have revealed that the production of wells of the lower aquifer is not small at all, as it ranges from 10 to 30 liters/second. Conclusively, the development of the lower aquifer is possible as long as the well site is properly located based on duly conducted hydrogeological investigations.

7.2.2 Local Hydrogeological Structure and Aquifer Characteristics

(1) Local Hydrogeological Features

Aerial photograph interpretation, geological field reconnaissance, and a water quality survey were conducted in and around the 54 municipalities. These surveys were focused on the following points.

a) Classification of rock facies and hydrogeological features of the basement rocks, Tertiary volcanic rocks, and Quaternary volcanic rocks and sediments;

b) Confirmation and discrimination of hydrogeological characteristics of faults (lineaments), fractured zones, weathered zones and basin structure, which were observed on aerial photographs;

c) Confirmation of various information obtained from existing geological data;

d) Confirmation of actual conditions of existing water sources such as springs and wells, and estimation of the probability of groundwater development in terms of quantity and quality.

Based on all the hydrogeological information obtained through the above surveys, the hydrogeological maps (1/50,000) were prepared categorizing groundwater basins and sub-basins, and the potential for groundwater development was assessed by area and municipality. Results of the above survey are summarized in Table 7.2.2.

A printed final hydrogeological map was prepared for each of the unit hydrogeological basins, where the prioritized municipalities are located, at a scale of 1/50,000. The hydrogeological maps are shown in Fig.7.2.1((1)-(5)). The results of the field hydrogeological reconnaissance of each municipal area are summarized as follows.

1) The basement rock area

This area extends in the northern part of the Study Area and comprises mainly basement rocks such as metamorphic rocks, Cretaceous series and the intrusive rocks, which are partially and unconformably overlain by the Tertiary and the Quaternary volcanic rocks. The municipalities of San Raymundo, Chuarrancho, San Pedro Ayampuc, San José del

Golfo, San Juan Sacatepéquez, and Huitán are situated in this basement rock area.

In general, areas consisting of basement rocks are hydrogeologically classified as "difficult areas" for groundwater development due to geological and lithological conditions. However, San Raymundo, San Pedro Ayampuc and San Juan Sacatepéquez have sub-groundwater basins of local scale, where the aquifer is comprised of Tertiary and Quaternary volcanic rocks, and weathered granitic rocks, as shown in Fig.7.2.1(1). These areas' potential for groundwater development has been classified as class "A" or "B" as shown in Table 7.2.2.

2) The Tertiary Volcanic Rock Area

The areas classified into this category are the municipalities of San Bartolomé Milpas Altas, Santa Catarina Palopó, San Antonio Palopó, Santa Catarina Ixtahuacán, San José Poaquil, Momostenango, and Palestina de los Altos. These areas are underlain by Tertiary volcanic rocks consisting of latitic to dacitic welded tuffs (lower), rhyolitic lava flows, andesitic/basaltic lava flows, pyroclastic flows, volcanic mud flows and tuffs (upper).

The existing water sources of these municipalities are mostly springs discharging from fractured zones and local perched aquifers, except the municipalities of San Bartolomé Milpas Altas, and Palestina de los Altos where the wells (6.50 - 13.89 ℓ/sec/well) are used for domestic water supply.

The area around Momostenango is composed entirely of the upper sub-group of the above mentioned Tertiary volcanic materials, accompanied with a fault system. The aquifer of the sheared and fractured zones were expected along or near the faults, according to the results of hydrogeological reconnaissance and electrical resistivity sounding. Hot spring (48.1°C, pH 6.5, EC 94µ℧/cm.) flows out from one of the faulted zones at the river bed of Rio Paja. If the well is located at or near a similar fault zone, it may end up producing hot water instead.

The area around Santa Catarina Ixtahuacán is situated in a geotectonic intramountain river basin consisting of the upper subgroup of Tertiary volcanic rocks, which are controlled by granitic intrusive rocks and faults, as shown in Fig.7.2.1(4). This municipality has sufficient water sources like springs for drinking (7.29 ℓ/sec), and rivers for domestic and agricultural use (196 ℓ/sec.).

Santa Catarina Palopó and San Antonio Palopó are situated in a topographically and geologically difficult area for groundwater development, as shown in Fig.7.2.1(3).

3) Combined area of the Tertiary (Tv) and Pleistocene

volcanic (Qp)

As described above, Pleistocene volcanic materials (Qp) are composed mainly of pumice sediments of fall deposits and pyroclastic flow types with clastic beds. It overlies a vast surface area of the Study Area, including "the upper aquifer".

However, thick Pleistocene volcanic materials (Qp) with good aquifer are confined within large valleys of the intramountain basins, such as the Guatemala Valley (Graben), Río Pixcayá basin (Chimaltenango), and Río Salama basin (Quetzaltenango). The following 9 candidate municipalities are situated in these areas where the productivity of existing wells is relatively high (Fig.7.2.1(1),(2) and (4)).

- Santa Catarina Pinula (11.04 ℓ/sec/well)
- Chinautla
- Villa Nueva (12.30 ℓ/sec/well)
- El Tejar (10.23 ℓ/sec/well)
- San Andrés Xecul
- Olintepeque (11.13 ℓ/sec/well)
- Cajolá
- San Martín Sacatepéquez
- Almolonga (12.30 ℓ/sec/well)

The area where the following 18 municipalities are located and their surroundings are composed mostly of Tertiary volcanic materials (Tv), intercalated "with a lower aquifer", and is widely but thinly covered from a few meters to 30 m by Pleistocene volcanics (Qv). The productivity of existing wells in these areas is relatively low.

- San José Pinula (5.68 ℓ/sec/well)
- Mixco (7.69 ℓ/sec/well)
- San Pedro Sacatepéquez (3.40 ℓ/sec/well)
- Santa Lucía Milpas Altas (4.00 ℓ/sec/well)
- San Juan Comalapa (5.80 ℓ/sec/well)
- San Martín Jilotepeque (6.00 ℓ/sec/well)
- Patzún
- Patzicía
- Zaragoza (3.15 ℓ/sec/well)
- Sololá
- Santa Lucía Utatlán
- Nahualá
- San Andrés Semetabaj
- Santa Clara la Laguna
- San Francisco el Alto
- San Carlos Sija
- Concepción Chiquirichapa
- San Francisco La Unión

4) Combined Areas - Tertiary volcanic and alluvial deposits.

The areas classified in this category are the areas around the following municipalities.

- Villa Canales
- Jocotenango (13.13 ℓ/sec/well)
- San Antonio Aguas Calientes (1.70 ℓ/sec/well)
- Santa Catarina Barahona
- Santa Cruz La Laguna
- San Pablo La Laguna
- San Marcos La Laguna

The four municipalities located on the shore area of Lake Atitlan (Santa Catarina Barahona, Santa Cruz La Laguna, San Pablo La Laguna and San Marcos La Laguna) have been eliminated from the detailed survey due to poor accessibility. A hydrogeological map was prepared to evaluate the potential for groundwater development, as shown in Fig.7.2.1(3). This figure indicates the possibility of developing groundwater from shallow aquifers of alluvial deposits.

5) The Holocene volcanic (Qv) area

The areas classified in this category are the areas of the following municipalities and their surroundings.

- Ciudad Vieja (13.37 ℓ/sec/well)
- Santa María de Jesús (6.00 ℓ/sec/well)
- Génova
- Flores Costa Cuca (9.27 ℓ/sec/well)
- Colomba

The area around Ciudad Vieja is located on a flat plain of the western foot of Volcan de Agua and consists of pyroclastic flows and basaltic to andesitic lava flows (Qv). The productivity of the 3 wells existing in this area is relatively high (Fig. 7.2.1(2)).

The local hydrogeological features of the areas around Santa María de Jesús, Génova and Flores Costa Cuca are described in the next paragraph, based on the electrical resistivity sounding, test drilling and pumping test results.

The municipal area of Colomba is composed of volcanic mud flows and pyroclastic flows of the Volcano Chicabal, and the area has high potential for the development of new water source such as groundwater and spring water, as shown in Fig. 7.2.1(5). The existing water sources of the municipality are 2 springs with a total productivity of 17.37 liters/sec.

(2) Geophysical Prospecting

In this Study, electrical resistivity sounding was conducted at 3 to 5 selected points in the 15 prioritized municipalities employing the equally spaced 4-electrode arrangement and McOHM type resistivity meter. The breakdown of the field works in Phase I and Phase II is shown in Table 7.2.3.

The survey points were selected based on the topographical and hydrogeological conditions resulting from geological field reconnaissance and aero-photo interpretation. The major purposes of the electrical prospecting activity were:

- To investigate the hydrogeological structures in the 15 prioritized areas
- To pinpoint the location of the test drilling sites in the 10 municipalities for the feasibility study during Phase II of the Study
- To determine the drilling depth of the test wells

The field data obtained from electrical prospecting were hydrogeologically analyzed and the apparent electric resistivity values were correlated with the lithofacies, as shown in Fig. 7.2.2 to 7.2.16.

As shown in the figures, the areas around the prioritized municipalities are composed mainly of Tertiary volcanic rocks (Tv) and the Quaternary volcanic rocks (Qv). The productivity of the wells existing in these areas is, however, generally low. Discharge ranges from 3.40 to 6.00 liters/sec, indicating the importance of proper site selection for well construction. The test wells constructed in these areas are more productive than the existing wells, because they were properly located based on the electric resistivity sounding results. Groundwater development has never been carried out in the 4 municipalities of Sololá, Santa Lucía Utatlán, Momostenango and San Francisco La Unión, hence the absence of deep wells.

The drilling site and the depth of the test wells were mainly determined based on the resistivity sounding results. The results were compared and analyzed to determine the site most likely to produce water.

(3) Test Well Drilling Works

1) Test well drilling

After completion of hydrogeological investigations in Phase I and Phase II, the points shown in Fig. 7.2.1(1) to 7.2.1(5) were selected as the sites for test drilling. The purposes of the test drilling were:

- To confirm groundwater occurrence and aquifer characteristics and to evaluate the potential for groundwater development in the 10 prioritized municipalities

- To examine suitability of groundwater as drinking water, and also to study groundwater flow mechanism by comparing the chemical components of groundwater of different aquifers in the groundwater basins or sub-basins

- To formulate the groundwater development plan and the project implementation plan

Test well construction, which was followed by pumping tests, commenced on August 22, 1994 and was completed on December 16, 1994. The cumulative drilling depth of 10 test wells was 1,950 meters. The results are summarized in Table 7.2.4 and Fig. 7.2.2 to 7.2.11, and the detailed drilling records and well logs are presented in the Supporting Report and Data Book.

The major findings from the test well are as follows.

A. Test well at San José Pinula

The site is located in the graben-type groundwater basin, which is one of the sub-basins situated at the upper most streams of the Plátanos River basin. This test well was drilled to investigate groundwater occurrence and aquifer characteristics in the said groundwater sub-basin.

The existing geological information suggests that the upper aquifer of the sub-basin is composed of Pleistocene pumice sediments and the lower aquifer of Tertiary volcanic rocks consisting mainly of rhyolitic welded tuffs. However, this test well has revealed that the lower aquifer is composed of basaltic to rhyolitic brecciated lavas and gravel beds with quartz sand.

Based on the results of electrical resistivity sounding and the test well, the hydrogeological structure in this area is assumed to be as illustrated in Fig. 7.2.2. The characteristics of the lower aquifer, confirmed by this test well, are as follows.

- Estimated thickness of aquifer: 72 meters
- Discharge: 2,698 m3/day (495 GPM)
- Static water level: 6.84 meters B.G.L.
- Drawdown: 11.90 meters at pumping rate of 1,874 liters/min
- Specific capacity: 227 m3/day/m
- Transmissivity: 223 m2/day

B. Test well at San Pedro Sacatepéquez

The site is located in a geotectonic intramountain river basin consisting of Tertiary volcanic rocks and Pleistocene pumice sediments, which are controlled by faults. There are many but small scale springs discharging from pleistocene pumice sediments, which are important water resources for domestic and agricultural uses. This test well was drilled to investigate groundwater occurrence and aquifer characteristics in Tertiary volcanic rocks (Lower aquifer) unconformably overlain by pleistocene pumice sediments (Upper aquifer).

The findings from the test well are as follows, and the confirmed geological structures are illustrated in Fig. 7.2.3.

a) The thickness of pleistocene pumice sediments is about 30 meters, being accompanied by clayey materials at depths of 12 - 15 meters and 21 - 25 meters. The basal part of it consists of sand and gravel beds with a thickness of about 3 meters.

b) The artisan flow of about 10 ℓ/m was observed at the drilling depth ranging between 13.5 and 24 meters, after which the water table came down to 11.5 meters B.G.L.

c) Tertiary volcanic rocks at the site are composed of basaltic tuffbreccias with thin lavas (30 - 134 meters) and fractured andesitic lava flows with thin tuffbreccias (138 - 219 meters), and are accompanied by the following materials:

- Weathered and clayey volcanic ejecta (brown fossil soil, at depths of 84-90, 140-146 and 219-228 meters)

- Tuffaceous coarse sandstone with pale green tuffs (at 228 - 250 meters)

- White grey clayey material (probable fault clay, at 134 - 140 meters)

d) Static water level in Tertiary volcanic rocks is GL-41 meters. The water level in the well was gradually lowered from GL-11.5 to 41 meters when drilling between 30 and 123 meters. The Tertiary volcanic rocks between 30 and 41 meters seem to form unsaturated dry zones and those between 41 and 123 meters are regarded as low permeable zones.

e) Resulting from the above mentioned lithological conditions and variation of water level in the borehole, it is understood that the main aquifer in Tertiary volcanic rocks in the area exists in the layers of basaltic tuffbreccia thinly covered with lavas (123 - 134 meters), fractured andesitic lava flows (138 - 219 meters) and tuffaceous coarse sandstone (228 - 250 meters).

f) The aquifer characteristics confirmed by this test well are as follows.

- Estimated thickness of aquifer:	61 meters
- Discharge:	1,744 m3/day
- Static water level:	41.56 B.G.L. meters
- Drawdown:	67.29 meters at a pumping rate of 1,211 ℓ/min
- Specific capacity:	26 m3/day/m
- Transmissivity:	46 m2/day

C. Test well at Santa María de Jesús

As shown in Fig. 7.2.1(2) and 7.2.4, the site is located on a flat plain (Sabana Grande) which is enclosed by mountains with steep slopes made up of Tertiary volcanic rocks. Part of the basin is made up of Quaternary volcanic rocks from Volcan de Agua and alluvial deposits. These topographical and geological characteristics indicate that the basin was formerly a crater lake (Fig. 7.2.4). This test well was drilled to investigate groundwater occurrence and aquifer characteristics in the basin.

a) The lithological features at this well is summarized below.

0 - 49 m:	Alluvial deposits consisting mainly of volcanic rock fragments (Qv and Tv) and sand with clay
49 - 72 m:	Dark black porous basaltic lava flow (Qv)
72 - 86 m:	Dark grey basaltic pyroclastic flow (Qv)
72 - 83 m:	Clayey volcanic mud flow
83 - 86 m:	Scoria flow
86 -116 m:	Dark grey fractured andesitic lava flow (Qv)
116 -152 m:	Dark grey fractured porous basaltic lava flows (Qv)
152 -165 m:	Dark grey pyroclastic flow with scoria (Qv)
165 -200 m:	Brownish grey/dark grey pyroclastic flow with scoria and clastic deposits (sand & clay) (Qv)
200 -210 m:	Dark grey basaltic to andesitic thin lavas with scoria (Qv)
200 -212 m:	Brown clayey beds with volcanic ash

b) Fig. 7.2.17 shows the fluctuation in mud water level during the drilling work. When the drilled depth reached 116 meters, the water level in the well suddenly dropped resulting in the elimination of mud water from the borehole. Drilling was then continued by repetition of cementation and mud filling works. The final water level in the borehole was 163 meters.

c) Based on the lithological features and the fluctuation in water table mentioned above, the following can be pointed out (See Fig. 7.2.4):

- Basaltic/Andesitic lava flows between 49 and 116 meters form an unconfined upper aquifer that is mainly recharged from the area of Volcan de Agua.

- Fractured/Porous basaltic lava flows between 116 and 152 meters form an unsaturated dry zone.

- Pyroclastic flow with scoria (152 - 165 meters), pyroclastic flow with scoria and clastic deposits such as sand and clay (165 - 200 meters) and basaltic to andesitic thin lavas with scoria form the semi-confined lower aquifer.

d) The characteristics of the lower aquifer are as follows:

- Estimated thickness of aquifer:	49 meters
- Discharge:	1,537 m3/day (282 GPM)
- Static water level:	163.16 meters B.G.L.
- Drawdown:	3.53 meters at a pumping rate of 1,067 ℓ/min
- Specific capacity:	435 m3/day/m
- Transmissivity:	567 m2/day

D. Test well at San Martín Jilotepeque

The site is located in the intramountain basin of the Pixcayá River basin and consists mainly of Tertiary volcanic rocks. The test well was drilled to investigate groundwater occurrence and aquifer characteristics in the basin.

The findings from this test well are the following (Fig. 7.2.5).

a) The lithological features are summarized below:

0 - 6 m:	Dark brown soil
6 - 24 m:	Weathered tuffaceous sandstone and sandy tuff (Tv)
24 - 36 m:	White grey pumiceous tuff (Tv)
36 - 58 m:	Dark black basaltic tuffbreccia with tuffaceous sandstone (Tv)
58 - 64 m:	Dark brown tuff with fossil soil (Tv)
64 -110 m:	Brownish grey-white grey pumiceous tuff with tuffaceous sandstone (91-98 m) (Tv)
110 -113 m:	Brown tuff with fossil soil (Tv)
113 -130 m:	Dark grey-purplish grey hard Andesitic/ Basaltic lavas (partially fractured) (Tv)
130 -181 m:	Dark grey-reddish brown Andesitic/ Basaltic lavas (autobrecciated and

fractured) (Tv)

181 -196 m:	Dark grey hard Andesitic/Basaltic lavas (partially fractured) (Tv)

b) From the lithological conditions mentioned above, the Tertiary volcanic rocks are divided into 2 sub-groups: the lower sub-group consists of fractured and auto-brecciated andesitic to basaltic lavas, while the upper sub-group is made up of volcanic fall sediments with clastic materials.

c) The results of geophysical logging and bailing confirmed that the main aquifer of the site is fractured and that the auto-brecciated andesitic to basaltic lavas of the lower group and volcanic fall sediments of the upper group form an aquifer of low permeability, with the exception of the brownish grey pumiceous tuff with tuffaceous sandstone observed between a depth of 85 and 110 meters.

d) The aquifer characteristics revealed by this test well are as follows.

- Estimated thickness of aquifer: 82 meters
- Discharge: 2,185 m3/day (401 GPM)
- Static water level: 80.25 GL meters
- Drawdown: 9.63 meters at a pumping rate of 1,517 ℓ/min
- Specific capacity: 227 m3/day/m
- Transmissivity: 559 m2/day

E. Test well at San Juan Comalapa

The site is located in the intramountain basin of the Pixcayá River system and consists mainly of pleistocene pumice sediments and Tertiary volcanic rocks. This test well was drilled to investigate groundwater occurrence and aquifer characteristics in the Tertiary volcanic layer of the basin.

a) The lithological features of this site are:

0 - 18 m:	White grey pumice sediments (Qp)
18 - 26 m:	Brownish white grey pumice sediments with clay and sand (Qp)
26 - 32 m:	Brownish white grey pumice sediments (Qp)
32 -215 m:	Grey to white grey partially fractured welded tuff with andesitic to basaltic rock fragments (Tv)

b) Two aquifers exist in this area as shown in Fig. 7.2.6. The major aquifer is the lower aquifer of fractured Tertiary welded tuffs (Tv).

c) The characteristics of the lower aquifer are:

- Estimated thickness of aquifer: 100 meters
- Discharge: 1,363 m3/day (250 GPM)
- Static water level: 28.94 meters B.G.L.
- Drawdown: 156.4 meters at a pumping rate of 947 ℓ/min
- Specific capacity: 8.70 m3/day/m
- Transmissivity: 6.05 m2/day

F. Test well at Sololá

The city area and its surroundings are situated on a flat plateau composed of Pleistocene pumice sediments and Tertiary volcanic rocks. Since the city area consists of low permeable and thick Tertiary welded tuffs, as seen in the northern caldera wall of Lake Atitlán, the drilling site was established on the flat plateau, about 2 kilometers north of the city area, based on the geological survey and electrical resistivity sounding results (Fig. 7.2.7). This test well was drilled to investigate geological structure, groundwater occurrence and aquifer characteristics in the Tertiary volcanic rocks of the plateau.

a) The lithological conditions in this site are:

0 - 9 m:	Brown pyroclastic deposits (Qp)
9 -104 m:	Grey to dark grey pyroclastic flow with thin basaltic lavas (Tv)
104 -107 m:	Brown fossil soil (Tv)
107 -120 m:	Reddish dark grey auto-brecciated basaltic lava flow (Tv)
120 -146 m:	White grey to brownish grey pyroclastic flows (dacitic) (Tv)
146 -157 m:	Brown clayey tuff (fossil soil) (Tv)
157 -171 m:	Brown to brownish grey tuffaceous coarse sandstone (Tv)

b) The target drilling depth for this test well was 200 meters, but drilling was terminated at 171 meters, because a difficult formation, e.g. unstable and mud water loss, was encountered.

c) The major aquifers in this area are observed in the layers of the auto-brecciated basaltic lava flow (107-120 meters) and tuffaceous coarse grained sandstone (157-171 meters)

d) The aquifer characteristics are:

- Estimated thickness of aquifer: 48 meters
- Discharge: 2,125 m3/day (390 GPM)
- Static water level: 71.63 meters B.G.L.
- Drawdown: 54.86 meters at a pumping rate of 1,476 ℓ/min
- Specific capacity: 38.7 m3/day/m
- Transmissivity: 28.55 m2/day

G. Test well at Santa Lucía Utatlán

The city area and its surroundings are situated on the mesas of the intramountain basin of Río Quiscab, and consists mainly of Tertiary volcanic rocks unconformably overlain by thin pumice sediments of the Pleistocene. The drilling site was established in the fractured zone along the NE-SW lineament which sharply controls the flow directions of streams (Fig. 7.2.1(3) and 7.2.8), about 1.5 kilometers northwest of the city area. This test well was drilled to investigate the geological structure and groundwater occurrence in the area.

a) The lithological features, by depth, are:

0 - 26 m:	Brownish grey dacite (Tv)
26 - 79 m:	Pale greenish grey dacite (Tv)
79 -175 m:	Purplish red to reddish grey auto-brecciated dacite
175 -210 m:	Pale greenish grey to grey fractured dacite

b) Lost circulation occurred 3 times at the depths shown below and in Fig. 7.2.17.

GL - 119 m:	19 m3
GL - 157 m:	could not be measured
GL - 174 m:	220 ℓ/min

Since the final water table in the borehole is 131.54 meters below the ground, the area between a depth of 26 and 131.54 meters is presumably an unsaturated dry zone.

c) The aquifer of the site is in the layer of auto-brecciated and fractured dacite located at a depth between 146 and 195 meters; this layer is probably of the dacite intrusive rock group.

d) The aquifer characteristics are:

- Discharge:	883 m3/day (162 GPM)
- Static water level:	131.54 meters B.G.L.
- Drawdown:	9.13 meters at a pumping rate of 613 ℓ/min
- Specific capacity:	96.7 m3/day/m
- Transmissivity:	375 m2/d

H. Test well at Momostenango

The city area and its surroundings are situated on the mountainous highland consisting of Tertiary volcanic rocks. The drilling site was established at the river side, about 700 meters west of the city area where river flow direction is controlled by the NE-SW fault (Fig. 7.2.1(4)).

A hot spring (48.1°C, pH 6.5, EC 94 µs/cm) gushes from the river bed, which is commonly used by the inhabitants for bathing. This test well was drilled to investigate the probability of potable groundwater development in the geothermal area.

The findings are as follows (Fig. 7.2.9).

a) The lithological features are:

0 - 3 m:	Brown soil
3 - 9 m:	Brownish white grey acidic tuff (Tv)
9 - 29 m:	White grey compact acidic tuff (Tv)
29 - 79 m:	Pale greenish white grey to purplish white grey compact acidic tuff (partially fractured) (Tv)
79 - 81 m:	Brown clay (fossil soil)
81 -104 m:	Grey to dark grey fractured dacitic lava (Tv)
104 -110 m:	Brown clayey tuff (fossil soil) (Tv)
110 -126 m:	Brownish grey clayey tuff (Tv)
126 -133 m:	Grey tuffaceous coarse sandstone (Tv)
133 -134 m:	Grey clayey tuff (Tv)
134 -158 m:	Grey tuffaceous coarse sandstone with fine gravel (Tv)
158 -165 m:	Greenish grey clayey tuff (Tv)
165 -169 m:	Dark grey fractured andesite lava (Tv)
169 -178 m:	Greenish grey clayey tuff (Tv)
178 -183 m:	Grey tuffaceous coarse sandstone (Tv)

b) The main aquifers of the area are in layers of fractured dacitic and andesitic lavas (81 - 104 m, 165 - 169 m) and tuffaceous coarse sandstones (126 - 133 m, 134 - 158 m, 178 - 183 m).

c) The geothermal logging conducted in this test well indicated a constant temperature of 18.5°C from 10 m to 180 m, revealing the possibility of potable water, even near the geothermal area.

d) The aquifer characteristics confirmed from this test well are as follows:

- Estimated thickness of aquifer: 59 meters
- Discharge: 1,090 m3/day (200 GPM)
- Static water level: 63.5 meters B.G.L.
- Drawdown: 70.3 meters at a pumping rate of 757 ℓ/min
- Specific capacity: 15.50 m3/day/m
- Transmissivity: 10.41 m2/day

I. Test well at San Francisco La Unión

The area is situated in the intramountain basin of Río Samalá system and consists of pleistocene pumice sediments and Tertiary volcanic rocks. The existing water sources are shallow dug wells, handpump wells and springs gushing from the layer of pleistocene pumice sediments (upper aquifer). This test well was drilled to investigate the groundwater development potential in the Tertiary volcanic rocks (lower aquifer) of the area (Fig. 7.2.10).

The test well was drilled to a depth of 190 meters. However, construction of the well for water production could not be completed because of frequent mud water circulation loss. It was also difficult to confirm the lithofacies after a depth of 79 m. The drilling condition of the well was as follows.

a) When the drilled depth reached 52 meters, the water level in the well suddenly dropped resulting in the total loss of mud water from the borehole. Drilling was then continued by repetition of cementing and mud filling works up to a depth of 79 meters. Nevertheless the full lost circulation could not be recovered. The mud water level in the well was 73 meters.

b) The lithological features within 79 meters below the ground are:

0 - 9 m:	White grey pumice sediments (Qp)
9 - 34 m:	Brownish dark grey strongly weathered and fractured andesite lava (Tv)
34 - 38 m:	Full lost circulation (drill cuttings were not recovered, but mud water level was 12 meters B.G.S.)
38 - 52 m:	Brownish dark grey fractured andesite lava (Tv)
52 - 79 m:	Total loss of mud water and drill cuttings from the borehole (mud water level was 73 meters B.G.S.)

c) From the above mentioned (a) and (b) items, the layer of strongly weathered and fractured andesite lava (12 - 38 m) is presumably the local aquifer in Tertiary volcanic rocks (Tv). The lithofacies between 52 and 73 meters is estimated as very porous, and fractured andesitic lava forms an unsaturated dry zone.

d) After cementing was carried out fully between 38 and 79 meters, drilling recommenced. However, after drilling through the cemented portion, mud water loss occurred again.

e) The mud water level in the well was finally 73 meters below ground surface. The lithofacies between 79 and 190 meters could not be confirmed because there was no return of the mud water with drill cuttings. Screens were installed between 88 and 186 meters presuming that the lithofacies is of andesitic lava flows based on electrical resistivity sounding and geological logging results.

Although well cleaning was continued by airlifting and bailing for about 30 hours, the water level in the well continued to recede, frequently reaching the bottom. Consequently, this well could not be completed.

J. Test well at Génova

The area is situated on a flat plain at the foot of Quaternary volcanoes consisting of pyroclastics with thin lavas and volcanic mud flows. This test well was drilled to investigate the groundwater development potential in the area.

The findings of this test well are as follows (see Fig. 7.2.11).

a) The lithological features are:

0 - 6 m:	Brown soil
6 - 21 m:	Brownish dark grey andesitic tuff (Qv)
21 - 38 m:	Dark grey andesitic tuff (Qv)
38 - 49 m:	Dark grey andesitic tuffbreccia Qv)
49 - 85 m:	Dark grey andesitic tuff (Qv)
85 - 88 m:	Dark grey andesitic tuffbreccia (Qv)
88 -104 m:	Dark grey fractured andesitic lava (Qv) The discharge of about 200 GPM was confirmed by airlifting, and the drilling method was converted from airhammer drilling to mud circulation drilling at a drilled depth of 89 meters
104 - 134 m:	Dark grey andesitic tuffbreccia (Qv)
134 - 150 m:	Dark grey to purplish dark grey andesitic tuffbreccia with thin brecciated lavas (Qv)

b) The main aquifers of the site are in the layers of fractured andesitic lava (88 - 104 meters) and andesitic tuffbreccia with thin brecciated lavas (134 - 150 meters), and are characterized as:

- Estimated thickness of aquifer: 52 meters
- Discharge: 1,096 m3/day (201 GPM)
- Static water level: 27.85 meters B.G.L.
- Drawdown: 88.36 meters at a pumping rate of 761 ℓ/min
- Specific capacity: 12.40 m3/day/m
- Transmissivity: 11.90 m2/day

2) Water level measurement during drilling

The static water level in the well (drilling mud level) was accurately measured daily by use of water level indicator, during the entire period of the drilling works. This drilling mud levelling was measured twice daily, before the start of the day's drilling work and at the end of the day's work, in order to get the following information:

- Water level fluctuation in relation with aquifer characteristics (confined or unconfined aquifer)

- Depth of partial "lost circulation" occurrence, which indicates the existence of good aquifer for positioning of screen

- Depth of full "lost circulation" occurrence which suggests the existence of a cracky zone

The drilling mud levelling results are presented in Fig. 7.2.17.

3) Geophysical logging

Prior to the casing and screening of the borehole, the following 4 types of logging were conducted in order to determine the most effective position for the screen.

- Electrical resistivity logging
- Spontaneous potential logging
- Radio-active logging
- Temperature logging

The geophysical logging data was correlated with the lithofacies.

(4) Pumping Test

Step drawdown, constant rate and recovery tests were conducted in 9 out of 10 drilled wells, using submersible motor pumps, in order to estimate aquifer properties.

The number of steps, the pumping duration and other pumping conditions are as follows.

(a) Step Drawdown Test

Five (5) step drawdown tests were conducted in order to estimate the optimum discharge, formation loss and well loss of a single well. During the test, the pumping rate was gradually increased to the fifth (5) step at regular intervals. The pumping rate at each interval was determined based on the results of the preliminary pumping test. The pumping duration of each step was 2 hours.

(b) Constant Rate Test

This test was conducted after the step drawdown test when the water level recovered up to its original static water level. The constant pumping rate was determined from the results of the step drawdown test. The pumping duration was 48 hours.

(c) Recovery Test

The water recovery period of the level took 24 hours, immediately after constant rate pumping was terminated.

Time-drawdown and time-recovery were plotted on log-log and semi-log graphic paper in order to calculate transmissivity, permeability, and storage coefficients. Methods of analysis used in this study were Theis and Jacobs which are applicable to unconfined aquifers in unstable condition.

The details of pumping test results are given in the Supporting Report and Data Book and the summarized aquifer parameters are shown in Table 7.2.5.

The main aquifer characteristics in the 9 municipalities are described in the former section on "Test well drilling".

7.2.3 Analysis for Ion Component in Groundwater

The ion component in water quality was analysed to evaluate the groundwater flow system (i.e., analysis for chemical compound of groundwater).

Water samples were taken from 9 test wells and the following 10 points:

Location	Type and Number
San José Pinula	Spring - 4 Shallow Well - 1
Comalapa	Spring - 2 (Small spring about 1 km from the town on the way to Panabajal, same way at the crossing point with Quebrada de Xetonex)
Sololá	Spring - 1 (spring water collected in the Existing Tank) Waterfall - 1 (Waterfall on the way to Panajachel)
San Pedro Sacatepéquez	Spring - 1 (Spring water used for irrigation in Vista Hermosa)

The results of analysis are shown in Table 7.2.6. Fig. 7.2.19 is a trilinear diagram plotting ion components of