However, the hydrometeorologic monitoring network in and around the Study area is limited, and long-term, accurate records necessary for the envisaged Project are extremely incomplete.

Of the 10 stations with compartively long-term records, only one is of first ranking, one is of second ranking, and the remainder are fourth ranked.

Mean values for meteorological phenomena in the Study area based on available reliable data are as follows:

(1) 15 year mean annual rainfall (1970-1984)

northern sector	188 x $10^6 m^3$/year
southern sector	344.9 x $10^6 m^3$/year
eastern sector	429.8 x $10^6 m^3$/year

(2) 15 year mean temperature

annual maximum temp.	31.1°C
annual minimum temp.	5.8°C
15 year mean temp.	18.7° - 21.5°C
monthly maximum temp.	24.2° - 27.2°C
monthly minimum temp.	14.5° - 15.1°C

(3) Evapotranspiration

80% of observed value (905mm/year): 720mm/year

(4) Solar radiation

Mean solar radiation: 209.2cal/cm ^{2} hour (15 year mean)

(5) Wind velocity

maximum wind velocity	75km/H
Minimum wind velocity	15.2km/H

3.2.5 Water Resources

Sources of domestic water utilized by inhabitants of Metropolitan Guatemala and its environs are rivers, groundwater, lake water and springs.

(1) Approximately 70 percent (1.80m ^{3}/s) of annual water service by EMPAGUA is derived from surface water of rivers in and around the Project area.

Major river water utilization is as follows:

Plant	River	Production (Average)
Lo de Coy	Xaya-Pixcaya	1.2 (m^3/s)
Santa Luisa	Teocinte	0.3
	Acatan	0065
	Canalitos	0.02
Cambray	Pinula, Las Minas	0.08
Las Ilusiones	Teocinte, Acatan, Ocotes, El Bijague	0.18

Not only is river water a source for EMPAGUA's water service, it is also utilized directly by a segment of the population for laundry, bathing and drinking.

Rivers in the Study area are classified as belonging to the Las Vacas river system to the north of the continental divide, and the Michatoya river system to the south of the same. Each river and respective catchment area comprising these river systems are as shown in FIG. 3-7.

As most rivers of the Michatoya river system feed into Lake Amatitlan, intake at the upper reaches of these rivers would affect the water level of the lake. Consequently, their availability as water resources for the Project is considered low.

The Las Vacas system in the north, which is part of the large Motagua river system, is comprised of 20 tributaries with the overall watershed dissected into numerous small catchment areas. River discharges are small and as a result, the system is not considered qualified as a principal water source, although it has potential for supplemental supply. River discharge is particularly inadequate in the dry season.

At present, EMPAGUA diverts approximately $0.525m^3/s$ when discharge is ample from 7 tributaries of the Las Canas river, which is part of the Las Vacas river system. However, at times during the dry season actual diverted amount drops to 30% that in the rainy season. Consequently, those rivers are unstable as a water service supply source.

Furthermore banks of rivers in the Study area consist of plateaus of 200-300m layer of pyroclastic accumulation, heavily fractured limestone, and basaltic lava with danger of seepage in the event of high dam construction to store river discharge.

Also, in recent years contamination of river discharge has progressively worsened, with subsequent suitability as a domestic water source steadily declining.

In the future PLAMABAG proposes to develop a combined $8.5m^3$/sec of water resources from the Xaya, Pixcaya, Guacalate, Motagua, Negro, Cuilco, and other rivers outside the Study area as long-term and stable water sources.

(2) Lake Water

Lake Amatitlan situated in the south of the Study area is not considered an appropriate water source at present due to decreasing water level and increasing contamination. However, if the lake were to be utilized as a reservoir for discharge transdiverted from basins in and around the Study area, the lake development potential would be high.

(3) Springs

There are numerous springs in the Study area, particularly in the southern sector. The largest is Ojo de Agua, from which an average 300 l/sec is diverted by EMPAGUA, for service water supply. Other small springs are utilized directly for domestic water by the nearby population. These small springs offer too little discharge to be systematically developed as a water service system source.

(4) Groundwater

Groundwater is determined as exhibiting the most appropriate potential as a stable water source for offsetting water shortages over the short term.

There are over 300 deep wells, including the 57 managed by EMPAGUA, and around 4000 shallow wells within the Study area. An estimated 45-50 million m^3 of groundwater is currently drafted from these wells.

PLAMABAG proposed groundwater as the stable water source for Emergency Plan (I) on the basis of the following criteria:

i) short implementation period for development;

ii) low project costs, particularly for water treatment and conveyance facilities; and

iii) possibility for early commencement of project implementation.

PLAMABAG anticipates potential development of $1 m^3/s$ of groundwater in the Guatemala City Valley under Emergency Plan (I).

3.3 Groundwater

3.3.1 Aquifer

Two types of groundwater were the subject of study. One type is the unconfined aquifer, hereinafter referred to as the upper aquifer. The other type exhibits characteristics midway between an unconfined and confined aquifer, and consists of groundwater found in the confining layer between the unconfined aquifer and the true confined aquifer. This second type is hereinafter referred to as the lower aquifer. The two types of aquifer differ in aquifer and recharge mechanism and their lithological units and structural conditions are as follows:

The upper aquifer is the topmost and generalized aquifer formed by refill of loose pyroclastic materials of the Quaternary period. This unconfined aquifer is of around 50 m thickness with highly variable hydrogeological characteristics. The average production of this aquifer is around 12 l/sec (200 G/m) for phreatic level abatement of several tens of meters. This aquifer is the one most exploited due to its accessibility. In uplifted blocks and higher parts of topography, this type of free aquifer is commonly exploited for domestic use. Phreatic level in these areas is generally close to the surface (within the first 20 m) and shows great seasonal variations.

The lower aquifer comprises the deep aquifer formed of consolidated volcanic material, lava and Tertiary tuff, as well as Cretaceous limestone highly affected by fault, fractures, and fissures. The aquifer is located approximately between, 1,000 m and 1,300 m above sea level and the lateral extent is controlled by the location and density of the tensional fault.

This type of aquifer is relatively unknown and is consequently very little exploited. However, in the few cases in which this aquifer has been reached by drillings and properly designed wells, its productive importance has been evident, with a volume of 63 l/sec. (1,000 G/m) frequently being obtained.

An example of this is the deep well No. 139 Ojo de Agua (EL 1,300 m, depth 274 m) in the southern sector. This well becomes fractured andesite at depths below 110 m, with artesian flow from the cracks in the rock. This suggests that the water has the character of a confined aquifer with a water head level slightly higher than the elevation of 1,300 m.

Furthermore, the Project 4-3 deep well (EL 1,467, depth 274 m) of the northern sector is fractured limestone at depths below 115 m. Here, the water level is 167 m, and there is a pump-up volume of 63 l/sec. the water level elevation is 1,300 m, or the same as the formerly cited well.

This indicates the possibility of a lower aquifer in the basement rock of this sector, and that the water head of this aquifer is roughly the same as the elevation of 1,300 m. In other words, water from the lower aquifer can be extracted from the basement below EL 1,300 m.

3.3.2 Groundwater Circulation

According to the characteristics of the regional hydrogeological structure, it is understood that there exists a regional circulation pattern of groundwater flow, which within the Study area from the boundary with the Guatemala Valley basin at a UTM coordinate point 772.00E/1,619.00N has an ENE direction (see FIG. 3-6).

Locally the circulation in its most generalized form is expressed as follows: from the main recharge zones of the south, movement begins with directions varying from NNW to north, and subsequently towards the northeast under the ash basin.

Circulation in the lower aquifer follows the preferential ducts of high density fracture, according to the main fault patterns, while in the upper aquifer it conforms to permeability vectors. In the latter case, the flow is more uniform.

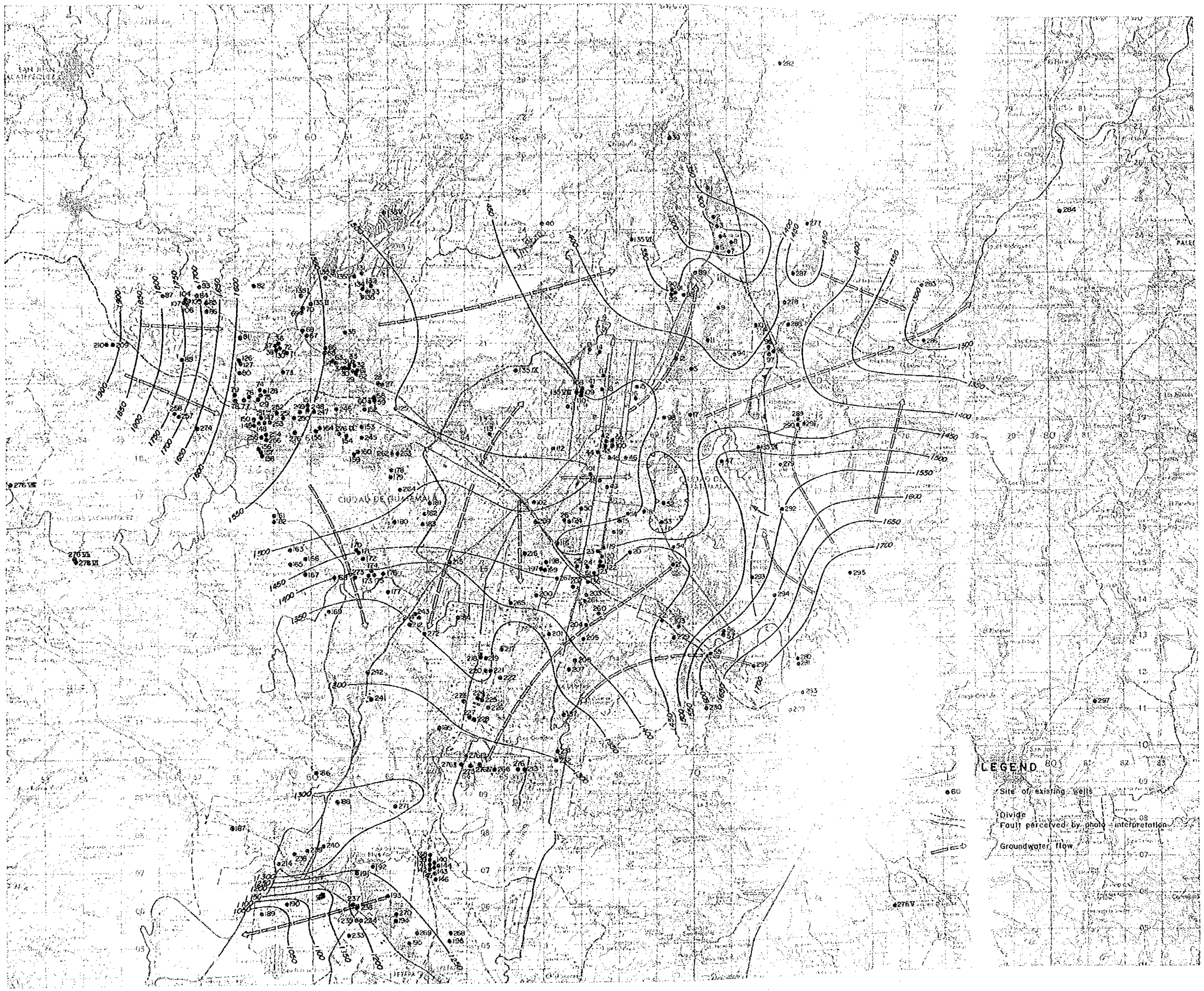


FIG. V-5 GROUNDWATER FLOW REGIME

3.3.3 Groundwater Level

The groundwater level was investigated on the basis of Appendix-I, 5.1.3 (FIG. V-1) and 5.2 (FIG. V-2, V-3 and V-4).

In Appendix I 5.2, it was explained that a linear relationship was obtained for the difference between the groundwater level and the elevation on the deep well and shallow well maps. The distance to the points plotted from the 45° line on the map is thought to be the groundwater.

In the northern sector, two classes of water level, one representing the upper aquifer and one representing the lower aquifer were found at 110 m (average 50 m) and 150 - 160 m, respectively. The elevation of the deepest water level was around EL 1300 m.

The groundwater levels in the southern sector can be broadly classified into two groups, those less than 120 m (average 70 m), and depths between 150 - 180 m. There are also several artesian wells in the Ojo de Agua sector, and their water level is around EL 1300 m. It is therefore concluded that both upper aquifers and lower aquifers exist in the southern sector. (See Appendix I FIG. V-6)

The eastern sector has many extremely shallow pump-up wells and many of these have groundwater levels of less than 50 m. Unlike the two sectors described above, this is thought to show that groundwater is being taken from the upper aquifer. Furthermore, many of these with depths below around EL 1300 m lie on the 45° line in Appendix I FIG. V-2, and are thought to indicate surface artesian flow of the lower aquifer.

3.3.4 Electric Prospecting

The details of the electric propecting conducted by the Team during the field survey period, is described in Appendix I-(VI). The results of electrical prospecting for the eastern and northern (Cerro el Naranjo vicinity) sectors are summarized as follows:

(1) Eastern Sector

In terms of geological structure, the eastern sector is an uplifted zone bounded by two north-south faults. However, there is the possibility that an east-west fault exists along national highway 9 (along the saddle topography). Owing to this, the flow

BASIN	AREA KMS²	LENGTH OF RIVER	DENSITY
N – I	86.82	84.67	0.975
N – II	96.34	74.42	0.772
N – III	56.90	38.08	0.669
S – I	119.16	77.50	0.650
S – II	73.05	45.30	0.620
S – III	125.93	135.10	1.075
S – IV	96.26	16.00	0.166
S – V	166.75	69.60	0.417
E – I	20.81	21.40	1.028
E – II	69.98	39.50	0.564
E – III	82.88	65.50	0.790
E – IV	17.00	16.70	0.982
E – V	46.87	39.16	0.836
E – VI	80.55	30.00	0.372
E – VII	209.48	191.75	0.915
W – I	117.60	129.30	1.099
W – II	54.05	62.90	1.163
W – III	93.25	84.60	0.907
W – IV	56.36	54.30	0.963

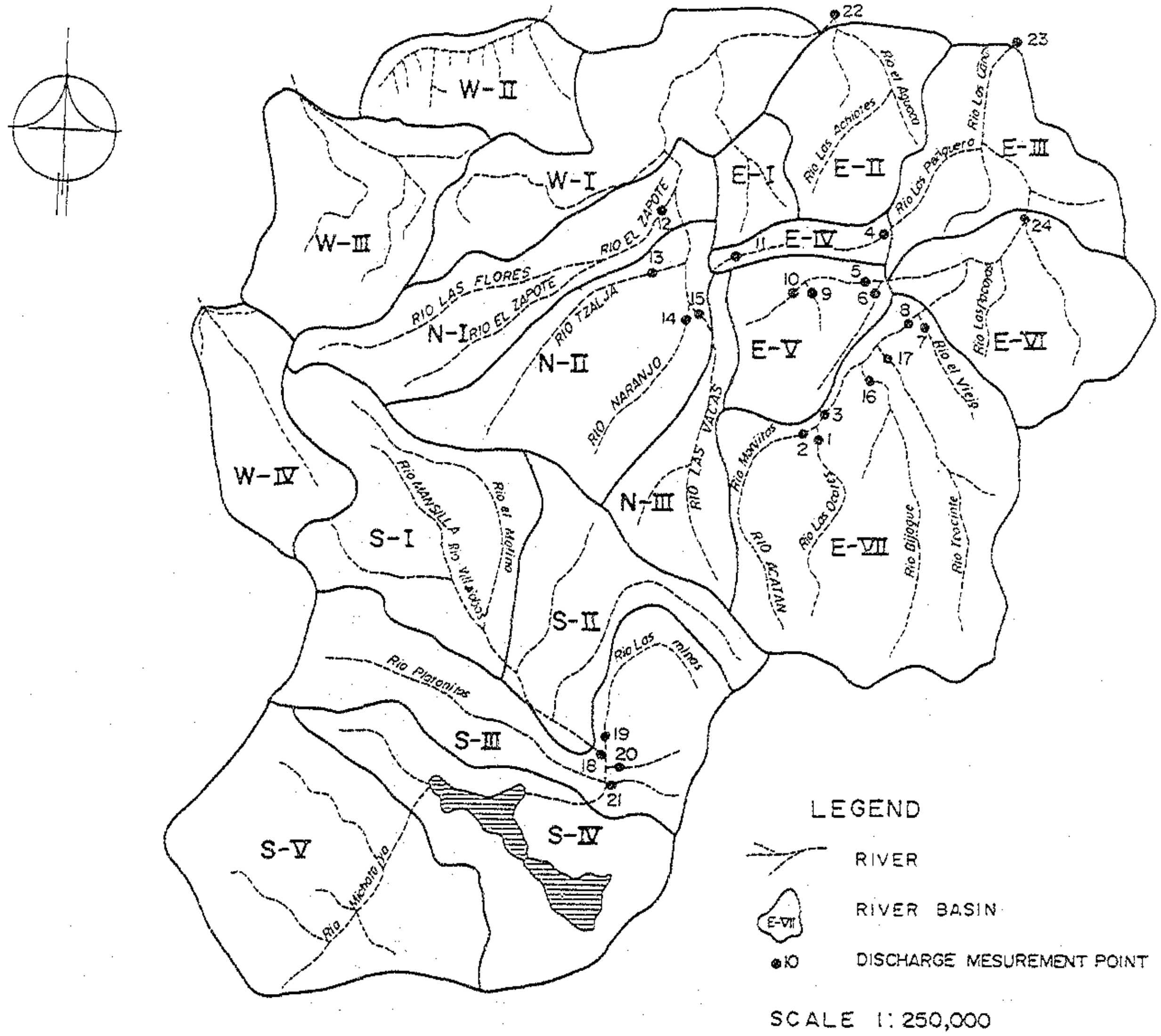
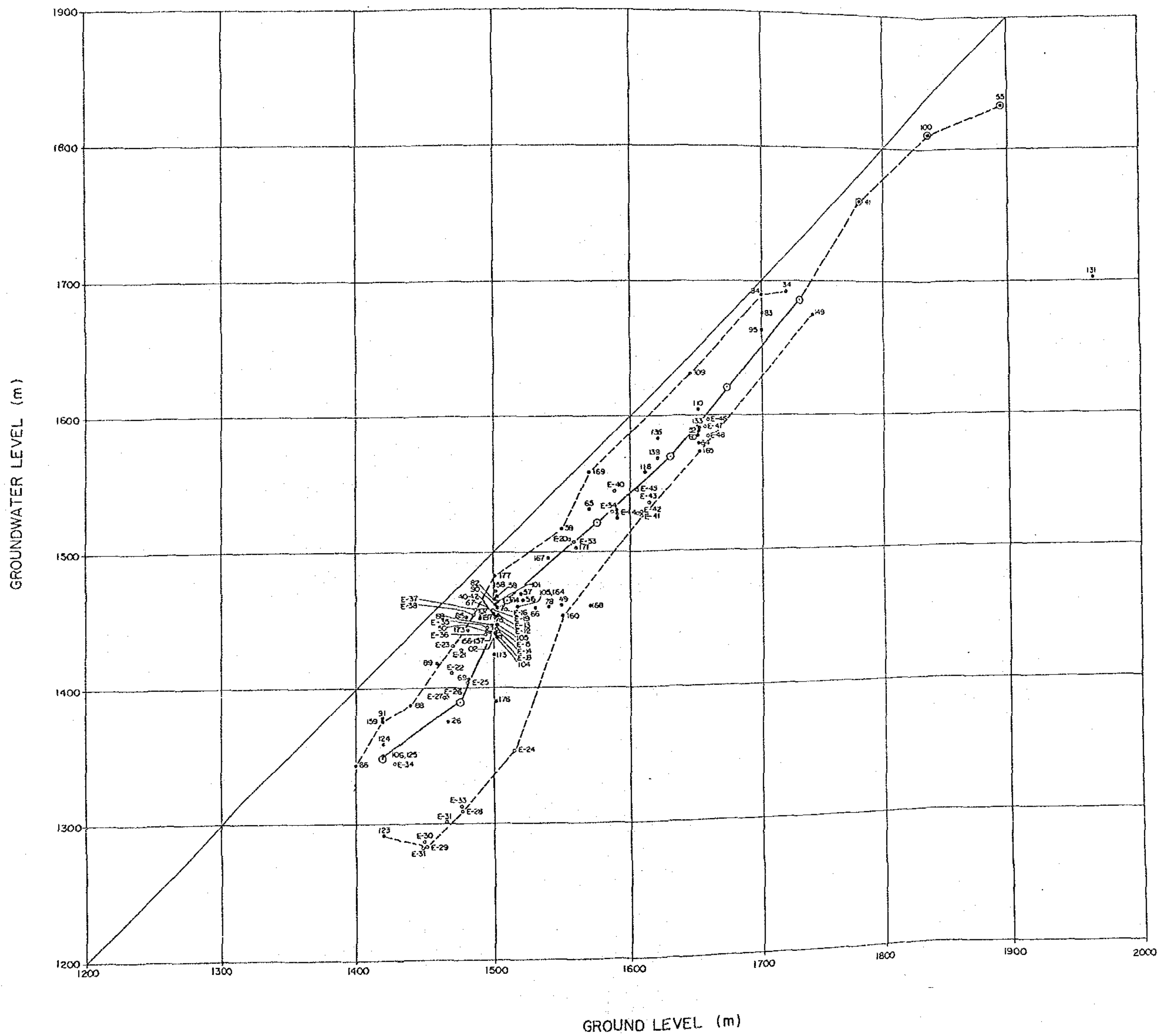


Fig. 3-8 RIVER BASIN

Fig.3-9 DIAGRAM OF GROUNDWATER LEVEL & GROUND LEVEL

NORTHERN AREA



patterns of the upper aquifer groundwater in this region are thought to consist of i) those that are recharged from the plateau near Puerta Parada to the south, and that flow to the north, ii) those that are recharged by the highlands to the west, and that flow to the east of the east-west saddle-topography, and iii) those that are partially recharged from the high land to the north, and that meet to flow north-east along national highway 9.

Three planar distribution maps (EL 1400 m, EL 1300 m and EL 1200 m) were compiled from the results of VES curve analysis and indicated no large difference in the apparent resistivity distributions for each level. The correspondence between the type of rock structure and the apparent resistivity values for this area are shown in Appendix-I, TABLE VI-4. The following is a brief description of these relationship.

- o The 50Ω m or less range corresponds to pyroclastic material or tuff while there is the possibility that it may also be saturated by groundwater.
- o The 100Ω m or more range corresponds to welded tuff or andesitic-basaltic lava, while the 1000Ω m or more range is thought to correspond to limestone or basalt (Cretaceous).

FIG. Appendix I III-16 (1) (2) show the apparent resistivity distribution diagram and the groundwater depth distribution diagram for EL 1200 m of this region. According to these figures, there is an extermely good correspondence between the low resistivity band (50 to 100Ω m) and the groundwater level distribution conditions at depths of below 100 m. This suggests the relatively thick sedimentation of quarternary tuff and pyroclastic material with a high ratio of gaps for this range, and therefore the high possibility of the existence of an upper aquifer at depths below 100 m.

On the other hand in the high resistivity band thought to correspond to coal shale and basalt, the water level of the upper aquifer is generally about 70 m below the surface (and thought to be directly above the basement) and has an extremely small pump-up volume. This is thought to suggest that the basement is located at a shallow depth and that in regions of sloping ground, the groundwater flows down to follow the slope and therefore has a small storage volume. Accordingly, either the central portion of the sedimentary basin or the grabens forming the arteries should be the object groundwater aquifer of large volume. For test well #2 (depth of 300 m) implemented as part of this survey, there were pyroclastics to a depth of 240 m and andesite below that, with the water level being at approximately 95 m. Because of this, it is thought that an upper aquifer exists in a saturated state between the depths of 95 m and 240 m. A pump-up test was performed for the andesite, with there being practically no lowering of the water level when water was pumped at 50 l/sec. This is interpreted as indicating that water was being pumped-up from the lower aquifer, and not from the upper aquifer.

At the Project 3-4 bores in the northern block and the Ojo de Agua sector in the southern sector, the presence of a lower aquifer in the basement was confirmed at EL 1300 m, leading to the expectation of a lower aquifer for below 1300 m in this region. However, in test wells No. 1 and No. 3, despite the groundwater levels in the basement being 1300 m and 1213 m respectively, the pump-up volume was extremely small at 5-6 l/sec for both. For both places, this indicates the possibility of there being a hard basement with little cracking, and therefore necessitating the implementation of a detailed geological survey to determine the elaborate range for which the lower aquifer exists.

(2) Northern Sector (Cerro el Naranjo)

When compared to the eastern sector, this sector has a relatively high value for the apparent resistivity, with coal shale, andesite and granite being recognized on the surface. The basement is therefore thought to exist at a relatively shallow depth. Nevertheless, because Guatemala City rests on a basin structure, few borings down to the basement have been performed for this sector and the average pump-up potential was estimated to be 11-14 l/sec for groundwater levels at depths of 30 m - 100 m, with the greater part thought to be the upper aquifer.

The deep well in this sector was the Project 4-3 bore (EL 1467 m, 304 m deep) in the north. For this bore, there was basement coal shale at a depth of 115 m, with the groundwater level being 167 m (EL 1300 m) and the pump-up volume being very large at 63 l/sec.

The water level is in conformity with the artesian flowing well level for the Ojo de Agua block in the southern sector, and extremely similar to the water level of the test wells #1 and #2 in the eastern sector.

This means that this groundwater is from the lower aquifer, and that future test bores should be implemented with this lower aquifer as the target. However, the landform of this sector is high at EL 1500 m or more and so it is therefore desirable that the boring depth be increased or that borings be implemented in the lowland sector to the east in order to explore this aquifer.

3.3.5 Water Balance

(1) Upper Aquifer

As shown in FIG. III-10, the Study area has been delineated into 3-hydrogeological basins (north, south and east) based on river basin, structural and geological boundaries.

Under the conditions imposed by the following factors, the water balance has been estimated for the three hydrological basins. However, the distribution network loss water that percolates into the ground has been omitted.

Annual area rainfall	: estimated from existing rainfall records of respective area.
Annual evapotranspiration	: 724 m/m
Surface runoff:	
Northern sector	: 5.24 $l/sec/km^2$
Southern sector	: 7.2 $l/sec/km^2$
Eastern sector	: 9.0 $l/sec/km^2$
Safe yield	: 40% of basin reserve

The estimated upper aquifer groundwater availability is sumarized as shown TABLE 3-1.

(2) Lower Aquifer

1) Lower Aquifer Catchment Conditions

According to the data of the Ojo de Agua #1 (No. 139) bore (EL 1300 m, depth 274 m) in the southern sector, there is fractured andesite at depths of below 110 m, with crack seepage from this producing artesian flow. In addition, the majority of the nearby deep bores No. 138 through No. 146 also have artesian flow, with the results of pumping tests showing extremely large values between 50 l/sec and 189 l/sec. The elevations of the bore heads were between EL 1240 m and EL 1320 m. Subsurface geological conditions are unclear but are assumed to be the same as for No. 139 with seepage from fractured andesite. Furthermore, the deep well of the Project 4-3 (No. 2) bore (EL 1467 m, depth 247 m) in the northern sector had fractured limestone below a depth of 115 m with the water level at a depth of 167 m (EL 1300 m). The pump-up volume was relatively great at 63 l/sec, thus suggesting groundwater having the nature of a lower aquifer. Moreover, as deep wells in the southern and northern sectors exhibited identical water head near EL 1300 m it is assumed that a lower aquifer is also present in these sectors. The test well #2 bore (EL 1536.9 m, depth 300 m) in the eastern sector became fractured andesite at depths below 240 m (EL 1296), while pump-up of 50 l/sec or more was possible nearby. The water level of this bore indicated 95.81 m from ground level and is thought to be the result of presence of both upper and lower aquifers for this sector.

2) Estimated Storage

In general, lower aquifers contained in water-bearing layers in monocline and basin structures are thought to be non-flowing, in all but special cases, with measurement of the discharge being difficult. Lower aquifers such as these have recharge proportional to the amount of water taken from them.

This recharge is from higher places that are not covered by impermeable strata, and is often regulated by large-scale geological formations extending outside the subject region.

The lower aquifer for the Study area has water-bearing layers consisting of fractured Cretaceous coal-shale and basalt, as well as Tertiary lava and welded tuff, etc. These fractured strata are dominated by the faults within the Study area and are thought to have a high permeability. Points where they intersect are thought to be extremely promising. At the present stage, a detailed geological study has yet to be performed and it is therefore impossible to pinpoint these positions. A further survey is therefore desirable.

As explained earlier, results of prior test borings give an estimated water head for the lower aquifer near EL 1300 m, and indicate a general productive potential of 60 l/sec. Because of this, it is necessary for the object of future lower aquifer prospecting to be the fractured layers in the previously described rock below EL 1300 m.

The lower aquifer in this area requires further investigation to determine whether it is a confined aquifer or not.

Extent of basement at EL 1300 m:	North; 50%, East, South; 30%
Extent of fracture zone in basement rock:	10%
Fracture porosity:	30%
Fracture zone:	50 m
Pump-up possible probability:	30%

The results of calculation are given in TABLE

However;

- the probability of existence of the lower aquifer in the basement fracture zone was estimated on the basis of the results of the boring core checks such as those by RQD (crack frequency index) and electric logging, but the lack of data at the present stage led to the extent of fracture zone in basement rock being assumed at roughly 10% on the basis of the geological characteristics over the greater area, and

- the fracture porosity was set at 30% on the basis of the 10^{-2} to 10^{-4} coefficient of permeability for the metamorphic rock and the igneous rock cracks from the standpoint of soil engineering.

Estimating the storage for this aquifer was calculated from the landform and the surface geology, and involved the following assumptions.

TABLE 3-1 **SUMMARY OF WATER BALANCE (UPPER AQUIFER)**

Basin		Area	Annual Rainfal (P)		Evapotranspiration (E)	Total Runoff (R)	Surface Runoff (Qs)	Basin Reserve	Safe Yield of Groundwater Basin	Actual Pumping Volume (Qc)	Groundwater Availability
		(km^2)	(mm)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
Northern Area	N-I	86.82	1,072	2.95	1.98	0.97	0.47	0.50	0.20	0.01	0.19
	N-II	96.34	1,240	3.79	2.20	1.59	0.52	1.07	0.43	0.18	0.25
	N-III	56.90	1,248	2.25	1.30	0.95	0.31	0.64	0.26	0.13 (0.07)*	0.13
	Sub-Total	240.06	1,130	8.97	5.48	3.51	1.30	2.21	0.89	0.32	0.57
Southern Area	S-I	119.16	1,141	4.31	2.72	1.59	0.86	0.73	0.29	0.09	0.20
	S-II	73.05	1.144	2.65	1.67	0.98	0.52	0.46	0.18	0.15 (0.45)	0.03
	S-III	125.93	1,114	4.45	2.88	1.57	0.91	0.66	0.26	0.05	0.21
	Sub-Total	318.14	1.131	11.41	7.27	4.14	2.29	1.85	0.73	0.29	0.44
Eastern Area	E-III	82.88	950	2.50	1.89	0.61	0.75	-0.14	-	-	-
	E-IV	17.00	1,023	0.55	0.39	0.16	0.15	0.01	0	0.01	0.06
	E-V	46.87	1,118	1.66	1.07	0.59	0.42	0.17	0.07	0.01	0.06
	E-VI	80.55	1,091	2.79	1.84	0.95	0.72	0.23	0.09	0	0.09
	E-VII	209.48	1,382	9.18	4.78	4.40	1.89	2.51	1.00	0.02	0.98
	Sub-Total	436.78	1,204	16.68	9.97	6.71	3.93	2.78	1.16	0.03	1.13
	Total	994.98	1,198	37.08	22.72	14.36	7.52	6.84	2.78	0.64	2.14

* The quantities indicated in parentheses are thought to result from the lower aquifer, and were excluded from the calculation for the actual pumping volume.

TABLE 3-2

Storage Capacity of Lower Aquifer

Basin	Area km^2	Deep m	Extent of basement at EL 1300 m %	Extent of fracture zone in basement rock %	Fracture Porosity %	Storage m^3
N-I	86.82	50	50	10	30	65.12×10^6
N-II	96.34	50	50	10	30	72.25×10^6
N-III	56.90	50	50	10	30	42.66×10^6
Sub-total	240,06	50	50	10	30	180.03×10^6
S-I	119.16	50	30	10	30	53.61×10^6
S-II	73.06	50	30	10	30	32.87×10^6
S-III	125.93	50	30	10	30	56.66×10^6
Sub-total	318.14	50	30	10	30	143.14×10^6
E-III	82.88	50	30	10	30	37.30×10^6
E-IV	17.0	50	30	10	30	7.65×10^6
E-V	46.87	50	30	10	30	21.08×10^6
E-VI	80.55	50	30	10	30	36.25×10^6
E-VII	209.48	50	30	10	30	94.26×10^6
Sub-total	436.78	50	30	10	30	196.54×10^6
Total	994.98	50				519.43×10^6

Here, if the pump-up probability is assumed to be 30%, then the storage capacity is $54.0 \times 10^6 m^3$ for the northern sector, $43.94 \times 10^6 m^3$ for the southern sector, and $58.96 \times 10^6 m^3$ for the eastern sector.

3) Estimated Discharge

In general, recharge to lower aquifers occurs when pump-up is performed, and this recharge is from the surrounding recharge area (where there are outcrops of rock forming water-bearing layers). There are therefore usually no problems with the discharge as long as excessive pump-up is not performed. However, excessive pump-up of large volumes will bring about either local or temporary lowering of the groundwater level, and may lead to disasters such as ground subsidence. This local lowering of the groundwater level occurs when the pump-up volume at a certain point exceeds the recharge (or discharge) that is possible within the water-bearing layer. Predicting the discharge therefore provides a guide for pump-up. In general, the discharge can be estimated from the coefficient of permeability for the water-bearing layer. The permeabilities of test wells No. 1, No. 2 and No. 3, were used to estimate the discharges as shown in the following table.

Estimation of Flow Movement Capacity

	Section Type B x H		K	ø	Q (m^3/sec)
When K of No. 2 bore is used	Andesite (Fractured) 2500 x 50 m	T J	9.45×10^{-5} 7.75×10^{-5}	0.05	0.597 0.485
When K of No. 1 bore is used	Welded Tuff (Non-fractured?) 2500 m x 50 m	T J	1.40×10^{-5} 1.20×10^{-5}	0.03	0.042 0.036
When K of No. 3 bore is used	Limestone (Non-fractured?) 2500 m x 50 m	T J	5.40×10^{-6} 6.25×10^{-6}	0.03	0.021 0.024

Where: Discharge GL = B·H x K x ø

T non-equilibrium
Theis-type curve analysis

J non-equilibrium
Jacob-type straight-line analysis

3.3.6. Test Boring

During the survey period, test boring was conducted at 6 locations to determine groundwater characteristics and geologic nature of the aquifer.

Boring specifications, and results of electric prospecting, test pumping, and water quality analysis are as follows.

Test well No.	Boring diameter	Well diameter	Boring depth	Ground elevation	Average boring speed
No. 1	17 1/2"	12" (300nm)	305m	EL 1410m	50cm/hr
No. 2	"	"	300	1530	70cm/hr
No. 3	"	"	300	1285	20cm/hr 100cm/hr
No. 4	12 1/2"	4" (100")	220	1410	110cm/hr
No. 5	"	"	120	1375	110cm/hr
No. 6	"	"	350	1452	300cm/hr

boring device: rotary type

strainer: production wells (12"): Johnson type; 30 m

observation well (4"): straight type

Test well No.	Deep structure	Maximum pump-up	Water level (from GL)
No. 1	Welded Tuff	6.3 l/sec	108.7m
No. 2	Sand with Clay	54.0 l/sec	95.8
No. 3	Limestone	12.62 l/sec	63.0
No. 4	Clay	-	110.0
No. 5	Sand	-	7.0
No. 6	Limestone	-	170.0

	Transmissivity coefficient	Storage coefficient	Permeability coefficient
No. 1 (1)	3.4×10^{-4}	2.9×10^{-4}	1.4×10^{-5}
(2)	2.9×10^{-4}	6.5×10^{-6}	1.2×10^{-5}
(3)	4.3×10^{-5}	-	1.8×10^{-6}
No. 2 (1)	2.3×10^{-3}	0.04	9.6×10^{-5}
(2)	1.9×10^{-3}	0.36	7.9×10^{-5}
(3)	-	-	-
No. 3 (1)	1.3×10^{-4}	0.037	5.4×10^{-6}
(2)	1.5×10^{-4}	0.034	6.25×10^{-6}
(3)	3.8×10^{-5}	-	1.58×10^{-6}

(1) by the Theis formula
(2) by the Jacob formula
(3) by the Recovery formula

(See FIGs. 7, 8, 9, 10, 11, 12)

On the basis of the above described test boring, production potential is determined as follows:

Test well No. 1: Small potential as a production well

No. 2: Extremely high production discharge anticipated

No. 3: Has development potential, but requires boring to 340-400m

No. 4 No potential as a production well

No. 5: Has development potential as a production well

No. 6: Extremely high production discharge anticipated

Water samples were taken from wells No. 1-3 between 48 to 60 hours following commencement of pump-up, and said samples were subjected to standard water quality analysis by LERIS to determine potability. Water potability for the 3 wells is evaluated as follows:

No. 1: No problems in suitability for drinking

No. 2 Resampling and analysis are necessary following an appropriate waiting period to determine if contamination found in the initial sampling is from the well itself or was introduced by boring procedures. At present, water sampled was not suitable for drinking without proper biological treatment.

No. 3: Sample exhibited high values for turbidity, color, total iron, total solids and mineral content. To be rendered suitable for drinking, water requires appropriate treatment to reduce these values to acceptable levels.

TABLE 3-10-1 DRILLING LOG TEST BORING N°1

NAME OF PROJECT: Guatemala City Ground Water Development Project			NO. OF HOLE 1
LOCATION PINARES	BORE HOLE DIA 17" 1/2		DEPTH OF HOLE 305m
ELEVATION 1410 masl	DRILL MACHINE		OPERATOR DAHO
UNDER GROUND WATER TABLE GL-108.7 m	NO. 1		SUPERVISOR K.K

THICKNESS (m)	DESCRIPTION
9	welded tuff, basalt with some pemice
24	welded tuff
6	clay with welded tuff
42	welded tuff weathered
24	welded tuff
6	w.t. with quartz
5	welded tuff
4	basalt
30	welded tuff
4	w.t. weathered
17	w.t. non weathered
3	w.t. with calcium vein
15	w.t. weathered
27	w.t. in some place with calcium vein
9	w.t. non weathered
7	w.t. weathered
35	w.t. non weathered
3	w.t. weathered
19	w.t. with sand
11	w.t. weathered

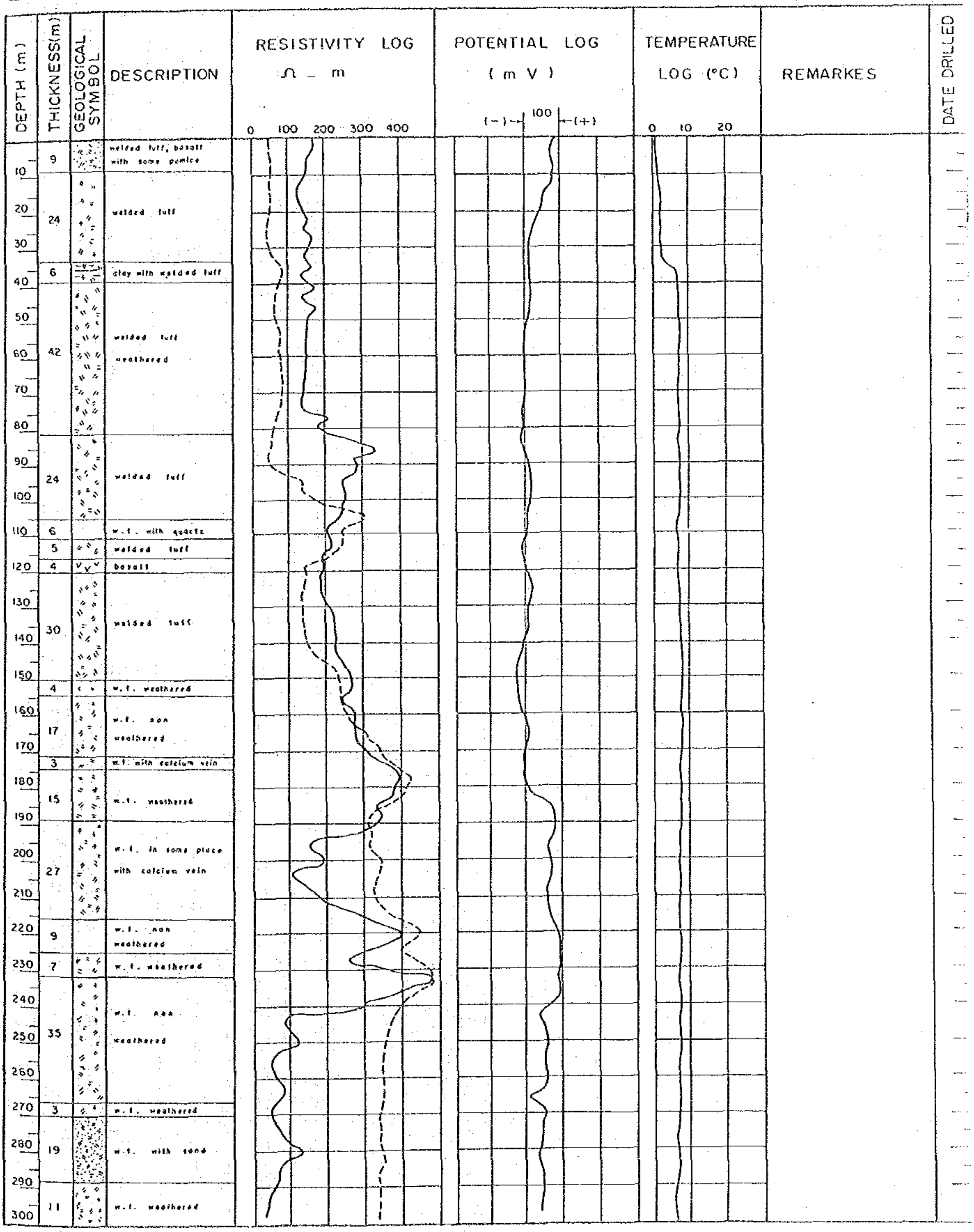


TABLE 3-10-2 DRILLING LOG TEST BORING N°2

NAME OF PROJECT: Guatemala City Ground Water Development Project	NO. OF HOLE 2
LOCATION CANALITOS — BORE HOLE DIA 17" 1/2	DEPTH OF HOLE 300
ELEVATION 1537 masl — DRILL MACHINE SKY TOP	OPERATOR DAHO
UNDER GROUND WATER TABLE GL 95.8 m — NO. 2	SUPERVISOR K·K

DEPTH (m)	THICKNESS (m)	DESCRIPTION	REMARKES
0–9	9	medium sand with pumice	
9–21	12	pumice with fine sand	
21–33	12	fine sand with basalt and pumice	
33–51	18	medium sand with pumice and basalt	
51–63	12	fine sand with pumice	
63–195	160	There aren't samples May be sand with gravel and pumice	Clay stratum
195–233	38	weathered basalt	
233–245	12	basalt with pumice	
245–272	27	sand with gravel and basalt	
272–290	20	basalt	
290–300	10	medium sand	

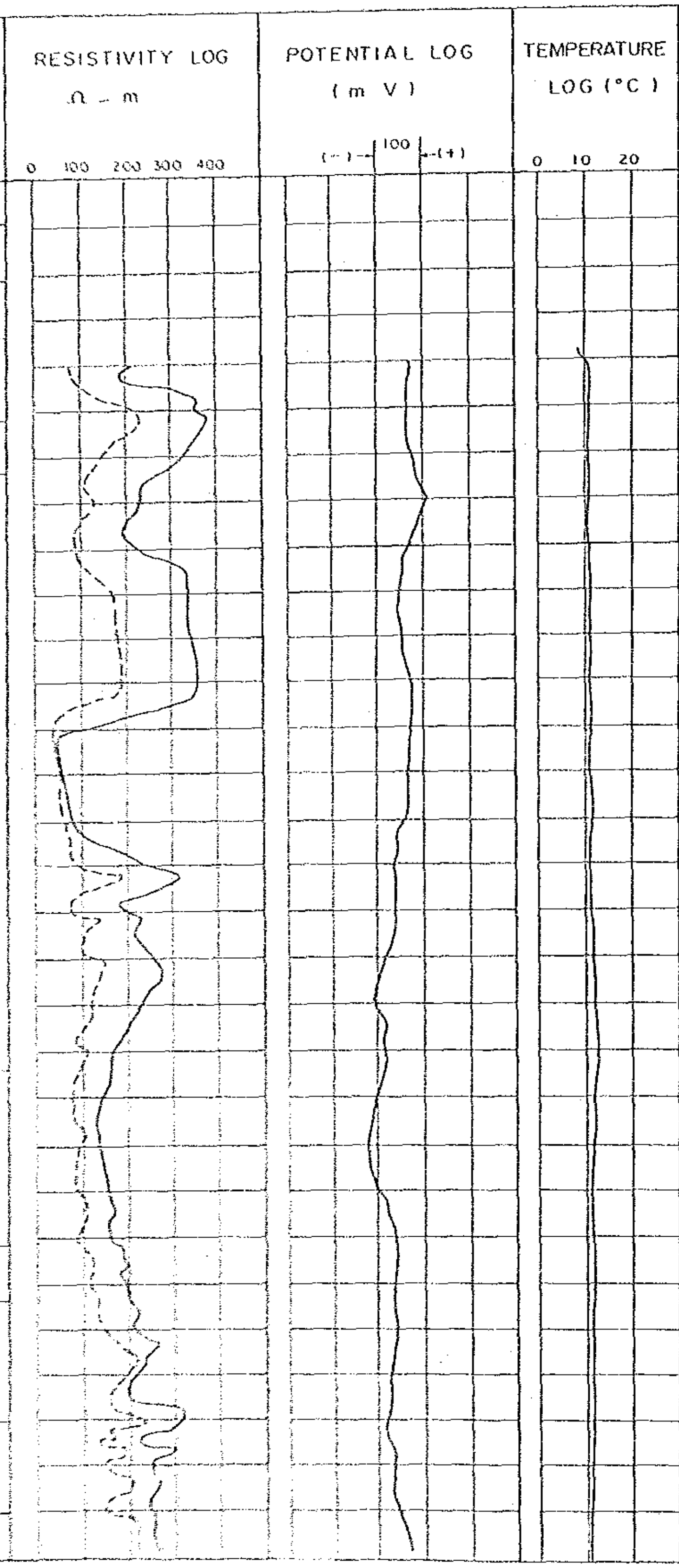


TABLE 3-10-3 DRILLING LOG TEST BORING N°3

NAME OF PROJECT : Guatemala City Ground Water Development Project — NO. OF HOLE 3

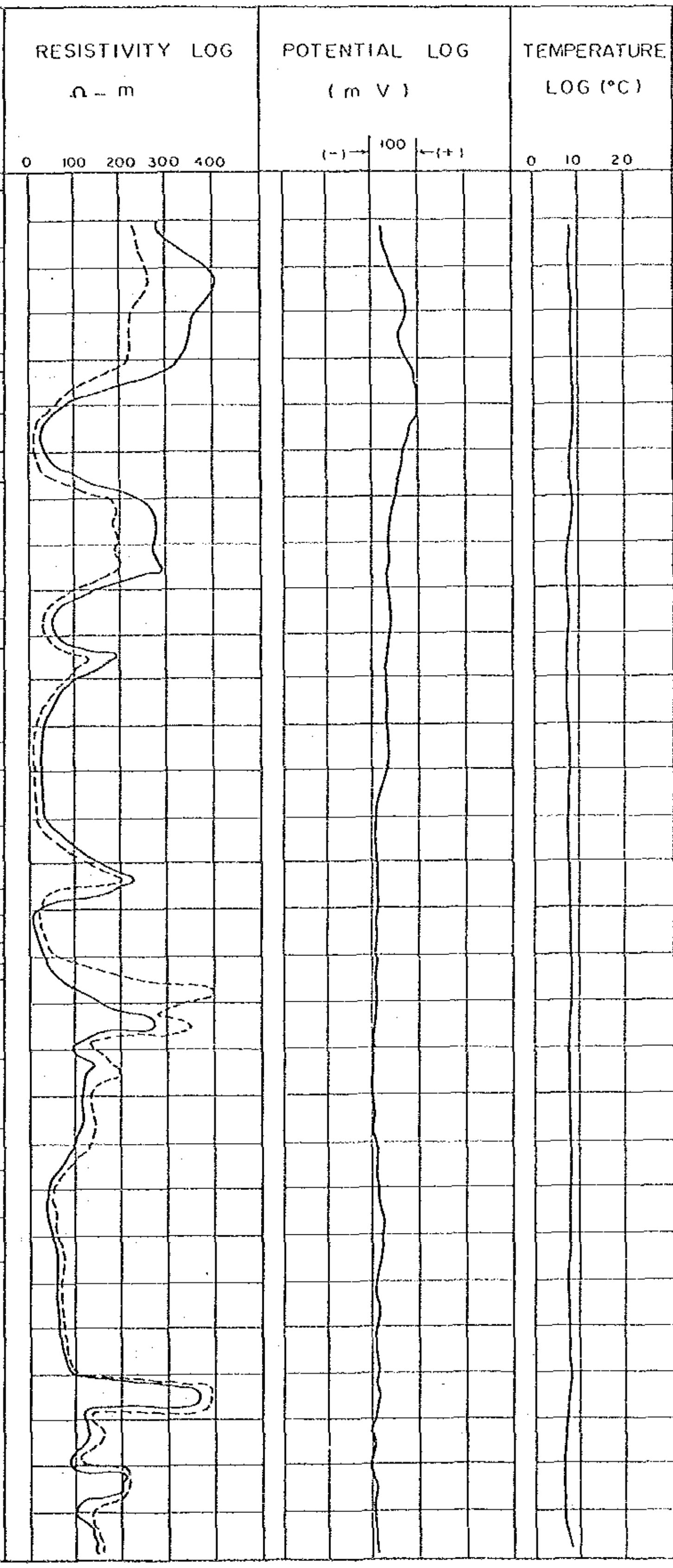
LOCATION RODRIGUITOS — BORE HOLE DIA 17" 1/2 — DEPTH OF HOLE 300

ELEVATION 1285 masl — DRILL MACHINE SKYTOP — OPERATOR DAHO

UNDER GROUND WATER TABLE GL-63 m — NO. 3 — SUPERVISOR K·K

THICKNESS (m)	GEOLOGICAL SYMBOL	DESCRIPTION
3		volcanic ash
12		volcanic ash with pumice
3		pumice with sand
12		volcanic ash
9		fine sand
3		fine sand with pumice
9		fine sand
9		basalt with calcite and squist
6		weathered basalt with coarse sand
24		weathered basalt with calcite and quartz
6		basalt
6		consolidated clay with basalt
21		basalt with calcite vein
6		basalt with sand and calcite
12		coarse sand with basalt and calcite
14		weathered basalt with calcite
6		coarse sand w/ basalt
6		basalt with sand
3		basalt with calcite
3		basalt with andesite
18		andesite
15		basalt
9		basalt with calcite
10		medium sand
9		coarse sand with calcite
65		limestone

DEPTH (m): 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300



REMARKES

DATE DRILLED

TABLE 3-10-4 DRILLING LOG TEST BORING N°4

NAME OF PROJECT: Guatemala City Ground Water Development Project
NO. OF HOLE 4
DEPTH OF HOLE 220

LOCATION PINARES
BORE HOLE DIA 12^{*} 1/4

ELEVATION 1410
DRILL MACHINE
OPERATOR

UNDER GROUND WATER TABLE GL-110 m
NO. 4
SUPERVISOR

DEPTH (m)	THICKNESS (m)	DESCRIPTION
0–9	9	volcanic ash with some welded tuff
9–18	9	welded tuff with calcite
18–24	6	welded tuff with volcanic ash
24–30	6	welded tuff with calcite
30–33	3	w.t. weathered
33–36	3	w.t. weathered with sand
36–42	6	w.t. with calcite
42–54	12	welded tuff weathered
54–66	12	welded tuff
66–72	6	welded tuff with calcite
72–78	6	sand with w.t.
78–90	12	welded tuff weathered
90–114	24	welded tuff with sand and some calcite
114–120	6	medim sand with w.t.
120–129	9	medium sand with andesite and w.t.
129–132	3	w.t. weathered
132–138	6	fine sand
138–150	12	fine sand with welded tuff
150–162	12	medium sand with basalt andesite and limestone
162–165	3	limestone and basalt
165–177	12	medium sand with limestone
177–180	3	limestone with basalt
180–183	3	limestone
183–209	26	medium sand with limestone

RESISTIVITY LOG Ω – m (0, 100, 200, 300, 400)

POTENTIAL LOG (m V) (−) 100 (+)

TEMPERATURE LOG (°C) (0, 10, 20)

REMARKES

DATE DRILLED

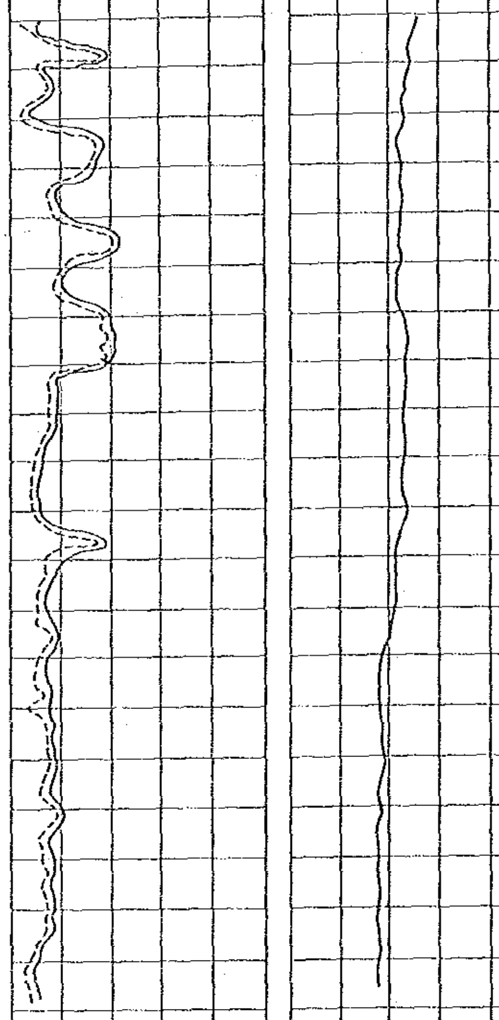


TABLE 3-10-5 DRILLING LOG TEST BORING N°5

NAME OF PROJECT : Guatemala City Ground Water Development Project — Nº. OF HOLE 5

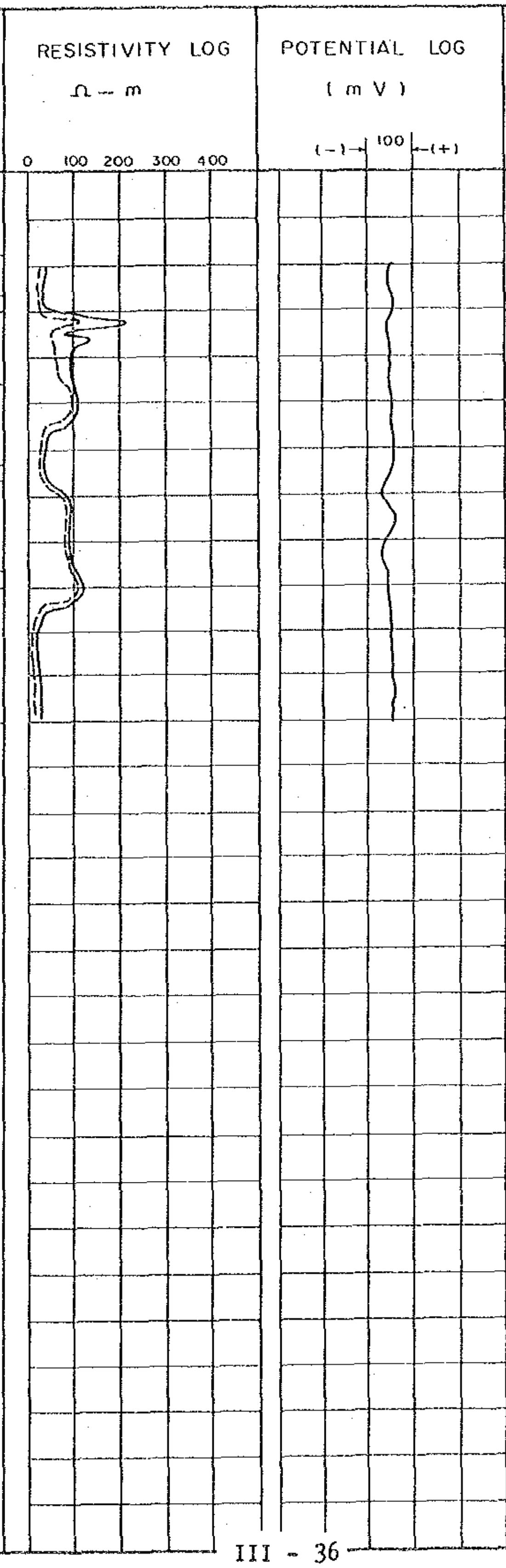
LOCATION CANALITOS — BORE HOLE DIA 12" 1/4 — DEPTH OF HOLE 120

ELEVATION 1381 masl — DRILL MACHINE INGERSOLL-RAND — OPERATOR DAHO

UNDER GROUND WATER TABLE: GL - 7 m — NO. 5 — SUPERVISOR K.K

THICKNESS (m)	GEOLOGICAL SYMBOL	DESCRIPTION
18		fine sand with gravel
9		pumice with fine sand
3		pumice
15		fine sand
18		fine sand with gravel
3		pumice
21		pumice with medium sand
3		sand with gravel
30		fine sand

DEPTH (m): 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300



TEMPERATURE LOG (°C): 0 10 20

REMARKES

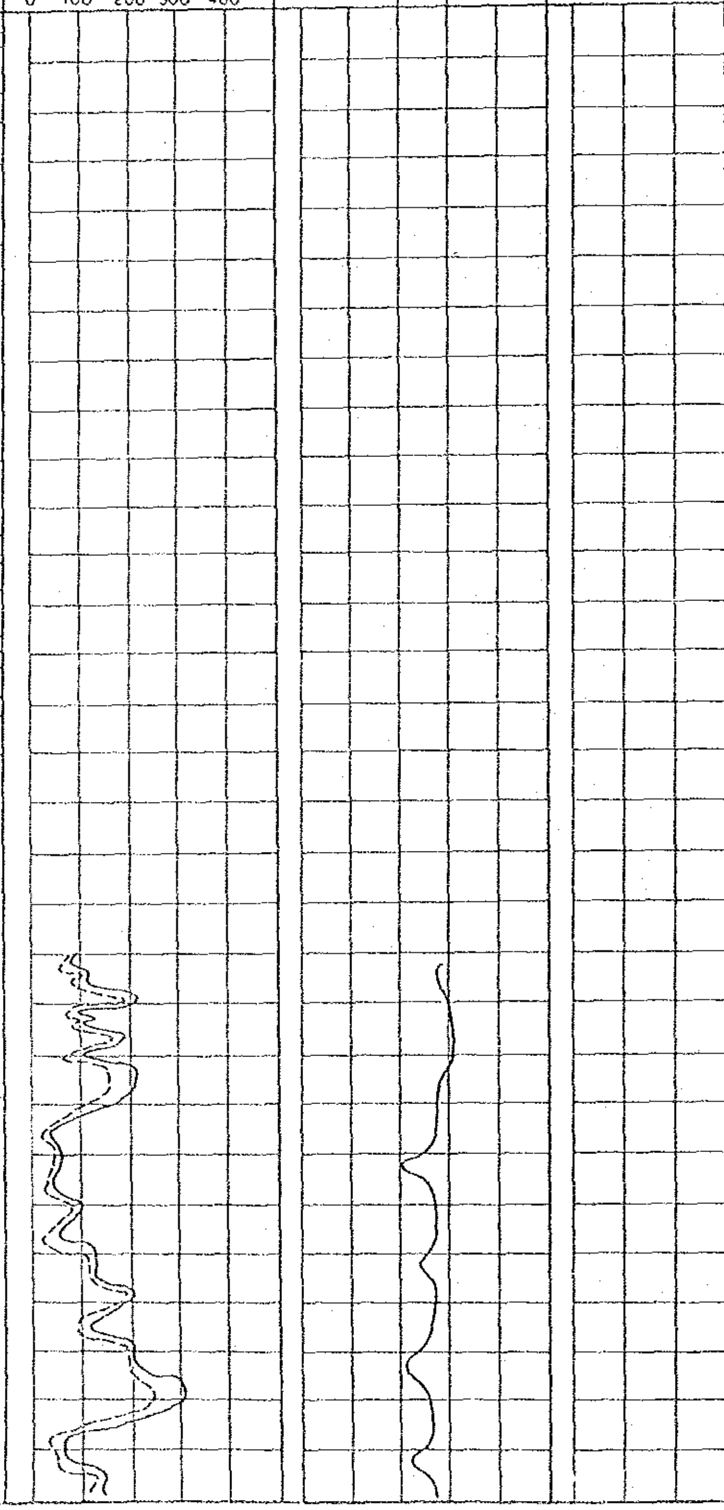
DATE DRILLED

TABLE 3-10-6 DRILLING LOG TEST BORING N°6

NAME OF PROJECT : Guatemala City Ground Water Development Project	NO. OF HOLE 6
LOCATION PROYECTO4-4 BORE HOLE DIA 12" 1/4	DEPTH OF HOLE 350
ELEVATION 1452 masl DRILL MACHINE INGERSOLL-RAND	OPERATOR DAHO
UNDER GROUND WATER TABLE GL-170m NO. 6	SUPERVISOR K.K.

DEPTH (m)	THICKNESS (m)	GEOLOGICAL SYMBOL	DESCRIPTION
	3		volcanic ash with sand
	3		pumice with fine sand
10	9		gravel with fine sand and pumice
20	6		fine sand with gravel and pumice
30	9		gravel with pumice
40	15		pumice with sand and weathered basalt
50, 60	21		pumice with fine sand
70, 80, 90	24		fine sand with weathered basalt
100	15		fine sand with weathered basalt
110	6		fine sand with pumice and basalt
	6		coarse sand
120	9		pumice with medium sand
130	3		pumice with basalt
	3		pumice with calcite
	6		pumice with basalt
140	3		fine sand with pumice
150	9		pumice with basalt
160–220	69		pumice
220–300	131		limestone

RESISTIVITY LOG Ω - m (0 100 200 300 400) | POTENTIAL LOG (mV) (−) ← 100 → (+) | TEMPERATURE LOG (°C) (0 10 20) | REMARKES | DATE DRILLED



3.4 Socio-Economic Characteristics

3.4.1 Population

The population of Metropolitan Guatemala in 1985 is estimated at 1.5 million which represents 19% of the total national population. According to the most recent census in 1981, the area population was 1,134,702 which indicated a 2.12% growth rate in the 8 years following the previous 1973 census. This is lower than the national population growth rate of 3.03%. The smaller value is attributable to the extremely low growth rate of 0.93% for the municipality of Guatemala City.

Future population projections for Metropolitan Guatemala have been formulated by EMPAGUA, PLAMABAG and EDOM. All of these projections foresee a greater population growth rate than that identified in the 1981 census. Projected rates are 5% by EMPAGUA, 4.5% by PLAMABAG and 4.8% by EDOM.

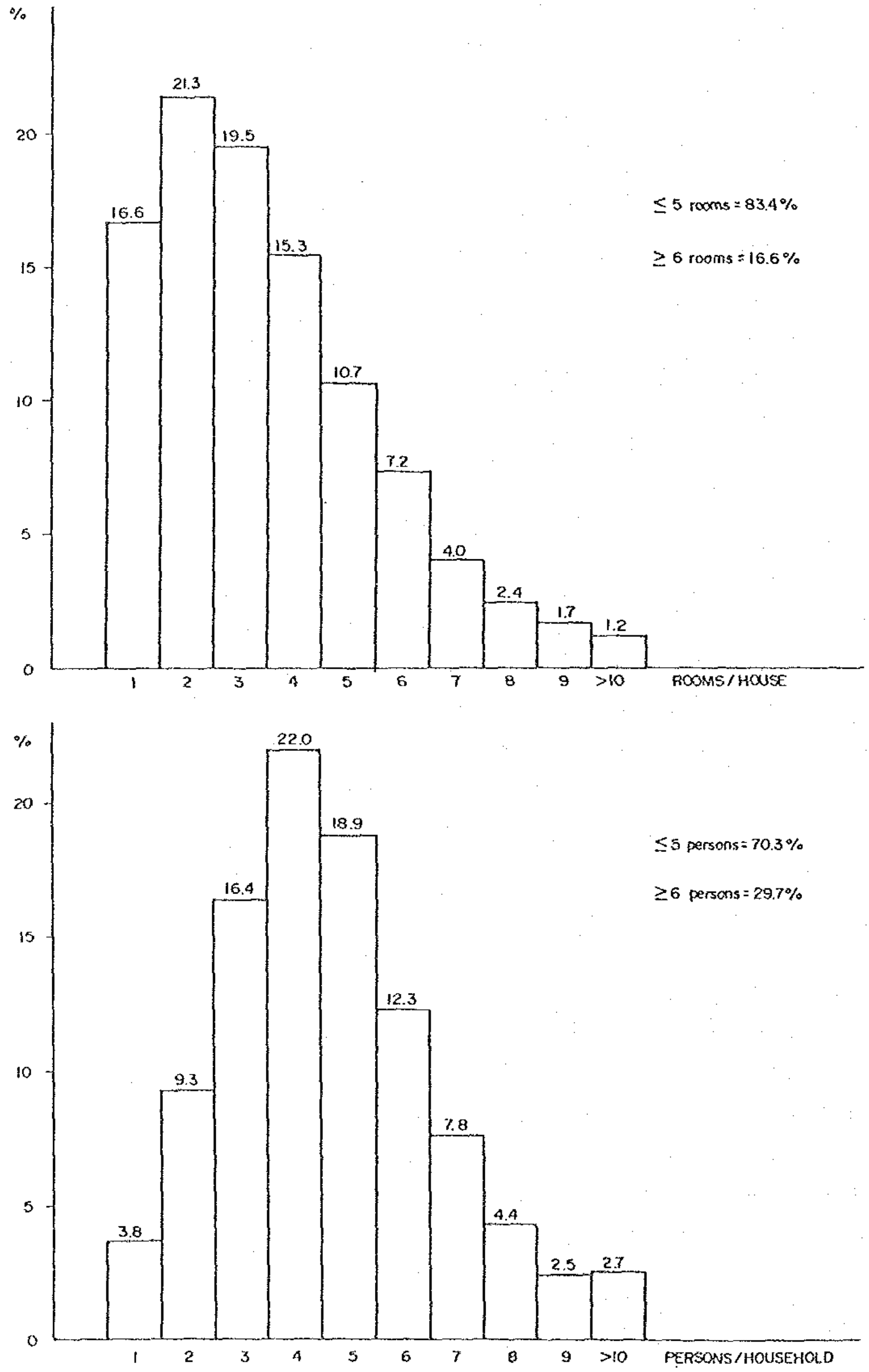
3.4.2 Socio-Economy

In 1980, the Metropolitan Guatemala population was estimated at 960,564 for a total of 204,509 households yielding an average 4.7 persons per household. FIG. 3-13 shows the frequency distribution of rooms per house and persons per household. Two-room housing was the most frequent with 21.3 percent while housing with five rooms or less accounted for 83.4 percent and with six rooms or more for 16.6 percent. Families of four persons were the most frequent amounting to 22.0 percent, while those with five persons or less accounted for 70.3 percent and those with six persons or more for 7.7 percent.

The economically active population was estimated at 35 percent and unemployment at 3.6 percent in 1980.

Income earners in Metropolitan Guatemala were estimated at 379,723 equivalent to 1.9 per household. Of income earners, 61.5 percent were employees (70% male, 30% female) and 25.7 percent were self-empoyed (56.2% male, 43.8% female). More than half of both male and female employees were between 20 and 39 years old. More than half of self-employed male and female were 40 years or older.

Fig 3-11 HOUSING AND HOUSEHOLD SIZES IN METROPOLITAN GUATEMALA, 1980



With respect to income level, families earning between Q2,400 and Q4,800 per year were most numerous at 33%. Households earning less than Q4,800 per year amounted to 55%, while receiving less than 25% of total income.

3.4.3 Land Use

Since its establishment in 1775 as the capital of Guatemala, Guatemala City has developed as the political and economic nucleus of the country. The area has expanded to encompass what is known as Metropolitan Guatemala, with a current population of 1.5 million.

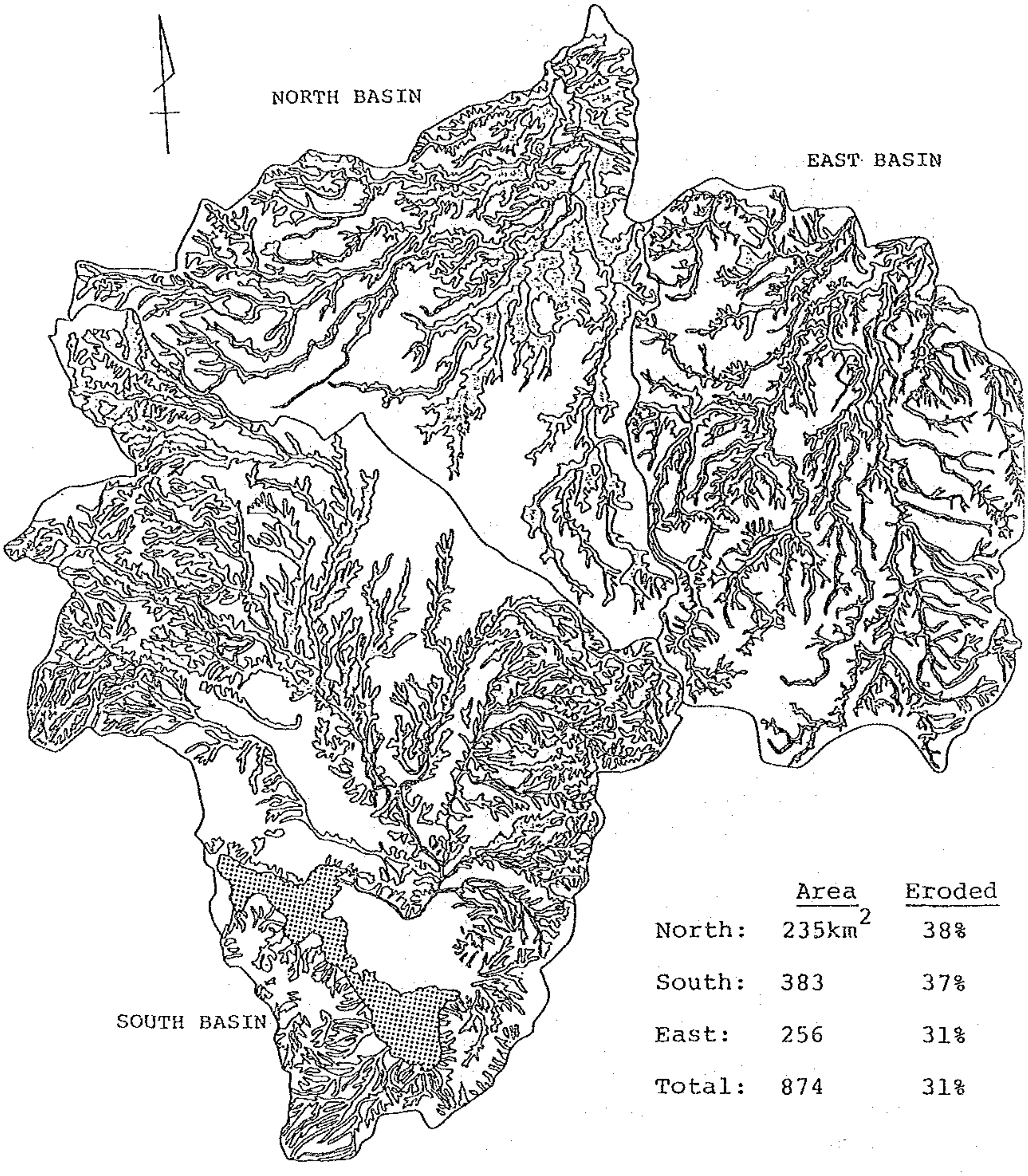
As can be seen from the land dissection distribution map in FIG. 3-14, ravine erosion occupies an estimated 36% of total land area in Metoropolitan Guatemala and immediate environs. Within Metropolitan Guatemala, urbanization is most intense in the vicinity of the continental divide where land dissection is least present.

Based on data from INAFOR, the status of land use in Metropolitan Guatemala is as follows: (FIG. 3-15)

Present Land Use

	Area	Percentage of Total
Residential	97.9	20.9
Commercial	3.7	0.8
Public	10.8	2.3
Industrial	8.4	1.8
Wooded	88.5	18.9
Agricultural	119.0	25.4
Others	140.1	29.9
Total	468.4	100.0

The current population growth rate is 3-4% for Metropolitan Guatemala. In response to this population increase, level terrain on the urban periphery has been steadily converted into residential area. Parallel to this trend, management and conservation of agricultural, pasture and the afforested area has deteriorated.



	Area	Eroded
North:	235km^2	38%
South:	383	37%
East:	256	31%
Total:	874	31%

FIG. 3-12 SURFACE SOIL EROSION AND GULLEY INTRUSION

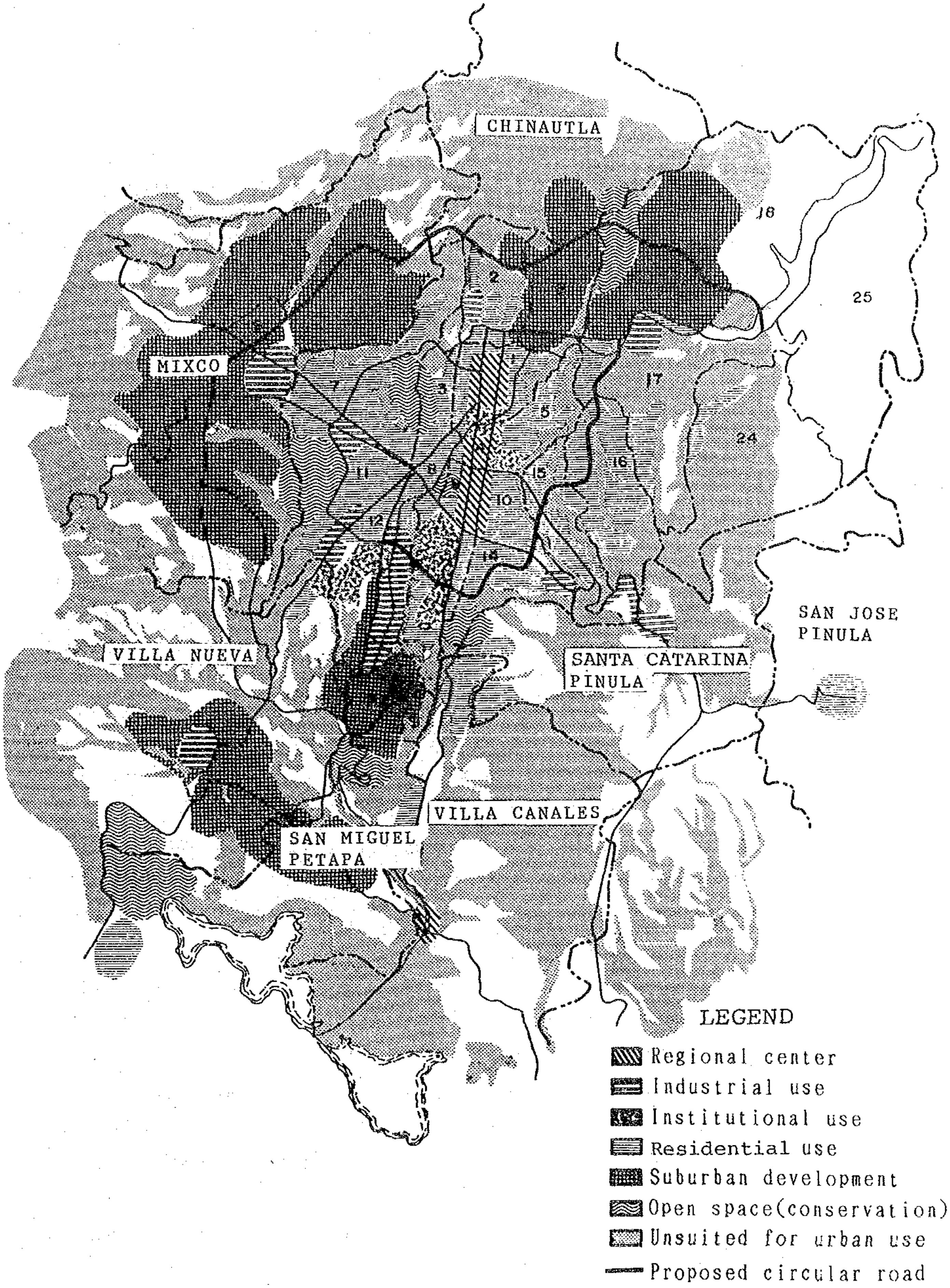


FIG.3-13 FUTURE LAND USE

3.5 Water Service Conditions

3.5.1 Water Service Institutions

At present, water service within EMPAGUA service area in Metropolitan Guatemala is provided from the following sources:

(1) EMPAGUA

(2) Agua Del Mariscal, S.A. (a private water supply company)

(3) individual water supply systems of the military and government institutions, public schools, public hospitals, etc.

(4) privately owned wells

(5) direct consumer utilization of spring and river water

(6) privately marketed bottled water

EMPAGUA is a public corporation created in 1972 to provide water service to Guatemala City and the satellite urban areas which comprise Metropolitan Guatemala. The institution is responsible for the improvement, expansion, planning and implementation for new development, and operation and maintenance of water service facilities. As of 1985, EMPAGUA produces between 2.374m ^{3}/sec and 2.717m ^{3}/sec (average of 2.553m ^{3}/sec) of service water which is supplied to 114,000 households comprising approximately 620,000 to 800,000 persons.

Aqua Del Mariscal, S.A. constitutes a private company which services approximately 10,000 customers in principally downtown Guatemala City. The company utilizes groundwater as its water source and produces around 20,000m ^{3}/day (0.2315m ^{3}/sec).

Water use for public schools, public hospitals and other public facilities is administered by the Ministry of Public Works, and consists mainly of groundwater supply from individual wells.

Water supply for military establishments such as barracks and military bases is provided by water production and conveyance facilities constructed and managed by the Army itself. Supply consists primarily of groundwater from individual wells.

Various hotels, commercial establishments and some residences operate privately owned wells.

In rural areas, the population utilizes individual as well as cooperative wells, in addition to direct obtainment of water from springs and rivers.

In addition to the above sources, bottled potable water is produced by private companies and marketed at Q1.25 per gallon.

Both EMPAGUA and MARISCAL apply monthly fixed rates with a surplus charge for excess use. A comparison between water rates charged by EMPAGUA and MARISCAL is summarized in the following table.

EMPAGUA WATER RATE

Service Category	Water Title	Volume	Cost of Water Title (Paid in Cash)	Fixed Payment	Excess
	Paja	m^3/month	Quetzal	Q/month	Q/m^3
Marginal	1/3	up to 20	350	2.00	0.25
Economical	1/2	20-30	600	3.50	0.40
Normal	1	30-60	1,050	8.25	0.40
Intermediate	1-5	60-300	----	12.35	0.45
High consumption	over 5	over 300	----	16.45	0.50

EL MARISCAL WATER RATE

Water Title	Volume	Cost of Water Title (Paid in Cash)	Fixed Payment	Excess
Paja	m^3/month	Quetzal	Q/month	Q/m^3
1/4	15	300	3.30	0.50
1/3	20	400	5.00	0.50
1/2	30	600	7.50	0.50
1	60	1,200	15.00	0.50

3.5.2 Water Supply System and Facilities

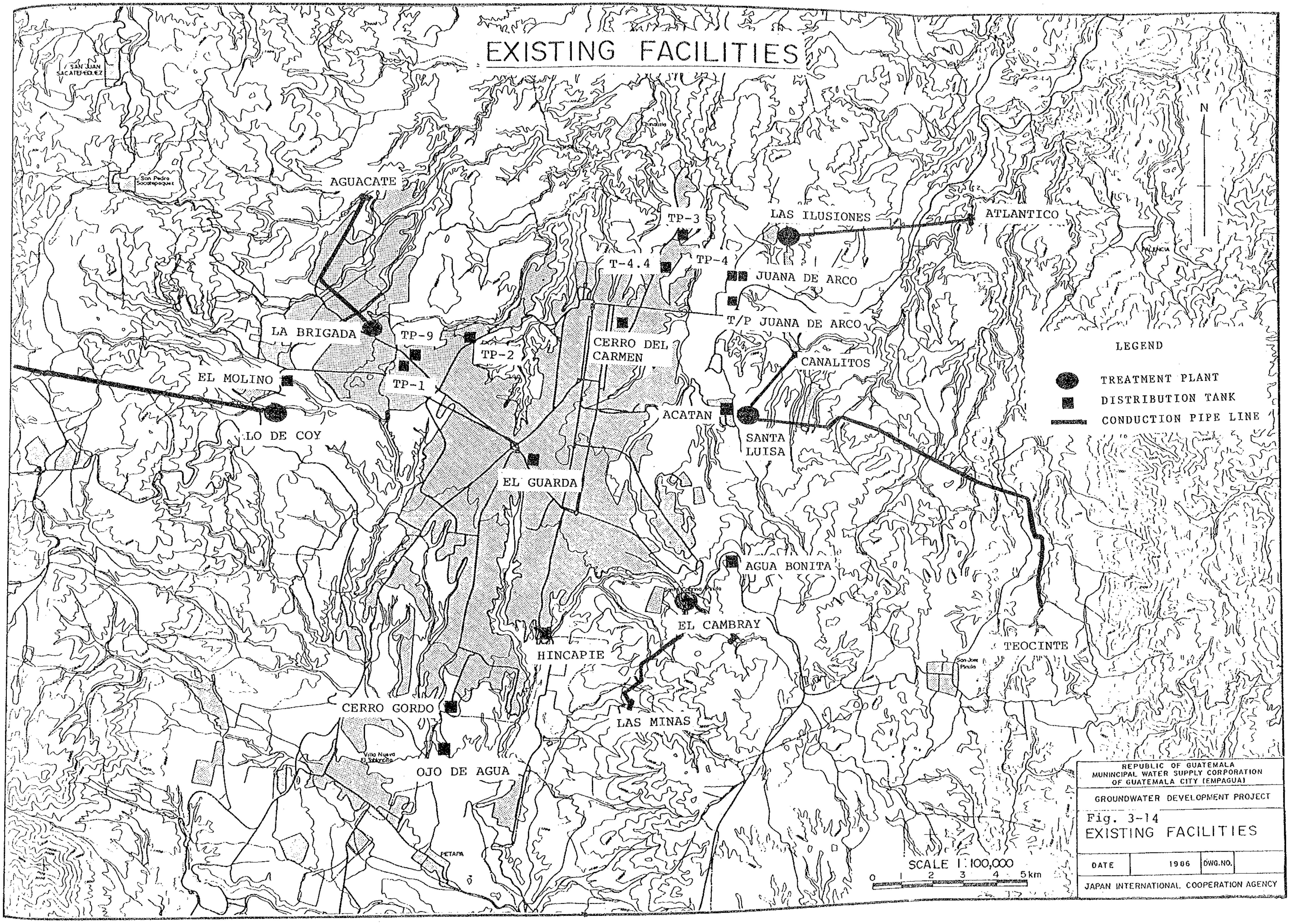
(1) Production System

EMPAGUA operates and maintains seven water production systems, producing a maximum of $2.717m^3/s$, a minimum of $2.374m^3/s$ and an average of $2.553m^3/s$. (Figures were recorded over the 1 year period from October 1984 to September 1985.)

The plants for the seven production systems are as shown in FIG. 3-16. With the exception of wells, production facilities are located on the periphery of EMPAGUA's water service area.

Water source, existing facilities, percentage of total production, and principal service area for the seven systems is as shown in the table below.

Production & Supply System	Water Source	Facilities	Percentage of Total Production	Service Zone
EL Cambray	Surface water	Treatment plant Tank Pump station	7	10,13,14,15
La Brigada	Surface water Wells (6)	Treatment plant Tank Pump station	4	7,11,19
Santa Luisa	Surface water Wells	Treatment plant Tank Pump station	14	1,5,10,17,6 2,4,9 Colonias
Wells in City Center	Groundwater	Pump station	6	10,9,45/26 1,13,14
Ojo de Agua	Wells Spring	Reservoir Pump station	23	1,3,8,11,12, 9,13, Colonias
Las Ilusiones	Surface water Spring	Treatment plant Pump station	8	17,18 Colonias
Lo de Coy	Surface water	Treatment plant Tanks Aqueduct Pump station	38	1,8,9,11,12,13 7,3


EXISTING FACILITIES
AGUACATE
LA BRIGADA
TP-9
TP-2
TP-1
EL MOLINO
LO DE COY
TP-3
T-4.4
TP-4
LAS ILUSIONES
ATLANTICO
JUANA DE ARCO
T/P JUANA DE ARCO
CERRO DEL CARMEN
CANALITOS
ACATAN
SANTA LUISA
EL GUARDA
AGUA BONITA
EL CAMBRAY
HINCAPIE
TEOCINTE
LAS MINAS
CERRO GORDO
OJO DE AGUA
PETAPA
PALENCIA
N
LEGEND
TREATMENT PLANT
DISTRIBUTION TANK
CONDUCTION PIPE LINE
SCALE 1:100,000
0 1 2 3 4 5km
REPUBLIC OF GUATEMALA
MUNICIPAL WATER SUPPLY CORPORATION
OF GUATEMALA CITY (EMPAGUA)
GROUNDWATER DEVELOPMENT PROJECT
Fig. 3-14
EXISTING FACILITIES
DATE
1986
DWG.NO.
JAPAN INTERNATIONAL COOPERATION AGENCY

(2) Water Production

Average water production over the past 6 years for each of the 7 EMPAGUA production systems is as follows, based on data from EMPAGUA.

YEAR	SANTA LUISA	EL CAMBRAY	LO DE COY	LA BRIGADA	OJO DE AGUA	LAS ILUSIONES	CITY WELLS	TOTAL
1980	0.363	0.174	0.697	0.055	0.582	0.161	0.133	2.165
1981	0.367	0.186	0.795	0.084	0.543	0.164	0.124	2.263
1982	0.331	0.179	1.043	0.123	0.543	0.177	0.154	2.541
1983	0.332	0.167	1.000	0.055	0.607	0.211	0.140	2.512
1984	0.331	0.174	1.000	0.062	0.562	0.233	0.180	2.542
1985	0.325	0.177	1.022	0.097	0.539	0.219	0.177	2.556
Average	0.342	0.176	0.926	0.079	0.561	0.194	0.151	2.429
% of TOTAL	14%	8%	38%	3¢	23%	8%	6%	100%

Year	Annual average yield	Min.	Max.	Growth index
1980	2.17	2.05	2.25	1.00
1981	2.26	2.10	2.56	1.04
1982	2.54	2.36	2.67	1.17
1983	2.54	2.41	2.62	1.17
1984	2.52	2.36	2.72	1.16
1986	2.56	2.37	2.74	1.18
Average	2.43	1.18	1.59	—

Based on the above data, water production in EMPAGUA's system in 1982 showed more than 12% increase over the previous year. However, after 1982, overall production levels remained essentially the same.

However, data indicates considerable fluctuation in the output rates per production system, implying instability in the production structure.

The difference between maximum production and minimum production is 15%-20% for the production systems. At Ojo de Agua specifically, however, the annual said value is over 50%, at times reaching 70%.

This instability in production is not only due to seasonal fluctuations in discharge at water sources, but also reductions in operating effeciency due to superannuation of facilities and inadequate O/M.

(3) Water Sources

Of EMPAGUA's seven production systems, five rely principally on river discharge as the water source.

Approximately 63% of EMPAGUA production is from surface flows, while the remaining 37% is from groundwater (including spring water). Almost all source rivers (60% of total production) are situated outside the Study area.

An average of 0.30m^3/sec is drafted by EMPAGUA from Ojo de Agua. An additional 0.62m^3/sec of groundwater is obtained from some approximately 40 wells in the area.

	Max.	Mean	Min.
Required Production	2,836	2,836	2,836m^3/sec
Actual Production	2,717	2,553	2,374
Shortage	0.119	0.283	0.462
	4%	10%	15%

The gap in water demand and supply capacity mainfests itself in both geographic shortages and interruptions in existing water service. Furthermore, shortfall exhibits an increasing trend.

TABLE 3-2 indicates the status of water supply in Guatemala City. Service is divided into 3 categories depending on the nature thereof: continuous (N), intermittent (I) and discontinuous (D).

TABLE 3-3

SUPPLY STATUS OF DRINKING WATER IN GUATEMALA CITY BY POSTAL ZONE, IN 1985

N = Normal : 24 hr full supply   I = Intermittent : Low pressure most of the day   D = Deficient : Acceptable part of the day

ZONE	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	SUMMARY
1	N-95	N-80	I-60	I-100	I-100	N-80	N-95	N-80	N-80	N-80	N-80	N-80	N - 60
2	N-85	N-85	I-100	I-100	I-80	N-50	N-50	N-50	N-50	N-50	N-50	N-100	I - 60
3	N-100	N-60	I-70	I-70	I-70	N-60	N-60	N-60	N-60	N-60	N-60	N-100	I - 60
4	I-70	I-70	I-100	I-100	I-100	I-60	N-100	N-100	N-100	N-100	N-100	N-100	N - 50
5	N-70	N-70	N-70	N-70	N-70	N-100	N-100	N-100	N-100	N-100	N-100	N-100	N - 90
6	N-85	N-60	N-60	I-60	I-70	N-50	N-60	N-60	N-60	N-60	N-60	N-50	I - 60
7	N-95	N-60	I-60	I-70	I-70	N-70	N-80	N-80	N-95	N-100	N-100	N-100	N - 65
8	I-80	I-80	I-80	I-100	I-100	I-100	I-100	I-100	I-100	I-80	I-80	I-80	I - 90
9	N-100	N-100	N-100	N-100	N-100	N-100	N-100	N-100	N-100	N-100	N-100	N-100	N - 100
10	N-90	N-90	I-70	I-70	I-70	I-70	N-60	N-90	N-90	N-09	N-90	N-90	N - 60
11	N-85	N-85	I-80	I-90	I-90	N-60	N-85	N-70	N-70	N-80	N-75	N-75	N - 60
12	N-70	N-60	I-80	I-90	I-90	I-60	N-80	N-80	N-90	N-90	N-80	N-80	N - 50
13	N-70	N-70	D-60	D-60	D-60	I-100	N-80	N-80	N-80	N-80	N-80	N-80	I - 50
14	N-100	N-100	N-100	I-100	N-100	N-100	N-100	N-100	N-100	N-100	N-100	N-100	N - 80
15	N-100	N-75	N-75	I-50	N-75	N-50	N-100	N-100	N-100	N-100	N-100	N-100	N - 80
16	N-100	N-100	I-100	I-100	N-100	N-100	N-100	N-100	N-100	N-100	N-100	N-100	N - 80
17	I-100	I-60	I-100	I-100	I-100	I-100	I-60	I-60	I-60	N-100	N-100	N-100	I - 60
18	I-100	I-100	I-100	I-100	D-100	I-100	I-100	I-100	I-100	D-80	D-80	I-80	I - 100
19	N-100	I-100	I-100	I-100	I-100	I-100	I-100	I-100	I-100	I-100	I-100	I-100	I - 90

3.6 EMPAGUA

3.6.1 General

EMPAGUA, the Guatemala City Municipal Water Supply Corporation, was created by the Guatemala City Municipal Council on Nov. 28, 1972. EMPAGUA commenced operation on Jan. 1, 1973.

The objectives of EMPAGUA are provision, maintenance, improvement and expansion of potable water service in Guatemala City, and neighboring municipalities in the event that lawful intermunicipal agreements are signed.

Administratively, EMPAGUA's management reports to a Board of Directors whose president is the Guatemala City Mayor, and whose secretary is the General Manager of EMPAGUA. Assisting the General Manager are one Engineering Manager and one Administrative Manager. EMPAGUA's organizational structure as 1985 is given in FIG. 3-17.

Both functionally and financially, EMPAGUA is an independent organization. However, as regards major administrative actions such as modification of utility tariffs, the management decision must be approved by the Board of Directors and by the Guatemala City Municipal Council.

EMPAGUA has a close working relationship with the Ministry of Public Works (MCOPyT) which has been in charge of constructing the Xaya-Pixcaya National Aqueduct. This cooperation is likely to continue with the Ministry developing new water sources and EMPAGUA assuming responsibility for the administration of newly found water.

3.6.2 Financial Status

The recent financial status of EMPAGUA is indicated in TABLE. 3-4-(1), 3-4-(2) and 3-4-(3).

The bulk of EMPAGUA assets is comprised of Property, Plant and Equipment which, net of depreciation, amounted to nearly 70 percent of total assets in the past three years. Physical assets were transferred to EMPAGUA, upon its creation, by the Guatemala City Municipality. Subsequently, in addition to EMPAGUA's own construction projects, Guatemala City water supply related facilities have been transferred to

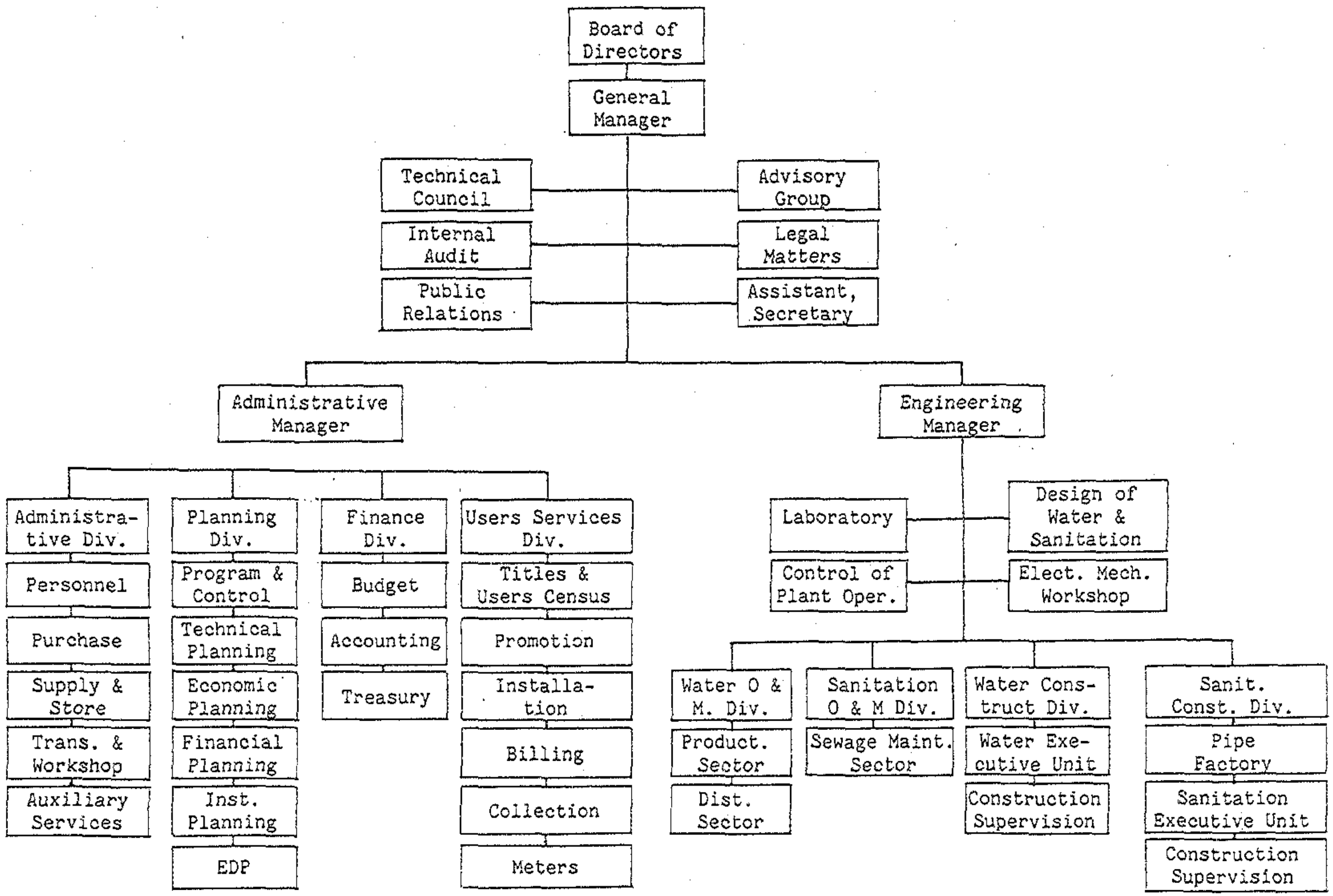


Fig. 3-15 ORGANIZATION CHART OF EMPAGUA, 1985

EMPAGUA, even where the construction thereof was carried out by other government agencies (e.g. Xaya-Pixcaya National Aqueduct). However, in the case of some of these projects, administrative authority only and not ownership has been ceded to EMPAGUA.

Accumulated amount for accounts receivable has steadily increased from 8.1% in 1982 to 8.5% in 1983 and 11.4% in 1984. Accumulated losses were Q13,747,144 or 25.1% of total liabilities in 1982. By 1984, cumulative losses increased to Q19,362,710 equivalent to 35.7% of total liabilities.

Accounts payable have increased yearly amounting to 47.9% of total liabilities in 1984. The greatest proportion of accounts payable was attributable in 1984 to power rates (Q21,648,454, or 39.9% of total liabilities) and social security payables (Q3,079,485, or 5.7% of total liabilities).

Annual EMPAGUA revenue in 1984 was Q11,515,637. The most important sources of revenue were water sales (84%) and sale of water titles (13.3%).

Expenditures in 1984 were Q13,814,336, or 20% in excess of revenues. Operation and Maintenance costs accounted for roughly 70% of total expenditures in the past three years. Although the overall EMPAGUA expenditures exceeded revenues, direct costs (O/M) were less than total income. The resulting operating income in 1981 amounted to 26.2% of total revenues, 25.6% in 1982, 7.7% in 1983 and 14.4% in 1984.

The largest expense item in O/M costs has been electricity, accounting for over one-half, even though a downward trend can be observed over the past three years (58.2% in 1982, 55.7% in 1983, 52.3% in 1984). The second O/M expense item has been wages and salaries, accounting for around one-fifth, also with a downward trend in the past three years (22.4% in 1982, 20.8% in 1983, 19.4% in 1984). Expenses for chemicals increased drastically from 9.3 percent in 1983 to 15.0 percent in 1984, while depreciation expenses stood at a stable 7.7 percent.

3.6.3 Financial Ratios

The information contained in the EMPAGUA financial statements from 1982 to 1984 were summarized as financial ratios and are presented in TABLE 3-7. These ratios pertain to three groups, namely, liquidity ratios, leverage ratios and profitability ratios.

EMPAGUA's liquidity problem during the 1982-1984 period was evident in the fact that current assets covered less than half of current liabilities. The liquidity problem become particularly aggravated from 1983 to 1984. Also, the average collection period for water bills has shown an increasing trend. As a result, receivables in 1984 amounted to nearly half of annual sales suggesting a serious collection problem due to the high proportion of late accounts.

The EMPAGUA debt ratio has steadily increased during the past four years and in 1984 almost 60% of EMPAGUA's assets were financed with borrowed funds. Significant is the fact that a disproportionately high share of debt is comprised of short-term debt.

The net profit margin, or the ratio of net income to net sales, for EMPAGUA continues to be negative due to chronic financial losses since its creation. The ratio of operating income to total assets has fluctuated between 1.5 and 5.9% for the period 1981-1984. EMPAGUA's negative return on investment is due to the negative profit margins described above which are in turn caused by excessive expenditures in relation to sales. A low asset turnover ratio further contributes to the unfavorable return on investment of EMPAGUA.

3.6.4 Institutional Aspects

(1) Management System Improvement

The Guatemala accounting and auditing firm Arevalo Perez y Asociados in a report dated December 1983 diagnosed EMPAGUA management in regards to the following area:

TABLE 3-4(1)

EMPAGUA Balance Sheet

Assets

Assets	1984 Q	1984 %	1983 Q	1983 %	1982 Q	1982 %
PROPERTY, PLANT & EQUIPMENT						
Public service	35,576,204	65.6	32,771,053	62.9	28,629,151	52.3
General use	2,479,904	4.6	2,202,251	4.2	2,081,238	3.8
Work underway	8,858,515	16.3	9,843,318	18.9	13,889,468	25.4
Total P.P & E	46,914,623	86.5	44,816,622	86.0	44,599,857	81.4
Accumulated Depreciation	(9,602,567)	17.7	(7,951,231)	15.3	(6,848,496)	12.5
Net P,P & E	37,312,056	68.8	36,865,391	70.8	37,751,361	68.9
CASH AND BANKS	2,438,745	4.5	3,595,556	6.9	2,174,232	4.0
ACCOUNTS RECEIVABLE						
Service to water users	3,847,635	7.1	2,817,416	5.4	4,930,887	9.0
Water titles	1,975,177	3.6	1,700,225	3.3	-	
Guatemala City Municipality	1,096,225	2.0	691,269	1.3	408,588	0.8
Others	176,156	0.3	137,092	0.3	22,374	0.0
Total Accounts Receivable	7,095,193	13.1	5,346,002	10.3	5,361,849	9.8
Uncollectables	(925,164)	1.7	(923,747)	1.8	(902,705)	1.7
Net Accounts Receivable	6,170,029	11.4	4,422,255	8.5	4,459,144	8.1
ASSETS TO BE REALIZED	-		-		5,532,700	10.1
INVENTORY	918,567	1.7	990,327	1.9	62,017	0.1
PREPAID EXPENSES	79,201	0.1	76,583	0.1	205,888	0.4
DEFERRED CHARGES	5,393,940	10.0	4,066,829	7.8	3,628,174	6.6
OTHER ASSETS	1,886,959	3.5	2,075,355	4.0	954,210	1.7
TOTAL ASSETS	54,201,497		52,092,296		54,767,726	

TABLE 3-4(2)

EMPAGUA Balance Sheet

Liabilities

Liabilities	1984 Q	1984 %	1983 Q	1983 %	1982 Q	1982 %
CAPITAL						
Capital	41,555,351	76.7	41,555,351	79.8	41,244,798	75.3
Accumulated losses	19,362,710	35.7	16,302,251	31.3	13,747,144	25.1
Net Capital	22,192,641	40.9	25,253,100	48.6	27,497,654	50.2
LONG-TERM DEBT	3,913,754	7.2	4,498,648	8.6	4,294,229	7.8
ACCOUNTS PAYABLE						
Guatemala Electric Co.	21,648,454	39.9	16,874,857	32.4	11,994,283	21.9
Guatemala Social Security	3,079,485	5.7	2,627,470	5.0	2,228,099	4.1
Suppliers	524,977	1.0	177,585	0.3	302,253	0.5
Loans currently due	-	-	-	-	400,000	0.7
Others	708,574	1.3	556,499	1.1	419,199	0.8
	25,961,490	47.9	20,236,411	38.8	15,343,834	28.0
RECEIVED DEPOSITS	460,355	0.8	430,880	0.8	426,052	0.8
DEFERRED CREDITS	1,673,257	3.1	1,673,257	3.2	7,205,957	13.2
TOTAL LIABILITIES	54,201,497		52,092,296		54,767,726	

TABLE 3-4-(3)

EMPAGUA INCOME STATMENT

	1984		1983		1982	
	Q	% of Revenues	Q	% of Revenues	Q	% of Revenues
REVENUES	11,515,637	100.0	10,183,675	100.0	11,372,051	100.0
Water Services	9,685,567	84.1	8,331,811	81.8	9,512,752	83.7
Water Titles	1,531,810	13.3	1,583,794	15.6	1,605,230	14.1
Others	298,260	2.6	268,070	2.6	254,069	2.2
EXPENDITURES	13,814,336	120.0	12,972,869	127.4	12,291,739	108.1
Direct Costs: O/M	(9,854,050)	85.6	(9,394,540)	92.3	(8,463,827)	74.4
Operating Income	1,661,587	14.4	789,135	7.7	2,908,224	25.6
Indirect Costs: Administrative	(3,960,286)	34.4	(3,578,329)	35.1	(3,827,912)	33.7
Wages & Salaries	1,417,874	12.3	1,219,367	12.0	1,223,608	10.8
Labor Benefits	526,515	4.6	459,945	4.5	436,804	3.8
Employer Share of Workers Benefits	601,352	5.2	457,193	4.5	467,752	4.1
Fuel & Lubricants	327,764	2.8	326,632	3.2	573,796	5.0
Depreciation	295,387	2.6	290,269	2.9	108,238	1.0
Stationery	156,084	1.4	109,406	1.1	125,439	1.1
Rent	147,801	1.3	102,503	1.0	97,767	0.9
Other Adm Expenses	267,412	2.3	147,275	1.4	618,576	5.4
	(3,749,189)	32.6	(3,112,590)	30.6	(3,651,980)	32.1
Operating Loss	(2,087,602)	18.1	(2,323,455)	22.8	(743,756)	6.5
Other expenses	(211,097)	1.8	(465,739)	4.6	(175,932)	1.5
NET LOSS	(2,298,699)	20.0	(2,789,194)	27.4	(919,688)	8.1

TABLE 3-4-(4) Selected EMPAGUA Financial Ratios

Financial Ratios	1984	1983	1982
<u>Liquidity Ratios</u>			
Current Ratio	0.370	0.449	0.438
Avg. collection period (days)	172	163	121
<u>Leverage Ratios</u>			
Debt Ratio	0.591	0.515	0.498
Long-term Debt Ratio	0.072	0.086	0.078
Short-term Debt Ratio	0.519	0.429	0.420
<u>Profitability Ratios</u>			
In relation to sales			
Net Profit Margin	(0.205)	(0.281)	(0.083)
In relation to investment			
Operating Income Rate of Return	0.031	0.015	0.053
Return on Investment (ROI)	(0.042)	(0.054)	(0.017)
a) Net income/Net sales	(0.205)	(0.281)	(0.083)
b) Net sales/Total assets	0.207	0.190	0.203

i) Organization
ii) Accounting
iii) Internal Audit
iv) Electronic Data Processing
v) Billing and Collection

The Arevalo Perez report recommended relocation of EMPAGUA offices and upgrading Commercial Services from the level of Unit to that of Division, recommendations which have already been implemented. Speeding up of accounting and financial reports, replacement or repair and maintenance of water meters, assignment of sufficient personnel as meter readers, observance of schedule for meter reading and billing and collection, and autonomy to change water rates in response to changing circumstances were also recommended in the said report.

Many of the Arevalo Perez recommendations have been implemented or are in the process of implementation.

A February 1985 financial and institutional study by Sturla, a PAHO consultant, recommended a gradual or immediate phasing-out of "pajas" or water titles on grounds that while titles are conferred in perpetuity, the useful life of water supply facilities does not exceed 40 years. A recommendation on debt cancellation through government subsidies would permit an increasing EMPAGUA capitalization. Classifying receivables by age is a recommendation which would permit EMPAGUA's administration to take necessary measure to reduce Accounts Receivable to the equivalent of one-month billing.

Continued implementation of the recommendations contained in the above reports, coupled with appropriate and timely adjustments, should result in a significant institutional strengthening of EMPAGUA which would be achieved through improvements in its management system and its financial situation.

One commendable action taken by the new EMPAGUA administration consists of setting up, as weekend shifts, teams composed of three managers and engineers who can expedite solutions to any water user problems that might arise during weekends. This measure should considerably improve EMPAGUA's services as well as the public perception of services rendered by EMPAGUA.

(2) Financial Improvement

Financially, EMPAGUA should be able to obtain enough revenues to cover operation and maintenance costs, depreciation costs, administrative expenses, repayment of loans, and to finance at least part of future expansions. This underscores the importance of being able to change water rates as circumstances warrant.

Water rate increases occurred once in 1974, once in 1980 and twice in 1981, the last three rate hikes with a magnitude of 33% each. The new EMPAGUA administration, realizing the urgency to increase water rates if service is to be improved or expanded in response to demand, has implemented a new water rate effective July 1, 1986 except for the marginal service category (1/3 paja = $20m^3$/mo.) due to social considerations. The new tariff seems to be well founded since according to historical data, although marginal service connections account for 10% of all connections, they amount to only 5% of consumption and 3% of revenues.

An indication on the ability of consumers to pay for water is given by the proportion of expenditures on water relative to the yearly family income in 1980 which amounted to 1.41% for those earning less than Q1,200 per year and 1.01% for those earning less than Q2,400 per year. For higher income levels, spending on water amounted to less than 1%, and less than 0.5% for those earning over Q7,200 per year. Even taking into account the three rate hikes amounting to 100% that took place in 1980-1981, expenses on water constitute a minimal fraction of the family income. Since the tariff increase excludes the marginal service group, the remaining consumer groups should be able to absorb the rate hike without major hardship.

3.7 Environmental Impact

3.7.1 Natural Environment

The population of Metropolitan Guatemala in 1985 was 10 times that of 1940, 5 times that of 1950 and 3 times that of 1960. This rapid growth of the Metropolitan Guatemala area has brought with it changing land use patterns causing alteration and sometimes destruction of natural topographic and drainage features, reduction of vegetation as well as other ecological problems.

Specifically in regards to domestic water sources in the Metropolitan Guatemala area, the above described rapid population growth and urbanization poses the following environmental impacts:

i) Destruction of water source recharge mechanism
ii) Contamination of rivers and other water sources
iii) Over drafting of groundwater and possible parching of the aquifer

Although data is not available to quantitatively clarify the degree of urbanization of formerly agricultural and forested land, it is clear that if recent and current trends continue over the long-term without parallel concern for the natural environment, the destruction of vegetation and natural topographical features will render it impossible to conserve water resources in the area.

Failure of adequate sewerage facilities to keep pace with urban growth has resulted in the contamination of area rivers. Status of river contamination is as described in Appendix-IV. It is evident that the water quality of area rivers is steadily losing its suitability for drinking and other domestic uses.

Excessive groundwater development impairs the recharge mechanism of the area and has resulted in a drop in water level at Lake Amatitlan.

3.7.2 Daily Living Environment

According to WHO/PAHO data for 1982, mortality rates due to intestinal diseases by age group in Metropolitan Guatemala are as set out below. The mortality rate for the age bracket 1 month to 14 years is particularly high.

Age group	Mortality rate (%)
28 days - less than 1 year	30.0
1 year - 4 years	33.5
5 years - 14 years	23.4
15 years - 44 years	9.5
45 years - 69 years	13.3
Over 65 years	11.3
Unknown	4.1
Intestinal disease mortality/ total mortality	18.7

Principal diseases causing death are diarrhea, malnutrition parasites, etc.

High death rate and disease incidence is attributed to the following:

i) Shortage of potable water

ii) Inadequate sewerage facilities

iii) Lack of awareness among general populace concerning health and sanitation

According to the 1981 census, 88.5% of the population of Metropolitan Guatemala is supplied with drinking water from public or private facilities. The remaining 11.5% draft water for domestic use directly from shallow wells, rivers, springs and lakes.

The status of sewerage facility development lags considerably behind that of water service. At present, only 56.6% of the area population has access to public sewerage facilities. With the inclusion of privately operated facilities, 62% of the population benefits from sewerage service. Approximately 5% of the population has no toilet facilities.

The status of waste disposal and sewerage facilities is as described in Appendix-IV.

3.7.3 Water Quality

Sampling of water quality for potability was performed for principal water sources of the Metropolitan Guatemala population. These included shallow wells, deep wells, springs and rivers. Analysis results are summarized below. (Details are presented in Appendix-III.)

(1) Springs

Springs are located sporadically through the Study area. Nearby residents draft water for domestic use directly from springs without treatment.

Samples from 5 springs were subjected to standard analysis, while water at 13 springs water was investigated by means of a portable water checker. Although some excessive microbiological presence was detected at certain springs, water from the springs overall showed suitability for drinking in terms of physical and chemical characteristics. (See Appendix-III for analysis results)

(2) Rivers

Water at upper reaches of rivers in the Study area was generally clear, although in some cases slight turbidity and an earthy odor were present.

Results of river water analysis are summarized below. (Details are set out in Appendix-III.)

Color:	24 - 80 TCU
Turbidity:	8.6 - 26 NTU
Total solids:	154 - 193 mg/l
Suspended solids:	20.8mg/l
Bacterial number:	above tolerable levels
pH:	7.5 - 9.0 (average: 8)
Hardness ($CaCO_3$):	42 - 72 (average: 55.5) mg/l
Total iron:	0.035 - 1.97 (average: 0.758) mg/l
Alkalinity:	74.6 mg/l

As described in detail in Appendix-III, samples taken from the confluence of the Monjitas and Canalitos rivers, as well as the Las Canas rivers into which these rivers flow, showed higher values for color, turbidity, suspended solids, electroconductivity, etc. than samples from other rivers in the area. However, on the basis of Biological Oxygen Demand (5.0mg/l), Chemical Oxygen Demand

(10.0mg/l) and dissolved oxygen (9.4mg/l), it may be concluded that pollution is not advanced. Nevertheless, bacteria and coliform organisms were detected in relatively large numbers.

(3) Water Quality of Polluted Rivers

As detailed in Appendix-III, samples taken from the various rivers of the Villalobos system showed a large degree of pollution. Values for all test items were high.

The Las Vacas and San Juan river systems also exhibited advanced pollution, attributable to human settlements and industrial establishments located on the headwaters of these systems. However, below average values were obtained in the case of some test items.

(4) Shallow Wells

Shallow wells range in depth from 3 to 40m. Water drafting is performed by either rope and bucket or small motor pump.

Details of analysis results for 5 shallow wells are presented in Appendix-III. In the case of 2 of the 5 wells, where water is presently drafted for domestic use except drinking, the bacteria content is considered excessive for any type of household utilization.

Regarding the remaining 3 wells, water from 2 is not considered suitable for drinking without proper biological treatment.

(5) Deep Wells

Water from 9 wells was analyzed at LERIS applying standard methods. Samples from the remaining 5 wells were examined by a portable water checker. Details of test results are presented in Appendix-III. (Well breakdown is as follows: 2 EMPAGUA wells; 1 industrial well; 7 private wells; 1 hotel well; 2 cooperative wells and 1 colony well.)

Investigation results indicated a bacterial number in excess of 100/ml for 4 wells. At one well utilized by a milk production factory, coliform organisms were detected. For these wells, biological treatment is necessary prior to water use. In the case of wells where water is widely consumed, such as at the aforementioned milk factory, periodic inspection by the relevant authority is considered particularly desirable.

CHAPTER IV

PROPOSED PROJECT

CHAPTER IV

PROPOSED PROJECT

4.1 Project Objectives

(1) The general objective of the proposed Project is to improve public health and living standards through the stable supply of safe drinking water at an affordable price as based on national policy and goals of national development for water supply and sanitation. The Project envisages development of new water sources with a view to improving and expanding the current water service system.

Through establishment of a safe and ample water supply, the Project will serve to constrain disease outbreak caused by water shortage and contamination, thereby contributing significantly to improved sanitation and living environment for the population of Metropolitan Guatemala.

(2) The Project corresponds to the Emergency Plan (I) component of the Guatemala City Water Supply Master Plan (PLAMABAG), and is accorded top priority for early implementation. Emergency Plan (I) seeks to resolve water shortage in Metropolitan Guatemala over the short term from 1988 to 1992, and envisages new development of $1m^3/s$ of groundwater for supply through EMPAGUA's existing water service system.

(3) The operational objectives of the proposed Project are to accomplish the target yield through the implementation of the proposed groundwater development plan and proposed rehabilitation.

In consideration of the present water service status and the implementation schedule for the additional water resources development plan, the proposed Project aims to supply 1 m^3/s of the new developed water and as much additional water as possible through implementation of a rehabilitation plan. The proposed Project is planned for commencement in 1987 and completion in 1990.

4.1.1 Basic Concept of Development

This development is to be implemented to fulfill the previously described objectives on the basis of the optimum plan formulated in line with the following basic concepts.

(1) Groundwater is to be given priority as the water resource to be developed, because of consideration of required development expenses, required development period, long-term stability etc.

(2) The newly-developed water is to be supplied in principal through the existing water supply system of EMPAGUA. However, new supply system will be introduced where the socio-economic effect of such is judged to be great, and for where there will be no impact on the existing system.

(3) After the implementation of the project, the O/M system will be improved and strengthened in order to promote the effective operation and management of water and facilities.

(4) The EMPAGUA water supply service will be stabilized and strengthened through functional rehabilitation of the existing EMPAGUA groundwater facilities.

(5) Promoting stabilization of EMPAGUA groundwater production through maintenance and observation of groundwater resources.

Moreover the implementation of this development plan is to give the minimum deleterious influence to lives of the people and the natural environment in general.

The formulation of this development plan is to be achieved through a process involving the formulation of a number of alternative plans, and the final selection made for the optimum project that is economically and technically feasible and minimizes adverse environmental impacts.

4.1.2 Component Elements

The development plan is to be formulated in accordance with a basic concept, consisting of the following elements.

(1) Groundwater development plan

- Groundwater development plan: determination of groundwater development areas, development priorities, development volumes
- Water production plan: $1 m^3/s$ groundwater production plan
- Water supply plan: $1 m^3/s$ newly-developed water distribution plan
- Rehabilitation plan: rehabilitation plan for existing wells of EMPAGUA
- Operation and maintenance

(2) Groundwater conservation plan

- Groundwater monitoring plan
- Groundwater recharge plan (Recommendation)

However, regarding the groundwater recharge plan, the team will only assess its effect and make recommendations regarding future surveys to be carried out.

4.2 Groundwater Development Plan

4.2.1 Basic Approach

(1) Objective Area

As shown in FIG. 3-1, the objective area for the groundwater development under the proposed Project is divided into the following three areas according to hydrological basin boundaries (the total area is approximately 815 km^2).

a) Southern sector: Villalobos river system basin (excluding the Lake Amatitlan basin itself); 318 km^2

b) Northern sector: Las Vacas river system basin; 240 km^2

c) Eastern sector: Las Canas river system upper basin; 256 km^2:

(2) Objective Aquifer

The objective area has both upper and lower aquifers, and these have been effectively utilized as water resources for the citizens of Metropolitan Guatemala.

According to the result of this Study, it is assessed that the development potential yield in the said area is greater than the development target yield of 1m ^{3}/s.

In particular, on the basis of the hydrogeological structure and lithological units, it is estimated that the said area has a considerable sum of developable lower aquifer storage.

The potential head of the lower aquifers in this area is confirmed at approximately EL 1300m. The required depth of the well to pump up the lower aquifers is estimated to be from 250 to 300 m, making it economically possible to utilize and develop the lower aquifer.

Accordingly, the main objective aquifer for the proposed groundwater development is determined as the lower aquifer.

The respective estimated development potential capacities of the groundwater are as follows:

Upper aquifer

	Effective Storage	Actual pumping Volume	Pump-up Potential
Northern sector	0.89 m^3/s	0.32	0.57
Southern sector	0.73 m^3/s	0.29	0.44
Eastern sector	1.16 m^3/s	0.03	1.13
Total	2.78 m^3/s	0.64	2.14

Lower aquifer

	Estimated Storage	Pump-up potential	
Northern sector	180 x $10^6 m^3$	54 x $10^6 m^3$	1,710 ℓ/sec.
Southern sector	143 x $10^6 m^3$	43 x $10^6 m^3$	1,360 ℓ/sec.
Eastern sector	196 x $10^6 m^3$	59 x $10^6 m^3$	1,860 ℓ/sec.
Total	519 x $10^6 m^3$	156 x $10^6 m^3$	4,430ℓ/sec.

Lower aquifers represent effective sources for the proposed Project, but the pumping-up of lower and upper aquifer water from the same well should be avoided. As the fluctuation between water table from wet to dry season is pronounced, the static head during the wet season becomes excessive as the submersible pump must be set below the lowest water level during the dry season. Accordingly, the pressure to the pump and motor is large and may exceed the standard pressure for which the pump and motor are designed.

(3) Priority of the Development area

The priorities of the three basins were assessed while taking the following factors into consideration.

a) Attainment of maximum benefits from potable water service;

b) Existence of groundwater arteries and potential for groundwater development in the area;

c) Topographical features and geographical conditions;

d) Technical feasibility and financial viability of additional groundwater development and the required water supply facilities; and

e) Minimization of environmental impact caused by the additional groundwater development.

1) <u>Eastern Sector</u>

East of the Project area, the hydrogeological boundary is formed by raised blocks of Palencia, which are located within the north/south fault system and known as Teocinte/Palencia. In addition, it seems that this area comprises a saddle formed by the faults in E/W direction.

The results of electrical prospecting conducted for the proposed Project and the aquifer properties in the said area are as described in Appendix-I. In this sector there are pyroclastic sediments and volcanic fall deposits that are all of the Quaternary period, and their thickness is approximately 200m to 100m.

The pyroclastic sediments have a poor groundwater transmissability due to the great granulometric variability and the high percentage of fine grains. However, due to their high porosity, they are good storage materials with a good regulatory capacity.

Sloping ground has basement at a considerably shallow depth, and the thickness of Quaternary deposits is not great.

Accordingly, the storage capacities of upper aquifers is considered to be small.

According to the results of pumping test at the test well No.2, lowering of the water table does not occur even under the condition of continuous pumping-up of 50 l/sec. The pumped water at the test well can thus be regarded as coming from the lower aquifer which has a plentiful storage capacity. Generally, the basement in this area is formed by consolidated volcanic material, lava, and tertiary tuft as well as Cretaceous limestone highly affected by faults, fractures, and fissures. The basement lower than EL 1300m can be assumed to comprise the lower aquifer.

The results of the pumping test at the test wells No.1 and No.3 were poor since the actual pumped water was only 20 - 30% of the target yield. This was probably due to drilling into a basement which has undeveloped fractures.

Some of the potable water intake of EMPAGUA water service systems is from local rivers such as the Teociente, Ocotes, Acatan, Canalitos and El Bijague rivers. The utilization of groundwater is however, undeveloped. At present, the actual production of groundwater is estimated at only 0.1m ^{3}/s. There are two water treatment plants for the treatment of the river flow water intake in the nearby area. These are the Las Ilusiones and Santa Luisa plants.

There is only a short distance to convey the new developed groundwater from the proposed well fields to these treatment plants, and the residential programs to be advanced around these treatment plants are expected to rapidly increase the water demand each year.

The coefficient of permeability and groundwater discharge defining the hydraulic characteristics of aquifers on the basis of the pumping test are as follows:

	Section of basin (B · H)	K	ø	Q (m^3/sec)
No.2 test well	Andesite (Fractured) 2500m x 50m	9.54×10^{-5} 7.75×10^{-5}	0.05	0.597 0.485
No.1 test well	Welded Tuft (Non-fractured) 2500m x 50m	1.40×10^{-5} 1.20×10^{-5}	0.03	0.042 0.036
No.3 test well	Limestone (Non-fractured) 2500m x 50m	5.40×10^{-6} 6.24×10^{-6}	0.03	0.021 0.047

2) Northern Sector

In the northern sector, the structural conditions discussed seem to indicate that there is hydro-geological communication with the basin of Las Vacas river, approximately between the coordinate UTM 16,15.50/16,12.00N, for the axis 772.00E. In this area, the upheaval blocks have uncovered gross deposits of Tertiary volcanic rocks, as well as Cretaceous limestones. The thickness of the Quaternary sediments is estimated at approximately 100m.

There is an estimated 0.5 m^3/s of flow of water percolating from the neighborhood basin but the route of this percolating water is not yet definite. In the light of the hydrogeological structure of this area, it may flow in from the west part and flow out to the north, being controlled by the fault system.

The basin reserves of this area are estimated at approximately 2.2 m^3/s and there is pump up of 0.4 - 0.5 m^3/s. Most of pumped-up groundwater are taken to be from upper aquifers.

EMPAGUA's Project 4-3 well and a few other wells have been able to tap the lower aquifer by properly selected sites and properly designed wells. The water table of the these wells is estimated at approximately EL 1300m, and the average yield at 63 l/sec.

However, there are many topographic variations and the elevation of the area is sometimes more than EL 1500m, requiring a greater well depth to pump up from the lower aquifer. Consequently, the high potential area for the development of the lower aquifer will be limited to the lowland area having an elevation of less than EL 1500m.

This area contains a lower aquifer with high storage capacity and consequently high development potential for the proposed Project judging from the hydrogeological structures and concentrated fault systems in the north/south direction and the tensional fractures in the east/west direction.

3) Southern Sector

In the southern sector, groundwater recharge is good as there is ample inflow into the sector from higher terrain to the east and west. However, 30 million cubic meters is already being pumped-up annually and another 70 million cubic meters is estimated as running off from the sector into Lake Amatitlan.

Recently, the surface water level of Lake Amatitlan is decreasing due to the influence of the groundwater development and it is an obvious necessity that additional groundwater development be regulated to maintain the water level of the lake.

4) Development Priority

As has been mentioned, the actual pumped water in the southern sector is over the safe yield and further development should be avoided. Actually, the water tables of some wells are decreasing and it is sometimes impossible to pump-up groundwater.

In the northern sector, at present, there are many publicly and privately owned wells around the southern and western parts of the said sector, which comprise the city center. The potential development area in the northern sector for this proposed Project is only the northeastern part of this said sector.

In the eastern sector, there are areas for which groundwater is undeveloped and the groundwater development potential is expected to be high on the basis of electrical prospecting and other studies. This is particulary true in the central and northeastern parts of this sector.

The resulting priority of the three areas is as follows:

Top priority	:	Eastern Sector
Second Priority	:	Northern Sector
Third Priority	:	Southern Sector

The proposed groundwater development plan should be formulated in consideration of these classifications.

4.2.2 Alternative Water Resources

In determining the water sources for the Project, both river discharge and groundwater were considered. However, due to the factors outlined below, groundwater was selected as the optimum water source.

Rivers:

(1) Although discharge is generally ample, large seasonal fluctuations render them unstable.

(2) Distance is large from potential diversion points to demand centers. Construction of extensive pipeline facilities would be necessary.

(3) The closest river water to demand centers is heavily polluted from sewerage, and would require the construction of large-scale purification facilities.

(4) According to the results of the PLAMABAG study, development of surface flows costs 2 - 3 times that of groundwater.

Groundwater:

(1) Well construction is possible in areas adjacent to demand centers, minimizing the construction of pipeline conveyance facilities.

(2) Purification facilities may be greatly simplified, facilitating operation and maintenance as well as reducing the cost.

(3) Construction of recommended wells may be pursued in stages and this imbues the investment schedule with considerable flexibility. At the same time, there is a fast benefit accrual. Accordingly, it was concluded that groundwater development was most appropriate after taking into consideration factors of:

1) Water source stability;
2) Reduction of required implementation period;
3) Simplicity of required works;
4) Ease of implementation phasing; and
5) Potentiality for groundwater development.

4.2.3 Proposed Wellfield Block

As shown in FIG. 4-1, eight proposed wellfield blocks were delinated primarily in consideration of volume of groundwater available for development. Two blocks are located in the northern sector and six blocks is the eastern sector. All blocks in both sectors are located near the boundary separating the two sectors.

The hydrogeological properties of the eight proposed wellfield blocks are briefly described in Appendix-I.

At present, the maximum pump-up volume per well of existing wells only averages 10 l/sec for upper aquifers. In the case of lower aquifers, the performance of existing wells where the groundwater level is below EL 1300 m varies greatly between 3 l/sec and 189 l/sec, with large well discharges considered due to pump-up from the lower aquifer. Nevertheless, at the present stage accurate predication of well discharge is difficult because of the lack of geological profile for proposed wells. Therefore, on the basis of the above observed well discharges from the lower aquifer, the average pump-up volume per bore under the subject Project is assumed at 40 l/sec. However, results of test well Nos. 1 and 3 gave 10 l/sec for Block IV of the eastern sector which highlights the need to carefully select those wellfields from which adequate discharge is most likely to be obtained.

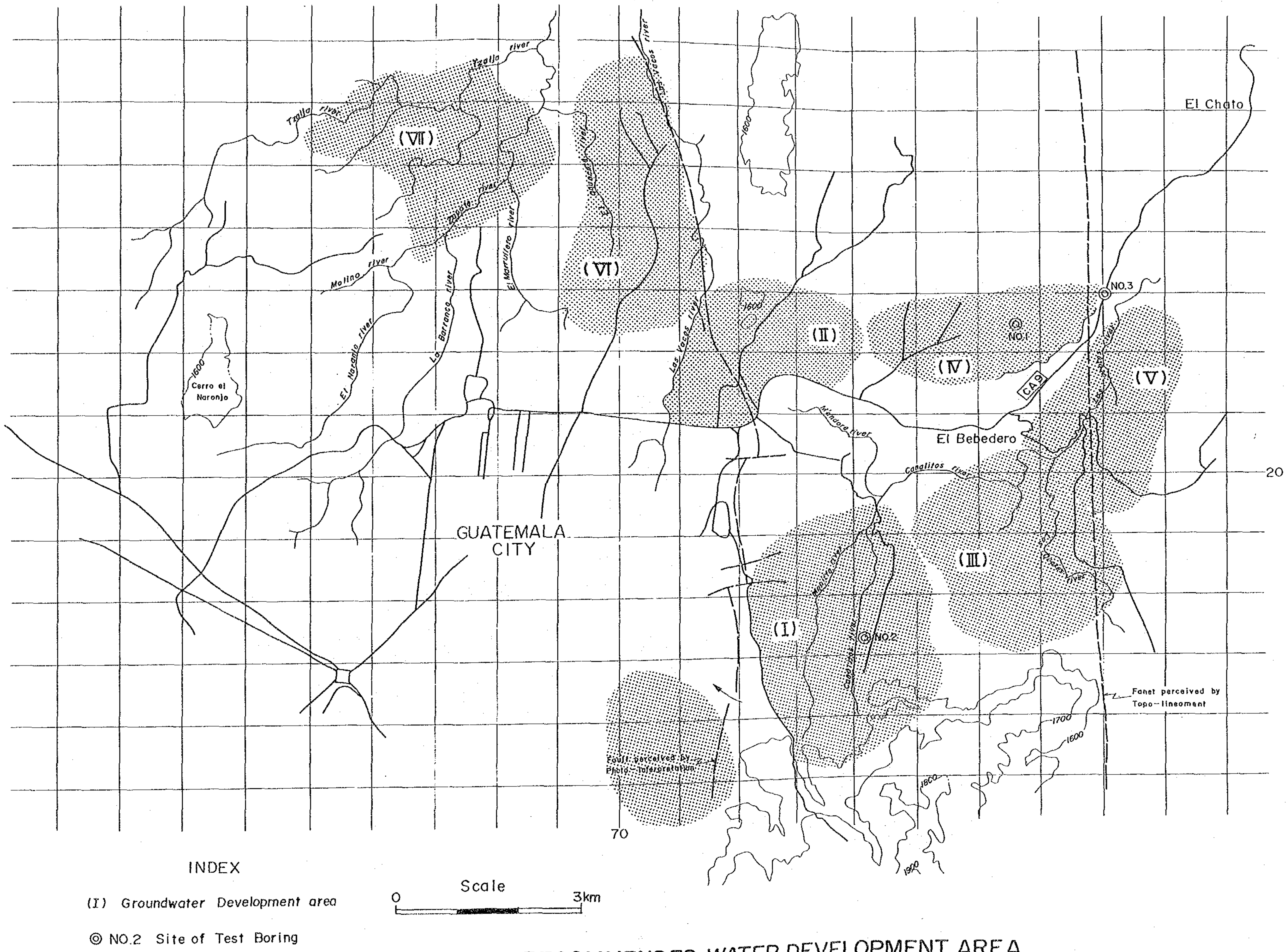


FIG.4-1 RECOMMENDED WATER DEVELOPMENT AREA

4.3 Water Supply Plan

4.3.1 Basic Approach

The main constraint to water supply in the proposed Project area is insufficient water production to meet total demand in the area. This is due to a decline in the production efficiency of the EMPAGUA system and the delay in development of new water resources. The EMPAGUA water service network is unsystematic and coverage is uneven due to sporadic expansion. This results in a substantial distribution loss.

There are remarkable local disparities in water shortage especially in the newly developed residential area and the center of Guatemala city. The proposed water supply plan should be formulated to remedy these local disparities in water supply. Accordingly, the proposed water supply plan should be designed according to the objective of alleviating local water supply shortages through additional new groundwater development. The groundwater development plan which is the major component of the proposed Project should be formulated according to the following basic criteria to realize the objectives of the water supply.

- The distribution plan for supplementary water supply should consider not only the present water shortage but also the response to future demand.
- Newly developed ground water supply will provide clean potable water through the existing EMPAGUA water service system.
- Basically, newly developed additional water supply will be transmitted to the nearest existing distribution plants or existing water works.
- Future water distribution plans should be considered in formulation of the supply plan under the Project so as not to maximize benefits for all future development plans for water resources and water supply
- However, where feasible and warranted by local demand for water, water produced under the Project should be distributed directly from wells to local residents by means of public tap.

4.3.2 Water Distribution Plan

(1) Selection of Service Area

Characteristics of water supply and demand in 1985 according to EMPAGUA are as follows: (see TABLE 4.1)

a) The overall water shortage rate is 18%; however, when water shortage in each zone is examined, the largest water shortage occurs from the city center to the northern area with a rate of 30% in the northeast area, 26% in the north area and 22% in the city center.

b) The northeast area is mainly comprised of zones 17 and 18 and water is supplied from the Las Ilusiones water production plant.

c) The north area consists of Zone 6, and water is supplied from the Santa Luisa water production plant.

d) Water supply to the city center is derived from wells in the vicinity and several water production plants.

In order to remedy regional disparities in water supply, EMPAGUA has proposed the following improvement plan.

a) A submerged motor pump is to be installed in existing wells in Zone 6 which are at present not operated.

b) The 22% water shortage rate in the city center is predominantly due to the inadequate distribution network. EMPAGUA proposes division of the network into smaller units (sectors) to minimize loss.

c) The greatest water shortage problem occurs in zones 17 and 18. Rapid development of these zones as residential area and the sudden increase in population and residences has resulted in a corresponding increase in water demand. In the next fifteen years, demand is forecast to increase to 1.02m^3/sec, three times the present rate.

The intake of Las Ilusiones plant which mainly serves Zone 17, 18 and is at Atlantico, obtains water from the Ocotes and Bijague rivers at a rate of 0.18m^3/sec. Santa Luisa plant mainly serves the city center and derives its intake from the Teocinte, Acatan and Canalitos rivers at a rate of 0.345m^3/sec. Although the total river discharge may be sufficient for adequate water supply, flow is unstable due to

Table 4.1 SUPPLY AND DEMAND

Section of Metropolitan Guatemala:	Center	North	North-East	South-East	West	South	Total	
							Total	(%)
							m^3/sec	
<u>Supply</u>								
Santa Luisa	0.24	0.10	-	-	-	-	0.34	14.0
El Cambray	0.07	-	-	0.08	-	-	0.15	6.0
Lo de Coy	0.21	-	-	-	0.62	-	0.83	35.0
La Brigada	-	-	-	-	0.07	-	0.07	3.0
Ojo de Agua	0.32	-	-	-	-	0.22	0.54	23.0
Wells in the City	0.11	0.10	-	-	-	-	0.21	9.0
Las Ilusiones	-	-	0.23	-	-	-	0.23	10.0
Total	0.95	0.20	0.23	0.08	0.69	0.22	2.37	100.0
Demand	1.22	0.27	0.33	0.09	0.74	0.25	2.90	-
Shortage/Demand x 100	22.0	26.0	30.0	11.0	7.0	12.0	18.0	-

pronounced seasonal fluctuations. Water quality is contaminating and the rivers capacity to function as a safe water source is gradually diminishing. Accordingly, use of river discharge as the water source will require not only construction of a large scale treatment plant but also require costs for settling basin and long distance conduit pipeline. Groundwater is a desirable supplementary water supply source due to its high stability and capacity for expanded production in response to increased demand.

Estimated water demand for 1985, 1990, 1995 and 2000 in the city center area, north area, and east area (which show marked water shortages) is based on the assumptions below and tabulated in TABLE 4.2-1.

- Demand per day per customer at tap: 1.4 m^3/day/customer
- Annual rate of customer increase: 6.287%
- Distribution loss: 32%

Water Demand in EMPAGUA Water Service Area

Area	City center	North	East
1985	1.22m^3/sec	0.27m^3/sec	0.33m^3/sec
1990	1.48	0.30	0.48
1995	1.80	0.34	0.70
2000	2.18	0.38	1.02

At present and in the future, local water shortages will be remarkable in the north-eastern part of the metropolitan area which is mainly composed of zones 17 and 18.

There are newly developed residential zones in Zone 18 for which the water demand is also increasing rapidly.

The water demand growth rate is estimated to result in a 145% increase over of the present demand in 1990, 212% in 1995, and 310% in 2000.

One the other hand, additional new development of rivers in the Study area which form the main water source at present is considered unfeasible, with a very low potential for additional development, and PLAMABAG has proposed to convey water from basins by pump from outside the Guatemala City Valley.

The water demand growth for the northern part of Metropolitan Guatemala is not so large and is estimated to be at 140% of the present demand by the year 2000. In addition, there are also several new wells which were constructed by EMPAGUA in 1985. They will begin water production within 1986. Accordingly, little supplementary water will be required.

In the year 2000, the water demand of the central part of Metropolitan Guatemala is estimated at 285% of the present demand in the said area but there are new water sources targeted for development to satisfy this demand (transbasin diversion plans, etc.).

Accordingly, under the proposed Project, new development of $1 m^3$/sec of groundwater is proposed. Likewise, in conformity with PLAMABAG planning and projections, the water sevice areas are delineated as the eastern (Zone 17, 18), northern (Zone 6) and city center areas of Metropolitan Guatemala.

(2) Annual Distribution Programs

In view of the current situation and future water demand trends, planning under PLAMABAG calls for production of $1 m^3$/sec under the initial Emergency Plan (1) to be distributed as indicated in the following table.

(Including distribution loss)

Area of Metropolitan Guatemala	1990	1995	2000
Center	0.5 m^3/sec	0.54 m^3/sec	0.18 m^3/sec
Northeastern	0.2	0.42	0.74
Northern		0.04	0.08
Total	0.70 m^3/sec1/	1.0 m^3/sec	1.0 m^3/sec

1/: implementation will commence in 1987 and will be completed by the end of 1990.