

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

No. 17

MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)  
THE REPUBLIC OF GUATEMALA

THE STUDY  
ON  
THE IMPROVEMENT  
OF  
WASTEWATER MANAGEMENT  
IN  
THE GUATEMALA METROPOLITAN AREA

FINAL REPORT

VOLUME V  
SUPPORTING REPORT (III)

AUGUST 1996

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## ABBREVIATIONS

### ABBREVIATIONS OF ORGANIZATION / SIGLAS DE ORGANIZACION

|         |   |  |
|---------|---|--|
| AID     | = | Agency for International Development<br>Agencia Internacional para el desarrollo   |
| ANAM    | = | National Association of Municipalities<br>Asociacion Nacional de Municipalidades   |
| BANVI   | = | National Housing Bank<br>Banco Nacional de Vivienda  |
| BANGUAT | = | Central Bank of Guatemala<br>Banco de Guatemala  |
| BCIE    | = | Central American Economic Integration Bank<br>Banco Centroamericano de Integracion Economica   |
| CIDA    | = | Canadian International Development Agency<br>Agencia Canadiense de Desarrollo Internacional  |
| CACIF   | = | Coordinator Committee of Agricultural, Industrial and Financial Associations<br>Comite Coordinador de Asociaciones Agricolas, Industriales y Financieras   |
| CAPRE   | = | Regional Coordinating Committee of Drinking Water and Sanitation of Central America, Panama and Dominican Republic<br>Comite Coordinador Regional de Instituciones de Agua Potable y Saneamiento de Centroamerica, Panama y Republica Dominicana |
| CIEN    | = | National Economic Research Center<br>Centro de Investigaciones Economicas Nacionales   |
| CNPE    | = | National Council of Economic Planning<br>Consejo Nacional de Planificacion Economica   |
| CONAMA  | = | National Environmental Commission<br>Comision Nacional del Medio Ambiente  |
| CONAP   | = | National Council of Protected Area<br>Consejo Nacional de Areas Protegidas   |
| COPECAS | = | Permanent Committee of Coordination of Water and Sanitation<br>Comite Permanente de Coordinacion de Agua y Saneamiento   |
| EDOM    | = | Study of Metropolitan Orderliness<br>Estudio de Ordenamiento Metropolitana   |
| DGSS    | = | General Bureau of Health Services<br>Direccion General de Servicios de Salud   |
| DST     | = | Environmental Sanitation Department<br>Division de Saneamiento del Medio   |
| EMPAGUA | = | Guatemala Municipal Water Supply Corporation<br>Empresa Municipal de Agua de la Ciudad de Guatemala  |
| ERIS    | = | Regional School of Sanitary Engineering<br>Escuela Regional de Ingenieria Sanitaria  |
| FAO     | = | Food and Agricultural Organization<br>Organizacion de Comidas y Agricultura  |
| GOG     | = | Government of Guatemala<br>Gobierno de Guatemala   |
| GOJ     | = | Government of Japan<br>Gobierno de Japon   |
| GTZ     | = | German Cooperation Agency<br>Sociedad Alemana de Cooperacion   |
| IBRD    | = | See "WB"<br>Vease "WB"   |
| IDA     | = | International Development Association<br>Asociacion Internacional de Desarrollo  |
| IDB     | = | Inter-American Development Bank<br>Banco Interamericano de Desarrollo  |
| IGM     | = | Military Geographic Institute<br>Instituto Geografico Militar  |

|            |   |   |
|------------|---|---|
| IGSS       | = | Guatemalan Institute of Social Security<br>Instituto Guatemala de Seguridad Social  |
| INAFOR     | = | National Institute of Forestation<br>Instituto Nacional de Forestacion  |
| INDE       | = | National Institute of Electrification<br>Instituto Nacional de Electrificacion  |
| INE        | = | National Institute of Statistics<br>Instituto Nacional de Estadística   |
| INFOM      | = | National Institute of Municipal Development<br>Instituto Nacional de Fomento Municipal  |
| INSIVUMEH  | = | National Institute of Seismology, Vulcanology, Meteorology and Hydrology<br>Instituto Nacional de Sismologia, Vulcanologia, Meteorologia e Hidrologia |
| INTECAP    | = | Technical Institute of Training and Productivity<br>Instituto Tecnico de Capacitacion y Productividad   |
| JICA       | = | Japan International Cooperation Agency<br>Agencia de Cooperacion Internacional del Japon  |
| MCTyOP     | = | Ministry of Communications, Transportation and Public Works<br>Ministerio de Comunicacion, Transportacion y Obras Publicas                            |
| MINFIN     | = | Ministry of Public Finance<br>Ministerio de Finanzas Publicas   |
| MSPyAS     | = | Ministry of Public Health and Social Assistance<br>Ministerio de Salud Publica y Asistencia Social  |
| MUNI       | = | Municipality of Guatemala<br>Municipalidad de Guatemala   |
| OECE       | = | Overseas Economic Cooperation Fund of Japan<br>Fondo Japonés de Cooperacion Economica Ultramar  |
| PAHO       | = | Panamerican Health Organization<br>Organizacion Panamericana de Salud   |
| PLAMABAG   | = | Guatemala City Water Supply Master Plan<br>Plan Maestro de Abastecimiento de Agua a la Ciudad de Guatemala  |
| SEGEPLAN   | = | General Secretariat of Economic Planning<br>Secretaria General de Planificacion Economica   |
| SRH        | = | Secretariat of Hydraulic Resources<br>Secretaria de Recursos Hidraulicos  |
| UEA        | = | Emergency Water Unit<br>Unidad de Emergencia de Agua  |
| UENIA      | = | Study Unit of New Water Introduction<br>Unidad de Estudios de Nuevas Introducciones de Agua   |
| UN         | = | United Nations<br>Organizacion de Naciones Unidas   |
| UNDP       | = | United Nations Development Program<br>Programa de Naciones Unidas para el Desarrollo  |
| UNEHIVAGUA | = | Executant Unit of Hydrological Study of Guatemalan Valley<br>Unidad Ejecutora del Estudio Hidrologico del Valle de Guatemala                          |
| UNEPAR     | = | Executant Unit of Rural Aqueduct Program<br>Unidad Ejecutora del Programa de Acueductos Rurales   |
| UNESCO     | = | United Nations Educational Scientific and Cultural Organization<br>Organizacion Educacional, Cientifica y Cultural de Naciones Unidas                 |
| UNICEF     | = | United Nations International Children's Emergency Fund<br>Fondo de Naciones Unidas para la Infancia   |
| USAC       | = | University of San Carlos of Guatemala<br>Universidad San Carlos de Guatemala  |
| USAID      | = | United States Agency for International Development<br>Agencia Internacional de Desarrollo de Estados Unidos   |
| WB         | = | World Bank<br>Banco Mundial   |
| WHO        | = | World Health Organization<br>Organizacion Mundial de Salud  |

## ABBREVIATIONS OF TERMS USED IN THIS REPORT

|      |   |                                   |
|------|---|-----------------------------------|
| B/C  | - | Benefit Cost Ratio                |
| BOD  | - | Biochemical Oxygen Demand         |
| CCTV | - | Closed Circuit Television         |
| COD  | - | Chemical Oxygen Demand            |
| DSR  | - | Debt Service Ratio                |
| EIA  | - | Environmental Impact Assessment   |
| EIRR | - | Economic Internal Rate of Return  |
| FIRR | - | Financial Internal Rate of Return |
| GDP  | - | Gross Domestic Product            |
| GDE  | - | Gross Domestic Expenditure        |
| GFCF | - | Gross Fixed Capital Formation     |
| HWL  | - | High Water Level                  |
| IC   | - | Intermediate Clarifier            |
| IEE  | - | Initial Environmental Examination |
| NPV  | - | Net Present Value                 |
| O/M  | - | Operation and Management          |
| PDWF | - | Peak Dry Weather Flow             |
| PST  | - | Primary Sedimentation Tank        |
| RCP  | - | Reinforced Concrete Pipe          |
| SCF  | - | Standard Conversion Factor        |
| SDB  | - | Sludge Drying Bed                 |
| SDT  | - | Sludge Digester Tank              |
| SGC  | - | Screen • Grit Chamber             |
| TF   | - | Trickling Filter                  |
| TOR  | - | Terms of Reference                |
| VA   | - | Value Added                       |
| VAT  | - | Value Added Tax                   |
| WWTP | - | Wastewater Treatment Plant        |

## ABBREVIATIONS OF MEASURES

|   |                         |   |   |
|---|-------------------------|---|---|
| 1 | Length                  |   |   |
|   | mm                      | = | millimeter                              |
|   | cm                      | = | centimeter                              |
|   | m                       | = | meter                                   |
|   | km                      | = | kilometer                               |
|   | "                       | = | inch                                    |
| 2 | Area                    |   |   |
|   | m <sup>2</sup> , sq.m   | = | square meter                            |
|   | ha                      | = | hectare                                 |
|   | km <sup>2</sup> , sq.km | = | square kilometer                        |
| 3 | Volume                  |   |   |
|   | cc                      | = | cubic centimeter                        |
|   | lit, l, L               | = | liter                                   |
|   | lcd                     | = | liter per capita per day                |
|   | m <sup>3</sup> , cu.m   | = | cubic meter                             |
|   | Gal, Gallon (US)        | = | 3.785 liter                             |
| 4 | Weight                  |   |   |
|   | mg                      | = | milligram                               |
|   | g                       | = | gram                                    |
|   | kg                      | = | kilogram                                |
|   | t                       | = | ton                                     |
| 5 | Time                    |   |   |
|   | s, sec                  | = | second                                  |
|   | min                     | = | minute                                  |
|   | h, hr                   | = | hour                                    |
|   | d                       | = | day                                     |
|   | yr                      | = | year                                    |
| 6 | Money                   |   |   |
|   | Q                       | = | Quetzales (unit of Guatemalan currency) |
|   | US\$, \$                | = | US Dollar                               |
|   | ¥                       | = | Japanese Yen                            |
| 7 | Electric Measures       |   |   |
|   | A                       | = | ampere                                  |
|   | V                       | = | volt                                    |
|   | kV                      | = | kilovolt                                |
|   | kW                      | = | kilowatt                                |

|     |   |                 |
|-----|---|-----------------|
| kWh | = | kilowatt hour   |
| kVA | = | kilovolt ampere |
| Hz  | = | hertz           |

#### 8 Other Measures

|           |   |                         |
|-----------|---|-------------------------|
| mS        | = | milli Siemens           |
| $\mu$ mho | = | micromho = conductivity |
| ppb       | = | parts per billion       |
| ppm       | = | parts per million       |
| MPN       | = | most probable number    |
| ‰         | = | per thousand            |
| %         | = | percent                 |
| PS        | = | 0.736 kW                |
| °         | = | degree                  |
| '         | = | minute                  |
| "         | = | second                  |
| °C        | = | degree centigrade       |

#### 9 Derived Measures Based on the Same Symbols

|                                     |   |  |
|-------------------------------------|---|--|
| cm/sec                              | = | centimeter per second                  |
| m/s, m/sec                          | = | meter per second                       |
| cm <sup>3</sup> /min                | = | cubic centimeter per minute            |
| m <sup>3</sup> /sec, cu.m/sec       | = | cubic meter per second                 |
| m <sup>3</sup> /s, cu.m/s           | = | cubic meter per second                 |
| m <sup>3</sup> /min, cu.m/min       | = | cubic meter per minute                 |
| m <sup>3</sup> /h, cu.m/h           | = | cubic meter per hour                   |
| m <sup>3</sup> /day, cu.m/day       | = | cubic meter per day                    |
| m <sup>3</sup> /d, cu.m/d           | = | cubic meter per day                    |
| lpcd                                | = | liter per capita per day               |
| m <sup>3</sup> /m <sup>2</sup> /day | = | cubic meter per square meter per day   |
| m <sup>3</sup> /sec/km <sup>2</sup> | = | specific discharge                     |
| kg/day                              | = | pollutant load                         |
| ton/m <sup>2</sup>                  | = | ton per square meter                   |
| kg/day/km <sup>2</sup>              | = | unit areal pollutant load              |
| kg/(ha·mm)                          | = | areal pollutant load per unit rainfall |
| mg/kg                               | = | milligram per kilogram                 |
| mS/cm                               | = | milli Siemens per centimeter           |
| mg/L                                | = | milligram per litre                    |
| g/cm <sup>3</sup>                   | = | gram per cubic centimeter              |
| GPM                                 | = | Gallon per minute                      |

## EXCHANGE RATES USED IN THIS STUDY

### 1. Selection of Priority Regions (Master Plan)

1 US\$ = Q 5.71 = Yen 100.75 (average of May '95~April '94)

### 2. First Stage Project

1 US\$ = Q 5.88 = Yen 99.12 (average of July '95~December '94)

**SUPPORTING REPORT Q**  
**TOPOGRAPHIC SURVEYS**

**SUPPORTING REPORT Q  
TOPOGRAPHIC SURVEYS**

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## **Q TOPOGRAPHIC SURVEY**

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### **Q1 INTRODUCTION**

#### **Q1.1 PURPOSE**

Topographic maps available are either 1 : 15,000 or 1 : 50,000 scale and are not suitable for facility planning in the Feasibility Study. Therefore, topographic surveys were carried at selected locations along the main collector sewer route, at WWTP sites and at colonies for sanitation system. Fig. Q - 1 a) and Q - 1 b) show the topographic survey locations.

#### **Q1.2 SCOPE OF SURVEY**

##### **Q1.2.1 Main Collector Sewer Route**

Topographical surveys for main collector sewer routes were as follows :

##### **a) Cross-sectional Surveys at River-Crossings**

Purpose was to establish the locations of river crossings for pipe bridge so that pipe bridge span does not exceed 20 m. Locations and altitude were established using GPS (Global Positioning System) and leveling from Bench Marks as follows :

- Central Region - 4 river crossings (B-6,7, B-8, B-9, and B-10)
- South 3 Region - one river crossing (B-12)

##### **b) Longitudinal Survey along Pinula Main Collector (South 3 Region)**

Excavation of Pinula Main Collector near Los Alamos area changes from tunnelling method to open - cut method. Therefore, longitudinal survey was carried out in this area to establish the location of where change in excavation method is necessary. Distance surveyed was 1.2 km.

##### **Q1.2.2 WWTP Site**

Topographic survey was conducted at the proposed WWTP sites for Central Region and South 3 Region. Scale of the map is 1 : 2,000 and the interval of contour is 5 m.

### Q1.2.3 Sanitation System

Longitudinal survey was carried out for those colonies where sanitation system is proposed. Scale of the map is 1 : 1,000, and that of longitudinal profile is vertical scale of 1 : 200 and horizontal scale of 1 : 1,000.

### Q1.2.4 Results

Results of the topographic surveys are shown on Drawings, Volume VI.

## Q1.3 PERSONNEL AND EQUIPMENT

Following staff worked in this survey:

|             |    |
|-------------|----|
| Engineer    | 4  |
| Supervisor  | 2  |
| Calculator  | 3  |
| Draughtsman | 3  |
| Topographer | 4  |
| Chainman    | 8  |
| Laborer     | 10 |

The followings were used to carry on this survey :

- \* Two WILD T-16 Theodolites
- \* One WILD T-1 Theodolite
- \* One SOKKISHA TM-20 Es Theodolite
- \* One KERN 778GK0-A Level
- \* One ZEISS NI 52 Level
- \* One WILD N2 Level
- \* Distomat Electronic PENTAX
- \* DTK Computer PENTIUM 75MHz
- \* 486 OCTEK Computer 33 MHz
- \* EPSON FX-1050 Printer
- \* EPSON FX-1170 Printer
- \* And Other Survey Equipment Required in the Works

### GPS EQUIPMENT

- \* Pathfinder Trimble Basic Plus
- \* 9 Channel Base Station

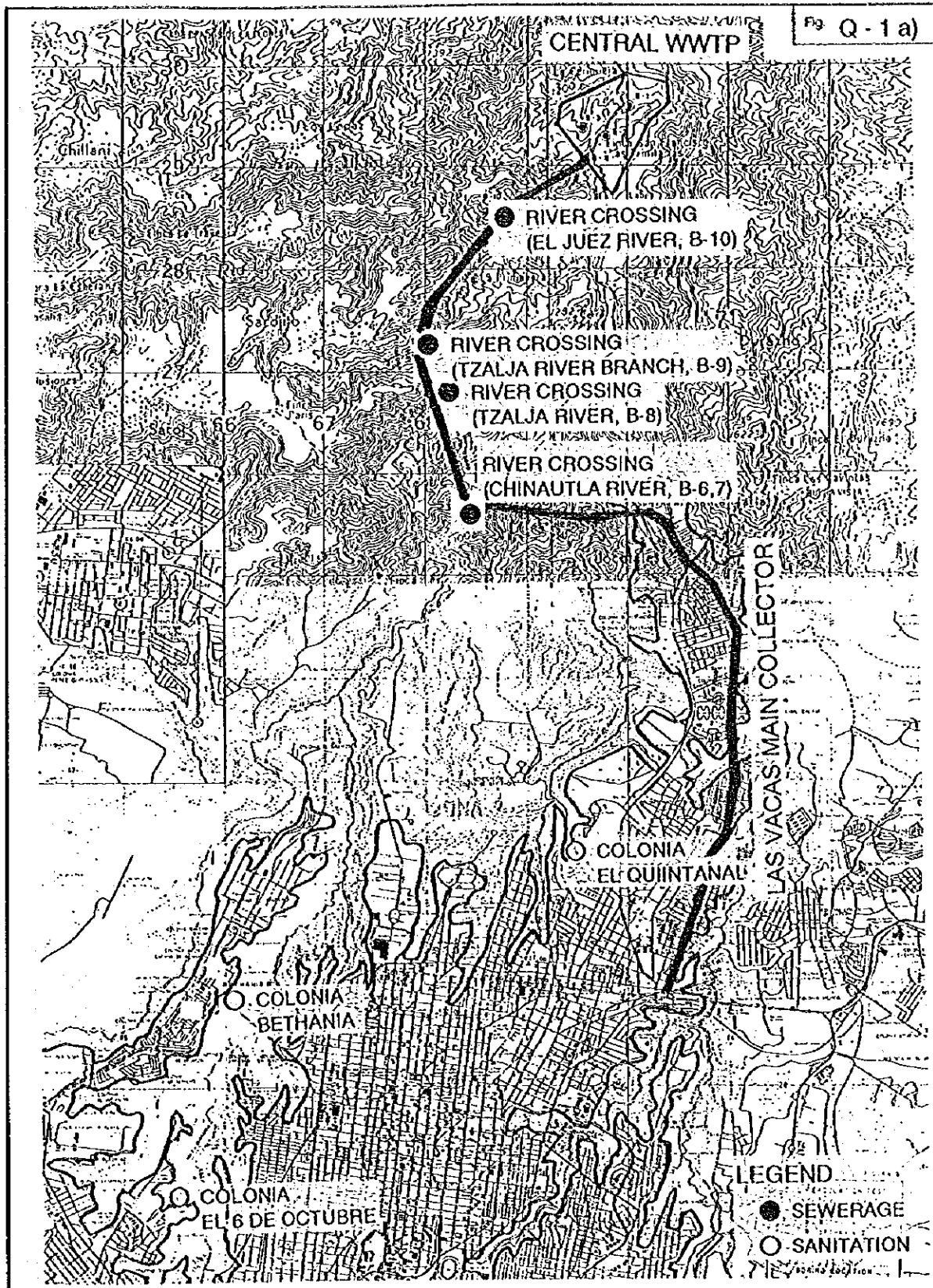
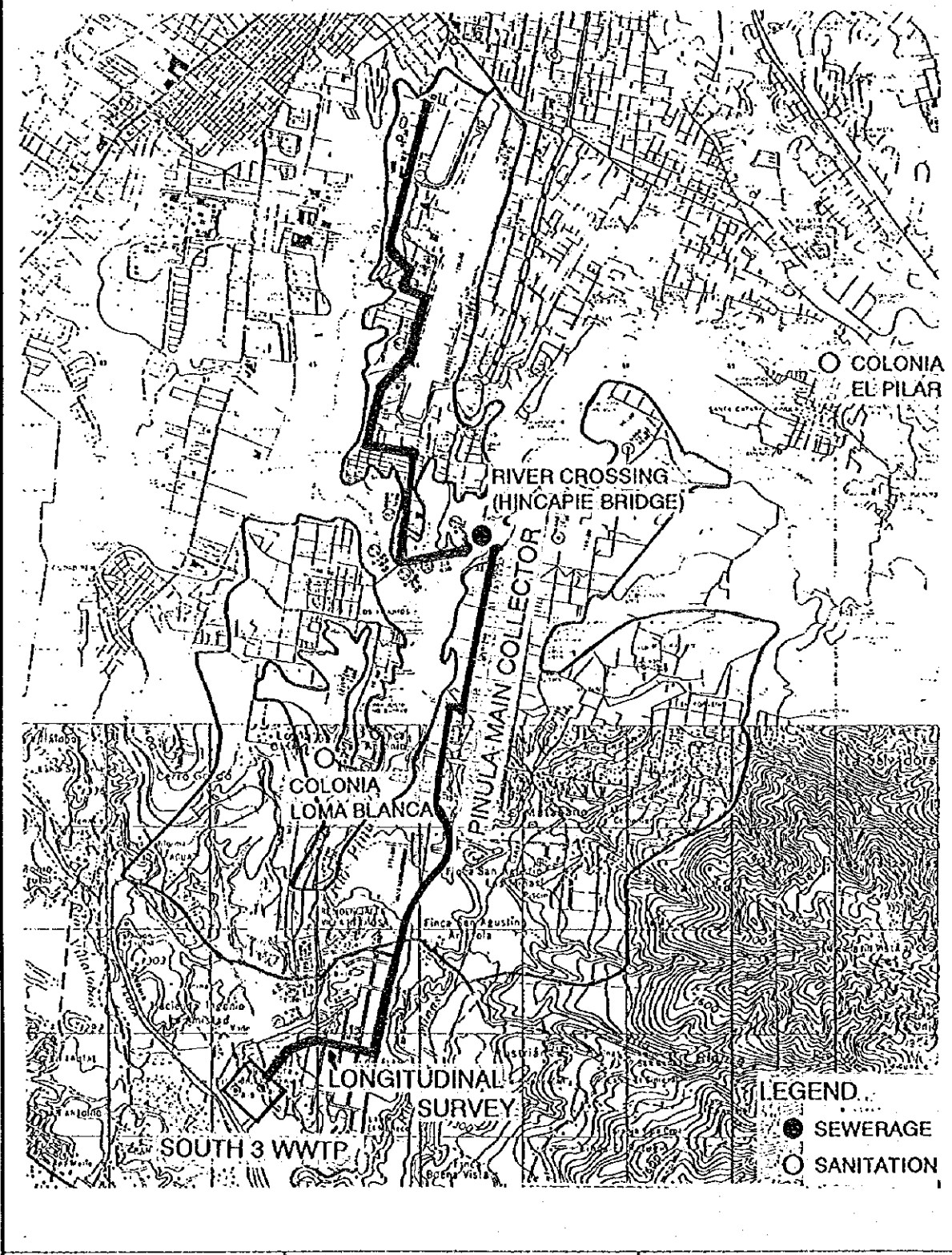


Fig. Q-1 a)

|   |   |   |
|---|---|---|
| <p>THE REPUBLIC OF GUATEMALA</p> <p>GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)</p> | <p>THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA</p> | <p>TITLE</p> <p>LOCATION MAP OF TOPOGRAPHIC SURVEYS: CENTRAL REGION</p> |
|   | <p>JAPAN INTERNATIONAL COOPERATION AGENCY</p>   |   |

Fig. Q-1 b)



THE REPUBLIC OF GUATEMALA  
GUATEMALA MUNICIPAL WATER  
SUPPLY PUBLIC CORPORATION  
(EMPAGUA)

THE STUDY ON  
THE IMPROVEMENT OF WASTEWATER  
MANAGEMENT IN THE GUATEMALA  
METROPOLITAN AREA  
JAPAN INTERNATIONAL COOPERATION AGENCY

TITLE  
LOCATION MAP OF  
TOPOGRAPHIC SURVEYS :  
SOUTH 3 REGION

## **Q2 TOPOGRAPHIC MEASUREMENTS**

### **Q2.1 Topographical Measurements of the Proposed site for the wwtp**

#### **Q2.1.1 Central WWTP (Chinautla)**

To obtain the site configuration, the land surveying procedure was applied, taking the isolated configuration points. For this purpose, a base polygon was measured and from the same vertexes the site points were radiated, thus obtaining their distance and drop, which makes it possible to locate them with an angle, distance and elevation, since in these works the conspicuous isolated points of the site are taken. For the drawing, contour lines were obtained by interpolating them between the cotas of the fixed points. Moreover, important details were taken as reference points such as constructions, boundaries, rivers, communications, and different level stratum.

To establish the site's configuration, reckoning was accomplished from the BMIAP-7, with an elevation of 1,180.8891 m above mean sea level (MSL). This bench mark (BM) is located in a bridge near the entrance of Finca Las Trinitarias and on the road from Guatemala City to San Rafael Las Flores.

The final map was made to A-1 size and to a 1 : 2,000 scale, showing contour lines every 5 meters.

#### **Q2.1.2 South 3 WWTP (Los Alamos)**

The topographic survey was accomplished using the method of cross sections. An open polygon was traced, which was marked every 30 m; besides, points where the ground changed slope or direction due to topographic accidents were taken into account. Then this axis was leveled in order to obtain the cotas of all the points, and later cross sections were made in all and every one of the axis points marked every 30 m. Sections were normal at the axis. Important details such as constructions, boundaries, towers from INDE (National Institute of Electrification), rivers, communications, etc., were also taken into account.

The base in this leveling was BM KKK-7A, which is located in the road from Guatemala to Villa Canales, with an elevation of 1,292.7566 m MSL.

The map was made to A-1 size and to 1 : 2,000 scale showing contour lines every 5 meters in uneven areas. In flat areas contour lines were interpolated to every meter.

## **Q2.2 CROSS - SECTION SURVEYS AT THE RIVER - CROSSING FOR THE LAS VACAS MAIN COLLECTOR**

Using as base BM IAP-7, with an elevation of 1,180.8891 m above the sea level, a closed leveling was obtained. This BM is located in a bridge near the entrance of Finca Las Trinitarias and on the road from Guatemala to San Rafael Las Flores. In this closed leveling it was necessary to have a six kilometer reckoning due to the fact that this BM was the only one available, so it was necessary to reduce distance between the leveling points related to the initial BM and the places where the cross sections were to be measured.

Following this closed leveling, the 1,220 m elevation was located in each cross section and it was established that the place where the points had initially been located on the plans of 1:15,000 scale did not coincide with the actual location established in this survey.

Therefore, the following reckonings were made:

### **a) Cross Sectional Survey B-6 And B-7**

A 1,285 meter reckoning was made to determine the 1220 m elevation in the cross section B6 and 7. Five cross sections were made from this point plus three upstream sections and two downstream sections.

### **b) Cross Sectional Survey B-8**

A 1,800 meter reckoning was made in cross section B-8 on the Tzala River to locate the 1,220 m elevation. From this point, sections were made every fifty meters, as well as in the points where change in direction occurred. There was a total of nine cross sections, one corresponding to the 1,220m elevation, four upstream sections and four downstream sections.

### **c) Cross Sectional Survey B-9**

With the purpose of establishing the 1,220 m elevation above the sea level in cross section B-9, a 1,720 m reckoning was made. Cross sections were made every fifty meters and in the points of intersection. There were a total of eleven cross sections, one corresponded to the 1,220 m elevation, six upstream sections and four downstream sections.

**d) Cross Sectional Survey B-10**

A closed leveling was performed to establish a 1,220 m elevation. Cross sections at every fifty meters were taken, also in the points where there was a change in direction. In total, there were fifteen cross sections: one at 1,220 m elevation, six downstream and eight upstream.

**e) Hincapie Bridge**

Leveling was started from BM KKK-4, that has an elevation of 1296.5249 m MSL; the point of 1,290 m elevation was located on the river bed. Cross sections were taken every fifty meters and in the places of change in direction, because the river trail showed meandering. Ten cross sections were taken: one at 1,290 m elevation, five upstream, and four downstream.

**Q2.3 LONGITUDINAL SURVEY ALONG PINULA MAIN COLLECTOR**

This survey was conducted in Los Alamos area. Leveling was started from BM KKK-7A, which is situated in the road from Guatemala to Villa Canales and whose elevation above sea level is 1,292.7566 m. During this study total of 1,206.04 m were reckoned. The longitudinal measure covered 30 m in width throughout the route. The plans show street intersections, directions, houses, vacant lands, distances, marker banks, at a horizontal scale of 1 : 2,000 and a vertical scale of 1 : 200.

**Q2.4 LONGITUDINAL SURVEY OF COLLECTOR SEWER IN THE SANITATION AREAS**

Survey was conducted in the following colonies:

**a) Central Region**

- 1) Colonia El Quintanal (Zone 6)
- 2) Colonia Seis de Octubre (Zone 7)
- 3) Colonia El Pilar (Zone 14)
- 4) Colonia Bethania (Zone 7)

**b) South 3 Region**

- 5) Colonia Loma Blanca (Zone 12)

For El Quintanal, Calzada Milla IGM 1964, which is situated at Calzada Jose Milla Y Vidaurre "La Parroquia", about 1,770 m from El Quintanal with an elevation of

1,474.6869 m MSL was used as reference Bench Mark. The total length of main sewer route surveyed in El Quintanal was 572.70 m identified by the JICA Study Team. In case of Colony Seis de Octubre, BM Hospital (near entrance of Sanm identified by the JICA Study Team. In case of Colony Seis de Octubre, BM Hospital (near entrance of San Juan de Dios Hospital on Avenida Elena), about 5,568.50 from Seis de Octubre with an elevation of 1,509.8428 m MSL was used as reference Bench Mark. The total length of main sewer route surveyed in Seis de Octubre was 455.615 m.

In case of El Pilar, BM City 23 (located in the El Cambray water treatment plant), about 1,057 m from El Pilar colony, with an elevation of 1,619.5735 m MSL was used as reference point and total length surveyed in El Pilar was about 656.48 m. For Loma Blanca, BM City 21 (located in the village Boca del Monte) with an elevation of 1,367.2840 which is 4,800 m from Loma Blanca was used as reference Bench Mark. Longitudinal profile was plotted for the length of 2,151.88 m. For Colony Bethania BM Hospital with an elevation of 1,504.6388 m MSL was used as reference Bench Mark. Longitudinal profile was plotted for the length of 2,003.68 m of main sewer route identified by the JICA Study Team.

For each colony, map with the scale of 1 : 1,000 on horizontal and 1 : 200 on vertical was plotted to show longitudinal profile of main sewer route. Also street intersections, identification marks, houses, site of Community plant and point of effluent discharge were marked.

### Q3 GPS SURVEY

As part of the topographic surveys five locations of river crossings were established using Global Positioning System (GPS).

These five points were located in deep, narrow valleys where the 1220 m elevation (in four points of the Chinautla area) and the 1290 m elevation (in one point at Pinula River, near the Hincapie Bridge) were found. These topographic peculiarities in several instances made it difficult to obtain precise measures due to the inconveniences of the related positioning of the satellites.

Table Q-1 shows the coordinates of the river crossings established by GPS Survey..



**Table Q-1 Results of the GPS Survey**

| River Crossing | Location        | UTM Coodinates |             | Level (m MSL) |
|----------------|-----------------|----------------|-------------|---------------|
|                |                 | North          | West        |               |
| B-6,7          | Chinautla       | 1,625,803.674  | 768,539.516 | 1220          |
| B-8            | Chinautla       | 1,626,666.785  | 768,158.627 | 1220          |
| B-9            | Chinautla       | 1,627,443.399  | 768,284.237 | 1220          |
| B-10           | Chinautla       | 1,628,589.967  | 769,210.003 | 1220          |
| B-11           | Hincapie Bridge | 1,610,778.205  | 766,600.702 | 1290          |

## **Annex QA**

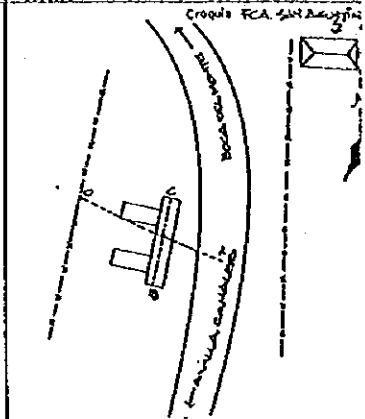
### **List of Benchmarks**

|                        |   |                         |
|------------------------|---|-------------------------|
| Nación                 | Características de la Marca Ficha de 6 cms. | Designación             |
| Guatemala              | Incrustada en alcantarilla.                 | BM KKK-6                |
| Provincia              | Establecida por (Organización)              | Elevación               |
| Guatemala              | I.O.N.                                      | 1309.4047               |
| Municipio              | Organización (fundida en la Marca)          | Orden                   |
| Villa Canales          | I.A.O.S.                                    | Primer (Final (Primer)) |
| Línea KKK              | Estampada                                   | Datum                   |
| Guatemala - Amatitlán. | BM KKK-6 1971 I.O.N.                        | MSNM                    |

Descripción Detallada del punto

LUGAR: La marca se encuentra localizada en muro de piedra de la alcantarilla, aproximadamente a 150 mts. de la entrada a la Finca San Agustín y dista 1.7 Kms. del BM KKK-5.

| REFERENCIAS:            | AZIMUT: | DISTANCIA ( mts.) |
|-------------------------|---------|-------------------|
| A) Centro de carretera. | 115°    | 5.65 "            |
| B) Orilla alcantarilla. | 190°    | 1.28 "            |
| C) Orilla alcantarilla. | 10°     | 0.30 "            |
| D) Cerco.               |         | 3.75 "            |



Elaborado/Revisado por Jorge Vidal López. Organización IGM Fecha 1, 994

MONOGRAFÍA DE LA COTA FIJA

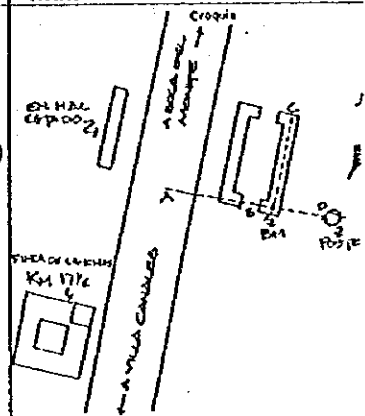
1292.7566

|                       |   |                         |
|-----------------------|---|-------------------------|
| Nación                | Características de la Marca Ficha de 6 cms. | Designación             |
| Guatemala             | Incrustada concreto alcantar.               | BM KKK-7A               |
| Provincia             | Establecida por (Organización)              | Elevación               |
| Guatemala             | I.O.N.                                      | 1292.7566               |
| Municipio             | Organización (fundida en la Marca)          | Orden                   |
| Villa Canales         |   | Primer (Final (Primer)) |
| Línea KKK             | Estampada                                   | Datum                   |
| Guatemala - Amatitlán | BM KKK-7A 1994 I.O.M.                       | MSNM                    |

Descripción Detallada del punto

LUGAR: La marca se encuentra localizada en el muro de concreto de una alcantarilla casi frente a la Fábrica de Lanchas en un lugar llamado Los Álamos y dista aproximadamente 2Kms. del BM KKK-6.

| REFERENCIAS:               | AZIMUT: | DISTANCIA ( mts.) |
|----------------------------|---------|-------------------|
| A) Centro de carretera.    | 280°    | 5.50 "            |
| B) Orilla de alcantarilla. | 280°    | 1.00 "            |
| C) Orilla de alcantarilla. | 10°     | 1.15 "            |
| D) Poste de Luz.           | 100°    | 10.00 "           |



Elaborado/Revisado por Jorge Vidal López. Organización IGM Fecha 1, 994

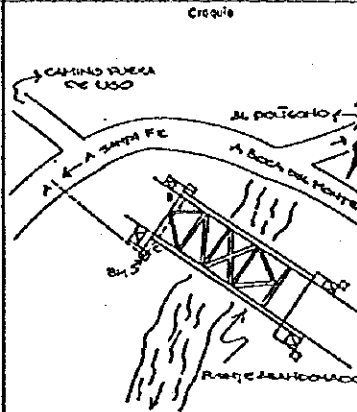
MONOGRAFÍA DE LA COTA FIJA

|                       |                                    |                     |             |
|-----------------------|------------------------------------|---------------------|-------------|
| Nación                | Característica de la Marca         | Ficha de 6 cms.     | Designación |
| Guatemala             | Incrustada                         | concreto de puente. | BM KKK-4    |
| Provincia             | Establecida por (Organización)     |                     | Elevación   |
| Guatemala             | I.G.N.                             |                     | 1296.5249   |
| Municipio             | Organización (Fundido en la Marca) |                     | Orden       |
| Puente Incapié        | I.A.G.S.                           |                     | Primer      |
| Línea KKK             | Estampado                          |                     | Orden       |
| Guatemala - Amatitlán | BM KKK-4                           | 1971 I.G.N.         | MSNM        |

Descripción Detallada del punto

lugar: La marca se encuentra localizada en muro "NW", parte baja del Puente Incapié y dista 2.3 Km. del BM KKK-3B.

| REFERENCIAS:            | AZIMUT: | DISTANCIA (mts.) |
|-------------------------|---------|------------------|
| A) Centro de carretera. | 310°    | 19.00 "          |
| B) Esquina muro.        | 35°     | 5.00 "           |
| C) Esquina muro.        | 35°     | 2.70 "           |



Descripción Recorrido por Jorge Vidal López. Organización I.G.N. Fecha 1,994

MONOGRAFÍA DE LA COTA FIJA

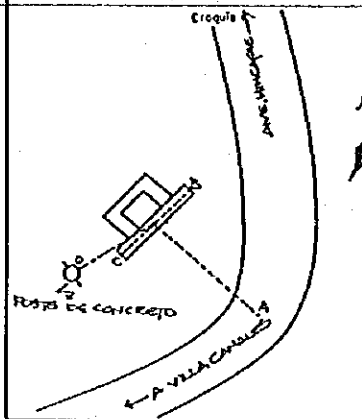
13292501

|                       |                                    |                    |             |
|-----------------------|------------------------------------|--------------------|-------------|
| Nación                | Característica de la Marca         | Ficha de 6 cms.    | Designación |
| Guatemala             | Incrustada                         | concreto alcantar. | BM KKK-5    |
| Provincia             | Establecida por (Organización)     |                    | Elevación   |
| Guatemala             | I.G.N.                             |                    | 1339.3501   |
| Municipio             | Organización (Fundido en la Marca) |                    | Orden       |
| Villa Canales         | I.A.G.S.                           |                    | Primer      |
| Línea KKK             | Estampado                          |                    | Orden       |
| Guatemala - Amatitlán | BM KKK-5                           | 1971 I.G.N.        | MSNM        |

Descripción Detallada del punto

LUGAR: La marca se encuentra localizada en la pared de alcantarilla en un lugar llamado La Vuelta Grande, de la carretera que conduce del Puente Incapié a villa Canales y dista 2.1 Kms. del BM KKK-4.

| REFERENCIAS:               | AZIMUT: | DISTANCIA (metros) |
|----------------------------|---------|--------------------|
| A) Centro de carretera.    | 130°    | 5.00 "             |
| B) Orilla de alcantarilla. | 45°     | 0.80 "             |
| C) Orilla de alcantarilla. | 225°    | 0.70 "             |
| D) Poste de concreto.      | 237°    | 6.20 "             |



Descripción Recorrido por Jorge Vidal López. Organización I.G.N. Fecha 1,994

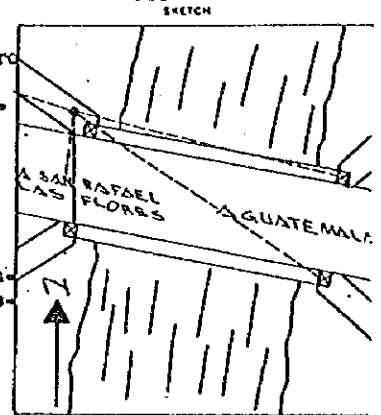
MONOGRAFÍA DE LA COTA FIJA

|                                   |  |                     |
|-----------------------------------|--|---------------------|
| COUNTRY                           | TYPE OF MARK                                       | DESIGNATION OF MARK |
| Guatemala,                        | Disco de 6 Cms.<br>Incrustado Concreto Muro Puente | B.M. IAP-7          |
| PROVINCE, STATE OR DEPARTMENT     | ESTABLISHED BY (AGENCY)                            | ELEVATION           |
| Guatemala,                        | I.G.N.   | 1180.8391           |
| MUNICIPALITY, COMMUNITY OR REGION | AGENCY (CAST IN MARK)                              | ORDER               |
| Chinautla,                        | I.A.G.S.   | (FINAL) (PREL)      |
| LINE                              | MARK IS STAMPED                                    | DATUM               |
| Guatemala a Las Trinitarias.      | B.M. IAP-7 1,969.                                  |                     |

DESCRIPTION

La marca está situada al N.E. del centro de la carretera que va de Guatemala a San Rafael Las Flores, incrustada en el muro del puente, a 1.94 Kms. del B.M. IAP-6, a 5.19 Kms. del B.M. IAP-4 que se encuentra en la Pilita en la casa de Marcos Castro, a 1.90 Kms. del B.M. IAP-8 que se encuentra en el cruce de caminos a San Rafael Las Flores y finca San Francisco Las Trinitarias.

La marca está situada a 2.75 Mts. al N 19 E del centro de la carretera, a 7.66 Mts. al N 52 W del centro del puente, a 4.90 Mts. al N 6 W de la esquina del muro N. del puente, a 16.50 Mts. al N 52 W de la esquina del muro S. del mismo puente, a 17.25 Mts. al N 72 W. de la esquina del muro E. del mismo puente y a 38.00 Mts. del poste del Km. 13.  
NO HAY MAS DATOS.



(DESCRIBED) OR (RECOVERED) BY: \_\_\_\_\_ AGENCY I.G.N. DATE 1,969.

IAGS Form 100 (17 Oct 55)

DESCRIPTION OF BENCHMARK

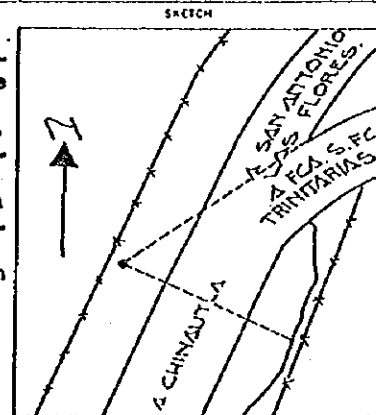
ARMY CORRAL C. 2.

|                                   |  |                     |
|-----------------------------------|--|---------------------|
| COUNTRY                           | TYPE OF MARK                                       | DESIGNATION OF MARK |
| Guatemala,                        | Disco de 6 Cms.<br>Incrustado Monumento de 30 x 30 | B.M. IAP-8          |
| PROVINCE, STATE OR DEPARTMENT     | ESTABLISHED BY (AGENCY)                            | ELEVATION           |
| Guatemala,                        | I.G.N.   | 1212.3817           |
| MUNICIPALITY, COMMUNITY OR REGION | AGENCY (CAST IN MARK)                              | ORDER               |
| Chinautla,                        | I.A.G.S.   | (FINAL) (PREL)      |
| LINE                              | MARK IS STAMPED                                    | DATUM               |
| Guatemala a Las Trinitarias.      | B.M. IAP-8 1,969.                                  |                     |

DESCRIPTION

La marca está situada al N.W. del centro de la carretera que va de Chinautla a San Antonio las Flores y finca Las Trinitarias, incrustada en un monumento que se encuentra en el cruce de caminos a San Rafael Las Flores y Fca. San Francisco las Trinitarias, a 1.90 Kms. del B.M. IAP-8, a 7.09 Kms. del B.M. IAP-4 que se encuentra en la Pilita en la casa de Marcos Castro y a nivel del suelo.

La marca está situada a 10.50 Mts. al N 65 W del centro de la carretera, a 28.50 Mts. al S 45 W de la intersección de caminos, a 15.75 Mts. al N 65 W. de la orilla de un paredón, a 0.45 Mts. al S 75 E de un cerco, a 31.50 Mts. al S 75 E de un árbol de roble.



(DESCRIBED) OR (RECOVERED) BY: \_\_\_\_\_ AGENCY I.G.N. DATE 1,969.

IAGS Form 100 (17 Oct 55)

DESCRIPTION OF BENCHMARK

ARMY CORRAL C. 2.

**SUPPORTING REPORT R**  
**GEO TECHNICAL SURVEYS**

**SUPPORTING REPORT R**  
**GEOTECHNICAL SURVEYS**

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## **R1 INTRODUCTION**

### **R1.1 PURPOSE**

The geotechnical survey aims at identifying the subsurface geological condition of the main collector sewer route, the wastewater treatment plant sites and the sanitation facilities.

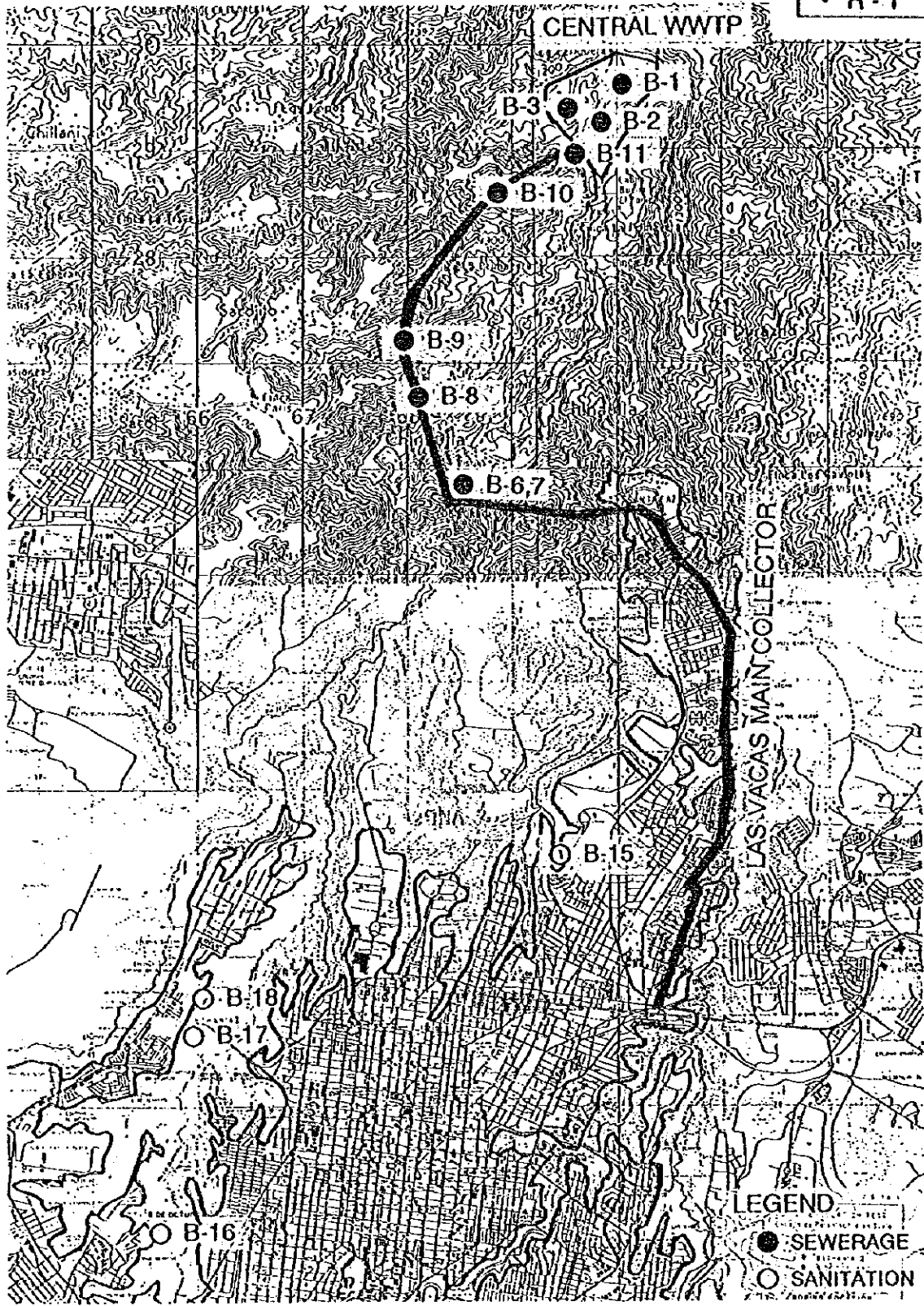
Survey included the following items

- Borings, SPT, Observation of borehole logs and Core Samplings
- Soil Percolation Tests
- Laboratory Tests of Core Samples

Field investigation was carried out by Swiss Boring Co. Ltd. employed by JICA Study Team from Dec. '95. to Mar. '96. In the same period, topographic survey was also carried out by the same company.

Location map of Boreholes are shown in Fig. R-1, and Fig. R-2.

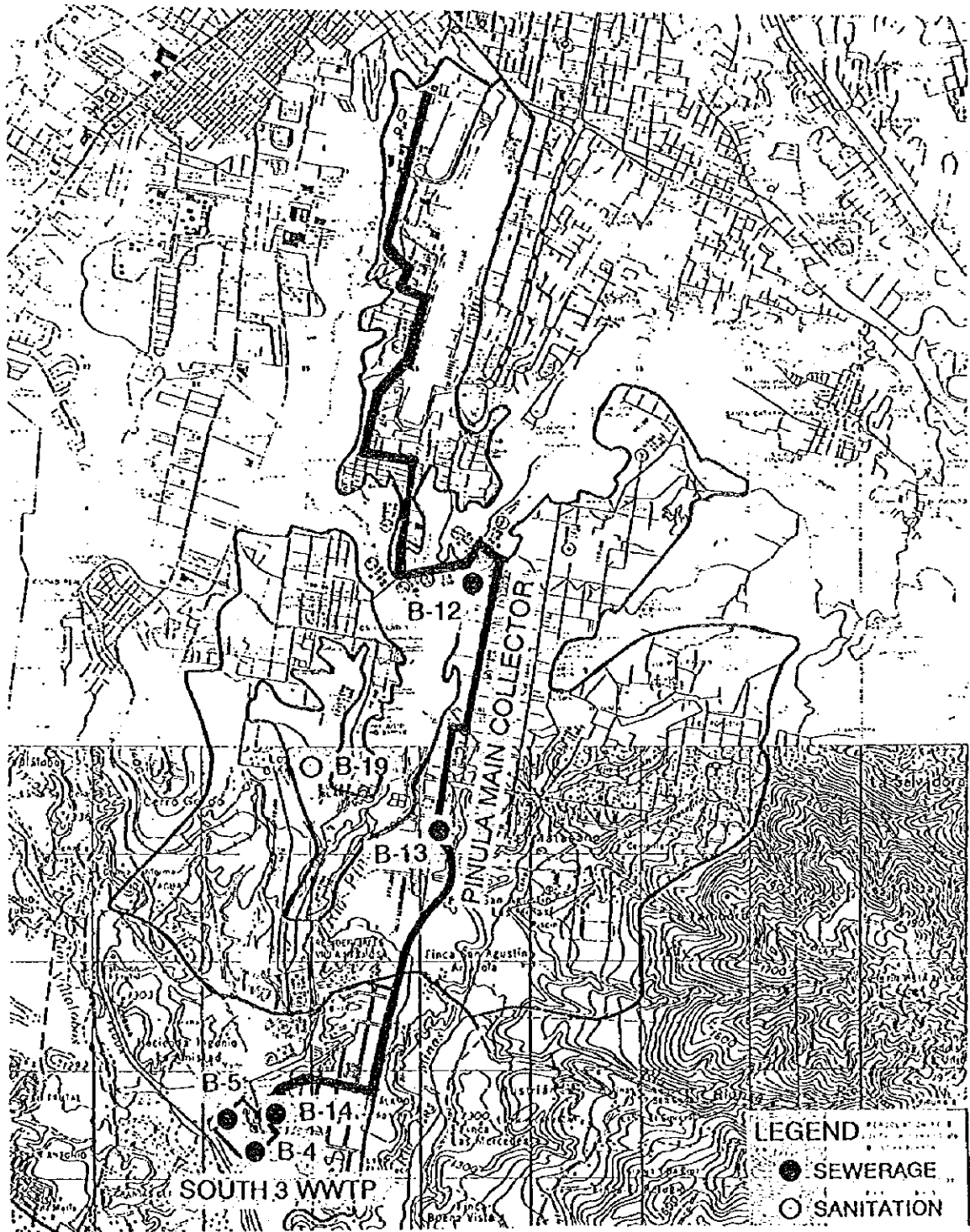
Fig. R-1



THE REPUBLIC OF GUATEMALA  
 GUATEMALA MUNICIPAL WATER  
 SUPPLY PUBLIC CORPORATION  
 (EMPAGUA)

THE STUDY ON  
 THE IMPROVEMENT OF WASTEWATER  
 MANAGEMENT IN THE GUATEMALA  
 METROPOLITAN AREA  
 JAPAN INTERNATIONAL COOPERATION AGENCY

TITLE  
 LOCATION MAP OF  
 BOREHOLES :  
 CENTRAL REGION



|   |   |  |
|---|---|--|
| <p>THE REPUBLIC OF GUATEMALA</p> <p>GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)</p> | <p>THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA</p> <p>JAPAN INTERNATIONAL COOPERATION AGENCY</p> | <p>TITLE</p> <p>LOCATION MAP OF BOREHOLES : SOUTH 3 REGION</p> |
|---|---|--|

## **R1.2 SUMMARY OF INVESTIGATION**

The field work consisted of 13 drillings, for a total of 370 m, obtaining core recuperation samples and/or soil by helicoidal auger, 296 standard penetration tests (SPT) and undisturbed samples with Shelby tube, and core samples for unconfined compression strength test. The study included other five drillings of 20 m in depth each, for soil percolation tests for sanitation facilities. This amounts to a total drilled depth of 470m.

Detailed topographic survey was carried out, covering poligonals in proposed zones for the treatment plants (WWTP), longitudinal profiles for collector routes of wastewater and sanitation areas, collateral sections. Geographical location of drilling points were determined by Geographic Positioning System (GPS). Topographic surveys are reported in Supporting Report Q, Volume V.

### **R1.2.1 Quantity of Investigation**

The geotechnical and topographic investigations program were carried out from December 1, 1995 to March 1996. The drilling program started out in the Chinautla zone (WWTP Central Region), on December 7th. 1995 with borehole B-1.

Table R-1 shows the summary of geotechnical investigations and the rock and soil laboratory test.

**Table R-1 Summary of Geotechnical Investigations**

| Item  | Number                                     | Remarks           |
|---|--|-------------------|
| Boreholes<br>for Sewerage System<br>for Sanitation System   | 18 (470m)<br>- 13 (100m) -<br>- 5 (370m) - |                   |
| Soil Percolation Test   | 5  | Sanitation System |
| Samples<br>Soil Samples<br>Rock Samples   | 12<br>- 8 -<br>- 4 -                       | Sewerage System   |
| Standard Penetration Test<br>Central Region<br>South 3 Region   | 296<br>- 142 -<br>- 154 -                  |                   |
| Soil Laboratory Test<br>Visual Soil Classification<br>Grain Size<br>Direct Shear (Undrained, Unconsolidated)<br>Unconfined Compression<br>Density<br>Moisture Content | 16<br>8<br>6<br>2<br>8<br>6                |                   |
| Rock Mechanics Test<br>Unconfined Compression in Core Rock/Soil   | 4  |                   |

**Table-R-2 Summary of Rock and Soil Laboratory Test**

| Borehole No. | SPT | Visual Soil Clasif. | Grain Size | Direct Share | Moisture Contest | UNCONFINED COMPRESSION |
|--------------|-----|---------------------|------------|--------------|------------------|------------------------|
| B-1          | 20  | 2                   | 1          | 1            | 1                | 1s                     |
| B-2          | 20  |                     |            |              |                  |                        |
| B-3          | 19  | 4                   | 2          | 1            | 1                |                        |
| B-4          | 19  | 3                   | 1          | 1            | 1                | 1s                     |
| B-5          | 19  | 2                   | 1          | 1            | 1                |                        |
| B-6,7        | 31  |                     |            |              |                  | 1r                     |
| B-8          | 12  |                     |            |              |                  | 1r                     |
| B-9          | 7   |                     |            |              |                  | 1r                     |
| B-10         | 8   |                     |            |              |                  | 1r                     |
| B-11         | 25  | 2                   | 1          | 1            | 1                |                        |
| B-12         | 29  |                     |            |              |                  |                        |
| B-13         | 58  | 2                   | 1          | 1            | 1                |                        |
| B-14         | 29  | 1                   | 1          |              |                  |                        |
| Total        | 296 | 16                  | 8          | 6            | 6                |                        |

Note : R : Rocks and S : Soil

**Table R-3 Borhole Characteristics**

| Boring No.            | Level (mm) | Depth (m) | Location                 | Date              |
|-----------------------|------------|-----------|--------------------------|-------------------|
| For Sewerage System   |            |           |                          |                   |
| B-1                   | 1157       | 20        | CHINAUTLA                | 07/12/95-08/12/95 |
| B-2                   | 1208       | 20        | CHINAUTLA                | 18/12/95          |
| B-3                   | 1215       | 20        | CHINAUTLA                | 24/02/96-26/02/96 |
| B-4                   | 1240       | 20        | ALAMOS                   | 07/02/96-09/02/96 |
| B-5                   | 1233       | 20        | ALAMOS                   | 12/02/96-13/02/96 |
| B-6.7                 | 1235       | 34        | CHINAUTLA                | 16/02/96-18/02/96 |
| B-8                   | 1220       | 30        | CHINAUTLA                | 03/03/96-05/03/96 |
| B-9                   | 1220       | 30        | CHINAUTLA                | 23/01/96-09/02/96 |
| B-10                  | 1220       | 30        | CHINAUTLA                | 04/01/96-18/02/96 |
| B-11                  | 1213       | 26        | CHINAUTLA                | 12/12/95-15/12/95 |
| B-12                  | 1293       | 30        | INCAPIE                  | 01/02/96-03/02/96 |
| B-13                  | 1302       | 60        | BOCA DEL MONTE           | 24/02/96-27/02/96 |
| B-14                  | 1271       | 30        | ALAMOS                   | 01/02/96-03/02/96 |
| Sub Total             |            | 370       |                          |                   |
| For Sanitation System |            |           |                          |                   |
| B-15                  | 1487       | 20        | BETHANIA I<br>(Zone.7)   | 07/01/96          |
| B-16                  | 1482       | 20        | BETHANIA II<br>(Zone.7)  | 11/01/96          |
| B-17                  | 1508       | 20        | 6 DE OCTUBRE<br>(Zone.7) | 12/01/96          |
| B-18                  | 1324       | 20        | LOMA BLANCA<br>(Zone.12) | 12/01/96          |
| B-19                  | 1451       | 20        | QUINTANAL<br>(Zone.6)    | 16/01/96          |
| Sub Total             |            | 100       |                          |                   |
| Total                 |            | 470       |                          |                   |



### **R1.2.2 Investigation Procedure**

Several pieces of equipment were used according to the different aspects of every borehole site:

- Access conditions to every site
- Existence of water sources for boring fluids
- Borehole depth
- Different kind of materials

A total of 296 Standard Penetration Tests (SPT) were done and 5 undisturbed samples were obtained from thin wall (shelby tube) samplers (the sample of boring B-14 wasn't good), others 4 core samples were obtained for unconfined compression test.

Borehole depths varied from 20 to 60 m, diameters of HQ (96.00 mm hole/63.5 mm core) and hollow stem augers (6 1/2" O.D. 3 1/4" I.D.)

All drillings were performed in the metropolitan area of Guatemala City, including the municipalities of Villa Canales, Chinautla and Guatemala.

Boreholes B-1, B-2, B-3 and B-11 were drilled in the low zone of Chinautla (WWTP), and boreholes B-6.7, B-8, B-9, B-10 in surrounding areas, in the river crossing for the main collector.

Boreholes B-12 and B-13 were drilled in the border Guatemala and Villa Canales, and boreholes B-14, B-4 and B-5 in Los Alamos area (WWTP-South 3 Region).

Soil percolation tests were carried out at Boreholes B-15, 16, 17, 18 in the locations identified for sanitation system.

### **R1.3 DRILLING SCHEDULE**

The investigation program is based on mechanical drillings, and insitu tests, as well as five soil percolation tests.

The objectives of the drillings, are:

**1) Soil and Rock Investigation through mechanical drillings in:**

- a) Proposed sites for the construction of two wastewater treatment plants.
- b) River crossings for collectors
- c) Junction of main collector sewer
- d) Main collector sewer inlets to the proposed wastewater treatment plants.

**2) Soil Percolation Test**

- a) Soil percolation test and visual soil classification at proposed sites, for the construction of absorption wells.

## **R1.4 PERSONNEL AND EQUIPMENT**

### **R1.4.1 Personnel**

Three drilling crews were working for one shift to complete the work. Each crew composed by 1 driller, 1 assistant driller and 2 workers. Other assisted workers in the mobilization and construction of access roads and drilling platforms.

Four crews were working for topographical works, each one consisted of 1 topographer and 5 helpers. All works were coordinated by a Civil Engineer.

### **R1.4.2 Equipment**

**a) Drilling Rigs**

- Longyear 34 No. 1, rotary and hydraulic pressure, 54 HP diesel Deutz engine and drilling capacity of 375 m with NQ diameter.
- Truck mounted drill auger
- With B/O, mounted in treads
- Rodio SR-2 Model, with wireline system, with HQ and NQ mechanical schuck

**b) Pumps**

- FMC 535, lister engine, 2 single action pistons, flow rate of 135 L/min at 500 psi

- FMC 535, Deutz engine, 1 single action piston with maximum flowrate of 80 L/min at 500 psi

**c) Electric Generator and Welding Equipment**

- Miller
- Lincoln

**d) Piping and Drill Bits**

- HQ-NQ drilling rods for wireline system
- HW-NW casing
- HQ-NQ drilling pipes
- HQ-NQ corebarrels
- Tungsten carbide and diamond for triple tube bites, HQ-NQ, widias, diamond.
- Several reamers, diamond and tungsten carbide drilling shoes HQ and NW diameter
- Cutter head, conical type
- Center plug w/drag bit
- Octagonal hollow stem augers 6 1/4'

## R2 METHODOLOGY

### R2.1 DRILLING TECHNIQUES

The drilling techniques used throughout the program varied according to the conditions encountered at the different borehole sites. Most of the drilling were carried out with double tube HQ diameter ( 96.00 mm hole / 63.5 mm core) core barrels. These core barrels were equipped with surface set diamond or tungsten carbide drill bits.

The boreholes drilled with this type of tools had to be cased with NW casing (114.3 mm O.D. / 101.6 I.D.) in order to prevent caving and to ensure that the borehole bottom was free of any loose material prior to every Standard Penetration Test (SPT) or every time an undisturbed sample was to be obtained.

When an SPT test was performed, the core barrel's inner tube had to be removed and the SPT sampler lowered inside the HQ rods string. In this case of undisturbed sampling, with the 3" O.D. Shelby Tube, all the HQ rods string were removed and the hole cased with HW casing (4" ID).

Almost all drillings were performed with water, as drilling fluid, due to presence of gravels and sands, mainly borings B-4, B-5, B-12, B-13 and B-6.7.

At the sites where ground conditions permitted, drilling was carried out with hollow stem augers (6 1/4" O.D. / 3 1/4" I.D.). The hollow stem augers were equipped with an inner, finger type drill bit which was retrieved to the surface every time a SPT was to be performed or an undisturbed sample was to be obtained. The sampling tools were lowered to the borehole bottom through the stem.

The drilling for percolation tests in soil was performed with a driller with hollow stem augers.

The core was placed in wooden core boxes for storage.

## **R2.2 GEOTECHNICAL TEST**

For the geological and geotechnical descriptions of the soil and rock samples obtained in the drillings, the following parameters were used: The earth manual U.S. bureau of Reclamation and Deere's rock quality index.

The Geologic and Geotechnical description of soil and rock samples obtained during the drillings, is based on the Earth Manual U.S. Bureau of Reclamation and Deere's Rock Quality Index (See Tables R-4 to R-7), among others.

## **R2.3 UNDISTURBED SAMPLING**

Undisturbed sampling from the boreholes was carried out with 3" O.D. x 2 7/8" I.D. thin wall shelby Tubes. For this sampling technique the thin walled tube was attached to the sampler head and was lowered to the borehole bottom through the casing or hollow stem augers using AW drill rods (44.4 mm O.D.). When the sampler reached the bottom of the borehole, the tube was pushed into the ground by means of the rig's hydraulic system. The maximum pressure required to push the sampler into the ground was recorded and the sampler was then retrieved to the surface. Every tube was protected at both ends with paraffin, labeled and sent to the laboratory for testing.

## **R2.4 STANDARD PENETRATION TESTS**

The Standard Penetration Tests were performed according to ASTM D1586 specification. The SPT split spoon samplers used were 2" O.D. x 1 1/2" I.D. When used in free flowing sands or silts, the samplers were equipped with inner basket retainers and plastic sleeves in order to prevent loose soils from falling out during retrieval to the surface. The percussion hammers used were donut type weighing 140 pounds with a 30" drop and a rope-cathead hammer drop system. The sampling rods used were AW rods with an outside diameter of 44.4 mm. The catheads were mounted on the drillrigs and were propelled by the drill rig's engine.

## **R2.5 LABORATORY TEST**

Every undisturbed and disturbed soil sample as well as all the rock core obtained during the program, was identified and described in situ. Disturbed samples were stored in glass jars and properly labeled. Undisturbed samples were covered with paraffin to avoid loss of water content.

**Table R-4 Weathering Intensity**

| Class | Term                     | Description   |
|-------|--------------------------|---|
| 1     | FRESH(F)                 | No visible signs of weathering on the rock material, maybe a slight decoloration on the surface discontinuities.  |
| 2     | SLIGHTLY WEATHERING (SI) | Decoloration indicates alteration of the rock material and the discontinuities surfaces. The whole rock material maybe decolored and also softer than fresh.            |
| 3     | MODERATE WEATHERING (MI) | Less than half on the rock material is altered and/or disintegrated to soil. Fresh rock or decolored is present either as discontinuous bands or fresh rocks intervals. |
| 4     | HIGHLY WEATHERING (HI)   | More than half of the rock material is altered and/or disintegrated to soil. Fresh rock or decolored is resent either as discontinuous strips or fresh rock cores       |
| 5     | FULLY WEATHERING (FM)    | All the rock material is altered or disintegrated to soil. The original structure of the rock mass is intact.   |

**Table R-5 Fractures Specimen**

| Class | Specimen (mm) | Denomination |    |
|-------|---------------|--------------|----|
| 1     | > 2000        | VERY WIDE    | VW |
| 2     | 600 - 2000    | WIDE         | W  |
| 3     | 200 - 600     | MODERATE     | M  |
| 4     | 60 - 200      | NARROW       | N  |
| 5     | < 60          | VERY NARROW  | VN |

**Table R-6 Rock Quality Index of Deere**

| Class | %        | Denomination |    |
|-------|----------|--------------|----|
| 1     | 100 - 90 | EXCELLENT    | E  |
| 2     | 90 - 75  | GOOD         | G  |
| 3     | 75 - 50  | REGULAR      | R  |
| 4     | 50 - 25  | BAD          | B  |
| 5     | 25 - 00  | VERY BAD     | VB |

**Table R-7 Joint Characteristics**

| SUMMARY OF THE JOINT CONDITIONS |   |
|---------------------------------|---|
| TYPE                            | <ol style="list-style-type: none"> <li>1. Principal joint</li> <li>2. Open joint</li> <li>3. Closed joint</li> <li>4. Geological contact</li> <li>5. Secondary joint</li> </ol>                         |
| CLASS                           | <ol style="list-style-type: none"> <li>1. Joint and/or joint with movement evidence</li> <li>2. Joint without movement evidence</li> <li>3. Artificial fracture</li> </ol>                              |
| FORM                            | <ol style="list-style-type: none"> <li>1. Stair step</li> <li>2. Undulated</li> <li>3. Plane</li> </ol>   |
| ROUGHNESS                       | <ol style="list-style-type: none"> <li>1. Rough</li> <li>2. Soft</li> <li>3. Polished</li> </ol>  |
| FILLING                         | <ol style="list-style-type: none"> <li>1. Clean</li> <li>2. Oxidation</li> <li>3. Clay</li> <li>4. Crush rock</li> <li>5. Calcite</li> <li>6. Silt</li> <li>7. Crusts</li> <li>8. Sand, etc.</li> </ol> |
| OPENING                         | <ol style="list-style-type: none"> <li>1. (&lt; 0.5mm) closed</li> <li>2. (0.5 - 10 mm) open</li> <li>3. (&gt; 10mm) very open</li> </ol>   |

Some rock cores were sent to the laboratory to obtain tests of unconfined compression.

The 8 undisturbed samples are:

- . B-1 (3.00 - 3.70 m)
- . B-3 (1.70 - 2.05 m)
- . B-3 (2.05 - 2.15 m)
- . B-4 (11.00 - 11.45 m)
- . B-5 (5.00 - 5.70 m)
- . B-11 (11.55 - 11.75 m)
- . B-13 (21.00 - 21.16 m)
- . B-14 (4.00 - 4.45 m) (sample unadecuated for the test)

Unconfined compression tests were only applied to samples B-1 and B-4 due to the condition and type of materials in this sites. The following tests were applied to the rest of the samples (Table R-8).

**Table R-8 Number of Laboratory Tests**

| Item                  | Number of Tests |
|-----------------------|-----------------|
| Visual classification | 16              |
| Particle size         | 8               |
| Unit weight           | 6               |
| Moisture Content      | 6               |
| Direct shear          | 6               |

Rock cores were obtained for tests of unconfined compression (see Annex RB).

The samples and boring are:

- . B-6.7 (26.90 m)
- . B-8 (6.50 m)
- . B-9 (10.50 m)
- . B-10 (10.50 m)



## R2.6 SOIL PERCOLATION TEST

Soil percolation tests were performed at five locations to determine the soil absorption capacity which is required to calculate the size of soil absorption system in order to effectively dispose the effluent of the septic tank.

These boreholes were situated in plains or volcanic terraces, formed by tuffaceous deposits, pumice and pumiceous ashes with different thickness, alternation of these materials and their physical conditions.

In general terms, the drilled materials are fairly clayey (heavy thickness of weathering), that do not favor water percolation. Besides, one site, Bethania II showed a depression, channel or duct, considerably permeable.

The drillings were performed with hollow stem augers to a depth of 20 m and diameter of 200 mm. Material samples were obtained every meter to identify and classify the type of soil. The descriptions are shown in Annex RC.

Once the drilling was concluded, the borehole was filled with clean water and was left overnight to saturate the soil strata. On next day, the level of water was measured every hour during seven hours. Percolation rate of soil was measured in terms of min./100mm.

## **R3 GENERAL GEOLOGY**

### **R3.1 REGIONAL GEOLOGY**

Guatemala is part of northern Central America, which includes Belize, El Salvador, and Honduras. A typical continental crust exists, formed by Pre-Cambrian-Paleozoic metamorphic rocks, and overlying upper Paleozoic (Pennsylvanian and Permian) sedimentary rocks.

These rocks are covered by big extensions of Mesozoic sediments, mainly Cretacic carbonatic rocks, minor extensions of Tertiary sedimentary rocks and diverse intrusive rocks crops, and Tertiary and Quaternary volcanic rocks located in the southern part of the country.

Two structural and physiographical trends are predominant in Guatemala and are strongly associated to its rock-type formations:

**a) An East-West Arch:**

Convex towards the South, with predominant plutonic, metamorphic and Paleozoic-Mesozoic sedimentary rocks, which form the country's base. This arch goes from Chiapas (Mexico), through Guatemala, up to the Caribbean Sea.

**b) North West-South trend:**

It goes through all the central and southern part of Central America; it is formed by volcanic rocks from the Tertiary and Quaternary periods, showing a volcanic chain of high cones and volcanic plateaus.

The continuous interaction and sliding of three main tectonic plates; Caribbean, Coco and North American, make of Guatemala a country with continuous and strong earthquakes and dynamical deformation of rocks and soils. For this reason, the seismic and volcanic risk here is high. Peten region does not register active tectonic stress that can produce seismicity or volcanic activity.

#### **R3.1.1 Physiographic Provinces of Guatemala**

There are four physiographic provinces in Guatemala, characterized by the distribution of rock formations and closely related to the regional tectonics. From South to North, the provinces are (see Fig. R-3).

- a) PACIFIC COASTAL PLAINS
- b) VOLCANIC PROVINCE
- c) CENTRAL RANGE
- d) PETEN LOWLANDS

**a) Pacific Coastal Plains**

It reaches from Tehuantepec Isthmus in Mexico to Acajutla in El Salvador, with an approximate length of 700 km, its major width is Guatemala on the west part (San Jose Port). Its average width is 40-50 km, and its elevations range from sea level to 500 masl.

The Coastal Plain originated from the sedimentation of materials from volcanic chains. Volcanic activity and erosion produce large amounts of loose materials in high elevations, and strong slopes which are transported by water streams, and when deposited, a extense plain is deposited. The shape of the coast is irregular, convex to the sea shore west from San Jose Port and concave to the east. The width of the coastal plain is considerably larger to the West.

Sediments consist of boulders, gravel, sands, pumiceous ash, laharic deposits, alluvium and coastal environment deposits (channels, deltas, sand bars) close to the sea shore.

In the upper part of the coastal plain, the materials change gradually to volcanic piedmont deposits (colluvial, detritus, etc.) Toward the South, near the coast, the grain size is reduced to silt-clay size materials.

**b) Volcanic Province**

It covers the west, east and southern parts of Guatemala, reaching to the other Central American nations. It is formed by volcanic products from Tertiary and Quaternary ages.

The Tertiary volcanism was characterized by fissural eruptions, producing big amounts of rhyodacitic products, tuffs, and andesitic and basaltic lava flows. The quaternary activity is distinguished by important pyroclastic deposits, pumiceous tuff andesitic cones and lava domes (actual volcanic chain). The valley where Guatemala city is located, is formed by deposits of tuffs.

In the South-East, the quaternary volcanism presents important lithological changes, with big andesitic cones, groups of small cinder cones and basaltic flows, most of them affected by North-Southern trend fissures.

The average width of Guatemala is about 25 km. Two zones can be seen, the first one in the northwest part, goes from Tecuamburro to Tacana volcanos, and is constituted by active and high volcanoes. The second one is a group of small cones and volcanoes of little activity, influenced by the Jocotan fault system.

In Guatemala, there have been defined more than 300 volcanic structures, at least 14 of these are considered the main apparatus or strato volcanoes of higher elevations, ranging from 2000 to 4210 m. Tajumulco Volcano is the highest peak in Central America (4210 m).

#### c) Guatemalan Central Range

This is a Paleozoic strip of plutonic metamorphic and folded sedimentary rock, in the central part of the country, formed by the oldest rocks of Guatemala. It is part of an important regional mountainous system, starting in Chiapas, Mexico up to Islas de la Bahia in Honduras.

Guatemala has a very extensive topographical relief. The Cuchumatanes range, Chuacus, De Las Minas, Chama, Merendon and other Sierras are part of this relief. Big depressions such as Motagua, Polochic, Chixoy, Selegua and Cuilco river valleys and the Izabal lake are also part of this range.

The southern part of the strip is mainly formed by metamorphic and plutonic rocks, that include Paleozoic schists, gneiss serpentinites and granites. They are partially overlaid by volcanic deposits, mainly tuff and pumiceous ash, especially in Quiche, Totonicapan and Huehuetenango. Chinautla is in the limit of this volcanic area.

Inmerse in the Central range we find the Jocotan-Motagua-Polochic fault system. This system divides the tectonic plates of North America and Caribbean, where strong historical earthquakes have been taken place, such as the one of February 4th. 1976, with a magnitude of 7.6 Mb and maximum horizontal displacement of 3m.

#### d) Peten Lowlands

This province is located in the northern part of Guatemala. Its average height is 200 m and the maximum 1000 (Sierra del Lacandon and Montañas Mayas). It is mainly formed by carbonatic sedimentary deposits, strongly karstic.

As part of the karstic process, the most important and largest rivers of Central America and Mexico, are located in Peten lowlands, such as Lacantun, San Juan, La Pasión, Chixoy and

Usumacinta, the last one is the main and final water collector, that has an average flow rate of 1200 m<sup>3</sup>/s and an average annual level oscillation of 30 m.

### **R3.2 GEOLOGICAL ASPECTS OF GUATEMALAN VALLEY**

The valley of Guatemala (where Guatemala City and neighboring municipalities are located) is part of the physiographic province called "Volcanic Lands"

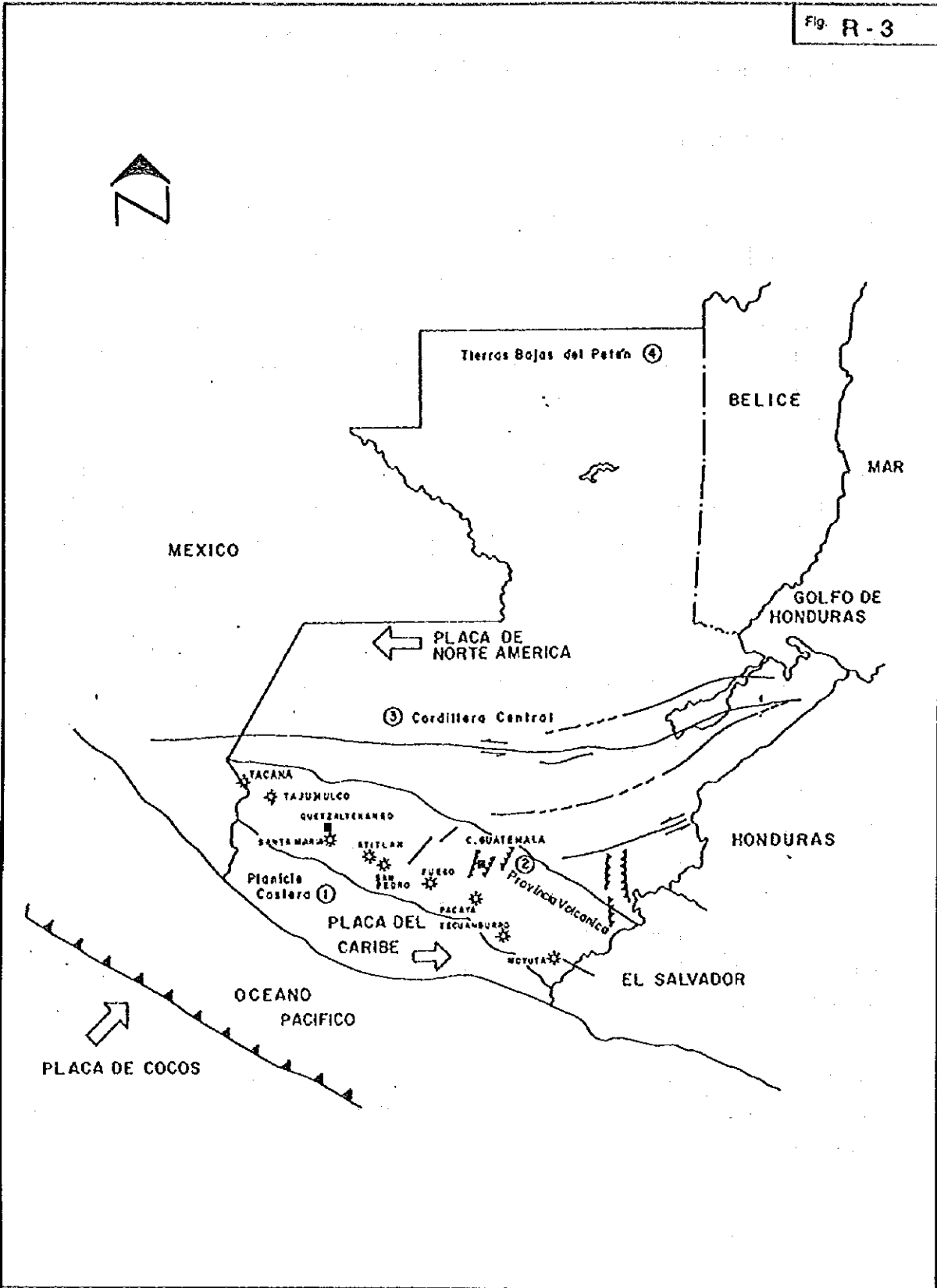
The valley has a lengthwise shape, north to south, and is drained by two hydrographic basins: the sub-basin of Amatitlan lake at the south and the basin of Las Vacas river at the north. The border of both basins constitutes the Continental Divide.

The geological structure of the valley is known as the graben of Guatemala city, and has normal systems of faults in steeped shape. This is known as Mixco faults system that limits the valley on the western zone and the Santa Catarina Pinula faults system on the eastern zone.

The valley is properly named as a depression, partially filled in by a series of relatively recent ash flows of tuffaceous and pumiceous types, in addition to other sedimentation process (lacustrine flow). In the north part of the valley, the limits are related with limestones uplift blocks and intrusive rocks, mainly of granite type.

The geomorphologic features of the valley are characterized for being plains or terraces at similar topographic levels, crossed by deep and narrow valleys and escarpments and/or ravines. Most of the ravines are deeper than wide. This is caused by tuffaceous and pumiceous deposits which are susceptible to remotions provoked by the concentrated water flows (the materials have a lower density rather than the water). Therefore, the valleys are of considerable depths and small hydrographic basins.

Another geomorphologic unit is constituted by the valleys of Villalobos, Pinula, Chinautla, Las Vacas river, etc., which are formed by fluvial- lacustrine sediments of considerable thickness.



|   |   |  |
|---|---|--|
| <p>THE REPUBLIC OF GUATEMALA</p> <p>GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)</p> | <p>THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA</p> <hr/> <p>JAPAN INTERNATIONAL COOPERATION AGENCY</p> | <p>TITLE</p> <p>PHYSIOGRAPHIC PROVINCES OF GUATEMALA</p> |
|---|---|--|

## **R4 RESULTS**

### **R4.1 GEOTECHNICAL ASPECTS OF MAIN COLLECTOR SEWER**

#### **R4.1.1 Geotechnical Description of Boreholes**

##### **a) BOREHOLES B-1, B-2, B-3**

These boreholes are located in the low area of Chinautla, and were performed with the purpose of finding out the characteristics of the materials where the WWTP Central region treatment plant will be located. It is the limit between the volcanic materials (tuff and pumiceous ashes, re-worked in part), the granite rocks (in full weathering condition) and the fluvial valley of Las Vacas River.

The slope is small with round hills and short terraces of alluvial and/or volcanic type. Recently, faults have been discovered in this zone, and there are also unstable slopes, one of them of great importance, in the central part of the project area, next to Las Vacas River, the old road Chinautla-San Antonio Las Flores is located in this zone.

The drilled materials were pumiceous ashes and weathered tuffaceous to silts and clay, meteorized and fractured granites, and fine alluvion layers (sand and silts).

##### **b) BOREHOLES B-8, B-9, B-10 AND B-11**

These boreholes were drilled in deep rivers that run from west to east in narrow valleys, where also second grade fissures are found (Tzalja river, La Primavera and La Juez). However, the B-11 was realized in a small plain.

The drilled materials were intrusive rocks of granite type, massive, with weathered thickness of up to 25 m, however, this aspect may be related to the boreholes position in the bottom of the valleys.

The borehole B-9 crossed some dikes of hypabisales rocks that form the confined acuiferous. One of the dikes was crossed at a depth of 18 m, with an estimated pressure of 5 bar.

c) **BOREHOLE B-6.7**

At first, it was planned to drill two boreholes, but the narrow valley only permitted one (Chinautla river, right margin). This borehole was completely performed, and it was found volcanic materials and thick paleosoils. It is very probable that this drilling point is the limit of southeast with calcareous rocks at depth and the northwest with granite rocks.

d) **BOREHOLES B-12, B-13 AND B-14**

These boreholes are located in the southern zone of the valley and/or hydrographic sub-basin of Amatitlan lake. The borehole B-12 was drilled near the Hincapie bridge, at the right margin of the Pinula River. The materials drilled were sand, gravel, and clayey silts.

The borehole B-13 is located in Boca del Monte highway and the B-14 is in Los Alamos zone. The first 18 m of borehole B-13 were pumiceous ashes, and there on (more than 40 m) fine sands. The borehole B-14 passed through by tuff and pumiceous ashes, smooth and loose.

e) **BOREHOLES B-4 AND B-5**

These boreholes were drilled in a fluvial-lacustrine valley, in the confluence of Villalobos and Pinula Rivers (left margin). In this place the WWTP South 3 Region treatment plant is located.

The borehole B-4 is located at the bottom of the hillside. This drilling initiated with tuffaceous materials, but after 7 m sand and gravel were crossed. B-5 located on alluvial terraces, crossed gravels and sand layers, fragments of pumices and clays and silts. Minimum thickness of the materials is 20 m.

**R4.1.2 Las Vacas Main Collector**

Unconfined compression strengths were 40.4 kg/cm<sup>2</sup> (B-8), 75.0 kg/cm<sup>2</sup> (B-7) and 94.1 kg/cm<sup>2</sup> (B-10), which are very low in relation to the origin of the rocks (granite and igneous). Sampling locations were in river valleys close to river bed and there are many locations on the surface which are weathered.

Las Vacas Main Collector passes through mountainous area (altitude 1250 - 1350m) between Chinautla River (B-6.7) and Central WWTP for about 4 km, In some locations earth cover exceeds 150 m. In these areas tunnel is envisaged to pass through origin of the rocks



(granite and igneous) and the unconfined compression strength will be many times of that measured at boreholes. Based on this, medium - hard rock is expected in this section of collector with an unconfined compression strength in the range of 200 to 500 kg/cm<sup>2</sup>.

Most of the tunnel will be constructed in granite rock, found between Chinautla and Tzalja rivers and up to the outlet in B-11 site.

Slopes or topographic depressions were studied in the borings B-8, B-9 and B-10, determining an alteration of thickness up to 25 m. This characterizes a rocky mass of poor quality with a Rock Quality Rate (RQD) less than 25%.

This apparent alteration, does not extend laterally, although the granite rock is broken. This is a characteristic of poor quality rocky mass or RQD between 25 and 50%, seen in the sites of rough slopes or topographic depressions.

The geological materials found in B-6.7 borehole, in the Chinautla River, are clay and silty clays layers, soft, probable produced by the alteration of pumiceous ashes and alluvial deposits of fine grain.

In this section (possibly 300 m) the materials are of poor quality and require reinforcement of the tunnels' profiles.

It is probable that the upstream of boreholes B-6 and B-7, is through calcareous rocks. Especially limestone strongly fractured, fragile of medium quality (See Fig. R-4).

#### **R4.1.3 Pinula Main Collector**

The estimated length of the collector is about 10 km and its diameter is 1,500 mm.

It starts with pumiceous ashes, soft, low resistance, easy to excavate and susceptible to erosions, therefore it requires protection to avoid undermining and slidings.

Then, it was found layers of alluvial origin, gravel and silts of medium grain interpolated with sandy silts and clayey silts with materials of pumiceous and tuffaceous ashes. These deposits are very inconsistent, and granulated, with unstable geotechnical properties, difficult to excavate and to build a strong support for the channel-tunnel.

To cross the valley of the Pinula river (Hincapie bridge), a pipebridge will be used. The construction of the tunnel-channel under the Boca del Monte colony, would be in granule

sandy materials, sandy silts, pumiceous ashes in a silt master. Geotechnically, these materials are unstable, and could present water pressures through layers of permeable materials causing irruptions of water into the tunnel.

The B-13 boring crossed more than 40 m of this kind of materials and although it presented an average N value, moderated to high, could provoke subsidency (compaction loss and disintegration of the sandy materials).

The freatic level was found under 10 m from the surface, therefore, great part of the tunnel has to be constructed below this depth.

This geotechnical characteristics require autosupportable structures, with tunnel profile type III and IV.

Towards the south of the Boca del Monte, passing through the cross of Villa Hermosa and up to Los Alamos, volcanic materials are found, such as pumiceous and tuffaceous, loose and soft, easy to excavate, and moderate to good stability, but it is susceptible to erosions caused by concentrated water flows, reason why the structure must have a profile type III.

The final part of the collector will be by open excavation which will be set in pumiceous ashes, with sections of clayey silts. This final part must be protected against erosion and undermining.

In summary, the geotechnical characteristics give a parameter of technical measurements to be taken in the construction of the tunnel. (See Fig.R-5)

#### **R4.1.4 Profile Types**

Main collectors should have tunnels. The following security measures will be taken: (See Fig. R-6)

##### **a) TYPE I**

Granitic and calcareous rocks are massive and firm, with no need of great support. In areas of intense fracturations or formed by clay stuff materials, a support is needed, this support should be isolated ground anchors.

**b) TYPE II**

Strongly fractured and weathered rock in alternate hard and soft beds, of poor cohesion, such as big, weathered granites, and tuffaceous materials of moderate consistency. This type of materials have a limited stability, therefore need a superficial protection and rigid support.

The profile consists of protecting the surface with a shortcrete bed with net and eventually ground anchors.

**c) TYPE III**

Rocks totally fractured and decomposed as well as tuffaceous volcanic materials loose and smooth affected by the water flow. They require a limited stability to be used as metallic supports with hangers, sheets and ground anchors.

**d) TYPE IV**

Soft rocks of clayey type, plastics with low resistance, that may cause plastic deformations around the excavation. In a provisional way, this process should be contrarrested by placing, after the excavation, systematic supports with ground anchors, hanged and eventually shortcrete.

Definite stability will be achieved by placing a concrete covered ring, it is necessary to excavate, in circle, to diminish the magnitude push.

The dimensions of the transversal section of the tunnel will depend on the excavation form and the machinery used in this job. Due to the extension of the two sections of the tunnels, it was considered to excavate with conventional methods, such as:

- Drilling and blasting
- Manual or small drilling excavation equipment and material remover

The tunnel of the Central Region section will be of enough size to carry the rubble, pipes to be used as fan conduct.

In rocks, of good or poor conditions, it is considered a section with form of window with vertical doors and semi-circular vault.

In the rocks and/or materials of low quality, the section will have a horseshoe shape or circular.

The medium distances and the ground anchors longitudes will be calculated in relation to the extension of the rocks and the classification of the massive rocks, as well as the TUNNELS QUALITY INDEX (NGI) or the Deere ROCKS QUALITY INDEX.

The longitude of the ground anchors may vary according to the type of rock between 1m and 2m from good to middle rock; and from 2 to 3.5 m in bad rock; the interval distances of the hanging will be between 0.75 to 1.50 m. In zones with firm rock and with high cover, the vertical walls must be protected with ground anchors against local disclose.

At the profile type IV, the cover thickness can be up to 0.45 m, notwithstanding, it should be exactly determined thru analytical calculations from rocks (mechanic of rocks) parameters.

The cement that will be used should only be of high resistance against sulphate, and of type HS, according to DIN 1164 (equivalent to the type V as known in Guatemala).

The metallic supports will consist of steel arcs covered with steel sheets or any other appropriate metal.

#### **R4.1.5 Excavation Methods**

According to the type of materials, the excavation methods are classified in two systems.

- 1) Excavations in rock, performed in materials predominantly rocky that require drilling and blast for expansion.
- 2) Excavations in soft rock/soil predominantly volcanic materials, such as tuffaceous and pumice type, alluvial and colluvial deposits, faults or any other type of material that do not require blasting to obtain its expansion. This excavation method is manual, small drilling, and equipment to remove materials.

Both methods should consider acceptable procedures that will allow a permanent control of the work and also to avoid tunnel failure during excavation.

#### **R4.1.6 Construction Difficulties**

In the gallery excavations, some construction difficulties may be found due to bad conditions of the rock or soil, also possible presence of water pressure associated to failures and fractures, and dike cuts or rock beds with pressure of water (artesian watering).

The water irruption may be of three types according to the materials found:

- a) Water duct by materials removal (volcanic and alluvial materials)
- b) Faults and fractures (all types of materials)
- c) Dikes or materials beds confined (Granitic rocks and alluvial beds between imperious materials)

In the first case, it may cause sliding or detachment especially with volcanic materials of tuffaceous and pumice type.

This situation might arise at the crossing zone of the Chinautla river (B-6.7), where the conduction structure runs through volcanic materials, at least 2kms.

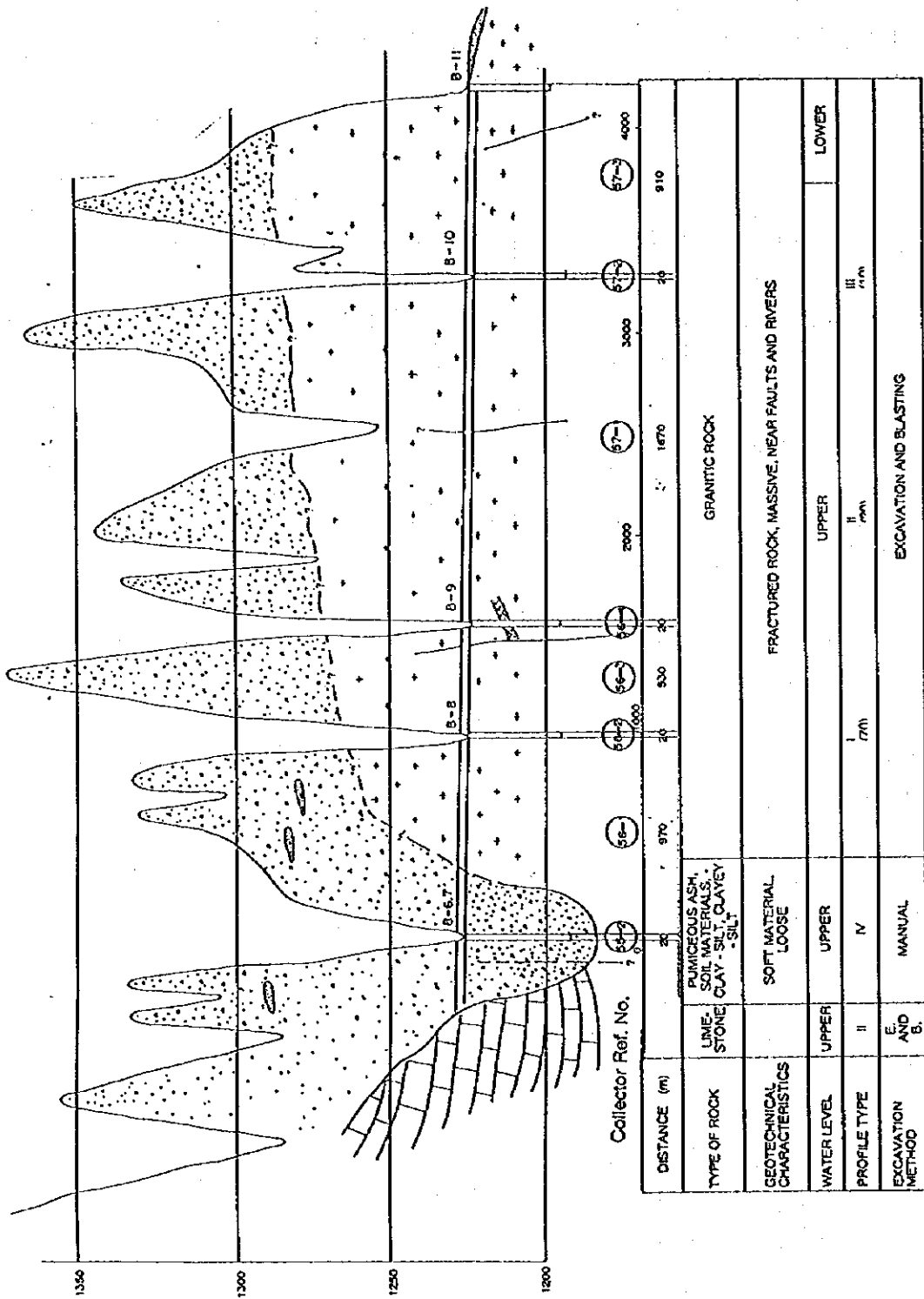
This risk is higher at the south 3 collector, because the longitude of volcanic materials stratum is bigger.

It is probable the entrance of water through faults or fractures, especially in the Chinautla zone, between B-6.7 and B-11 drillings, due to faults systems with general direction E-W.

In the drilling B-9 performed in granitic rocks at the Tzalja River to 18 m of depth (1202 m elevation) a hypabyssal dike type was cutted with water pressure (approx 5 bar).

Other construction topographical inconveniences are related to the narrow of the valleys of the Chinautla, (B-6.7); Tzala (B-8); La Primavera (B-9) and La Juez (B-10) rivers. It requires strong material excavations to open the access to these points and to remove the materials from the tunnel.

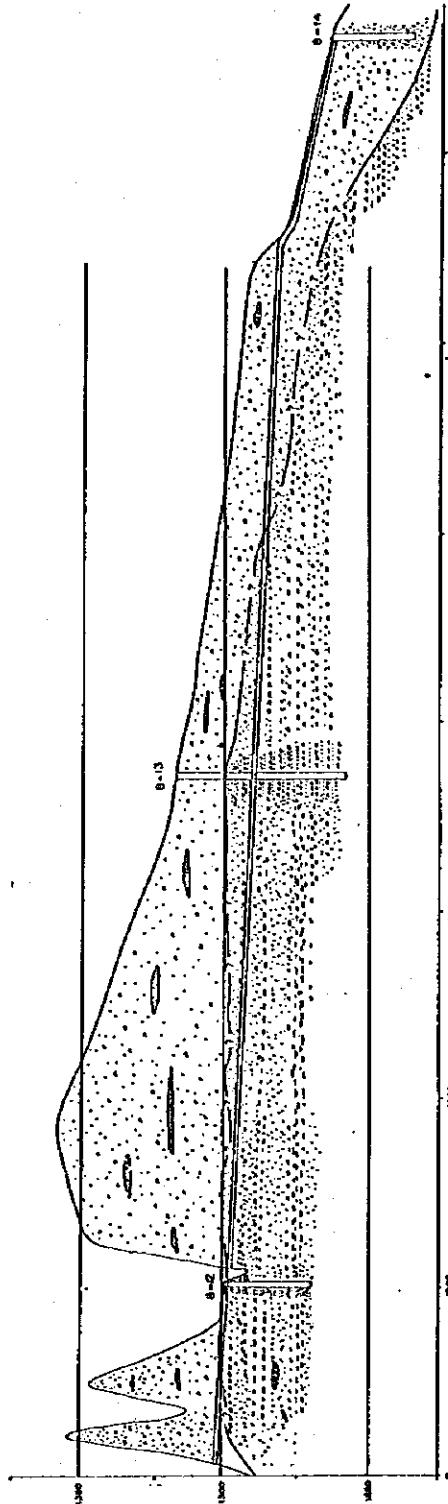
The south collector tunnel has an extension of approximately 4 km. in alluvial deposits of sand, and occasionally gravels. This will make difficult the excavation of tunnel and also excavation costs will be higher (Borehole B-13 crossed more than 40 m of loose silty sand layer).



THE REPUBLIC OF GUATEMALA  
 GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)

THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA  
 JAPAN INTERNATIONAL COOPERATION AGENCY

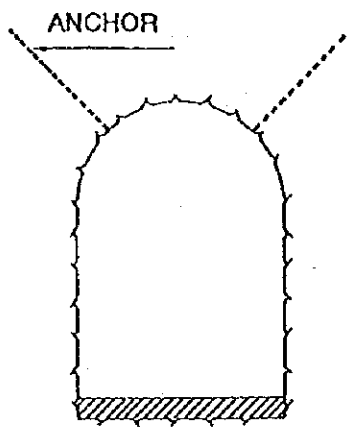
TITLE  
 GEOTECHNICAL PROFILE OF LAS VACAS MAIN COLLECTOR (CENTRAL REGION)



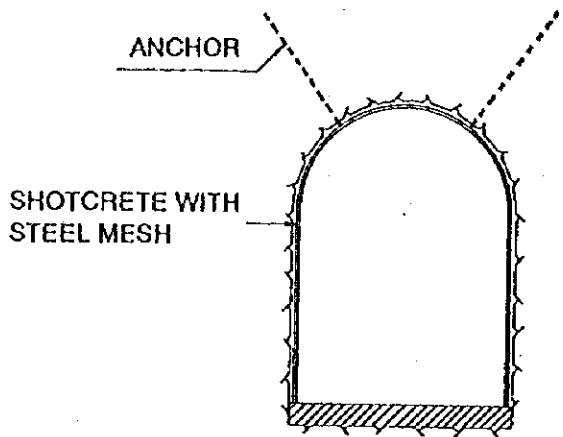
| Collector Ref. No.           | 1                             | 2   | 3   | 4                                     | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   | 15   | 16   | 17  |
|------------------------------|-------------------------------|-----|-----|---------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|---|
| DISTANCE (m)                 | 430                           | 470 | 740 | 1330                                  | 1810 | 2210 | 2610 | 3010 | 3410 | 3810 | 4210 | 4610 | 5010 | 5410 | 5810 | 6210 | 6610  |
| ROCK TYPE                    | PUMICE ASH                    |     |     | ALLUVIAL GRAVEL, SAND AND SILT        |      |      |      |      |      |      |      |      |      |      |      |      | PUMICE ASH WITH PUMICE FRAGMENTS AND SAND LENS                    |
| GEOTECHNICAL CHARACTERISTICS | SMOOTH, LOOSE, GOOD STABILITY |     |     | DETRITAL DEPOSITS, LOOSE INCONSISTENT |      |      |      |      |      |      |      |      |      |      |      |      | SMOOTH MATERIAL, LOOSE, GOOD STABILITY AND VERY SENSIBLE TO ERODE |
| WATER LEVEL                  | UPPER                         |     |     | UPPER                                 |      |      |      |      |      |      |      |      |      |      |      |      | LOWER   |
| PROFILE TYPE                 | III                           |     |     | IV                                    |      |      |      |      |      |      |      |      |      |      |      |      | III 90%   |
| EXCAVATION METHOD            |                               |     |     | MANUAL AND / OR SMALL MACHINER        |      |      |      |      |      |      |      |      |      |      |      |      |   |

|  |  |   |
|--|--|---|
| THE REPUBLIC OF GUATEMALA<br><br>GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA) | THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA | TITLE<br><br>GEOTECHNICAL PROFILE OF PINULA MAIN COLLECTOR (SOUTH 3 REGION) |
|  | JAPAN INTERNATIONAL COOPERATION AGENCY   |   |

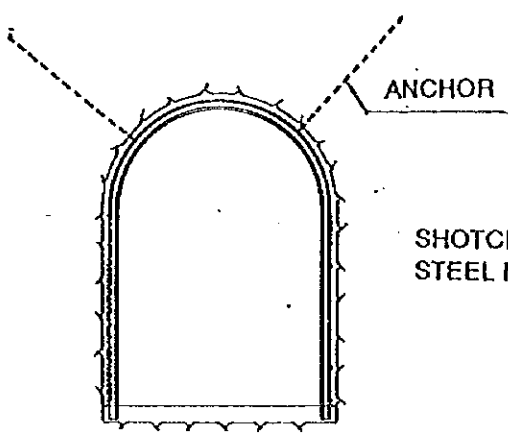
**TYPE I**  
STABLE AND FIRM ROCK



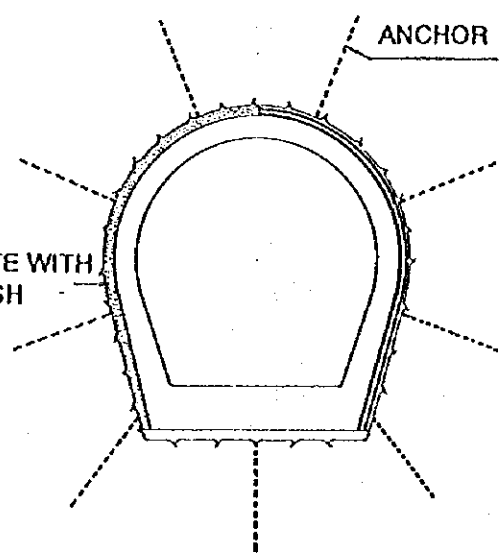
**TYPE II**  
FRACTURED AND HIGHLY WEATHERED ROCK



**TYPE III**  
HIGHLY FRACTURED, ALTERED ROCK



**TYPE IV**  
DEFORMED, SOFT ROCK



|   |   |  |
|---|---|--|
| <p>THE REPUBLIC OF GUATEMALA</p> <p>GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)</p> | <p>THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA</p> <p>JAPAN INTERNATIONAL COOPERATION AGENCY</p> | <p>TITLE</p> <p>TUNNEL CROSS - SECTIONS FOR MAIN COLLECTOR</p> |
|---|---|--|



## **R4.2 GEOTECHNICAL ASPECTS OF THE PROPOSED SITES FOR WASTEWATER TREATMENT PLANT**

### **R4.2.1 Geological Characteristics of the South 3 Region WWTP**

The WWPT South 3 Region is located in the left side of Pinula River, at the Villabobos river confluence. Two geomorphological units have been recognized, the first one consists of small hills to the north, and the other unit in an extense alluvial terrace to the south (See Fig.R-7).

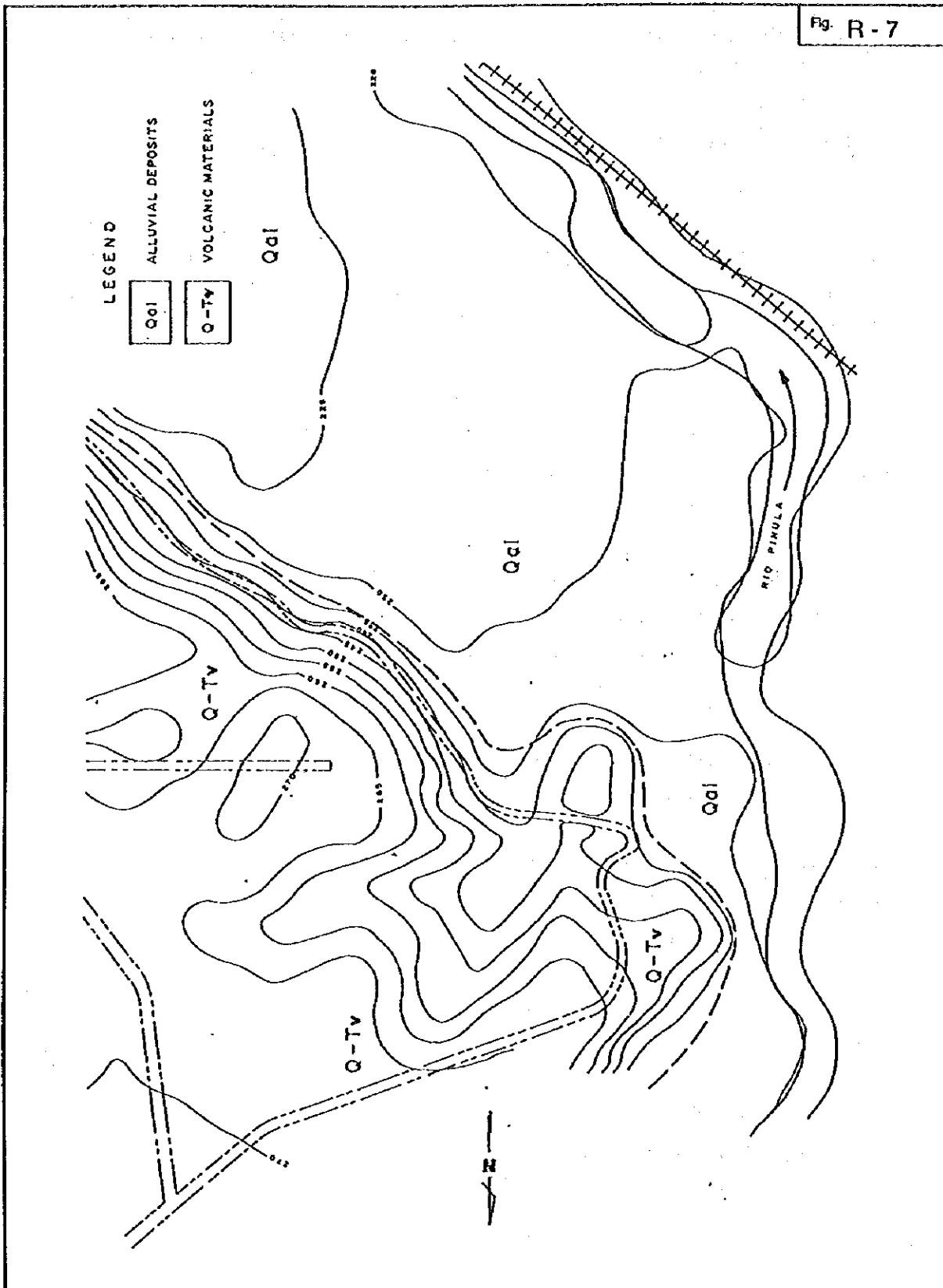
The hills are formed by volcanic materials; tuffaceous and pumiceous ash, loose and soft, with at least 6 m of weathering silts and clayey silts. In relation to slope unstability, no identified ancient and/or potencilally unstable zones were identified, the pumiceous deposits are not susceptible to slides.

The second unit is constituted by several types of alluvial and fluvial deposits in the river margins and in the surroundings of the ancient lake (recent deposits). They consist in sequence of fine to medium sands, fine gravels and silty sands, thicknesses greater than 30 m.

The south region presents two well defined materials. The highly formation is adecquate for superficial foundations such as footings, provided the residual soil is removed. If any cut must be done in such material, a slope of 1:0.3 (Vertical : Horizontal) should be considered. It is very important to protect the surface after a cut is made, to avoid erosion due to loss of humidity, or existence of water flows. The surface of the slopes should be protected by either grass or by shotcrete.

The lower area presents a more difficult situation for foundation considerations. The presence of fine-satured sand layers could eventually produce liquefaction, if the soil is subjected to dynamic forces. A drainage system should be developed in order to dry these fine sands. In addition, a controlled compaction procedure should be implemented and if necesarry, a pre-loading procedure too, in order to avoid future settlements.

Fig. R-7



|   |   |   |
|---|---|---|
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|---|---|---|

#### **R4.2.2 Geological Characteristics of the Central WWTP**

It is located at the left margin of Las Vacas River, composed by small hills and reduced plains with one continuous and descending slope towards the NE, cut by rough slopes and small rivers.

The proposed site for the plant is in the border of the mountain scarp at S-SW and the alluvial valley of Las Vacas River characterized by colluvial and alluvial materials of low thickness (gravel and sands).

The base material is granite rocks, weathered and fractured with thickness of more than 20 m and deposits of pumiceous ashes of fine grain, possibly reworked and slide (colluvial and alluvial layers, gravel, sands and lime of fluvial and lacustrine origin).

This heterogeneity of the materials and the presence of faults in sites with slopes and possibly undermined by rivers, have generated instability and sliding of faults.

One of them was found within the proposed area for the plant, and it caused the change of the route between Chinautla and San Antonio Las Flores. Nevertheless, most of the proposed area does not present unstable taluds.

The results of soil laboratory tests show that the colluvial material of the upper layers, eventhough, it shows high cohesion values, the values are relatively low, which could result in small loading capacity of the soil. In order to obtain a more homogeneous basement for the structures, the volcanic and colluvial materials of the upper layers (0-3.00 m) should be removed.

Regarding slope stability, eventhough there is no visual sign of instability, any cut should maintain slopes with a minimum slope of 1:0.5 (Vertical : Horizontal).

### R4.2.3 Bearing Capacity

The formula developed by Peck, Hansen, and Thornburn, is a correlation results from a correlation between blow-count (SPT), and internal friction angle. From the following figure, the factor  $N_c$  and  $N_q$  are determined, which incorporate the allowance for local shear failure, in dry soil, over water level.

The formula will give the bearing capacity for a given foundation width  $B$ . For this case, the foundation width is unknown, and a value of 3 feet is assumed (0.90 m.). thus,

$$\hat{q} (q_u) = \frac{\delta B N_c + \delta d N_q}{2}$$

where:  $N_c$  and  $N_q$  = bearing capacity factors.

Northern Region:                      Southern Region:

$$\delta = 106 \text{ lb/ft}^2$$

$$\delta = 88 \text{ lb/ft}^2$$

$$\phi = 34$$

$$\phi = 33$$

$$N (\text{SPT}) = 38$$

$$N (\text{SPT}) = 25$$

Thus, for the above parameters, the bearing capacities are:

Northern Region:

$$\text{From graph: } N_c = 25$$

$$N_q = 24$$

$$\begin{aligned} \text{Bearing capacity} &= 19,500 \text{ lbs/ft}^2 = 19.5 \text{ ton/ft}^2 = 5.5 \text{ ton/ft}^2 \\ &= 5.0 \text{ kg/cm}^2 \end{aligned}$$

Southern Region:

$$\text{From graph: } N_c = 25$$

$$N_q = 24$$

$$\text{Bearing capacity} = 14,784 \text{ lb/ft}^2 = 4.9 \text{ ton/ft}^2 = 4.0 \text{ kg/cm}^2$$

## **R4.3 SOIL PERCOLATION TEST FOR SANITATION SYSTEM**

### **R4.3.1 Geological Characteristics of The Test**

The materials found in the boreholes, are mainly clay and clayey silt, product of the weathering volcanic deposits. Thickness of these materials are higher than 20 m (Bethania I). Levels of paleosol (clayey silts to clay) between pumice ash beds were usually found. The high weathering thickness is attributed to the closeness of scarpments, and the intensity of the slopes.

In general, they show an heterogeneous physical disposition in relation to the grain size, composition, thickness, density and hydraulic characteristics. Some sites showed stuffed materials, possibly from old rivers or permeable underground zones.

The characteristics found at the drilling sites and the results of the percolation tests are not favorable for the construction or implementation of absorption wells in these locations.

### **R4.3.2 Results of The Test**

Table R-9 and R-10 show the drop of water level in every percolation test, the rate and time.

#### **a) Bethania I**

The drilled materials consist of mixture of clay and clayey silts of medium to high plasticity, dark brown color, with thickness of more than 20 m (see pictures of the core boxes) and the stratigraphic description.

In the first meter of drilling, there were found stuff materials which were used in the construction of the colony and the highway. The percolation rate is 429 min./100 mm.

#### **b) Bethania II**

At this site, the soil strata consisted of clayey silts of little to medium plasticity and in the deepest zones it consisted of sand traces, fine to medium. The drilled hole could not be filled with water up to saturation, anyhow, it was filled with 7,000 L. It indicated that the borehole has a stratum of porous materials, highly permeable. Another borehole was tried in the nearby, but it showed the same.

**c) 6 De Octubre**

The drilled materials were alternate beds of clayey silt and silt, little to medium plasticity, with levels of fine sand and pumice fragments, which steadily continued until 20 m depth. The percolation rate is 375 min./100 mm.

**d) Loma Blanca**

At the upper part, the materials are clayey silts, smooth, slight plasticity, then, it changed to pumice ashes, fine sand and clayey silts, in more than 15 m depth. This disposition of materials and its characteristics favor the objectives of the project. The percolation rate is 50 min./100mm.

**e) Quintanal**

At this location, soil strata consisted of silty-clays and silt, medium plasticity, smooth, and major contents of pumice ash, deeply, which continues through the depth of the drilling (20 m). The percolation rate is 171 min./100mm.

**Table R-9 Data of Soil Percolation Test**

| Time Elapsed (hour) | BETHANIA I |           | BETHANIA II |           | 6DE OCTUBRE |           | LOMA BLANCA |           | QUINTANAL |           |
|---------------------|------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-----------|-----------|
|                     | WL (m)     | Drop (mm) | WL (m)      | Drop (mm) | WL (m)      | Drop (mm) | WL (m)      | Drop (mm) | WL (m)    | Drop (mm) |
|                     | 9.35       |           |             |           | 5.06        |           | 9.38        |           | 5.45      |           |
| 1.0                 | 9.38       | 30        | -           | -         | 5.10        | 38        | 9.65        | 270       | 5.51      | 65        |
| 2.0                 | 9.41       | 25        | -           | -         | 5.12        | 20        | 9.85        | 200       | 5.57      | 60        |
| 3.0                 | 9.43       | 20        | -           | -         | 5.14        | 17        | 10.07       | 220       | 5.62      | 50        |
| 4.0                 | 9.44       | 15        | -           | -         | 5.16        | 18        | 10.17       | 100       | 5.66      | 40        |
| 5.0                 | 9.45       | 13        | -           | -         | 5.17        | 15        | 10.29       | 120       | 5.70      | 40        |
| 6.0                 | 9.47       | 14        | -           | -         | 5.19        | 15        | 10.43       | 140       | 5.73      | 30        |
| 7.0                 | 9.48       | 12        | -           | -         | 5.20        | 13        | 10.55       | 120       | 5.76      | 30        |

**Table R-10 The Results of Soil Percolation Rate**

| Borehole Site | Water Level Drop Rate |            |
|---------------|-----------------------|------------|
|               | mm/1 hour             | min/100 mm |
| Bethania I    | 14                    | 429        |
| Bethania II   | -                     | -          |
| 6 De Octubre  | 16                    | 375        |
| Loma Blanca   | 120                   | 50         |
| Quintanal     | 35                    | 171        |

## R5 CONCLUSIONS AND RECOMMENDATIONS

### R5.1 MAIN COLLECTOR

#### R5.1.1 Central Region

From south to north, the collector will cross three types of rocky material : limestone, volcanic tuffaceous and granite. All of them present different physical conditions, therefore, diverse types of support are required.

According to the Terzaghi classification system, all along the tunnel there are : 1) rocks (somewhat broken), 2) rocks broken in block sizes 3) triturated rocks. And according to the DEERE Rock Quality Index, the quality of the rocks is very bad (lower than 25% RQD).

The boreholes B-6.7, B-8, B-9, B-10 and B-11 showed high density of meteorized and fractured materials, soil and rock weathering.

The Unconfined Compression Tests indicated a value between 40.43 and 94.1 kg/cm<sup>2</sup>, which are very low in relation to the type and origin of the rock (granites and intrusive rocks).

Due to the mentioned characteristics of the points that cross the tunnel, this tunnel has to be reinforced with concrete revestment. The point on Tzalja river (boring B-8) is the only exception because it is located on granitic and cuarciferous rock (the boring B-8 was performed downstream of the 1,220 level, the rock at this point is of low quality).

All the points that cross the tunnel, present topographical difficulties for the construction of access routes to the place and the preparation of platforms for the machinery needed to build the entrance to the tunnel.

Several conclusions and recommendations to overcome the difficulties the construction phases, are presented in paragraph R2.5

Based on the physical status of the site, and the types of materials found, it is recommended that the conventional methods for excavating tunnels be used (drilling and blasting). In some points, there could be soft materials, which might be excavated with small machinery.

In some points, the excavation can be performed facing the front of the tunnel and inclined to its upper part, in order to investigate whether water flows exist. These points may be located in the southern part of Chinautla river (B-6.7), and near borehole B-9.

The crossing of creeks, will required a concrete coating, and rip rap upstream and downstream protection, for the prevention of erosion. It is necessary to make soil movements in order to prepare a long platform above the tunnel, where the rivers will to flow. The high slopes of the creeks, at level 1220, fasten the mentioned platforms.

Another recommendation is to make drillings near borehole B-6.7, to make contact with the re-worked tuffaceous/soil, limestone and granite.

It is very important to perform drillings in extensive areas with the purpose of determining the phreatic level and the hydraulic load at the tunnel level.

It is also important to practice Pressure Permeability Tests (Lugcon Type), and geophysical lines (Seismic refraction).

These surveys will help to obtain full information for the application of the best methods and geotechnical parameters to classify the massive rock.

### **R5.1.2 South 3 Region**

The change of the topographic level in the valley of Pinula river, will permit the location of the collector in an external pipe placed over the metallic bridge, not in use at present (Incapie bridge).

The valley of the Pinula river has more than 30 meters of alluvion, gravel, sands and clayey silts. These granular materials are very consistent but no dense.

An underground structure needs strong reinforcement and manual excavation methods.

The tunnel structure has to be dig taking into consideration the increasement of the Pinula river. Nevertheless, the background of the metallic bridge indicates that it is fairly possible that the overflows of the Pinula river might affect the proposed structure.

The geological profile from this collector to Los Alamos, presents two types of rock that should be crossed, pumiccous ashes and sands (medium to fine size) with clayey silts.



A tunnel constructed in pumiceous ashes presents a good stability and smooth excavation with manual methods, but its walls have to be protected to avoid erosion caused by water flows.

The geological correlation between the valley of the Pinula river (B-12) and the borehole B-13 (Boca del Monte) indicates that there is a high possibility that the collector will be located on fine sands and clayey silts with reworked tuffaceous layers. It requires conventional excavations methods, with small machinery, and reinforced tunnel profiles.

It is necessary to perform, at least, two drillings between the valley of the Pinula river (Incapic bridge) and the site of borehole B-13, in order to confirm the materials and phreatic level in the site. This information is necessary to determine the tunnel profile and the required reinforcements, and also to calculate the costs.

It is also recommended to perform a borehole between the valley of the Pinula river and the unloading of the present collector, to determine the type of materials and geotechnical characteristics.

Between the sites of boreholes B-13 and B-14 in Los Alamos, there is a geological contact with alluvial materials and pumiceous ashes and tuffaceous.

Due to the geotechnical characteristics of these materials, the excavation method and profile types, it is necessary to perform two boreholes and find the contact point. This was indicated in the geotechnical profile. (See Fig. R-5)

The materials along the proposed tunnel are granitic and weathering materials, especially sands and fine gravel, which requires that the tunnel profile be very strong in order to avoid erosion and intervention of water flows.

The excavation in tuffaceous and volcanic materials, is easier to realize and presents better stability. It also needs reinforcement because the materials provoke erosion.

## **R5.2 WASTEWATER TREATMENT PLANT**

### **R5.2.1 South 3 WWTP**

Volcanic materials are adequate for superficial footing. These materials will have a bearing capacity above 5 kg/cm<sup>2</sup>, at a depth of 4.00 m. Depending on the weight of the structures the upper layers must be removed. In the event of cuts, it is important to protect the slopes

and to maintain the slope ratio over 1:0.3 V:H. It is recommended slopes no higher than 5 m, and if higher slopes are required, there must be steps 1 to 1.5 m wide. These steps must be with a counter slop, about 3% towards the slope, and a water collector must be provided.

In the lower area, saturated sands present difficult founding conditions. A deep foundation method (piles) could be utilized. Alternatively, these sands may be drained and comparted in order to densify them and avoid any possibility of liquefaction.

### **R5.2.2 Central WWTP**

The proposed site for the Central Region WWTP seem to be adequate with bearing capacity over 4 kg/cm<sup>2</sup>, provided the superficial heretogenous material is removed. The slopes should maintain a slope of over 1:0.5. In this case, it is also recommended slopes no ther than 5 meters, and if higher slopes are required, these must be setps 1 to 1.5m wide. These steps must be with a counter slop, about 3% towards the slope, and a water collector must be provided. It is recommended that surfaces are protected by means of synthetical lining (geo-membrance), shotcrete or natural methods such as grass and vegetation.

### **R5.3 SANITATION SYSTEM**

The results of the soil percolation tests practiced in the mentioned sites, do not favor the construction or implementation of absortion wells. The percolated materials consist of interbedded clays, limes, clayey limes with thin layers of pumiceous ashes, the thicknesses exceed the 20 m. In the case of the first indicated materials, they form waterproof layers , pumiceous ashes due to their susceptibility to be removed by water concentrated flows, form cavities (paleochannels) or very waterproof hydraulic conductors.

In Loma Blanca, the percolation rate was 50 min./100mm, the best for the study's purpose, meanwhile in Bethania I, it was 429 min./100mm, as well in Bethania II there were loses of 7500 L, while trying to fill the boring, possibly due to the presence of a paleochannel or waterproof hydraulic conduct.

The possible construction of absorption wells in other sites should be based in the existence of materials with relatively less weathering and reduced possibilities of conducts or underground sewers, this characteristics could be determined by geological and hydrological studies in the cuts of the ravines, with background information of nearby wells or septic tanks nearby, and the application of the techniques described in the present study.

## **Annex-RA Boring Logs**

**Borehole B - 1**

**Borehole B - 2**

**Borehole B - 3**

**Borehole B - 4**

**Borehole B - 5**

**Borehole B - 6.7**

**Borehole B - 8**

**Borehole B - 9**

**Borehole B - 10**

**Borehole B - 11**

**Borehole B - 12**

**Borehole B - 13**

**Borehole B - 14**

| Elevation, Center of Core (Centímetros) | STRAT-GRAPHIC DESCRIPTION<br>Descripción Estratigráfica  | Grain Size Distribution | DATE    | DEPTH | SAMPLES | SPT DATA | CORE NO. | SAMPLE NO. | WATER LEVEL | COMMENTS | BORE-HOLE INFORMATION  |
|---|--|-------------------------|---------|-------|---------|----------|----------|------------|-------------|----------|--|
|   |  |                         |         |       |         |          |          |            |             |          |  |
| 0.60                                    | CLAYEY SILTS, DARK BROWN TO BLACK MEDIUM PLASTICITY, WITH SOME SANDS AND ORGANIC MATTER (TOP SOIL)<br>Limp arcillosa, café oscuro a negro, plástica, con restos de arena y restos vegetales (0-5)  |                         | 7/12/93 | 1     | 1       | 1        | 1        | 0.35       | 78          |          | BORE-HOLE INFORMATION<br>Perforación B-1<br>LOCATION Localización CHINAUTLA<br>SURFACE ELEVATION Elevación Superficial 1156.940<br>DATE STARTED Fecha de Inicio 7/12/93<br>DATE FINISHED Fecha de Finalización 8/12/93<br>DRILL RIG Perforadora TRUCK MOUNTED AUGER DRILL<br>Cónico Auger CNE-53<br>INCLINATION Vertical inclinación<br>TOTAL DEPTH Profundidad Total 20.00 m<br><br>METHOD OF DRILLING Método de Perforación<br>ROTARY WASH BORING Lavado de Muestra<br>AUGER BORING Perforación con Auger 0.00 - 20.00 m<br>ROCK CORING Núcleo de Roca<br><br>DRILLING FLUIDS Líquido de Perforación<br>CLEAN WATER Agua clara<br>BENTONITE MUD Lodo Bentonítico |
| 3.00                                    | CLAYEY SILTS, BROWN, MEDIUM PLASTICITY, WITH FINE GRAVEL AND SANDS<br>Limp arcillosa, café, plástica, con arena y grava fina (ML)  |                         |         | 2     | 2       | 2        | 2        | 0.45       | 100         |          |  |
| 3.70                                    | SILTY CLAYS, YELLOWISH ORANGE, WITH FINE SANDS<br>Arcillosa limosa, café amarillento, con arena fina (CL)  |                         |         | 3     | 3       | 3        | 3        | 0.40       | 89          |          |  |
|   | SILTY SANDS, GREENISH GRAY MEDIUM DENSE, WITH SOME FINE GRAVEL AND VOLCANIC MATERIALS.<br>Limp arenoso, gris verdoso, moderadamente denso, con tramos de grava fina y materiales volcánicos tabacoc. (SM)  |                         |         | 4     | 4       | 4        | 4        | 0.45       | 100         |          |  |
|   |  |                         |         | 5     | 5       | 5        | 5        | 0.45       | 100         |          |  |
|   |  |                         |         | 6     | 6       | 6        | 6        | 0.45       | 100         |          |  |
|   |  |                         |         | 7     | 7       | 7        | 7        | 0.45       | 100         |          |  |
|   |  |                         |         | 8     | 8       | 8        | 8        | 0.45       | 100         |          |  |
| 6.70                                    | SILTY SAND, WITH CLAYS LIGHT BROWN, WITH SLIGHT PLASTICITY<br>GRANITIC ROCKS<br>Limp arenoso con arcilla café clara ligeramente plástica con tramos de arena granítica completamente alterada (SM)   |                         |         | 9     | 9       | 9        | 9        | 0.45       | 100         |          |  |
| 9.25                                    |  |                         |         | 10    | 10      | 10       | 10       | 0.25       | 100         |          |  |
|   |  |                         |         | 11    | 11      | 11       | 11       | 0.25       | 100         |          |  |
|   |  |                         |         | 12    | 12      | 12       | 12       | 0.25       | 100         |          |  |
|   |  |                         |         | 13    | 13      | 13       | 13       | 0.25       | 100         |          |  |
|   | GRANITIC ROCKS, HIGHLY TO COMPLETELY WEATHERING, ROCK MATERIAL DISCOMPOSE AND/OR DESINTEGRATE TO SOIL AND/OR SOME PARTS OF WEATHERED ROCK<br>Roca granítica, alta e completamente meteorizada o desintegrada en suelo y/o tramos de roca alterada. |                         |         | 14    | 14      | 14       | 14       | 0.15       | 100         |          |  |
|   |  |                         |         | 15    | 15      | 15       | 15       | 0.10       | 100         |          |  |
|   |  |                         |         | 16    | 16      | 16       | 16       | 0.15       | 100         |          |  |
|   |  |                         |         | 17    | 17      | 17       | 17       | 0.15       | 100         |          |  |
|   |  |                         |         | 18    | 18      | 18       | 18       | 0.10       | 100         |          |  |
|   |  |                         |         | 19    | 19      | 19       | 19       | 0.10       | 100         |          |  |
|   |  |                         |         | 20    | 20      | 20       | 20       | 0.25       | 100         |          |  |

swissboring

WASTEWATER MANAGEMENT FOR THE GUATEMALA METROPOLITAN AREA  
Plan Maestro de Saneamiento del Área Metropolitana

GEOCHEMICAL INVESTIGATION  
Investigación Geoquímica

BORING Perforación N° B-1

SCALE 1:50 DRAWN BY Ing. R. Alvarado

| Stratigraphic Change<br>Cambios Estratigráficos | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica   | LITHOLOGICAL SYMBOL<br>Símbolo Litológico | DATE<br>Fecha | DEPTH<br>Profundidad | DISTURBED<br>Disturbado | DISTURBED<br>Disturbado | DATE<br>Fecha | DATE<br>Fecha | CORE RUN<br>Número Muestra | SAMPLE NO./CANTIDAD<br>Número Muestra | SAMPLE NO./CANTIDAD<br>Número Muestra | SPT<br>No. de SPT<br>por Pie | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios                 | BOREHOLE INFORMATION<br>Información del Sondeo   |
|---|---|---|---------------|----------------------|-------------------------|-------------------------|---------------|---------------|----------------------------|---------------------------------------|---------------------------------------|------------------------------|------------------------------|---|--|
|   |   |   |               |                      |                         |                         |               |               |                            |                                       |                                       |                              |                              |   |  |
|   | SILT SANDS WITH CLAY, DARK BROWN, LIGHT PLASTICITY, WITH HIGH ORGANIC CONTENTS.<br>Limo arenoso, canchillo, color oscuro, ligamento plástico, con alto contenido orgánico   |   |               | 1                    |                         |                         | 01 15 00      | 02 15 00      | 1                          | 0.30                                  | 0.67                                  |                              |                              | POLE DIAMETER 6 7/8"<br>Diámetro sondeo | <b>BOREHOLE</b><br>Perforación: B-2<br><b>LOCATION</b><br>Localización: WWTP, CENTRAL REGION<br><b>SURFACE ELEVATION</b><br>Elevación Superficial: 1207.87<br><b>DATE STARTED</b><br>Fecha de Inicio: 12/18/95<br><b>DATE FINISHED</b><br>Fecha de Finalización: 12/18/95<br><b>DRILL RIG</b><br>Perforadora: TRUCK MOUNTED AUGER DRILL<br>CAMION AUGER CME-55<br><b>INCLINATION</b><br>Inclinación: VERTICAL<br><b>TOTAL DEPTH</b><br>Profundidad Total: 20.00 m<br><br><b>METHOD OF DRILLING</b><br>Método de Perforación<br>ROTARY WASH BORING<br>Lavado de Muestra<br><b>AUGER BORING</b><br>Perforación con Auger: 0.00 - 20.00 m.<br><b>ROCK CORING</b><br>Núcleo de Roca<br><br><b>DRILLING FLUIDS</b><br>Fluido de Perforación<br>CLEAN WATER<br>Agua Clara<br>BENTONITE MUD<br>Lodo Bentonítico |
|   | MEDIUM TO FINE SANDS WITH SILT, YELLOWISH ORANGE WITH TRACES OF PUMICEOUS TUFF, MEDIUM DENSE<br>Arena media a fina, con limo color amarillento, con trazos de tufa pumicea moderadamente densa (SM)   |   |               | 2                    |                         |                         | 03 15 00      | 04 15 00      | 2                          | 0.45                                  | 100                                   |                              |                              |   |  |
|   | FINE SANDS WITH CLAY SANDS-CLAY MIXTURES, BEIGE, VERY LOOSE, WITH PUMICEOUS FRAGMENTS.<br>Arena fina, con arcilla, blanca-beige con fragmentos pumiceos (SC)  |   |               | 3                    |                         |                         | 05 15 00      | 06 15 00      | 3                          | 0.40                                  | 0.68                                  |                              |                              |   |  |
|   |   |   |               | 4                    |                         |                         | 07 15 00      | 08 15 00      | 4                          | 0.40                                  | 0.68                                  |                              |                              |   |  |
|   |   |   |               | 5                    |                         |                         | 09 15 00      | 10 15 00      | 5                          | 0.35                                  | 0.78                                  |                              |                              |   |  |
|   |   |   |               | 6                    |                         |                         | 11 15 00      | 12 15 00      | 6                          | 0.45                                  | 100                                   |                              |                              |   |  |
|   |   |   |               | 7                    |                         |                         | 13 15 00      | 14 15 00      | 7                          | 0.45                                  | 100                                   |                              |                              |   |  |
|   |   |   |               | 8                    |                         |                         | 15 15 00      | 16 15 00      | 8                          | 0.45                                  | 100                                   |                              |                              |   |  |
|   |   |   |               | 9                    |                         |                         | 17 15 00      | 18 15 00      | 9                          | 0.45                                  | 100                                   |                              |                              |   |  |
|   |   |   |               | 10                   |                         |                         | 19 15 00      | 20 15 00      | 10                         | 0.45                                  | 100                                   |                              |                              |   |  |
|   |   |   |               | 11                   |                         |                         | 21 15 00      | 22 15 00      | 11                         | 0.40                                  | 0.68                                  |                              |                              |   |  |
|   |   |   |               | 12                   |                         |                         | 23 15 00      | 24 15 00      | 12                         | 0.45                                  | 100                                   |                              |                              |   |  |
|   | FINE SANDS AND SILTY-SANDS INTERBEDDED, YELLOWISH ORANGE, MEDIUM DENSE, WITH PUMICEOUS TUFF FRAGMENTS, SMOOTH, SIZES TO 3/4" OF DIAMETER.<br>Atravesada de capas de arena fina con limo, color amarillento de densidad moderada, con fragmentos de tufa pumicea, suaves de tamaño 3/4" de diámetro. |   |               | 13                   |                         |                         | 25 15 00      | 26 15 00      | 13                         | 0.45                                  | 100                                   |                              |                              |   |  |
|   |   |   |               | 14                   |                         |                         | 27 15 00      | 28 15 00      | 14                         | 0.30                                  | 0.67                                  |                              |                              |   |  |
|   |   |   |               | 15                   |                         |                         | 29 15 00      | 30 15 00      | 15                         | 0.45                                  | 100                                   |                              |                              |   |  |
|   |   |   |               | 16                   |                         |                         | 31 15 00      | 32 15 00      | 16                         | 0.45                                  | 100                                   |                              |                              |   |  |
|   |   |   |               | 17                   |                         |                         | 33 15 00      | 34 15 00      | 17                         | 0.45                                  | 100                                   |                              |                              |   |  |
|   |   |   |               | 18                   |                         |                         | 35 15 00      | 36 15 00      | 18                         | 0.28                                  | 0.68                                  |                              |                              |   |  |
|   |   |   |               | 19                   |                         |                         | 37 15 00      | 38 15 00      | 19                         | 0.30                                  | 0.67                                  |                              |                              |   |  |
|   |   |   |               | 20                   |                         |                         | 39 15 00      | 40 15 00      | 20                         | 0.45                                  | 100                                   |                              |                              |   |  |

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WASTEWATER MANAGEMENT FOR THE  
 GUATEMALA METROPOLITAN AREA  
 Pica Maestro de Saneamiento del  
 Area Metropolitana  
 GEOTECNIC INVESTIGATION  
 Investigación Geotécnica  
 BORING  
 Perforación Nº B-2

SCALE 1:50 LOGGED BY  
 Escala 1:50 Descrito por Ing. R. Alvarado

| Stratigraphic Change<br>Cambios Estratigráficos | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica            | GRAPHIC SYMBOL<br>Símbolo Gráfico | DATE<br>Fecha | DEPTH<br>Profundidad | TEST<br>No. Disturbado | DISTURBED<br>Disturbado | SPY DATA<br>SPY Data | CONC. NAME<br>Nombre | SAMPLE ACCOMPLISHED<br>Muestra Recobrada | NO. RECORDS SAMPLE<br>No. Registros Muestras | SPY<br>No. S. H. Tests<br>por Test | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios  | BOREHOLE INFORMATION<br>Información del Sondeo |
|---|--|-----------------------------------|---------------|----------------------|------------------------|-------------------------|----------------------|----------------------|--|--|------------------------------------|------------------------------|--|--|
|   | Clayey silt, dark brown, with mica fragments and fine sand.        |                                   | 24/02/96      | 1                    |                        |                         | 4 5 5 10             |                      | 0.10                                     | 0.22   |                                    |                              | BOREHOLE : B-3<br>Perforación : B-3<br>LOCATION : CHINAUTLA<br>Localización : CHINAUTLA<br>SURFACE ELEVATION : 1215 m.<br>Elevación Superficial : 1215 m.<br>DATE STARTED : 24/02/96<br>Fecha de Inicio : 24/02/96<br>DATE FINISHED : 26/02/96<br>Fecha de Finalización : 26/02/96<br>DRILL RIG : SR-2<br>Perforadora : SR-2<br>INCLINATION : VERTICAL<br>Inclinación : VERTICAL<br>TOTAL DEPTH : 20.00 m.<br>Profundidad Total : 20.00 m.<br><br>METHOD OF DRILLING<br>Método de Perforación<br>ROTARY WASH BORING,<br>Lavadura de Muestra,<br>AUGER BORING<br>Perforación con Auger<br>ROCK CORING : 0.00 - 20.00 m<br>Núcleo de Roca :<br><br>DRILLING FLUIDS<br>Líquido de Perforación<br>CLEAN WATER : 0.00 - 20.00 m.<br>Agua Clara :<br>BENTONITE MUD :<br>Lodo Bentonítico |  |
|   | Clayey silt, dark brown, smooth, with sand and fine gravel traces. |                                   |               | 2                    |                        |                         | 7 6 9 15             |                      | 0.40                                     | 0.85   |                                    |                              |  |  |
|   | Clayey silt, dark brown, smooth, with sand and fine gravel traces. |                                   |               | 3                    |                        |                         | 5 3 3 6              |                      | 0.40                                     | 0.49   |                                    |                              |  |  |
|   | Clayey silt, dark brown, smooth, with sand and fine gravel traces. |                                   |               | 4                    |                        |                         | 8 8 11 18            |                      | 0.50                                     | 0.97   |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   | 25/02/96      | 5                    |                        |                         | 7 12 20 32           |                      | 0.43                                     | 1.00   |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   |               | 6                    |                        |                         | 8 12 20 32           |                      | 0.43                                     | 1.00   |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   |               | 7                    |                        |                         | 0 50 - 50            |                      | 0.23                                     | 1.00   |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   |               | 8                    |                        |                         | 13 23 32 50          |                      | 0.43                                     | 1.00   |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   | 26/02/96      | 9                    |                        |                         | 50 50 - 50           |                      | 0.12                                     | 0.48   |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   |               | 10                   |                        |                         | 13 23 32 50          |                      | 0.43                                     | 1.00   |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   |               | 11                   |                        |                         | 13 23 32 50          |                      | 0.43                                     | 1.00   |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   |               | 12                   |                        |                         | 16 23 30 53          |                      | 0.43                                     | 1.00   |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   | 26/02/96      | 13                   |                        |                         | 17 50 - 50           |                      | 0.43                                     | 1.00   |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   |               | 14                   |                        |                         | 15 50 - 50           |                      | 0.23                                     | 0.8  |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   |               | 15                   |                        |                         | 13 15 43 54          |                      | 0.37                                     | 0.82   |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   |               | 16                   |                        |                         | 14 23 32 57          |                      | 0.23                                     | 0.4  |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   | 26/02/96      | 17                   |                        |                         | 12 23 50 79          |                      | 0.11                                     | 0.24   |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   |               | 18                   |                        |                         | 21 34 50 64          |                      | 0.35                                     | 0.83   |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   |               | 19                   |                        |                         | 0 50 - 50            |                      | 0  | 0  |                                    |                              |  |  |
|   | Silty sand, dark brown with fine gravel.                           |                                   |               | 20                   |                        |                         |                      |                      |  |  |                                    |                              |  |  |

Water level 9.50 m  
Nivel de agua  
125/02/96



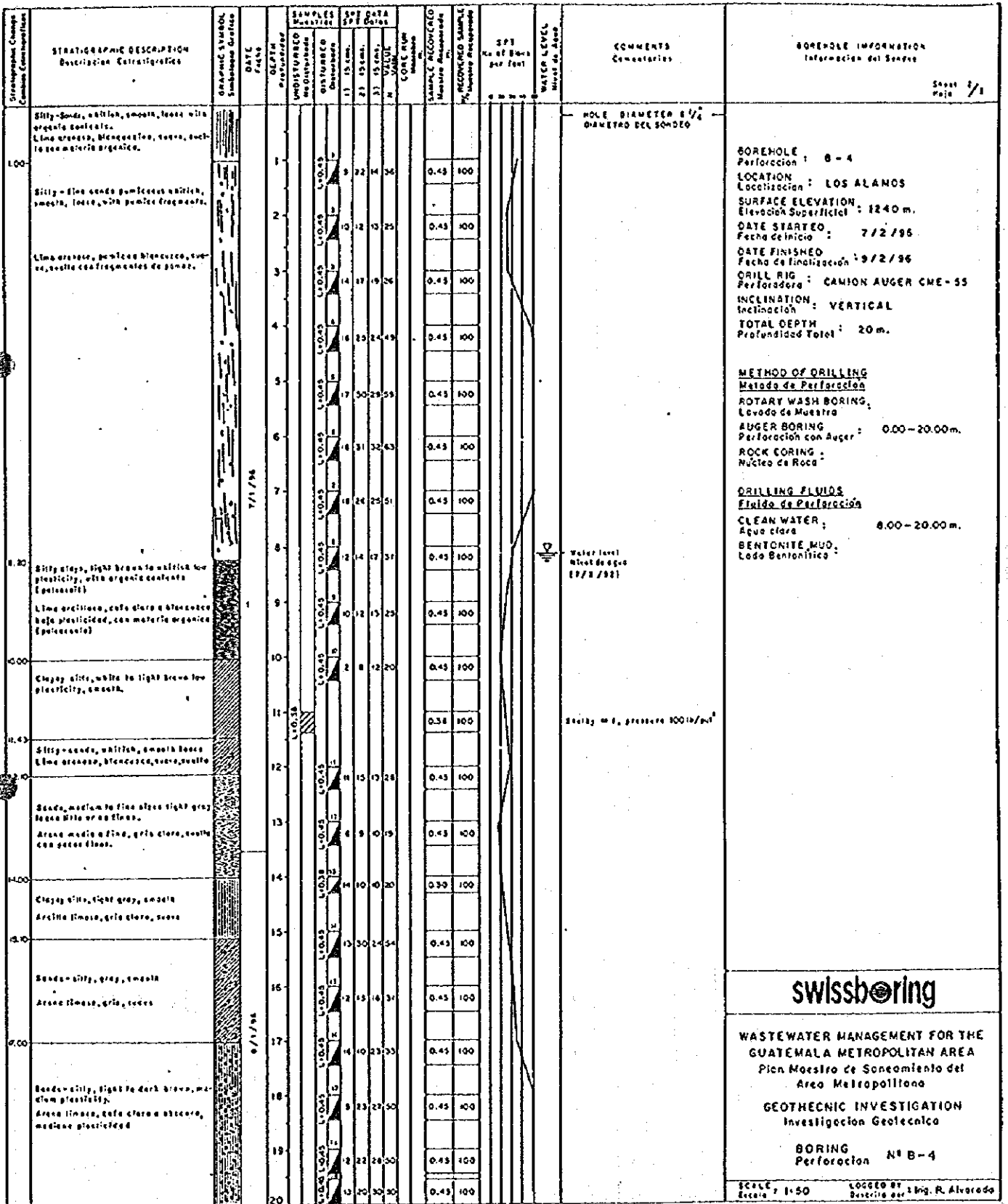
WASTEWATER MANAGEMENT FOR THE  
GUATEMALA METROPOLITAN AREA  
Plan Maestro de Saneamiento del  
Área Metropolitana

GEOHECNIC INVESTIGATION  
Investigación Geotécnica

BORING  
Perforación N° B-3

SCALE  
Escala 1:50

LOGGED BY  
Escrito por Ing. R. Alvarado



| Stratigraphic Change<br>Cambios Estratigráficos | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica  | GRAPHIC SYMBOL<br>Símbolos Gráficos | DATE<br>Fecha | DEPTH<br>Profundidad | SAMPLES<br>Muestras          |                         | SPT<br>Blows<br>per foot | DATA<br>Date | CORRECTION<br>Corrección | SAMPLE RECOVERED<br>Muestra Recuperada | RECORDED SAMPLE<br>Muestra Registrada | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios  | BOREHOLE INFORMATION<br>Información del Sondeo |
|---|--|-------------------------------------|---------------|----------------------|------------------------------|-------------------------|--------------------------|--------------|--------------------------|--|---------------------------------------|------------------------------|--|--|
|   |  |                                     |               |                      | UNDISTURBED<br>no Disturbado | DISTURBED<br>Disturbado |                          |              |                          |  |                                       |                              |  |  |
|   | Sand - silt, light brown to whitish, loose, angular, with organic silt, coarse with matter organic |                                     | 12/2/96       | 1                    | 1                            | 1                       | 13                       | 18           | 0                        | 0.43                                   | 100                                   |                              | <b>BOREHOLE INFORMATION</b><br>Información del Sondeo<br>Sheet No. 1/1<br><br><b>BOREHOLE :</b> B-5<br><b>Perforación :</b> B-5<br><b>LOCATION :</b> LOS ALAMOS<br><b>Localización :</b> LOS ALAMOS<br><b>SURFACE ELEVATION :</b> 1233 m.<br><b>Elevación Superficial :</b> 1233 m.<br><b>DATE STARTED :</b> 12/2/96<br><b>Fecha de inicio :</b> 12/2/96<br><b>DATE FINISHED :</b> 13/2/98<br><b>Fecha de finalización :</b> 13/2/98<br><b>DRILL RIG :</b> TRUCK MOUNTED DRILL RIG<br><b>Perforadora :</b> CAMION PERFORADOR<br><b>INCLINATION :</b> VERTICAL<br><b>Inclinación :</b><br><b>TOTAL DEPTH :</b> 20.00 m.<br><b>Profundidad Total :</b><br><br><b>METHOD OF DRILLING</b><br><b>Método de Perforación</b><br><b>ROTARY WASH BORING</b><br><b>Lavado de Muestra</b><br><b>AUGER BORING</b><br><b>Perforación con Auger :</b> 0.00-20.00 m.<br><b>ROCK CORING :</b><br><b>Núcleo de Roca :</b><br><br><b>DRILLING FLUIDS</b><br><b>Fluido de Perforación</b><br><b>CLEAN WATER :</b> 2.00-20.00 m.<br><b>Agua clara :</b><br><b>BENTONITE MUD :</b><br><b>Lodo Bentonítico :</b> |  |
|   | Pumiceous ash, white to light brown, loose, with amorph sand.                                      |                                     |               | 2                    | 2                            | 2                       | 4                        | 6            | 0                        | 0.43                                   | 100                                   |                              |  |  |
|   | Canje pumiceo, blanco a café claro, suelta, arenosa, con   |                                     |               | 3                    | 3                            | 3                       | 3                        | 7            | 0                        | 0.40                                   | 89                                    |                              |  |  |
|   | Canje pumiceo, blanco a café claro, suelta, arenosa, con   |                                     |               | 4                    | 4                            | 4                       | 4                        | 8            | 0                        | 0.35                                   | 88                                    |                              |  |  |
|   | Sand silt fine to medium grained, dark grey, loose   |                                     |               | 5                    | 5                            | 5                       | 12                       | 12           | 0                        | 0.48                                   | 100                                   |                              |  |  |
|   | Arceo limoso, grano 1/2 a fino, suelta gris oscuro.  |                                     |               | 6                    | 6                            | 6                       | 3                        | 5            | 12                       | 0.48                                   | 100                                   |                              |  |  |
|   |  |                                     |               | 7                    | 7                            | 7                       | 4                        | 3            | 2                        | 0.40                                   | 89                                    |                              |  |  |
|   |  |                                     |               | 8                    | 8                            | 8                       | 2                        | 3            | 9                        | 0.40                                   | 88                                    |                              |  |  |
|   |  |                                     |               | 9                    | 9                            | 9                       | 1                        | 11           | 12                       | 0.34                                   | 84                                    |                              |  |  |
|   |  |                                     |               | 10                   | 10                           | 10                      | 11                       | 14           | 24                       | 0.40                                   | 89                                    |                              |  |  |
|   |  |                                     |               | 11                   | 11                           | 11                      | 11                       | 16           | 14                       | 0.35                                   | 88                                    |                              |  |  |
|   |  |                                     |               | 12                   | 12                           | 12                      | 14                       | 20           | 24                       | 0.43                                   | 89                                    |                              |  |  |
|   |  |                                     |               | 13                   | 13                           | 13                      | 4                        | 7            | 3                        | 0.34                                   | 76                                    |                              |  |  |
|   |  |                                     |               | 14                   | 14                           | 14                      | 8                        | 12           | 2                        | 0.34                                   | 80                                    |                              |  |  |
|   |  |                                     |               | 15                   | 15                           | 15                      | 3                        | 4            | 6                        | 0.40                                   | 87                                    |                              |  |  |
|   |  |                                     |               | 16                   | 16                           | 16                      | 3                        | 3            | 4                        | 0.35                                   | 88                                    |                              |  |  |
|   |  |                                     |               | 17                   | 17                           | 17                      | 3                        | 6            | 12                       | 0.30                                   | 87                                    |                              |  |  |
|   |  |                                     |               | 18                   | 18                           | 18                      | 2                        | 3            | 4                        | 0.32                                   | 71                                    |                              |  |  |
|   |  |                                     |               | 19                   | 19                           | 19                      | 2                        | 3            | 3                        | 0.36                                   | 83                                    |                              |  |  |
|   |  |                                     |               | 20                   | 20                           | 20                      | 4                        | 4            | 3                        | 0.28                                   | 82                                    |                              |  |  |



| Stratigraphic Column<br>Column Estratigráfica | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica   | GRAPHIC SYMBOL<br>Símbolo Gráfico | DATE<br>Fecha | DEPTH<br>Profundidad | SAMPLES                      |                         | DISTURBED<br>Disturbado | SP. GR.<br>Grav. Espec. | W. CONTENT<br>Cont. Agua | DATA<br>Datos | CORRECTION<br>Corrección | RECOVERED SAMPLE<br>Muestra Recuperada | SPZ<br>No. of Blows<br>por Pie | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios | BOREHOLE INFORMATION<br>Información del Sondeo  |
|---|---|-----------------------------------|---------------|----------------------|------------------------------|-------------------------|-------------------------|-------------------------|--------------------------|---------------|--------------------------|--|--------------------------------|------------------------------|-------------------------|---|
|   |   |                                   |               |                      | UNDISTURBED<br>No Disturbado | DISTURBED<br>Disturbado |                         |                         |                          |               |                          |  |                                |                              |                         |   |
|   | Clayey silt, light brown, smooth with clay and fine sand.<br>Lima arcillosa, gris clara, suave con arcilla y arena fina.  |                                   | 14/2/96       | 1                    |                              |                         |                         |                         |                          |               |                          |  |                                |                              |                         | <p>NO HOLE DIAMETER<br/>Diámetro orificio</p> <p>Water level 4.10 m.<br/>Nivel de Agua<br/>(15/2/96)</p> <p>BOREHOLE : B-6.7<br/>Perforación : B-6.7</p> <p>LOCATION : CHINAUTLA<br/>Localización : CHINAUTLA</p> <p>SURFACE ELEVATION : 1235 m.<br/>Elevación Superficial : 1235 m.</p> <p>DATE STARTED : 16/2/96<br/>Fecha de inicio : 16/2/96</p> <p>DATE FINISHED : 18/2/96<br/>Fecha de finalización : 18/2/96</p> <p>DRILL RIG : SR-2<br/>Perforadora : SR-2</p> <p>INCLINATION : VERTICAL<br/>Inclinación : VERTICAL</p> <p>TOTAL DEPTH : 34.00 m.<br/>Profundidad Total : 34.00 m.</p> <p>METHOD OF DRILLING<br/>Método de Perforación<br/>ROTARY WASH BORING,<br/>Lavado de Muestra<br/>AUGER BORING<br/>Perforación con Auger</p> <p>ROCK CORING : 0.00-34.00 m.<br/>Núcleo de Roca : 0.00-34.00 m.</p> <p>DRILLING FLUIDS<br/>Fluidos de Perforación<br/>CLEAN WATER : 0.00-34.00 m.<br/>Agua clara : 0.00-34.00 m.<br/>BENTONITE MUD :<br/>Lodo Bentonítico</p> |
| 1.45  | Gravel, medium graded, with clayey silt, light brown<br>Grava gruesa media con limo arcilloso gris claro.   |                                   |               | 2                    | L-0.45                       | 13                      | 17                      | 28                      | 0.45                     | 56            |                          |  |                                |                              |                         |   |
| 2.35  | Clayey silt, light brown<br>Limo arcilloso, gris claro.   |                                   |               | 3                    | L-0.37                       | 20                      | 35                      | 30                      | 0.30                     | 81            |                          |  |                                |                              |                         |   |
| 3.45  | Coarse to fine sand, with silt<br>Arena gruesa a fina con limo.   |                                   |               | 4                    | L-0.45                       | 32                      | 44                      | 22                      | 0.40                     | 89            |                          |  |                                |                              |                         |   |
| 4.10  | Silty sand, dark brown, with gravel<br>Arena gruesa, café oscuro con grava.   |                                   |               | 5                    | L-0.07                       | 50                      |                         |                         | 0.35                     | 100           |                          |  |                                |                              |                         |   |
| 5.20  | Coarse gravel, of volcanic ash<br>Grava gruesa, de material volcánico   |                                   |               | 6                    | L-0.14                       | 50                      |                         |                         | 0.42                     | 84            |                          |  |                                |                              |                         |   |
|   |   |                                   | 15/2/96       | 7                    | L-0.12                       | 50                      |                         |                         | 0.47                     | 78            |                          |  |                                |                              |                         |   |
|   |   |                                   |               | 8                    | L-0.27                       | 50                      |                         |                         | 0.17                     | 23            |                          |  |                                |                              |                         |   |
|   |   |                                   |               | 9                    | L-0.12                       | 50                      |                         |                         | 0.23                     | 26            |                          |  |                                |                              |                         |   |
|   | Fine sand and silty sand, interbedded, light brown to grey, with traces of gravel and pebble fragments.<br>Arena fina y limosa con trazos de grava interbedada, color café claro a gris con fragmentos de pedregal. |                                   |               | 10                   | L-0.12                       | 50                      |                         |                         | 0.48                     | 89            |                          |  |                                |                              |                         |   |
|   |   |                                   |               | 11                   | L-0.10                       | 50                      |                         |                         | 0.07                     | 20            |                          |  |                                |                              |                         |   |
|   |   |                                   |               | 12                   | L-0.09                       | 50                      |                         |                         | 0.24                     | 29            |                          |  |                                |                              |                         |   |
|   |   |                                   | 16/2/96       | 13                   | L-0.08                       | 50                      |                         |                         | 0.27                     | 29            |                          |  |                                |                              |                         |   |
|   |   |                                   |               | 14                   | L-0.06                       | 50                      |                         |                         | 0.30                     | 33            |                          |  |                                |                              |                         |   |
|   |   |                                   |               | 15                   | L-0.12                       | 50                      |                         |                         | 0.30                     | 34            |                          |  |                                |                              |                         |   |
|   |   |                                   |               | 16                   | L-0.19                       | 50                      |                         |                         | 0.07                     | 24            |                          |  |                                |                              |                         |   |
| 4.00  |   |                                   | 17/2/96       | 17                   | L-0.12                       | 50                      |                         |                         | 0.10                     | 31            |                          |  |                                |                              |                         |   |
|   | Peas and light brown to white, coarse, coarse fragments.<br>Copa de guisantes, café claro, fragmentos gruesos.  |                                   |               | 18                   | L-0.04                       | 50                      |                         |                         | 0.00                     | 0             |                          |  |                                |                              |                         |   |
|   |   |                                   |               | 19                   | L-0.03                       | 50                      |                         |                         | 0.23                     | 24            |                          |  |                                |                              |                         |   |
|   |   |                                   |               | 20                   | L-0.03                       | 50                      |                         |                         | 0.34                     | 1.34          |                          |  |                                |                              |                         |   |
|   | Silty sand, light brown with traces of coarse sand and pebble fragments<br>Arena limosa, café claro, con trazos de arena gruesa y fragmentos de pedregal.   |                                   |               |                      | L-0.00                       |                         |                         |                         |                          |               |                          |  |                                |                              |                         |   |

| Stratigraphic Column<br>Columna Estratigráfica | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica  | GRAPHIC SYMBOL<br>Símbolo Gráfico | DATE<br>Fecha | DEPTH<br>Profundidad | SAMPLES<br>Muestras          |                         | SPT<br>Blows<br>por 30 cm | RECOVERED SAMPLE<br>Muestra Recuperada | CORE RIM<br>Muestra | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios | BOREHOLE INFORMATION<br>Información del Sondeo   |
|--|--|-----------------------------------|---------------|----------------------|------------------------------|-------------------------|---------------------------|--|---------------------|------------------------------|-------------------------|--|
|  |  |                                   |               |                      | UNDISTURBED<br>No Disturbada | DISTURBED<br>Disturbada |                           |  |                     |                              |                         |  |
|  | Clayey sand, brown-gray, medium plasticity, with medium grained fine silt.   |                                   |               | 21                   |                              |                         |                           |  | 1.00                |                              |                         | <b>BOREHOLE</b><br>Perforación: 0-6.7<br><b>LOCATION</b><br>Localización: CHINAUTLA<br><b>SURFACE ELEVATION:</b> 1235 m.<br>Elevación Superficial:<br><b>DATE STARTED:</b> 16/2/96<br>Fecha de Inicio:<br><b>DATE FINISHED:</b> 18/2/96<br>Fecha de Finalización:<br><b>DRILL RIG:</b> SR-2<br>Perforadora:<br><b>INCLINATION:</b> VERTICAL<br>Inclinación:<br><b>TOTAL DEPTH:</b> 34.00 m.<br>Profundidad Total:<br><br><b>METHOD OF DRILLING</b><br>Método de Perforación:<br>ROTARY WASH BORING,<br>Levado de Muestra<br>AUGER BORING<br>Perforación con Auger:<br><b>ROCK CORING:</b> 0.00 - 34.00 m.<br>Núcleo de Roca:<br><br><b>DRILLING FLUIDS</b><br>Fluido de Perforación:<br><b>CLEAN WATER:</b> 0.00 - 34.00 m.<br>Agua Clara:<br><b>BENTONITE MUD:</b><br>Lodo Bentonítico: |
|  | 22.30  |                                   |               | 22                   |                              |                         |                           |  | 1.30                |                              |                         |  |
|  | Silty sand - clayey sand, gray and light brown, low plasticity, with fine sand and pebble fragments.                       |                                   |               | 23                   |                              |                         |                           |  | 1.43                |                              |                         |  |
|  | 23.75  |                                   |               | 24                   |                              |                         |                           |  | 1.63                |                              |                         |  |
|  | Arco limoso - arena arcillosa gris - café claro, con fragmentos de arena y arena fina plasticidad baja.                    |                                   |               | 25                   |                              |                         |                           |  | 1.63                |                              |                         |  |
|  | Silty sand, dark brown, silt in some parts slightly plasticity, dense, hard, with gravel traces, and pebbles in situ.      |                                   |               | 26                   |                              |                         |                           |  | 1.32                |                              |                         |  |
|  | 26.00 - 29.00  |                                   | 18/2/96       | 27                   |                              |                         |                           |  | 0.48                |                              |                         |  |
|  | Arco limoso café oscuro y negro, altamente plástico, denso, duro con trazos de grava con fragmentos de canto (patecavate). |                                   |               | 28                   |                              |                         |                           |  | 0.42                |                              |                         |  |
|  | Perforación patecavate   |                                   |               | 29                   |                              |                         |                           |  | 1.30                |                              |                         |  |
|  | Sandy material, with slight plasticity variations.   |                                   |               | 30                   |                              |                         |                           |  | 1.50                |                              |                         |  |
|  | Continúa el mismo material, con ligeras variaciones en la plasticidad.   |                                   |               | 31                   |                              |                         |                           |  | 1.50                |                              |                         |  |
|  |  |                                   |               | 32                   |                              |                         |                           |  | 1.10                |                              |                         |  |
|  |  |                                   |               | 33                   |                              |                         |                           |  | 1.10                |                              |                         |  |
|  |  |                                   |               | 34                   |                              |                         |                           |  |                     |                              |                         |  |

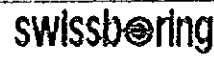
**swissboring**

WASTEWATER MANAGEMENT FOR THE  
 GUATEMALA METROPOLITAN AREA  
 Plan Maestro de Saneamiento del  
 Área Metropolitana  
 GEOTECHNIC INVESTIGATION  
 Investigación Geotécnica

BORING  
 Perforación N° B-6.7

Scale 1:50  
 Escala 1:50  
 Logged by  
 Registrado por Ing. R. Alvarado

| Stratigraphic Column<br>Column Geológica | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica  | DATE<br>FECHA | DEPTH<br>Profundidad | SAMPLES<br>Muestras | DISTURBED<br>Disturbada | SPT<br>Blows | DATA<br>Datos | CORC<br>Cone | SAMPLE RECOVERED<br>Muestra Recuperada | RECOVERED SAMPLE<br>Muestra Recuperada | SPT<br>Blows per foot | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios                 | BOREHOLE INFORMATION<br>Información del Sondeo   |   |   |   |   |   |
|--|--|---------------|----------------------|---------------------|-------------------------|--------------|---------------|--------------|--|--|-----------------------|------------------------------|---|--|---|---|---|---|---|
|  |  |               |                      |                     |                         |              |               |              |  |  |                       |                              |   |  | 1 | 2 | 3 | 4 | 5 |
| 1.00                                     | Clay silt, yellowish orange, loose, with weathered pumice and granitic rock fragments (collected material).<br>Lima arcillosa, café amarillento, suelta con fragmentos alterados de póvolca y roca granítica (material colectado).                             | 3/03/96       | 1                    | L-0.05              | 13                      | 21           | 33            | 54           | 0.43                                   | 29                                     |                       | Water level<br>Nivel de agua | NO HOLE DIAMETER<br>Diámetro del sondeo | <b>BOREHOLE</b><br>Perforación : B-8<br><b>LOCATION</b><br>Localización : CHINAUTLA<br><b>SURFACE ELEVATION</b><br>Elevación Superficial : 1220 m.<br><b>DATE STARTED</b><br>Fecha de Inicio : 3/03/96<br><b>DATE FINISHED</b><br>Fecha de Finalización : 5/03/96<br><b>DRILL RIG</b><br>Perforadora : LONG YEAR 34<br><b>INCLINATION</b><br>Inclinación : VERTICAL<br><b>TOTAL DEPTH</b><br>Profundidad Total : 30.00 m.<br><br><b>METHOD OF DRILLING</b><br>Método de Perforación :<br>ROTARY WASH BORING,<br>Levado de Muestra<br>AUGER BORING<br>Perforación con Auger :<br>ROCK CORING :<br>Núcleos de Roca : 0.00-30.00 m.<br><br><b>DRILLING FLUIDS</b><br>Fluidos de Perforación :<br>CLEAN WATER,<br>Agua clara : 0.00-30.00 m.<br>BENTONITE MUD,<br>Lodo Bentonítico : |   |   |   |   |   |
|  | Granitic rock, slightly to fully intemperized, light brown, some part with clayey silt, the original structure of the rock mass is intact.   |               | 2                    | L-0.05              | 9                       | 14           | 26            | 40           | 0.36                                   | 60                                     |                       |                              |   |  |   |   |   |   |   |
|  | Roca granítica, alta a completamente intemperizada, café claro a pardo, en parte limosa arcillosa, la estructura original de la roca permanece intacta.  |               | 3                    | L-0.05              | 12                      | 23           | 31            | 54           | 0.28                                   | 61                                     |                       |                              |   |  |   |   |   |   |   |
|  |  |               | 4                    | L-0.05              | 21                      | 34           | 50            | 84           | 0.32                                   | 74                                     |                       |                              |   |  |   |   |   |   |   |
|  |  |               | 5                    | L-0.05              | 18                      | 42           | 48            | 88           | 0.45                                   | 100                                    |                       |                              |   |  |   |   |   |   |   |
| 5.45                                     | Increase the weathering of the rock, some parts to clayey silt, light brown to greenish gray, hard, with rocky fragments.<br>Aumenta la intemperización de la roca, en partes arcillosa limosa, color café claro a gris verdoso, dura, con fragmentos rocosos. | 4/03/96       | 6                    | L-0.05              | 13                      | 33           | 50            | 83           | 0.25                                   | 55                                     |                       |                              |   |  |   |   |   |   |   |
|  |  |               | 7                    | L-0.14              | 50                      | -            | -             | 50           | 0.14                                   | 100                                    |                       |                              |   |  |   |   |   |   |   |
|  |  |               | 8                    | L-0.13              | 50                      | -            | -             | 50           | 0.15                                   | 100                                    |                       |                              |   |  |   |   |   |   |   |
|  |  |               | 9                    | L-0.12              | 50                      | -            | -             | 50           | 0.07                                   | 100                                    |                       |                              |   |  |   |   |   |   |   |
|  |  |               | 10                   | L-0.10              | 50                      | -            | -             | 50           | 0.11                                   | 100                                    |                       |                              |   |  |   |   |   |   |   |
| 8.30                                     | Granitic rock, brown to greenish, open fractures, soft, with clay and silt.<br>Roca granítica, color café a café verdoso, moderada a alta intemperización, fracturas abiertas, suelta con arcilla y siltes.  | 4/03/96       | 11                   | L-0.10              | 50                      | -            | 50            | 0.10         | 100                                    |  |                       |                              |   |  |   |   |   |   |   |
|  |  |               | 12                   | L-0.05              | 50                      | -            | 50            | 0.05         | 100                                    |  |                       |                              |   |  |   |   |   |   |   |
|  |  |               | 13                   |                     |                         |              |               |              | 0.70                                   | 55                                     |                       |                              |   |  |   |   |   |   |   |
|  | Granitic rock, moderate intemperized, greenish gray, open fractures, rough, and soft, with clay and silt.  |               | 14                   |                     |                         |              |               |              | 0.70                                   | 70                                     |                       |                              |   |  |   |   |   |   |   |
|  | Granito moderadamente intemperizado, gris verdoso, fracturas abiertas rugosas y sueltas con arcilla y siltes.  |               | 15                   |                     |                         |              |               |              | 1.10                                   | 85                                     |                       |                              |   |  |   |   |   |   |   |
| 15.30-20.40                              | Fracture zone gray silt rock   |               | 16                   |                     |                         |              |               | 1.17         | 78                                     |  |                       |                              |   |  |   |   |   |   |   |
|  |  |               | 17                   |                     |                         |              |               | 0.24         | 70                                     |  |                       |                              |   |  |   |   |   |   |   |
|  |  |               | 18                   |                     |                         |              |               | 0.90         | 82                                     |  |                       |                              |   |  |   |   |   |   |   |
|  |  |               | 19                   |                     |                         |              |               | 0.40         | 60                                     |  |                       |                              |   |  |   |   |   |   |   |
|  |  |               | 20                   |                     |                         |              |               | 0.45         | 60                                     |  |                       |                              |   |  |   |   |   |   |   |



WASTEWATER MANAGEMENT FOR THE  
 GUATEMALA METROPOLITAN AREA  
 Plan Maestro de Saneamiento del  
 Área Metropolitana  
 GEOTECHNIC INVESTIGATION  
 Investigación Geotécnica

BORING  
 Perforación N° B-8

SCALE  
 Escala 1:50  
 LOGGED BY  
 Descrito por: Ing. R. Alvarado

| Stratigraphic Change<br>Cambios Estratigráficos | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica  | GRAPHIC SYMBOL<br>Simbología Grafica | DATE<br>Fecha | DEPTH<br>Profundidad | UNDISTURBED<br>No. Disturbada | DISTURBED<br>Disturbada | 15 cm.<br>15 cm. | 25 cm.<br>25 cm. | 30 cm.<br>30 cm. | DATA<br>Date | CORE RUN<br>Muestra | SAMPLE RECOVERY<br>Puntos Recuperados | % RECOVERED SAMPLE<br>Porcentaje Recuperado | SPT<br>Blows<br>Por Foot | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios | BOREHOLE INFORMATION<br>Información del Sondeo   |
|---|--|--------------------------------------|---------------|----------------------|-------------------------------|-------------------------|------------------|------------------|------------------|--------------|---------------------|---------------------------------------|---|--------------------------|------------------------------|-------------------------|--|
|   |  |                                      |               |                      |                               |                         |                  |                  |                  |              |                     |                                       |   |                          |                              |                         |  |
|   | Grassile rock, moderate weathered, (con fracturas, bien perforada, with asides and clay.<br>Roca granítica moderadamente intemperizada, fracturas rugosas, alisada con asides y arcilla. |                                      |               | 21                   |                               |                         |                  |                  |                  |              |                     | 0.75                                  | 47  |                          |                              |                         | <b>BOREHOLE</b><br>Perforación : B-8<br><b>LOCATION</b><br>Localización : CHINAUTLA<br><b>SURFACE ELEVATION</b><br>Elevación Superficial : 1220 m.<br><b>DATE STARTED</b><br>Fecha de Inicio : 3/03/76<br><b>DATE FINISHED</b><br>Fecha de Terminación : 5/05/76<br><b>DRILL RIG</b><br>Perforadora : LONG YEAR 34<br><b>INCLINATION</b><br>Inclinación : VERTICAL<br><b>TOTAL DEPTH</b><br>Profundidad Total : 30.00 m.<br><br><b>METHOD OF DRILLING</b><br>Método de Perforación<br><b>ROTARY WASH BORING</b><br>Levado de Muestra<br><b>AUGER BORING</b><br>Perforación con Auger :<br><b>ROCK CORING</b><br>Núcleo de Roca : 0.00-30.00 m.<br><br><b>DRILLING FLUIDS</b><br>Fluidos de Perforación<br><b>CLEAN WATER</b><br>Agua clara : 0.00-30.00 m.<br><b>BENTONITE MUD</b><br>Lodo Bentonítico |
| 22-5  | Slavite clay, slightly intemperized dark brown, with clay matrix, fragille, fractured, physical bad condition.   |                                      | 5/03/76       | 22                   |                               |                         |                  |                  |                  |              |                     | 0.30                                  | 100   |                          |                              |                         |  |
|   |  |                                      |               | 23                   |                               |                         |                  |                  |                  |              |                     | 0.33                                  | 100   |                          |                              |                         |  |
|   |  |                                      |               | 24                   |                               |                         |                  |                  |                  |              |                     | 0.55                                  | 100   |                          |                              |                         |  |
|   |  |                                      |               | 25                   |                               |                         |                  |                  |                  |              |                     | 1.22                                  | 18  |                          |                              |                         |  |
|   | Block disintegrated (extremely weathered, color like coarse granitic, material fine crystalline, fragil fractured de bajo conductividad.   |                                      |               | 26                   |                               |                         |                  |                  |                  |              |                     | 0.60                                  | 89  |                          |                              |                         |  |
|   |  |                                      |               | 27                   |                               |                         |                  |                  |                  |              |                     | 1.20                                  | 60  |                          |                              |                         |  |
| 27-5  | Grassile rock, moderate to highly intemperized, fractured, with asides and clay.   |                                      |               | 28                   |                               |                         |                  |                  |                  |              |                     | 0.45                                  | 72  |                          |                              |                         |  |
|   |  |                                      |               | 29                   |                               |                         |                  |                  |                  |              |                     | 1.15                                  | 72  |                          |                              |                         |  |
|   | Roca granítica, moderada a altamente intemperizada, gran gruesa, fracturada con asides y arcillas en fracturas.  |                                      |               | 30                   |                               |                         |                  |                  |                  |              |                     | 0.85                                  | 68  |                          |                              |                         |  |

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WASTEWATER MANAGEMENT FOR THE  
GUATEMALA METROPOLITAN AREA  
Piso Muestra de Saneamiento del  
Area Metropolitana

GEOHECNIC INVESTIGATION  
Investigación Geotécnica

BORING  
Perforación N° B-8

SCALE  
Escala : 1:50

LOGGED BY  
Escrito por : Ing. R. Alvarez

| Stratigraphic Change<br>Cambios Estratigráficos | SEMI-GRAPHIC DESCRIPTION<br>Descripción Estratigráfica   | GRAPHIC SYMBOL<br>Símbolo Gráfico | DATE<br>Fecha | DEPTH<br>Profundidad | SAMPLES<br>Muestras          |                         | SPT<br>No. of Blows<br>por Pie | WATER LEVEL<br>Nivel de Agua | REMARKS<br>Comentarios | BORE-HOLE INFORMATION<br>Información del Sondeo   |
|---|--|-----------------------------------|---------------|----------------------|------------------------------|-------------------------|--------------------------------|------------------------------|------------------------|---|
|   |  |                                   |               |                      | UNDISTURBED<br>No perturbada | DISTURBED<br>Disturbada |                                |                              |                        |   |
|   | Granitic rock, fully weathered, light brown<br>Roca granítica, completamente meteorizada, color café claro | [Symbol]                          | 23/07/96      | 1                    | 1.00                         | 100                     | 100                            | 0.00                         | 100                    | <b>WATER LEVEL</b><br>Nivel de agua: 0.00 (23/07/96)<br><br><b>NO HOLE DIAMETER</b><br>Diámetro del sondeo<br><br><b>BOREHOLE :</b> B-9<br><b>Perforación :</b><br><b>LOCATION :</b> CHINAUTLA<br>Localización : CHINAUTLA<br><b>SURFACE ELEVATION :</b> 1220 m.<br>Elevación Superficial : 1220 m.<br><b>DATE STARTED :</b> 23/7/96<br>Fecha de inicio : 23/7/96<br><b>DATE FINISHED :</b> 28/7/96<br>Fecha de finalización : 28/7/96<br><b>DRILL RIG :</b> LONGYEAR 34<br>Perforadora : LONGYEAR 34<br><b>INCLINATION :</b> VERTICAL<br>Inclinación : VERTICAL<br><b>TOTAL DEPTH :</b> 30 m<br>Profundidad Total : 30 m<br><br><b>METHOD OF DRILLING</b><br>Método de Perforación<br><b>POTARY WASH BORING :</b> 0-30 m<br>Lavado de Muestra : 0-30 m<br><b>AUGER BORING :</b><br>Perforación con Auger<br><b>ROCK CORING :</b> 0-30 m<br>Núcleo de Roca : 0-30 m<br><br><b>DRILLING FLUIDS</b><br>Líquido de Perforación<br><b>CLEAN WATER :</b> 0-30 m<br>Agua clara : 0-30 m<br><b>BENTONITE MUD :</b><br>Lodo Bentonítico |
|   |  |                                   |               | 2                    | 0.30                         | 42                      |                                |                              |                        |   |
|   |  |                                   |               | 3                    | 0.03                         | 100                     |                                |                              |                        |   |
|   |  |                                   |               | 4                    | 0.50                         | 58                      |                                |                              |                        |   |
|   |  |                                   |               | 5                    | 0.40                         | 89                      |                                |                              |                        |   |
|   |  |                                   |               | 6                    | 0.43                         | 89                      |                                |                              |                        |   |
|   |  |                                   |               | 7                    | 0.08                         | 100                     |                                |                              |                        |   |
|   |  |                                   |               | 8                    | 0                            | 0                       |                                |                              |                        |   |
|   |  |                                   |               | 9                    | 0.04                         | 100                     |                                |                              |                        |   |
|   |  |                                   |               | 10                   | 0.40                         | 42                      |                                |                              |                        |   |
|   |  |                                   |               | 11                   | 0.05                         | 100                     |                                |                              |                        |   |
|   |  |                                   |               | 12                   | 0.28                         | 23                      |                                |                              |                        |   |
|   |  |                                   |               | 13                   | 0.65                         | 67                      |                                |                              |                        |   |
|   |  |                                   |               | 14                   | 0.25                         | 29                      |                                |                              |                        |   |
|   |  |                                   |               | 15                   | 0.05                         | 7                       |                                |                              |                        |   |
|   |  |                                   |               | 16                   | 0.70                         | 93                      |                                |                              |                        |   |
|   |  |                                   |               | 17                   | 0.15                         | 100                     |                                |                              |                        |   |
|   |  |                                   |               | 18                   | 1.27                         | 79                      |                                |                              |                        |   |
|   |  |                                   |               | 19                   | 1.14                         | 78                      |                                |                              |                        |   |
|   |  |                                   |               | 20                   | 0.70                         | 42                      |                                |                              |                        |   |
|   |  |                                   |               | 21                   | 1.15                         | 83                      |                                |                              |                        |   |
|   |  |                                   |               | 22                   | 0.27                         | 27                      |                                |                              |                        |   |
|   |  |                                   |               | 23                   | 1.15                         | 73                      |                                |                              |                        |   |
|   |  |                                   |               | 24                   | 1.15                         | 400                     |                                |                              |                        |   |
|   |  |                                   |               | 25                   | 0.93                         | 100                     |                                |                              |                        |   |
|   |  |                                   |               | 26                   | 0.85                         | 100                     |                                |                              |                        |   |

**swissboring**

WASTEWATER MANAGEMENT FOR THE  
GUATEMALA METROPOLITAN AREA  
Plan Maestro de Saneamiento del  
Área Metropolitana

GEOHECNIC INVESTIGATION  
Investigación Geotécnica

**BORING**  
Perforación N° B-9

SCALE: Escala: 1:50      LOGGED BY: Descrito por: Ing. R. Alvaredo

| Stratigraphic Change<br>Cambios Estratigráficos | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica   | GRAPHIC SYMBOL<br>Símbolo Gráfico | DATE<br>Fecha | DEPTH<br>Profundidad | SAMPLES<br>ANALYZED<br>Muestras<br>Analizadas | DISTURBED<br>Disturbado | SPT DATA<br>SPT<br>Blows<br>m | CORE NUM<br>Número<br>Muestra | SAMPLE RECOVERED<br>Muestra recuperada<br>%<br>Muestra Recuperada | RECOVERED SAMPLE<br>Muestra Recuperada | SPT<br>Blows<br>per foot | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios | BOREHOLE INFORMATION<br>Información del Boreo  |
|---|---|-----------------------------------|---------------|----------------------|---|-------------------------|-------------------------------|-------------------------------|---|--|--------------------------|------------------------------|-------------------------|--|
|   |   |                                   |               |                      |   |                         |                               |                               |   |  |                          |                              |                         |  |
|   | 21-22 Yellow clay, green, very fractured.<br>Diques azules, verdes, fuertemente fracturados.  |                                   |               | 21                   |   |                         |                               | 0.75                          | 100   |  |                          |                              |                         | <b>BOREHOLE</b><br>Perforación : B-9<br><b>LOCATION</b><br>Localización : CHINAUTLA<br><b>SURFACE ELEVATION</b><br>Elevación Superficial : 1220 m.<br><b>DATE STARTED</b><br>Fecha de Inicio : 23/1/96<br><b>DATE FINISHED</b><br>Fecha de finalización : 26/1/96<br><b>DRILL RIG</b><br>Perforadora : LONGYEAR 34<br><b>INCLINATION</b><br>Inclinación : VERTICAL<br><b>TOTAL DEPTH</b><br>Profundidad Total : 30 m.<br><br><b>METHOD OF DRILLING</b><br>Método de Perforación<br><b>ROTARY WASH BORING</b><br>Levado de Muestra : 0.00 - 30.00m.<br><b>AUGER BORING</b><br>Perforación con Auger :<br><b>ROCK CORING</b><br>Núcleo de Roca : 0.00 - 30.00m.<br><br><b>DRILLING FLUIDS</b><br>Líquido de Perforación<br><b>CLEAN WATER</b><br>Agua clara : 0.00 - 30.00<br><b>BENTONITE MUD</b><br>Lodo Bentonítico : |
|   | 22-23 calcareous rock, highly fractured, light gray, coarse grained.  |                                   |               | 22                   |   |                         |                               | 0.52                          | 93  |  |                          |                              |                         |  |
|   | 23-24 calcareous rock, highly fractured, light gray, coarse grained, some sandstone, rough and undulating, some sandstone with calcite.                   |                                   |               | 23                   |   |                         |                               | 1.43                          | 100   |  |                          |                              |                         |  |
|   | 24-25 fine calcareous, highly fractured, gray clay, coarse grained, densely fractured, some sandstone, rough and undulating, some sandstone with calcite. |                                   |               | 24                   |   |                         |                               | 0.82                          | 88  |  |                          |                              |                         |  |
|   | 25-26 fine calcareous, highly fractured, gray clay, coarse grained, densely fractured, some sandstone, rough and undulating, some sandstone with calcite. |                                   |               | 25                   |   |                         |                               | 0.50                          | 100   |  |                          |                              |                         |  |
|   | 26-27 fine calcareous, highly fractured, gray clay, coarse grained, densely fractured, some sandstone, rough and undulating, some sandstone with calcite. |                                   |               | 26                   |   |                         |                               | 0.70                          | 100   |  |                          |                              |                         |  |
|   | 27-28 fine calcareous, highly fractured, gray clay, coarse grained, densely fractured, some sandstone, rough and undulating, some sandstone with calcite. |                                   |               | 27                   |   |                         |                               | 0.45                          | 100   |  |                          |                              |                         |  |
|   | 28-29 fine calcareous, highly fractured, gray clay, coarse grained, densely fractured, some sandstone, rough and undulating, some sandstone with calcite. |                                   |               | 28                   |   |                         |                               | 0.85                          | 100   |  |                          |                              |                         |  |
|   | 29-30 fine calcareous, highly fractured, gray clay, coarse grained, densely fractured, some sandstone, rough and undulating, some sandstone with calcite. |                                   |               | 29                   |   |                         |                               | 1.00                          | 100   |  |                          |                              |                         |  |
|   | 30-31 fine calcareous, highly fractured, gray clay, coarse grained, densely fractured, some sandstone, rough and undulating, some sandstone with calcite. |                                   |               | 30                   |   |                         |                               | 0.90                          | 100   |  |                          |                              |                         |  |
|   | 31-32 fine calcareous, highly fractured, gray clay, coarse grained, densely fractured, some sandstone, rough and undulating, some sandstone with calcite. |                                   |               | 31                   |   |                         |                               | 0.90                          | 100   |  |                          |                              |                         |  |
|   | 32-33 fine calcareous, highly fractured, gray clay, coarse grained, densely fractured, some sandstone, rough and undulating, some sandstone with calcite. |                                   |               | 32                   |   |                         |                               | 0.75                          | 78  |  |                          |                              |                         |  |

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WASTEWATER MANAGEMENT FOR THE  
 GUATEMALA METROPOLITAN AREA  
 Plan Maestro de Saneamiento del  
 Área Metropolitana  
 GEOTECHNIC INVESTIGATION  
 Investigación Geotécnica  
 BORING  
 Perforación N° B-9

SCALE 1:50  
 DISEÑO Y  
 DIBUJO por Ing. R. Alarcón

| Stratigraphic Change<br>Cambios Estratigráficos | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica   | GRAPHIC SYMBOL<br>Símbolo Gráfico | DATE<br>Fecha | DEPTH<br>Profundidad | SAMPLES<br>Muestras          |                         |           | SPT DATA<br>SPT Datos |           |             | CORE RUN<br>Muestra | SAMPLE RECOVERY<br>Muestra Recuperada | RECOVERED SAMPLE<br>Muestra Recuperada | SPT<br>Blows per Foot | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios | BOREHOLE INFORMATION<br>Información del Sondeo |
|---|---|-----------------------------------|---------------|----------------------|------------------------------|-------------------------|-----------|-----------------------|-----------|-------------|---------------------|---------------------------------------|--|-----------------------|------------------------------|-------------------------|--|
|   |   |                                   |               |                      | UNDISTURBED<br>No perturbada | DISTURBED<br>Perturbada | 11 15 cm. | 21 15 cm.             | 31 15 cm. | NO. OF BLWS |                     |                                       |  |                       |                              |                         |  |
|   | Rock material, granite type full weathering (FWS) Light gray to light brown.  |                                   |               |                      |                              |                         |           |                       |           |             |                     |                                       |  |                       |                              |                         |  |
|   | Material fresco, tipo granito completamente meteorizado (CM), color gris claro a café.  |                                   |               |                      |                              |                         |           |                       |           |             |                     |                                       |  |                       |                              |                         |  |
|   | Granite rock, fully to slightly inter-massified, coarse grained.  |                                   |               |                      |                              |                         |           |                       |           |             |                     |                                       |  |                       |                              |                         |  |
|   | Roca granítica, completamente a altamente meteorizada, grano grueso.  |                                   |               |                      |                              |                         |           |                       |           |             |                     |                                       |  |                       |                              |                         |  |
| 3.19  | Granite rock, moderate intermassified, light brown, open fractures, with step and outcrop planes.                                       |                                   |               |                      |                              |                         |           |                       |           |             |                     |                                       |  |                       |                              |                         |  |
|   | Roca granítica, moderadamente intermasificada, color claro a blanquecino, fracturas abiertas con aristas y salidas en planos.           |                                   |               |                      |                              |                         |           |                       |           |             |                     |                                       |  |                       |                              |                         |  |
| 0.19  | Granite rock, moderate intermassified, light brown, open fractures, with step and outcrop planes.                                       |                                   |               |                      |                              |                         |           |                       |           |             |                     |                                       |  |                       |                              |                         |  |
|   | Roca granítica, moderadamente intermasificada, color claro a blanquecino, fracturas abiertas con aristas y salidas en planos.           |                                   |               |                      |                              |                         |           |                       |           |             |                     |                                       |  |                       |                              |                         |  |
| 0.42  | Granite, coarse grained, discolored, slightly to moderate intermassified, open fractures, rough, with step and outcrop.                 |                                   |               |                      |                              |                         |           |                       |           |             |                     |                                       |  |                       |                              |                         |  |
|   | Granito, cristales grandes, descolorido ligeramente a moderadamente intermasificado, fracturas abiertas, rugosas con aristas y salidas. |                                   |               |                      |                              |                         |           |                       |           |             |                     |                                       |  |                       |                              |                         |  |
|   | Granite, crystals coarse, discolored, slightly to moderate intermassified, open fractures, rough, with step and outcrop.                |                                   |               |                      |                              |                         |           |                       |           |             |                     |                                       |  |                       |                              |                         |  |
|   | Granito, cristales gruesos, descolorido ligeramente a moderadamente intermasificado, fracturas abiertas, rugosas con aristas y salidas. |                                   |               |                      |                              |                         |           |                       |           |             |                     |                                       |  |                       |                              |                         |  |
| 18.0  | Fractured zone, highly intermassified   |                                   |               |                      |                              |                         |           |                       |           |             |                     |                                       |  |                       |                              |                         |  |
|   | Zona fracturada y altamente intermasificada   |                                   |               |                      |                              |                         |           |                       |           |             |                     |                                       |  |                       |                              |                         |  |

Water level  
Nivel de agua  
4/1/96

BOREHOLE INFORMATION  
Información del Sondeo

Sheet 1/2

BOREHOLE : B-10  
Perforación : B-10

LOCATION : 1A JUEZ CREEK CHINAUTLA  
Localización : Quebrada la Juez

SURFACE ELEVATION : 1220 m.  
Elevación Superficial :

DATE STARTED : 04/01/96  
Fecha de Inicio :

DATE FINISHED : 09/01/96  
Fecha de finalización :

DRILL RIG : LONGYEAR 34  
Perforadora :

INCLINATION : VERTICAL  
Inclinación :

TOTAL DEPTH : 30 m.  
Profundidad Total :

METHOD OF DRILLING  
Método de Perforación

ROTARY WASH BORING  
Lavado de Muestra

AUGER BORING  
Perforación con Auger :

ROCK CORING : 0.00 - 30.00 m.  
Núcleo de Roca :

DRILLING FLUIDS  
Fluidos de Perforación

CLEAN WATER : 0.00 - 30.00 m.  
Agua clara :

BENTONITE MUD  
Lodo Bentonítico :

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WASTE WATER MANAGEMENT FOR THE  
GUATEMALA METROPOLITAN AREA  
Plan Maestro de Saneamiento del  
Área Metropolitana

GEOHECNIC INVESTIGATION  
Investigación Geotécnica

BORING Nº B-10  
Perforación Nº B-10

SCALE 1:50 LOGGED BY  
Escala 1:50 Registrado por Ing. R. Alvarez

| Stratigraphic Change<br>Cambios Estratigráficos | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica  | GRANULIC SYMBOL<br>Símbolo Granulico | DATE<br>Fecha | DEPTH<br>Profundidad | UNDISTURBED<br>No Disturbado | DISTURBED<br>Disturbado | 11-15 cm.<br>11-15 cm. | 21-25 cm.<br>21-25 cm. | 31-35 cm.<br>31-35 cm. | M. VALUE<br>M. Valor | CORE RATIO<br>Rat. Núcleo | SAMPLE NO.<br>Número Muestra | RECORDED SAMPLE<br>Muestra Registrada | SPT<br>No. of Blows<br>por Pie | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios | BOREHOLE INFORMATION<br>Información del Sondeo   |
|---|--|--------------------------------------|---------------|----------------------|------------------------------|-------------------------|------------------------|------------------------|------------------------|----------------------|---------------------------|------------------------------|---------------------------------------|--------------------------------|------------------------------|-------------------------|--|
|   |  |                                      |               |                      |                              |                         |                        |                        |                        |                      |                           |                              |                                       |                                |                              |                         |  |
|   | Granitic rock, slightly weathered, light brown and white. Some fractures, in general rough, with clay and silts.               |                                      |               | 21                   |                              |                         |                        |                        |                        |                      | 1.37                      | L37                          | 100                                   |                                |                              |                         | <b>BOREHOLE INFORMATION</b><br>Perforación : 8-10<br><b>LOCATION</b> : LA JUEZ CREEK CHINAUTLA<br>Localización : Quebrado la Juez<br><b>SURFACE ELEVATION</b> : 1220 m.<br>Elevación Superficial :<br><b>DATE STARTED</b> : 04/01/98<br>Fecha de Inicio :<br><b>DATE FINISHED</b> : 09/01/98<br>Fecha de Finalización :<br><b>DRILL RIG</b> : LONGYEAR 34<br>Perforadora :<br><b>INCLINATION</b> : VERTICAL<br>Inclinación :<br><b>TOTAL DEPTH</b> : 30 m.<br>Profundidad Total :<br><br><b>METHOD OF DRILLING</b><br>Método de Perforación<br><b>ROTARY WASH BORING</b><br>Lavado de Muestra<br><b>AUGER BORING</b><br>Perforación con Auger :<br><b>ROCK CORING</b> : 0.00 - 30.00 m.<br>Núcleo de Roca :<br><br><b>DRILLING FLUIDS</b><br>Fluido de Perforación<br><b>CLEAN WATER</b> : 0.00 - 30.00 m.<br>Agua Clara :<br><b>BENTONITE MUD</b> :<br>Lodo Bentonítico : |
|   | Granite, fragmentos atravesados en su estructura. Fracturas discretas, en general rugosas con arcilla y silts.                 |                                      |               | 22                   |                              |                         |                        |                        |                        |                      | 1.43                      | L43                          | 100                                   |                                |                              |                         |  |
|   |  |                                      |               | 23                   |                              |                         |                        |                        |                        |                      | 1.09                      | L09                          | 100                                   |                                |                              |                         |  |
|   |  |                                      |               | 24                   |                              |                         |                        |                        |                        |                      | 1.07                      | 107                          | 99                                    |                                |                              |                         |  |
|   | Mediumly weathered condition<br>Condición litica moderada  |                                      |               | 25                   |                              |                         |                        |                        |                        |                      | 1.27                      | L27                          | 100                                   |                                |                              |                         |  |
|   |  |                                      |               | 26                   |                              |                         |                        |                        |                        |                      | 1.42                      | L42                          | 100                                   |                                |                              |                         |  |
| 2140  | fractured zone<br>Zona de fracturación   |                                      |               | 27                   |                              |                         |                        |                        |                        |                      | 1.50                      | L50                          | 100                                   |                                |                              |                         |  |
| 2140  | Granitic rock, fresh, hard, dense, light brown to white.<br>Roca granítica, fresca, dura, densa, de color café claro a blanco. |                                      |               | 28                   |                              |                         |                        |                        |                        |                      | 0.70                      | 070                          | 100                                   |                                |                              |                         |  |
|   |  |                                      |               | 29                   |                              |                         |                        |                        |                        |                      |                           |                              |                                       |                                |                              |                         |  |
|   |  |                                      |               | 30                   |                              |                         |                        |                        |                        |                      |                           |                              |                                       |                                |                              |                         |  |

Sheet 2/2  
Hoja



WASTEWATER MANAGEMENT FOR THE  
 GUATEMALA METROPOLITAN AREA  
 Plan Maestro de Saneamiento del  
 Área Metropolitana  
 GEOTECHNIC INVESTIGATION  
 Investigación Geotécnica

BOREHOLE : N° 8-10  
 Perforación

SCALE : 1:50  
 Escala  
 LOGGED BY :  
 Escrito por: Ing. R. Alvaredo



| Stratigraphic Column<br>Columna Estratigráfica | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica   | Geologic Symbols<br>Símbolos Geológicos | DATE<br>Fecha | DEPTH<br>Profundidad | SAMPLES<br>Muestras          |                         | SPT<br>Blows<br>Golpes | CORRECTION<br>Corrección | SPT<br>Blows<br>Golpes | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios | BORE-HOLE INFORMATION<br>Información del Sondeo   |
|--|---|---|---------------|----------------------|------------------------------|-------------------------|------------------------|--------------------------|------------------------|------------------------------|-------------------------|---|
|  |   |   |               |                      | UNDISTURBED<br>No Disturbado | DISTURBED<br>Disturbado |                        |                          |                        |                              |                         |   |
| 6.55   | SILTY AND VERY FINE SANDS, BROWN, LOW PLASTICITY WITH ORGANIC MATTER.<br>Lima arcillosa, café, con arcilla, baja plasticidad con materia orgánica (MLI-O)   |   |               | 1                    |                              |                         | 3                      |                          | 0.35                   | 0.78                         |                         | <p>HOLE DIAMETER 8 1/4"<br/>Diámetro del sondeo</p> <p>WATER LEVEL 4.65m (12/12/98)<br/>Nivel de Agua</p> <p>PENETRATION PRESSURE:<br/>400 (12/98)</p> <p>METHOD OF DRILLING<br/>Método de Perforación<br/>ROTOR/WASH BORING<br/>Léveda de Muestra<br/>AUGER BORING<br/>Perforación con Auger 0.00 - 24.30 m<br/>ROCK CORING<br/>Método de Roca 24.30 - 26.00 m</p> <p>DRILLING FLUIDS<br/>Fluido de Perforación<br/>CLEAN WATER<br/>Agua Clara 24.30 - 26.00 m<br/>BENTONITE MUD<br/>Lodo Bentonítico</p> <p>swissboring</p> <p>WASTEWATER MANAGEMENT FOR THE GUATEMALA METROPOLITAN AREA<br/>Plan Maestro de Saneamiento del Área Metropolitana<br/>GEOTECHNIC INVESTIGATION<br/>Investigación Geotécnica</p> <p>SPRING<br/>Perforación N° 8-II</p> |
|  | FINE TO MEDIUM SANDS, BEIGE, WITH SILT, MEDIUM DENSE, WITH SOME VOLCANIC FRAGMENTS (ASH FLOW)<br>Arena fina a media, color beige-cremoso, con fragmentos volcánicos (cenizas púrficas)                      |   |               | 2                    |                              |                         | 3                      |                          | 0.35                   | 0.78                         |                         |   |
|  | INCREASE THE DENSITY<br>Aumentar la densidad  |   |               | 3                    |                              |                         | 3                      |                          | 0.45                   | 1.00                         |                         |   |
|  |   |   |               | 4                    |                              |                         | 16                     |                          | 0.40                   | 89                           |                         |   |
|  |   |   |               | 5                    |                              |                         | 13                     |                          | 0.40                   | 89                           |                         |   |
|  |   |   |               | 6                    |                              |                         | 19                     |                          | 0.45                   | 100                          |                         |   |
| 7.00   | SILTY SANDS, LIGHT GRAY, DENSE OF VOLCANIC COMPONENTS<br>Arena limosa, gris clara, densa de componentes volcánicos.   |   |               | 7                    |                              |                         | 64                     |                          | 0.40                   | 89                           |                         |   |
|  |   |   |               | 8                    |                              |                         | 53                     |                          | 0.35                   | 100                          |                         |   |
| 8.53   | MEDIUM TO COARSE SANDS, LIGHT BROWN, VERY DENSE, WITH SILT.<br>Arena 1/2 a gruesa, café claro muy densa, con limo.  |   |               | 9                    |                              |                         | 92                     |                          | 0.40                   | 89                           |                         |   |
| 9.55   | CLAYEY SILTS, WITH FINE SANDS, GREENISH GRAY, MEDIUM PLASTICITY, DENSE<br>Lima arcillosa, con arena fina, gris verdoso, mediana plasticidad, compacta (MH)  |   |               | 10                   |                              |                         | 30                     |                          | 0.45                   | 100                          |                         |   |
|  |   |   |               | 11                   |                              |                         | 55                     |                          | 0.45                   | 100                          |                         |   |
| 10.20  |   |   |               | 12                   |                              |                         | 6                      |                          | 0.20                   | 100                          |                         |   |
| 11.35  | COARSE SANDS WITH SILT, ORANGE YELLOWISH TO GRAY WITH FINE GRAVEL, QUARCIFEROUS, HARD.<br>Lima, café amarillento a gris, con arena fina cuarcifera muy dura   |   |               | 13                   |                              |                         | 30                     |                          | 0.30                   | 100                          |                         |   |
|  |   |   |               | 14                   |                              |                         | 50                     |                          | 0.35                   | 100                          |                         |   |
| 14.30  | CLAYEY SILTS WITH FINE SANDS, GREENISH GRAY, MEDIUM PLASTICITY, DENSE, WITH LENS OF COARSE SANDS<br>Lima arcillosa con arena fina, gris verdoso, mediana plasticidad, compacta, con lentes de arena gruesa. |   |               | 15                   |                              |                         | 40                     |                          | 0.45                   | 100                          |                         |   |
|  |   |   |               | 16                   |                              |                         | 57                     |                          | 0.43                   | 100                          |                         |   |
|  |   |   |               | 17                   |                              |                         | 30                     |                          | 0.45                   | 100                          |                         |   |
| 18.00  |   |   |               | 18                   |                              |                         | 30                     |                          | 0.45                   | 100                          |                         |   |
| 19.00  | CLAYEY, GRANITIC ROCK, GRAY, FULLY IMPREGNEZED, LOOSE   |   |               | 19                   |                              |                         | 72                     |                          | 0.45                   | 100                          |                         |   |
| 20.00  |   |   |               | 20                   |                              |                         | 72                     |                          | 0.45                   | 100                          |                         |   |

| Stratigraphic Change<br>Cambios Estratigráficos | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica  | GRAPHIC SYMBOL<br>Símbolo Gráfico | DATE<br>Fecha | DEPTH<br>Profundidad | DISTURBED<br>Disturbado |       | 15<br>15 cm | 21<br>21 cm | 27<br>27 cm | 33<br>33 cm | 39<br>39 cm | CORRECTION<br>CORRECCIÓN | RECOVERED SAMPLE<br>Muestra Recuperada | SPZ<br>No. of Blows<br>por Zap | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios  | BOREHOLE INFORMATION<br>Información del Sondeo   |
|---|--|-----------------------------------|---------------|----------------------|-------------------------|-------|-------------|-------------|-------------|-------------|-------------|--------------------------|--|--------------------------------|------------------------------|--|--|
|   |  |                                   |               |                      | 15 cm                   | 30 cm |             |             |             |             |             |                          |  |                                |                              |  |  |
|   | MICACIOUS GRANITIC ROCK, GAY,<br>HIGHLY INTENSIFIED<br>Granito micáceo, gris, altamente<br>alterado.   |                                   |               | 21                   | L-005                   | 50    | 50          |             |             |             |             | 0.25                     | 100                                    |                                |                              | HOLE DIAMETER 6 1/2"<br>Diámetro del sondeo<br><br>NO HOLE DIAMETER<br>Diámetro del sondeo<br><br>24.30 to 26.00 ROCK CORING<br>Nucleo de roca<br><br>NO HOLE DIAMETER<br>Diámetro del sondeo NO | <b>BOREHOLE INFORMATION</b><br>Perforación 18-11<br><b>LOCATION</b><br>Localización : CHINAUTLA<br><b>SURFACE ELEVATION</b><br>Elevación Superficial : 1212.545<br><b>DATE STARTED</b><br>Fecha de inicio : 12/12/95<br><b>DATE FINISHED</b><br>Fecha de finalización : 15/12/95<br><b>DRILL RIG</b> : TRUCK MOUNTED AUGER DRILL<br>Perforadora : CAMION PERFORADOR CME-55<br><b>INCLINATION</b><br>Inclinación : VERTICAL<br><b>TOTAL DEPTH</b><br>Profundidad Total : 26.00m<br><br><b>METHOD OF DRILLING</b><br>Método de Perforación<br>ROTARY WASH BORING<br>Levada de Muestra<br><b>AUGER BORING</b><br>Perforación con Auger : 0.00 - 24.30 m<br><b>ROCK CORING</b><br>Núcleo de Roca : 2.30 - 26.00 m<br><br><b>DRILLING FLUIDS</b><br>Fluido de Perforación<br><b>CLEAN WATER</b> : 24.30 - 26.00 m<br>Agua clara<br><b>BENTONITE MUD</b><br>Lodo Bentonítico |
| 2250  | GRANITIC ROCKS, FULLY INTENSIFIED<br>Granito completamente alterado  |                                   | 22            | L-000                | 50                      | 50    |             |             |             |             |             |                          | 0.10                                   | 100                            |                              |  |  |
| 2300  | GRANITIC ROCKS, MODERATE INTENSIFIED,<br>OPEN FRACTURES, SOME<br>WITH CLAY, DENSE, HARD<br>Granito moderadamente alterado,<br>fracturas abiertas, algunas con arcilla<br>denso y duro. |                                   | 23            | L-005                | 50                      | 50    |             |             |             |             |             |                          | 0.05                                   | 100                            |                              |  |  |
|   |  |                                   | 24            |                      | 50                      | 50    |             |             |             |             |             |                          | 0.58                                   | 74                             |                              |  |  |
|   |  |                                   | 25            |                      | 50                      | 50    |             |             |             |             |             |                          | 0.43                                   | 100                            |                              |  |  |
|   |  |                                   | 26            |                      | 50                      | 50    |             |             |             |             |             |                          | 0.45                                   | 100                            |                              |  |  |

| Stratigraphic Change<br>Cambios Estratigráficos | STRATIGRAPHIC DESCRIPTION -<br>Descripción Estratigráfica  | DATE<br>Fecha | DEPTH<br>Profundidad | S&W<br>No. de<br>Disturbado | PLIES<br>No. de<br>Disturbado | SPT<br>DATA<br>Cotes | CORRECTION<br>VALOR | SAMPLE RECOVERED<br>Muestra recuperada | RECORDED SAMPLE<br>Muestra Registrada | SPT<br>No. of Blows<br>por Test | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios | BOREHOLE INFORMATION<br>Información del Sondeo  |
|---|--|---------------|----------------------|-----------------------------|-------------------------------|----------------------|---------------------|--|---------------------------------------|---------------------------------|------------------------------|-------------------------|---|
|   |  |               |                      |                             |                               |                      |                     |  |                                       |                                 |                              |                         |   |
|   | Clay-silt, dark brown, some silt<br>gravel and organic content.<br>Lima arcillosa, café oscuro, con<br>grava y materia orgánica.   | 14/2/96       | 1                    | 1                           | 1                             | 15                   | 0                   | 0.40                                   | 89                                    |                                 |                              |                         | <p>HOLE DIAMETER 4 1/4"<br/>Diámetro del Sondeo</p> <p><b>BOREHOLE</b><br/>Perforación: B-12</p> <p><b>LOCATION</b><br/>Localización: INCAPIE</p> <p><b>SURFACE ELEVATION</b><br/>Elevación Superficial: 1293 m.</p> <p><b>DATE STARTED</b><br/>Fecha de inicio: 14/2/96</p> <p><b>DATE FINISHED</b><br/>Fecha de finalización: 16/2/96</p> <p><b>DRILL RIG</b> TRUCK MOUNTED AUGER DRILL CME<br/>Perforadora: CAMION PERFORADOR CME-35</p> <p><b>INCLINATION</b><br/>Inclinación: VERTICAL</p> <p><b>TOTAL DEPTH</b><br/>Profundidad Total: 30.45 m.</p> <p><b>METHOD OF DRILLING</b><br/>Método de Perforación:<br/>ROTARY WASH BORING,<br/>Lavado de Muestra<br/>AUGER BORING<br/>Perforación con Auger<br/>ROCK CORING<br/>Núcleo de Roca: 0.00 - 30.45 m.</p> <p><b>DRILLING FLUIDS</b><br/>Fluidos de Perforación:<br/>CLEAN WATER<br/>Agua clara: 0.00 - 30.45 m.<br/>BENTONITE MUD<br/>Lodo Bentonítico</p> <p><b>swissboring</b></p> <p>WASTEWATER MANAGEMENT FOR THE<br/>GUATEMALA METROPOLITAN AREA<br/>Plan Maestro de Saneamiento del<br/>Área Metropolitana</p> <p>GEOTECHNIC INVESTIGATION<br/>Investigación Geotécnica</p> <p>BORING<br/>Perforación N° B-12</p> <p>SCALE 1:150 LOGGED BY: Ing. R. Alvarado</p> |
| 1.00  | Gravelly sands, brown and gray, little<br>or no fines.<br>Arena gruesa, café y gris, pocas ma-<br>terias finas. (S&W)  |               | 2                    | 1                           | 1                             | 16                   | 0                   | 0.40                                   | 89                                    |                                 |                              |                         |   |
|   | Gravels, silt or no fines, medium to<br>coarse grades.<br>Gravas, con pocas finas tamaño 1/2 a<br>gruesas.   |               | 3                    | 2                           | 1                             | 11                   | 0                   | 0.25                                   | 56                                    |                                 |                              |                         |   |
|   |  |               | 4                    | 2                           | 1                             | 10                   | 0                   | 0.15                                   | 60                                    |                                 |                              |                         |   |
|   |  |               | 5                    | 2                           | 1                             | 24                   | 0                   | 0.15                                   | 33                                    |                                 |                              |                         |   |
|   |  |               | 6                    | 2                           | 1                             | 24                   | 0                   | 0.40                                   | 40                                    |                                 |                              |                         |   |
|   |  |               | 7                    | 2                           | 1                             | 34                   | 0                   | 0.20                                   | 20                                    |                                 |                              |                         |   |
|   |  |               | 8                    | 2                           | 1                             | 30                   | 0                   | 0                                      | 0                                     |                                 |                              |                         |   |
|   |  |               | 9                    | 2                           | 1                             | 24                   | 0                   | 0.45                                   | 100                                   |                                 |                              |                         |   |
|   | Silty-sands, light brown, with med-<br>ium sands.<br>Arena limosa, café claro, con arena<br>limosa.  |               | 10                   | 2                           | 1                             | 31                   | 0                   | 0.38                                   | 84                                    |                                 |                              |                         |   |
|   |  |               | 11                   | 2                           | 1                             | 32                   | 0                   | 0.40                                   | 89                                    |                                 |                              |                         |   |
|   | Medium sands, brown-gray, with silt,<br>Arise media, café gris con arena.  |               | 12                   | 2                           | 1                             | 24                   | 0                   | 0.38                                   | 84                                    |                                 |                              |                         |   |
|   | Silt and fine sands, light brown, loose.<br>Limo y arena fina, café claro, suelta.   | 15/2/96       | 13                   | 2                           | 1                             | 29                   | 0                   | 0.42                                   | 93                                    |                                 |                              |                         |   |
|   | Silt and fine sands interbedded with<br>coarse sand particles and fine gravels.<br>Limo y arena fina interestratigráfica<br>con partículas de arena gruesa, cenizas<br>fina y arena gruesa fina. |               | 14                   | 2                           | 1                             | 27                   | 0                   | 0.43                                   | 100                                   |                                 |                              |                         |   |
|   |  |               | 15                   | 2                           | 1                             | 27                   | 0                   | 0.35                                   | 78                                    |                                 |                              |                         |   |
|   |  |               | 16                   | 2                           | 1                             | 28                   | 0                   | 0.30                                   | 67                                    |                                 |                              |                         |   |
|   |  |               | 17                   | 2                           | 1                             | 29                   | 0                   | 0.38                                   | 87                                    |                                 |                              |                         |   |
|   |  |               | 18                   | 2                           | 1                             | 33                   | 0                   | 0.50                                   | 87                                    |                                 |                              |                         |   |
|   |  |               | 19                   | 2                           | 1                             | 14                   | 0                   | 0                                      | 0                                     |                                 |                              |                         |   |
|   |  |               | 20                   | 2                           | 1                             |                      |                     |  |                                       |                                 |                              |                         |   |



| Stratigraphic Change<br>Cambios Estratigráficos | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica  | GRAPHIC SYMBOL<br>Símbolo Gráfico | DATE<br>Fecha | DEPTH<br>Profundidad | UNDISTURBED<br>No Disturbado | SAMPLE NO.<br>No. Muestra | SPT<br>Blows | DATE<br>Fecha | COR. NUM.<br>Número | SAMPLE RECOVERED<br>Muestra Recuperada | RECOVERED SAMPLE<br>Muestra Recuperada | SPT<br>No. of Blows<br>por Pie | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios                     | BOREHOLE INFORMATION<br>Información del Sondeo  |                      |
|---|--|-----------------------------------|---------------|----------------------|------------------------------|---------------------------|--------------|---------------|---------------------|--|--|--------------------------------|------------------------------|---|---|----------------------|
|   |  |                                   |               |                      |                              |                           |              |               |                     |  |  |                                |                              |   |   | DEPTH<br>Profundidad |
|   | Clayey silt, and clay, dark brown, smooth with fragments pebbles and some salt levels (argenteo contains with clay or slightly plasticity) |                                   | 24/02/96      | 1                    |                              |                           |              |               |                     |  |  |                                |                              | NO HOLE DIAMETER<br>Diámetro de perforación | <b>BOREHOLE :</b> B-13<br><b>Perforación :</b><br><b>LOCATION :</b> BOCA DEL MONTE<br><b>Localización :</b><br><b>SURFACE ELEVATION :</b> 1302 m.<br><b>Elevación Superficial :</b><br><b>DATE STARTED :</b> 24/02/96<br><b>Fecha de Inicio :</b><br><b>DATE FINISHED :</b> 27/02/96<br><b>Fecha de Finalización :</b><br><b>DRILL RIG :</b> LONG YEAR 34<br><b>Perforadora :</b><br><b>INCLINATION :</b> VERTICAL<br><b>Inclinación :</b><br><b>TOTAL DEPTH :</b> 60.00 m.<br><b>Profundidad Total :</b><br><br><b>METHOD OF DRILLING</b><br><b>Método de Perforación</b><br>ROTARY WASH BORING,<br>Lavado de Muestra<br>AUGER BORING<br>Perforación con Auger<br>ROCK CORING<br>Núcleo de Roca : 0.00 - 60.00 m<br><br><b>DRILLING FLUIDS</b><br><b>Fluido de Perforación</b><br>CLEAN WATER,<br>Agua clara : 0.00 - 60.00 m.<br>BENTONITE MUD,<br>Lodo Bentonítico |                      |
|   | Lima arcillosa pastosa, color oscuro azulado, con algunas niveles de suelo (esta materia argentea y pastosa elemento plástico.)            |                                   |               | 2                    |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   | Silty sands, light brown, smooth, some with clay and little mica fragments   |                                   |               | 3                    |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   | Arenas limosas, color claro, suaves, texturas, con arcillas o pequeñas fragmentos de mica.   |                                   |               | 4                    |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   | Fine pebbles, whitish to light brown, no stem or root traces with little silt and sand pebbles fragments.                                  |                                   |               | 5                    |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   | Coquea pequeñas, blanquecinos a color claro, tamaño medio, texturas, con pequeñas capas de arena.  |                                   |               | 6                    |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   | Clayey silt, pale yellow orange, dense, possible pebbles level   |                                   |               | 7                    |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   | Lima arcillosa, color amarillento, densa, posible nivel de pedruzcos.  |                                   |               | 8                    |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   | Sandy silt, light brown, with pebbles and fragments.   |                                   |               | 9                    |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   | Lima arenosa, color claro, con fragmentos de coquea pastosa.   |                                   |               | 10                   |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   | Fine sands with silt, whitish, with large pebbles fragments.   |                                   |               | 11                   |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   | Arenas finas con limo, blanquecino con fragmentos grandes de pedruzcos.  |                                   |               | 12                   |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   | Tuffaceous and pebbles ash, fine grained white and pink colors with some salt levels.  |                                   |               | 13                   |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   | Coquea tobaca y pedruzcos, grano fino, color blanco y rosado, con algunos niveles de pedruzcos.  |                                   |               | 14                   |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   |  |                                   |               | 15                   |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   |  |                                   |               | 16                   |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   |  |                                   |               | 17                   |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   | Fine sands, interbedded with silt and fine ash, gray to light brown color, homogeneous.  |                                   |               | 18                   |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   | Alternancia de arenas finas con limo y cenizas finas, color claro a castaño rojizo, homogéneo.   |                                   |               | 19                   |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |
|   |  |                                   |               | 20                   |                              |                           |              |               |                     |  |  |                                |                              |   |   |                      |

| Stratigraphic Change<br>Cambio Estratigráfico | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica   | DATE<br>Fecha | DEPTH<br>Profundidad | SAMPLES<br>No. de Muestras | DISTURBED<br>Disturbado | SPT<br>Blows | DATA<br>Fecha | VALU<br>Valor | CORE NUM<br>No. de Muestra | SAMPLE RECOVERED<br>Muestra Recuperada | RECORDED SAMPLE<br>Muestra Registrada | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios   | BOREHOLE INFORMATION<br>Información del Sondeo  |                            |
|---|---|---------------|----------------------|----------------------------|-------------------------|--------------|---------------|---------------|----------------------------|--|---------------------------------------|------------------------------|---|---|----------------------------|
|   |   |               |                      |                            |                         |              |               |               |                            |  |                                       |                              |   |   | UNSATURATED<br>No Saturado |
|   | Fine sands, interbedded with silts and fine ash, grayish to light brown, homogeneous.               | 25/02/96      | 21                   | L-0.14                     | 11                      | 0-43         | 30-95         | 0.45          | 100                        |  |                                       |                              | NO HOLE DIAMETER<br>Diámetro del sondeo<br><br>Swilly #1, Pressure 200 l/pul. | <b>BOREHOLE</b><br>Perforación: B-13<br><b>LOCATION</b><br>Localización: BOCA DEL MONTE<br><b>SURFACE ELEVATION</b><br>Elevación Superficial: 1502 m.<br><b>DATE STARTED</b><br>Fecha de Inicio: 24/02/96<br><b>DATE FINISHED</b><br>Fecha de Finalización: 27/02/96<br><b>DRILL RIG</b><br>Perforadora: LONG YEAR 34<br><b>INCLINATION</b><br>Inclinación: VERTICAL<br><b>TOTAL DEPTH</b><br>Profundidad Total: 60.00 m. |                            |
|   |   |               | 22                   | L-0.15                     | 11                      | 0-43         | 25-28         | 27-53         | 0.43                       | 100                                    |                                       |                              |   |   |                            |
|   | Alternancia de arenas finas con limas y cenizas finas, gris claro a café claro, cohesión homogénea. |               | 23                   | L-0.16                     | 11                      | 0-43         | 47-50         | -50           | 0.25                       | 100                                    |                                       |                              |   |   |                            |
|   |   |               | 24                   | L-0.17                     | 11                      | 0-43         | 47-50         | -50           | 0.29                       | 100                                    |                                       |                              |   |   |                            |
|   |   |               | 25                   | L-0.18                     | 11                      | 0-43         | 49            | -50           | 0.20                       | 100                                    |                                       |                              |   |   |                            |
|   |   |               | 26                   | L-0.19                     | 11                      | 0-43         | 49            | -50           | 0.23                       | 100                                    |                                       |                              |   |   |                            |
|   |   |               | 27                   | L-0.20                     | 11                      | 0-43         | 46            | 50            | 0.25                       | 100                                    |                                       |                              |   |   |                            |
|   |   |               | 28                   | L-0.21                     | 11                      | 0-43         | 49            | -50           | 0.23                       | 100                                    |                                       |                              |   |   |                            |
|   | stem material   |               | 29                   | L-0.22                     | 11                      | 0-43         | 46            | 50            | 0.23                       | 100                                    |                                       |                              |   |   |                            |
|   |   |               | 30                   | L-0.23                     | 11                      | 0-43         | 30            | 50            | 0.23                       | 100                                    |                                       |                              |   |   |                            |
|   |   | 31            | L-0.24               | 11                         | 0-43                    | 13           | 21            | 4             | 37                         | 0.43                                   | 100                                   |                              |   |   |                            |
|   |   | 32            | L-0.25               | 11                         | 0-43                    | 20           | 50            | 0.30          | 100                        |  |                                       |                              |   |   |                            |
|   | Fine to coarse sands, grayish, interbedded with sandy silts, light brown.                           | 33            | L-0.26               | 11                         | 0-43                    | 32           | 50            | 0.30          | 100                        |  |                                       |                              |   |   |                            |
|   | Arenas finas a medias grises claro con limas arenosas, café claro.                                  | 34            | L-0.27               | 11                         | 0-43                    | 20           | 50            | 0.30          | 100                        |  |                                       |                              |   |   |                            |
|   |   | 35            | L-0.28               | 11                         | 0-43                    | 20           | 50            | 0.30          | 100                        |  |                                       |                              |   |   |                            |
|   |   | 36            | L-0.29               | 11                         | 0-43                    | 30           | 50            | 0.30          | 100                        |  |                                       |                              |   |   |                            |
|   |   | 37            | L-0.30               | 11                         | 0-43                    | 50           | -             | 0.13          | 100                        |  |                                       |                              |   |   |                            |
|   | Fine sands to silty sands, grayish, with some beds of clay silts.                                   | 38            | L-0.31               | 11                         | 0-43                    | 29-34        | 41-82         | 0.21          | 47                         |  |                                       |                              |   |   |                            |
|   | Arenas finas a medias grises, con algunas capas de limas arcillosas.                                | 39            | L-0.32               | 11                         | 0-43                    | 34           | 50            | 0.18          | 40                         |  |                                       |                              |   |   |                            |
|   |   | 40            | L-0.33               | 11                         | 0-43                    | -            | -             | -             | -                          |  |                                       |                              |   |   |                            |

Sheet 2/3  
Hoja



WASTEWATER MANAGEMENT FOR THE  
 GUATEMALA METROPOLITAN AREA  
 Plan Maestro de Saneamiento del  
 Área Metropolitana

GEO TECHNIC INVESTIGATION  
 Investigación Geotécnica

BOREHOLE  
 Perforación N° B-13

SCALE 1:50  
 LOGGED BY  
 DESCRITO POR Ing. R. Alvarado

| Stratigraphic Change<br>Cambio Estratigráfico | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica   | DATE<br>Fecha | DEPTH<br>Profundidad | DISTURBANCE<br>Perturbación | CORRECTION<br>Corrección | SPT<br>Blows<br>per foot | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios | BOREHOLE INFORMATION<br>Información del Sondeo   |
|---|---|---------------|----------------------|-----------------------------|--------------------------|--------------------------|------------------------------|-------------------------|--|
|   |   |               |                      |                             |                          |                          |                              |                         |  |
|   | Thin sands in silty sands, grayish with some beds of clayey silts.  | 24/02/96      | 41                   | L-0010                      | 0.04                     | 29                       |                              |                         | <b>BOREHOLE:</b><br>Perforación: B-13<br><b>LOCATION:</b><br>Localización: BOCA DEL MONTE<br><b>SURFACE ELEVATION:</b><br>Elevación Superficial: 1302 m.<br><b>DATE STARTED:</b><br>Fecha de Inicio: 24/02/96<br><b>DATE FINISHED:</b><br>Fecha de Finalización: 27/02/96<br><b>DRILL RIG:</b><br>Perforadora: LONG YEAR 34<br><b>INCLINATION:</b><br>Inclinación: VERTICAL<br><b>TOTAL DEPTH:</b><br>Profundidad Total: 160.00 m. |
|   | Ardenas finas a arena limosa, gris clara, con algunas capas de limo arcillosa.  |               | 42                   | L-0011                      | 0.20                     | 62                       |                              |                         |  |
|   |   |               | 43                   | L-0012                      | 0.16                     | 60                       |                              |                         |  |
|   |   |               | 44                   | L-0013                      | 0.17                     | 55                       |                              |                         |  |
|   | Fine to medium grained sands, grayish to dark gray, loose, with some of silty light brown.                                      |               | 45                   | L-0014                      | 0.14                     | 100                      |                              |                         |  |
|   | Ardenas finas a medias, gris clara a oscura, sueltas, con limos arena de color claro.   |               | 46                   | L-0015                      | 0.15                     | 78                       |                              |                         |  |
|   |   |               | 47                   | L-0016                      | 0.14                     | 81                       |                              |                         |  |
|   |   |               | 48                   | L-0017                      | 0.13                     | 100                      |                              |                         |  |
|   |   |               | 49                   | L-0018                      | 0.23                     | 55                       |                              |                         |  |
|   |   |               | 50                   | L-0019                      | 0.14                     | 90                       |                              |                         |  |
|   |   | 27/02/96      | 51                   | L-0020                      | 0.15                     | 100                      |                              |                         |  |
|   |   |               | 52                   | L-0021                      | 0.19                     | 100                      |                              |                         |  |
|   |   |               | 53                   | L-0022                      | 0.23                     | 100                      |                              |                         |  |
|   | Pefferaceous and pumiceous, dark brown, dense, hard, with large pebbles. Fragmentos de arena oscura, gruesa.                    |               | 54                   | L-0023                      | 0.18                     | 62                       |                              |                         |  |
|   |   |               | 55                   | L-0024                      | 0.11                     | 44                       |                              |                         |  |
|   | Coarse to heavy and pebbles, calcareous, dense, con fragmentos grandes de conchas y algunos fragmentos de arena oscura, gruesa. |               | 56                   | L-0025                      | 0.07                     | 63                       |                              |                         |  |
|   |   |               | 57                   | L-0026                      | 0.10                     | 59                       |                              |                         |  |
|   |   |               | 58                   | L-0027                      | 0.12                     | 48                       |                              |                         |  |
|   |   |               | 59                   | L-0028                      |                          |                          |                              |                         |  |
|   |   |               | 60                   | L-0029                      |                          |                          |                              |                         |  |

Sheet No. 3/3



WASTEWATER MANAGEMENT FOR THE GUATEMALA METROPOLITAN AREA  
 Plan Maestro de Saneamiento del Area Metropolitana  
 GEOTECHNIC INVESTIGATION  
 Investigación Geotécnica  
 BORING Perforación N° B-13  
 SCALE Escala: 1:50 LOGGED BY: Ing. R. Alvarado  
 Drawn by: [Signature]

| Stratigraphic Change<br>Cambios Estratigráficos | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica   | GRAPHIC SYMBOL<br>Símbolo Gráfico | DATE<br>Fecha | DEPTH<br>Profundidad | UNDISTURBED<br>Registros | DISTURBED<br>Disturbado | SPT<br>Blows | DATA<br>Notes | WATER LEVEL<br>Nivel del Agua | COMMENTS<br>Comentarios | BOREHOLE INFORMATION<br>Información del Sondeo  |
|---|---|-----------------------------------|---------------|----------------------|--------------------------|-------------------------|--------------|---------------|-------------------------------|-------------------------|---|
|   | Clay-silt, light brown, loose with organic contents.<br>Lima arcillosa, castaño, suelta con materia orgánica.         |                                   | 1/2/96        | 1                    | L-0.27                   | 8                       | 3            | 10-15         | 0.27                          | 60                      | HOLE DIAMETER 6 1/4"<br>Diámetro del sondeo<br><br>BOREHOLE Perforación : 8-14<br>LOCATION Localización : LOS ALAMOS<br>SURFACE ELEVATION Elevación Superficial : 1271 m.<br>DATE STARTED Fecha de Inicio : 1/2/96<br>DATE FINISHED Fecha de finalización : 3/2/96<br>DRILL RIG Perforadora : WIRTH<br>INCLINATION Inclinación : VERTICAL<br>TOTAL DEPTH Profundidad Total : 30.45 m.<br><br>METHOD OF DRILLING Método de Perforación : ROTARY WASH BORING, Levado de Muestra<br>AUGER BORING Perforación con Auger : 0.00 - 30.45 m.<br>ROCK CORING Núcleo de Roca :<br><br>DRILLING FLUIDS Fluido de Perforación : CLEAN WATER, Agua clara, 0.00 - 30.45 m.<br>BENTONITE MUD Lodo Bentonítico |
|   | Clay-silt, light brown, with calcareous fragments.<br>Lima arcillosa, café claro, con fragmentos calcáreos.           |                                   |               | 2                    | L-0.45                   | 7                       | 10           | 11-22         | 0.45                          | 100                     |   |
|   | Pumiceous ash, white and light brown, loose, smooth.  |                                   |               | 3                    | L-0.48                   | 7                       | 9            | 7-14          | 0.45                          | 100                     |   |
|   | Calcarenaceous, blocky calcareous, coarse, sandy.   |                                   |               | 4                    | L-0.70                   | 4                       | 9            | 14            |                               |                         |   |
|   |   |                                   |               | 5                    | L-0.47                   | 4                       | 9            | 14            | 0.45                          | 100                     |   |
|   |   |                                   |               | 6                    | L-0.45                   | 8                       | 11           | 10-22         | 0.45                          | 100                     |   |
|   |   |                                   |               | 7                    | L-0.45                   | 7                       | 12           | 13-25         | 0.45                          | 100                     |   |
|   |   |                                   |               | 8                    | L-0.45                   | 6                       | 7            | 4-13          | 0.45                          | 100                     |   |
|   | Silty-clay, light brown, smooth<br>Arcilla limosa, café claro, suelta   |                                   |               | 9                    | L-0.45                   | 6                       | 7            | 8-15          | 0.45                          | 100                     |   |
|   |   |                                   |               | 10                   | L-0.45                   | 4                       | 12           | 16-28         | 0.45                          | 100                     |   |
|   | Clay-silt, light brown, with calcareous levels (paleosol)<br>Arcilla, limosa, suelta, con niveles de suelo (paleosol) |                                   | 11            | L-0.45               | 9                        | 12                      | 15-27        | 0.45          | 100                           |                         |   |
|   | Pumiceous ash, white and light brown, smooth, loose.<br>Ceniza pumicea, blanca o café claro, suelta, suelta.          |                                   | 12            | L-0.45               | 0                        | 14                      | 9-9          | 0.45          | 100                           |                         |   |
|   |   |                                   | 13            | L-0.45               | 2                        | 13                      | 35-48        | 0.45          | 100                           |                         |   |
|   | Clay-silt, fine pumiceous ash white to whitish, dense, loose, with small pumice fragments.                            |                                   | 14            | L-0.45               | 17                       | 33                      | 43-79        | 0.45          | 100                           |                         |   |
|   | Lima arcillosa, ceniza pumicea fina blanca o blanquecina, suelta con pequeños fragmentos de cenizas.                  |                                   | 15            | L-0.45               | 22                       | 34                      | 34-68        | 0.45          | 100                           |                         |   |
|   |   |                                   | 16            | L-0.45               | 20                       | 41                      | 47-83        | 0.45          | 100                           |                         |   |
|   |   |                                   | 17            | L-0.45               | 23                       | 48                      | 50-94        | 0.45          | 100                           |                         |   |
|   |   |                                   | 18            | L-0.45               | 23                       | 48                      | 50-96        | 0.45          | 100                           |                         |   |
|   | Non. material   |                                   | 19            | L-0.45               | 24                       | 50                      | - 50         | 0.45          | 100                           |                         |   |
|   |   |                                   | 20            |                      |                          |                         |              |               |                               |                         |   |



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BORING Perforación N° B-14

SCALE Escala : 1:50 LOGGED BY Registrado por : Ing. R. Alvarado



| Stratigraphic Change<br>Cambios Litológicos | STRATIGRAPHIC DESCRIPTION<br>Descripción Estratigráfica  | GRAPHIC SYMBOL<br>Símbolos Gráficos | DATE<br>Fecha | DEPTH<br>Profundidad | UNDISTURBED<br>No Disturbado | DISTURBED<br>Disturbado | SPT<br>Blows | SPT DATA<br>SPT Data | CORE RUN<br>Muestra | SAMPLE NO./CONCRETO<br>Número de Muestra | RECOVERED SAMPLE<br>Muestra Recuperada | SPS<br>No. of Blows<br>por Pie | WATER LEVEL<br>Nivel de Agua | COMMENTS<br>Comentarios | BOREHOLE INFORMATION<br>Información del Sondeo |  |        |
|---|--|-------------------------------------|---------------|----------------------|------------------------------|-------------------------|--------------|----------------------|---------------------|--|--|--------------------------------|------------------------------|-------------------------|--|--|--------|
|   |  |                                     |               |                      |                              |                         |              |                      |                     |  |  |                                |                              |                         |  | 15 cm.   | 30 cm. |
|   | Clayey-silt, fine particles and white to whitish, dense, tests with small particle fragments.<br>Lima arcillosa, con partículas grana fine, blanco blanquecino, densa, con fragmentos pequeños de arena. |                                     | 2/2/96        | 21                   |                              |                         |              | 23 38                | 24 75               |  | 0.45                                   | 100                            |                              |                         |  | <p><b>BOREHOLE</b><br/>Perforación : B-14</p> <p><b>LOCATION</b><br/>Localización : LOS ALAMOS</p> <p><b>SURFACE ELEVATION</b><br/>Elevación Superficial : 1271 m.</p> <p><b>DATE STARTED</b><br/>Fecha de inicio : 1/2/96</p> <p><b>DATE FINISHED</b><br/>Fecha de finalización : 3/2/96</p> <p><b>DRILL RIG</b><br/>Perforadora : WIRTH</p> <p><b>INCLINATION</b><br/>Inclinación : VERTICAL</p> <p><b>TOTAL DEPTH</b><br/>Profundidad Total : 30.45 m.</p> <p><b>METHOD OF DRILLING</b><br/>Método de Perforación<br/>ROTARY WASH BORING,<br/>Lavado de Muestras<br/>AUGER BORING<br/>Perforación con Auger : 0.00 - 30.45 m.<br/>ROCK CORING :<br/>Núcleos de Roca</p> <p><b>DRILLING FLUIDS</b><br/>Fluido de Perforación<br/>CLEAN WATER : 0.00 - 30.45 m.<br/>Agua clara<br/>BENTONITE MUD :<br/>Lodo Bentonítico</p> |        |
| 22  |  |                                     |               |                      |                              |                         | 12 35        | 37 72                |                     | 0.45                                     | 100                                    |                                |                              |                         |  |  |        |
| 23  |  |                                     |               |                      |                              |                         | 14 31        | 35 64                |                     | 0.45                                     | 100                                    |                                |                              |                         |  |  |        |
| 24  |  |                                     |               |                      |                              |                         | 15 31        | 37 68                |                     | 0.45                                     | 100                                    |                                |                              |                         |  |  |        |
| 25  |  |                                     |               |                      |                              |                         | 13 30        | 34 64                |                     | 0.45                                     | 100                                    |                                |                              |                         |  |  |        |
| 26  |  |                                     |               |                      |                              |                         | 14 34        | 41 79                |                     | 0.45                                     | 100                                    |                                |                              |                         |  |  |        |
| 27  |  |                                     |               |                      |                              |                         | 10 40        | 35 75                |                     | 0.45                                     | 100                                    |                                |                              |                         |  |  |        |
| 28  |  |                                     |               |                      |                              |                         | 12 41        | 46 87                |                     | 0.45                                     | 89                                     |                                |                              |                         |  |  |        |
| 29  |  |                                     |               |                      |                              |                         | 6 33         | 42 75                |                     | 0.45                                     | 100                                    |                                |                              |                         |  |  |        |
| 30  |  |                                     |               |                      |                              |                         | 30 00        | 100                  |                     | 0.45                                     | 100                                    |                                |                              |                         |  |  |        |
|   |  |                                     | 3/2/96        | 30                   |                              |                         |              | 27 42                | 48 90               |  | 0.45                                   | 100                            |                              |                         |  |  |        |

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Escala