1.7.3 Types of Waste to be Disposed of

The landfill is part of the SWM service operated by the GDF. Therefore, the types of waste is those whose management is within the jurisdiction of the GDF: that is, they are solid waste from household and institutions (offices, schools, etc.), non-hazardous industrial waste and disinfected medical waste.

1.7.4 Key Design Data

Key data for landfill design are set as follows.

- bulk density of waste after compaction in landfill: 800kg/m^3
- operation schedule of landfill: 24 hours/day, 365 days/year
- life year of trucks and heavy equipment: 7 years
- life year of building and civil works: 30 years
- daily (intermediate) soil cover: 30cm
- final landfill elevation: 24m

1.7.5 Landfill Capacity

Capacity of the planed landfill is 30,242m^3. Of the capacity, 29,032m^3 will be occupied with waste and 1,210 m^3 with soil (See Table 1-5 and Figure 1-2).

All the waste disposed of in 2002, 2003 and 2004, and part of waste in 2007 are to be placed in the lift of 0-8m elevation. The rest of waste in 2007 and all waste in 2008 are to be disposed of in the lift of 8-16m elevation. The remaining capacity of the landfill after 2010 will be 7,598m^3 for waste disposal, i.e., 6,078 ton of waste (See Table 1-4).

Table 1-4: Waste Disposal Amount in Etapa V

Unit: 1,000m^3

Elevation	Landfill capacity	Waste disposal amount 2002	2003	2004	2007	2008	Total	Remaining capacity
0-8m	14,720	4,511	4,366	4,231	1,612		14,720	0
8-16m	9,220				2,563	4,151	6,714	2,506
16-24m	5,092							5,092
Total	29,032	4,511	4,366	4,231	4,175	4,151	21,434	7,598

Table 1-5: Landfill Capacity of Etapa V

Height (m)	Total volume ($1,000m^3$)	Waste volume ($1,000m^3$)	Soil volume ($1,000m^3$)
0	0	0	0
1	2,012	1,932	80
2	3,996	3,836	160
3	5,952	5,714	238
4	7,881	7,566	315
5	9,784	9,393	391
6	11,660	11,194	466
7	13,509	12,969	540
8	15,333	14,720	613
9	16,599	15,935	664
10	17,846	17,132	714
11	19,074	18,311	763
12	20,284	19,473	811
13	21,474	20,615	859
14	22,647	21,741	906
15	23,801	22,849	952
16	24,937	23,940	997
17	25,652	24,626	1,026
18	26,351	25,297	1,054
19	27,036	25,955	1,081
20	27,705	26,597	1,108
21	28,361	27,227	1,134
22	29,002	27,842	1,160
23	29,629	28,444	1,185
24	30,242	29,032	1,210

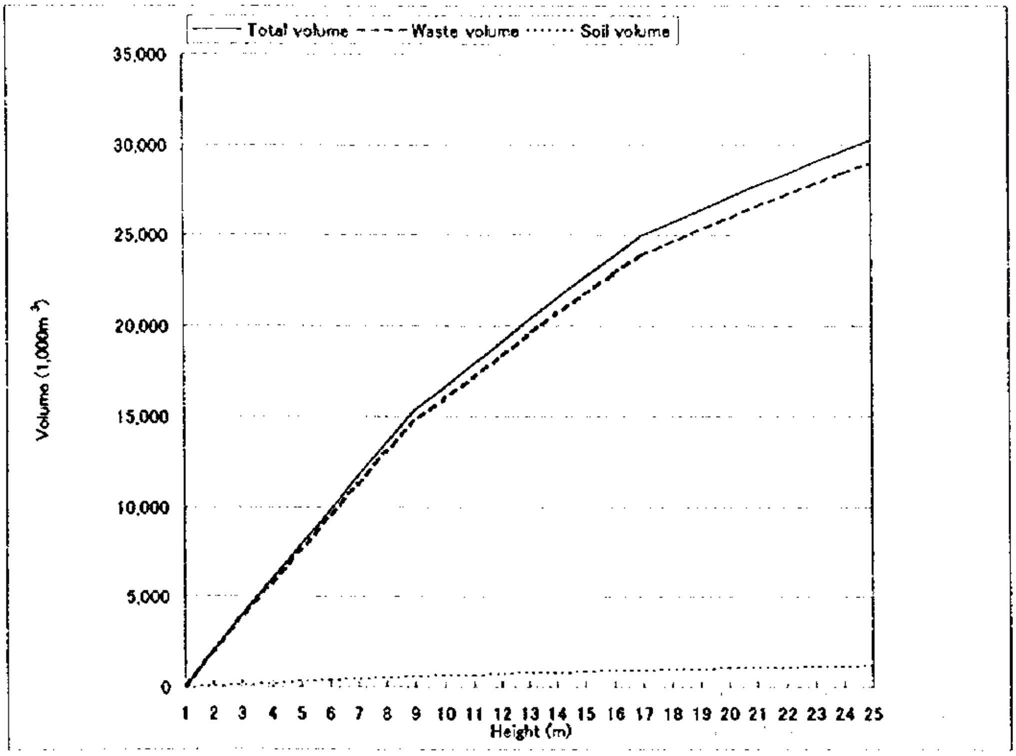


Figure 1-2: Height - Volume Curve (Etapa V)

1.7.6 Site Preparation

When the site is prepared for landfill, it is important to properly seal the salt making wells on the site in order to avoid potential risk of leachate to deeply infiltrate into the stratum under the landfill. Bentonite is used to seal them.

1.7.7 Access

1.7.7.1 Access to the Site

An access road of 605m will be constructed from the autopista to the site. The road has dimensions of:

- Carriage width: 20.0m
- Sidewalk width: 4.0m at both sides
- Shoulder width: 1.0m at both sides
- Pavement: asphalt t =10cm, gravel t =40cm

1.7.7.2 Access in the site

A ring road will be constructed along the filling area at 0m elevation. The road functions as a main road in the site, and connects the access road to inner roads. Also the ring road will be utilized as a maintenance and monitoring road. In order to approach to waste unloading areas, inner roads in the filling area at 0m elevation will be constructed.

At 8m and 16m elevation, inner roads and outer roads establish a network to secure accessibility to waste unloading areas.

Dimension of the ring road:

- Carriage width: 20.0m
- Sidewalk width: 4.0m at both sides
- Shoulder width: 1.0m at both sides
- Pavement: asphalt t =10cm, gravel t =40cm

Dimension of the inner and outer road:

- Carriage width: 9.0m
- Shoulder width: 0.5 m at both sides
- Pavement: volcanic porous rocks or equivalent material, t =30cm

1.7.8 Landfill Layout

The landfill has facilities to operate sound waste disposal management. The facilities proposed are:

- a gate;
- weighbridges (2) and a control room;
- a tire washing pit;
- a site office;
- a garage;

- a car park; and
- a parking area for heavy equipment and/or a storage yard.

Layout of the landfill is shown in Figure 1-3, and waste transport control facilities are presented in Figure 1-4.

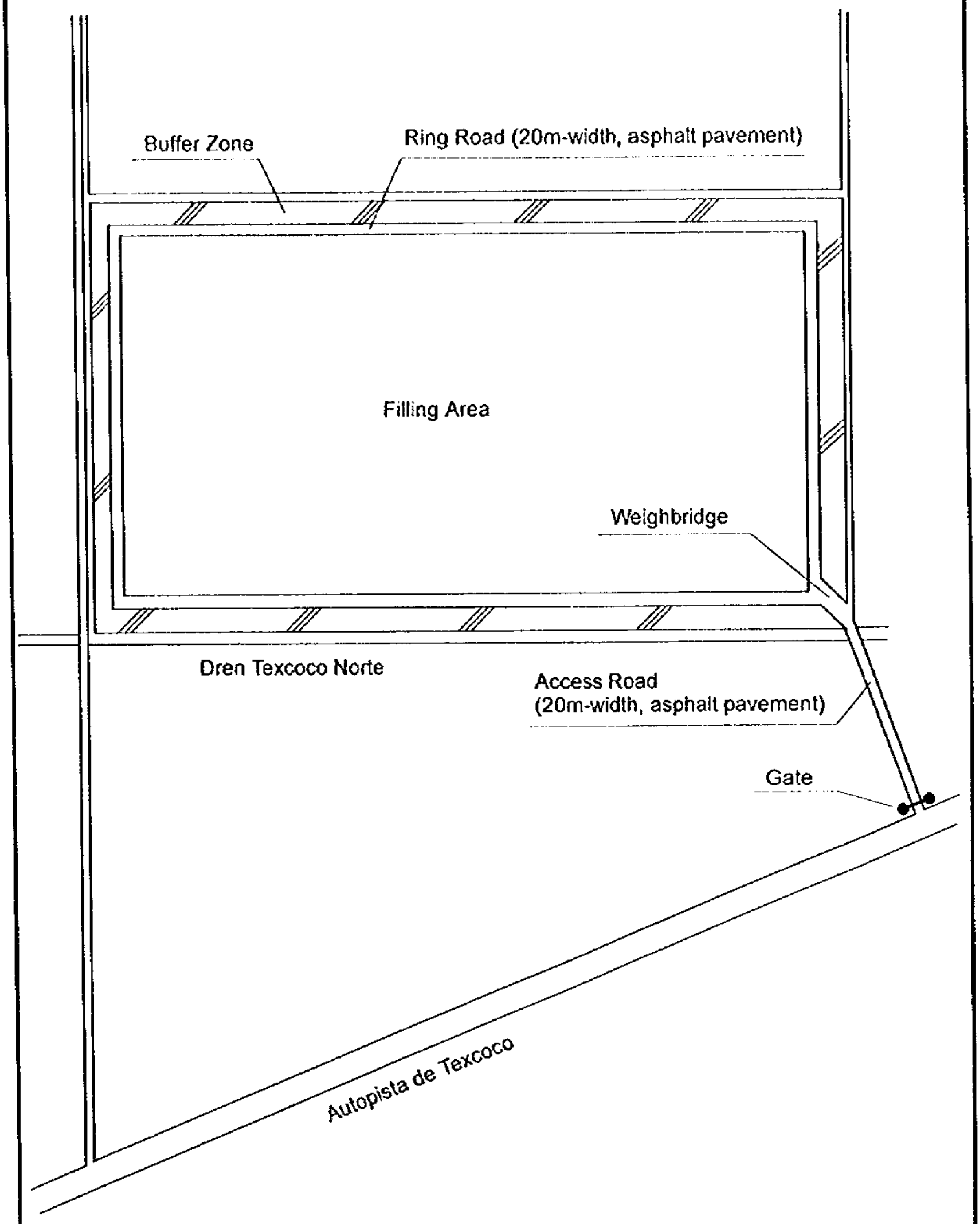


Figure 1-3:

Landfill Layout of Etapa V

KOKUSAI KOGYO Co., Ltd.

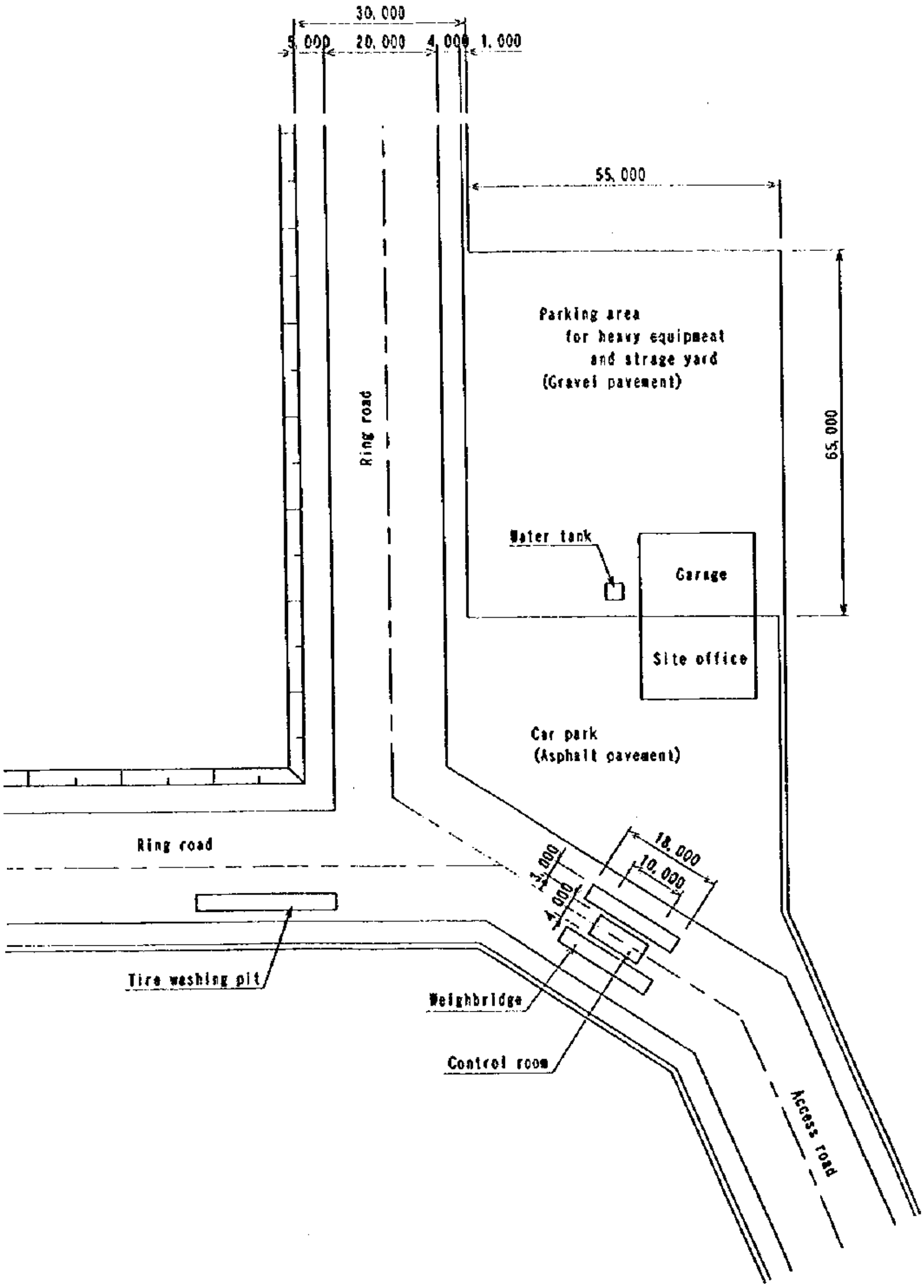


Figure1-4:

Plan of Waste Transport Control Facilities

KOKUSAI KOGYO Co., Ltd.

1.7.9 Leachate Management

Daily (intermediate) cover, whether native soil or compost, must properly be placed in order to minimize infiltration of rainfall. The top surface of the landfill should have an inclination for encouraging runoff on it.

Leachate generated in the landfill is to be sprayed by submergible pumps from leachate extraction wells. Pumps are necessary to get leachate out of the landfill due to the site's character (flat ground and anticipated subsoil settlement). Spraying leachate is to make good use of the climate character (small precipitation and large evaporation).

During operation, it is anticipated that 101mm/year of leachate will be generated[2]. This results in 196,000m^3/year of leachate generation in total. This amount of leachate will be extracted and sprayed by 15 submergible pumps. Leachate will show acidity in a certain stage of waste decomposition, and will contain a large amount of suspended solid. Therefore, it is anticipated that such character of leachate will make the lifetime of pumps short. The life time is assumed to be two years, although it depends on actual quality and quantity of leachate.

1.7.10 Landfill Gas Management

The passive control manner is to be employed for the landfill gas management. Uncontrolled dispersion of the gas from the landfill surface will be minimized by installation of gas removal pipes. PVC pipes with diameter of 200mm will be constructed along the ring road and the outer roads, and concrete pipes with 600mm diameter will be the inner part of the landfill. Some of the concrete pipes are also to be used for leachate extraction wells.

1.7.11 Surface Water Management

As mentioned above, the top surface of landfill should be sloped in order to encourage runoff on it. An inclination of 2% is applied.

1.7.12 Aesthetic Design Consideration

70m width of buffer zone is to be secured in order to mitigate harmful effects of landfilling on the surroundings.

To avoid waste to be blown to the surroundings, mobile screens are used near the operating area.

Proper daily (intermediate) soil cover should be practiced in order to control birds, pests and vectors as well as to avoid wind-blown wastes.

[2] Under a set of assumptions and a given precipitation of 597mm/year, the following is estimated:

Runoff	83mm/year
Infiltration	514mm/year
Evapotranspiration	413mm/year
Percolation through cover soil	101mm/year
Retention capacity under the soil cover	282mm/year (to be filled in about 3 years)
Leacate generation	101mm/year (in the 4th year onward)

1.7.13 Closure and Post-closure Care

60cm of thickness of final cover will be employed when the landfill operation is completed. Major purposes of the final cover are i) to reduce leachate generation, ii) to avoid uncontrolled landfill gas diffusion, and iii) to improve outward appearance.

Greening of the landfill surface is to be effective to encourage evapotranspiration on the surface, and this results in the reduction of leachate generation. It will also have an effect on improving the appearance of the site.

1.7.14 Landfill Equipment

Equipment will be used alternately in Etapa IV and Etapa V, comprising:

- four (4) bulldozers (300hp class) for spreading and compacting both waste and cover material;
- two (2) sprinkler trucks (15,000liters class) for dust control; and
- two (2) excavators (85hp class) for maintenance of roads and landfill slopes.

The bulldozers should properly be equipped for landfilling, e.g., trash blade for waste handling, measures to prevent a radiator from being plugged with waste, etc.

1.7.15 Operation

Etapa IV landfill has been operated in a proper manner, e.g., impermeable bottom liner installation, daily (intermediate) soil cover, recording waste amount disposed of by using weighbridges, etc., so that such manner will be employed for the operation of Etapa V. What should be paid attention will only be a way of leachate disposal and filling plan for the multi-lift. The way of leachate disposal is mentioned before in the section of Leachate Management, and how to pile up the landfill is described in the next section of Sequence of BP-V Construction.

1.8 Sequence of BP-V Construction

In view of current problems related with leachate in the BP-IV, improvement in design and construction sequence should be elaborated for the BP-V project. The bottom impermeabilization should be a holistic: i.e., it should be continuos from one cell to another and to the roads bottom as well) and its outer anchorage should be in such an elevation that the leachate generated from the buried wastes should always be contained in the holistic bottom impermeabilization.

In order to attain a holistic impermeability and to carry out efficient landfilling operation and leachate management for the BP-V project, the following components should be carried out in an appropriate sequential manner:

a. Site preparation work
b. Impermeabilization
c. Leachate collection and drainage line along outer road slope bottom
d. Inner road on impermeabilization
e. Leachate collection and drainage line on the inner road slope bottom
f. East-west inner roads and leachate drainage line
g. Construction of leachate suction pit with vertical pump-up shaft

h. Off-limits marking around suction pits
i. Landfilling operation (0.0 meter to 8.0 meter elevation)
j. Approach road (from 0.0 meter to 8.0 meter elevation) construction
k. Expansion of vertical shaft and landfilling of off-limits marking area
l. Leachate pump-up and spray (and/or impound) at 8.0 meter elevation

c'. Outer road and leachate drainage line along it (8.0 meter elevation)
d'. Inner road (8.0 meter elevation) construction
e'. Inner road as leachate collection and drainage line (8.0 meter elevation)
f'. East-west inner roads and leachate drainage line
g'. Extension of vertical pump-up shaft (8.0 meter elevation)
h'. Off-limits marking around vertical shafts (8.0 meter elevation)
i'. Landfilling operation (8.0 meter to 16.0 meter elevation)
j'. Approach road (from 8.0 meter to 16.0 meter elevation) construction
k'. Expansion of vertical shaft and landfilling of off-limits marking area
l'. Leachate pump-up and spray (and/or impound) at 16.0 meter elevation

c''. Outer road and leachate drainage line along it (16.0 meter elevation)
d''. Inner road (16.0 meter elevation) construction
e''. Inner road as leachate collection and drainage line (16.0 meter elevation)
f''. East-west inner roads and leachate drainage line
g''. Extension of vertical pump-up shaft (16.0 meter elevation)
h''. Off-limits marking around vertical shafts (16.0 meter elevation)
i''. Landfilling operation (16.0 meter to 24.0 meter elevation)
j''. Approach road (from 16.0 meter to 24.0 meter elevation) construction
k''. Expansion of vertical shaft and landfilling of off-limits marking area
l''. Leachate pump-up and spray (and/or impound) at 24.0 meter elevation.

a. Site Preparation Earthwork

Meanwhile, the formation level of the outer road should be determined so that the outer road is passable in all weather condition, in addition to what mentioned above (i.e., the anchorage level should be high enough for containing the leachate inside the cells even if when its generation fluctuates with precipitation etc.).

In this context, it is recommended that when the cells' bottom impermeabilization is assumed to be placed on the 0.0 meter elevation, the outer anchorage of the impermeabilization should be on about **1.50** meter elevation.

Therefore, the site preparation earthwork should take place before impermeabilization work, in which the cells' bottom should be smoothly leveled as the 0.0 meter elevation, and the embankment for the outer road is formed with the dimensions of: top width about **30** meter on the **1.50** meter elevation, with **1:2.0 slope**.

b. Impermeabilization

The impermeable liner should be **anchored** at about **4.0** meter off-set from the inner top edge of the outer road embankment with sufficient anchorage length and depth and should be extended from the anchorage point to: 4.0 meter width flat embankment top, its inner slope, and toward the cell area. For the liner protection, tepetate should be placed on the road part (50 cm thick in avoiding possible damage by traffic), the inner slope (30 cm thick) and the cell area (50 cm thick).

c. Outer Road Construction

The embankment of the outer road has the top width about 30 meter consisting of 20 meter road width and 5 meter width sidewalk on both sides. The 20 meter road should be an asphalt pavement on a crushed stone road base layer. All inner edge of the inner sidewalk should receive **asphalt bituminous treatment** in order to comply satisfactory impermeabilization for the containment of leachate inside the cells and to protect the bottom of landfill slope from possible rainwater erosion in a long period of landfill service life.

c.1 Leachate Collection and Drainage Lines Along Outer Road Slope Bottom

It is recommended that the leachate collection and drainage lines should form a holistic net. Therefore, as the outer ring of the leachate drainage net, the inner slope and bottom of the outer road should receive gabion of porous volcanic rocks (**30 cm thick**).

d. Inner Road on Impermeabilization

The initial inner road should be extended from the south end outer road on the E-coordinate: **E-120.00** (which is **120 meter** west offset from the east end outer road) northward, in order to enclose the first cell with four roads (1.0 km east end out road, 120 meter south end road from E-0.00 to E120.00, 1.0 km initial inner road on E-120.00, and 120 meter north end road from E-0.00 to E-120.00).

The second inner road, with the same manner for the initial inner road, should be constructed on the E coordinate E-240.00 northward from the south end outer road. The third should be on E-360.00 and the fourth on E-480.00 etc. Consequently, **15 south-north** inner roads in total will be constructed.

The 2nd cell is enclosed with the 1st and 2nd inner roads, the 3rd cell with the 2nd and 3rd inner roads.

The dimensions of inner road should be: 10 meter width on the road top at 1.0 meter elevation and 1:2.0 slopes on both sides.

e. Leachate Collection and Drainage Lines on the Inner Road Slope

Porous volcanic rocks with a sectional dimension of about **2.0 meter width by 50 cm height** should be provided as a leachate drainage line along the inner road slope. The **leachate drainage line** should always be allocated at the **western slope** of inner roads, since the eastern slope first receive the wastes to be disposed of and the inner road should be indispensable for constructing the leachate suction pits and vertical pump-up shafts.

Consequently **15 south-north** leachate drainage lines in total on the inner road western slope bottom will be constructed.

f. East-West Inner Roads and Leachate Drainage Line

With an objective of appropriately integrating the outer ring leachate draining line and **15 south-north** leachate drainage lines on the inner road western slope bottom, it is proposed to provide two (2) numbers of **east-west** leachate draining lines with an interval of **350** meters.

In this context, two (2) numbers of **east-west** inner roads with an interval of **350** meters should be constructed. The **east-west leachate drainage line** should be allocated at the **northern slope** of the roads, since the southern slope first receive the wastes to be disposed of and the inner road is utilized for constructing the leachate suction pits and vertical pump-up shafts.

By allocating two **east-west** inner roads, the 1st Cell is divided into three cells of: **1A**, **1B** and **1C** from south to north. In the same manner, the 2nd Cell is divided into: **2A**, **2B** and **2C**.

g. Construction of Leachate Suction Pit with Vertical Pump-Up Shaft

As the BP-V site is also located on a flat plain area, the leachate collection system can not employ gravity draining to a treatment (e.g., evaporation lagoon/regulation pond, biological or physical-chemical treatment). Therefore, it is recommended to install suction pits (with vertical pump-up shaft) on porous volcanic leachate draining lines on **0.5 meter elevation** with an appropriate interval with each other. The interval of suction pits are recommended to be, as the vertical shafts for pumping up leachate can also be utilized as biogas removal facilities (i.e., chimneys).

The suction pits with vertical shafts should be constructed prior to the landfilling operation nearby. The vertical shaft, in the initial instance, should be constructed up to such an elevation (e.g. about up to 3.0 meter elevation) that the works can be easily carried out with an access from the inner road elevation.

h. Off-limits Marking around Suction Pit

In order to avoid damage to the suction pits and half-extended vertical shafts by trailers and landfill machinery, off-limits marking with temporary poles and colorful plastic tape fencing should be provided encircling the suction pits with a sufficient radius distance.

i. Landfilling Operation (0.0 to 8.0 meter elevation)

The landfilling operation in the BP-V should be started from the **1A** cell to northward, then the **1B** and **1C** cells.

When the **1A** cell is landfilled, the area enclosed with four (4) roads should be landfilled northward from the south end outer road. Embankment shaping and soil cover operations should also be proceeded northward from the south end outer road.

When the **1B** cell starts to be landfilled:

- the 110 meter section of the **east-west** inner road between 1A and 1B cells should also be landfilled at the same time except the "off-limits marking area" around the suction pits.

When the **1C** cell starts to be landfilled,

- the 110 meter sections on north end outer roads should also be landfilled, except the "off-limits marking area" around the suction pits, in order to form final shaping of northern slope from the northern outer road to 8.0 meter elevation.

When the **2A** cell starts to be landfilled northward,

- the 350 meter section of the **south-north** inner road between 1A and 2A cells should also be landfilled at the same time except the "off-limits marking area" around the suction pits.

When the **2B** cell starts to be landfilled northward:

- the 110 meter section of the **east-west** inner road between 2A and 2B cells; and
- the 350 meter section of the **south-north** inner road between 1B and 2B cells should also be landfilled at the same time except the "off-limits marking area" around the suction pits.

When the **2C** cell starts to be landfilled northward:

- the 110 meter section of the northern outer road; and
- the 350 meter section of the **south-north** inner roads should also be landfilled at the same time except the "off-limits marking area" around the suction pits.

The same manner of landfilling operation should be repeated for the other cells as well.

j. Approach Road to 8.0 Meter Elevation

An approach road (ramp) to the 8.0 meter elevation should be planned prior to any work to be implemented from the 8.0 meter elevation.

As the trailers pass the weighbridge located in the entrance of the BP-V site, the ramp is recommended to be located at the No. 1A Cell. The slope will have to be about 5.0% (8.0 meter lift on 160 meter approach) considering the trafficability in all weather condition.

The width of this ramp **(5% slope)** should be wide enough only to have **one-way** traffic of trailers. When the landfilling operation of 8.0 to 16.0 meter elevation takes place, traffic volume on the ramp becomes large, then at that time, this ramp (5% slope) should be exclusively used as ascending ramp and **another descending ramp (e.g. 10 to 15% slope)** will have to be provided at an appropriate location by that time.

k. Expansion of Vertical Shaft and Landfilling of Off-limits Marking Area

Works of vertical shafts expansion should be started, when landfilling (up to 8.0 meter elevation) operation nearby finishes.

This time, **access** for the works of "vertical shaft extension" and "off-limits marking area landfilling" should be from 8.0 meter elevation. These two types of works should **alternately** be raised by **a few meters** height, so that the vertical shaft expansion works can be easily and properly implemented.

l. Leachate Pump-Up and Spray (and/or Impound) on 8.0 Meter Elevation

When the off-limits marking area around vertical shaft is filled and flat 8.0 meter elevation areas are formed, leachate should be pumped up and sprayed (and/or impounded) at the flat area to be evaporated or re-infiltrated to the landfill.

m. Roads on 8.0 Meter Eelevation

When the BP-V landfill is going to be raised above 8.0 meter elevation, the outer ring roads on 8.0 meter elevation should be maintained as "monitoring and maintenance" roads. In response to this concept, coordinates of the outer roads on 8.0 meter elevation should be determined.

After the landfill is raised from 8.0 to 16.0 meter elevation, inner roads on 8.0 meter elevation should be utilized as leachate drainage lines. Therefore, when the landfill is raised to 8.0 meter elevation, the inner roads should be constructed with volcanic porous rocks, which are estimated to be cheap as a road construction material, and it will later work as french drain of leachate. The volcanic porous rocks should be laid thick enough to attain trafficability of trailers on 8.0 meter elevation roads, since they lie on highly compressible buried wastes.

The inner roads on 8.0 meter elevation should be constructed just a little off-set from the vertical shafts, as the roads should later function as leachate drainage lines, the drainage lines of volcanic porous rocks on 8.0 meter elevation should be connected to the vertical shafts nearby.

n. Landfilling Sequence of 8.0 to 16.0 Meter Elevation

In general, it might be recommendable that the second level landfilling should be started from the central part to outer area considering to promote stable settlement and consolidation and further to reduce the small possibility of slope failure on 0.0-8.0 meter landfills by spending more time to allow consolidation of ground under slopes.

Meanwhile, when expecting better trafficability on 16.0 meter elevation roads in the future, the cell which receives an approach ramp from 8.0 meter to 16 meter elevation should be initially constructed in order to allow longer time for stable settlement and consolidation of the cell.

Therefore, it is recommended that the landfilling of 8.0-16.0 meter should start from the cell that will later receive the approach ramp (8.0 to 16.0 meter), which will be about 100 meter offset from the ascending ramp of 0.0 to 8.0 meter.

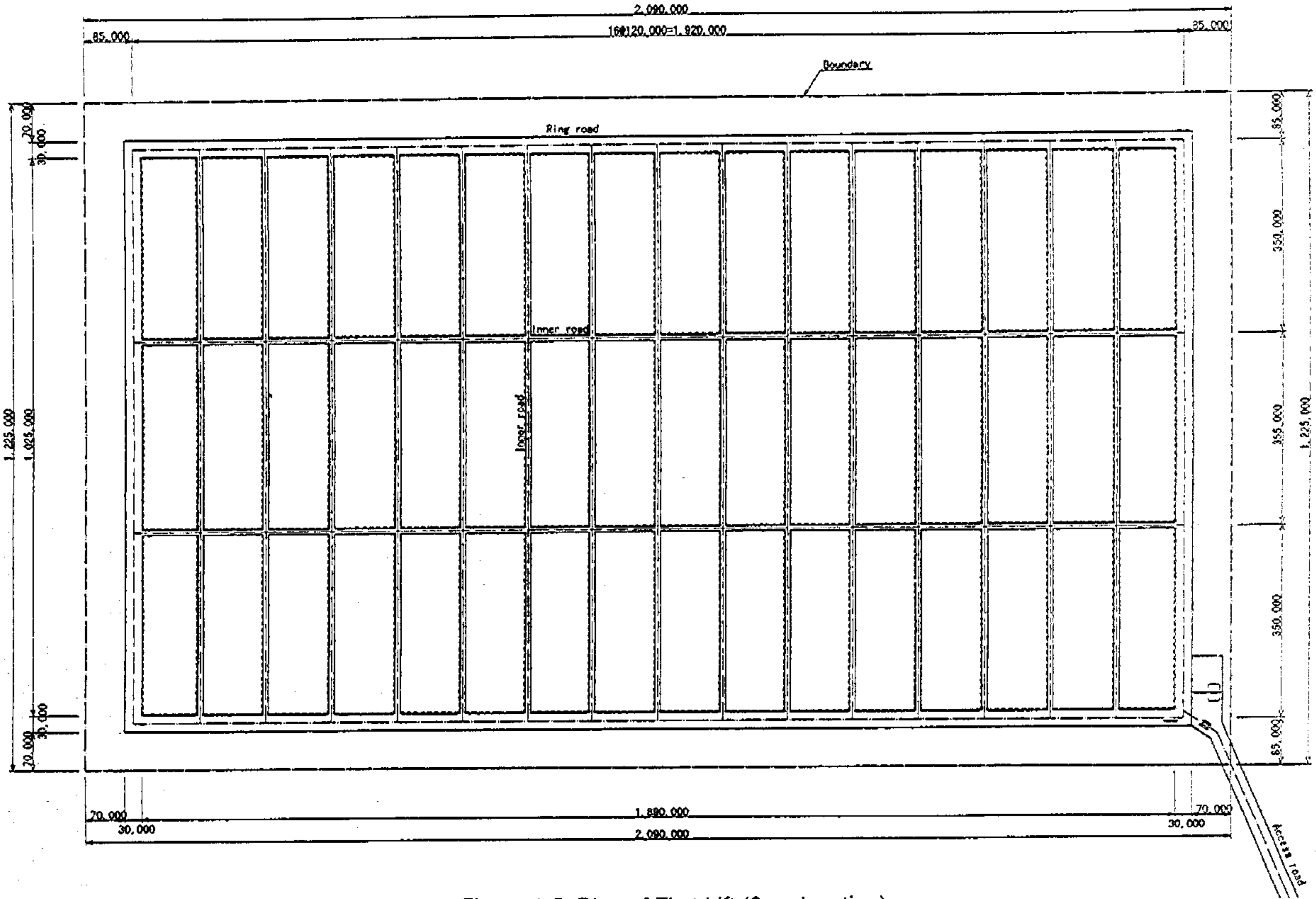


Figure 1-5: Plan of First Lift (0m elevation)

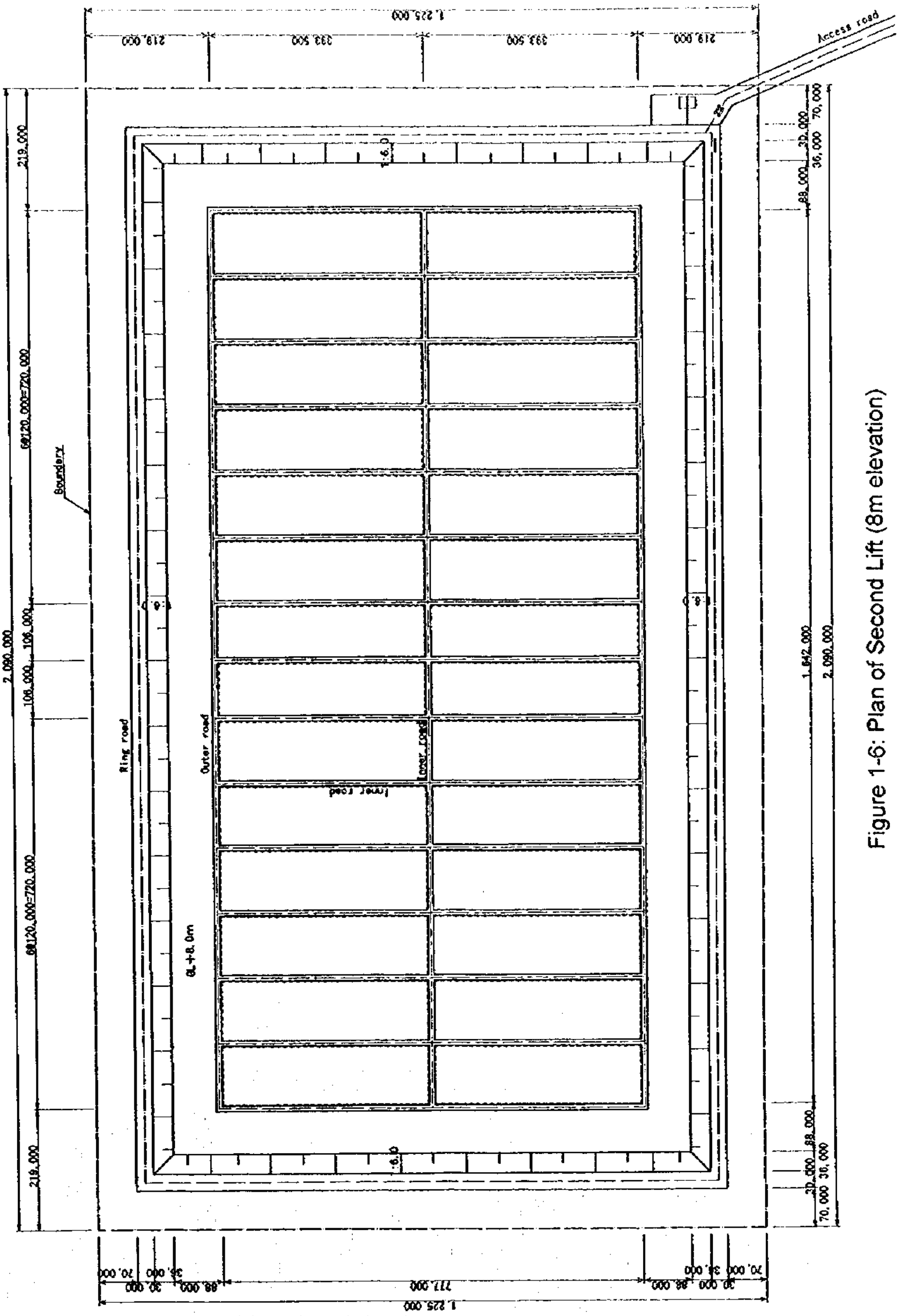


Figure 1-6: Plan of Second Lift (8m elevation)

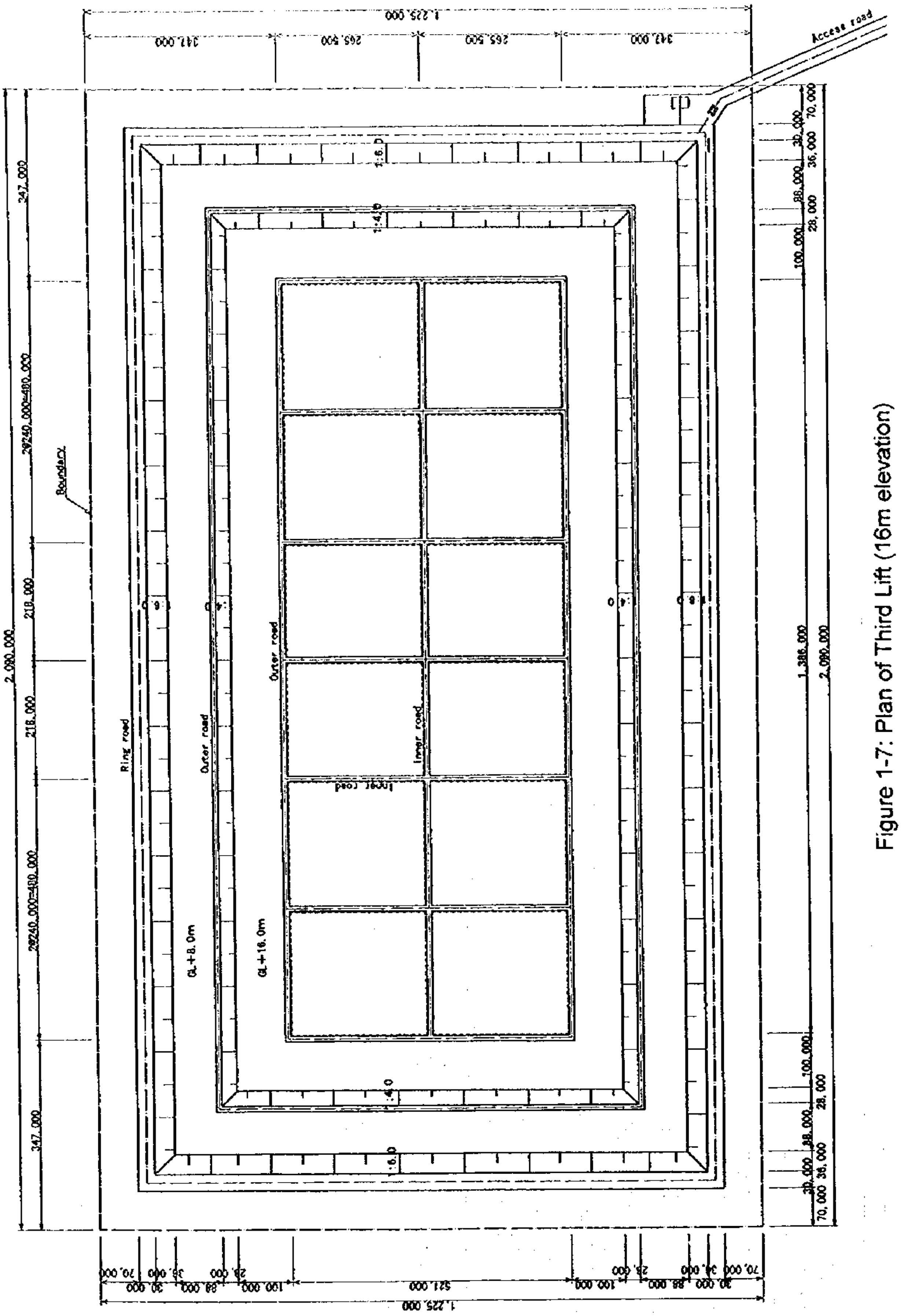


Figure 1-7: Plan of Third Lift (16m elevation)

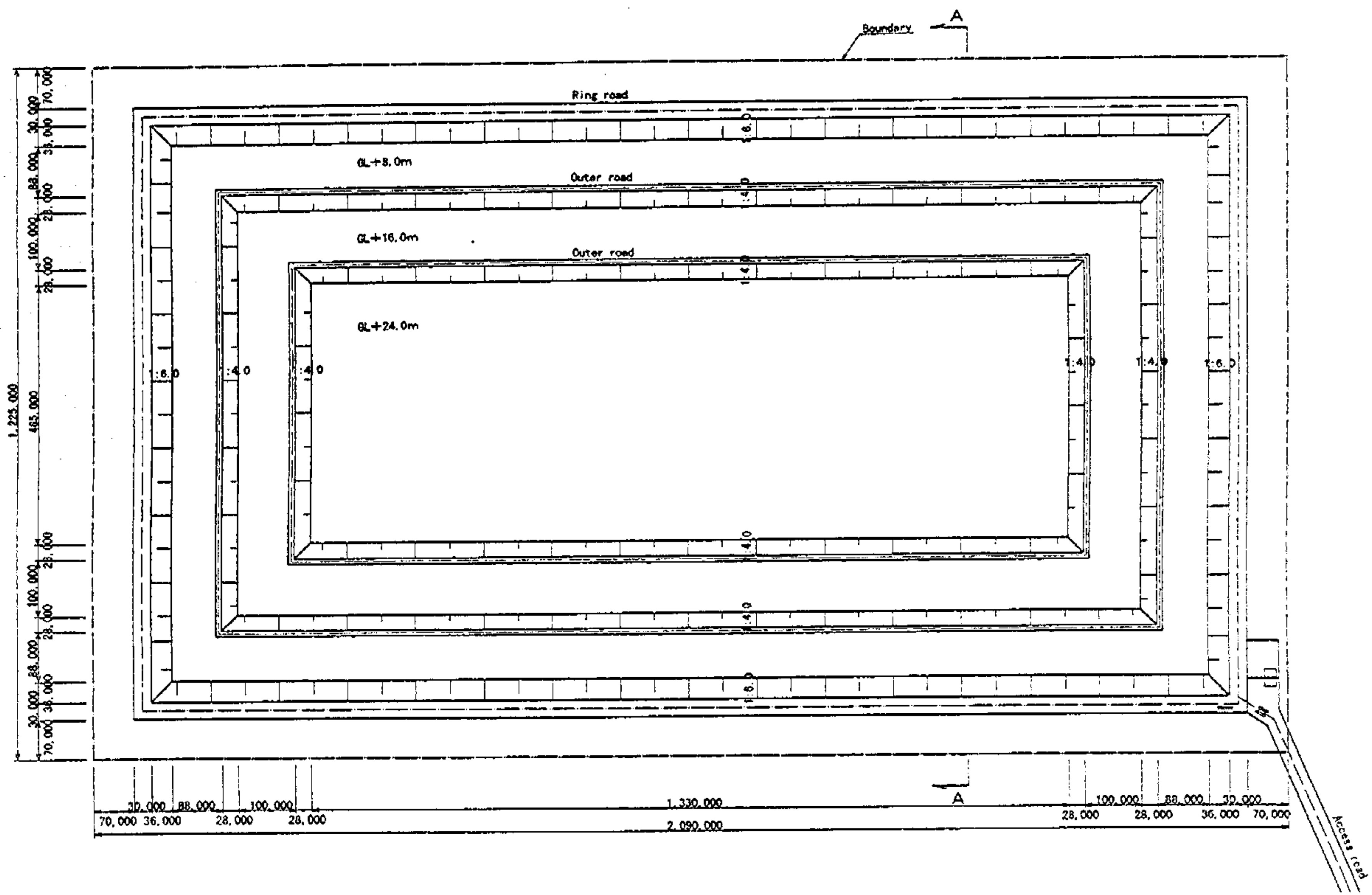


Figure 1-8: Plan of Finished Landfill

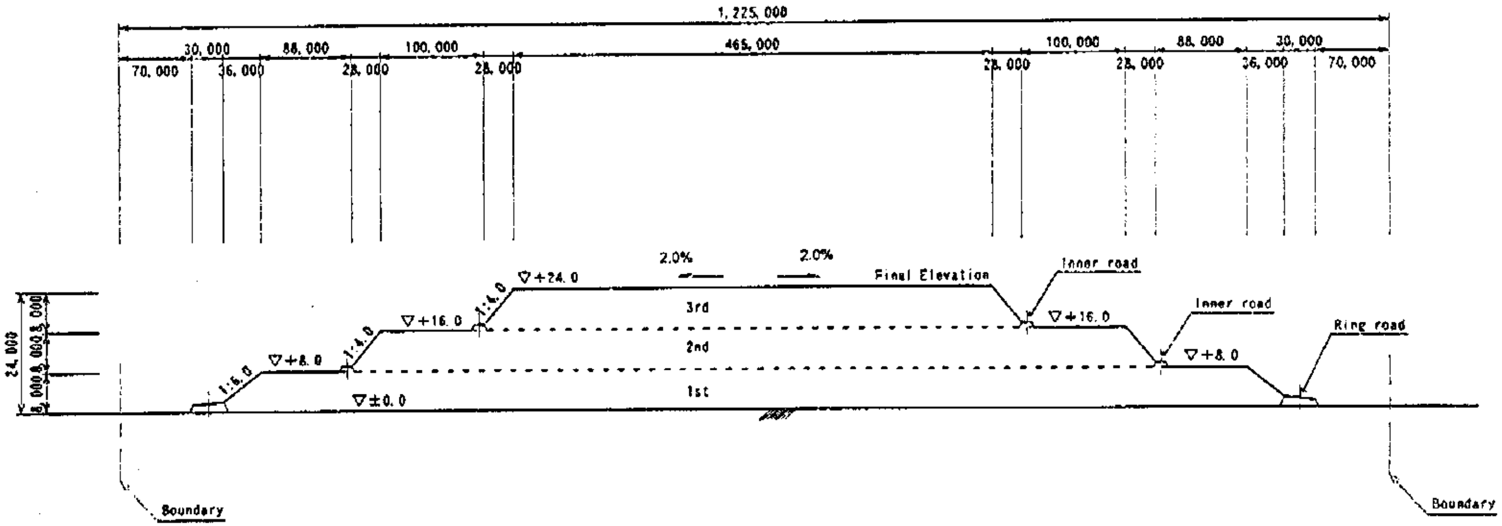
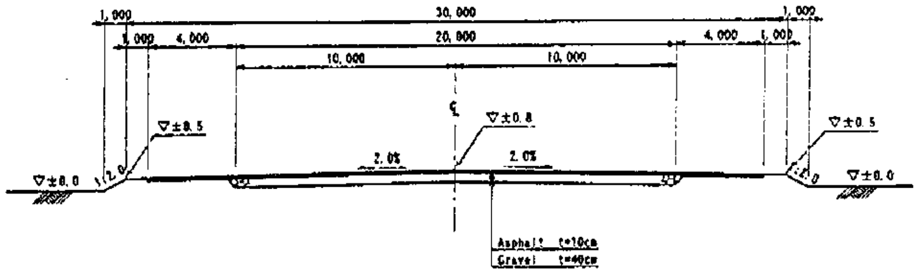
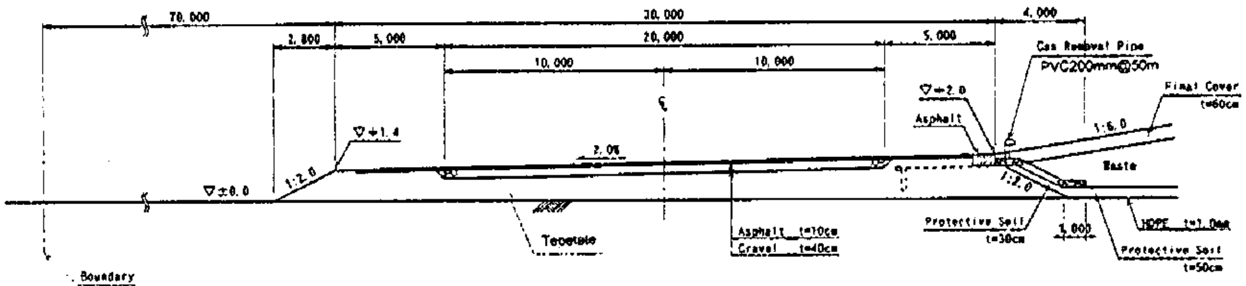


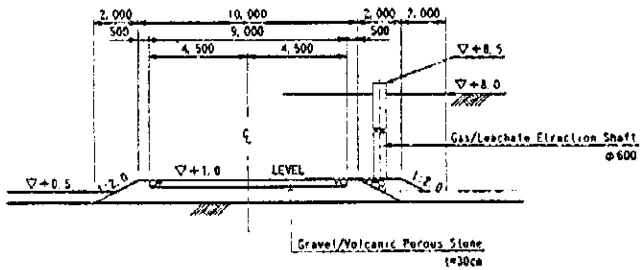
Figure 1-9: Cross Section of A-A



CROSS SECTION OF ACCESS ROAD



CROSS SECTION OF RING ROAD



CROSS SECTION OF INNER ROAD

Figure 1-10: Cross Section of Roads

Part B
Chapter 2

Natural and Socioeconomic Environment

2 Natural and Socioeconomic Environment

2.1 Natural Environment

2.1.1 Introduction

This chapter describes the environmental aspects of the project site in the ex-Lake Texcoco and its area of influence, stressing those items which might be affected by the implementation of the project.

2.1.2 Area of Influence

The area of study of the Bordo Poniente Etapa V sanitary landfill project is located at the eastern part of Mexico City in the ex-Lake Texcoco. The site is limited by canals that carry wastewaters coming from one of the branches of Dren Texcoco Norte. The entrance to the site on Autopista Mexico Texcoco. There is no productive activity carried out at the surroundings of the site.

The area of influence of the sanitary landfill project is located in the physiographic zone of the *Eje Neovolcanico* axis in the sub-province of the Anahuac lakes and volcanoes, in the Mexico Valley basin. From a hydrological point of view, the project is located in the hydrological region of Panuco river, in the Moctezuma river basin.

Construction and operation of the sanitary landfill encompass earthworks and carriage of wastes, which implies the circulation of a great amount of vehicles that use several avenues to reach the site, such as Boulevard Puerto Aereo, Eje 5 Norte, Via Tapo and Autopista Mexico Texcoco.

2.1.3 Climatology

Regarding the information required to analyze the climatic features of the site concerned, data of the meteorological station in the "Benito Juarez" International Airport and from the station located in the Nezahualcoyotl municipal hall in the State of Mexico was gathered, as well as the information obtained from Bordo Poniente's meteorological station.

Weather

The predominant climate in the region is dry steppe-type and cold, with rainfall during the summer (BKS'w). Taking the ex-lake as a central point, when climbing up to the eastern and western zone, the weather changes to temperate (Cwb), and in the higher zones of the sierra, to a cold temperate climate (Cwc).

Temperature

The annual average temperature in the region ranges between 12-20° C, being January, February, November and December with the lowest temperature. In the hottest months (May and June) the temperature reaches mean averages between 18-19 °C.

Table 2-1 shows the temperature behavior for the period of 1970-1989, whereas Figure 2-1 for 1994-1997. As can be perceived, the monthly average at a surface level during the last 4 years shows a cyclical behavior between 12.5° and 20° C, with maximum values in May and the minimum ones in January.

During the 1970-1989 period, the maximum annual extreme temperature was between 28° and 31°C, being March, April and June the months with the highest values (Table 2-2).

Regarding the monthly extreme temperatures for the 1994-1997 period, the highest temperature recorded during those years was 33° C in May (Figure 2-2).

The minimum extreme temperature for the months of January, February, March, November and December ranged between 0°C and 2°C (Table 2-3).

Relative moisture

Figure 2-3 shows the relative moisture for the 1994-1997 period.

This average relative humidity pattern illustrates a stage of the year with low relative moisture between January-April, whereas the high relative humidity stage takes place from July to September. It is important to point out that the high relative humidity level presents a gradual reduction of its average level in 1994-1997, with levels of 72% and 63% relatively.

According to a micro-location scale in the ex-Lake Texcoco, the highest humidity is found in the lacustrian zone with superficial water bodies, and the lowest humidity is found towards the zone of the project.

Precipitation

In general terms, rainfall in this region ranges between 500 and 600 mm. This fact classifies the area into one of the zones with the lowest precipitation in the Mexico Valley.

The precipitation behavior for the 1979-1988 period is shown in Table 2-4.

Most of the annual rainfall took place between May and October, in which almost 90% of total precipitation is accumulated.

During the period of 1994-1997, it is observed that the rain season is more intense between July and October (Figure 2-4), due to the presence of tropical humid air coming from the Pacific Ocean and the Gulf of Mexico. The lowest precipitation levels are found in the area of study.

Table 2-1: Average Temperature

Station: Airport of Mexico City

unit: °C

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	12.0	13.1	15.9	20.2	17.8	17.2	16.8	17.3	16.5	16.2	12.9	12.5
1971	13.4	14.4	16.5	21.0	19.4	16.9	16.6	16.8	16.9	16.0	14.7	12.8
1972	13.2	13.6	15.6	18.8	18.2	17.8	16.4	16.8	17.1	16.5	14.6	12.6
1973	13.0	14.5	18.0	18.0	18.1	21.6	15.8	15.8	16.6	14.2	13.7	10.6
1974	12.9	13.9					15.1	16.5	16.1	15.2	13.0	12.9
1975	11.7	14.2	17.7	19.3	17.4	17.0	15.2	16.4	15.3	15.2	16.8	11.3
1976	11.4	11.8	16.3	16.9	17.2	17.3	16.1	15.4	16.6	15.6	13.5	13.3
1977	13.8	14.2	17.8	16.1	17.9	17.2	16.4	17.4	17.1	16.2	14.0	12.9
1978	13.1	13.6	15.7	18.9	19.2	17.0	16.7	17.5	16.6	15.3	15.1	14.3
1979	13.3	14.2	17.0	18.3		17.8	17.3	16.5	15.8	15.9	13.9	13.2
1980	12.9	14.1	18.2	17.2	19.2	18.3	17.9	17.3	17.0	16.2	14.1	12.3
1981	11.3	14.2	16.9	17.8	18.7	18.1	17.0	17.5	17.3	16.9	13.9	14.0
1982	14.5	15.2	17.9	20.1	18.8	19.4	17.0	17.5	17.8	16.1	14.5	13.6
1983	12.6	13.3	16.4	19.6	21.4	20.2	17.5	17.6	17.0	16.1	15.5	13.9
1984	13.2	14.7	17.7	20.3	17.4	17.7	16.6	16.5	15.9	17.2	13.9	12.9
1985	13.1	14.5	16.9	16.4	18.4	17.6	16.7	17.3	17.1	16.3	14.9	13.6
1986	11.5	14.8	15.2	18.0	18.5	17.4	16.9	17.3	17.7	16.3	15.4	14.0
1987	13.6	15.3	17.1	17.8	18.2	17.9	17.5	18.0	18.5	15.1	15.1	14.8
1988	12.7	15.2	16.5	19.2	19.7	18.6	17.6	17.8	17.2	15.9	15.4	13.4
1989	14.3	14.5	15.4	17.0	19.3							
Average	**12.9**	**14.2**	**16.8**	**18.5**	**18.6**	**18.1**	**16.7**	**17.0**	**16.8**	**15.9**	**14.5**	**13.1**

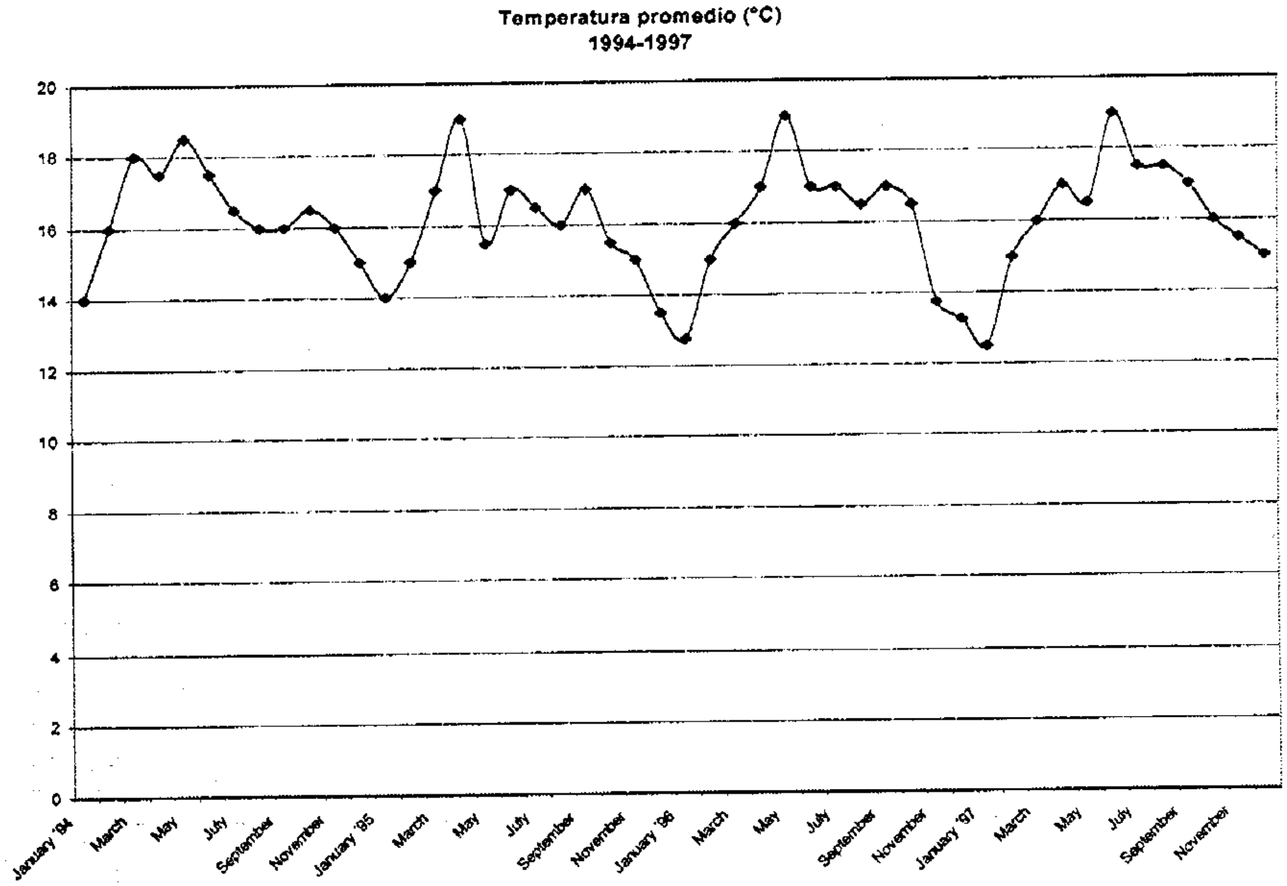


Figure 2-1: Average Temperature (°C) (1994-1997)

Table 2-2: Maximum Temperature

Airport of Mexico City

unit: °C

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	25.7	21.2	31.4	33.5	32.0	30.5	27.5	27.4	26.5	26.8	25.6	19.2
1971	27.0	29.4	29.0	31.8	30.6	28.0	26.8	25.5	26.8	26.3	26.3	24.7
1972	25.0	27.4	28.5	31.0	31.7	30.4	27.3	26.6	28.1	27.6	27.6	25.3
1973	28.4	27.8	31.2	31.0	31.7	30.8	25.1	24.5	25.7	25.5	26.2	24.2
1974	34.3						24.9	26.7	25.8	25.1	24.5	26.3
1975	23.9	27.4	30.5	30.5	30.5	27.0	24.9	24.5	25.5	26.5	25.5	24.5
1976	24.0	26.3	29.4	28.7	29.4	28.5	24.5	25.6	25.5	25.5	25.3	25.5
1977	27.5	26.6	32.2	30.7	30.3	26.4	26.6	26.9	27.3	27.8	25.5	25.4
1978	25.7	27.4	29.3	31.7	31.8	28.5	26.0	27.2	26.6	26.3	25.3	25.2
1979	27.3	26.1	30.1	30.0		28.0	26.6	25.1	24.5	27.5	26.2	24.5
1980	25.6	29.0	30.7	30.5	33.5	29.6	28.2	25.8	25.6	26.0	23.5	24.3
1981	25.0	27.5	29.1	30.5	29.7	27.8	25.8	26.7	27.2	26.6	24.8	25.5
1982	27.0	26.6	31.4	31.4	29.6	32.2	26.3	28.1	28.3	27.1	25.9	26.0
1983	24.7	27.7	31.0	33.1	34.7	31.0	27.3	27.2	27.3	27.0	25.1	25.0
1984	24.2	27.8	31.0	32.6	30.1	27.5	25.7	25.4	25.3	27.6	26.4	24.6
1985	25.0	26.4	30.0	29.2	31.4	28.0	25.7	26.5	26.6	26.7	26.8	25.6
1986	24.6	27.4	29.1	30.8	31.7	26.7	26.7	27.8	27.1	27.0	28.7	25.9
1987	28.4	29.0	31.5	30.5	30.0	28.8	27.2	27.9	29.0	27.0	26.4	27.0
1988	25.3	30.6	29.7	32.0	31.5	24.5	27.4	27.2	27.5	18.4	27.6	25.7
1989	26.6	27.6	29.6	29.8	32.5							
Average	**26.3**	**27.3**	**30.2**	**31.0**	**31.3**	**28.6**	**26.3**	**26.5**	**26.6**	**26.2**	**26.0**	**25.0**

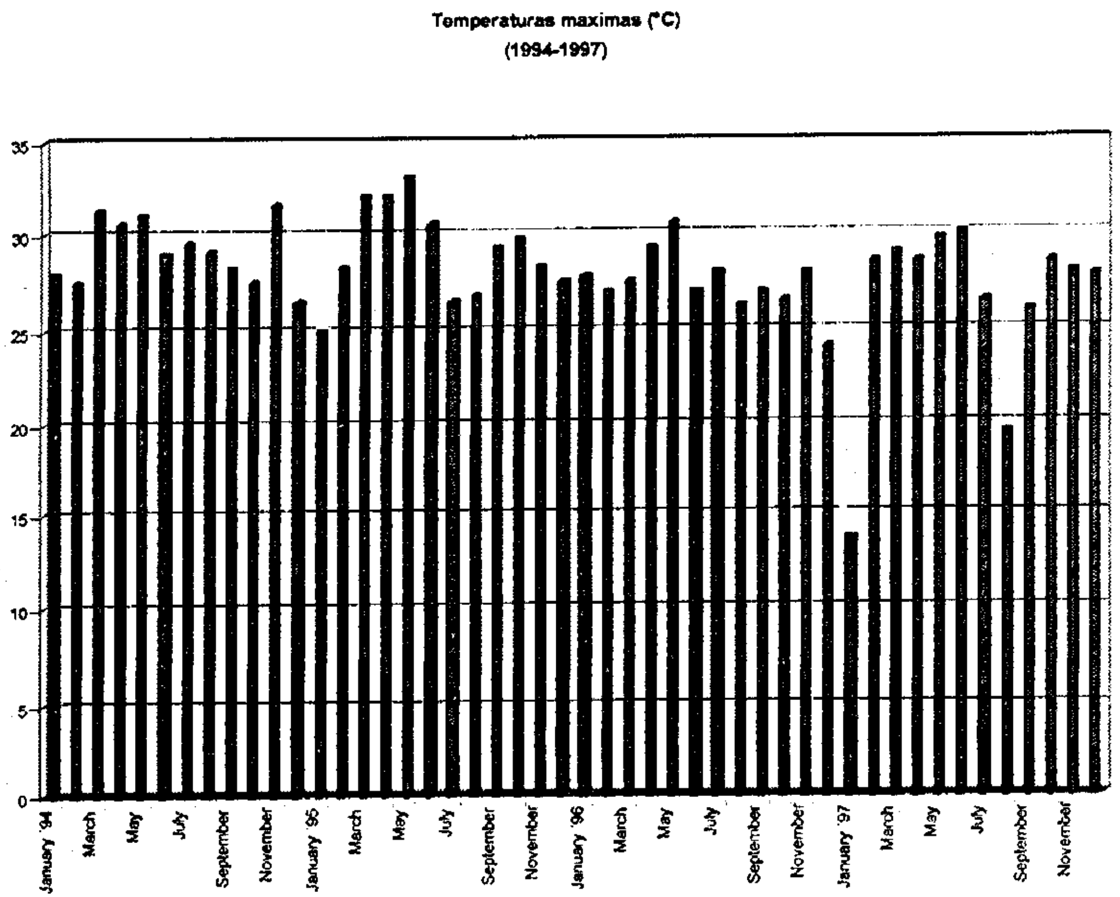


Figure 2-2: Maximum Temperature (°C) (1994-1997)

Table 2-3: Minimum Temperature (°C) (1994-1997)

Airport of Mexico City

unit: °C

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	-1.2	-1.5	2.4	5.6	5.2	8.4	9.4	8.6	9.9	3.5	-1.6	-0.8
1971	0.5	0.4	2.0	1.0	7.3	7.9	9.2	8.4	9.9	4.1	3.0	-1.8
1972	0.5	-1.5	3.0	4.5	7.5	7.0	9.2	9.0	9.2	7.0	5.5	-2.0
1973	4.9	-0.5	1.6	3.3	6.5	7.0	8.9	9.2	8.5	6.5	0.0	-1.2
1974	1.1						6.4	7.7	2.2	2.0	-4.4	0.0
1975	-4.1	0.5	2.0	6.6	7.5	9.0	8.6	9.5	3.2	3.1	-1.0	-1.3
1976	-2.0	-5.5	3.4	6.2	6.8	8.1	10.0	8.3	9.0	7.7	4.1	3.4
1977	-0.5	0.6	0.5	1.6	4.8	5.6	8.7	8.8	7.7	3.6	0.8	-1.4
1978	-0.3	-1.4	0.0	5.3	3.5	6.4	7.5	8.3	5.6	5.0	5.8	11.5
1979	-2.0	1.9	2.0	5.9		3.6	6.7	8.9	2.0	2.4	-0.1	2.0
1980	-1.8	-2.6	3.0	4.2	6.4	7.2	6.0	10.0	6.4	5.4	1.8	-2.9
1981	-1.6	1.5	2.2	6.8	8.4	7.5	10.4	8.7	8.4	6.5	0.0	2.3
1982	1.5	-1.0	2.6	9.0	8.9	7.9	8.3	8.0	6.9	3.6	0.4	-1.5
1983	-2.5	-3.5	2.0	3.7	9.0	8.1	9.6	9.3	7.8	3.3	4.0	-1.8
1984	-0.6	-1.0	4.0	6.2	7.4	6.5	10.0	9.0	7.0	7.0	1.0	-1.0
1985	-1.0	1.2	4.6	2.9	7.0	8.5	7.3	9.3	6.8	5.0	3.0	-2.4
1986	-4.6	0.6	-1.5	7.0	8.0	11.2	8.2	8.7	8.8	3.0	13.2	0.5
1987	-2.8	-2.2	-1.9	5.3	8.0	10.8	1.2	11.0	9.3	21.5	1.5	1.8
1988	-3.7	3.2	2.6	7.4	9.0	9.5	11.6	10.0	4.8	4.5	1.2	-1.2
1989	1.8	-3.3	-2.0	4.8	7.0							
Average	**-0.9**	**-0.7**	**1.7**	**5.1**	**7.1**	**7.8**	**8.3**	**9.0**	**7.0**	**5.5**	**2.0**	**0.1**

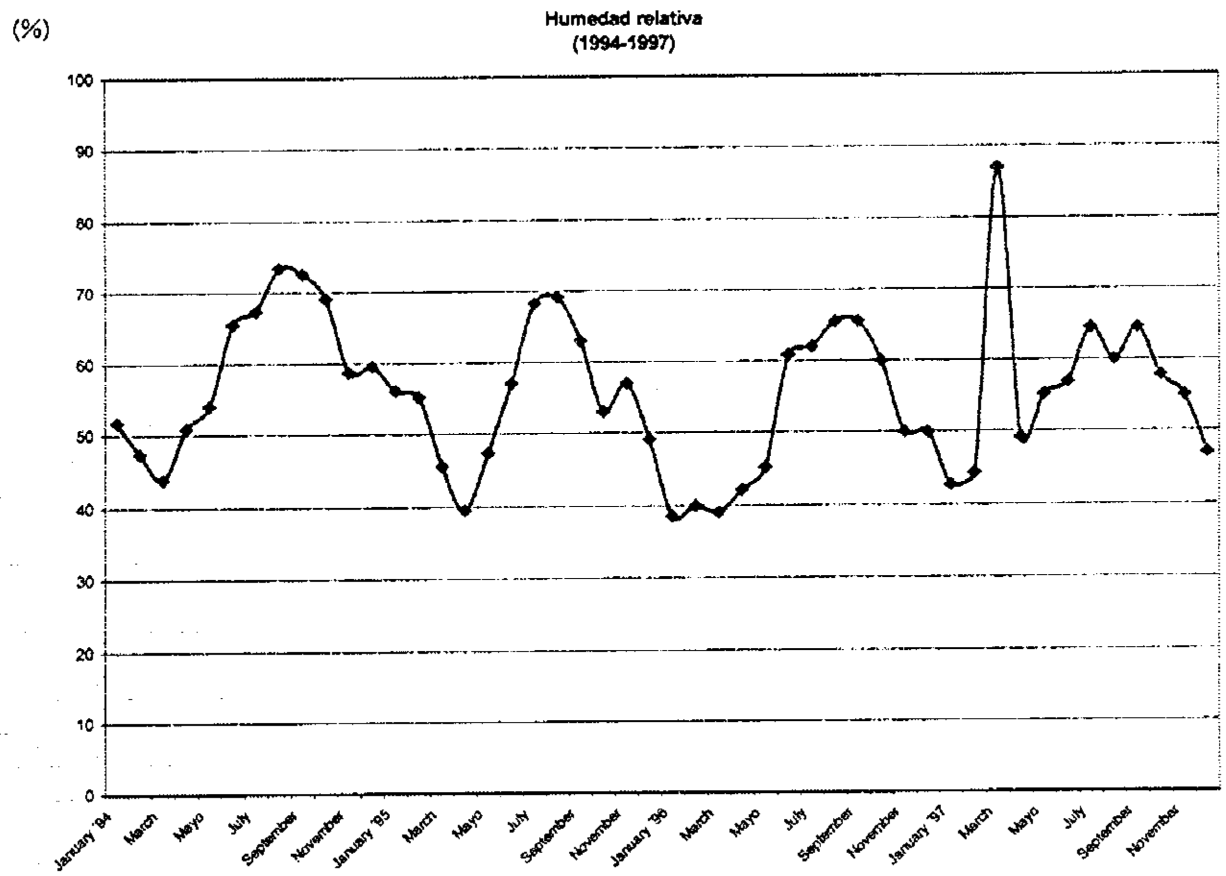


Figure 2-3: Relative Humidity (1994-1997)

Table 2-4: Total Precipitation (mm)

Station: Mexico City Airport

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1970	1.2	2.4	3.3	3.6	22.6	114.1	171.2	87.3	97.8	23.8	0.1	0.0	**527.4**
1971	0.5	1.1	14.0	6.6	17.5	158.3	110.1	105.8	99.4	93.2	7.5	5.6	**619.6**
1972	0.7	1.2	5.8	47.5	105.5	117.6	114.2	98.2	57.1	60.8	11.4	1.0	**621.0**
1973	0.3	4.5		43.6	33.5	59.9	166.9	147.5	58.1	28.7	28.8		**571.8**
1974	2.0	4.0					135.8	52.3	84.1	13.6		0.0	**291.8**
1975	35.7	3.7	0.0	16.6	78.1	66.9	90.1	99.8	96.5	39.4	0.0	0.0	**526.8**
1976		17.3	5.0	28.9	54.9	30.1	112.5	256.4	104.7	124.4	3.1	36.1	**773.4**
1977	3.1	3.6	0.0	11.3	46.8	70.7	143.5	48.3	140.4	53.8	1.8	1.5	**524.8**
1978	3.9	12.6	47.2	1.6	50.6	205.0	78.2	27.0	60.4	152.6	18.3	14.6	**672.0**
1979		19.1	3.0	21.8		77.0	130.0	149.3	122.8	2.0		14.7	**539.7**
1980	34.2	5.5	4.7	39.8	59.6	47.7	69.7	162.8	118.9	45.2	12.9	0.0	**601.0**
1981	19.9	20.3	10.2	40.1	23.9	177.6	148.4	67.5	50.7	35.3	1.6	1.3	**596.8**
1982	0.0	9.1	16.9	28.0	66.4	108.9	178.2	57.1	21.7	64.0	1.9	3.3	**555.5**
1983	13.5	0.7	3.9		35.2	66.4	109.2	102.8	82.0	50.7	10.1	15.6	**490.1**
1984	5.3	6.7	0.4		52.5	65.5	179.4	119.6	169.0	36.6	0.2	1.3	**636.5**
1985	9.4	2.1	14.4	91.3	44.6	159.6	79.4	60.8	65.6	15.1	0.7	0.0	**543.0**
1986	0.0		0.0	10.4	57.4	193.8	69.3	70.6	50.8	28.1	5.2	0.0	**485.6**
1987	0.0	1.7	2.6	12.7	36.3	97.3	135.2	94.4	125.0	0.0	18.9	0.0	**524.1**
1988	0.5	13.6	37.8	11.1	56.2	144.0	106.0	135.6	89.4	4.7	7.9	0.0	**606.8**
1989		0.5	9.7	8.5	41.2								59.9
Average	**7.7**	**6.8**	**9.9**	**24.9**	**49.0**	**108.9**	**122.5**	**102.3**	**89.2**	**45.9**	**7.7**	**5.3**	

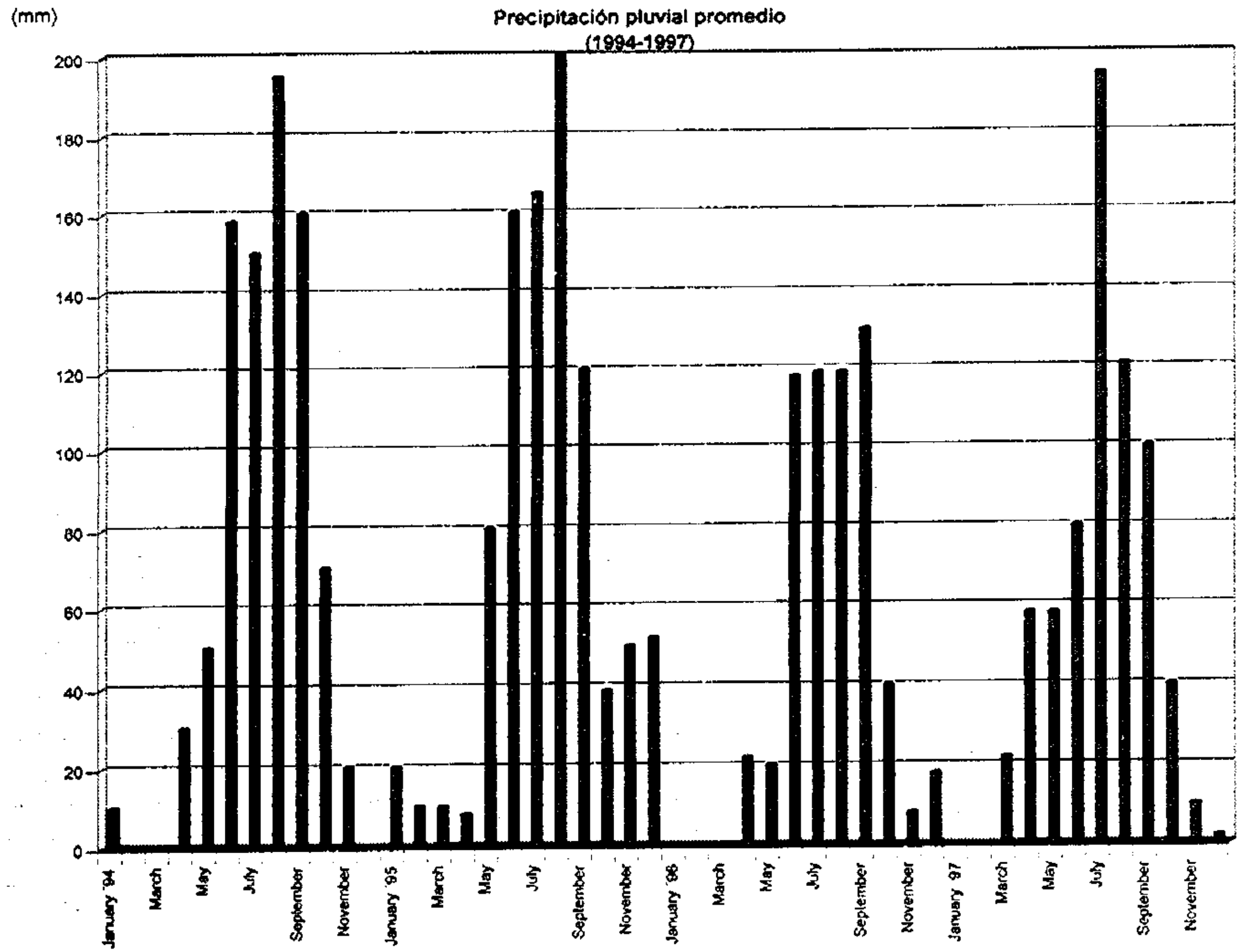


Figure 2-4: Average Rainfall (1994-1997)

Maximum rainfall in 24 hours

The graphic behavior is similar to that of total precipitation, except that the values are variable: from June to September there is a maximum rainfall level of 23 mm, whereas from November to March the values are less than 6 mm.

Table 2-5 shows the data on the maximum rainfall in 24 hours, recorded at the International Airport and at the Nezahualcoyotl station.

Evaporation

Potential evaporation in the Texcoco lake area ranges between 1700-1950 mm, which is a greater value than rainfall. March, April, May and June commonly have the greater evaporation values.

Regarding the evaporation, the area of study has a greater evaporation level during the summer season, with the lowest values being recorded during winter.

With respect to the division into zones of the evaporation in the area, it should be indicated that it is more remarkable at the ex-Lake Texcoco than in the rest of Mexico City. In this regard, Table 2-6 shows the variations in evaporation of the zone concerned.

Frequency of Elements and Special Phenomena

Table 2-7 and Table 2-8 show the elements and special phenomena that took place in the last 10 years at the meteorological stations of Mexico City's International Airport and at Nezahualcoyotl, respectively.

Dominant Winds

It is observed that during a long period of time the wind direction varied considerably, with several directions from the four cardinal points; however, as of 1985, a trend that lasted until the last year of recording was observed, and it indicates that the dominant winds have a speed of no more than 4m/sec throughout the year and with a northern direction (Table 2-9).

Likewise, Table 2-10 shows the daily average direction and velocity of dominant winds during July and August 1998 of the Bordo Poniente's meteorological station, where the same trend of previous years is observed.

Maximum wind speed

For the 1970-1989 period, the maximum wind speed ranges between 12 and 22m/sec with a northern direction (Table 2-11).

The height of the mixed layer for the zone is normally between an altitude of 0 and 200m and the predominant atmospheric stability according to Pasquill is type D.

Table 2-5: Maximum Rainfall in 24 Hours

Station: Mexico City Airport

unit: mm

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	1.3	1.0	3.3	3.5	5.0	16.1	33.5	28.3	20.2	15.9	0.1	0.0
1971	0.5	1.1	8.6	2.2	7.9	39.8	27.4	29.7	32.6	24.0	6.1	3.5
1972	0.3	0.7	2.6	19.6	35.9	31.0	18.2	25.6	16.6	34.6	4.8	1.0
1973	0.0	4.5		33.8	14.0	14.0	23.4	31.1	16.9	12.5	26.6	
1974	2.0						26.1	14.1	30.7	10.9		0.0
1975	14.1	2.4	0.0	15.0	11.3	12.2	14.9	28.3	31.4	11.9	0.0	0.0
1976		9.1	3.4	10.3	8.8	11.6	19.8	55.0	23.7	35.6	2.2	18.3
1977	2.3	3.4	0.0	3.9	18.6	21.7	32.3	10.4	32.5	12.9	1.3	1.4
1978	3.9	7.4	20.8	1.6	12.0	28.1	15.3	10.3	13.9	38.4	7.3	9.3
1979		9.1	2.3	10.5		16.1	24.8	20.6	49.9	1.3		11.9
1980	10.3	3.2	4.7	9.8	13.9	12.5	20.0	36.7	23.9	12.7	4.8	0.0
1981	11.1	14.2	5.4	12.2	5.9	49.8	24.8	24.1	15.4	16.0	1.6	0.7
1982	0.0	5.1	8.8	9.5	10.2	36.0	51.7	10.1	12.3	30.9	1.8	2.0
1983	9.0	0.9	3.5		12.2	18.9	20.9	22.8	12.7	15.5	5.5	14.0
1984	3.3	3.4	0.4		15.4	12.4	24.8	20.7	56.2	10.7	0.2	0.7
1985	9.2	1.3	8.0	28.9	13.7	41.2	21.1	14.0	12.4	8.0	0.7	0.0
1986	0.0		0.0	5.8	21.5	46.3	19.2	10.9	14.6	11.0	1.9	0.0
1987	0.0	0.9	1.0	5.6	10.3	18.5	30.6	23.8	44.0	0.0	10.1	0.0
1988	0.5	10.7	32.4	5.6	14.1	28.0	16.2	38.7	29.3	3.0	7.3	0.0
1989		0.5	4.8	6.5	15.4							
Average	**4.0**	**4.4**	**6.2**	**11.1**	**13.6**	**25.2**	**24.5**	**24.0**	**25.7**	**16.1**	**4.8**	**3.5**

Table 2-6: Total Evaporation (mm)

Airport of Mexico City

unit: mm

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1970	188.0	153.2	70.7	182.1	150.6	157.6	142.6	153.8	145.5	181.4	168.5	212.9	**1906.9**
1971	167.1	166.3	201.6	210.0	237.6	155.3	144.8	132.9	138.2	129.7	145.3	157.7	**1986.5**
1972	150.4	153.6	195.3	212.9	164.6	144.0	132.1	156.4	145.8	137.6	132.3	110.0	**1835.0**
1973	138.6	154.3	217.9	225.2	208.7	162.7	127.6	119.3	106.0	98.2	112.9	196.3	**1867.7**
1974	104.5						112.6	146.7	130.3	134.0	101.5	130.1	**859.7**
1975	99.0	144.2	193.0	225.2	153.2	110.9	129.6	115.4	107.0	136.4	130.5	135.1	**1679.5**
1976	131.0	138.1	154.1	152.4	140.7	159.5	185.7	115.1	114.3	97.7	11.7	70.9	**1471.2**
1977	97.5	107.4	178.8	155.2	161.0	116.3	116.7	140.5	135.8	120.7	89.7	82.9	**1502.5**
1978	111.0	117.7	177.6	199.6	193.3	117.4	119.0	126.7	99.8	79.2	90.8	85.9	**1518.0**
1979	106.5	109.8	179.0	160.4		148.9	151.1	112.1	100.1	142.6	99.4	89.2	**1399.1**
1980	93.3	147.0	197.1	160.0	145.7	153.9	141.1	121.0	105.1	118.0	88.3	87.1	**1557.6**
1981	86.9	105.3	158.2	163.7	160.4	39.1	130.1	119.5	88.4	97.3	99.0	92.2	**1340.1**
1982	86.5	114.8	119.0	104.0	140.1	174.2	135.1	146.4	139.1	112.7	76.3	87.3	**1435.5**
1983	110.6	104.9	107.8	173.3	196.6	173.1	128.1	128.6	97.0	120.2	91.4	88.8	**1520.4**
1984	94.0	121.5	175.3		158.5	130.9	117.1	111.6	86.7	125.7	103.6	79.3	**1304.2**
1985	91.7	124.7	164.4	125.9	154.3	118.3	116.5	119.8	142.7	113.0	99.1	81.4	**1451.8**
1986	96.5	142.3	195.5	160.7	143.8	109.6	129.3	108.3	121.5	102.3	91.4	96.6	**1497.8**
1987	118.0	149.2	183.8	171.6	179.8	130.8	108.3	144.6	154.8	154.4	108.3	108.0	**1711.6**
1988	109.0	134.6	153.8	172.7	178.1	141.5	123.0	128.3	122.2	114.3	110.0		**1487.5**
1989	76.9	94.8	183.3	152.4	159.5								**666.9**
Average	**112.9**	**130.7**	**168.7**	**172.6**	**168.1**	**135.8**	**131.1**	**128.8**	**120.0**	**121.9**	**102.6**	**110.7**	

Table 2-7: Monthly Frequencies of Elements and Special Phenomena (1)

Meteorology Station: Aeropuerto Internacional Benito Juarez; Gustavo A. Madero, D.F.

	Years	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
No. of days with perceivable rain	12	1.75	2.63	3.18	6.72	11.63	17	19.33	18.08	14.75	8.25	2.41	1.5	107.23
No. of days with non-perceivable rain	12	0.58	1	1.63	2.9	2.27	1.81	2.5	2.58	1	1.83	1.91	0.83	20.84
No. of clear days	11	15.25	12.63	10.9	10.81	4.45	2.36	3	2.5	3.33	6	9.63	12.81	93.67
No. of partly cloudy days	11	10.83	11	15.27	15.45	16.18	10.45	8.72	7.66	8	11.3	13.45	12.9	141.21
No. of cloudy days	11	4.91	4.63	4.81	3.72	7.63	17.18	19.27	20.83	18.66	13.7	6.9	5.18	127.42
No. of days with dew	2	0	0	0	0	0.18	0	0	0.08	0	0.66	0.58	0.08	1.58
No. of days with hail	12	0	0	0	0.27	0.18	0.18	0	0.25	0.08	0.08	0.08	0	1.12
No. of days with frost	12	5.41	2.09	0.27	0.36	0	0	0.08	0	0	0.25	1.91	2.5	12.87
No. of days with electric storm	12	0.16	0.09	0	0	1.45	1.72	1.16	2.58	0.91	0.58	0	0	8.65
No. of days with mist	12	4.83	4.09	9.09	9.09	6.09	6.63	9.91	4.58	7.66	8.08	6.33	7.66	84.04
Days with snow	12	0	0.27	0	0	0	0	0	0	0	0	0	0	0.27

Table 2-8: Monthly Frequencies of Elements and Special Phenomena (2)

Meteorology Station: Nezahualcoyotl (Palacio Municipal) Mex.

	Years	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
No. of days with perceivable rain	10	1.18	2.18	2.81	5.45	9.8	12.72	17.9	16.9	14	7.6	2.9	1.8	95.24
No. of days with non-perceivable rain	10	1.36	1.27	3.09	3.18	5.5	4.27	2.9	2.8	1.7	2.5	2	0.9	31.47
No. of clear days	10	20.09	18	16.36	12.54	8.1	5.45	2.5	3.2	6.4	11.4	14.2	16.8	135.04
No. of partly cloudy days	10	8.18	8.09	12.9	14.1	16.6	16.27	19.5	20	15.5	14.4	12.7	11.8	170.04
No. of cloudy days	10	2.72	2.18	1.72	3.36	6.3	8.27	9	7.8	8.1	5.2	3.1	2.4	60.15
No. of days with dew	10	0	0	0	0	0	0	0	0	0	0	0	0	0
No. of days with hail	10	0	0	0	0.18	0.4	0.27	1.2	0.4	0.1	0.1	0.3	0.2	3.15
No. of days with frost	10	6	1.81	0.09	0	0	0	0	0	0	0.6	1.9	7.4	17.8
No. of days with electric storm	10	0	0	0	1.36	1.8	2	1.7	0.9	0.6	0.3	0.4	0.1	9.16
No. of days with mist	10	1.54	0.45	0.18	0.09	0	0	0.3	0	0.3	1.1	1.5	1.9	7.36
Days with snow	10	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2-9: Dominant Directions and Average Velocity of Winds

Airport of Mexico City

unit: m/s

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	C	C	C	C	C	C	C	C	C	C	C	C
1971	C	C	C	C	C	N 2.4	N 1.6	NE 2.0	N 2.4	N 4.2	N 1.4	N 2.5
1972	SSE 2.8	N 2.5	N 2.3	N 1.1	S 2.6	N 1.4	N 3.0	N 1.8	N 1.7	N 1.8	N 1.6	N 1.8
1973	SE 2.3	SE 3.1	S 3.3	S 1.7	NE 3.6	NNE 2.6	N 2.3	NNE 2.2	N 1.3	N 1.9	N 1.7	N 1.4
1974	N 1.8						N 1.8	N 1.3	NNE 2.6	NNE 2.6	NNE 2.1	SSW 2.6
1975	NE 1.6	SE 2.8	SE 3.4	NNE 2.2	NNE 2.3	N 2.6	NE 2.6	NE 1.9	NNW 2	SE 2.3	NS 1.8	SE 1.5
1976	NE 2.2	E 1.9	SE 3.1	SE 2.6	SE 2.4	E 3.3	SW 2.21	SE 2.4	NE 1.6	E 2.0	N 1.7	ENE 1.5
1977	SSE 2.4	S 2.5	SSE 3.1	SE 2.2	NNE 2.0	NNE 2.4	NNE 2.3	NNE 2.7	NNE 2.0	N 1.6	ESE 2.1	
1978	ESE 2.3	N 1.8	SSE 4.2	SSE 2.6	NNE 2.1	NNE 1.8	NNE 1.4	N 1.9	NE 1.8	N 1.4	N 1.1	S 2.0
1979	S 1.7	N 2.0	SE 3.1	NNE 2.2		N 2.2	N 2.2	N 1.6	NNE 1.8	NNE 2.4	SE 3.4	NNE 1.7
1980	SSW 3.5	NNE 2.8	SSW 4.2	NNE 2.8	NNE 2	ENE 2.9	NNE 1.4	NW 1.9	N 1.8	NNE 1.4	NNE 1.5	NNE 1.2
1981	SSE 2.8	E 1.2	S 3.0	ENE 2.2	ENE 2.9	NE 2.9	NE 3.7	ENE 3.3	NNE 3.0	ENE 2.3	NE 2.9	SSE 3.6
1982	SSE 3.5	NE 2.1	ENE 3.1	ENE 2.2	ENE 2.0	ENE 2.8	ENE 2.6	NNE 2.7	NE 3.6	NWE 3.6	ENE 3.0	SSE 3.8
1983	SSE 3.9	SSE 3.6	SSW 5.6	SSW 5.3	SSW 5.0	NE 3.6	NNE 3.4	NNE 3.2	NNE 3.2	NNE 4.4	NE 2.7	SE 2.7
1984	ESE 1.6	ESE 2.0	ESE 4.0	SE 4.3	SSW 4.5	NE 3.2	NE 3.2	NE 3.2	NE 3.6	ESE 2.3	N 3.2	ESE 1.4
1985	SE 2.4	N 3.3	N 3.3	N 3.2	N 3.3	N 3.3	N 3.4	N 3.2	N 3.2	N 3.2	N 2.8	N 2.9
1986	N 2.8	N 3.8	N 3.0	N 3	N 2.7	N 2.3	N 3.5	N 3.2	N 3.3	N 3.3	N 3.6	SE 3.2
1987	S 3.6	N 3.4	N 2.9	N 2.9	N 3.6	N 3.9	N 3.8	N 3.9	N 4.0	N 3.9	N 3.0	N 2.5
1988	N 2.3	N 3.2	N 3.4	N 3.7	N 3.7	N 3.8	N 3.0	N 3.8	N 3.6	N 3.4	N 3.0	N 2.9
1989	N 3	N 4.1	N 4.0	N 3.4	N 4.2							

Table 2-10: Daily Average Dominant Direction and Velocity of Winds in July and August

Day	Direction	Velocity, m/sec	Day	Direction	Velocity, m/sec
01.07.98	NE	1.9	01.08.98	NE	2.7
02.07.98	NE	2.0	02.08.98	NE	2.9
03.07.98	SE	5.2	03.08.98	NE	1.7
04.07.98	NE	1.7	04.08.98	no. deter.	no. deter.
05.07.98	SE	2.5	05.08.98	NE	3.7
06.07.98	NE	2.4	06.08.98	NE	1.7
07.07.98	NW	3.0	07.08.98	SE	8.5
08.07.98	NW	3.8	08.08.98	NE	2.4
09.07.98	NE	5.7	09.08.98	NE	3.2
10.07.98	SE	2.7	10.08.98	NE	2.5
11.07.98	SE	3.0	11.08.98	NE	2.0
12.07.98	NE	2.0	12.08.98	NE	2.5
13.07.98	NE	2.2	13.08.98	NE	4.0
14.07.98	NE	3.2	14.08.98	SE	2.7
15.07.98	NE	3.0	15.08.98	SE	4.3
16.07.98	SE	2.3	16.08.98	SE	2.7
17.07.98	SE	2.9	17.08.98	SE	2.4
18.07.98	NE	3.0	18.08.98	NW	2.5
19.07.98	NE	2.2	19.08.98	NW	3.4
20.07.98	NE	3.1	20.08.98	NW	4.8
21.07.98	NW	2.8	21.08.98	NW	3.3
22.07.98	NE	2.8	22.08.98	NE	2.0
23.07.98	NE	3.4	23.08.98	NE	3.3
24.07.98	NE	3.2	24.08.98	NE	2.2
25.07.98	NE	3.9	25.08.98	NE	3.2
26.07.98	NE	4.2	26.08.98	NE	2.8
27.07.98	NE	4.0	27.08.98	NE	2.7
28.07.98	NE	3.0	28.09.98	MW	2.9
29.07.98	NE	2.1	29.08.98	NE	2.9
30.07.98	NE	1.6	30.08.98	NW	2.6
31.07.98	NW	2.6	31.08.98	NE	2.6

Monthly velocity average: 2.9 m/sec in July, 4.1 m/sec in August
Monthly direction average: Northeast 20 days in July and 19 days in August
Source: Bordo Poniente Meteorology Station

Table 2-11: Maximum Velocity and Direction of Winds

Airport of Mexico City

unit: m/s

Year \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	W 16.8	N 16.3	SE 21.0	N 22.8	NNW 18.2	N 18.8	N 15.9	SE 17.3	ENE 22.2	ESE 14.4	NNW 13.7	NNW 10.1
1971	NNE 18.3	SSE 15.9	SSE 20.2	N 20.1	E 20.2	N 17.8	NNE 17.3	NNE 13.8	NE 14.7	NNE 16.4	N 14.2	SSW 17.0
1972	N 15.0	SW 19.0	SE 16.2	E 19.0	NW 19.3	NE 22.9	SSE 15.3	NNE 15.0	N 18.5	NE 14.6	N 14.2	WSW 10.0
1973	S 16.3	S 14.6	SSE 20.0	SW 21.2	ESE 22.8	NNE 13.8	NNE 15.6	N 17.8	S 18.0	W 14.8	N 7.0	SSW 13.9
1974	SSE 14.0						SE 15.0	NNE 17.3	NNE 14.0	NNE 14.2	NNE 16.0	SSW 17.8
1975	S 16.4	SE 16.0	E 14.2	NW 16.0	SE 20.0	ENE 20.7	N 17.0	NW 5.0	SSE 13.9	E 14.8	S 16.8	NNW 14.0
1976	NNE 14.2	N 12.0	ESE 19.0	N 17.0	SSE 16.2	SW 17.2	SW 17.0	NW 15.0	SSE 13.9	E 14.8	S 16.8	WNW 12.5
1977	WSW 15.3	S 17.0	SW 17.0	NE 17.0	S 15.9	NNE 14.0	E 15.2	NNE 19.7	ESE 17.0	NE 14.1	WNW 12.4	
1978	SSE 13.8	SSE 24.0	S 16.0	SSE 16.8	NNE 20.2	S 17.8	NE 13.0	NNE 15.9	NE 12.0	E 14.7	SE 8.0	SE 12.0
1979	SSW 12.1	SE 19.0	SW 15.0	SE 20.0		NNE 18.9	NNE 17.0	ENE 20.0	NE 16.3	NNE 14.0	SE 12.2	SSE 11.9
1980	NNE 10.0	SSW 24.5	ENE 18.0	S 22.5	SE 14.0	E 19.0	NE 10.0	NNW 15.9	ENE 14.0	NNE 11.4	SW 13.0	ESE 12.0
1981	WSW 17.3	NNW 20.0	S 17.0	S 18.0	SSW 16.7	SE 16.7	NE 16.7	ENE 13.6	SE 15.3	SSE 16.1	NE 10.0	NE 12.8
1982	SW 13.5	S 16.0	SE 17.4	NNE 16.5	ESE 18.9	E 16.1	ESE 17.4	ESE 14.7	WNW 21.0	SSE 17.0	SSW 14.2	SSE 14.7
1983	WSW 15.4	SSE 19.2	SW 17.5	WSW 17.4	ESE 18.9	SSW 14.4	SE 18.8	E 16.8	NE 15.3	ENE 16.4	NE 14.7	SSW 13.3
1984	WNW 15.0	SSE 13.6	NW 17.2	N 16.7	NE 19.2	ESE 16.7	SE 18.3	E 19.6	SSW 13.3	SE 14.9	NE 14.1	SE 13.5
1985	SSW 15.6	SSW 14.4	SSE 18.2	ENE 16.8	SSW 15.8	ENE 15.0	NNE 17.2	E 12.8	NNE 16.3	N 15.3	N 16.8	NNE 11.8
1986	N 11.5	S 18.9	SW 16.7	SSE 16.8	N 15.0	ESE 15.9	SSE 17.2	ENE 16.6	N 15.0	S 14.1	N 12.0	SSW 15.4
1987	SSW 12.9	W 17.0	SW 17.0	SW 13.7	N 16.8	NNW 16.9	NE 14.7	N 12.2	N 18.2	ESE 19.2	N 13.0	
1988	S 16.2	NNW 12.7	NNW 12.7	SSW 22.8	NE 16.8	SSW 20.2	E 20.8	N 16.8	NNE 17.9	N 12.7	N 12.3	
1989	SSW 12.4	N 13.6	N 13.6	N 18.5	WNW 17.8	WNW 18.0						

2.1.4 Air

Thermal Inversion

One of the factors that aggravate the pollution problem in Mexico City is the frequency of thermal inversions, specially during the winter, when the high pressure systems and other meteorological phenomena retain the pollutants longer time than during the summer season. From November to March, the time for breaking up such inversion is at 9:00 AM, since the insolation at this time of the year is lower if compared with that of the summer. In this regard, Figure 2-5 illustrates the frequency of thermal inversions that took place in Mexico City, from 1994 to 1997, according to the data of the Environment Department of the GDF.

Air Pollution

Suspended particles are one of the important pollutants of the city's atmosphere, particularly in the project area, as dust storms are generated during the dry season.

Desiccation of the lake has induced the formation of an extensive area without vegetation, which has been exposed to the effects of the erosion by the dominant winds of this region. Said winds cause dust storms that carry particles towards Mexico City's metropolitan zone, and an significant portion of them remain in the air and their size is less than 10 micron.

This condition turns this region into an important emitter of particles, which are recorded mostly by the atmospheric monitoring network station at the Nezahualcoyotl municipality.

The maximum PM10 values of the Air Quality Metropolitan Index (IMECA) recorded at Nezahualcoyotl station between January 1996 and September 1998 show that the limit of the norm (100 IMECA points for the admissible breathable particles) is surpassed during the first three months of the year; however, in 1998 this situation continued critically until June, with a maximum average value in this month of 210 IMECA points.

During the analyzed period, the Nezahualcoyotl station recorded 17 months in which the limit was surpassed; i.e., 50% of monthly records indicated that the air quality was between the range of Non Satisfactory and Bad.

Due to the aforementioned, the Metropolitan Environmental Commission had to elaborate the Program to Strengthen Air Quality Improvement Actions in Mexico Valley. It states that the National Water Commission (CNA) is to strengthen the restoration activities of the ex-Lake Texcoco.

Likewise, the Government of the State of Mexico, by means of the Urban Development, Public Works, Farming Development and Ecology Departments and in coordination with the CNA, elaborated a program to mitigate the emission of suspended particles in the Mexico Valley. Such program establishes immediate actions for the ex-Lake Texcoco federal zone.

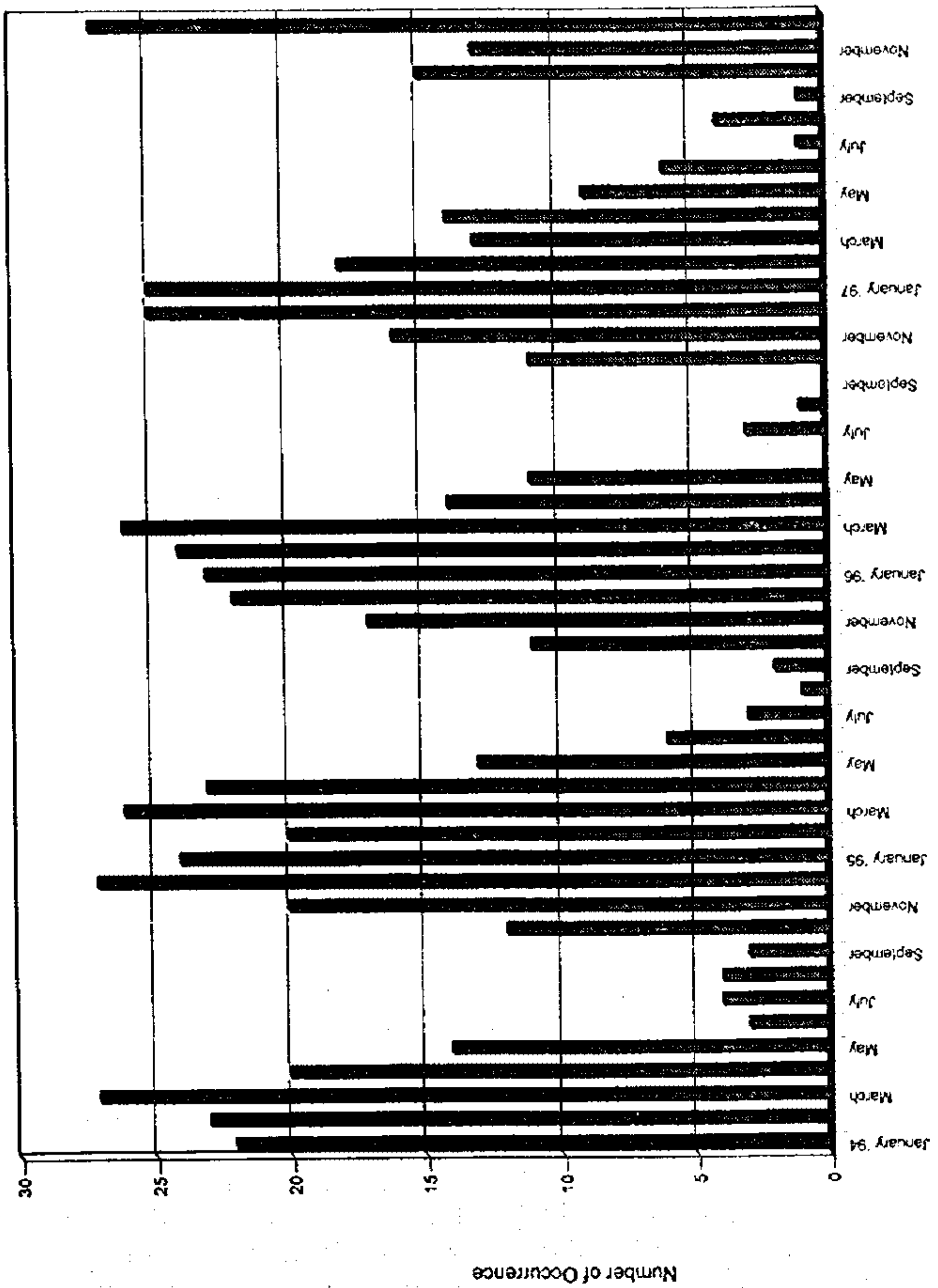


Figure 2-5: Number of Event of Thermal Inversion

Fourteen projects are highlighted from this program:

- Trees and grass seeding
- Forest lines
- Forest buffer zones
- Recovery and protection of soil at the eastern basin (sub-basin of San Juan Teotihuacan river)
- Recovery and protection of soil at the eastern basin (sub-basin of San Francisco river)
- Construction and operation of an irrigation system to control dust storms in "El Caracol" structure
- Drainage of the area flooded with wastewaters and construction of sport zones
- Rehabilitation and recovery of Churubusco regulation pond
- Wastewater treatment for irrigation
- Construction of treated water storage lake, Churubusco
- Construction of Lago Texcoco Norte treatment facility
- Pressurized irrigation, including operation and maintenance
- Drainage through the channeling of wastewater discharges

2.1.5 Geological and Geomorphologic Traits

The zone in which the sanitary landfills -currently operated by the GDF - are located, and in which the new landfill is proposed to be constructed, belongs to the ex-Lake Texcoco federal zone. It is at an elevation of 2,230 m above the sea level, located in the northeast of Mexico City.

Apart from being a receiver of the wastes coming from Mexico City, this zone also involves regulation ponds of superficial runoffs; likewise, Lago Nabor Carrillo and Lago de Regulación horaria were constructed here.

Among the activities developed within this zone there are the cultivation of halophyte species, which resistant to salinity, and diverse experiments on hydraulic, sanitary and farming works. Also, wastewater treatment facilities and an experimental module for the artificial recharge of aquifers with treated waters have been constructed there.

2.1.5.1 Regional Geology

The geographic site known as Mexico Valley Basin is located at the southern limit of the Mexican highland plain, between the 20° 15' and 19° 01', northern latitude, and 99° 31' and 98° 15' of western longitude.

In geological terms, said basin is located in the center of the volcanic strip that crosses from east to west the Mexican Republic. It has been subject to intense tectonic stress, as well as volcanic eruptions since the beginning of the Tertiary Period and up to recent times. The formations of the Middle Tertiary period include the remains of stratified volcanoes, tuffs, breccia and lava spillage and deposits. The type of rocks of this stage has a wide range: andesites, basaltic andesites, basalts, *dasitas*, and so on. These formations crop out at the lower part of the sierra bounding the basin. The strata belonging to the Tertiary Superior period show big lava deposits to the eastern and western zones of the basin.

Mexico basin was formed by the volcanic and tectonic processes that have been developing -sometimes slowly, sometimes abruptly. In the last 50 million years, as of the Eocene Superior period, such processes were particularly in a big scale and have affected the Trans-Mexican volcanic strip, and in general terms all the southern zone of the Mexican Republic from the Pacific coasts.

Before the Eocene period, the space in which the basin is currently located was flooded with shallow tropical seas. At the beginning of the Tertiary period, these waters withdrew when the limestone sediment folded and the continent gradually lifted. In this manner, the regression of the seas began in the Tertiary period and the volcanism stage began, which produced thickness of 2 km and more of lava, tuffs and breccia.

From a physiographic point of view, the basin is divided into three sections:

- Southern zone. It is bounded to the east by Sierra Nevada and Sierra de Rio Frio; to the west by Sierra de las Cruces; to the south by Sierra Chichinautzin and Ajusco; and to the north -though not completely- by the elevations of Sierra de Guadalupe, Cerro de Chiconautla and Sierra Patlachique. This zone is interrupted by a series of recent volcanoes, such as Cerro del Pino and Sierra de Santa Catarina; these volcanoes originate two sub-zones: the southern one that reaches Sierra de Santa Catarina and the range of mountains of the Ajusco, at the Xochimilco-Chalco sub-zone. The other sub-zone -Mexico-Texcoco- spreads from the Sierra de Santa Catarina to the south up to the northern boundary of the southern zone.

- Northern zone. This part of the basin is bonded to the southern zone through a bottleneck known as San Cristobal Strait, located between Cerro de Chiconautla and Sierra de Guadalupe. This partially represents the continuation of the Southern Level Ground and reaches the north towards the spurs of Sierra de Pachuca. Towards the east and west, several elevations such as Sierra de Monte Alto and Sierra de Tepotzotlan and other minor ridges form an irregular divide. Towards the east is the Tezontlalpan area, which is an old and faulted block settled to the south. It is also known as Zumpango-Xaltocan zone.

- Northeastern zone. Known also as Apan plain, it has a smaller surface than the other ones. It is a complex area with several minor volcanic elevations placed randomly in the landscape. It spreads as a thick strip towards the east, occupying a level and extensive space between Sierra de Pachuca and Sierra de Rio Frio.

During the Quaternary period a final volcanism cycle took place, and its outcome still exists, such as Cerro Gordo, Chimalhuacan and Chiconautla volcanoes, in which the Texcoco sub-basin is physically located.

From a geological point of view, the specific site under study is a structure formed by a powerful stratigraphy of lacustrian and alluvial materials, with remarkably soft, highly compressible clayey strata saturated with water, and with small layers of silt, sands and volcanic glass, which show hard consistency.

Within the study area, there are slopes that range from almost 0% at the ex-Lake Texcoco federal zone to more than 60% at Sierra Nevada. The slopes within the ex-Lake Texcoco federal zone are less than 2%. The level ground spreads to the south toward Cerro de Chimalhuacan, where the slope has values greater than 20%; to the north, it reaches Chiconautla, with slopes of 20%; finally, to the east, the plain areas slightly reach the eastern part of the former lake, where a zone with small hills begin, which represents the transition between the level ground and the sierra (Figure 2-6).

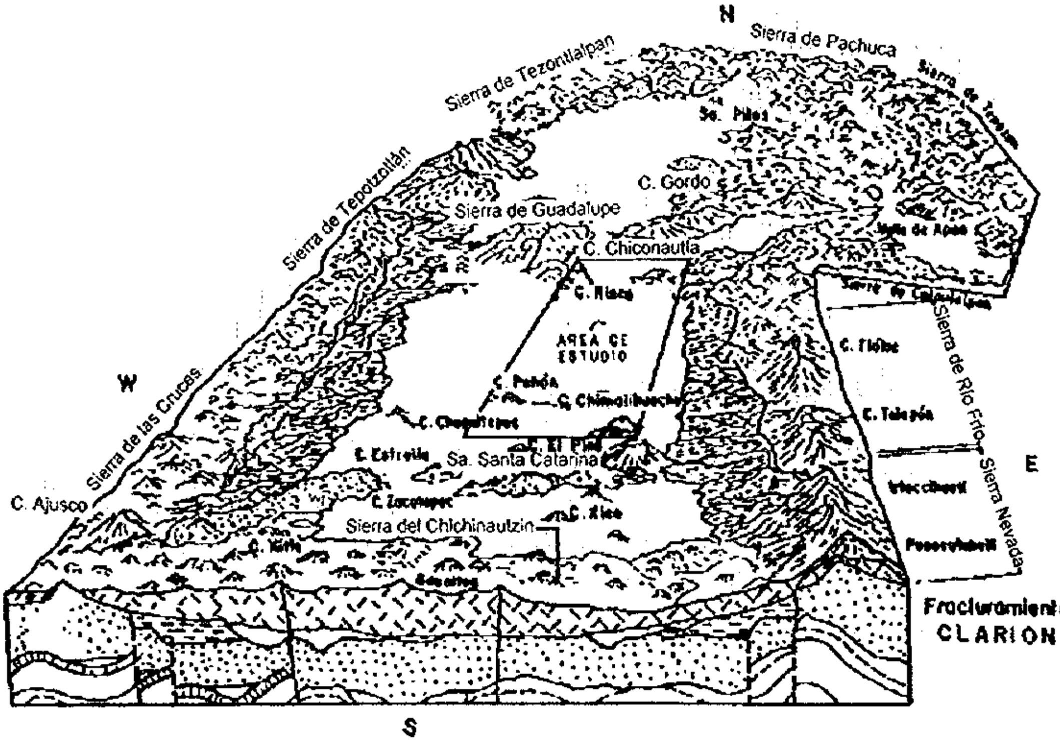


Figure 2-6: General View of Mexico Valley Basin

2.1.5.2 Evolution of Lakes in the Mexico Valley Basin

The Mexico Valley Basin is located in the central portion of the Trans-Mexican Volcanic Strip, whose origin is linked with the movement of the tectonic plates.

These processes led an intense igneous activity, as well as complex fault systems and associated fractures, some of which are still active; thus, the Mexico Valley Basin is a high-risk seismic zone.

Aguayo *et al.* (1989) carried out an structural stratigraphic study in the Mexico Valley to analyze the fracture and fault systems of the city, and the conclusion was that they are controlled by a regional S-NE and SE-NW fault. Besides, he also identified 16 main local distensible faults that have an effect on the inner part of Mexico Valley Basin.

Some of these faults gave origin to some of the depressions where the main lakes of the basin are located; an example of this is Lake Zumpango, which is found between two distensible faults: one is located close to the Presa de Guadalupe dam to the southeast, which goes on towards the northeast up to Tizayuca and Pachuquilla, Hidalgo; the other one goes from southwest to northeast, close to the following towns: Tepozotlan, San Andres Jaltengo, Zumpango, Zapotlan de Juarez and Mineral de Reforma, fault No. 13. Both faults form a tectonic pit that allows the formation of the lake.

The faults that form the Texcoco lake are the following: fault No. 8, that goes from the southwest in Contreras delegation and continues to the central zone of Mexico City (Napoles, Del Valle, Narvarte, Roma, Doctores, Juarez, Cuauhtemoc and other adjacent *colonias*), heading to the northeast where "El Caracol" in the ex-Lake Texcoc is located, and runs up to Otumba, Tlanalapan and Cuautepec de Hinojosa.

The other fault is No. 9: it begins at the southwest in the town known as El Zarco, heading towards the northeast, parallel to Constituyentes-Reforma avenue, crosses through the northern portion of El Caracol in the ex-Lake Texcoco and continues to San Martin de las Piramides, up to Singuilucan to the northeast. These geological structures cross a distensible zone with a NW-SE direction, forming the depression in which Lake Texcoco is found.

On the other hand, in 1978, Mooser utilized a division criterion for the lakes that takes into account the composition of salty water and fresh water lakes; the former ones were formed in the lower parts and constituted evaporation ponds, such as Xaltocan and Texcoco lakes; fresh water lakes were formed near Sierra Chichinautzin and were fed by springs, such as Xochimilco and Chalco lakes.

2.1.5.3 Local Geology

The area of study encompasses Sierra de Guadalupe, ex-Lake Texcoco and Cerro Chimalhuache. This zone is constituted mainly of volcanic and volcanoclastic units with acid and base composition, as well as alluvial and lacustrian materials.

A description of the features of the units located in the area is shown next, beginning with the oldest one.

Tm. (A) Tertiary Miocene, Andesites

This unit is constituted of Miocene-aged rocks, with a variable composition and within an intermediate range -from basic andesites to *dasitas*. Mooser (1962) considers these rocks to belong to the Xochitepec formation and to the Santa Isabel-Peñon series, which form the eastern base of Sierra de Guadalupe and Cerro del Peñon de los Baños; however, Schlaepfer (1968) rather calls them "volcanic rocks from the Middle Tertiary Period".

Andesites have a porphyritic texture, with plagioclase and ferro-magnesian crystals, as well as vesicles and fractures in flagstones. They are gray colored in recent samples and turn into ocher tonalities when exposed in the open air. They are covered with *clastic* and pyroclastic units. These rocks have a high degree of intemperance and their permeability is considered to be middle-ranged.

Type (T) Tertiary Pliocene, Tuffs

This unit crops out at Sierra de Guadalupe and at the skirts of Cerro Peñon de los Baños (the latter being encompassed in Tm. (A)). It constitutes a series of clastic and pyroclastic materials, such as sandy tuffs, ashes, pumice stones, old tuff and lacustrian soils, hybrid and flagstone tuffs, along with sandy conglomerating lenses and benthic layers.

This unit has been called a part of Tartago Formation (Secretaria de Programacion y Presupuesto; Hernandez H.M. 1983). Mooses (1973) calls them Nochistongo and Requena series. Due to the great variety of materials found, this unit is considered to have a permeability that ranges from middle to low.

Q (bbc) Quaternary, Basic Volcanic Breccia

This unit widely spreads to Cerro de Chimalihuache and its greatest concentration is at the southern part of it; it is pseudo-stratified with alternations of sandy material (*lapilli*), basalt and scoria (*tezontle*). As a whole, they have a dark gray color.

The breccia material is formed by basaltic rock fragments as well as scoria, with sizes ranging from 5 to 10 cm, with red-colored angular shapes and porous, with a sand matrix with the size of *lapilli*; besides, there are isolated tuffs (*tepetate*) with silt granulometry and yellow colored. Likewise, there are dark gray colored basalt filterings, with an aphanite texture and a vesicular structure, and middle to moderate fractures.

The unit of volcanic breccias is considered to have a great permeability due to the low compression and cohesion of the components, as well as the open fractures of basalts.

Q (tb) Quaternary, tuff

This unit is distributed at the northwestern portion of Cerro Chimalihuache; it is formed by a series of materials placed as semi-horizontal layers, which have a thickness of 20 m as a whole. They are constituted of pyroclastic volcanic materials with the size of clay and sand, with *lapilli* lentils not totally compacted in the base, as well as 5-10 cm basalt fragments.

Materials in general only change from package to package, due to the difference in granulometry and colors, and the thickest ones are at the base. The consistency of the unit varies from low to moderate, with easily disintegrating layers; no fractures or cracks are observed.

The unit formed by a series of volcanic and rhythmical emissions, and in each one of these, the materials are projected into the air.

Q (la) Quaternary, lacustrian

Mexico valley and the ex-Lake Texcoco are level grounds formed by a series of clayey stratums intercalated with sand, silt and volcanic glass layers. They are commonly referred to as a whole as lacustrian material, forming a package that sometimes may reach more than 180 m.

These deposits also mix with volcanic material and alluvial sediments. Since the materials are mostly clays, they are considered to have a low permeability. This is a dominant unit in and around the project site.

Q (al) Quaternary, alluvium

These are alluvial deposits without being compacted, which are derived from extrusive igneous rocks and composed by clastic materials of different sizes, ranging from sub-angular to rounded shapes. The grains are thick at the zones close to Chimalihuache volcano.

These materials are widely distributed at level grounds and as a filling of the valleys. The boundary of this unit with lacustrian deposits is transitional, since both sediments overlap each other.

Due to its granulometric features and to its reduced degree of compression, it is considered to have a high permeability.

2.1.5.4 Subsoil Geology

Due to the fact that the project will be located at the ex-Lake Texcoco lacustrian zone, a description of the sediments that form this area will be made next.

The ex-Lake Texcoco basin forms a plain of lacustrian deposits, which is the result of the erosion of rocks that form the mountain ranges surrounding the former lake, as well as pyroclastic products that volcanoes emitted during their creation.

Most of the deposits are clayey with silt-sandy layers. The depth and origin of the sediments are similar to those underneath Mexico City (Marsal and Mazari, 1959). This is the reason why the subsoil has been subject to several studies to analyze its mechanical properties, and the accurate determination of its stratigraphy becomes a secondary issue.

In view of the fact that the materials that filled the Mexico Valley Basin were carried and deposited in several ways, their distribution is therefore variable, as well as their texture; thus, the stratigraphic sequence is quite complicated.

The aforementioned is confirmed in the deposits that were studied, since the sedimentation process is controlled by different parameters. As a consequence, the deposit is not uniform in time or space; there are several fragments of other materials that developed -sometimes gradually, sometimes abruptly-, as well as sand and silt lenses, mainly. These features have been detected in most of the cross sections of wells; therefore, it is not easy to make a detailed lithology list.

In general terms, the clays of the ex-Lake Texcoco are complicated mixtures with clayey materials (*montmorillonite* and *illite* to a minor extent), with a great amount of glass, volcanic ashes, microorganisms, dissolved salts and animal fats (Morales, 1991). To explain this formation, it is necessary to take into account the drastic climatic changes undergone during the Quaternary period.

For instance, Sanchez Diaz (1989) provides an hypothesis to explain the origin of clayey materials within the ex-Lake Texcoco, stating that the winds carried aeolian soil to the lake, whose origin was volcanic dust (loess) and when deposited in the lake, they became hydrated; thus, this fact originated the clays of Mexico City.

On the other hand, Nieto (1973) explains the accumulation of clayey material as follows: during heavy rainfall seasons, the lake level increased, and clays were deposited in tranquil waters and far away from stream mouths. Since these materials were very fine, they were also carried by the wind at long distances.

During the drought seasons, evaporation decreased the lake level, and marshy vegetation outcropped (root spaces can be found at different depths in the wells bored by Compañia Sosa Texcoco, S.A.).

Volcanic water was deposited in this shallow water, which was the result of the great volcanic activity during the Quaternary period, and during the drought season it was hardened and dried, forming what is known as "hard layers", which will be described later.

Regardless of the lithological complexity of the subsoil in the ex-Lake Texcoco, the sequence of lacustrian sediments and the underlying rocks is being established; to achieve this, the drilling of deep well (numbered as PP1) was carried out, which was programmed down to 2065 m. This is the only one of its kind in the area and has been used to establish the stratigraphy in general of the Mexico Valley Basin.

However, no samples were collected in the first 180 m, therefore the drilling of deep level strata (BNP-1, BNP-2 and BNP-3) was carried out. These drillings had geotechnical purposes, but they were useful as well to set the stratigraphy of the first 180 m, since they were bored down to 200 m.

Marsal and Mazari (1959) established an informal terminology for Mexico City's subsoil from a viewpoint of soil, which is still being used nowadays. This terminology was also applied to Lake Texcoco, since similar features were found in it.

The units defined by such authors have been modified as time has passed by; nonetheless, most of these concepts match the definitions, which are described next.

Top layer or Superficial Stratum (CS[1])

It is formed by dried clays, clayey silts and silty sands. Its approximate thickness is 1.5 m, which increases towards Sierra de Guadalupe; these materials are furrowed with cracks filled with air-born components, specially at the zones close to Bordo de

[1] CS: Capa Superior

Socias, at the intersection of Bordo Poniente and Peñon-Texcoco road and at the airport zone. This stratum lies on the top clayey formation.

Top Clayey Formation (FAS[2])

It is formed by highly plastic soft clays with diverse thickness levels according to the place: 18 m at El Caracol zone, 40 m at Bordo de Socias, 6 m at the surroundings of Sierra de Guadalupe, 25 m at the center zone of Mexico City, from 39 to 17 m in a section at a distance of 3 to 13km from the Peñon-Texcoco road.

The clays that form this unit have a volcanic lacustrian origin, with sand, silt and volcanic glass intercalations and layers. It is above the hard layer.

Hard Layer (CD[3])

It is composed by sandy-silty materials, cemented by calcium carbonate and with desiccation traces; it has a variable thickness from 2.0 to 3.5 m; at the eastern zone, next to the surroundings of the Nezahualcoyotl municipality, it fades away.

This layer was formed during the Sangamon interglacial stage (Mooser, 1992), which is characterized for being a very dry period, and the soil became hardened and dried. This layer has clay intercalations that correspond to the wet cycles of this period.

Lower Clayey Formation (FAI[4])

Also known as sandy-clayey layer. It is a series of clay stratums with a high plasticity degree, sandy-silt and volcanic glass lenses and strata; it differs from the top clayey formation because it has less water. Its middle thickness at the center of the lake is 20 m, and gradually reducing towards the east and north. This formation fades away towards Sierra de Guadalupe.

Deep Deposits (DP[5])

They are constituted of compacted silts, gravel and clays with less plasticity than that of the top clayey formation. These materials are interstratified between fine sand layers and volcanic and alluvial material lenses. Thickness cannot be defined, since this formation goes deep into subsoil.

Some authors like Murillo (1978) and Torres G. (1992) use this terminology and simultaneously call these deep deposits "the second hard later". The former authors and Morales (1991) define a third clayey formation within deep deposits, with a thickness of more than 6 m and at a depth of 52 m in the center of the former lake and 64 m in Bordo Poniente.

Likewise, they call them the internal deep deposits or fourth clayey formation to the group of sandy, silty and sandy-silty strata found at a depth between 145-160 mm; sometimes these layers have clay and gravel.

Soil mechanics studies, probing and lab tests were carried out within the Bordo Poniente zone (Murillo y Laboratorios Tlalli, 1993) to know about the stratigraphy of

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[2] FAS: Formación Arcillosa Superior
[3] DF: Capa Dura
[4] FAI: Formación Arcillosa Inferior
[5] DP: Depósitos Profundos

the site's subsoil. Such studies showed the existence of a massive package of clays (FAS) with sand and volcanic ash intercalations, that were found at a depth of 9, 14, 20, 34 and 36 m.

A highly compacted sandy-silt material package was found at a depth of 38-42 m with greater compression, with an approximate thickness of 1.50 m and considered as the first hard layer.

After studies conducted by TGC in 1992, the depths to which the former sediments are located were determined: FAS between 1-36 m deep; CD between 36-38 m; FAI between 38-53 m and DP beyond 53 m.

On the other hand, from lithological cross sections of wells No. 536-19 and 35, a clayey package with a thickness between 80-90 m was observed. Within this package there are 1m-thick fine sand layers from a depth of 9 m.

2.1.5.5 Stratigraphy

The stratigraphy of deep materials in the Mexico Valley Basin is based on the drilling of deep well No. 1 (PP-1): Alvarez Jr. proposed a stratigraphic table without taking into consideration the first 180 m, from which no sample was obtained.

Nonetheless, he later considered Bryan's (1948) and Arellano's (1953) works, who recognized three lithological units from the Quaternary period in Mexico's basin; said units have not been displayed in cartographic drawings and they are known as Tacubaya, Caliche Morales and Becerra formations.

Other authors such as Mooser (1962) call these formations "Pluvial and Alluvial Clastic Series from the Quaternary period", whereas Schlaepfer (1968) names them "Alluviums, soils and lacustrian layers from the Quaternary period". On the other hand, Oviedo de Leon (1986) classifies the conglomerate known as Balsas formation by Alvarez Jr. as Texcoco conglomerate, and he calls the clayey limestone layers on top of it as Texcoco Anhydrite (Calcium sulfate), aged from the Oligocene period.

A modified stratigraphic column was defined while considering the aforementioned.

The units drilled by PP-1 are briefly described.

Balsas Formation

It is a calcareous conglomerate found at a depth of 2065 m with fauna from Cretaceous Superior period; its age is calculated to be from the Eocene Superior-Middle Oligocene period, according to Schlaepfer (1968) and Alvarez Jr. (1968). Oviedo de Leon (1967) classifies it as Texcoco conglomerate, with different phases to those of Balsas and the Morro conglomerates.

Texcoco Conglomerate

The matrix is formed by spathic calcite and lithic quartz fragments, whereas Balsas conglomerate only has spathic calcite matrix, and its lower limit is unknown. It is underneath a thick anhydrite layer.

Texcoco Anhydrite

It is found above the Texcoco conglomerate. It is found as intercalated stratum with thin limestone layers. It is calculated to be from Oligocene period.

Xochitepec Formation

It is a sequence of tuffs, breccias and trachyte-andesite lava (Schlaepfer, 1968). It is calculated to be from the Late Oligocene-Middle Miocene period and at a depth of 1125-1437 m from PP-1.

Tepoztlan Formation

It is found within a range of 1030-1125 m, corresponding to andesite, epiclastic volcanic rocks deposited by water and mud streams that formed layers with a depth of less than 10 m. It is calculated to be from the Late Oligocene-Early Miocene period.

Huatepec Trachy-Andesites

It is found within a range of 814-1030 m. It is a sequence constituted by andesite lava, clayey tuffs, agglomerates and sands. Alvarez Jr. calls them Huatepec rocks, and based on radiometric analysis, they were calculated to be from Miocene period.

Tlalyecac Formation

It is found within a range of 505-814 m. It is material carried by mud streams, not classified and inter-stratified with volcanic rocks. They have been defined as hybrid tuffs, and they also have rhyodacthic, lathitic and andesite lava spills. It is believed to be from the Pliocene-Pleistocene period (Alvarez Jr., 1968).

Tarango Formation

Found between 189 and 505 m deep. It is formed by marls, lacustrian limestones, tuffs, ashes, pumice stone, gravel, sand and clays, fluvial volcanic gravel, thin layers of pumice stones and alluvial deposits formed at the skirts of Sierra Nevada, due to the erosion undergone by volcanoes.

Most of the authors set this Tarango formation at a depth of 33 m, which would include the hard layer, the lower clayey formation and deep deposits, according to Marsal and Mazari.

Other units that are not described in PP-1 but reported by different researchers in other studies are described next.

Tacubaya Formation

It is constituted by alluviums, tuffs, breccias, pumice stones and volcanic ashes in its marginal surface (Cecear, 1952). The lacustrian surface is formed by montmorillontic clay with ash and pumice stone intercalations, diatoms and *ostracodos*; Schlaepfer (1968) defines it as semi-consolidated silty tuffs from a volcanic origin, deposited in a lacustrian means. Sediments that extend at a depth of 3-30 m in PP-1 correspond to this type and to the top clayey formation.

Caliche **Morales Formation**

Benthic clay, cracked and with an abundance of calcium carbonate in its lacustrian surface. Its fluvial surface has sediments known as *caliche* (lime crusts or flakes). It crops out at Lomas de Chapultepec zone.

Becerra Formation

Its marginal faces have alluviums, aeolic deposits, pyroclastic material and an abundant fauna of vertebrates. Bryan establishes three other units based on a edaphologic criterion and in accordance with Arellano and De Terra works; he calls them Noche Buena formation, which is constituted of sand, alluvium, aeolic materials, humus and soils, with several traces of roots left by aquatic plants.

Totoltzingo Formation

It is constituted of clay with a great amount of humus. It defines a post-glacial cold weather. Schlaepfer includes in this unit the Noche Buena deposits (alluvium soils) and *Caliche* Barrilaco, which represents a period with warm weather and constituted by plastic clays and *caliche*.

2.1.5.6 Geophysics

In order to complement the knowledge available on the subsoil stratigraphy, the geophysics works carried out in the ex-Lake Texcoco have been analyzed.

These geophysical studies date from 1952-1953, when gravimetry, refraction seismography and geoelectrical research were conducted.

The regional gravimetry survey was carried out at the flat section of the valley and it was only a qualitative interpretation of the subsoil, since the underground stratigraphy and the density of the rocks were unknown. Four underground sub-basins were determined from this survey: Texcoco, Teotihuacan, Mexico City and Chalco.

A gravimetric shoal was detected at the first sub-basin, close to Cerro Chimalhuacan; this zone was later used as a reference for additional seismic studies.

In 1966, a seismic survey was programmed (Proyecto Texcoco, SHCP), consisting of a series of lines. The first one is the base line and runs from Chimalhuacan to Cerro Gordo; this line matches the gravimetric shoal previously mentioned. The second line (line 2) goes from Cerro Peñon de los Baños to Chapingo, at the intersection of the base lines and where the drilling of deep well 1 (PP 1) was programmed (Figure 2-7).

The results of the seismic studies (profiles) detected two refractory contacts denominated "A" and "B". These have a semi-horizontal behavior at the base line, and before reaching PP-1 they start going down and heading southeast; i.e. towards Cerro Chimalhuacan, and when they are 3 km away northwest of PP-1, "A" is found at a depth of 770 m, whereas "B" is found 1850 m down. The spills from Chimalhuacan volcano apparently were deposited on refractor "A" (Figure 2-8).

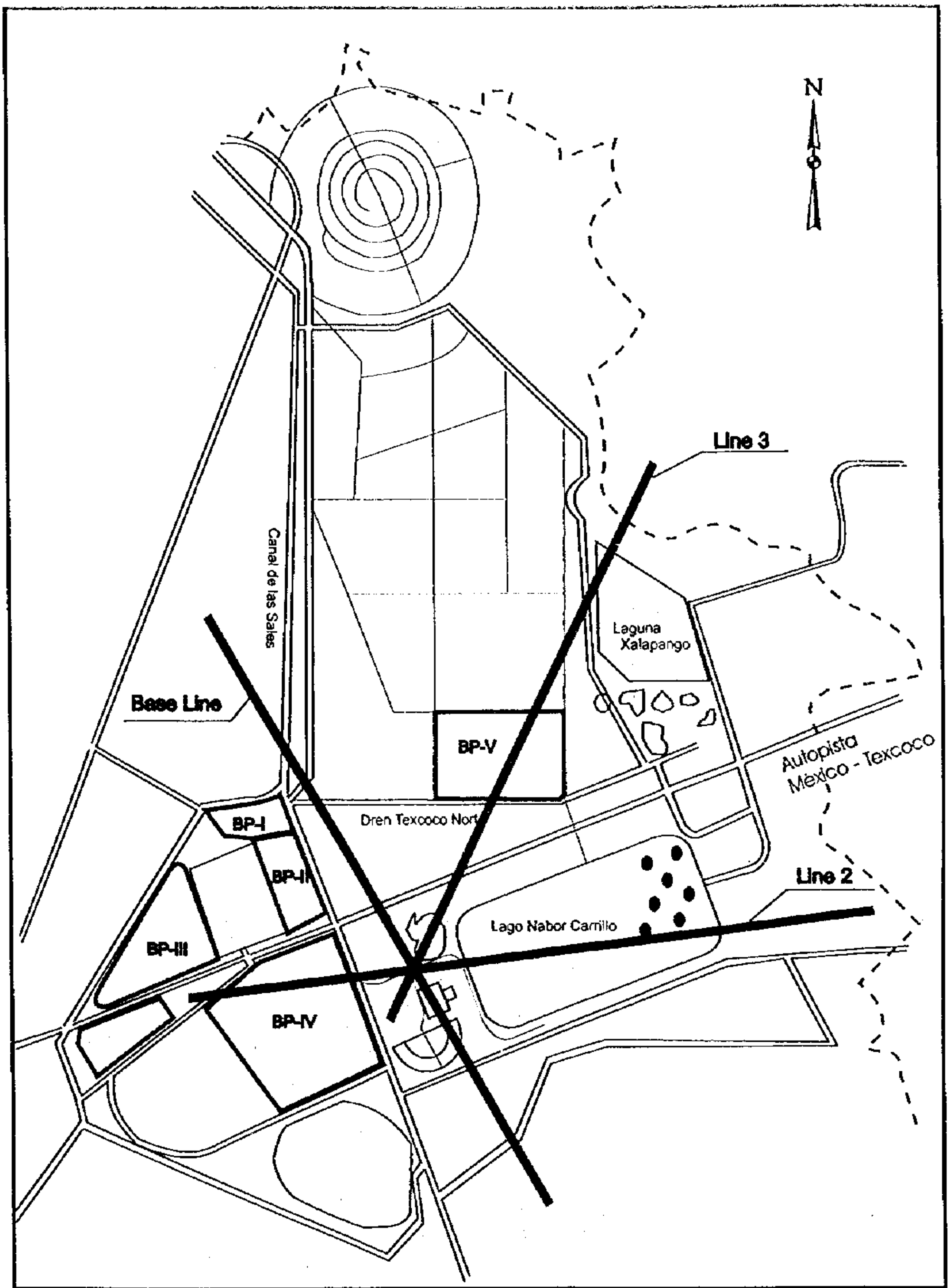

Figure 2-7:
Location of Seismic Lines

Line

KOKUSAI KOGYO Co., Ltd.

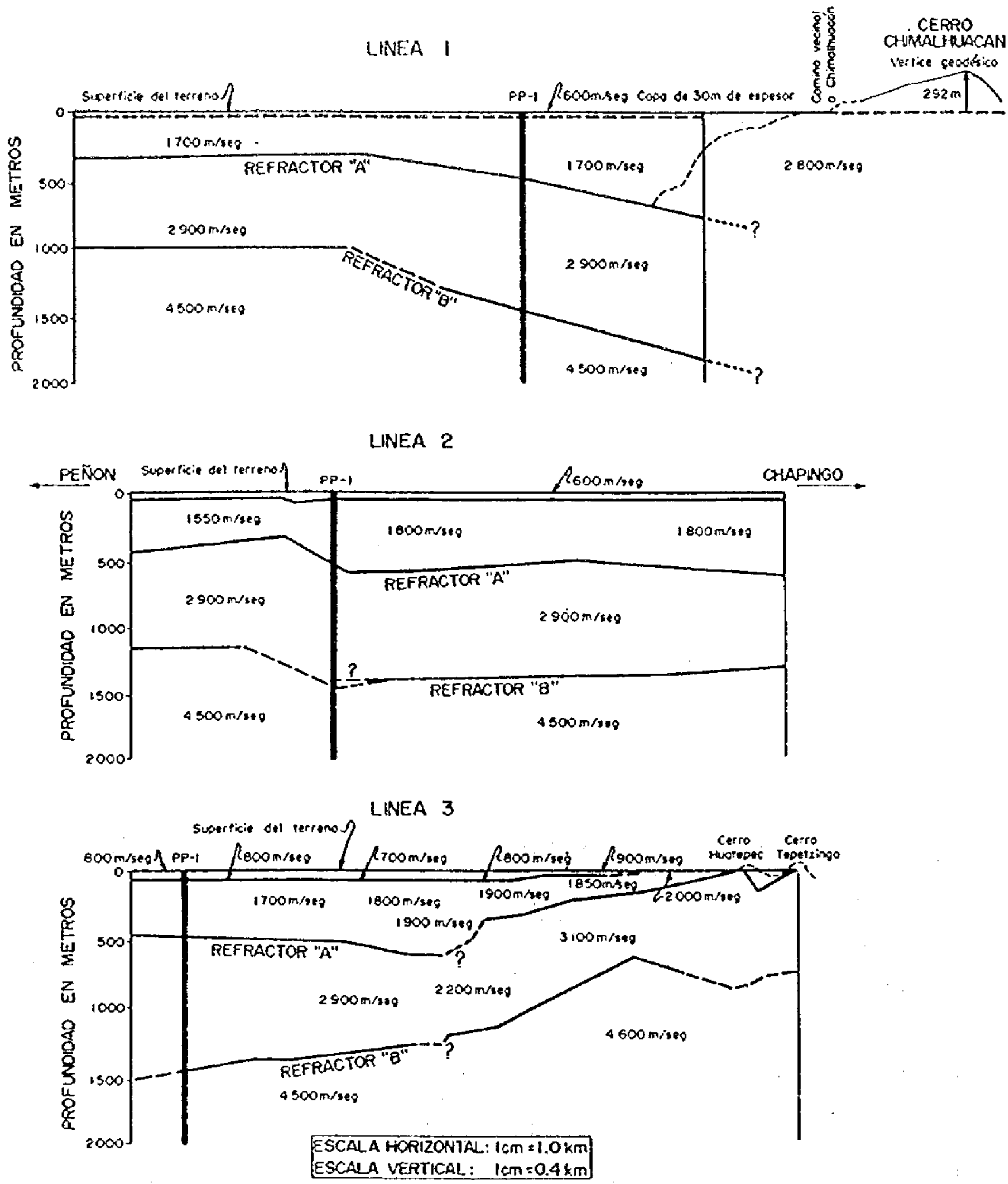

Figure 2-8: Profiles of the Seismic Exploration Lines of Refraction

With the previous note and with the gravimetric anomaly, it is concluded that close to Cerro Chimalhuacan there is a buried valley in a northeast-southwest direction, which probably represents a trace of the thickness of the sediments in the area.

The results of the refraction seismology determined four mantles, which are characterized by the different velocity of propagation of seismic waves and whose features are shown in the following table.

Table 2-12: Mantles and Refractors Determined at the Base Line

Mantle	Average velocity (m/sec)	Estimated depth (m)	Formation features
Top	600	0 to 30	Highly compressible clayey formation and saturated with water
First	1,700	30 to 520	Sandy-clayey formation, poorly compacted and saturated with water
Refractor "A"	--	520	--
Second	2,900	520 to 1,445	Compact tuffs with sandy horizon intercalations
Refractor "B"	--	1,445	--
Third	4,500	1,445 and beyond	Highly compacted rocks, probably igneous

The results obtained from the seismic refraction lines led to the conclusion that igneous rock spills and pyroclastic material at the ex-Lake Texcoco subsoil came from three volcanic systems:

- The first one from Huatepec volcano, whose deeper emissions reached to Cerro Chimalhuacan.

- The second one is formed by Cerro Gordo and Cerro Peñon de los Baños.

- The third one corresponds to Chimalhuacan volcano, whose emissions lay over the deep rocks of Huatepec volcano.

As a consequence of the 1985 earthquake, in 1987 the Geophysics Department of the Federal Electricity Commission (CFE) conducted subsoil studies in Mexico City to investigate on shallow deposits. Part of these studies encompassed the ex-Lake Texcoco area, which were taken into account for the geophysical survey.

Studies carried out included seismic refraction and vertical electric soundings (VES), with an approximate depth for the research of 500 m.

The seismic refraction studies conducted by the CFE also showed four mantles with the following features.

Table 2-13: Seismic Refraction Conducted by CFE in 1987

Mantle	Average velocity m/sec	Estimated depth m	Formation features
1	250 to 1,100	25	Superficial layer constituted by lacustrian clayey deposits (T3 laying)
2	850 to 1,500	70	Slightly compacted clayey deposits
3	1,700 – 2,000	300	Allumium deposits (T2- T1 laying)
4	2,000 – 3,000		Located only in laying T1 and T2

As it can be observed, the seismic studies carried out in 1966 and 1987 provided the features of four mantles:

The top stratum is the same in the two studies; its depth reaches 25-30 m and the velocity of seismic waves goes from 250 to 1,100 m/sec (and the velocity of 600 m/sec from the previous study included here).

In 1960 a velocity of around 1,700 m/sec and a thickness of 30-520 m was detected in the first mantle, up to the first refractor "A". In 1987, the CFE reports a speed of 850-1500 m/sec, yet at a depth of 70 m. In both cases this is related to sandy-clayey materials, but they are interpreted with a different granulometry.

The CFE detected another horizon at a depth from 70 to 300 m, which are regarded as regular-compaction alluvium deposits associated with lava spills; this layer is inside the first mantle of 1966 geophysics (Carrillo). Both stratums are made of the same material, but they were studied based on different granulometry techniques.

The last horizon detected by the CFE is found at a depth greater than 300 m, with velocities from 2,000 to 3,000 and even 4,000 m/sec, it is related to tuffs and lava spills and corresponds to the second mantle of the base line, with a different depth since the second layer is found beyond 520 m.

From the aforementioned, it can be concluded that the first layer is a slightly compacted clay with a thickness of 25 to 30 m. There is a second clayey sand stratum saturated with water at a depth of 70 m, which is lacustrian.

Below a depth of 70 m, the prevailing materials are sandy with a slight compression, which are probably associated with some lava spills and with water, with a depth of up to 300 m and 520 m in some sites (Chimalhuacan zone and up to Cerro Gordo area).

Compacted igneous rocks were found from these depths (300-500 m), which might be the foundation of granular alluvium-lacustrian materials that filled the ex-Lake Texcoco.

2.1.5.7 Electric Geophysics

Regarding the electric geophysics studies carried out by the CFE in 1987, only two geoelectrical lines penetrated in the ex-Lake Texcoco. Two big material packages were determined: one regarded as old (A), associated with volcanic rocks, and a recent one (R), related to filling materials of the lake.

In the section parallel to the Peñon Texcoco road four units were detected. Unit 1R is located between VES[6] 2581 to 1210; it has a depth of 225 m in its center (VES 1205) and merges towards its ends until it disappears. It is characterized for having a resistivity of 0.2 to 0.25 ohm-m in the first 20 m, and increasing to 1.2 in the rest of the unit. It has been related to lacustrian deposits with a predominance of fine elements (Figure 2-9). Locations of VES are shown in Figure 2-10.

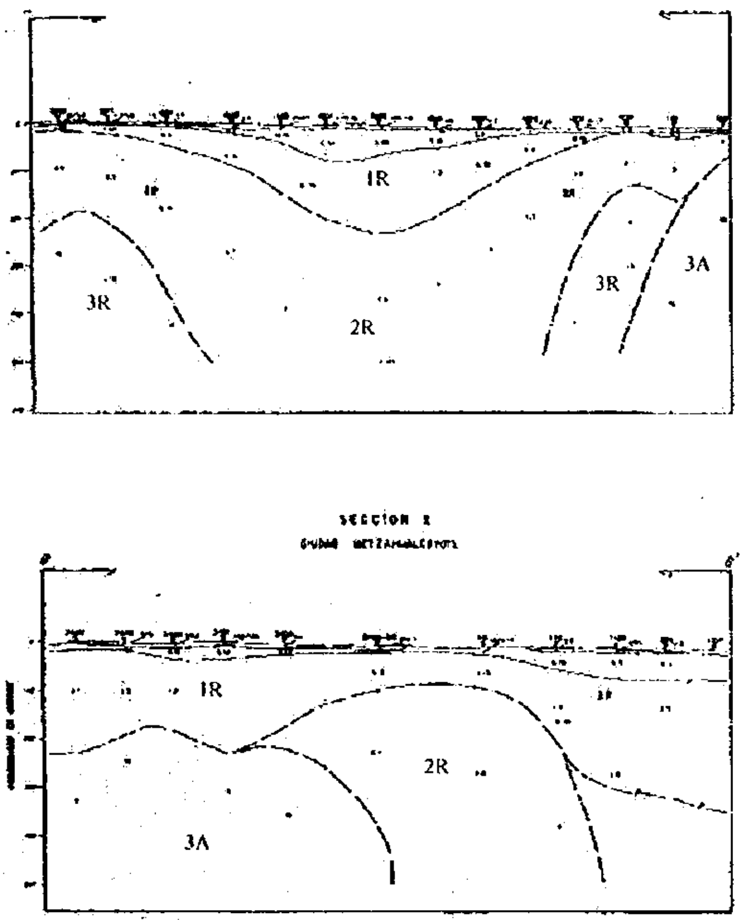

Figure 2-9: Electric Geophisics

[6] VES: Vertical Electrical Sounding

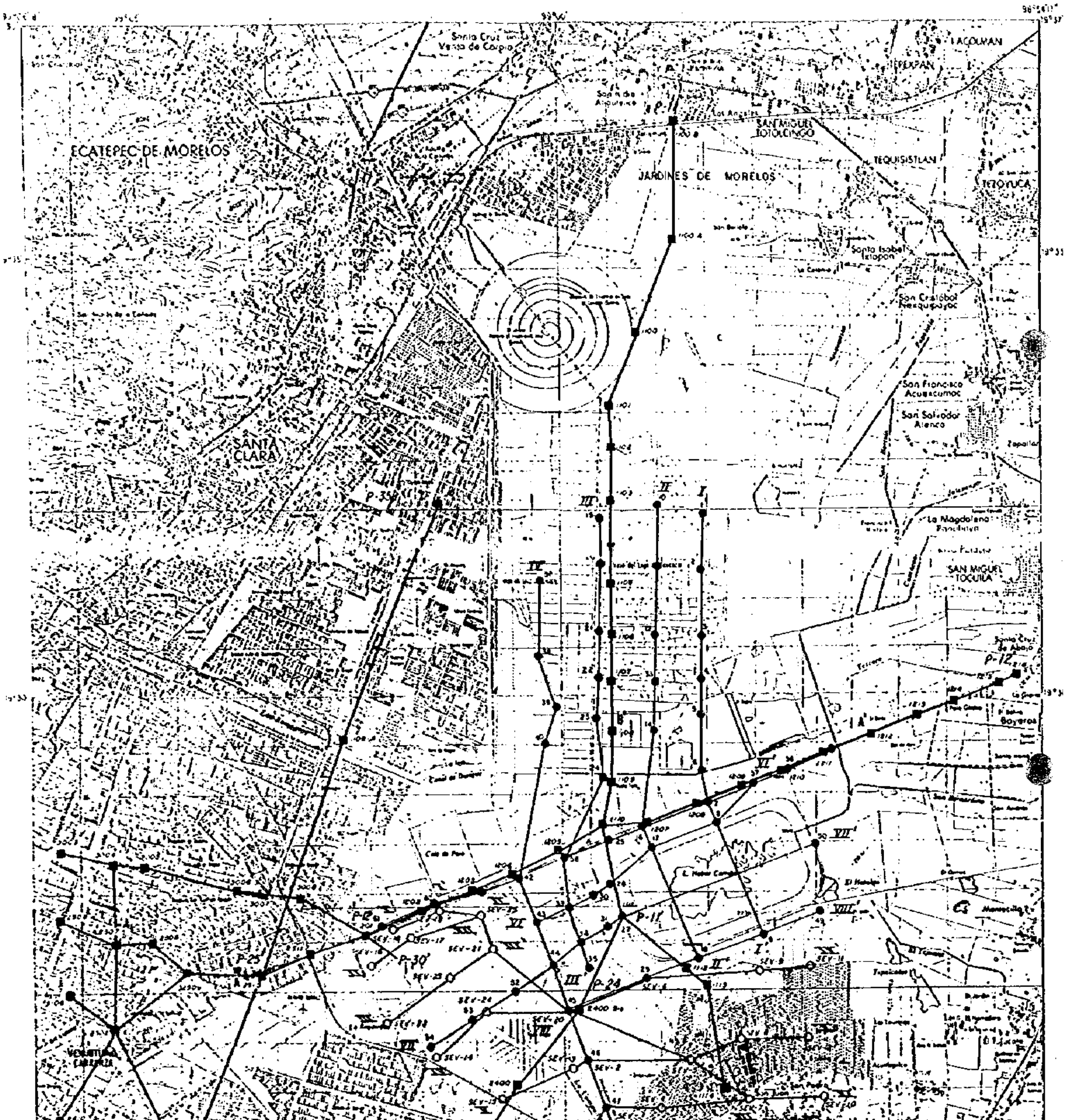

Figura 2-10: Ubicación del Sondeos Eléctricos Verticales

ESCALA GRAFICA
0 1 2 3 4 5
KILOMETROS

Unit 2R underlies the 1R and deepens indefinitely into the center of the area (VES 1203-1205); thickness decreases towards the ends of the section until it reaches an average of 100 m. The resistivity recorded is 6.2 to 6.8 ohm-m, which was related to old lacustrian and alluvium deposits with a clayey sand consistency.

Geoelectrical unit 3R is located at both sides of the section. It begins at 200 m and deepens indefinitely towards the southwest, and it is only 200 m thick towards the northeast. The resistivity recorded is from 12-15 ohm-m and is related to a alluvium-type material.

Geoelectrical unit 3A is located at the northeastern end (VES 1201-1212). The resistivity of this unit is 6-15 ohm-m and is related to volcanic material, such as breccias and compacted tuffs, which are generally altered.

The section heading north-south only appears in units 1R, 2R and 3A; the first one has an oscillating contact, with a thickness of 300 m at its ends (VES 1110 and 2404 to 2400) and decreases to the center to 80 m (VES 1111).

Unit 2R was recorded only at the northern end (VES 2400-1110); it is found at a depth of 80 m and deepens indefinitely.

Unit 3A is found in a lateral contact with 2R and below 1R; it is located south of the section (VES 2404-2400). It is 300 m away from the surface and deepens indefinitely.

The following table shows the summarized features, including the longitudinal seismic velocity values.

Table 2-14: Integration of Geophysical Study Conducted by CFE (1987) and LESSER y Asociados, S.A. (1988)

Geo-electrical unit	Thickness (meters)	Resistivity Ohm-m	Longitudinal seismic velocity m/sec	Characteristics
1 R	20 - 335	0.2 and 1.5	Vp= 300 and 550	Lacustrian horizons predominance of fine elements
2 R	100 m in sec 1, undefined in sec 2	1.5 and 4	Vp= 450 and 900	Lacustrian horizons with alluvium deposits
3 R	200 m undefined	5 and 14	Vp=800 and 1300	Alluvium materials
3A	Undefined	6 – 15	Vp=1500-1800	Volcanic material

On the other hand, in 1988 Lesser y Asociados, S.A. carried out vertical electric soundings in the central and eastern part of the ex-Lake Texcoco, obtaining the following results.

Geoelectrical unit 1 was found all around the zone with a thickness of 1-10 m, a low resistivity of 0.044 to 25 ohm-m that corresponds to lacustrian clayey materials, which have water with a salinity greater than 10,000 ppm.

Geoelectrical unit 2 was also found all around the area with an average thickness of 60 m, which becomes thinner and even disappears towards the east (VES 57 and 58) in the surroundings of Lago Nabor Carrillo and Cerro Chimalhuacan. At the zone close to the airport, thickness increases. The resistivity recorded was 0.017 to 9.7

ohm-m that was related to clayey material, saturated with salty water -5,000 to 10,000 ppm- and regarded as an *aquitard*.

Geoelectrical unit 3 was also found all around the ex-Lake Texcoco with a variable thickness at the center of the ex-Lake Texcoco federal zone (VES 29-18,16) and close to the wastewater treatment facility. The reduction in thickness is towards the north (VES 37,201) and southeast, where it may be possible that it merges at Cerro Chimalhuacan. The resistivity recorded is 1.4 to 71 ohm-m, which is related to sandy-clayey deposits and saturated with water of 2,000 ppm salinity, and it is regarded as the main aquifer unit in the zone.

Geoelectrical unit 4 is underneath all the previous units; its thickness varies -beyond 500 m-, and no other lower unit is defined. Its resistivity is 12.8-255 ohm-m and is related to tuff and clayey material, and it is unknown if it contains water.

Table 2-15 summarizes the above features.

Table 2-15: Features of Geoelectrial Units

Geo-electrical unit	Thickness (m)	Resistivity Ohm-m	Salinity ppm	Characteristics
1	1 – 10	0.044 – 25	10,000 (up to 54,000 in Sosa Texcoco)	Altered top layer, essentially clay
2	60	0.17 – 9.7	5,000 – 10,000	Saturated clayey material, which behaves as an *aquitard*
3	300 – 500	1.4 – 71	2,000	Sandy-clayey deposits, constituting the main aquifer of the zone
4	+ 500			

The following notes can be obtained from both geophysical studies:

From the vertical electrical soundings (VES) conducted over Peñon-Texcoco road, it was found that the CFE discovered a superficial layer (1R) that matches the geoelectrical units 1 and 2 of the second author. In both studies, the resistivity is similar -in the range of 0.2 to 1.6 ohm-m. Lesser y Asociados consider that layer 1 has a constant thickness of 15 m; unit 2 is semi-horizontal, with its lower limit being found at 80 or 100 m. The CFE regards the depth of unit 1R at the center of the section (VES 1205) down to 225 m. In both cases, it merges until it disappears towards the northeast, and it can also be considered that the materials are lacustrian clays for both instances.

CFE's geoelectrical unit 2R deepens into the subsoil, without reaching the foundation, in all the central zone (VES 1202-1110). This unit partially corresponds to Lesser's unit 3, since there is a boundary towards the southwestern part of the section 240 m deep, which increases up to 435 m to the northeast (VES 25).

According to the CFE, these are alluvium and lacustrian materials that also correspond to Lesser's alluvium materials, who regards them as the main aquifer; in both cases, the resistivity for the units is 1.5 to 5.8 ohm-m, and they are similar in this sense.

However, according to Lesser, there exists a semi-compact foundation located 240 m deep southwest and 435 m northeast, which is formed by tuffs and marl; in this case, the resistivity is radically different, since it is recorded at 28 to 61 ohm-m, whereas the CFE still maintains it at 1.5 to 4 for "2R".

Another difference is that the CFE detected unit 3R -regarded as alluvium material- towards the southwest (VES 1201-2510) and northeast (VES 1209), which was formed outside the lake. The first case is located 290 m down and goes down the subsoil indefinitely; the resistivity is 5-14 ohm-m, which is similar to Lesser's unit 4. For the second case, it also matches Lesser's unit 3.

At the northeastern zone, the CFE detected an old stratum (3A) to a depth of 300 m and related it to pyroclastic volcanic rocks with a resistivity of 15-40 ohm-s, which would probably match Lesser's unit 4.

As a conclusion, it can be mentioned that;

- A superficial horizon of altered material can be found, with a resistivity of 0.25 to 0.4 ohm-m and a thickness of 15 m in average.
- A second lacustrian clayey layer is found with a thickness ranging from 60 to 80 meters and a resistivity of 0.2 to 0.4 ohm-m and an average thickness of 15 m.
- A second lacustrian clayey layer is found with a thickness ranging from 60 to 80 meters and a resistivity of 0.2 to 1.6 ohm-m that merges to the ends.
- A third alluvium, sandy-clayey layer is found which forms the aquifer, with its resistivity ranging from 1.5 to 5.8 ohm-m, and its thickness has not been defined yet.
- The thickness of the fourth layer, just like the previous one, has not been defined yet: it is composed by more compacted material, with a resistivity ranging from 28 to 61 ohm-m. This unit may have volcanic rocks towards the east.

2.1.5.8 Prominence

The site for the project is located in a zone with a predominant flat prominence, with no important topographic unevenness.

2.1.5.9 Soils

Soils in the Area

In the Mexico Valley basin most of the soils originate from volcanic ashes and recent soils. Lacustrian soils from the Quaternary period are particularly found at the ex-Lake Texcoco area.

The soil found in the ex-Lake Texcoco is grouped according to FAO's classification as *Solonchak gleyico* and related to orthicon *Solonchak*, with a fine texture. On the other hand, in the surroundings of the project, specially in Ecatepec, there is Lithosol along with *haplico* and calcareous *Feozem*; sometimes these soils also appear along with *Vertisol pelico* and *Feozem haplico* with medium texture lithosol.

The *solonchank gleyico* is characterized for having a high salt content, and it has a bluish gray layer in the subsoil where water stagnates. It has a depth of more than 100 cm, and is limited by the phreatic level; it has an average thickness of 39 cm. Horizon

A is known as *Molico* and reacts slightly when in presence of hydrochloric acid, and with a fine texture. Its structure has fine blocks and a moderate development. It presents cracks, with a slight drainage and is in a sodium stage.

Some aspects analyzed by the former Comision del Lago de Texcoco (Texcoco Lake Commission) at the zone are described next.

Table 2-16: Soil Characteristics

SOIL CHARACTERISTICS		A	B	C	D
DEPTH cm		0 to 20	20 to 40	0 to 20	20 to 40
CONDUCTIVITY mmhos-cm		24.1	74.3	54	70
PH		9.5	9.6	10.2	10.2
SATURATION %		72.5	74.3	69.0	70.5
TEXTURE	Sand %	62.28	66.64	55.28	64.56
	Clay %	21.71	18.07	27.15	23.15
	Silt %	10.00	15.28	17.56	12.28
ORGANIC MATTER %		5.6	4.7	6.0	5.5
SOIL TYPE		sandy-clay	sand	sandy-clay	sand

SOURCE: COMISION DEL LAGO DE TEXCOCO, 1980.

Notes: The sections A and B correspond to a classification of Solonchak gléyico and the others C and D to a classification of Solonchak órtico.

On the other hand, the General Direction of Geography from the Budgeting and Programming Secretariat provided the physical and chemical features of the *solonchak gleyico* that was found at the ex-Lake Texcoco (1983) as Table 2-17.

Table 2-17: Physical and Chemical Features of the Soil

SOIL HORIZON		Cámbrico	Argílico	Argílico II	Cámbrico
DEPTH (cm)		0-13	13-31	31-52	52-100
TEXTURE	Clay %	22	36	34	34
	Silt %	10	22	22	26
	Sand %	68	42	44	40
TEXTURE CLASSIFICATION		Sandy Clayey bits	Clayey bits	Clayey bits	Clayey bits
COLOR WHEN DRY		10YR6/1	10YR5/1	10YR5/1	10YR5/1
COLOR WHEN WET		10YR4/1	10YR3/1	10YR3/1	10YR3/1
ELECTRICAL CONDUCTIVITY mmhos-cm		35.8	50.0	40.0	35.0
pH in water 1:1 ratio		10.3	10.7	10.7	10.7
ORGANIC MATTER %		0.1	1.2	1.3	0.5
C.I.C.T. (meq/100 g)		19.0	27.3	25.8	26.0
SATURATION OF BASES %		100	100	100	100
SODIUM (meq/100 g)		10.9	17.7	19.5	18.3
SODIUM SATURATION %		Greater than 40	Greater than 40	Greater than 40	Greater than 40
POTASSIUM (meq/100 g)		8.1	9.6	6.3	7.7
CALCIUM (meq/100 g)		4.7	4.4	5.3	5.9
MAGNESIUM (meq/100 g)		0.2	0.6	0.1	0.3
PHOSPHORUS (PPM)		53.4	35.8	34.3	not available

SOURCE: SPP (Secretaría de Programación y Presupuesto), 1983.

Filed Investigation of Soil

Borings and soil analysis were carried out by the JICA team. The results are shown in the following table. The location of borings is indicated in Figure 2-11.

Table 2-18: Soil Characteristics in Etapa V

Characters \ Location	SM-1		SM-2		SM-3		SM-4		SM-5			
	36.1-36.7m	39.7-40.3m	6.0-7.0m	33.3-34.3m	4.8-5.8m	12-12.6m	3.0-3.9m	18.9-19.5m	12.0-12.9m	18.6-19.2m	24.0-24.6m	55.0-55.6m
Type of soil (Visual observation)	clay	clay	clay	clay	clay	clay	clay	clay	clay	clay	clay	silty clay
Specific gravity	2.85	2.99	2.82	2.77	2.85	2.82	2.99	2.86	2.86	2.91	2.94	2.96
Unit weight (ton/m^3)	1.29	1.30	1.16	1.24	1.47	1.31	1.14	1.14	1.20	1.20	1.25	1.32
Void ratio	4.58	6.20	12.30	8.40	2.51	4.90	14.20	9.95	8.70	5.97	6.21	4.10
Degree of Saturation (%)	95.0	103.0	103.0	106.0	83.4	99.8	100.0	97.0	99.0	97.0	98.0	92.0
Water content (%)	152.0	136.0	447.1	321.7	83.4	173.7	398.0	302.0	281.0	147.0	193.0	129.0
Liquid limit (%)	140.7	158.8	354.0	244.8	108.8	259.0	443.0	356.0	320.0	148.0	202.0	134.0
Plastic limit (%)	31.7	33.4	29.8	32.7	34.2	33.8	78.8	33.2	32.7	25.6	24.1	31.0
Plasticity index (%)	109.0	125.4	324.2	212.1	74.6	225.2	364.2	322.8	287.3	122.4	177.9	103.0
Triaxial undrained C (ton/m^2)	9	0.4	1	2	0.03	0.16	0	0	0.05	1.4	0	5
Angle of internal friction (deg.)	9	1	3	6	1	0	5	7	0.5	0.29	5	11
Simple compression qu (ton/m^2)	14.4	6.3	0	5.8	1.0	0.98	0.15	0.85	0.9	2.3	0.9	14.3
N value	0	0	0	0	0	0	0	0	0	0	0	15
Coefficient of consolidation (cm^2/s))	0.02	0.0091	0.0021	0.0067	0.0071	0.0105	0.0025	0.0063	0.0765	0.0199	0.0071	0.1294

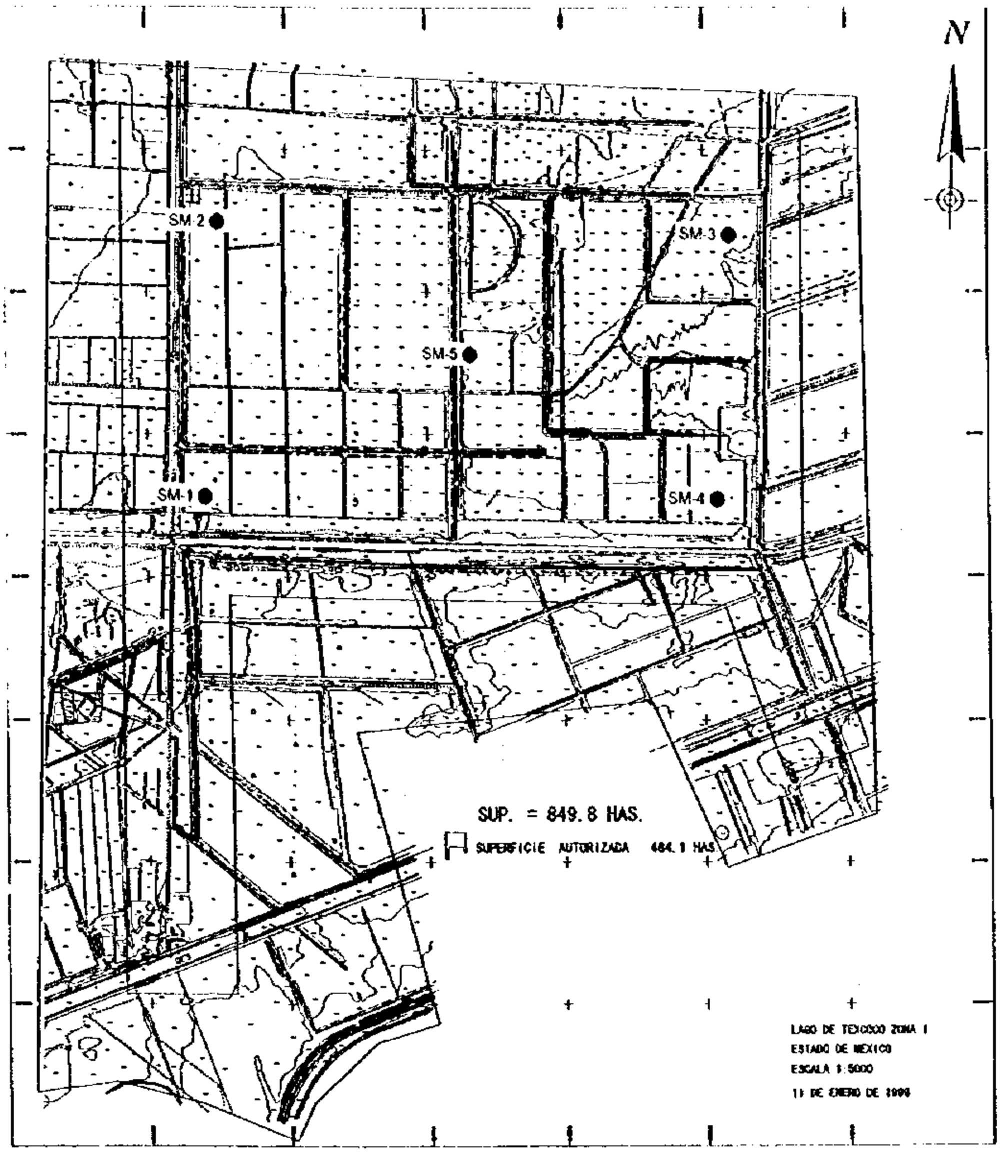

Figure 2-11: Location of Boring Points

Accordingly, it is understood that the soil type of the area is largely clay which is found down to 50 m depth. This clay formation shows significantly high water content. Therefore it is considered that the stratum is soft and compressible.

Soil Quality

Soil samples were taken in the project site of Etapa V landfill during December 1998 and the concentration of some contaminants was analyzed. The results are shown below. The sampling points are just beside the boring points, which is shown in Figure 2-11.

Table 2-19: Results of Sampling Analysis of Surface Soil

Site	CN	Cd	Cu	Pb	Cr(VI)	Hg	As	Total P
SM-1 (mg/kg)	n.d.	n.d.	7.019	27.188	n.d.	0.005	n.d.	139.250
SM-2 (mg/kg)	n.d.	n.d.	12.054	58.881	n.d.	0.001	n.d.	135.180
SM-3 (mg/kg)	n.d.	n.d.	9.053	40.516	n.d.	0.002	n.d.	213.860
SM-4 (mg/kg)	n.d.	n.d.	n.d.	25.462	n.d.	0.001	n.d.	190.490
SM-5 (mg/kg)	n.d.	n.d.	n.d.	28.437	n.d.	0.006	n.d.	376.350
Standard A (mg/kg)	-	9	-	600	-	3	50	-
Standard B (mg/l)	should not be detected		125		0.05		should not be detected	should not be detected*

Notes:
n.d.: not detected.
Standard A: Guide values in Japan as threashould to start countermeasures.
Standard B: Environmental standards of Japan to be complied with by any soil expressed as mg per litter of water which is added to the sample soil.
* Only applied to organic phosphorus

The table shows the regulation values used in Japan as a comparison purpose. For the parameters not included in Standard A, Standard B is shown only for reference purpose.

It is concluded from the table that all the values of heavy metals are sufficiently low. As for phosphorus, the measured value is total phosphorus, and it is unlikely that this contains organic phosphorus.

The figures in the table can be utilized as background values for the future investigation at the project site in order to determine the possibility of environmental contamination by the project.

2.1.5.10 Salinity of the Ex-Lake Texcoco

There are diverse theories on the salinity of the ex-Lake Texcoco, being one of them proposed by Aguayo in 1989; he explains that the high salt concentration is due to hydrothermal processes, since the distensible zone was found where were thermal springs such as Pathe, Tecozautla and others in the state of Hidalgo.

However, the most widely accepted theory explains this salt concentration as a consequence of the evaporation of great amounts of water during long drought seasons, or even due to a restricted circulation of water in the area. On the other hand, erosion and carriage of salts from the buried Huatepec volcano, which is northwest of the ex-Lake Texcoco, might have contributed to its salinity, as well as the volcanic zones and gaseous emissions that impregnated the rocks in the subsoil.

The salinity of the ex-Lake Texcoco is as high as two-folds that of the sea, and the Sosa Texcoco pumped up this highly mineralized underground water (brine) with a considerable amount of bicarbonates and sodium chloride to obtain sodium hydroxide (soda).

2.1.5.11 Superficial Hydrology

Rivers and Canals

In general terms, there is considerable variations in the hydrology of Mexico Valley Basin, despite of its reduced area if compared with other basins in the country; i.e. there exists a broad diversity among the streams formed in the basin because of the climatic variations and the geological and orographic features, which cause pronounced slopes of river beds and reduced catchment areas of the sub-basins that integrate them. Due to the aforementioned characteristics, almost all the streams in the valley are torrential and intermittent flows. This is why these rivers have water during the rainy season and are dry in the rest of the year. In spite of the above, they still represent a problem for the zones where they cross through, since their river beds are silted up or obstructed and can not control them adequately. Fortunately, this situation is being solved through hydraulic works.

The ex-Lake Texcoco is located within the "Alto Panuco" hydrological region (No. 26), which is one of the most important regions within the Mexican Republic, both for the volume of its superficial flows -ranged within the biggest five in the country- and for its surface.

It has the following sub-basins: Rio Prieto (26DF), Arroyo Zarco (26DG), Tula river (26DJ), Rio Rosas (26DK), Tlautla river (26DL), El Salto river (26DM), Tepotzotlan (26DO), Texcoco and Zumpango lakes (26DP), Rio Salado (26DQ), Rio Tezontepec (26DT) and Tochac and Tecomulco lakes.

Several rivers flow into the ex-Lake Texcoco area. Although they are called rivers (Ríos), as a matter of fact, it should be more appropriate to call them canals. Their prime role is to serve as open sewerage receiving wastewater from residential areas of the DF and some of the municipalities of the State of Mexico. For this reason, they are found to be a nuisance for residents who are exposed to their unfavorable odor.

Those canals are, from northeast, the Río San Juan Teotihuacán, Río Papalotla, Río Xalapango and Río Coxcacoaco; from east, the Río Texcoco, Río Chanpingo, Río San Bernardino, Río Santa Mónica and Río Coatepec; and from south, the Río San Francisco, Río Churubusco and Río de la Compañía. In terms of the flow volume, Río Churubusco and Río de la Compañía are the main water ingress into the area, with flow volume of 10.0 and 4.2 m^3/sec on average[7], while the total flow volume of the others is merely 0.4 m^3/sec and it could be nearly zero in dry season. The location of rivers is illustrated in Figure 2-12.

[7] Data from Texcoco Project

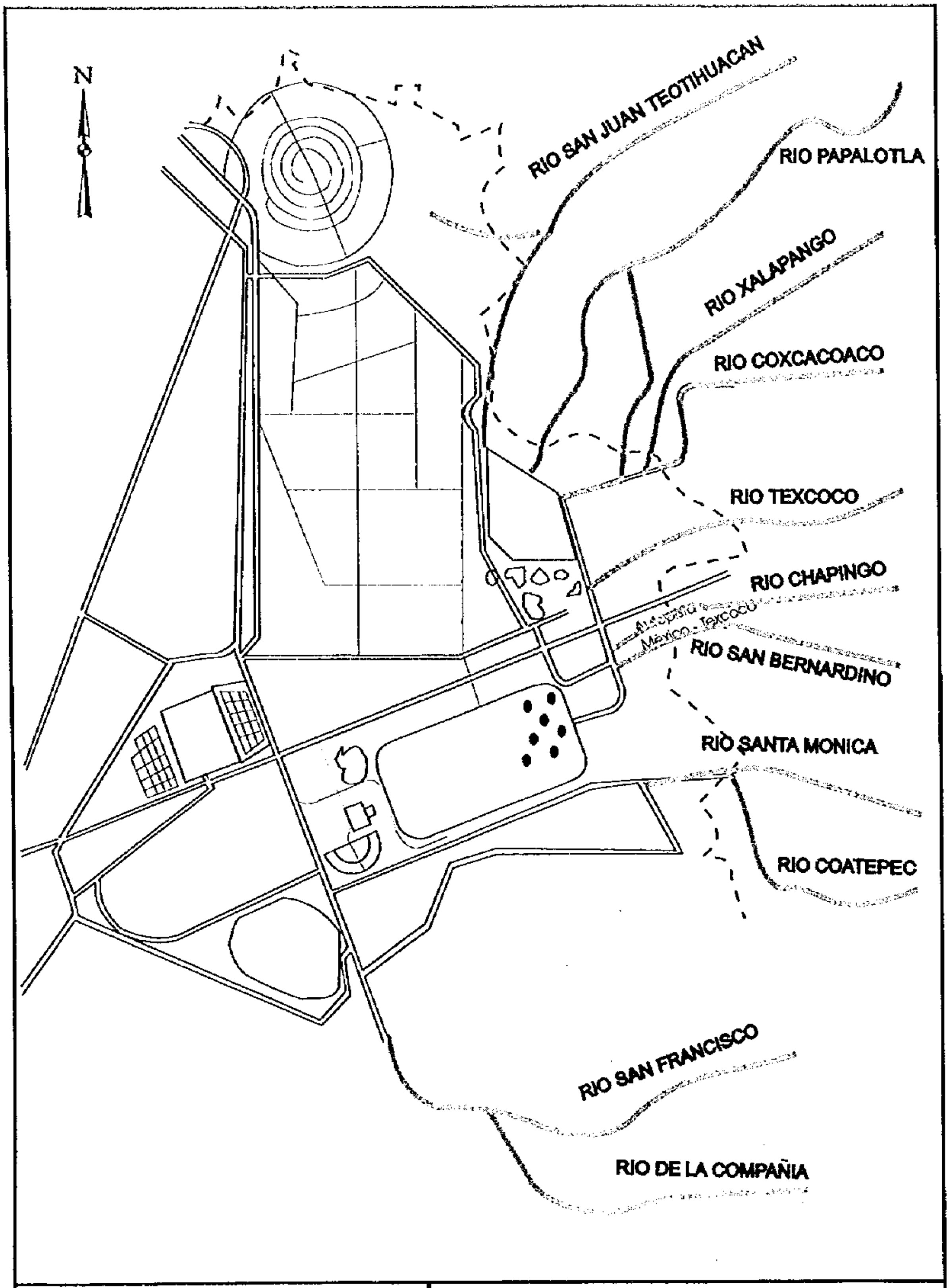

Figure 2-12:
Location of Rivers

River

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Water flown by those canals partly goes to several artificial lakes namely Lago Churubusco, Lago de Regulación Horaria, Lago Xolapango and Lago Nabor Carrillo, and water treatment facilities. The rest of water and some water from those water reservoir flow via canal network within and on the periphery of the ex-Lake Texcoco area. In the canal network, *Dren Texcoco Norte* will be of particular concern since it flows the south limit of Etapa V.

In general, water in the area finally finds its way at canals *Canal de Desagüe* or *Canal de las Sales* both of which flow from south to north on the west edge of the ex-Lake Texcoco area. They join the another large canal *Gran Canal* in the north of the Solar Evaporator (*Caracol*), and the Gran Canal runs towards a lake Lago Zumpango and further north.

Water Bodies

As stated above, there are four major water bodies in the area; Lake Churubusco, Regulation Lake, Lake Xolapango and Lake Nabor Carrillo. All of those are the major accomplishment of the early 80s by the Texcoco Project to control the surface hydrology of the area. Apart from the hydrologic purpose, they are also important in serving as a host of migratory birds during winter.

Lago Nabor Carrillo, with an area of 1,000 ha and a storage capacity of 36 million m^3, stores mainly treated wastewater as well as runoffs of pluvial waters of rivers coming from the east. Water, after collected here, is carried towards the Texcoco lake through a collection canal.

Lago Churubusco, with an area of 267 ha and a capacity of 5 million m^3, was formed by means of the consolidation of clays, originated by the water extraction from the subsoil. It also stores mainly treated water in addition to rainwater from Río Campañía.

The Hourly Regulation Lake (*Lago de Regulacion Horaria*) was constructed within a two-year lapse, excavating 4.5 million m^3 within a surface of 150 ha by means of a suction dredging machine. Crude wastewater flows into this lake together with rainwater from Brazo Derecho Río Churubusco.

These two lakes regulate the overflows from Rio Churubusco, which drains the southern zone of Mexico City's metropolitan area and whose controlled runoffs are incorporated to the Dren General del Valle to be discharged in the Gran Canal de Desagüe.

Lago Xalapango, whose sueface is 240ha and capacity is 3.6m^3, receives residential wastewater and rainwater from rivers coming from the eastern part of ex-Lake Texcoco area.

Surface Water Quality

Water samples were taken from the canals flowing beside the project site of the Etapa V landfill. The table below shows the results, followed by a figure to indicate the sampling sites.

Table 2-20: Results of Sampling Analysis of Surface Water

Site	pH	Cl mg/l	Total P mg/l	Total N mg/l	BOD mg/l	COD mg/l
Site 1	9.33	1,509.00	2.640	n.d.	25.00	398.00
Site 2	8.96	2,386.00	1.050	n.d.	6.20	311.00

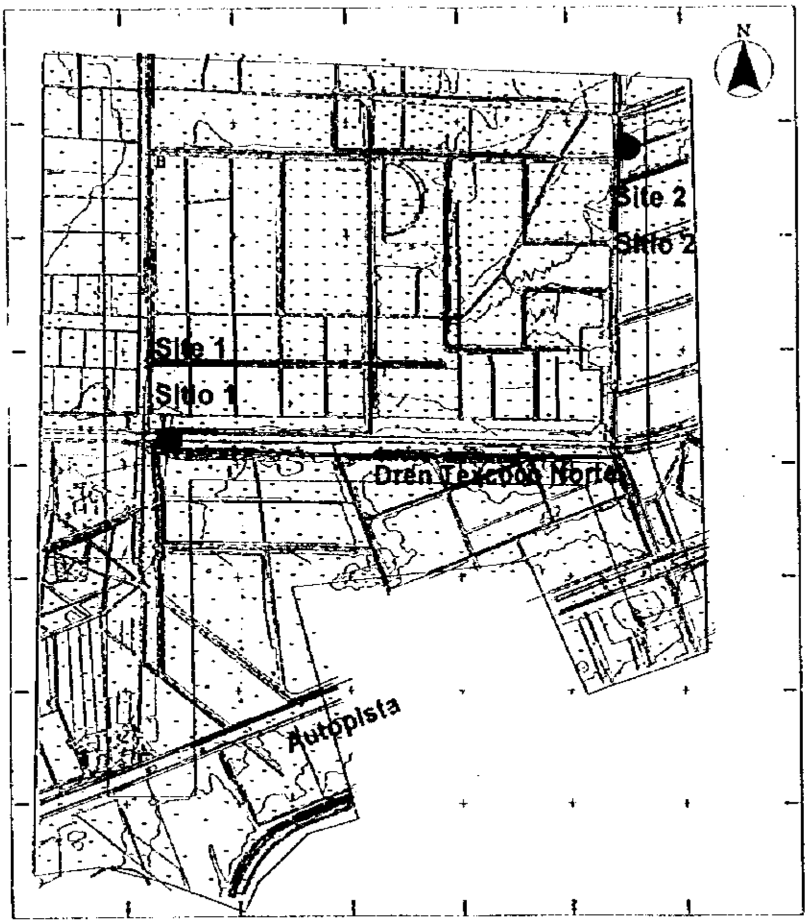

Figure 2-13: Surface Water Sampling Points

The outstanding feature will be the high COD values and large gap between COD and BOD, suggesting the high concentration of organic matter which is resistent to the biological breakdown. Some artificial input of such organic matter along the canal is suspicious, although it is not identified.

The figures in the table can be utilized as background values for the future investigation at the project site in order to determine the possibility of environmental contamination by the project.