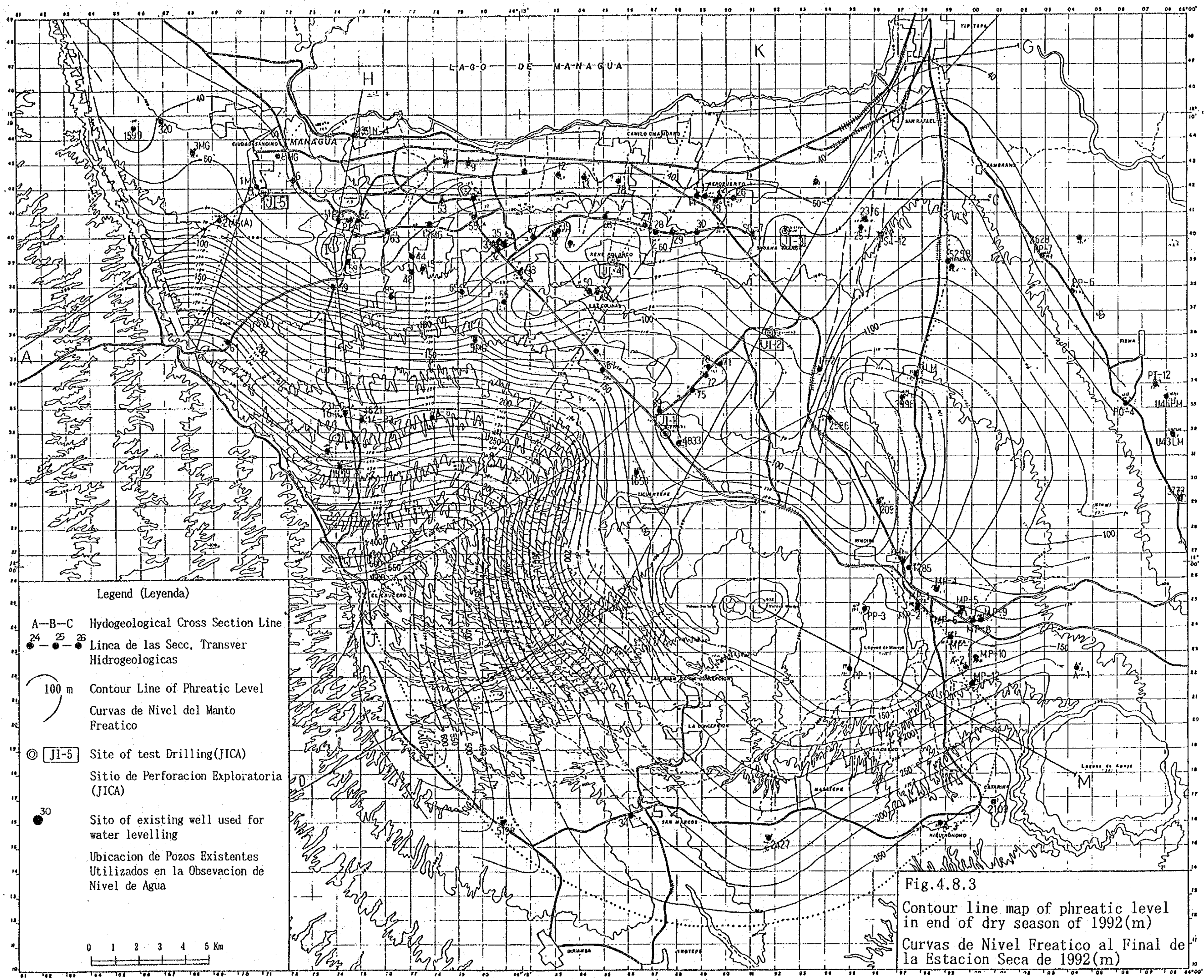


Fig.4.8.3

Contour line map of phreatic level in end of dry season of 1992(m)

Curvas de Nivel Freatico al Final de la Estacion Seca de 1992(m)

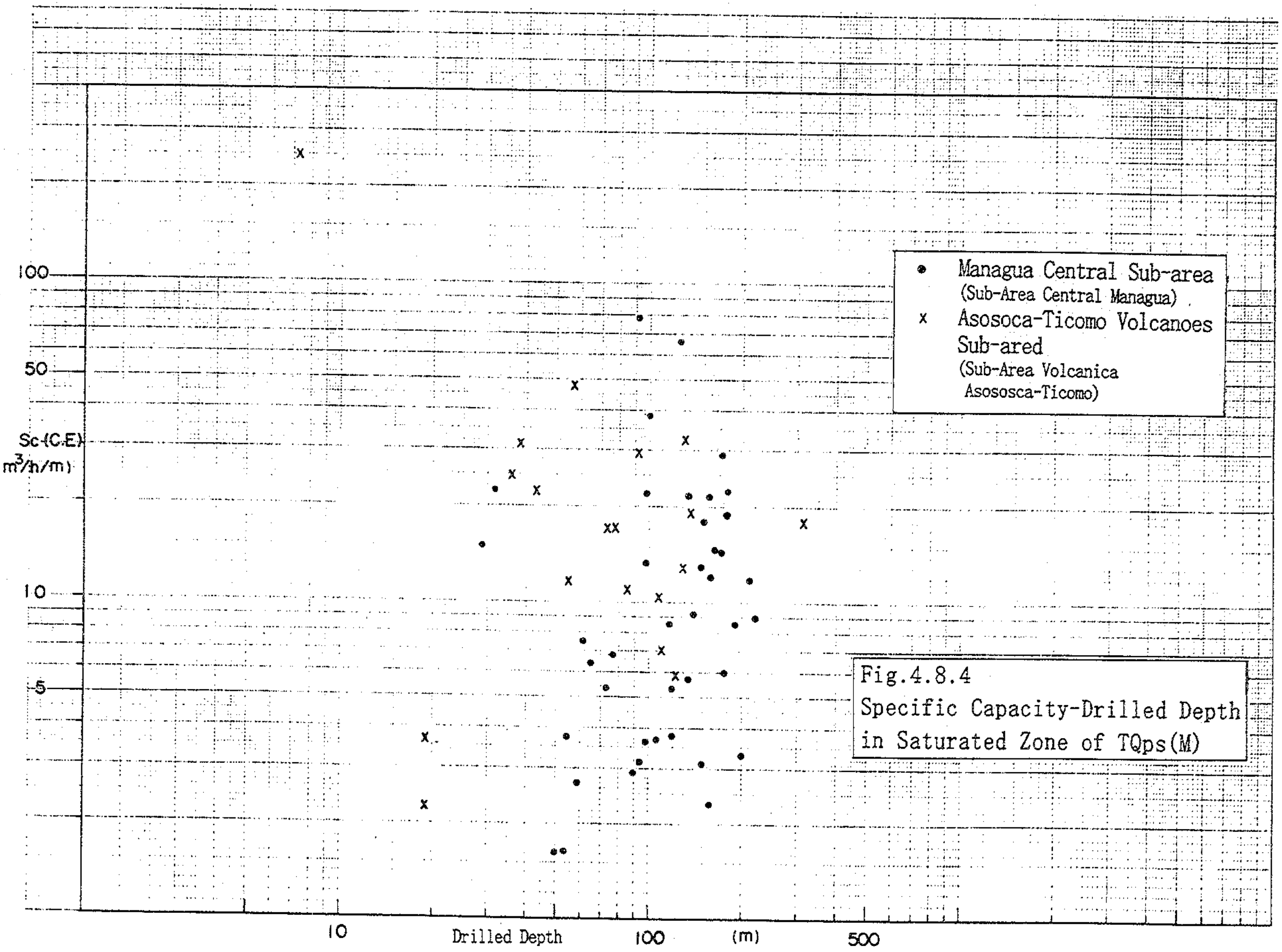


Fig.4.8.4
Specific Capacity-Drilled Depth in Saturated Zone of TQps(M)

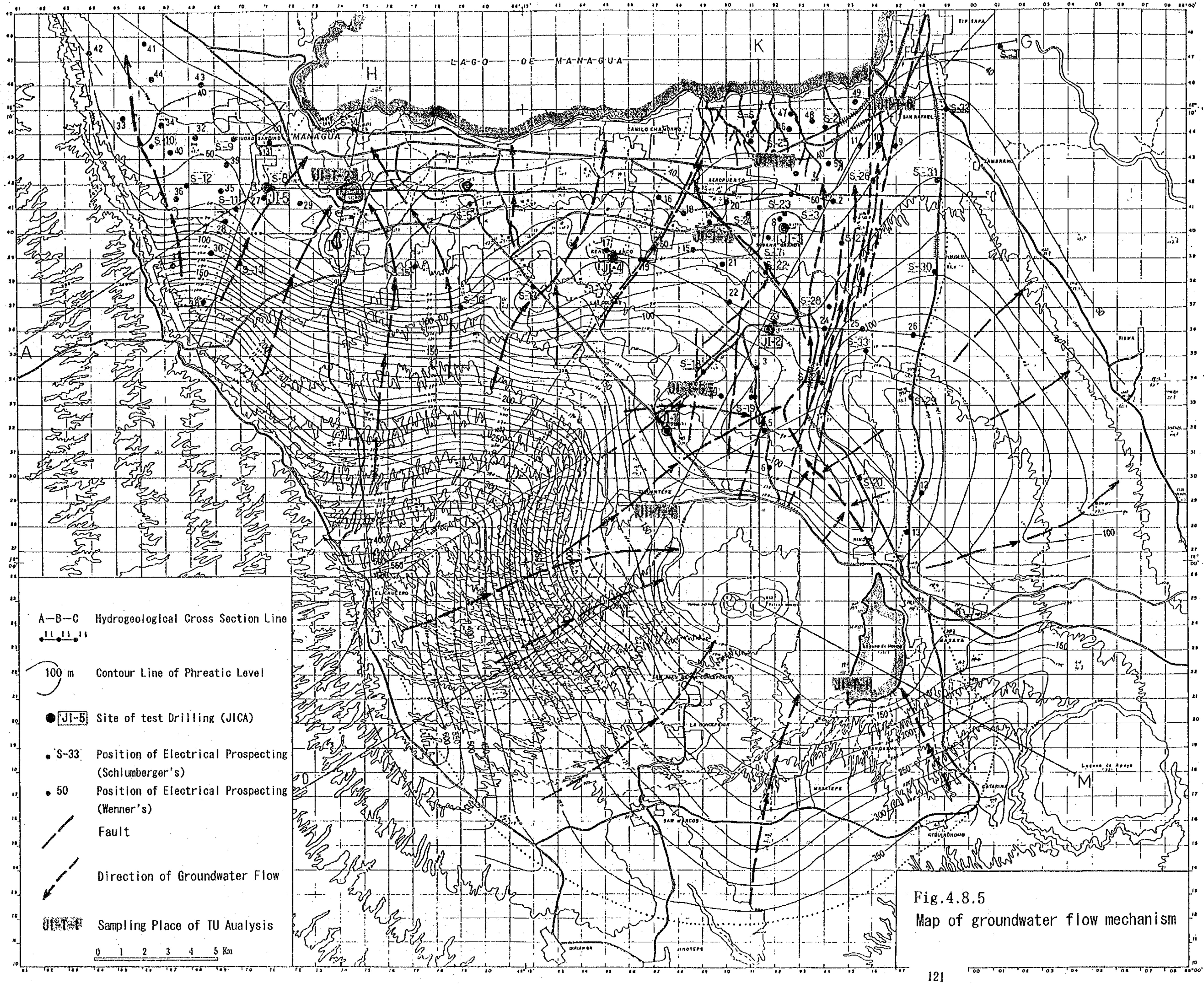


Fig.4.8.5
Map of groundwater flow mechanism

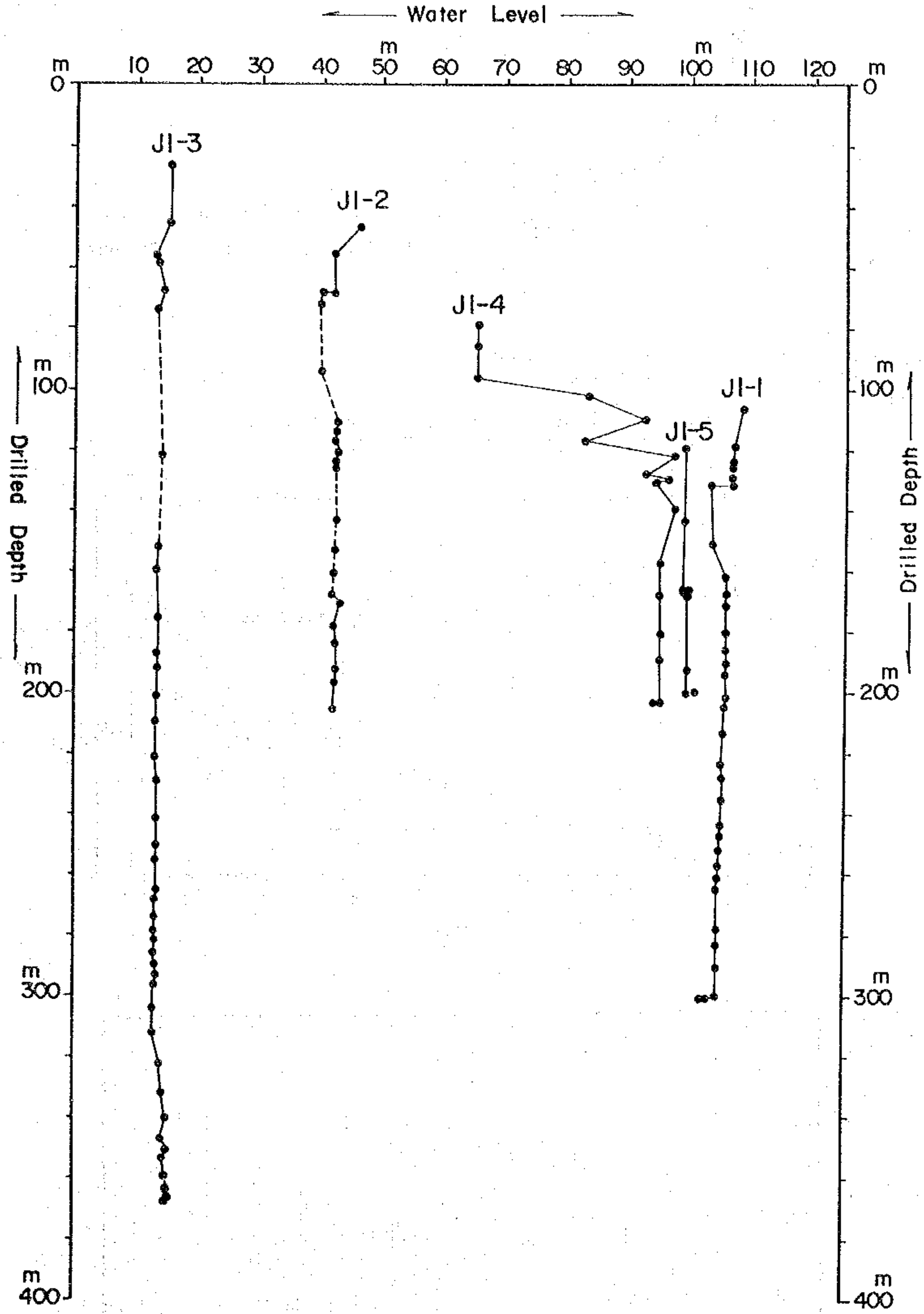


Fig.4.8.6 Fluctuations of groundwater level

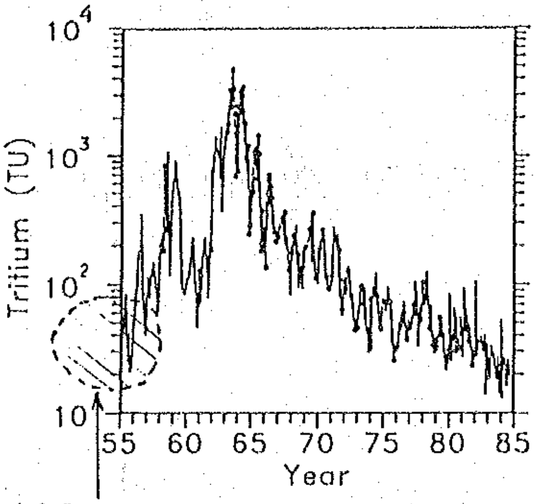
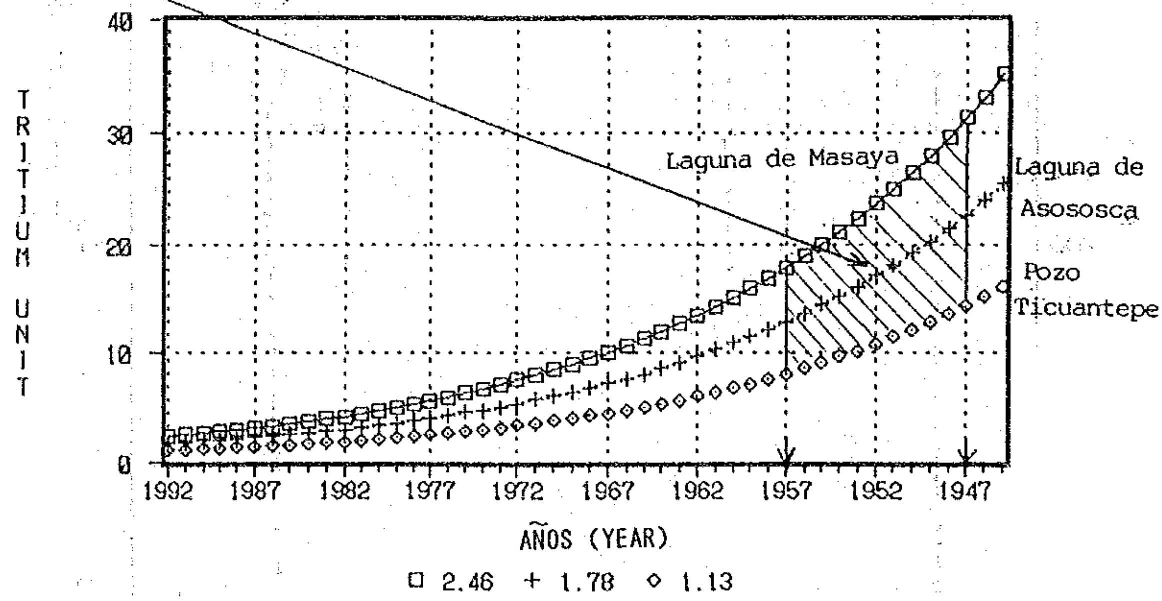
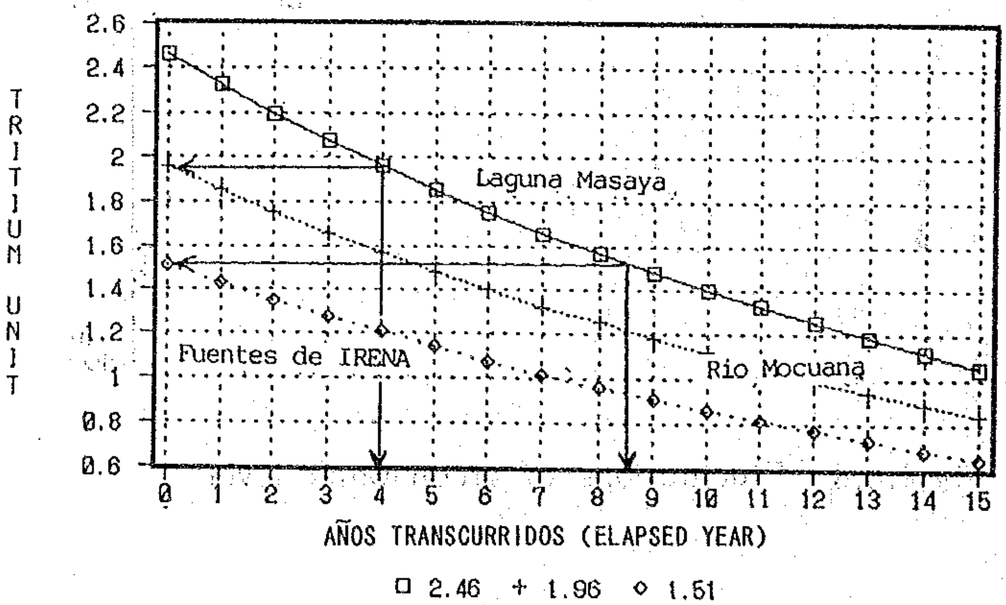


Fig.4.8.7
Registros sintetizado de Tritio en las Precipitaciones de Madison Wisconsin .

Fig.4.8.7 Synthesized record of tritium in precipitation at Madison, Wisconsin. Points indicate actual measurements at Madison.

Fig.4.8.8 Historia de la unidad Tritio .
Fig.4.8.8 HISTORY OF TRITIUM UNIT





4.9 Database

Information collected and surveyed on the meteorological, hydrogeological and water quality sectors have been arranged in a data base system in the computer.

The data base system mainly consists of two soft wares "Lotus-123" and "dbase III".

The summary of the input data is as follows:

(1) Meteorology

- Monthly temperature
- Monthly rainfall
- Monthly evaporation
- Monthly relative humidity
- Monthly wind velocity

(2) Well Inventory

(3) Water Quality

A part of the well inventory is attached in the Data Book.

CHAPTER 5 EVALUATION OF GROUNDWATER

Based on the hydrogeological study described in Chapter 4, the groundwater potential was evaluated by the water balance estimation and groundwater flow simulation analysis.

5.1 Water Balance

The evaluation of "recharge" is essential in groundwater potential evaluation. Various factors, i.e., land use and cover, geology, land slope, rainfall intensity, evapotranspiration, etc., have to be considered for the evaluation. However, there are some constraints in the data required for the verification of groundwater movement affected by rainfall and runoff condition.

In order to estimate areal recharge condition in the Study Area, annual rainfall and recharge ratios were used in 1 km x 1 km meshes applied in the model simulation to be discussed in the next section. Point rainfall was directly employed to estimate areal rainfall.
The results of the calculation are shown below.

Annual Water balance

Hydrogeological Basin	I	II	III
Area(km2)	54	237	499
Annual Rainfall(mm)	1151	1211	1289
Ratio(%)	18.0	18.1	21.0
Annual Groundwater Recharge(million m^3)	11.19	51.95	135.07
Annual Groundwater Potential(million m^3)	8.9	41.6	108.0
Pumping Discharge in 1991(million m3)	3.1	69.5	39.2
Balance	5.8	-27.9	68.8

The simple averages of annual rainfall(mm) and recharge ratio(%) calculated for each basin were used. According to the probability analysis, the 5-year non-exceeding probability rainfall value corresponds to around 80 % of the average rainfall. Therefore, the estimated potential amount is tentatively calculated according to this percentage.

The results indicate the following values:

(a) The results clearly indicate over-pumping in basin II even with the pumping discharge in 1991.

Around 28 million m^3 must be subtracted from the total pumping discharge to stabilize the hydrological cycle.

(b) Basin I was estimated to have a groundwater potential of around 6 million m^3.

(c) Basin III is expected to have a groundwater development potential of almost 69 million m^3.

5.2 Groundwater Flow Model Simulation

Flow model simulation was conducted based on the hydrogeological study. The digital model used for the Study is a quasi three-dimensional model (Q3P).

The modeled area is 31 km in the S-N and 38 km in the E-W direction, and one element is 1 km x 1 km mesh based on topographical map. The boundary condition and hydraulic parameters were given by the results of hydrogeological study and modified by calibration. Calibration (calculation steps) was based on a period of 20 years, starting in 1972. Initial head in 1972 was estimated by steady state calibration, using the groundwater table measured in 1992. Recharge was given by rainfall directly. Pumping discharge was applied mesh-wise based on the groundwater use survey. The results of the simulation are shown in Fig. 5.2.1.

Future prediction is provided by the combination of cases mentioned below.

	Conditions
Case 1:	Pumping Condition in 1991
Case 2:	Case 1 and Well Rehabilitation 1992-1993
Case 3:	Case 2 and 80% of pumping discharge at Lake Asososca
Case 4:	Case 2 and 60% of pumping discharge at Lake Asososca
Case 5:	Case 1 and 60% of pumping discharge at Lake Asososca
Case 6:	No Pumping
Case 7:	Case 2, Well Rehabilitation Program 1993-1995, 10 MGD extraction from Lake Asososca and 1995 stage Development in Veracruz-Ticuantepe
Case 8:	Case 7 and 2000 stage development in Sabana Grande-Cofradia Area
Case 9:	Case 1, 10 MGD of extraction from Asosoca and 1995 stage development in Veracruz-Ticuantepe
Case 10:	Case 9 and 2000 stage development in Sabana Grande-Cofradia Area

Results of the simulated groundwater level are given in the groundwater table map, elevation above sea level and levels at checking points. The selected checking points were those installed with the automatic water level recorders and other points in Sabana Grande area and center of the City.
Results of Case 1, 2 , 10 and 11 are shown in Fig.5.2.3,5.2.4.

In consideration of the described water balance and simulation studies, the following approaches are recommended:

(1) According to the values calculated with the water balance, additional groundwater developments should be conducted at the western and eastern hydrogeological basins. However, pumping discharge must be reduced in the central basin.
Calculated values are still rough estimates, and re-evaluation should be conducted along with the monitoring results of the groundwater level in the future.

(2) The groundwater level in the center of Managua City will be drawn down even with the existing extraction rate. INAA production wells No.7 (El Stadio), No.8 (San Antonio), No. 9 (Banco de America) and No.10 (Mercado Oriental) are located around 1 km from the lake coast with high pumping yields.

Monitoring wells are to be installed between Lake Managua and these production wells. Reduction of pumping discharge have to be considered with the monitoring results of the level of Lake Managua. Other pumping discharge, especially by the rehabilitation program, will also cause large draw down in the extraction area. Discharge control must be done with groundwater monitoring.

(3) Recovery of the water level up to 40 m.a.s.l. at Lake Asososca will be achieved by reducing the pumping discharge of the 1991 yield by more than 40%. Detailed regulations should be considered for the water level of the industrial area between Asososca and Managua lakes. This reduction should be made urgently because all pumpage must be stopped once industrial waste water permeates the water of Asososca.

(4) New groundwater development in Sabana Grande - Cofradia and Veracruz - Ticuantepe area will produce draw down in lower areas like Carlos Fonseca. Well interference in the Carlos Fonseca well field is discussed in Chapter 3, and a water level recovery averaging 7 m is expected from the effective coordination and control of the pumping discharge. The development scale of the 1995 stage which is considered to affect the drawdown of the existing wells like in Carlos Fonseca will still be acceptable.

However, the next development in 2000 stage is necessary to consider the results of the monitoring works which will be conducted in these areas.

Therefore, to implement the required reduction of the pumping discharge of Lake Asososca and other wells in the center of Managua City, studies for the development of other areas as potential water resources should commence as soon as possible.

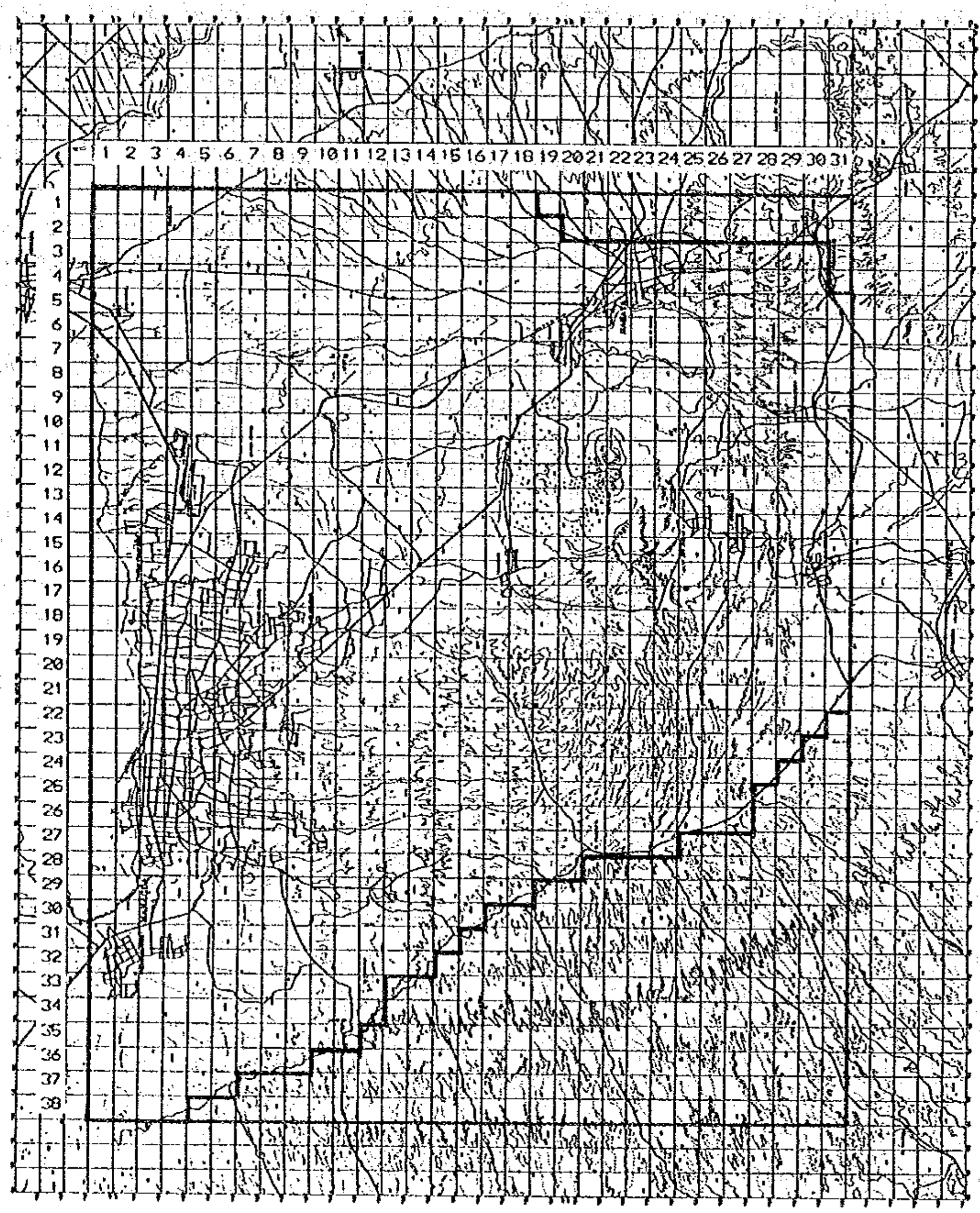


Fig. 5.2.1 Finite-element of the Model

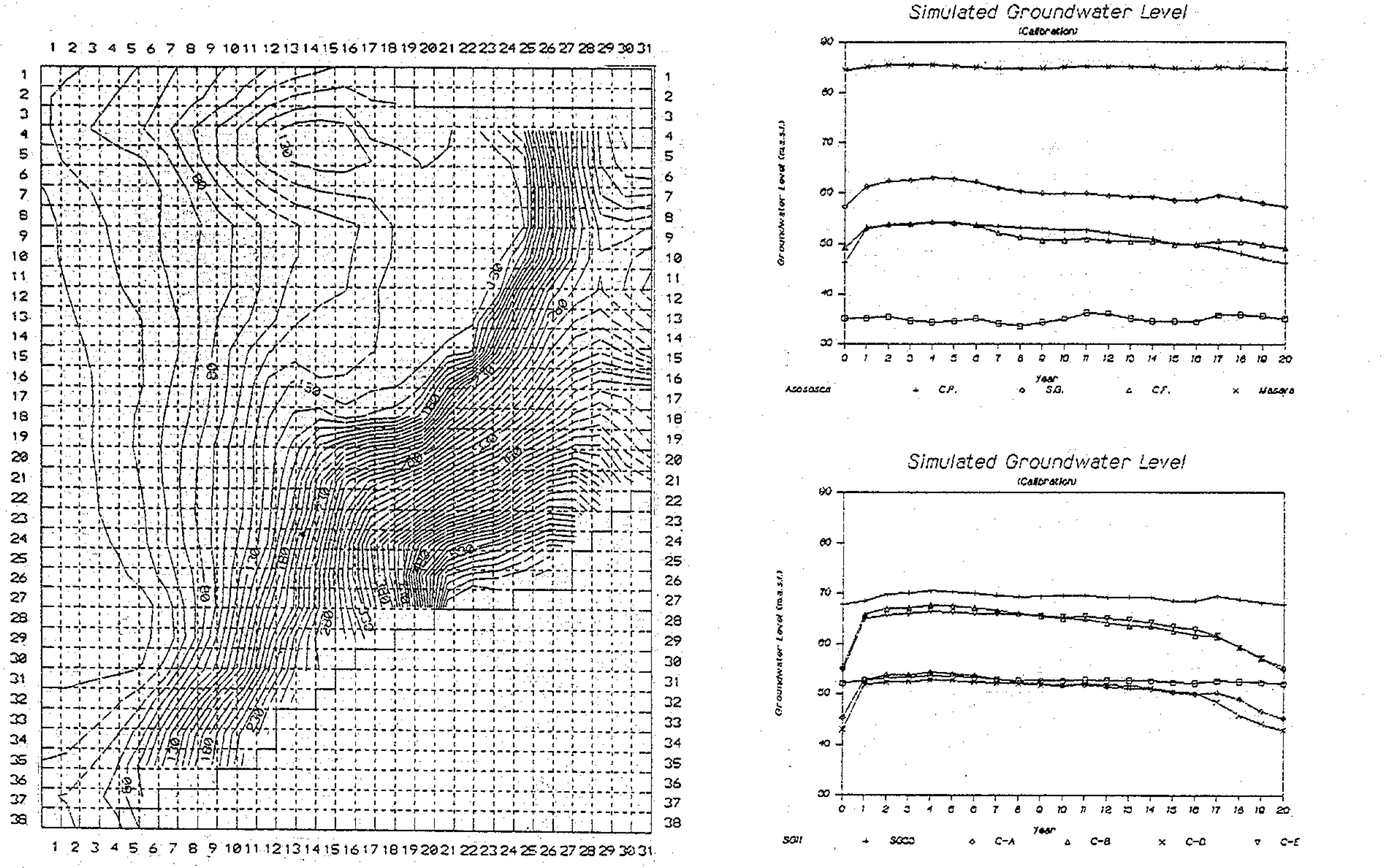


Fig. 5.2.2 Simulated Groundwater Level (Calibration)

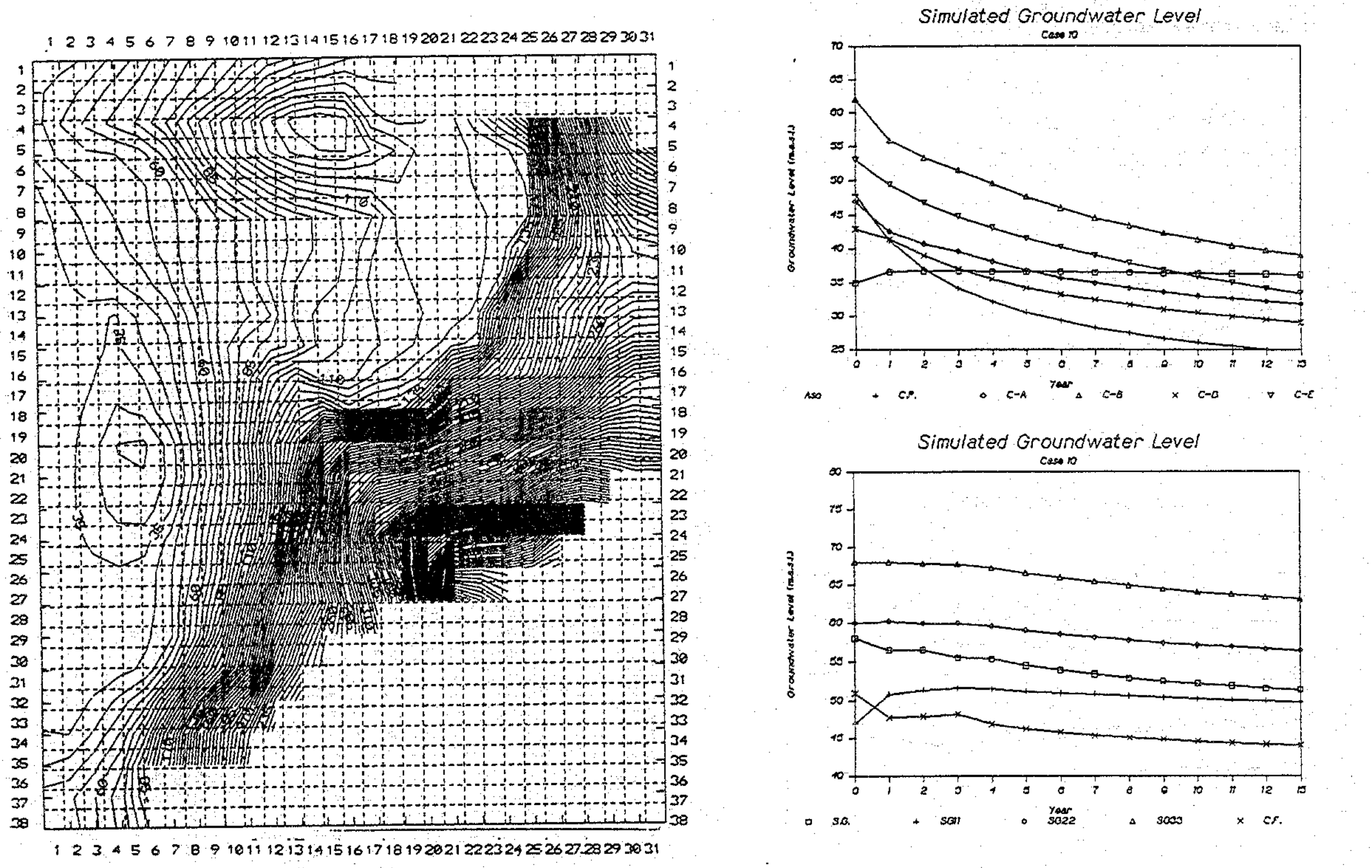
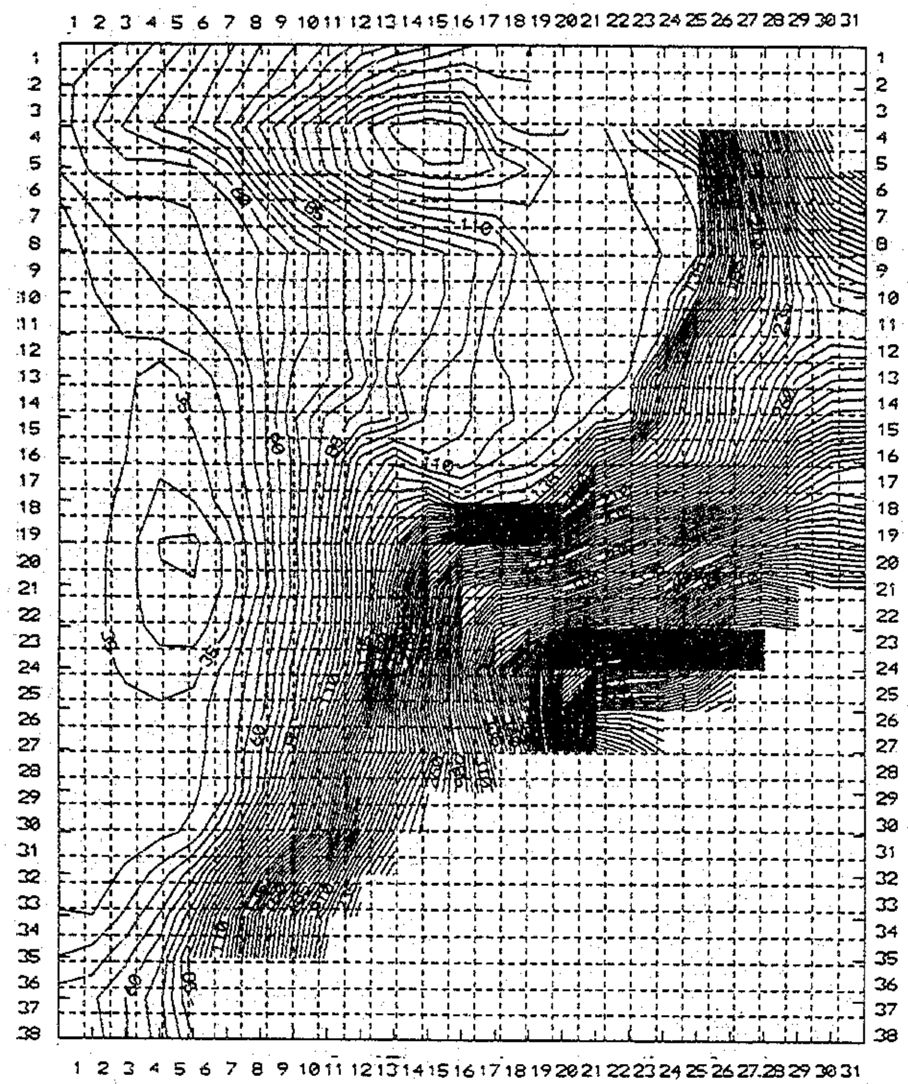
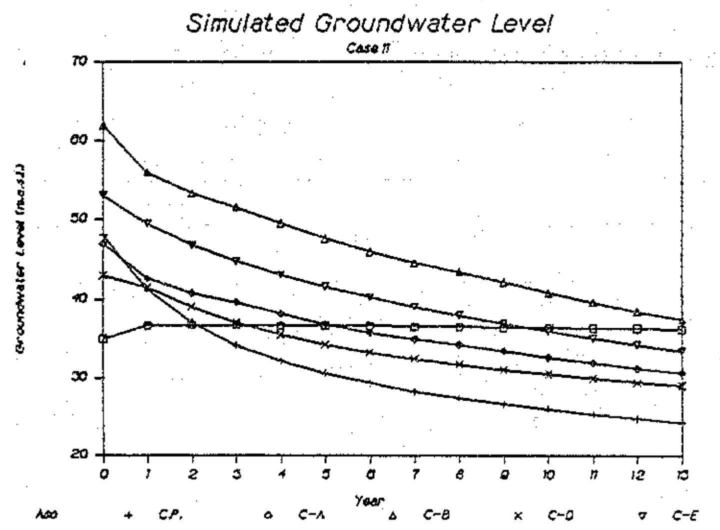


Fig. 5.2.3 Simulated Results (7)





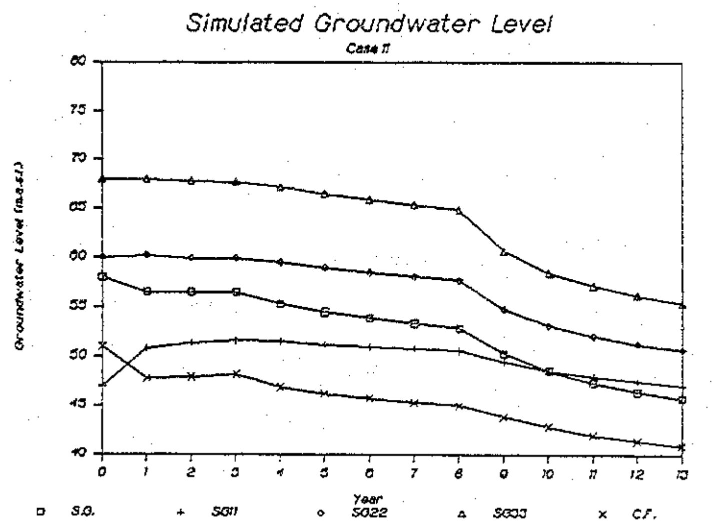


Fig. 5.2.4 Simulated Results (8)

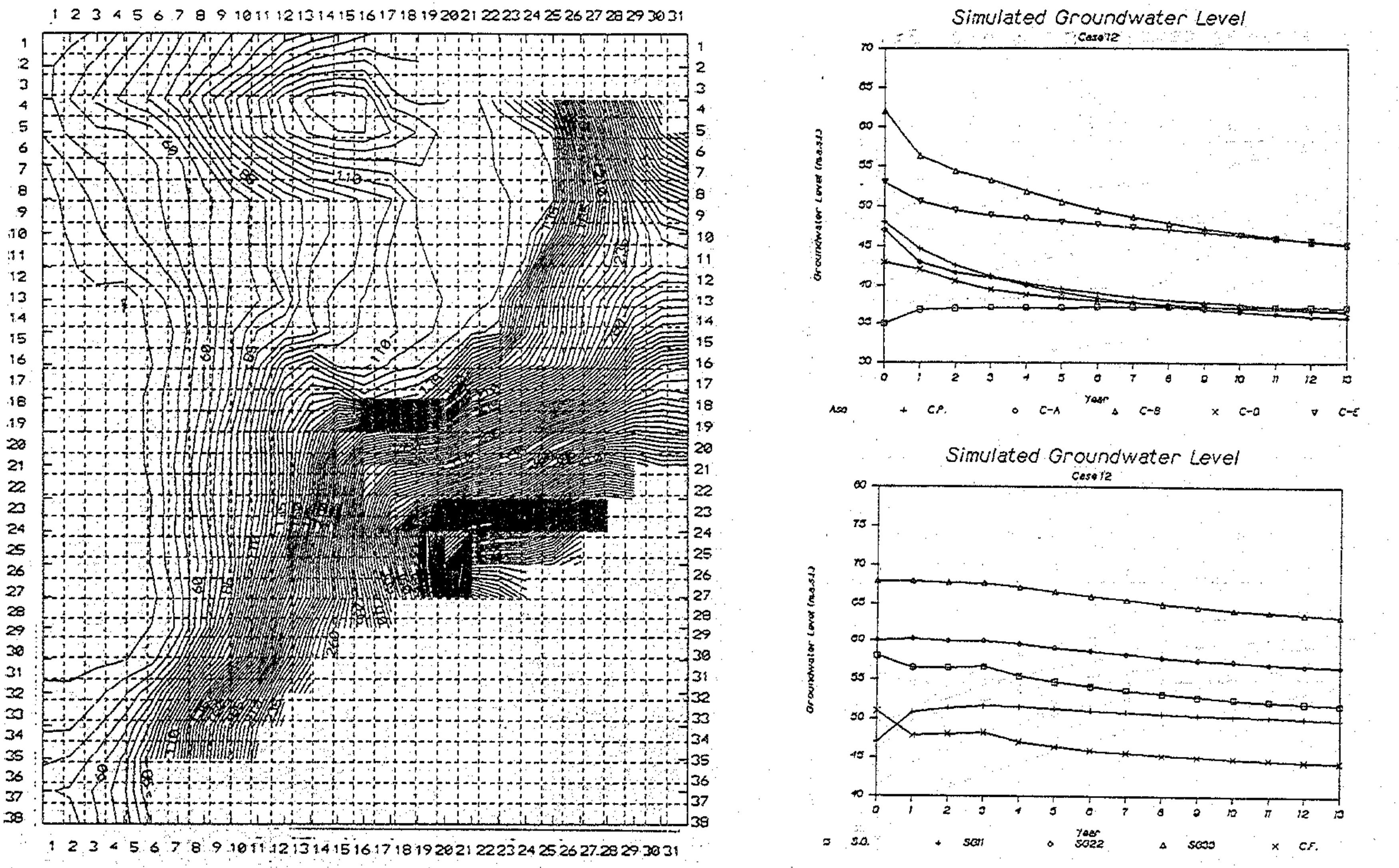
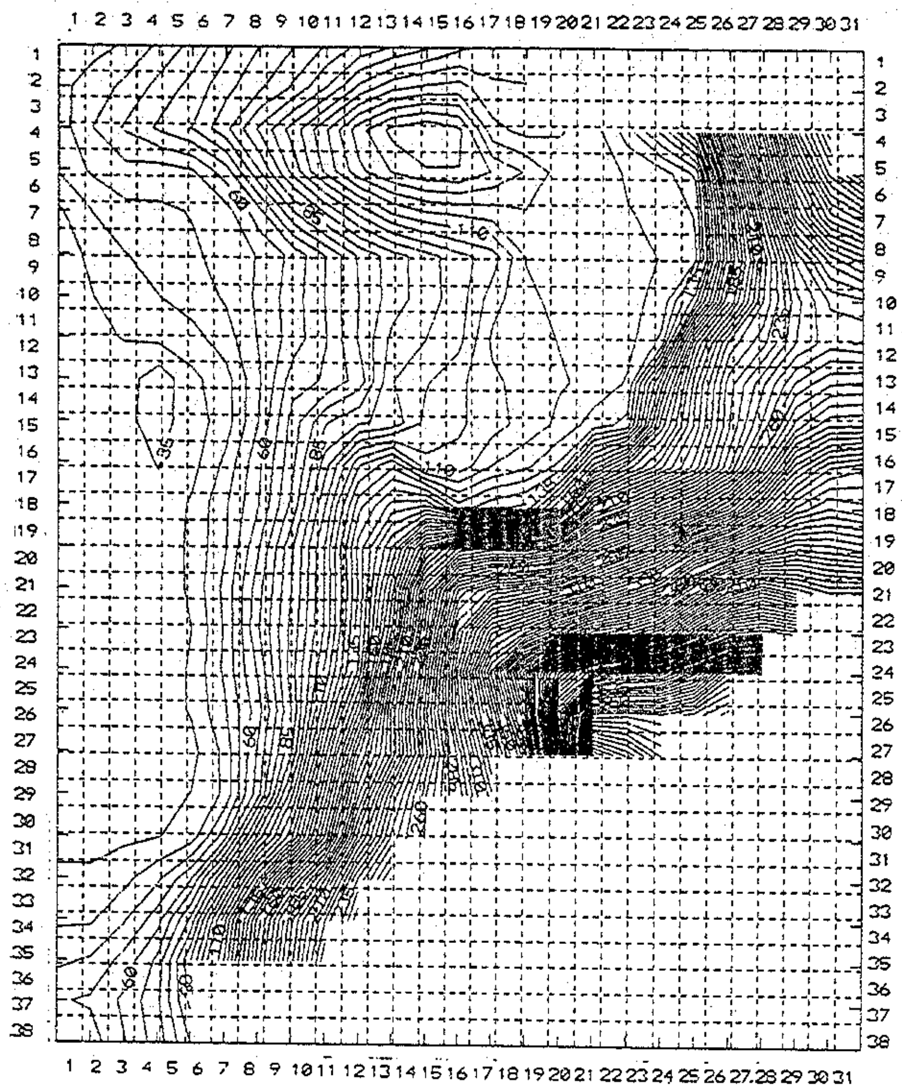
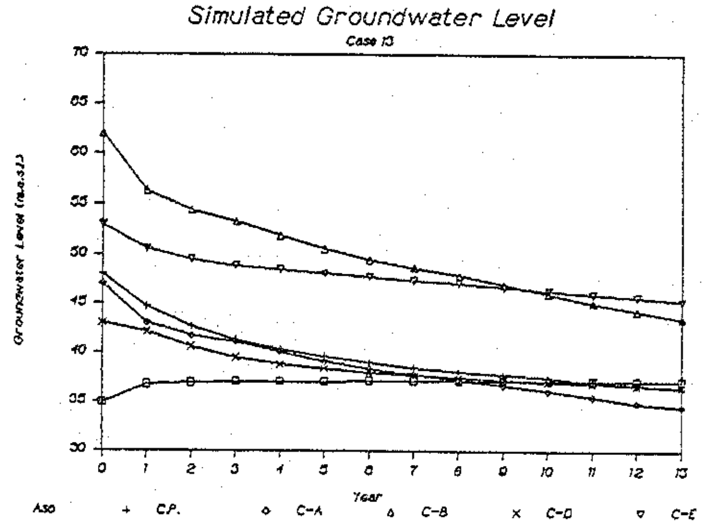


Fig. 5.2.5 Simulated Results (9)





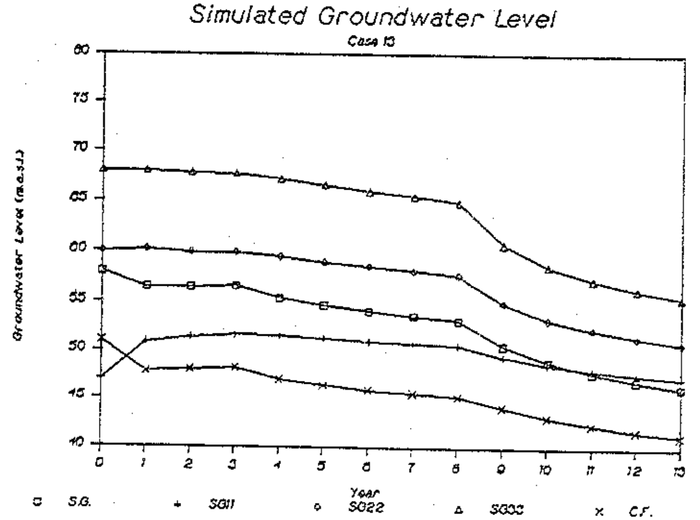


Fig. 5.2.6 Simulated Results (10)

CHAPTER 6 THE PROJECT

Based on the study on Managua's water supply discussed in Chapter 3 and the groundwater development potential within the catchment area of 880km² discussed in Chapter 5, a plan to develop groundwater as Managua's water supply source has been formulated as one part of the Study.

6.1. Basic Concept

The groundwater development plan is made under the following basic concepts:

a) The target year is the year 2000.

b) The water supply service area is the entire City of Managua which comprises seven Districts, but the Project shall cover Districts 2 to 6 and shall exclude the independent supply area of District 1 and the service level shall not be uniform. Rural service level is applied to District 7, while Districts 2 to 6 are designated as areas under the urban service level.

c) The population served in 2000 shall be the estimated total population of District 2 to 6 in 2000.

d) The water demand in 2000 is estimated to exceed the expected total production in the Study area. However, the planned supply service level is not to be lowered as benefits can be expected from the supplementary groundwater development outside of the Study area.

e) The project shall be implemented in three phases.
Phase 1 shall focus on the urgent supply plan at least to minimize the present severe inconveniences brought about by periodical water suspension and very limited supply to highly elevated areas. Phase 2 shall focus on a full-scale groundwater development by means of safe pumpage from areas with high development potential in the Study area in order to meet the demand in 2000 as much as possible.

The development of a supplementary water source outside the

Study area to meet the demand in 2000 shall be dealt with in phase 3.

f) The scope of the Project comprises groundwater development and construction of conveyance facilities to the existing reservoirs. The improvement of the distribution facilities should be covered by other projects.

6.2 Service Area

The existing service area of Managua water supply comprises the seven Districts shown in Fig. 3-1. Districts 2 to 7 are the concerned project area. The characteristics of the Districts in view of the supply system or service level are summarized below:

Districts 2 to 6 consist of the major urban areas of Managua. Districts 2, 4 and 6 extend from the low zone along the shore of Managua Lake to the high zone (35-135m in elevation). Districts 3 and 5 are situated in the higher zone which is elevated from 50 to 300m.

Except for the eastern parts of Districts 5 and 6, which are in the Eastern sub-area, most parts of the above Districts are included in the Central sub-area of the hydrogeological basin.

The water demand projection and the water consumption rate per capita per day are planned in all these Districts in compliance with the service level of the urban water supply.

District 7 is situated in the highest area at the southern end of Managua (more than 300m in elevation). Although this District is administratively included in the city area, the service level of this water supply system is not within the same level as those in other Districts. The plan for the year 2000 is kept within the present rural water supply service level, and the population or demand growth rate is to be kept at nearly half of the other Districts, because drastic social and industrial development is not expected in this District affected by an unfavorable topography.

6.3 Water Demand Projection

The population to be served in District 2 to 7 is estimated at 1,678,382, the projected population in 2000, based on the 1991 population estimate (1,164,103) and the following growth rates:

Growth rate	Period	Districts
5.2%	1991 - 1995	1 - 6
5.0%	1995 - 2000	
2.5%	1991 - 2000	7

The estimated population by District is shown in Table 6.1.(1).

The water demand in 2000 is estimated at 138.88 MGD (525,700 m^3/day) as shown in Table 6.1.(2).

The water demand, that is, the planned daily maximum amount of supply calculated by multiplying the projected population to be served by the daily quantity of maximum supply per head, differs in Districts 2 - 6 (urban level) and District 7 (rural level) as shown below:

	Daily Maximum quantity of	Population in 2000	Demand in 2000
District 2-6	82.5 gal/c.d	1,557,757	128.52 MGD
District 7	10.0 gal/l/d	120,625	1.21 MGD
Total		1,678,382	129.73 MGD

The population served is 100 percent of the population, as stated the basic concept of the plan.

The factors used in determining the daily maximum quantity of supply in the urban service level are as follows:

(1) Actual domestic water consumption rate as of 1991.........45.83 gal/c/day

(2) Daily average quantity of supply per head ((1) x 1.2).........55.0 gal/c/day

(3) Ratio of daily maximum supply 1.2

(4) Ratio of effectivity.................0.8

6.4 Groundwater Development Plan

6.4.1 Groundwater development potential by area

The groundwater development potential of the two hydrogeological sub-areas where Districts 2 to 6 are situated is as follows:

Central sub-area	:	41.6 million m^3/year	(30.11 MGD)
Eastern sub-area	:	108.0 million m^3/year	(78.17 MGD)
Total	:	149.6 million m^3/year	(108.28 MGD)

The potential will be unchanged as long as similar meteorological condition continues, but the potential of the groundwater allocated as Managua's water supply source will decrease along with the increase of demand in other categorized water use as shown below:

unit: MGD

	1991	1995	2000
Total groundwater potential	108.28	108.28	108.28
Potential allocated for agricultural and industrial uses and as rural water supply source	9.97	10.47	11.17
Potential allocated as Managua's water supply source	98.31	97.81	97.11

A total of 68.69 MGD of groundwater, including the water of Asososca Lake, has been developed as the source of the Managua water supply system as of 1991, and the remaining potential that has to be developed by area is shown in the following Table.

Remaining Groundwater Development Potential by Area

	1991		1995		2000	
	Central sub-area	Eastern sub-area	Central sub-arc	Eastern sub-area	Central sub-area	Eastern sub-area
Remaining capacity to be developed for Managua water supply	25.85	72.46	25.85	71.96	25.85	71.26
	98.31		97.81		97.11	
Production as of 1991	46.01	22.68				
	68.69					
Remaining development potential	-20.16	49.78	(-20.16)	(49.28)	(-20.16)	(45.58)
	29.62		(29.12)		(28.42)	

Note: (-) denotes excessive pumpage;
Figures in parenthesis ( ) are the remaining potentials estimated assuming that there are no other additional water resource developments conducted after 1991.

6.4.2 Balance in Groundwater Potential and Water Demand

As shown in the following Table, the water demands of Districts 2 to 7 in 1995 has been surpassed by the total groundwater potential of the Central and Eastern sub-areas, also by the demand in 2000, indicating the need to develop supplementary water sources from outside the Study Area to meet the demand in 2000.

Balance in Groundwater Potential and Water Demand for the Managua Water Supply System in the Central and Eastern Sub-areas

unit: MGD, (million m^3/year)

	1991	1995	2000
Groundwater development potential allocated to Managua water supply	98.31 (135.83)	97.81 (135.14)	97.11 (134.17)
Water demand in Managua water supply (Disrict 2-7)	83.18 (114.93)	101.77 (140.61)	129.73 (179.24)
Balance of Demand-Potential	15.13 (20.90)	-3.96 (-5.47)	-32.62 (-45.07)

6.4.3 Groundwater Development in the Eastern Sub-area

The groundwater development from the Eastern sub-area will be attained in the following two phases.

Phase 1: It is planned as an urgent supply plan to solve the existing severe problems of supply shortage such as periodical water suspension and very limited supply especially to highly elevated areas. 18.74 MGD of groundwater is to be developed by 1996.

Phase 2: The remaining groundwater potential in this area (29.84 MGD out of 71.26 MGD) will be fully developed in this phase to meet the water demand in 2000 as much as possible. The full development of this remaining potential will increase the total production of the Central and Eastern sub-areas to 117.27 MGD, only 12.46 MGD lesser than the estimated demand of 129.73 MGD in 2000.

6.4.4 Countermeasures for Over-pumping in the Central Sub-area

During the groundwater development project in the Eastern sub-area, problems on over-pumpage in the Central sub-area will be put aside and measures to increase supply source rather than the mitigation of excessive pumpage will be given priority.

Excessive pumpage in the Central sub-area should be counter-acted sooner or later though, in order to eliminate the fear of contaminated water intrusion from Lake Managua by reverse groundwater flow. However, since some safety factors such as the non counting of recharge by leakage from distribution pipes, were employed in the water balance analysis, the prevention of excessive pumpage is not so urgent, especially if groundwater development in the area is kept at the same amount (46.01 MGD) as of 1991 or less.

Accordingly, the use of developed water is fully planned as a supplement of the existing supply source and not as a replacement for the excessively pumped amount of water in the Central sub-area.

A detailed study on pumpage reduction in the Central sub-area is necessary. The excessively pumped amount shall be replaced by developing supplementary sources outside the Study Area. Further, the revision of the distribution system should be studied also for the replacement of 20.16 MGD, which shall come from a different source line.

6.4.5 Target Total Amount to Develop

In addition to the development of supply sources required to meet the demand in 2000 (129.73 MGD), some source will be developed outside the Study Area to mitigate over-pumpage in the Central sub-area, in the 3rd phase of the Project. The quantity ranges from zero (no mitigation) to 20.16 MGD (elimination of over-pumpage).

The total amount of groundwater to be developed, therefore, is as shown below:

Phase 1	18.74 MGD
Phase 2	29.84 MGD
Phase 3	12.46 MGD plus zero to 20.16 MGD
Total	61.04 MGD to 81.2 MGD

Since 68.69 MGD of groundwater has been developed by 1991, the required additional amount to develop to meet the demand in 2000, which is 129.73 MGD, is 61.04 MGD.

The amount necessary to mitigate over pumpage shall be studied in the 3rd phase of the project.

6.5 Selected Well Fields in the Study Area

The two sites in good hydrogeological condition in the Eastern sub-area have been selected as group well construction fields in order to effectively develop groundwater in the area.

One of the sites is located around Sabana Grande-Veracruz, while the other is located between North Ticuantepe and Veracruz, as shown in Fig. 6.3. The characteristics of the sites are listed below.

Table 6.2 Characteristics of the Selected Well Fields

	Sabana Grande	North Ticuantepe
Aquifer Geology	Masaya Group Volcanics in Middle Las Sierras Group	Various volcanic materials in Middle Las Sierras Group
Static Water Level	15 - 45m BGS	95 - 105m BGS
Specific Capacity	600 - 1100 m3/day/m	more than 10,000 m3/day/m (negligible drawdown at a pumping rate of 1500 m3/day)
Water Quality	good	excellent
Well Depth to drill	150 - 200m	200 - 250m
Ground Elevation	low and high zones (to Las Americas No. 4 reservoir)	highest zone (to Altamira reservoir)
Potential of further development for Urban Water Supply	80,000 - 120,000 m3/d	70,000 - 100,000 m3/d
Total	184,000 m3/d (48.58 MGD)	

6.6 Implementation Plan

6.6.1 Outline and Implementation Schedule of the Project

The Project on groundwater development is to be divided into three phases, as shown in Fig. 6.1, to meet the demand in 2000.

Phase 1 of the Project is focused on the urgent improvement of the insufficient service level of the present water supply. A condition that would produce an amount of 18.74 MGD is to be developed in one of the two promising areas in the Eastern sub-area (North Ticuantepe area), at least to mitigate the inconveniences of the periodical water suspension and unfair (too short) supply to highly elevated areas.

Phase 2 of the Project is focused on a full-scale groundwater development in the other promising area in the Eastern sub-area (Sabana Grande-Verasquez area), to produce the remaining development potential of the Eastern sub-area which is a maximum amount of 29.84 MGD, in order to catch up with the demand in the year 2000 as much as possible.

The remaining required amount of water will be produced by developing water supply sources outside the Study area in the 3rd project phase. The required additional amount of water to be produced to meet the demand in 2000 falls within the range of 12.46 and 32.62 MGD, depending on how the over pumpage condition in the Central sub-area is treated. Since the groundwater development potential in the area outside of the Study area is unknown, the 3rd phase of the Project is divided into two stages, namely the study stage and construction stage. The following two items should be studied prior to the construction stage:

(1) Groundwater development potential of the area

(2)Determination of when and how to replace the over pumped amount of water from the Central sub-area with the water from newly developed sources by analysing the result of groundwater monitoring undertaken since 1992.

The scope of the Project, through all phases, is limited to increase in water production by well construction and the construction of conveyance facilities from the wells to existing major reservoir tanks. The expansion or rehabilitation of the distribution facilities should be covered by other different projects.

Since one of the major purposes of this urgent program is to eliminate unfair supply of water to highly elevated areas, the water developed from a comparatively higher area in North Ticuantepe is to be transmitted to the Altamira reservoir where the present supply of water to highly elevated areas originates.

The area receiving supply from the distribution tank of Altamira reservoir will be expanded to the west and south, thus also covering parts of the area served by the Asososca water supply system as illustrated in Fig. 6.2.2. Also, increase in the inflow of Altamira reservoir will lighten the burden of the distribution reservoirs of San Cristobal and Las Americas No. 4, increasing the amount distributed to Low and High zones. The variations shown in Fig.6.2.1 to 6.2.2 not only indicate variations in service area but also increase in the amount supplied to almost the entire service area, thus eliminating periodical water suspension.

In the 2nd phase of the Project, groundwater developed from the lower Sabana Grande-Veracruz area is to be transmitted to Las Americas No. 4 reservoir.

By increasing the quantity of water coming in the Las Americas No. 4 distribution tank, the area supplied by this reservoir will be expanded to the west, thus considerably increasing the amount supplied to the entire service area. The comparison of Fig. 6.2.3 and Fig. 6.2.2 indicates the above variation.

However, the existing major reservoirs, especially Las americas No. 4, does not seem to be capable enough to receive all of the newly developed water. Therefore, the installation of a new reservoir near Las Americas No. 4 or a direct connection between Las Americas No.4 and the Altamira reservoir is believed to be necessary; this should be covered also by a different project beforehand or in parallel with the implementation of the 3rd project phase.

In consideration of the presumed shortage in the capacity of Las Americas No. 4 reservoir, a big capacity reservoir tank is to be designed in the 2nd phase to be able to accommodate 29.84 MGD of groundwater.

6.6.2 Facility plan for the 1st and 2nd Project Phases

Fig. 6.4 and Fig. 6.5 represents the total number of facilities to be constructed in phase 1 and phase 2, and the outline of the facility plan for each phase is as follows:

1) Facility plan for Phase 1

a. Well:
- Casing diameter : 12 inches or more
- Drilling depth : 200 - 250 (dynamic water level 100 - 110m)
- Pumping discharge : 3.79 m^3/min at total head of 117m
- Pump type : Submersible motor pump
- Number of wells : 14 wells
- Location arrangement : Grouped wells within 1km^2

b. Storage tanks beside the well group:
- Material : Concrete
- Capacity : 1,500 m^3 (Retention time: 0.5 hours)
- Ground elevation : 217 m
- Number : 2 sets

c. Pump station with chlorinator and electricity controller
- Transmission pump : 12.5 m^3/min. with total head of 82 m
- Number of pump : 5 sets (one is for spare)
- Chlorination facility : 1 set
- Pump house with electricity control panel: 1 set

d. Santo Domingo reservoir tank:
- Material : Prestressed Concrete or Iron reinforced concrete
- Capacity : 11,000 m^3 7.5 hour retention capacity by two tanks
- Number of tanks : 2 sets
- Ground elevation : 255 m

e. Transmission pipe:
- Well to storage tank : 300 mm L=1300m
- Pump station to reservoir tank : 700mm, L=5500m
- S. Domingo to Altamira: 500 - 600mm, L=5200m
- Material : Steel, and ductile iron with cement lining

2) Facility plan for Phase 2

a. Wells:

Casing diameter	:	12 inches or more
Drilling depth	:	150-200m (dynamic water level 20 - 60m BGS)
Pumping discharge	:	4.1 m^3/min with total head of 45 m.
Pump type	:	Top driven vertical pump
Number of wells	:	19 wells
Location arrangement	:	Grid arrangement with a space of 500m or more.

b. Reservoir tank:

Material	:	Pre-stressed concrete or iron rein forced concrete
Capacity	:	15,000 m^3
Number of tanks	:	2 sets
Ground elevation	:	84 m

C. Pump station with chlorinator and electricity controller

Transmission pump	:	19.6 m^3/min, with total head of 90 m
Number	:	5 units
Chlorination facility	:	1 set
Pump house with electricity control panel	:	1 set

d. Transmission pipe lines

Wells to tank	:	300 - 800 mm, L= 12900 m
Las America	:	1000 mm, L = 5800 m

6.6.3 Facility plan for Phase 3

The necessary amount to be produced from the source to be developed outside of the Study area, most probably at the east side of the Study area, ranges from 12.46 to 32.62 MGD. The development of the lowest amount, which is 12.46 MGD, is considered capable of satisfying the water demand in 2000, but if 32.62 MGD is developed, 20.16 MGD from additionally developed sources will be used to replace the over-pumped amount of water in the Central sub-area.

The groundwater development potential at the east of the Study area may not be as high as the Eastern sub-area's. Moreover, the transportation distance to Managua is farther. Therefore, the unit cost of the groundwater development in this area may be 30 to 40 % higher than that in the Eastern sub-area.

The details of the above shall be studied in the first stage of phase 3, however, the facility plan of phase 3 may be basically similar to that of phase 2. The following are the assumed facilities for the 3rd phase of the Project:

Wells	:	13 - 34 wells (Discharge of 2.3 m^3/min per well)
Storage tank	:	2 to 4 sets of 1,500 m^3 concrete tanks
Reservoir tank	:	1 to 2 sets of 11,000 m^3 concrete tanks
Pump station	:	1 main and sub-pump station
Transmission pipes	:	250 - 1000 mm L = 20,000 - 25,000 m

6.6.4 Project cost Estimation

Cost estimation was made in every phase of the Project, however, the estimation for Phase 3 was conducted differently. Since the 3rd phase of the Project involves a lot of unknown factors concerning both groundwater development potential and the necessary amount to be developed, cost estimation was simply conducted on the basis of the unit price of water developed from Sabana Grande area in the 2nd phase of the Project, and by the assumption that the unit development cost of water from outside of the Study area is 30% higher than that from Sabana Grande area. The expenses for the study in the 1st stage of phase is included.

The construction cost estimation of the 1st and 2nd phases of the Project was performed based on the following conditions:

a. Financial evaluation is based on the price rate as of April, 1993

b. Construction cost is divided into portions of foreign and local currency. Majority of the construction cost falls under foreign portion; and the local portion comprises mainly of land acquisition expenses, the costs of locally available constructing materials and manpower.

c. In conversion of foreign and local currency, the following rate is used:
1 US Dollar = 6.0 Nicaraguan Cordoba = 115 Japanese Yen.

d. The physical contingencies is estimated at 10% of the total of the above (1) to (3) items.

e. The price contingencies is estimated at 8 to 5% in the foreign portion and 20 to 10 % in the local portion of the total of the above (1) to (4) items.

The cost estimated for each phase of the Project is as follows:

Phase 1: C$ 213,187,000 (C$ 3,003 m³/ day)

Phase 2: C$ 348,962,000 (C$ 3,088 m³/ day)

Phase 3: C$ 188,658,000 for 47,000 m³/day developmenet

- C$ 493,722,000 for 123,000 m³/day development

by C$ 4,014/m³ day

6.7 Operation and maintenance plan

1) Operation of pumpage and conveyance system

A semi-automatic operation system is to be introduced in this Project, which comprises an automatic water level indication of the reservoir linked with automatic operation of electric valve (Altamira) and enables information exchange between the reservoir and pump station through radiophone and manual operation of the transportation pumps. An automatic level indication and alarm system for the intake facility are also included in this semi-automatic operation system.

A sub-operation center is to be opened in the project site in each phase, and the overall supervision of the 3 sub-operation center wil be undertaken by the Centralized Operation Cneter in the INAA headquarter by radio communication system.

Fig. 6.6 represents the general operation system.

2) Estimation of the operation and maintenance cost

The total cost for the operation and maintenance of the new construction facilities implemented in Phase 1 and 2 is estimated at C$ 14,318,400 per year. The unit production cost per cubic meter per day will be C$ 0.213, divided by the total production quantity of 183,900 m³/day (48.58 MGD).

Table 6.1 (1) Estimated population in 1991, 1995 and 2000

District	Low Zone			High Zone			Highest Zone			High Highest Zone			District I			Total		
	1991	1995	2000	1991	1995	2000	1991	1995	2000	1991	1995	2000	1991	1995	2000	1991	1995	2000
1	-	-	-	-	-	-	-	-	-	-	-	-	70.986	86.943	110.964	70.986	86.943	110.964
2	105.678	129.434	165.194	45.348	55.542	70.887	-	-	-	-	-	-	-	-	-	151.026	184.976	236.081
3	-	-	-	60.916	74.610	95.223	54.859	67.191	85.755	53.651	65.711	83.866	-	-	-	169.426	207.512	264.844
4	158.303	193.889	247.457	70.704	86.598	110.523	-	-	-	-	-	-	-	-	-	229.007	280.487	357.980
5	-	-	-	42.916	52.563	67.085	143.134	175.310	223.745	14.800	18.127	23.135	-	-	-	200.850	246.000	313.965
6	94.933	116.273	148.397	147.156	180.236	230.032	4.131	5.060	6.458	-	-	-	-	-	-	246.220	301.569	384.887
7	-	-	-	-	-	-	-	-	-	96.588	106.615	120.625	-	-	-	96.588	106.615	120.625
Total	358.914	439.596	561.048	367.040	449.549	573.750	202.124	247.561	315.958	165.039	190.453	227.626	70.986	86.943	110.964	1.164.103	1.414.102	1.789.316
																Total of District 2-7		
																1.093.117	1.327.159	1.678.382

Table 6.1 (2) Estimated water demand in 1991, 1995 and 2000

Unite:MGD

	Low Zone			High Zone			Highest Zone			High Highest Zone			District I			Total		
	1991	1995	2000	1991	1995	2000	1991	1995	2000	1991	1995	2000	1991	1995	2000	1991	1995	2000
1	-	-	-	-	-	-	-	-	-	-	-	-	5.86	7.17	9.15	5.86	7.17	9.15
2	8.72	10.68	13.63	3.74	4.58	5.85	-	-	-	-	-	-	-	-	-	12.46	15.26	19.48
3	-	-	-	5.03	6.16	7.86	4.52	5.54	7.07	4.43	5.42	6.92	-	-	-	13.98	17.12	21.85
4	13.06	16.00	20.42	5.83	7.14	9.12	-	-	-	-	-	-	-	-	-	18.89	23.14	29.54
5	-	-	-	3.54	4.34	5.53	11.81	14.46	18.46	1.22	1.50	1.91	-	-	-	16.57	20.30	25.90
6	7.83	9.59	12.24	12.14	14.87	18.98	-	-	-	0.34	0.42	0.53	-	-	-	20.31	24.88	31.75
7	-	-	-	-	-	-	-	-	-	0.97	1.07	1.21	-	-	-	0.97	1.07	1.21
Total	29.61	36.27	46.29	30.28	37.09	47.34	16.33	20.00	25.53	6.96	8.41	10.57	5.86	7.17	9.15	89.04	108.94	138.88
																Total of Distrcit 2-7		
																83.18	101.77	129.73

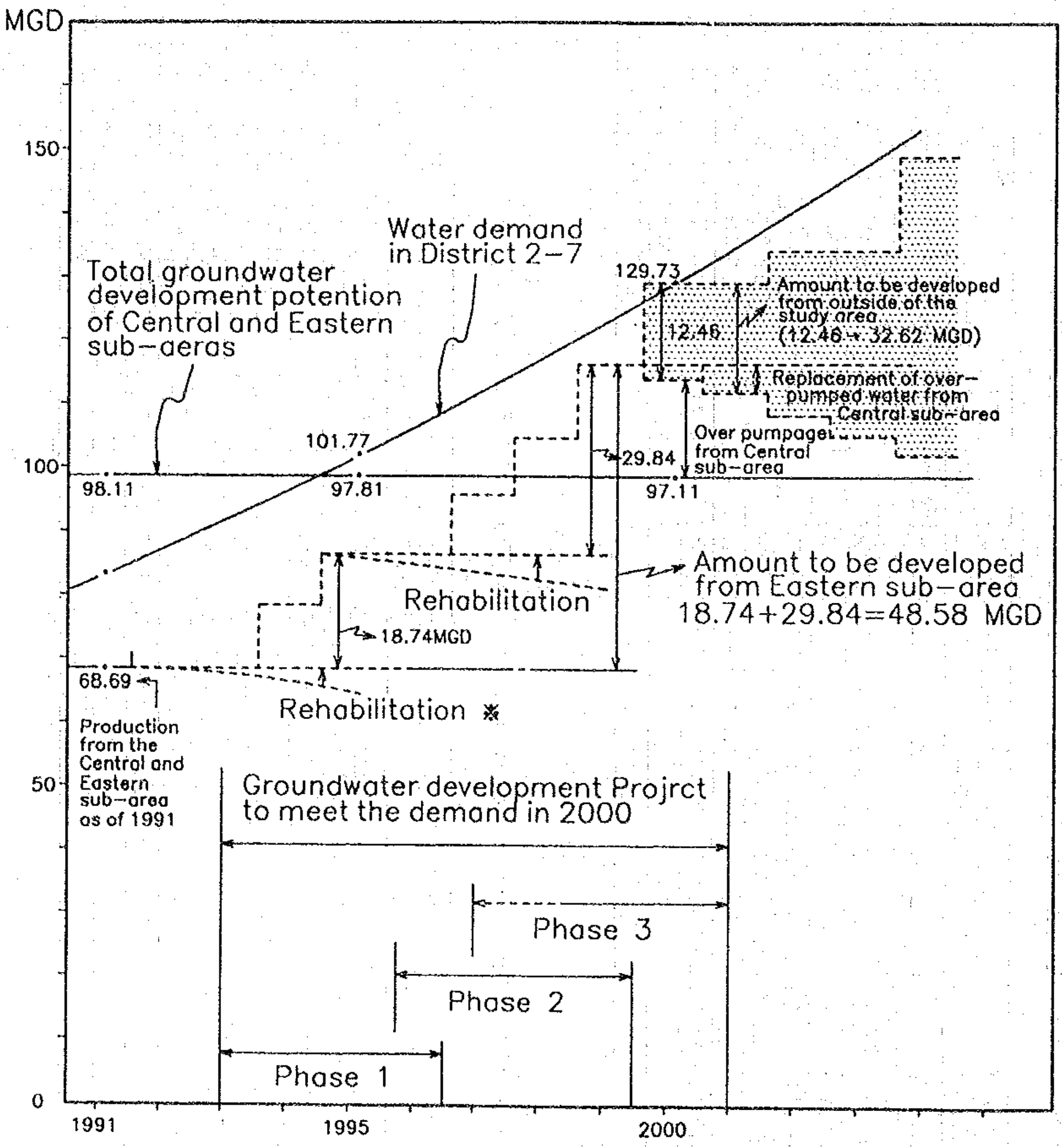


Fig. 6.1 Project Implementation Phases and Relation between Demand and Production

※ Well rehabilitation is recommended to limit to recovering the original capacity of the(aged)wells,especially those in the Central Sub-area,so as not to exacerbate the over-pumping of 20.16 MGD

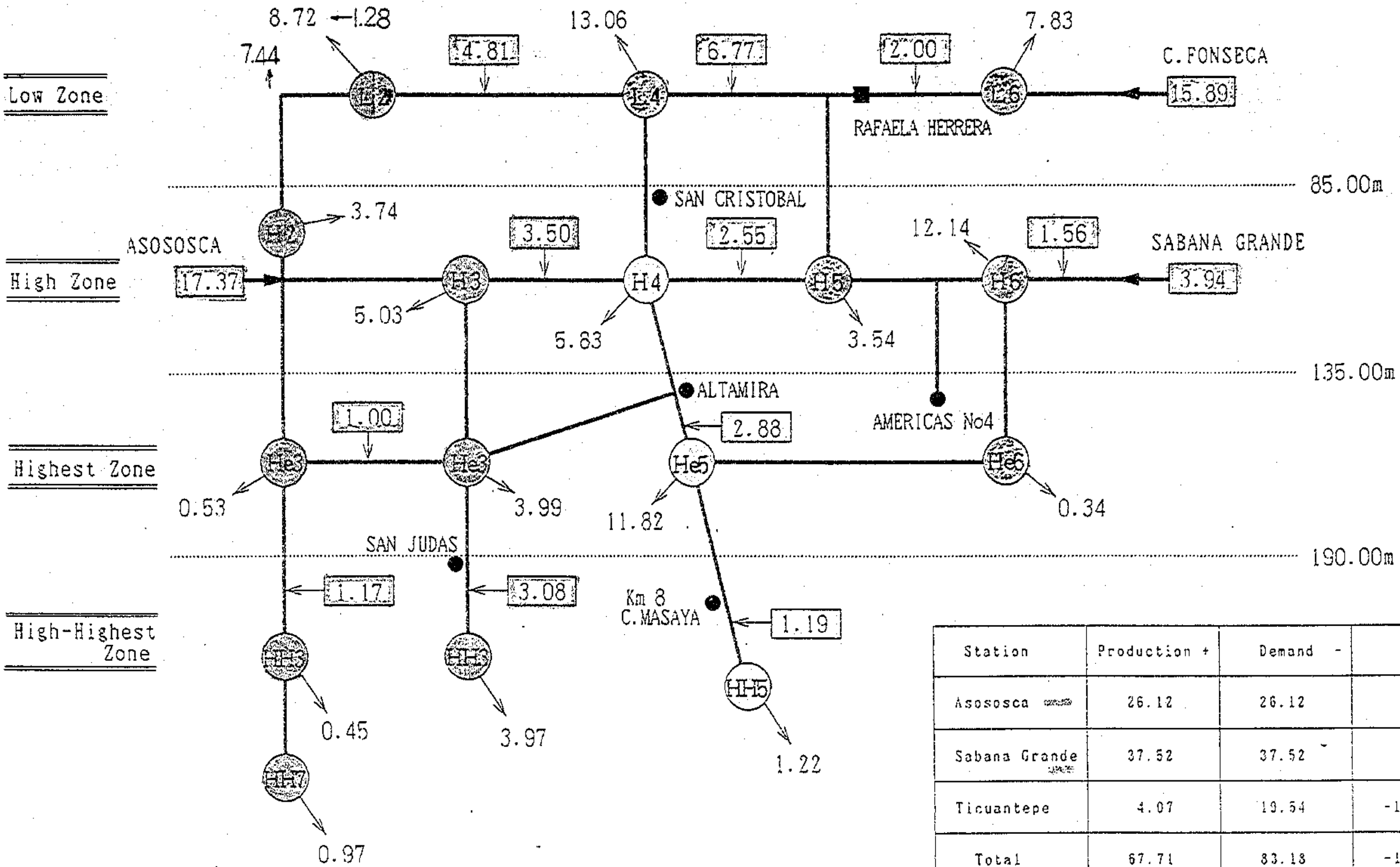
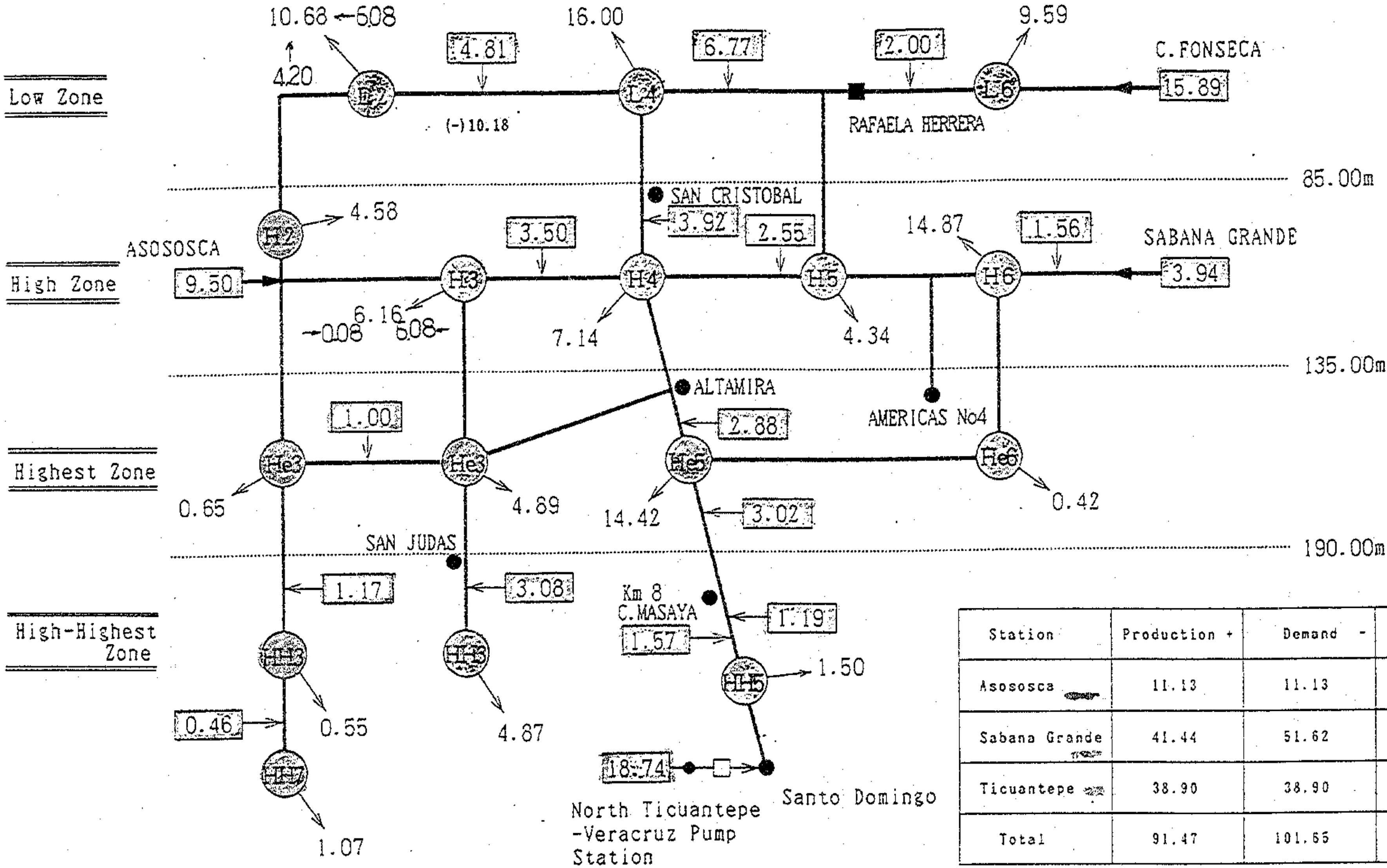


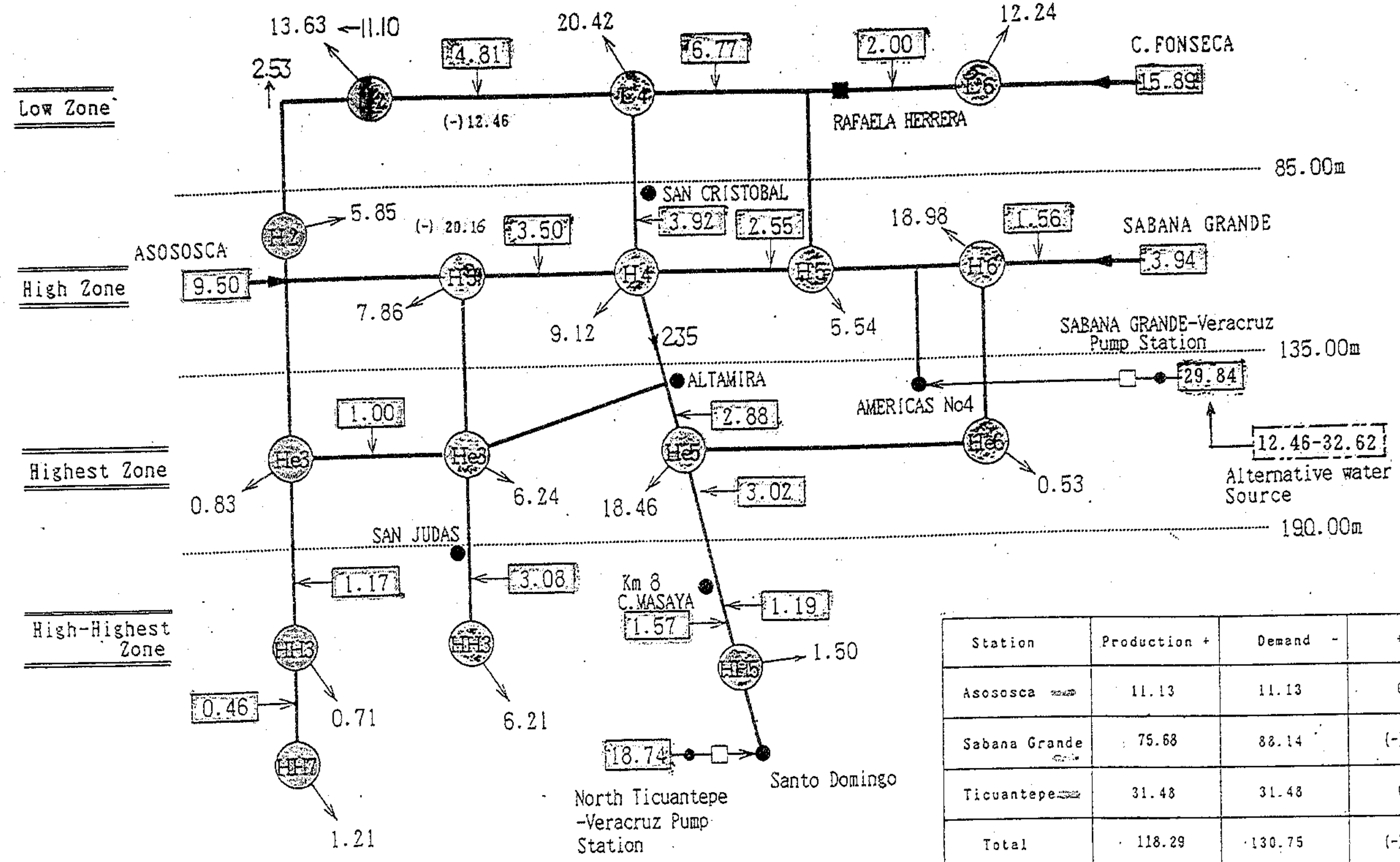
Fig. 6.2.1 General distribution system as of 1991

Station	Production +	Demand -	+ -
Asososca	26.12	26.12	0.00
Sabana Grande	37.52	37.52	0.00
Ticuantepe	4.07	19.54	-15.47
Total	67.71	83.18	-15.47



Station	Production +	Demand -	+ -
Asososca	11.13	11.13	0.00
Sabana Grande	41.44	51.62	-10.18
Ticuantepe	38.90	38.90	0.00
Total	91.47	101.65	- 10.18

Fig. 6.2.2 General distribution system after phase 1 of the Project



Station	Production +	Demand -	+ -
Asososca	11.13	11.13	0.00
Sabana Grande	75.68	88.14	(-)12.46
Ticuantepe	31.48	31.48	0.00
Total	118.29	130.75	(-)12.46

Fig. 6.2.3 General distribution system after phase 2 of the Project

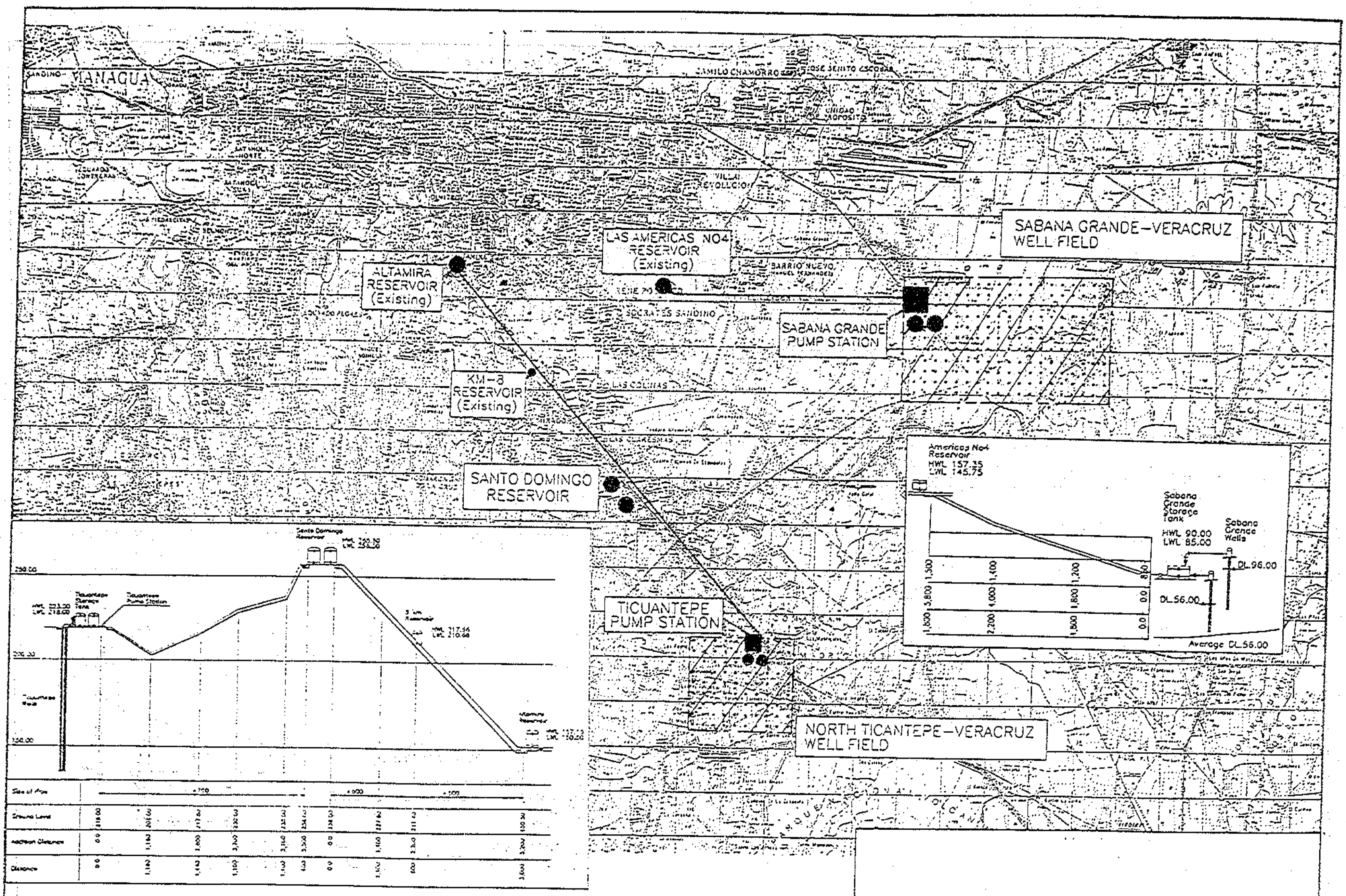
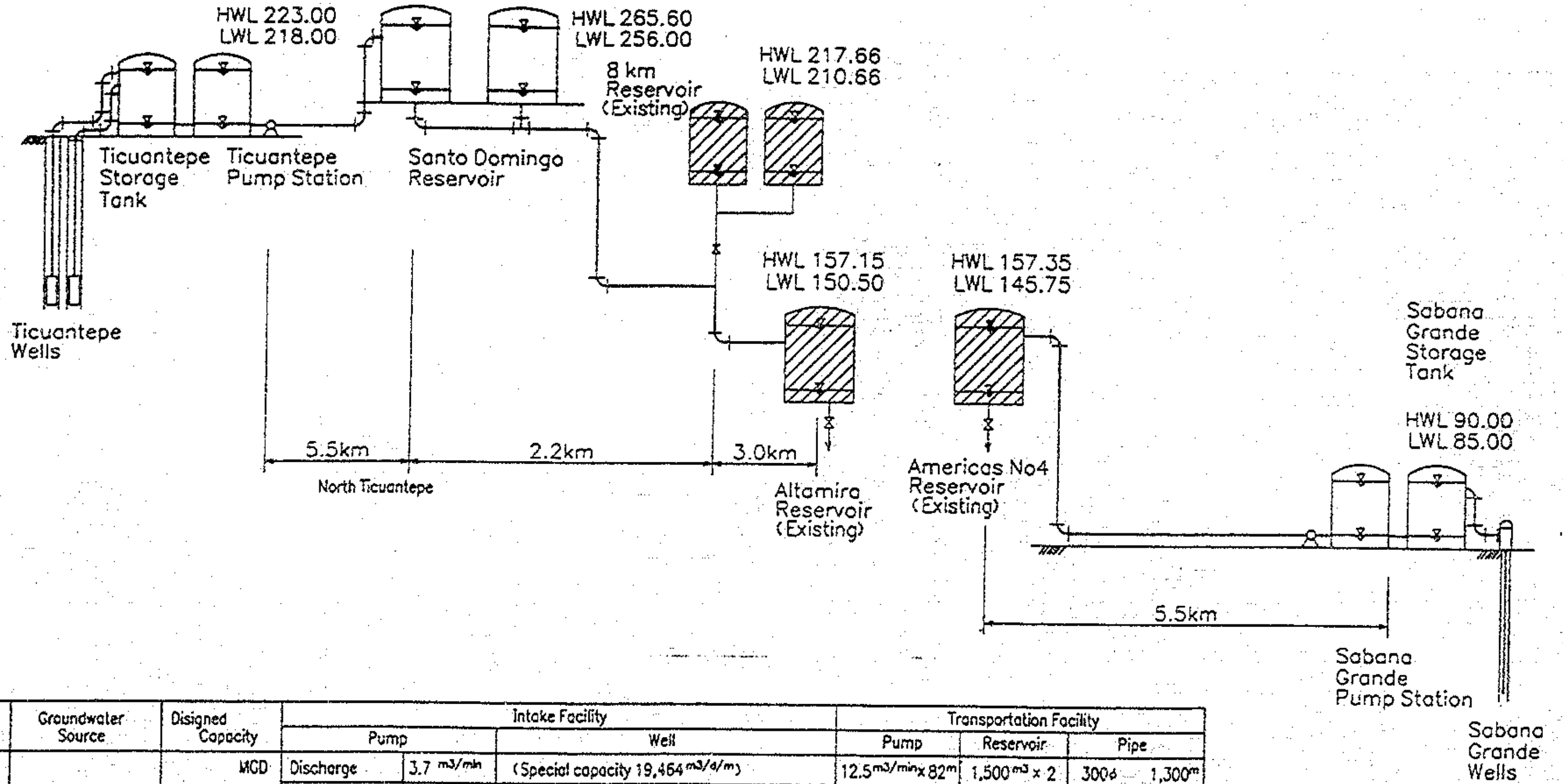


Fig. 6.3 Location map and profile



Phase	Groundwater Source	Disigned Capacity	Intake Facility: Pump		Intake Facility: Well	Transportation Facility: Pump	Transportation Facility: Reservoir	Transportation Facility: Pipe
I	North Ticuantepe – Veracug	MGD 18.74	Discharge	3.7 m3/min	(Special capacity 19,464 m3/d/m)	12.5m3/min x 82m	1,500m3 x 2	300φ 1,300m
			Head	117.0 m	(Dynamic water level EL.107m)	1800rpm x 250kw	11,000m3 x 2	500φ 3,800m
			Pump diameter	8 inch	Well diamiter 14"~12 3/4"	Pump House		600φ 1,400m
			Horse Power	132 kw	Well location arrengiment	240m2 x 1		700φ 5,500m
			Rotation	3600 rpm	group wells, 250m depth	40m2 x 14		total 12,000m
			Number of Unit	14 unit	Number of well 14 unit	5 unit		
II	Sabana Grande – Veracug	29.84	Discharge	4.1 m3/min	(Special capacity 687 m3/d/m)	19.6m3/min x 90m	15,000m3 x 2	300φ 700 m
			Head	45.0 m	(Dynamic water level EL.56~96m)	1800rpm x 400kw		400φ 3,700m
			Pump diameter	8 inch	Well diamiter 14"~12 3/4"	Pump House		450φ 2,000m 500φ 1,000m
			Horse Power	55 kw	Well location arrengiment	490m2 x 1		600φ 1,500m
			Rotation	1800 rpm	500 interval, 200m depth	40m2 x 19		700φ 2,000m 800φ 1,000m
			Number of Unit	19 unit	Number of well 19 unit	5 unit		1000φ 5,800m total 17,700m

Fig. 6.4

Total facility plan for phase 1 and 2 of the Project

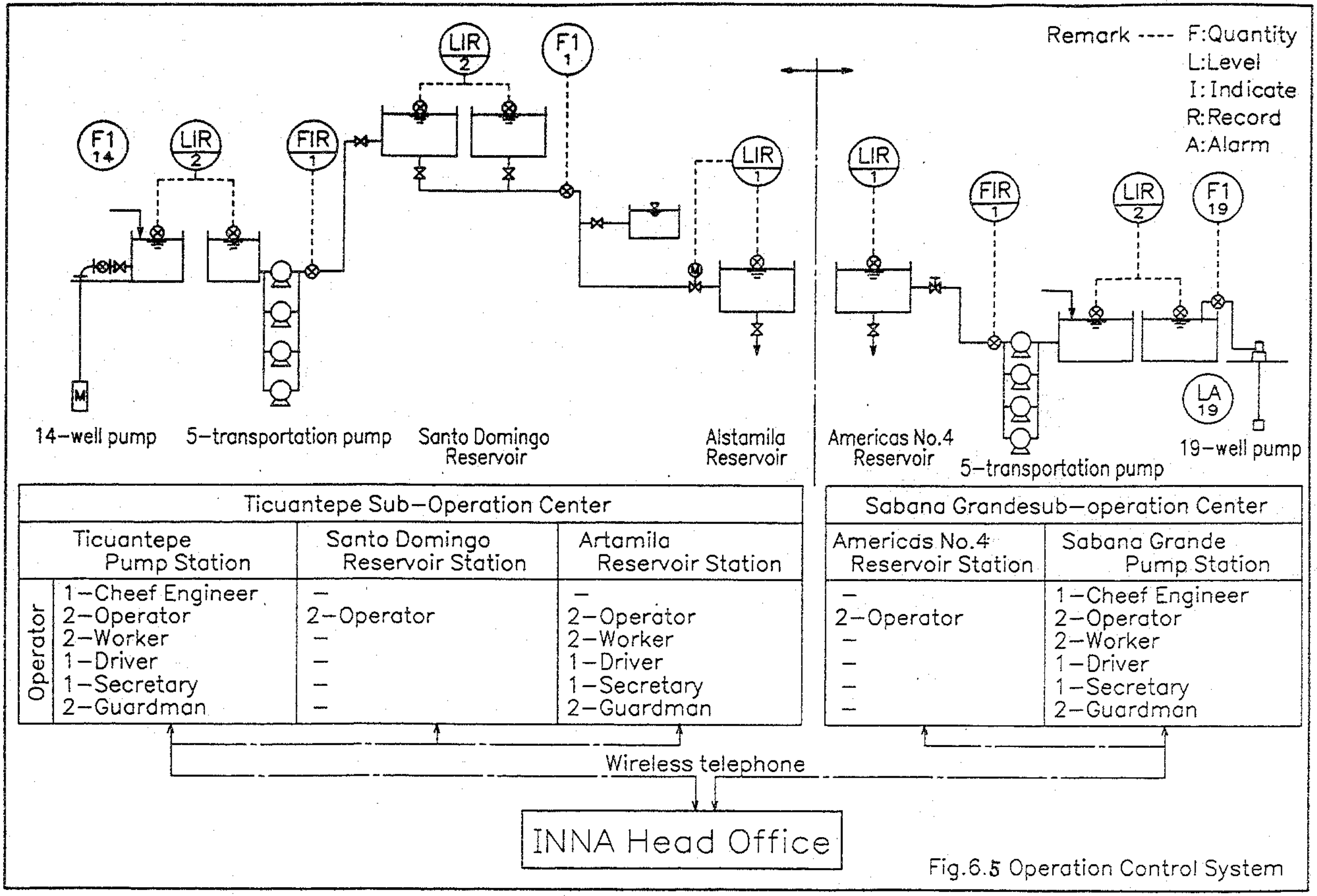


Fig.6.5 Operation Control System