H.1.2 Outline of the Projects

Table H-1 shows the outline of the projects.

Table H-1: Outline of the Projects

		*Present	1999	2000	2001	2002	2003	2004
Population		8,610,000	8,654,000	8,698,000	8,747,000	8,796,000	8,846,000	8,896,000
Waste generation amount		(ton/year)						
Household		1,925,000	1,946,000	1,956,000	1,967,000	1,976,000	1,989,000	1,999,000
Commercial		1,210,000	1,217,000	1,221,000	1,225,000	1,230,000	1,234,000	1,238,000
Service		636,000	639,000	641,000	645,000	647,000	650,000	657,000
Special		133,000	135,000	135,000	135,000	137,000	137,000	137,000
Others		265,000	267,000	269,000	269,000	272,000	273,000	274,000
Total		4,169,000	4,204,000	4,222,000	4,241,000	4,262,000	4,283,000	4,302,000
Composting								
**Construction and Operation schedule		F/S	B/D,P/P(1)	P/P(2),D/D, S/V	CON(3/5)	OP(3/5) / CON(1/5)	OP(4/5) / CON(1/5)	OP(5/5)
Treatment capacity (t/d)		-	-	-	-	750	1,000	1,250
Treatment amount (t/y)		-	-	-	-	253,000	338,000	424,000
Final disposal								
**Construction and Operation schedule	BP-IV	F/S	B/D	D/D, CON	OP	-	-	-
	BP-V		B/D	D/D	CON	OP	OP	OP
Site to be used		BP-IV	BP-IV	BP-IV	BP-IV	BP-V	BP-V	BP-V
Disposal amount (t/y)		3,751,000	3,903,000	3,889,000	3,876,000	3,609,000	3,493,000	3,385,000

* : 1997/1998 data
** F/S : feasibility study, B/D : basic design, D/D : detailed design, CON : construction, OP : operation, S/V: supervision, P/P : Pilot Project
t/d : ton/day
t/y : ton/year

H.2 Preliminary Design of Technical System

H.2.1 Composting Facility

a. Examination of Design Condition

a.1 Design Capacity

Capacity of the composting plant is set out under the condition that the whole amount of organic waste generated in the sub-system are to be delivered and fed into the plant.

It is planned that the separate collection in the sub-system is introduced in the year 2000 and its total diffusion (100%) will be achieved in the year 2004. The estimation of organic wastes input amount for the composting plant until 2010 is shown in Table H-3.

The operation of the composting plant is planned to start in the year 2002 and the organic waste separation in the year will be still about 60%, while the plant has to receive 100% of separated organic waste from the sub-system in the year 2004. Therefore, the plant should be constructed from 2001 to 2003 to improve its capacity in a stepwise manner, in order to meet the increase in the organic waste separation rate.

Table H-2: Separate Discharge and Collection Plan

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Separate Discharge and Collection Plan	Mixed Discharge					100%		Separate Discharge				

Table H-3: Organic Waste Collection Amount

unit : 1,000 ton/year

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Organic waste	0	84	168	253	338	424	425	426	428	429	430	431

a.2 Waste Composition

Composition of organic waste applied to the plant design is assumed as shown in Table H-4, based on the future waste amount and composition trends assumed in the M/P framework. Source separation compliance rate is set out as 90% with reference to the 92% compliance recorded in the DGSU's pilot projects for source separation.

The design moisture content can be assumed to be:

- about 78%, which is calculated from the DGSU's empirical data for respective composition items, and from a set of empirical data recorded in Japan; and
- about 68%, which is the moisture content obtained in the field investigation of waste composition by the team.

Therefore, the design moisture content is set out between the **maximum 78%** and **minimum 68%**.

Table H-4: Organic Waste Composition

Composition	Organic matter contents (%)	Moisture contents of each component (%)	Moisture contents (%)
Organic waste			
Vegetable fiber	2.29	*68	1.56
Bone	1.02	*68	0.69
Food waste	78.38	**90	70.54
Garden waste	8.3	***40	3.32
Organic total (a)	**90**	-	**76.11**
Recyclable waste			
Cardboard	0.99	***24	0.24
Synthetic fiber	0.19	***17	0.03
Vinyl	0.04	***17	0.01
Cans	0.27	***4	0.01
Metal	0.41	***4	0.02
Nonferrous metal	0.05	***4	0
Paper	0.46	***24	0.11
News paper	0.83	***24	0.2
Plastic film	0.77	***17	0.13
Hard plastic	0.67	***8	0.05
Color glass	0.34	***8	0.03
Transparent glass	0.58	***8	0.05

Composition	Organic matter contents (%)	Moisture contents of each component (%)	Moisture contents (%)
Recyclable total (b)	**5.58**	-	**0.88**
Non-recyclable waste			
Spatula	0	-	-
Cotton	0.23	***19	0.04
Leather	0.01	***9	0
Paper container	0.43	***24	0.1
Gauze	0	-	-
Disposable syringe	0	-	-
Ceramics	0.05	***8	0
Wood	0.33	***24	0.08
Construction waste	0.38	***8	0.03
Toilet paper	1.09	***24	0.26
Disposable diaper	0.25	***80	0.2
X-ray film	0	-	-
Polyurethane	0.02	***17	0
Foamed polyurethane	0.12	***17	0.02
Sanitary napkin	0	-	-
Rags	0.23	***19	0.04
Bandage	0	-	-
Fine fraction	0.92	***24	0.22
Others	0.35	***24	0.08
Non-recyclable total (c)	**4.42**	-	**1.07**
Total (a+b+c)	**100**	-	**78.06**

* : results of the waste composition survey

** : Harina Vegetal a Partir de Residuos Organicos, LUGARDA ARACELI SANTOS PEREZ, MARGARITA GUTIERREZ ROJAS, VICTOR MANUEL FLORES VALENZUELA, DGSU

***: Design guideline for municipal solid waste treatment facilities in Japan 1978(editorial supervision by ministry of health and welfare, JAPAN)

a.3 Geological Condition

Geological survey data in the composting plant candidate site is absent. However, the candidate site is located near the Bordo Poniente Etapa-IV, and its geological data (see Figure H-2) is used for examining the design of the composting plant.

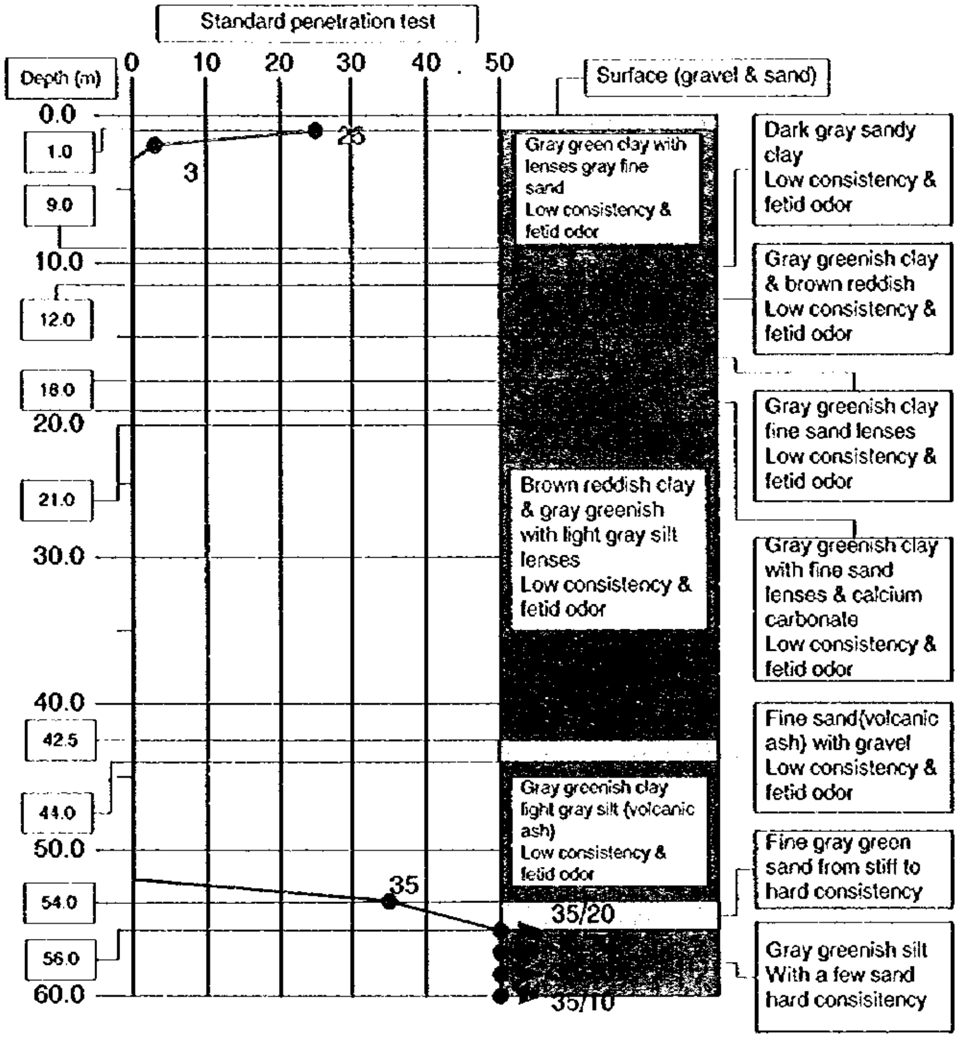


Figure H-2: Results of "Etapa IV" Core Boring (SM-8)

b. Examination of Technical Alternative

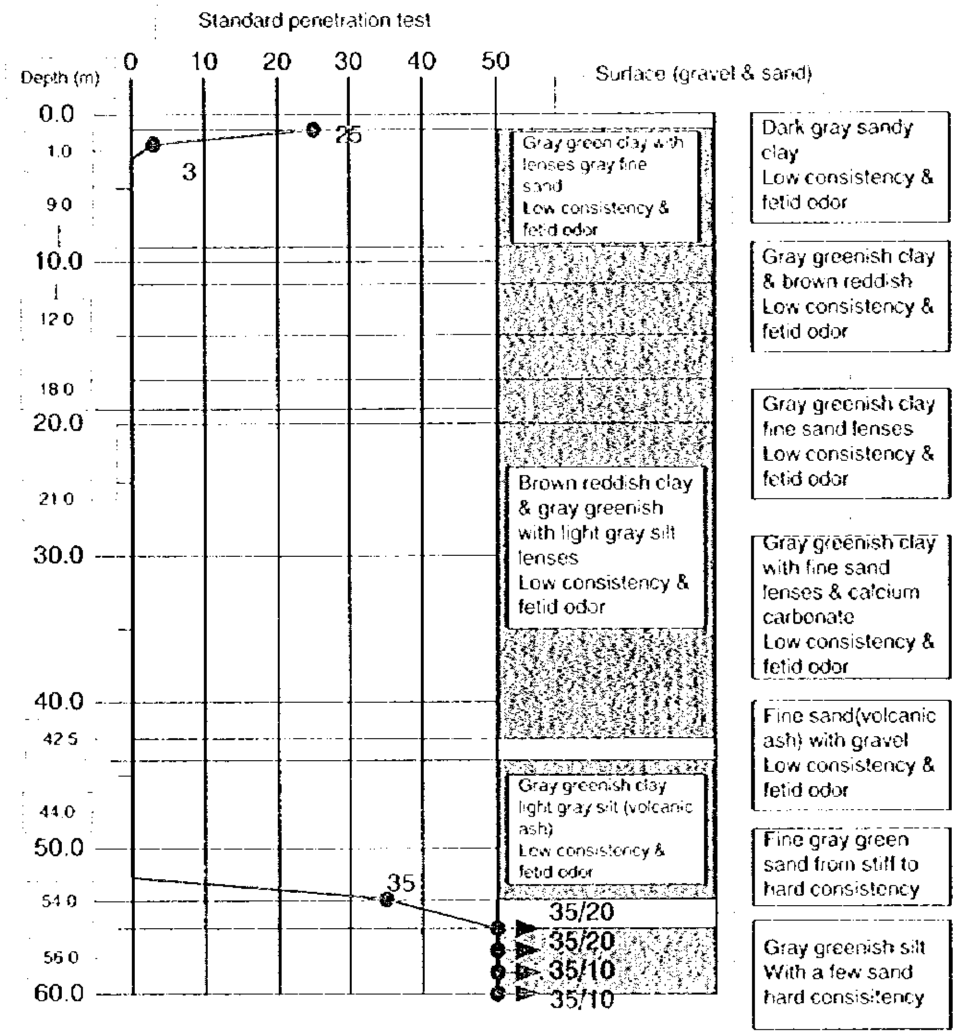
b.1 Basic Alternative

There are basically two types of composting process for organic fraction of municipal solid waste: "aerobic process" and "anaerobic process". Table H-5 shows the comparison of the two processes.

Table H-5: Comparison of Aerobic and Anaerobic Composting for Organic Fraction of Municipal SW

Characteristic	Aerobic process	Anaerobic process
Energy use	Net energy consumer	Net energy producer
End products	Humus, CO_2, H_2O	Sludge, CO_2, CH_4
Volume reduction	Up to 50%	Up to 50%
Processing time	20 to 30 days	20 to 40 days
Curing time	30 to 90 days	30 to 90 days
Primary goal	Volume reduction	Energy production
Secondary goal	Compost production	Volume reduction, waste stabilization

source : Integrated Solid Waste Management, McGraw-Hill



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Processing time	20 to 30 days	20 to 40 days
Curing time	30 to 90 days	30 to 90 days
Primary goal	Volume reduction	Energy production
Secondary goal	Compost production	Volume reduction, waste stabilization

source : Integrated Solid Waste Management, McGraw-Hill

As the composting plant is selected as one of the priority projects in the Study with the prime objective of "minimization of final disposal amount", the aerobic process is selected for the design of this project.

b.2 Examination of Technical Alternative

Aerobic composting can be operated by either: windrow composting; static pile composting; or in-vessel composting. Furthermore, the windrow composting has two types: minimal technology windrow; and high-rate windrow. Table H-6 shows the comparison of those composting methods.

In view of the present situation where the DGSU has attained practical experiences and know-how of the high-rate windrow method through the on-going project of composting pruned branches, and the land area available in the candidate site is wide enough for establishing the high-rate windrow method, this project will be designed in line with the high-rate windrow method.

Table H-6: Comparison of Composting Method

	Minimal technology windrow	High-rate windrow	Static pile	In-vessel
Outline	The minimal windrow technology approach involves forming large windrows (e.g. around 3.5m height by 7.3m width) that are turned only once a year with a front-end loader.	A high-rate windrow composting system employs windrow with smaller cross section, typically 1.5 to 2.0 m height by 4 to 5m width. The dimensions of the windrows depend on the type of equipment that will be used to turn the composting waste. Waste is turned twice per week while the temperature is maintained at around 55 Centigrade.	An aerated static pile system consists of a grid of aeration or exhaust piping over which the processed organic fraction of municipal solid waste is placed. Typical pile heights are 2 to 2.5 m. A layer of screened compost is often placed on top of the newly formed pile for insulation and odor control.	In-vessel composting contains an enclosed container vessel inside. The system can be divided into two major categories: plug flow and dynamic (agitated bed). In the plug flow system, the relationship between particles in the composting mass stays the same throughout the process, and system operates on first-in, first-out principle. In the dynamic system, the composting material is mixed mechanically during the processing.
Odors	Probably emits objectionable odors	Often releases offensive odors (accompanied by turning)	Controllable	Less than static pile and controllable
Degradation period	Three to five years	Three to four weeks (composting) Three to four months (curing)	Three to four weeks (composting) Three to four months (curing)	One to two weeks (composting) Four to twelve weeks (curing)
Required area	Very large	Large	Large	Small
Construction cost	Very cheap	Cheap	Intermediate	High
O & M cost	Very cheap	Cheap	Intermediate	High

source : Integrated Solid Waste Management, McGraw-Hill

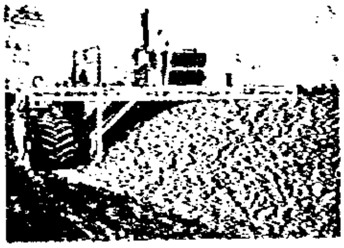
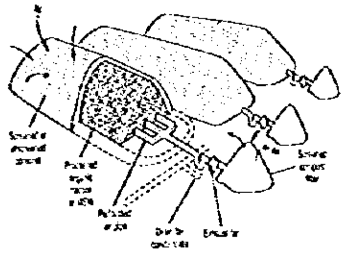
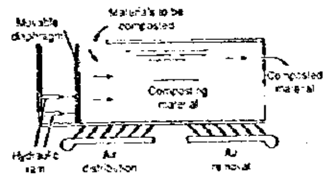
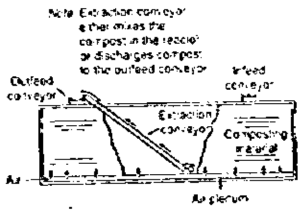
High-rate Windrow	Static Pile	In-vessel
		 Plug flow system  Dynamic system

Figure H-3: Major Composting System

c. Conceptual Design and Cost Estimation

c.1 Outline

The composting plant is planned to be located within a triangular shaped area of about 85 hectares enclosed by (refer to Figure H-6):

- the left branch of the Rio Churubusco adjacent to the Bordo Poniente Final Disposal Site-Etapa IV.
- the Mexico-Texcoco Toll Road.
- the Mexico City Peripheral Ring-Road.

Treatment capacity of the proposed plant is projected to be 1,250 ton/day, i.e.:

- by the Master Plan target year of 2010, 431,000 ton/year of organic waste is treated.
- the proposed plant operates 350 days per year.

Compost production is planned to be about 166 ton/day, or about 58,000 ton/year.

Main processes of the proposed facility comprise (refer to Figure H-4):

- a composting process.
- a curing process.
- a separation process.

The process times are assumed for the purpose of the preliminary design to be 28 days for composting and 120 days for curing.

Auxiliary facilities of the plant comprise:

- truck scale.
- waste reception areas.
- temporary storage areas.
- machine/equipment maintenance workshop.

- site office and laboratory.

c.2 Definition of Terms

- **Raw material:** the material to be fed into the composting facility. Source separated organic wastes from the sub-systems is designated as the raw material.
- **Composting:** the controlled biological decomposition of organic solid waste materials under aerobic conditions. The product of this process is defined as **young compost.**
- **Composting period:** the period of decomposition of the raw material. For this preliminary design it is assumed to be **28 days.**
- **Turning:** action of agitating the windrows in order to maintain aerobic conditions inside the windrow.
- **Curing:** time for stabilization of young compost. The product of this process is defined as **mature compost.**
- **Curing Period** is defined as the maturation period. For this preliminary design the curing period is assumed to be **120 days.**
- **Separation:** the process of removing large-size particles, and non-compostables (e.g., plastics, glass, cans, metal, etc.) and not-yet-decomposed materials (e.g., paper and wood). Mature compost is passed through a trommel which removes the large particles, then ferrous metal is removed with a magnetic separator.
- **Compost Product:** the end product resulting from the composting, curing, and separation processes.

c.3 Composting Facility Design Parameters

c.3.1 Design Principals

- It is planned that the composting plant starts operating in the year 2002, when separate collection of MSW from the subsystem is projected to reach about 60%. The required composting capacity at this time will be 750 ton/day. Separate collection is estimated to further increase to 80% by 2003, and to 100% by 2004.
- The implementation schedule for this design comprises phase 1 (a 750 ton/day windrow yard and a 240 ton/day curing yard in 2001) and phases 2 and 3, in 2002 and 2003 respectively (each consisting of a 250 ton/day windrow yard and a 80 ton/day curing yard). It is planned that the total composting capacity reaches 1,250 ton/day in 2004, and this capacity is maintained until 2010.
- Since stepwise improvement of the separation facility is neither practicable nor rational, it is planned to construct the 100% capacity separation facility in the year 2001.
- Considering that the proposed facility is to be constructed on highly compressible ground (in the ex-Lake Texcoco region), it is proposed that all

machinery and equipment are mobile, and buildings are lightweight, so that problems of ground subsidence will be reduced.

c.3.2 Main Design Parameters

c.3.2.1 Operation Time of Composting Plant

Operational conditions of the facility are proposed as follows:

- The composting plant is to be operated 24 hours a day, to minimize the cost and size of planned processing machinery.
- Receiving of raw materials will correspond with the collection program. Therefore, raw materials will be received for 12 hours per day.
- Annual operation time for the composting and curing sections is 350 days per year. 15 days are set aside for overall maintenance and national holidays.
- For the composting section operating for 24 hours a day, 20 hours is for operation and 4 hours is for routine maintenance for machinery and time required for shift changes, etc. Works in this section will be undertaken in 3 shifts.
- For the curing section operating for 16 hours a day, 14 hours is for operation and 2 hours is for routine maintenance for machinery and time required for shift change, etc. Works in this section will be undertaken in 2 shifts. Because the volume of material handled in the separation section is substantially less than in the other two sections, an operation time of 350 day/year, 16 hour/day is proposed for the separation section, with work done in 2 shifts.

c.3.2.2 Design Assumptions

Design assumptions for the preliminary design are listed below. However, it is strongly recommended that these assumptions be re-examined and verified through pilot projects undertaken before the final detailed design (in 2000) is formulated.

- **Composting Period:** In general practice, the composting period is in the order of 20 to 30 days. This preliminary design proposes a period of 28 days be allowed for the composting period, including a margin of safety that allows for variations in moisture content of the raw material.
- **Turning Frequency:** It is assumed to carry out 5 turnings in total during the 28-day composting period, with an interval between turnings of 5 or 6 days. Transferring the young compost to the curing area on the 28th day is counted as the 5th turning. When higher moisture contents are found in raw materials delivered to the facility, an additional turning to accelerate evaporation may be carried out 1 or 2 days after forming the raw material into windrows. Table H-7 shows the proposed work schedule for the composting process. The design assumes a windrow temperature of 55 °C.

Table H-7: Work Schedule in the Composting Process

1st day	Windrow formation
5th day	1st turning
10th day	2nd turning
16th day	3rd turning
22nd day	4th turning
28th day	Young compost transported to curing area (5th turning)

- **Curing Period:** This is generally in the order of 30 to 90 days. The preliminary design assumes a 120-day period in order to provide sufficient maturation time. The yard reserved for the 120-day curing period also serves as an on-site storage for mature compost.
- **Bulk Density and C/N ratio:** Bulk density and the C/N ratio obtained during the Team's field investigation of organic wastes in September 1998 are employed as the figures for the raw material. Meanwhile, the figures (i.e., bulk density) for young compost and mature compost are derived from empirical values recorded in Japan.
- **Moisture Content:** The design moisture content is assumed to be between 78% to 68%. Seventy-eight percent (78%) is derived from the DGSU's empirical data, whereas 68% is from the Team's field investigation results. Design moisture contents for young compost and mature compost are derived from empirical values recorded in Japan.
- **Compostable Content:** DGSU analysis classifies the raw material into 35 categories. These 35 categories are further classified into compostables and non-compostables for the preliminary design, with the compostables grouped into fast-rate compostables (putrescible); and slow-rate compostables (paper and wood) (see Table H-8).

Table H-8: Categorization of Raw Material

Grouping of Raw Materials	The 35 categories include
Fast-rate compostables (putrescible)	vegetable fiber, food waste, garden waste, etc.
Slow-rate compostables (paper and wood)	cardboard, paper, newspaper, wood, toilet paper, etc.
Metal (metal)	cans, ferrous and non-ferrous metal, etc.
Non-compostable	others

The solid content of respective waste groupings (putrescible, paper and wood, metals, and others) are listed for three moisture contents: 68%, 78%, and the average of the two (73%). Moisture contents for food wastes are also included in Table H-9.

Table H-9: Composition of Raw Material

Component (% by weight)	Moisture Content 1	Moisture Content 2	Moisture Content 3
Moisture content of raw material	68.00	73.00	78.00
Putrescible	23.61	18.61	13.61
Paper and wood	2.81	2.81	2.81
Metal	0.65	0.65	0.65
Non-compostable	4.93	4.93	4.93
Total	100.00	100.00	100.00
Moisture content of food wastes	77.16	83.54	89.92

Obtained from Table H-4.

c.3.2.3 Summary of Design Parameters

Table H-10 summarizes design parameters based on the design assumptions established above.

Table H-10: Design Parameters

Composting section				
Raw Material (Organic Waste)	Amount	431,000 ton/year		
	Compostable content	16.4 to 26.4 (% by wt.)		
	Moisture content	68 to 78 (% by wt.)		
	Bulk density	280 kg/m³		
	C/N ratio	20 - 27		
Operation		350 day/year 24 hour/day		
Treatment Capacity	Total	1,250 ton/day		
	Year 2002	750 ton/day		
	Year 2003	1,000 ton/day		
	Year 2004 and onward	1,250 ton/day		
Windrow		Trapezoidal shape	*1	
	Width (bottom)	5.0 m	*1	
	Width (top)	3.0 m	*1	
	Height	1.5 m	*1	
	Cross section area	6.0 m²	*1	
Composting Period		28 days		
Turning Frequency		1 time/5 - 6 days		
Windrow Temperature		55°C		
Curing section				
Operation		350 day/year 16 hour/day		
Treatment Capacity	Young compost production	400 ton/day (max.)	*2	
	Year 2002	240 ton/day		
	Year 2003	320 ton/day		
	Year 2004 and onward	400 ton/day		
	Moisture content	45 %		
	Bulk density	600 kg/m³		
Curing Period		120 days		
Separation				
Operation		350 day/year 16 hour/day		
Treatment Capacity	Mature compost production	300 ton/day (max.)	*2	
	Moisture content	30 %		
	Bulk density	600 kg/ m³		

*1 :These figures are referred to the specification of the turning machine used by the DGSU for composting green waste from public parks and gardens.

*2 :These figures are calculated from the *1 figures based on the conditions given in the section c.5 "Materials Balance".

c.3.3 Quantity and Quality of Compost Product

Table H-11 shows the target quality and quantity of the compost product in the preliminary design.

- Moisture content of the compost product is kept as low as possible (approx. 30%), for the purpose of mitigating the impact of odor on the surrounding environment.
- A water truck is included in the plant machinery plan in order to adjust the moisture level of the final product. There is the possibility that a compost product with a higher moisture content is demanded by the market. The water truck is also utilized for windrow moistening.

Table H-11: Quantity and Quality of Compost Product

Quantity		166 ton/day 58,000 ton/year
Quality	Moisture Content Bulk Density C/N ratio	30% by wt. 600 kg/m^3 < 15

c.4 Flow of Composting Process

Figure H-4 shows the flow of the proposed composting process.

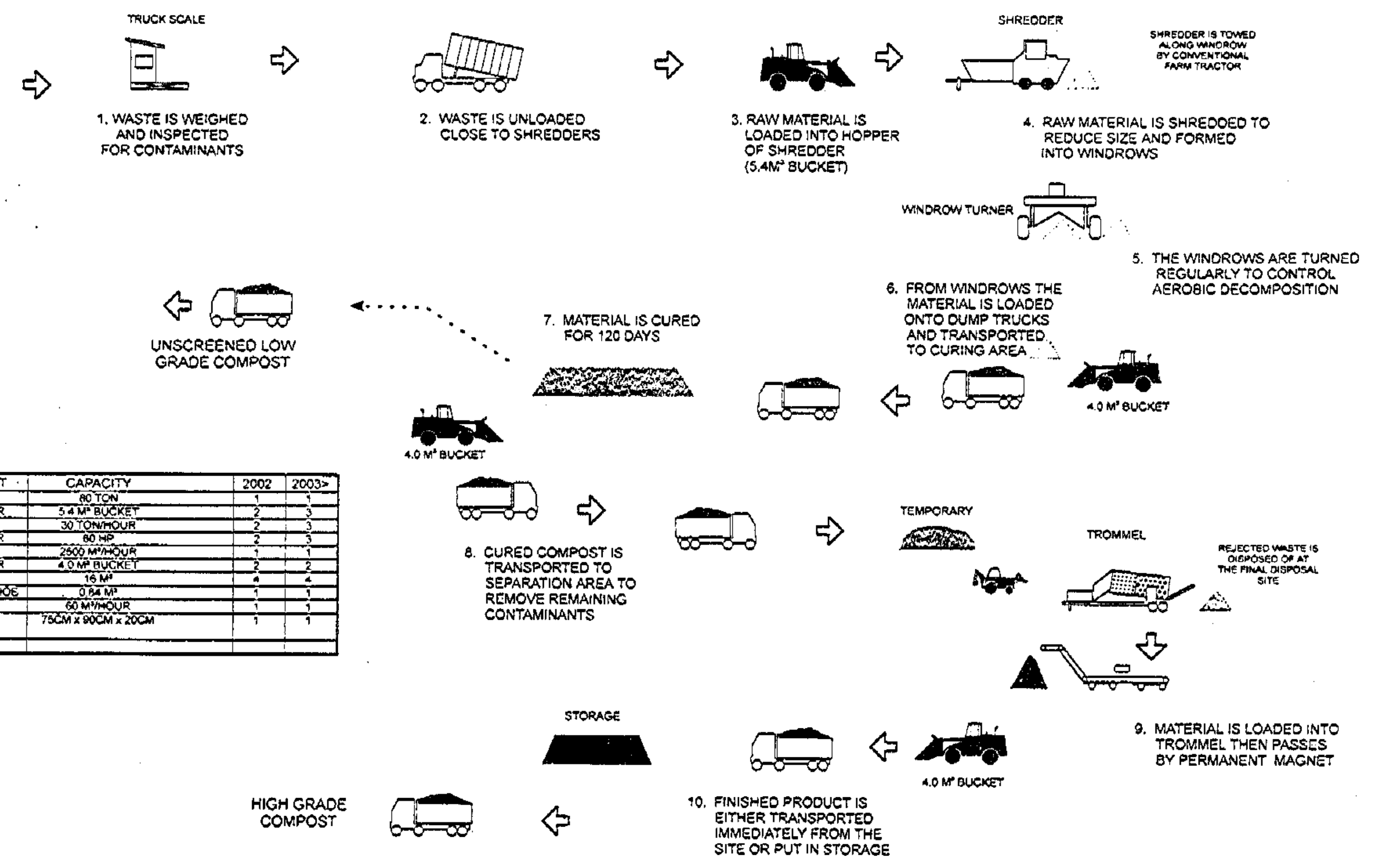
- Summarizing the order of processes: first is the composting process (shredding, formation of windrows, and turning of the raw material); second, the curing process (formation of piles and curing for 128 days); and third, the separation process (removal of objects larger than 25 mm in size with a trommel and magnetic separation).
- Alternative sequence of the processes (e.g., having the separation process first or second) are not recommended for the following reasons.

1) It is anticipated that most non-compostables will be separated at the generation source. Namely, separate collection of organic waste in the sub-system is considered to be primary separation procedure in the composting process.

2) Any non-compostables in the material provide voids within the windrow. Thus improving the supply of oxygen and assisting aerobic decomposition.

3) Separation of mature compost is more efficient than separation of young compost because, a) the moisture content of mature compost is lower than that of young compost making mature compost less cohesive and thus easier to separate, and b) the average size of mature compost particles is smaller than that of young compost, so less organic material will be rejected.

4) The quantity of mature compost is less than that of young compost, the separation facility can be smaller to save some costs.



EQUIPMENT	CAPACITY	2002	2003>
TRUCK SCALE	80 TON	1	1
WHEEL LOADER	5.4 M^3 BUCKET	2	3
SHREDDER	30 TON/HOUR	2	3
FARM TRACTOR	80 HP	2	3
TURNER	2500 M^3/HOUR	1	1
WHEEL LOADER	4.0 M^3 BUCKET	2	2
DUMP TRUCK	16 M^3	4	4
LOADER/BACKHOE	0.84 M^3	1	1
TROMMEL	60 M^3/HOUR	1	1
PERMANENT MAGNET	75CM x 90CM x 20CM	1	1

Figure H-4: Flow Sheet of Composting Facility

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c.5 Material Balance

Figure H-5 shows the material balance in the proposed composting facility for the case of 73% moisture content. 60% of decomposition rate for the fast-rate compostable materials and 40 % for the slow-rate compostable materials were assumed in this material balance on the basis of the experience in Japan.

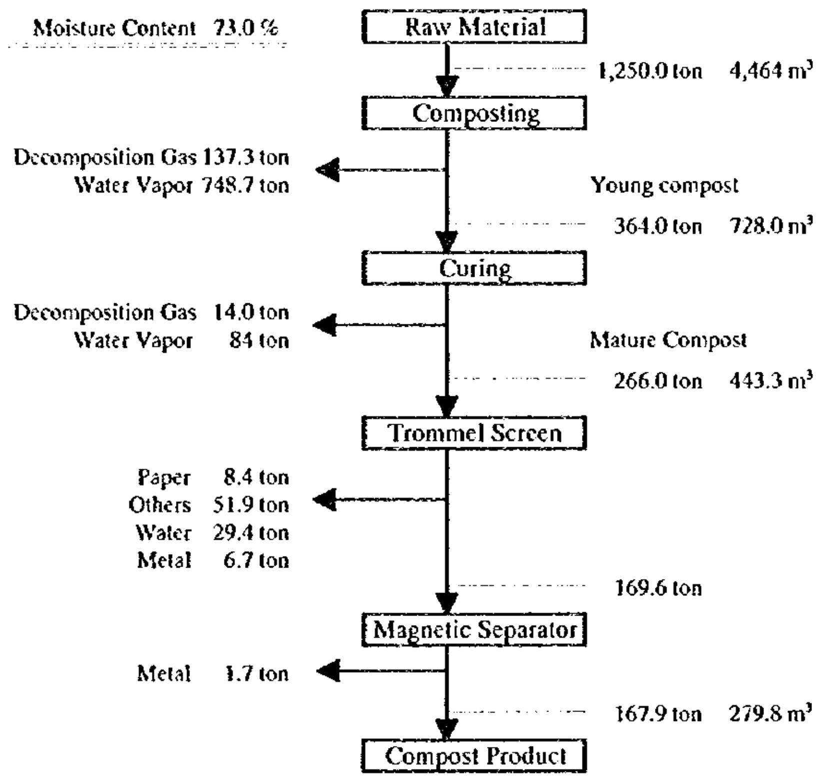

Figure H-5: Materials Balance of Composting Facility

c.6 Layout of Proposed Composting Facility

The proposed layout of the composting facility was prepared taking the following into account.

- To avoid damaging the canal structures, the proposed facility is off-set at least 60 meters from the bank of a canal *Río Churubusco Brazo Izquierdo*.
- The composting windrow area accounts for a large portion of the total facility area. Therefore, the layout pays attention to: primarily the layout of the windrows, and subsequently the layout of the curing and separation areas to attain efficient on-site transport.
- The proposed site is located next to the Bordo Poniente Disposal Site Etapa IV and the selection plant, Construction of bridges are, however, necessary to establish direct transport routes between these sites as the Rio Churbusco lies between these and the proposed composting plant, and it is estimated that costs for the bridges are prohibitively expensive. While the site of the composting plant adjoins the Periferal Ring Road. So, the road is to be used for

transportation of waste and compost without wasting a large expense for the construction of bridges.

- In order to mitigate odors and noise resulting from windrow formation and turning, at least 100 meters is maintained between the proposed windrows and nearby major roads.

- As strong winds often occur in the vicinity, the layout plan incorporates tree planting to act as a wind break. This buffer zone will also work as noise buffer and improve the appearance of the facility.

Figure H-6 shows the proposed layout of the composting facility, and Figure H-7 presents its cross section.

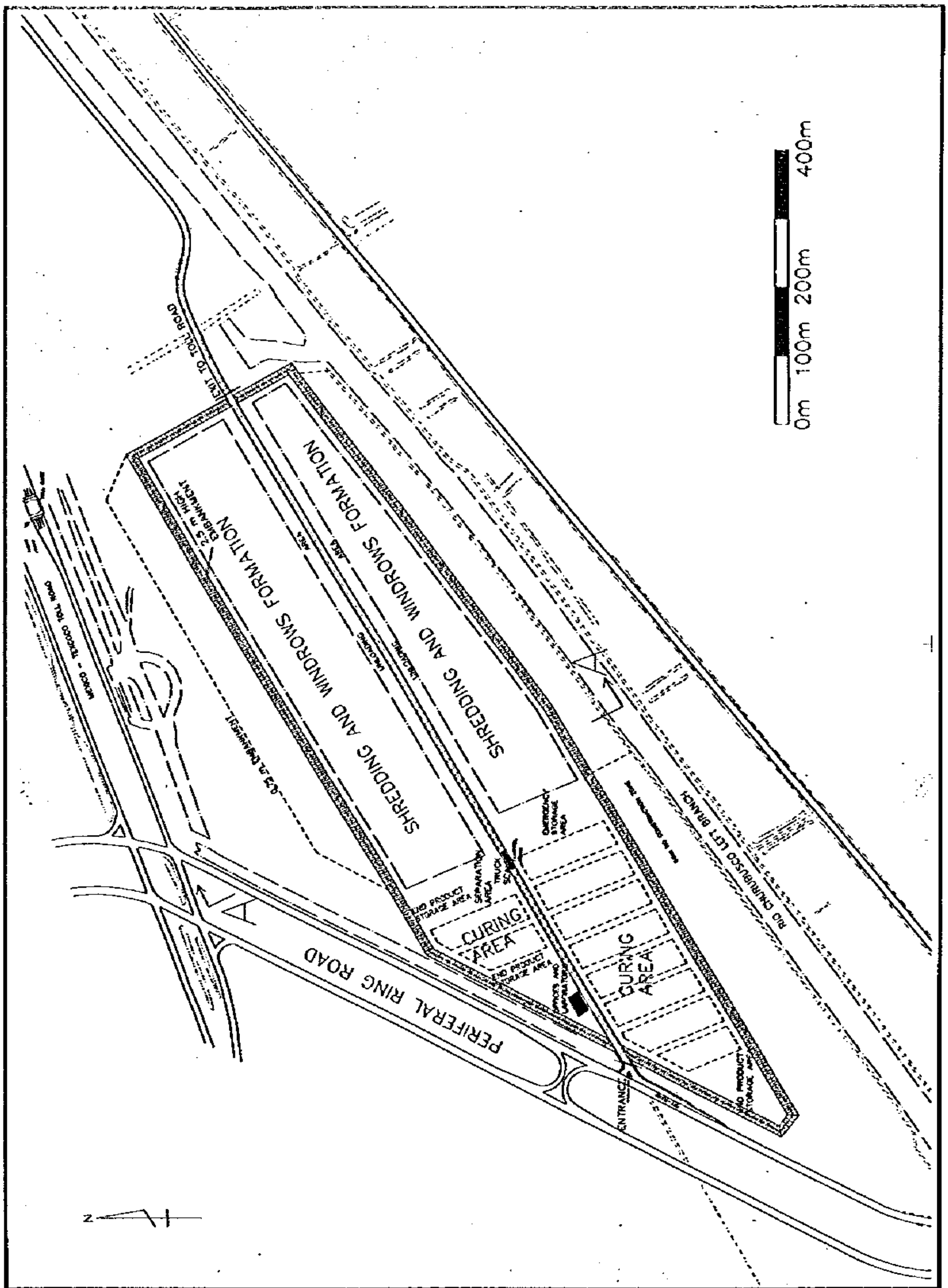

Figure H-6:

Layout of Proposed Composting Facility

SCALE (m)
0 100 200 300

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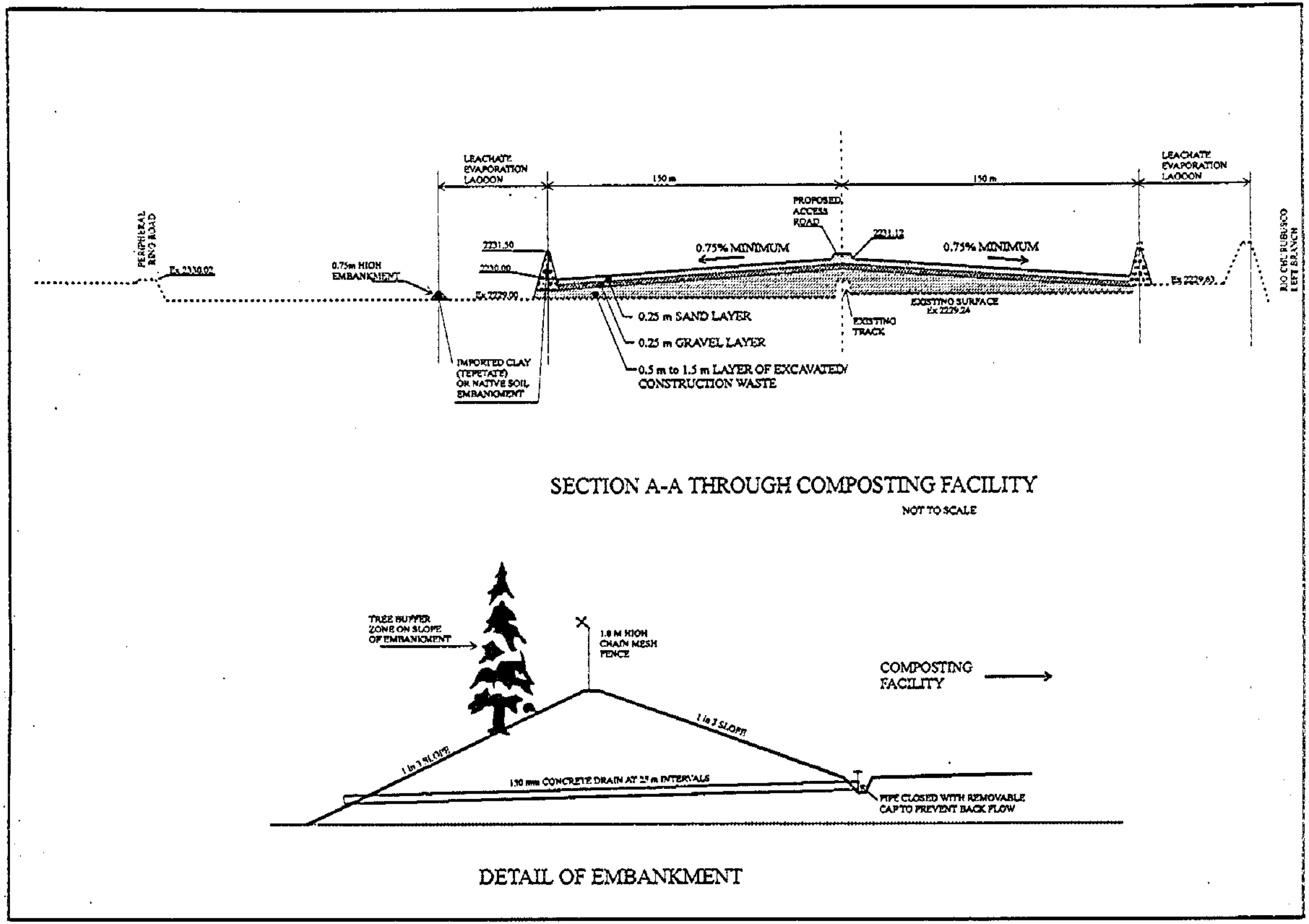

Figure H-7: Cross Section A-A of Proposed Composting Facility

c.7 Construction Schedule

Table H-12 shows the construction schedule of the composting plant.

Table H-12: Construction Schedule of Composting Facility

Year	2001	2002	2003	2004	2010
Required Capacity (ton/day)	---	750	1,000	1,250	1,250
Composting Section (ton/day)	750	250	250	---	---
Curing Section (ton/day)	240	80	80	---	---
Separation Section (ton/day)	300	---	---	---	---

c.8 Operation Plan

The proposed operation plan is as follows.

c.8.1 Truck Scale

A truck scale measures the quantities of: raw material waste entering, compost product leaving the site, ferrous materials recovered, and rejected waste to be disposed of.

c.8.2 Composting Section

Raw material input at 1,250 ton/day results in a total windrow length of 800 meters per day.

- Raw material delivered to the site is unloaded near the planned windrow location.
- A wheel loader and a mobile shredder are shifted to the windrow yard. The wheel loader is used to load the temporarily stockpiled raw material into the shredder. Windrows are formed by a conveyor connected to the shredder's outlet and shaped with the wheel loader and manual workers.
- Turning of windrows is carried out in accordance with the schedule mentioned in the prior section. Cleaning of the area and windrow re-shaping is undertaken with a wheel loader and manual workers.
- Temperature and moisture content of all windrows is periodically monitored and controlled.
- Young compost after the 28-day composting period is loaded onto a dump truck, with a wheel loader, to be transported to the curing yard. The windrow yard from which the young compost is removed is prepared, with a wheel loader and manual workers, to receive new shredded raw material.

c.8.3 Curing Section

Considering the young compost amount to be handled daily and the work efficiency expected, it is designed to allocate two curing yards.

- Young compost transported from composting yard is temporarily unloaded near the curing yard.

- Unloaded young compost is then formed into 3-meter high piles with a wheel loader.
- Temperature and moisture content of the all curing piles at different heights is periodically monitored and controlled.
- Mature compost after the 120-day curing period is loaded onto dump trucks with a wheel loader and transported to the separation yard. The curing yard from which the mature compost is removed is then prepared, with wheel loader and manual workers, to again receive young compost.

c.8.4 Separation Section

- Mature compost unloaded from dump trucks is fed (with a small wheal loader) into a hopper, which feeds the mature compost to a trommel. Staff is necessary for the feeding control and maintenance and cleaning of the separation yard.
- The trommel has screen sizes of 8mm and 25mm, classifying the fed mature compost into: high quality compost (8 mm and under); normal quality compost (8-25 mm) and the rejected material (over 25 mm).
- Compost after trommelling is transported to a compost product stock yard on a conveyor belt, passing a magnetic separator, which removes ferrous metal from the compost. Removed metal is periodically cleaned from the magnet and stored in the yard.
- Rejected waste (over 25 mm) is moved to another stock yard by a conveyor for disposal at the final disposal site.
- The compost product is loaded onto dump trucks with a wheel loader and delivered to users.

c.9 Staffing Schedule

Table II-13 is the staffing schedule for the proposed composting facility. The number of operators and manual workers is derived from the volume of material processed and facility operation capacity. It is planned that by 2003, when facility capacity is 80%, the number of staff will reach its maximum. It is estimated that from the year 2003, 93 persons will be working in the proposed facility. Biological, physical and chemical analyses of compost for controlling the process and product's quality are to be conducted in the SJA's laboratory and/or others.

Table H-13: Staffing Schedule

Position	2002				2003 -			
	Shift			total	Shift			total
	1	2	3		1	2	3	
ADMINISTRATION								
Site director	1	-	-	1	1	-	-	1
Finance and product promotion	1	-	-	1	1	-	-	1
Secretary	2	-	-	2	2	-	-	2
General helper	1	-	-	1	1	-	-	1
Driver	2	-	-	2	2	-	-	2
sub totals	7	0	0	7	7	0	0	7
OPERATION								
Sub-director process	1	-	-	1	1	-	-	1
Shredding supervisor	1	1	1	3	1	1	1	3
Turning and curing supervisor	1	-	-	1	1	-	-	1
Shredder operators	2	2	2	6	3	3	3	9
Loader operators	4	4	2	10	5	5	3	13
Tractor drivers	2	2	2	6	3	3	3	9
Small loader operators	1	1	-	2	1	1	-	2
Turner operator	1	-	-	1	1	-	-	1
Dump truck drivers	3	3	-	6	4	4	-	8
Waste inspectors	1	1	-	2	1	1	-	2
Traffic controllers	3	3	-	6	3	3	-	6
General Laborers	9	6	2	17	10	7	3	20
Truck scale attendant	1	1	-	2	1	1	-	2
Water truck driver	1	-	-	1	1	-	-	1
Security	2	2	2	6	2	2	2	6
sub totals	33	26	11	70	38	31	15	84
MAINTENANCE								
mechanics	1	1	-	2	1	1	-	2
sub totals	1	1	0	2	1	1	0	2
Totals	41	27	11	79	46	32	15	93

c.10 Cost Estimation

Preliminary cost estimate is presented in Table H-14. The estimate has been divided into two sections; site improvements and equipment.

Table H-14: Preliminary Cost Estimate of Composting Plant

Unit: US$ 1,000

Item	Details	unit	Unit Cost US$	Quantity	Cost US$	Cost Pesos P9.1=$1
SITE IMPROVEMENT						
earth works	spreading 1.0m layer of construction waste	m2	1.04	370,000	385,000	3,504,000
	gravel for base, t=0.25m, A=33ha	m3	4.2	91,000	382,000	3,476,000
	spreading sand surface, t=0.25m, A=33ha	m3	5.35	94,000	503,000	4,577,000
	grading of surface for drainage	m2	0.23	330,000	76,000	692,000
general improvements	embankment, exit track construction drainage, fencing, connect electricity lighting, access improvement, fuel tank water tank, portable buildings				599,000	5,451,000
Site improvement Total					1,945,000	17,700,000
Equipment						
truck scale	80 ton + foundations etc.	unit	60,000	1	60,000	546,000
wheel loader (A)	wheel loader with 5.4 m³ refuse bucket	unit	125,400	3	376,000	3,422,000
wheel loader (B)	wheel loader with 4.0 m³ refuse bucket	unit	100,320	2	201,000	1,829,000
compact loader	backhoe/loader, 2.36m/0.84m³ bucket	unit	34,320	1	34,000	309,000
dump truck	16 m³, 10 ton	unit	33,660	4	135,000	1,229,000
conventional farm tractor	60 hp (gross engine)	unit	33,000	3	99,000	901,000
water tanker	8,000 liters	unit	28,380	1	28,000	255,000
shredder	cap. 30 tons/hr, 175hp	unit	99,000	3	297,000	2,703,000
windrow turner	cap. 2500 tons/hr	unit	180,000	1	180,000	1,638,000
trommel	Screen 8 mm, & conveyors	unit	201,600	1	202,000	1,838,000
magnetic separator	permanent magnet + frame	unit	7,200	2	14,000	127,000
conveyors (separation)	w=600, side angle=25%	unit	15,000	3	45,000	410,000
pick up equipment	cap. 2 ton	unit	22,500	2	45,000	410,000
Equipment Total					1,716,000	15,617,000
sub-total (1)					3,661,000	33,317,000
miscellaneous	10%				367,000	3,332,000
Direct cost					4,028,000	36,649,000
general expenses/overhead	30%				1,209,000	10,995,000
total construction cost					5,237,000	47,644,000
physical contingency	10%				524,000	4,764,000
IVA	15%				785,000	7,147,000
Total Cost					6,546,000	59,555,000

Site improvements are based on the assumption that once it has been decided that the above site will be used for the composting facility, construction waste will be deposited at the site in order to form the platform on which the facility will be established.

The material is proposed to be compacted in layers forming a layer 0.5 m to 1.0 m thick. Over this sub-base will be placed a 0.25 m layer of gravel and over this a 0.25 m surface layer of sand. Surrounding the platform an embankment is proposed, rising 2.5 meters above the existing surface. This embankment is dual purpose, firstly, it provides a flood barrier against inundation resulting from the overflowing of the left branch of the Rio Churubusco. Secondly, by planting trees on the embankment a buffer zone will be formed. This buffer zone will help reduce dust, odor, and noise escaping from the site. It will also beautify the area for passers-by.

Unit costs for the supply and transport of soil and gravel and other civil works are based on those provided by DGSU.

Most equipment unit costs were obtained from local distributors. Some equipment selected for the feasibility study is not distributed in Mexico (i.e. the shredders) so manufacturers in the United States were contacted.

The exchange rate used in the cost estimation for the preliminary design is 9.1 pesos to the US dollar[1].

c.11 Priority Project Cost (Composting Facility)

Table H-16 shows costs for the composting project from 1999 to 2010 annually. Two cases shown below were set for the cost estimates.

- Case 1: Investment and operation by the DGSU
- Case 2: Investment by the DGSU and contracting out operation

Namely, the DGSU invests in all construction, procures all equipment and operates the compost facility directly in Case 1, whereas the DGSU invests in all construction, procures some equipment and a private company supplies other equipment and operates the compost facility under a contract with the DGSU in Case 2.

- truck scale
- shredder
- windrow turner
- trommel (include magnetic separator and conveyor)

Table H-15: Procurement of Equipment in Case 2

DGSU		Private company	
Truck scale:	1	Wheel loader (A):	3
Shredder:	3	Wheel loader (A):	2
Windrow turner:	1	Compact loader:	1
Trommel:	1	Dump truck:	4
Magnetic separator:	2	Farm tractor:	3
Conveyor:	3	Water tanker:	1
		Pick up equipment:	2

[1] Exchange rate based on the average of recent rates

Table H-16: Priority Project Cost (Composting Facility)

unit : US$ 1,000

Case	Year	Basic Design		Pilot projects		Detail Design + supervision		Construction		Equipment		O & M (contract)		O & M (direct)		Land rental fee		Total		
		domestic	foreign	domestic	foreign	domestic	foreign	domestic	foreign	domestic	foreign	domestic	foreign	domestic	foreign	domestic	foreign	domestic	foreign	domestic + foreign
Case 1	1999	50	-	8	2	-	-	-	-	-	-	-	-	-	-	-	-	58	2	60
	2000	-	-	8	2	164	-	-	-	-	-	-	-	-	-	-	-	172	2	174
	2001	-	-	-	-	99	-	2,376	-	-	2,548	-	-	-	-	33	-	2,508	2,548	5,056
	2002	-	-	-	-	33	-	551	-	-	520	-	-	530	132	33	-	1,147	652	1,799
	2003	-	-	-	-	33	-	551	-	-	-	-	-	656	164	33	-	1,273	164	1,437
	2004	-	-	-	-	-	-	-	-	-	-	-	-	656	164	33	-	689	164	853
	2005	-	-	-	-	-	-	-	-	-	-	-	-	656	164	33	-	689	164	853
	2006	-	-	-	-	-	-	-	-	-	-	-	-	656	164	33	-	689	164	853
	2007	-	-	-	-	3	-	-	-	-	-	-	-	656	164	33	-	689	164	866
	2008	-	-	-	-	2	-	-	-	-	2,441	-	-	656	164	33	-	689	2,605	3,296
	2009	-	-	-	-	-	-	-	-	-	520	-	-	656	164	33	-	689	684	1,373
	2010	-	-	-	-	-	-	-	-	-	-	-	-	656	164	33	-	689	164	853
	Total	50	-	16	4	344	-	3,478	-	-	6,029	-	-	5,778	1,444	330	-	9,996	7,477	17,473
		50		20		344		3,478		6,029		-		7,222		330		---		
Case 2	1999	50	-	8	2	-	-	-	-	-	-	-	-	-	-	-	-	58	2	60
	2000	-	-	8	2	164	-	-	-	-	-	-	-	-	-	-	-	172	2	174
	2001	-	-	-	-	99	-	2,376	-	-	1,250	-	-	-	-	33	-	2,508	1,250	3,758
	2002	-	-	-	-	33	-	551	-	-	177	1,051	-	81	20	33	-	1,749	197	1,946
	2003	-	-	-	-	33	-	551	-	-	-	1,186	-	99	25	33	-	1,902	25	1,927
	2004	-	-	-	-	-	-	-	-	-	-	1,186	-	99	25	33	-	1,318	25	1,343
	2005	-	-	-	-	-	-	-	-	-	-	1,186	-	99	25	33	-	1,318	25	1,343
	2006	-	-	-	-	-	-	-	-	-	-	1,186	-	99	25	33	-	1,318	25	1,343
	2007	-	-	-	-	13	-	-	-	-	-	1,186	-	99	25	33	-	1,318	25	1,356
	2008	-	-	-	-	2	-	-	-	-	1,142	1,186	-	99	25	33	-	1,318	1,167	2,487
	2009	-	-	-	-	-	-	-	-	-	177	1,186	-	99	25	33	-	1,318	202	1,520
	2010	-	-	-	-	-	-	-	-	-	-	1,186	-	99	25	33	-	1,318	25	1,343
	Total	50	-	16	4	344	-	3,478	-	-	2,746	10,539	-	873	220	330	-	15,630	2,970	18,600
		50		20		344		3,478		2,746		10,539		1,093		330		---		

H.2.2 Final disposal Sites

Several alternatives have been examined under the circumstances that the remaining lifetime of the presently operated landfill (Etapa IV) is expected to be limited. Mexican side's estimation states that the landfill to the 8m elevation will be filled until February 2001. The alternatives examined, in view of making the lifetime of the landfill extended and/or securing sustainable waste disposal, were landfill mining, composting, incineration plant, acquiring a new site for landfill, etc.

As a result, vertical expansion of the existing landfill (Etapa IV) and a new landfill development (Etapa V) have been chosen as two of three priority projects. In this section, design conditions and alternatives of the two projects are examined, and conceptual design and cost estimates are carried out.

H.2.2.1 Vertical Expansion Plan of Etapa IV

Etapa IV is a landfill that is presently operated. However, its lifetime is limited as mentioned above. The vertical expansion plan proposes to place waste to 24m elevation in order to expand the lifetime.

a. Examination of Design Conditions

There are some important restrictions regarding this vertical expansion plan of Etapa IV that are:

- the agreement with CNA.
- NOM-083-ECOL-1996.
- technical restrictions.

The agreement with CNA restricting the height of the landfill as 8m needs to be altered to realize this plan.

NOM-083 is one of the Mexican Official Norms which establishes the requirements to be applied to new landfill development of municipal solid waste. The norm was not yet in force when the design of Etapa IV was completed in 1992. However, the design took into consideration some criteria of the US EPA's regulations, such as secureness of the distance from an airport. Such criteria were eventually included in the requirements of the norm. In fact, the status quo of the landfill basically appears to fulfill the requirements.

Other restrictions are technical requirements on the design of the plan. The major technical requirements are the examination of:

- physical impacts (subsoil settlement, etc.) which will be caused by landfill load.
- improvement of the leachate disposal.
- waste disposal amount.

a.1 Physical Impacts of Proposed Vertical Expansion

The Bordo Poniente area stands on the 60-meter thick highly compressible clayey layer of the ex-lake Texcoco area. Etapa IV is located on such soil conditions. The waste load causes settlement of the subsoil under the landfill due to the soil character. In the vertical expansion plan, further placement of waste on the existing one is forecast to cause further subsoil settlement. **In the circumstances, it is anticipated that the further subsoil settlement would damage a drainage canal (Canal de la Compañia) flowing along the landfill which is one of major drainage canals in the area, and it would stretch the impermeable liner.**

It is also anticipated that the vertical expansion would make the landfill slope unstable.

In this section, issues examined regarding physical impacts of the proposed vertical expansion are:

- geological survey.
- influence on the Canal (Canal de la Compañia).
- influence on the impermeable liner.
- influence on stability of the landfill slope.

a.1.1 Geological Survey

i. Objectives of the Survey

The objectives of the geological survey is to acquire soil data of Etapa IV in order to examine the technical feasibility of the vertical expansion. The soil survey was carried out during the 2nd study work in Mexico.

ii. Survey Items

The survey was carried out at Bordo Poniente Etapa IV. Number of borings and survey items are shown in Table H-17.

Table H-17: Work Quantity of Soil Survey at Etapa IV

Survey Items	Survey Contents
Boring	2 bore holes (0 to 40 m deep, and 0 to 60m deep)
Soil tests	liquid limit, plastic limit, unit weight, consolidation, grain size, water content, tri-axial compression

iii. Results of the Survey

The groundwater levels are shown in Table H-18, and the soil characters acquired by the survey are summarized in Table H-19.

Table H-18: Groundwater level of Etapa IV

Site	Bore hole number	Groundwater level (m)
Etapa IV	SM-7	0.03
	SM-8	0.35

Table H-19: Results of Soil Survey at Etapa IV

Characters \ Location	SM-7		SM-8		
	8.0-9.0m	15.0-16.0m	16.0-17.0m	32.0-33.0m	42.0-43.0m
Type of soil (Visual observation)	clay	clay	clay	clay	clay
Specific gravity	2.48	2.632	2.52	2.54	2.54
Unit weight (ton/m^3)	1.13	1.26	1.18	1.18	1.67
Void ratio	4.037	5.139	10.399	6.28	4.837
Degree of Saturation (%)	102.996	97.7	102.1	100	98.6
Water content (%)	167.7	238	421.3	247.7	187.2
Liquid limit (%)	256	158.3	365.3	270	169.4
Plastic limit (%)	126.7	35	175.9	94.7	76.8
Plasticity index (%)	129.3	112.6	189.4	175.3	92.6
Tri-axial undrained C (ton/m^2)	0.3	0.2	1.4	0.9	1.1
Angle of internal friction (deg.)	2	9	4	0	11
Simple compression qu (ton/m^2)	0	2.3	2.03	1.73	8.4
Grain size	100F	100F	100F	100F	-
N value	0	0	0	0	0
Consolidation (compression index)	1.456	3.825	6.395	5.033	3.392

iv. Findings

The surface stratum at the site, Etapa IV, is occupied more than 50m thick clayey lacustrine deposit. Almost all N values of the stratum show 0, zero. A stable layer of which N value shows more than 50 exists below the depth of 55m. The lacustrine deposit shows considerably high natural water contents of from 160 to 420% and low unit weight of about 1.20 ton/m^3. Therefore, it is judged that the lacustrine is considerably soft clay according to the soil surveys result.

a.1.2 Vertical Expansion Influence on the Canal

Examination of influence on the canal caused by the vertical expansion was carried out by using soil data acquired through the soil survey mentioned previously. Conditions set for estimation of subsoil settlement and the results of the examination are presented below.

i. Conditions for Estimation of Influence

Data on soil layers at SM-8 bore hole are employed for the estimation. The lacustrine layer is subdivided into 10 layers as shown in Table H-20. The waste load is assumed to be the one when the landfill becomes 24m high and the unit weight of waste after initial compression at landfill is assumed to be 0.8 ton/m^3. And two cases are set depending on whether buoyancy caused by the groundwater is considered or not. Case 1 ignores such buoyancy, on the other hand, Case 2 takes buoyancy into consideration.

Table H-20: Subsoil Conditions

Layer	Thickness of layer (m)	Unit weight (ton/m^3)
1	1.0	1.80
2	5.5	1.13
3	1.0	1.80
4	8.5	1.26
5	5.0	1.18
6	5.0	1.18
7	6.0	1.18
8	10.0	1.18
9	2.0	1.67
10	10.0	1.18

Note: The water level is assumed at 0m depth, because the groundwater level at SM-7 was 0.03m and at SM-8 was 0.35m.

ii. Results of the Estimation

The results are schematized in Figure H-8. The result of Case 1, without consideration of the buoyancy, is that the final subsoil settlement (theoretical maximum) is 19.6 m in the landfill center which may cause 8cm settlement at the 80m off-set drainage canal. Meanwhile, the final subsoil settlement (theoretical maximum) of Case 2, with consideration of the buoyancy, is 12.6m in the landfill center which may cause 4cm subsidence at the 80m off-set drainage canal.

iii. Influence on the Canal (Canal de la Compañia)

The results shows the maximum subsoil settlement is 19.6m and the minimum one is 12.6m. However, this estimation assumes that water contained in the subsoil is drained due to the waste load pressure under the theoretically most favorable condition without any impedance. Therefore, the results shows theoretical maximum values of the settlement. In reality, the landfill has the impermeable liner which will hinder upward water drainage and the soil of surrounding areas are also saturated with water. Therefore, the drainage of water from the soil under the landfill must be impeded to a large extent. Consequently, the actual subsoil settlement should be fairly smaller than the estimated ones. **In conclusion, the estimation shows only 8cm subsidence of the drainage canal under the theoretical maximum subsoil settlement caused by the vertical expansion. So, it can be said that the vertical expansion plan will not pose a serious problem on the drainage canal structure.**

a.1.3 Vertical Expansion Influence on the Impermeable Liner

Figure H-9 schematizes the subsoil settlement. The part of liner under the first lift's slope will undergo the largest tensile stress. The tensile stress can be expressed as 3.0% in elongation terms (32.47m/32m=1.015, i.e., 1.5% of stretch, taking into consideration the stretch of two-dimension, $32.47^2/32^2=1.030$, i.e., 3.0% of stretch, see Figure H-9). This elongation would be absorbed in the tensile performance of the impermeable liner.

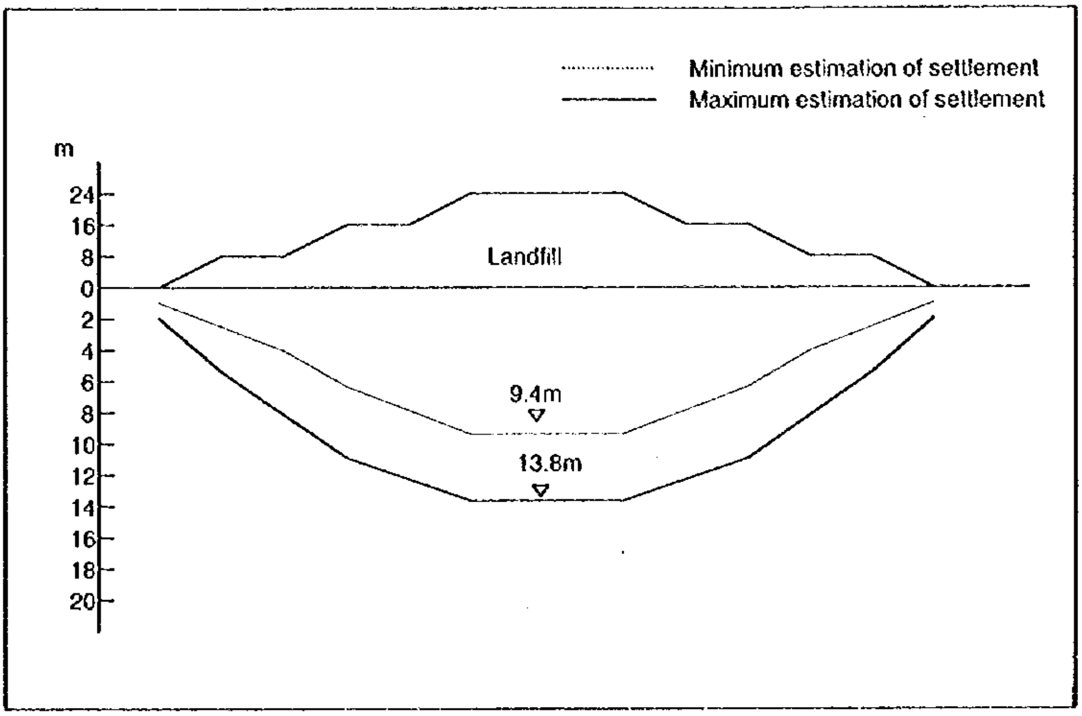

Figure H-8: Subsoil Settlement

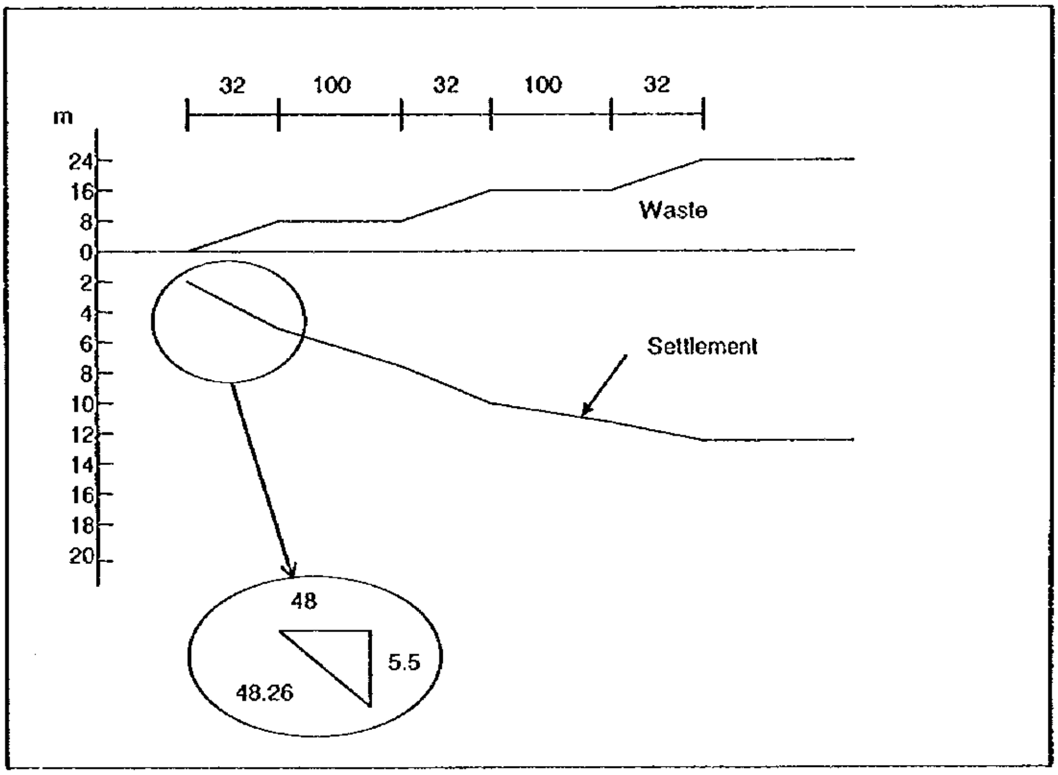

Figure H-9: Subsoil Settlement and Liner

a.1.4 Vertical Expansion Influence on Stability of Landfill Slope

The soil data presented in Table H-19 are employed in the Bishop Method for calculating the slope stability. The present landfill slope has an inclination of 1 in 4, and this inclination is also employed for both elevation of 8 to 16m and 16m to 24m. The minimum factor of the slope 0 to 8m shows 0.948 which is the least among others. Although a slope failure could occur as the minimum factor is less than 1.0 theoretically, it has not happened. On the other hand, minimum factors of other slopes exceed 1.0, therefore, the vertical expansion is viable from a viewpoint of landfill slope stability.

Table H-21: Result of Slope Stability Calculation (Etapa IV)

Slope	Landfill Height	Minimum Safety Factor	Coordinates of the Rotational Slope		Radius of the Rotational Slip (m)	Resist Moment (ton-m)	Slip Moment (ton-m)
			X	Y			
1	0 to 8m	0.948	10.00	15.00	30.13	2,001.15	2,111.67
2	8 to 16m	1.077	146.00	16.00	51.00	8,584.00	7,968.72
3	16 to24m	1.313	280.00	25.00	60.00	11,634.95	11,149.46

a.2 Leachate Management

i. Present Conditions

At present, leachate is sometimes seeping out at the cells bottom slope to the surrounding road. Trenches were dug around the cells to receive that leachate (possibly diluted with groundwater). Some amount of the leachate is collected by tank trucks and transported to an evaporation pond located at the east side of Etapa III. It is anticipated that the current leachate management in Etapa-IV is carried out irrelevant to estimation of leachate generation amount. Which should be very inefficient and ineffective in view of high possibility of dilution with groundwater and also the limited capacity of the evaporation pond.

ii. Existing Estimation of Leachate Generation

The existing estimation of leachate generation[2] says that 61 mm/year of leachate will be generated at the landfill under the present landfilling manner. However, the leachate presently generated is likely much more than the expected, although quantitative investigation has not been carried out. Meanwhile, another calculation in the same report shows that 182 mm/year of leachate will be generated.

The difference between the estimations is attributed to precipitation data used and estimation manner. The former estimation used the precipitation data of 347 mm/year at Bordo Poniente, and the duration subjected to the calculation was only one year. Meanwhile, the latter used the data of 617 mm/year at the airport next to the landfill area, and the duration was 5 years. The Bordo Poniente's precipitation data does not likely represent the actual data, because other precipitation data at a meteorological station, Gran Canal station, near the Bordo Poniente area, shows the data of 581 mm/year, similar to that of the airport. Furthermore, one year calculation tends to underestimate leachate generation due to characters of landfill, i.e. water coming into

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[2] Geo Ingenieria International, *Operacion de las celdas de evaporacion y experimentacion ubicadas en los III y IV Etapas de Bordo Poniente*, 1997

soil and waste does not go down until fulfilling the field absorptive capacities of them. Consequently, it is thought that the leachate estimation using the airport's data and 5 years duration, 182 mm/year, would be more appropriate.

Table H-22: Existing Leachate Generation Estimation

Station	Precipitation (mm/year)	Leachate generated (mm/year)
Bordo Poniente	347	61
Airport	617	182

iii. Leachate Generation Estimation

Estimation of leachate generation quantity, which will be generated under the existing situation, was carried out by using meteorological data at the Mexico City International Airport station (Estacion meteorologica Aeropuerto Internacional Benito Juarez). The result shows that 101 mm/year out of the precipitation will percolate through the cover soil, then water contents of waste and soil under the cover soil will reach the field capacities in 3 years, finally 101 mm/year of leachate will be generated at the bottom of the landfill in the 4th year and afterward (See Figure H-10). Detail of the estimation is described hereinafter.

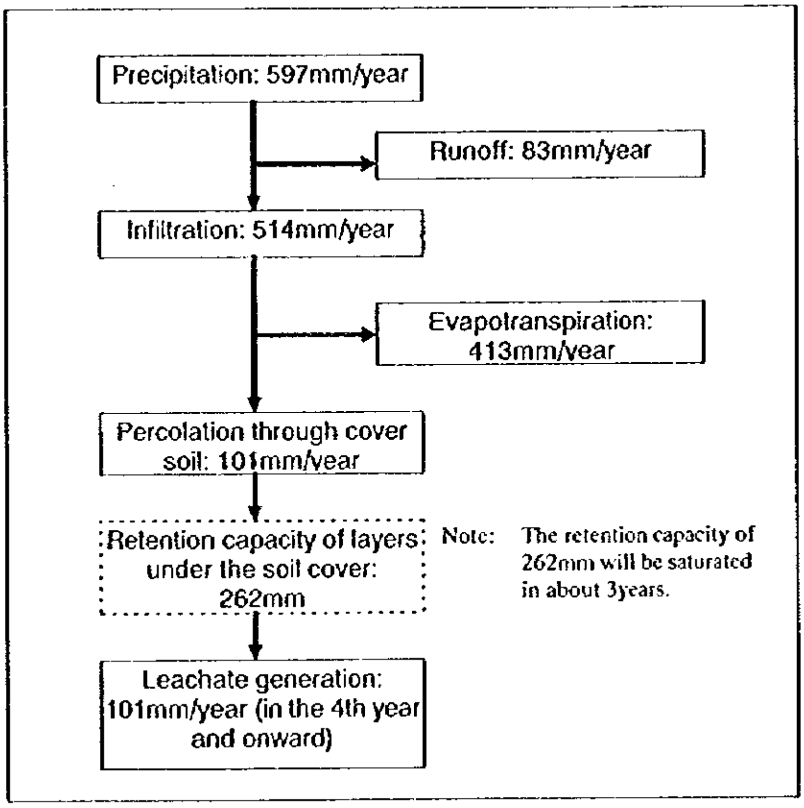

Figure H-10: Leachate generation

iv. Leachate Generation from the Existing Landfill (Etapa IV)

This section shows the sequence of estimating leachate quantity generated from Etapa IV under the present conditions. Flow of the estimation is schematized below.

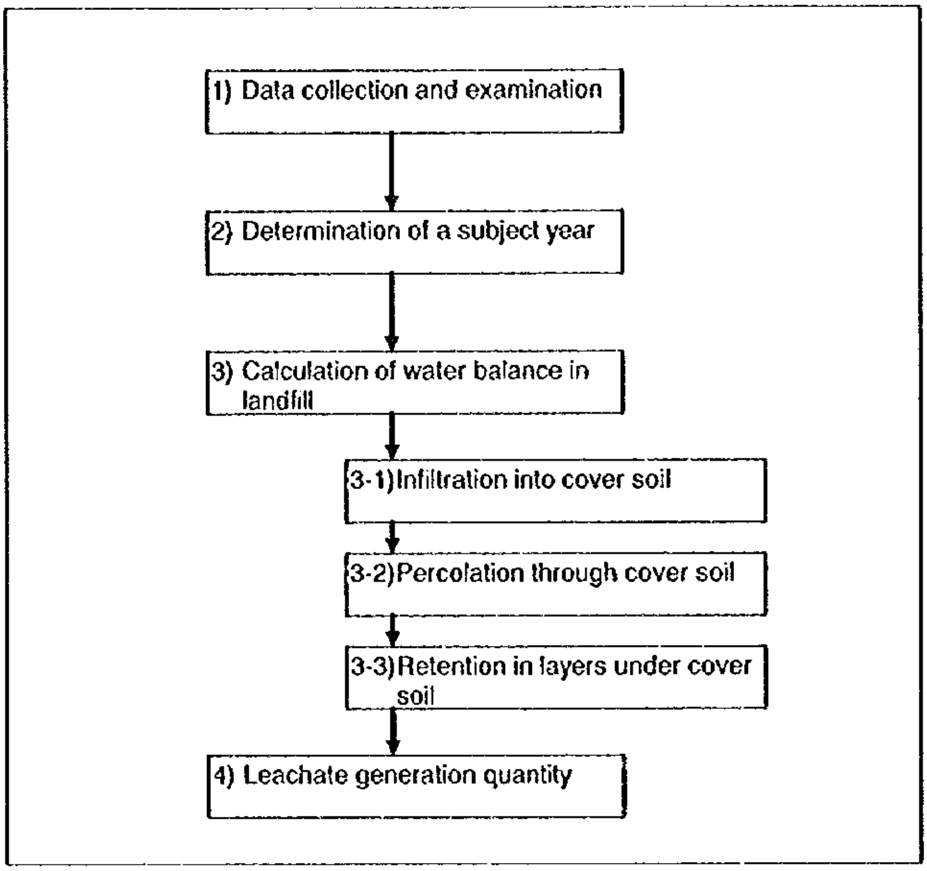

Table H-23: Leachate Generation Estimation Flow

1) Data Collection and Examination

Mean monthly precipitation data from 1970 to 1989 at the Mexico City International Airport station is available for this estimation. The station is located next to the Bordo Poniente area, about 4km to Etapa IV and 10 km to Etapa V. The coordinates are 19°26'N (latitude 19 degrees 26 minutes north) and 99°05'W (longitude 99 degrees 5 minutes west). And the altitude is 2,235m.

Not all the data are valid. Data of some years are incomplete, e.g., data in August was not recorded. Such years were excluded from the calculation. Finally, precipitation data of 14 years out of the 20 years were to be subject to the estimation (See Table H-24).

Table H-24: Precipitation Data from 1970 to 1989

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Remarks
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	invalid
1974	2.0	4.0					135.8	52.3	84.1	13.6		0.0	291.8	invalid
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	0.0	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	invalid
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	invalid
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	invalid
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	invalid
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	invalid

Station: Mexico City International Airport station (Estacion meteorologica Aeropuerto Internacional Benito Juarez)

2) Determination of a Subject Year

1981 was selected out of the 14 years as a subject year to the estimation by using Thomas Plot Method, as the total precipitation in 1981 is the closest to that of two-year return period that is representative of normal conditions.

The sequence of selecting the subject year of 1981 is shown below.

2-1) Arrangement of the Precipitation Data in Order of Depth

Table H-25: Precipitation in Order of Depth

Order (J)	Year	Rain (mm/year)
1	1976	773
2	1978	672
3	1972	621
4	1971	619
5	1988	607
6	1980	601
7	1981	597
8	1982	556
9	1985	543
10	1970	527
11	1975	527
12	1977	525
13	1987	524
14	1986	486

2-2) Calculation of Thomas Plot

Values of Thomas Plot are calculated by using the formula below.

$$P = \frac{J}{N+1}$$

P: Thomas Plot
J: order of precipitation
N: number of data

The following table shows the values of Thomas Plot for each precipitation data.

Table H-26: Thomas Plot and Precipitation

Order (J)	Px100	Rain (mm/year)
1	6.7	773
2	13.3	672
3	20.0	621
4	26.7	619
5	33.3	607
6	40.0	601
7	46.7	597
8	53.3	556
9	60.0	543
10	66.7	527
11	73.3	527
12	80.0	525
13	86.7	524
14	93.3	486

2-3) Least Square Method

Least square method was applied in order to acquire a formula which shows the relation between Thomas Plot and the precipitation data. The formula obtained is as follows.

$$y = -2.4665x + 707.46$$

y: precipitation (mm/year)
x: Thomas Plot (P*100)

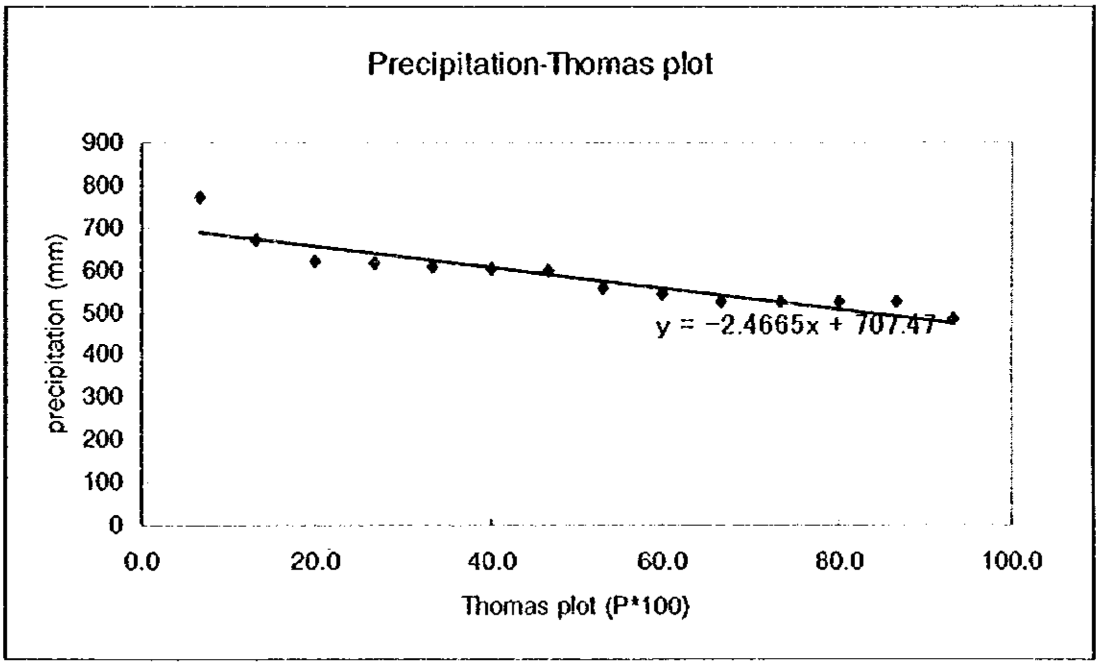

Figure H-11: Precipitation and Thomas Plot

2-4) Subject Year

Subject years can be obtained by using the following formula.

$$P = \frac{1}{2n+1}$$

n: return period

Here, 'n' is one in two years, so 1/2 is substituted for 'n.' Then, 0.5 is obtained for P, i.e., P*100=50. When this is substituted for the formula acquired by the least square method, 584 mm/year is calculated as the precipitation of two- year return period.

$$y = -2.4665x + 707.46$$
$$x = 50$$
$$then,$$
$$y = -2.4665 \times 50 + 707.46$$
$$y = 584(mm/year)$$

Finally, 1981 was selected as the subject year to this leachate generation estimation, as the total precipitation in 1981, 597 mm/year, is the closest to 584 mm/year.

3) Calculation of Water Balance in Landfill

In this section, infiltration of precipitation into the cover soil, percolation through the cover soil and retention in layers (waste and soil) under the cover soil are dealt with according to the present configuration of landfill layers (See Figure H-12).

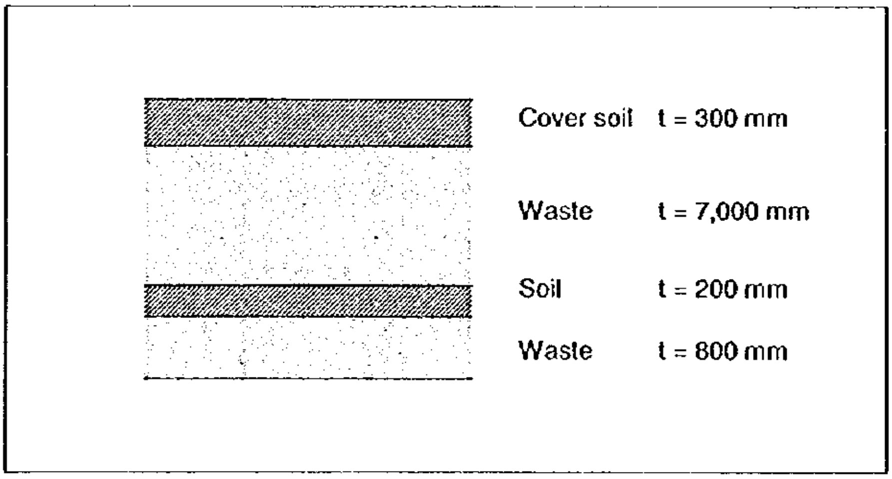

Figure H-12: Present Configuration of Landfill Layers

3-1) Infiltration into Cover Soil

Not all precipitation infiltrates into the cover soil. Part of it runs over the cover soil as runoff and the rest infiltrates. Generally, it is expected that the surface runoff coefficients for sanitary landfill conditions may lie within the range of 0.07 to 0.2[3], then 0.14 (the middle value between 0.07 and 0.2) of runoff coefficient was applied to this estimation.

In case of the precipitation pattern in 1981, 514 mm/year of precipitation will infiltrate into the cover soil with runoff coefficient of 0.14.

Table H-27: Runoff and infiltration

	Runoff coefficient, c = 0.14		
Month	Precipitation (mm)	Runoff (mm)	Infiltration (mm)
Jan	20	3	17
Feb	20	3	17
Mar	10	1	9
Apr	40	6	34
May	24	3	21
Jun	178	25	153
Jul	148	21	127
Aug	68	9	59
Sep	51	7	44
Oct	35	5	30
Nov	2	0	2
Dec	1	0	1
Total	597	83	514

3-2) Percolation thorough Cover Soil

Evapotranspiration is a major concern about percolation through cover soil. Soil has a certain capacity to retain water, i.e., field capacity (FC). When water content is beyond FC, part of the water exceeding FC will go down by gravity. In the meantime, there is water in soil which can not be extracted by evapotranspiration. The water content under which water can not be extracted is called as permanent wilting point (PWP). Therefore, the water between FC and PWP is subject to evapotranspiration.

Consequently, percolation will happen once water content exceeds the FC, and water content never become below the PWP under normal condition.

The way of calculating the percolation through cover soil is:

- determination of a depth where evapotranspiration is effective.
- determination of FC and PWP of the cover soil.
- calculation of potential evapotranspiration (PET).

then,

- calculation of percolation through the cover soil.

[3] Qasim S. R. and Chiang W., 1994, Sanitary landfill leachate, Technomic publication, USA

Determination of a depth where evapotranspiration is effective

It is assumed that the depth of the cover soil where evapotranspiration is effective is 150mm.

Determination of FC and PWP of the cover soil

The cover soil, Tepetate, is silty clay. Typical values of FC (31%) and PWP (15%)[4] for silty clay were applied. Then, FC and PWP of 150mm depth of the soil resulted in 50mm and 25 mm each.

$$FC = 150mm \times 31\% = 46.5mm \qquad say: 50mm$$

$$PWP = 150mm \times 15\% = 22.5mm \qquad say: 25mm$$

Calculation of potential evapotranspiration

Potential evapotranspiration (PET) was calculated by Thornthwaite method with the temperature data in 1981.

Table H-28: Potential Evapotranspiration (PET)

Month	Tm (°C)	im	a	Em	(Nm)	Nm	PET (mm)
Jan	11.3	3.4	1.6	34.39	11.0	0.92	32
Feb	14.2	4.79		49.57	11.5	0.96	48
Mar	16.9	6.21		65.49	12.0	1.00	65
Apr	17.8	6.72		71.16	12.6	1.05	75
May	18.7	7.23		77.00	13.1	1.09	84
Jun	18.1	6.89		73.09	13.3	1.11	81
Jul	17.0	6.27		66.11	13.2	1.10	73
Aug	17.5	6.55		69.25	12.8	1.07	74
Sep	17.3	6.44		67.99	12.3	1.03	70
Oct	16.9	6.21		65.49	11.7	0.98	64
Nov	13.9	4.64		47.91	11.2	0.93	45
Dec	14.0	4.69		48.46	10.9	0.91	44
Year	16.1	70.04					755

Tm: temperature (°C)
im: $(Tm/5)^{1.5}$
I: $\Sigma(im) = \Sigma(Tm/5)^{1.5}$
a: $6.7\times10^{-7}\times I^3 - 7.7\times10^{-5}\times I^2 + 1.8\times10^{-2}\times I + 0.49$
Em: unadjusted evapotranspiration, $16(10Tm/I)^a$
(Nm): Mean Daily Duration of Maximum Possible Sunshine Hours at 20°N
Nm: monthly adjustment factor, (Nm)/12
PET: Em x Nm

Calculation of Percolation through the Cover Soil

101 mm/year of percolation through the cover soil was calculated with taking into consideration FC, PWP, PET and actual evapotranspiration (AET). Table H-29 shows the calculation.

[4] Tchobanoglous, G. , Theisen, H. and Vigil S.A., 1993, Integrated solid waste management, McGraw-Hill, Inc., USA

Table II-29: Percolation through the Cover Soil

unit: mm

	I	PET	I-PET	APWL	Ws	ΔWs	AET	PERC
Jan	17	32	-15	-176	25	0	17	0
Feb	17	48	-31	-207	25	0	17	0
Mar	9	65	-56	-263	25	0	9	0
Apr	34	75	-41	-304	25	0	34	0
May	21	84	-63	-367	25	0	21	0
Jun	153	81	72	0	50	25	81	47
Jul	127	73	54	0	50	0	73	54
Aug	59	74	-15	-15	38	-12	71	0
Sep	44	70	-26	-41	25	-13	57	0
Oct	30	64	-34	-75	25	0	30	0
Nov	2	45	-43	-118	25	0	2	0
Dec	1	44	-43	-161	25	0	1	0
Year	514	755	-241			0	413	101

Assumption: fc of soil =31%, pwp = 15%, thickness of evapotranspiration depth =0.15m, FC=31%x0.15m=0.0465m=46.5mm, say 50mm, PWP=15%x0.15m=0.0225m=22.5mm, say 25mm

I: infiltration
PET: potential evapotranspiration
APWL: accumulated potential water loses
Ws: water in soil (never be more than FC nor less than PWP)
ΔWs: change in water in soil
AET: actual evapotranspiration
PERC: percolation through the cover soil

3-3) Retention in Layers under the Cover Soil

Layers under the cover soil have a capacity of retaining water, 262 mm, in total. This is equivalent to about three successive years percolation through the cover soil (101mm/year x 3years = 303mm).

7m thickness of waste, 0.2m of soil and again 0.8m of waste are laid under the cover soil. Furthermore, 0.15m thickness of the cover soil, which is under the layer affected by evapotranspiration, should be taken into account for the calculation of the percolation.

Waste has a field capacity similar to FC of soil. And in this section, initial moisture content (IMC) of both waste and soil is important instead of PWP. Waste and soil has a certain moisture initially, so that the water percolated through the cover soil is retained within the FC and the IMC of the layers under the cover soil. When the water content exceeds FC, water percolates down to the bottom of the landfill.

Typical FC value of municipal waste is between 20 and 35 % by volume[5]. With taking into account this typical value, 25 % is applied. Typical IMC value of municipal waste at landfill is from 15 to 40% by weight[6], then 27.5% is taken. In the meantime, 31% is applied to FC of soil[4]. And it is assumed that IMC of soil is 23% which is the middle value between 31% of FC and 15% of PWP. Finally, FC and IMC

[5] Qasim S. R. and Chiang W., 1994, Sanitary landfill leachate, Technomic publication, USA
[6] Tchobanoglous, G. , Theisen, H. and Vigil S.A., 1993, Integrated solid waste management, McGraw-Hill, Inc., USA

of layers under the surface layer of 0.15 thickness with evapotranspiration effect are calculated below.

Cover soil (t=150mm)

FC1 = 150mm x 31% = 46.5 = 47mm

IMC1 = 150mm x 23% = 34.5 = 35mm

Waste (t=7,000mm)

FC2 = 7,000mm x 25% = 1,750mm

IMC2 = 7,000mm x 0.8 x 27.5 % = 1,540mm

0.8 is the bulk density of waste at landfill

Soil (t=200mm)

FC3 = 200mm x 31% = 62mm

IMC3 = 200mm x 23% = 46mm

Waste (t=800mm)

FC4 = 800mm x 25% = 200mm

IMC4 = 800mm x 0.8 x 27.5 % = 176mm

Table H-30: FC, IMC and Retention Capacity

Layer	FC	IMC	Retention capacity
cover soil (t=150)	47	35	12
waste (t=7,000)	1,750	1,540	210
soil (t=200)	62	46	16
waste (t=800)	200	176	24
Total	2,059	1,797	262

4) Leachate Generation Quantity

The percolation through the cover soil is 101 mm/year, while the total water retention capacity under the cover soil is 262 mm. Therefore, the capacity will be filled in 3 years, then leachate equivalent to the percolation of 101 mm/year will be generated at the bottom of the landfill in the 4th year and after that.

a.3 Waste Disposal Amount

According to the Master Plan, the landfills of Etapa IV and V have to have enough capacity to secure sound final waste disposal from 2001 to 2010. The forecast of waste amount to be disposed of during the 10 years is shown in Table H-31.

Table H-31: Waste Disposal Amount from 2001 to 2010

Year	Disposed Waste					
	Total		Etapa IV		Etapa V	
	1000 ton	1000 m^3	1000 ton	1000 m^3	1000 ton	1000 m^3
2001	3,876	4,845	3,876	4,845		
2002	3,609	4,511			3,609	4,511
2003	3,493	4,366			3,493	4,366
2004	3,385	4,231			3,385	4,231
2005	3,373	4,216	3,373	4,216		
2006	3,358	4,198	3,358	4,198		
2007	3,340	4,175			3,340	4,175
2008	3,321	4,151			3,321	4,151
2009	3,300	4,125	3,300	4,125		
2010	3,278	4,098	3,278	4,098		
Total	34,333	42,916	17,185	21,482	17,148	21,434

Note: bulk density of the waste at landfill is assumed to be 800kg/m^3.

b. Examination of Technical Alternatives

Major causes giving serious impacts on the environment in landfill development are leachate and landfill gas. Also, mitigation measures against them make landfill construction, operation and, furthermore, closure costly. Therefore, alternatives of mitigation measures such as landfill bottom liner, intermediate cover, final cover, surface drainage, leachate collection, leachate disposal, landfill gas disposal, etc. are of much technical interest. Although some issues can not be modified because Etapa IV is the existing landfill, the issues shown in Table H-32 are examined technically, environmentally, and in view of costs in this section.

Table H-32: Issues to be Examined as Technical Alternatives

Leachate/gas	Purpose	Issues to be examined
Leachate	How to make leachate generation quantity smaller.	During operation - intermediate cover After closure - final cover
	How to dispose of leachate.	- spray - re-circulation - evaporation pond - treatment facility
Landfill gas	How to dispose of landfill gas.	- passive control - active control

b.1 Intermediate Cover

In the manner of landfilling at Etapa IV, daily soil cover will also serve as an intermediate soil cover which is placed at 8m elevation. The intermediate soil cover is expensive (about 20 pesos/m^3) as it is not available in the landfill area. Thus, placement of the intermediate soil cover considerably affects the operation costs. To find a way to make this cost smaller, i) thickness of the soil cover and ii) use of waste from the compost plant are examined. Finally, 30 cm thickness of cover soil as in the present operation is recommended.

i. Thickness of Cover

At present, 30 cm thickness of soil is employed as the intermediate (daily) cover material. This cover may allow 101 mm/year of rainfall to percolate, eventually leachate equivalent to this 101 mm/year will be generated in the 4^{th} year and after that.

In case that the cover is made thick, leachate generation may be delayed. However, the same quantity (101 mm/year) of leachate will theoretically be generated, once the landfill layers are filled with water. It can be said that sloping the top of landfill is more effective than thickening the cover material in order to enhance surface water runoff, i.e., to mitigate leachate generation.

Generally, 20 to 30 cm of soil is employed for daily cover mainly for sanitary purposes, e.g., to control birds, flown materials, dust, pests and vectors, rather than surface water control. In the meantime, purpose of intermediate cover is rather to control infiltration. Although more than 30 cm of thickness generally tends to be employed for it, the thickness used at present would be appropriate because:

- precipitation at the site is small.
- thickness of the cover is not effective to control infiltration in a longtime view (if vegetation does not develop).
- the present thickness fulfils the purpose of daily cover soil.

ii. Use of Compost as Cover Material

It is recommendable to make use of compost produced in the compost plant as cover material when the production exceeds the demand.

Compost can function as a daily and/or intermediate cover like native soil. An advantage of using compost is that part of the landfill capacity which would have been occupied with native soil is available for the disposal of waste material. In view of the whole waste management, the use of compost for covering waste considerably contributes waste volume reduction and prolongation of landfill lifetime.

b.2 Final Cover

A final cover should be employed to promote attenuation of landfills' harmful influence on surroundings, when they are closed. Major purposes of the final cover is i) to mitigate leachate generation, ii) to control landfill gas emission and iii) to improve landscape. With taking these purposes into account, 50 cm or more thickness of soil cover is recommended as the final cover.

i. Mitigation of Leachate Generation

Usually, the final cover has vegetation in order to make good use of evapotranspiration. Depth where evapotranspiration is effective depends on a type of vegetation. Generally, 50 cm and more thickness is suggested for grasses and shrubs which could grow under the dray climate condition of the site.

Percolation through cover soil of 50 cm was estimated. The result was that 51 mm/year of water will percolate through the cover soil. This is much less than percolation amount which was estimated under the present condition of the existing landfill at 101 mm/year.

Table H-33: Percolation through the Cover Soil (50cm)

unit: mm

	I	PET	I-PET	APWL	Ws	ΔWs	AET	PERC
Jan	17	32	-15	-176	75	0	17	0
Feb	17	48	-31	-207	75	0	17	0
Mar	9	65	-56	-263	75	0	9	0
Apr	34	75	-41	-304	75	0	34	0
May	21	84	-63	-367	75	0	21	0
Jun	153	81	72	-3	147	72	81	0
Jul	127	73	54	0	150	3	73	51
Aug	59	74	-15	-15	135	-15	74	0
Sep	44	70	-26	-41	114	-21	65	0
Oct	30	64	-34	-75	90	-24	54	0
Nov	2	45	-43	-118	75	-15	17	0
Dec	1	44	-43	-161	75	0	1	0
Year	514	755	-241			0	463	51

Assumption: fc of soil =31%, pwp = 15%, thickness of cover soil =0.5m, FC=31%x0.5m=0.155m=155mm, say 150mm, PWP=15%x0.5m=0.075m, say 75mm

ii. Control of Landfill Gas Emission

Strict control of landfill gas emission is not necessary, because there is no residential area and/or other important facilities. Therefore, a sophisticated landfill cover such as synthetic impermeable cover is not required. The soil cover can work effectively.

iii. Improvement of Landscape

Vegetation is good for improving the landscape. Also, the agreement with CNA says that future land use of the site will be grass land in order to improve the ecosystem of Bordo Poniente. However, it should be noted that the dry climate is severe for vegetation to grow. Only grasses or shrubs which are resistant to the dry climate could survive. As mentioned above, 50 cm and more thickness of final cover is recommended for such vegetation.

b.3 Leachate Disposal

The present conditions of the landfill need an appropriate leachate disposal manner. In this section, alternatives examined are the following:

- spray on the landfill.
- re-circulation into the landfill.
- evaporation pond.
- leachate treatment.

First of all, it should be noted that leachate can not be extracted from the landfill by gravity due to flat ground of the area and the settlement. Then, all the alternatives need pumps to get leachate out of the landfill.

Wells for leachate extraction can not be constructed at a periphery of the landfill, but should be inside of the landfill, because the inner part is deeper than the periphery due to settlement, leachate will gather the inner part. Due to this character of the landfill, re-circulation, evaporation pond and leachate treatment require facilities in addition to ones of the spray method. Then, the spray method is the least costs and uses the climatic advantage (small rainfall and large evaporation) efficiently for leachate disposal as stated in Table H-34. Consequently, the spray method is a recommendable manner of leachate disposal.

Table H-34: Comparison of Leachate Disposal Alternatives

Alternatives	Facility needed	Advantages	Disadvantages
Spray	- pumps - wells - nozzle (to spray)	- the least cost - the most efficient use of evaporation action (leachate can contact with air efficiently)	- unpleasant odor on the landfill surface
Re-circulation	- pumps - wells - pipes (to landfill gas extraction wells)	- the second least cost (pipes to connect landfill gas extraction wells are necessary in addition to the spray method) - attenuation of leachate quality	- need great care for landfill gas control (landfill gas tends to be larger in leachate re-circulation systems) - not efficient on reduction of leachate amount - may require further leachate treatment
Evaporation	- pumps - wells - pipes (to a evaporation pond) - evaporation pond	- simple operation	- requiring a large area - unpleasant odor on the evaporation pond - sludge disposal is necessary
Treatment	- pumps - wells - pipes (to treatment facilities) - treatment facilities	- it can control quality of discharge water.	- huge investment and operation costs - need a high level of technique for construction, operation and maintenance

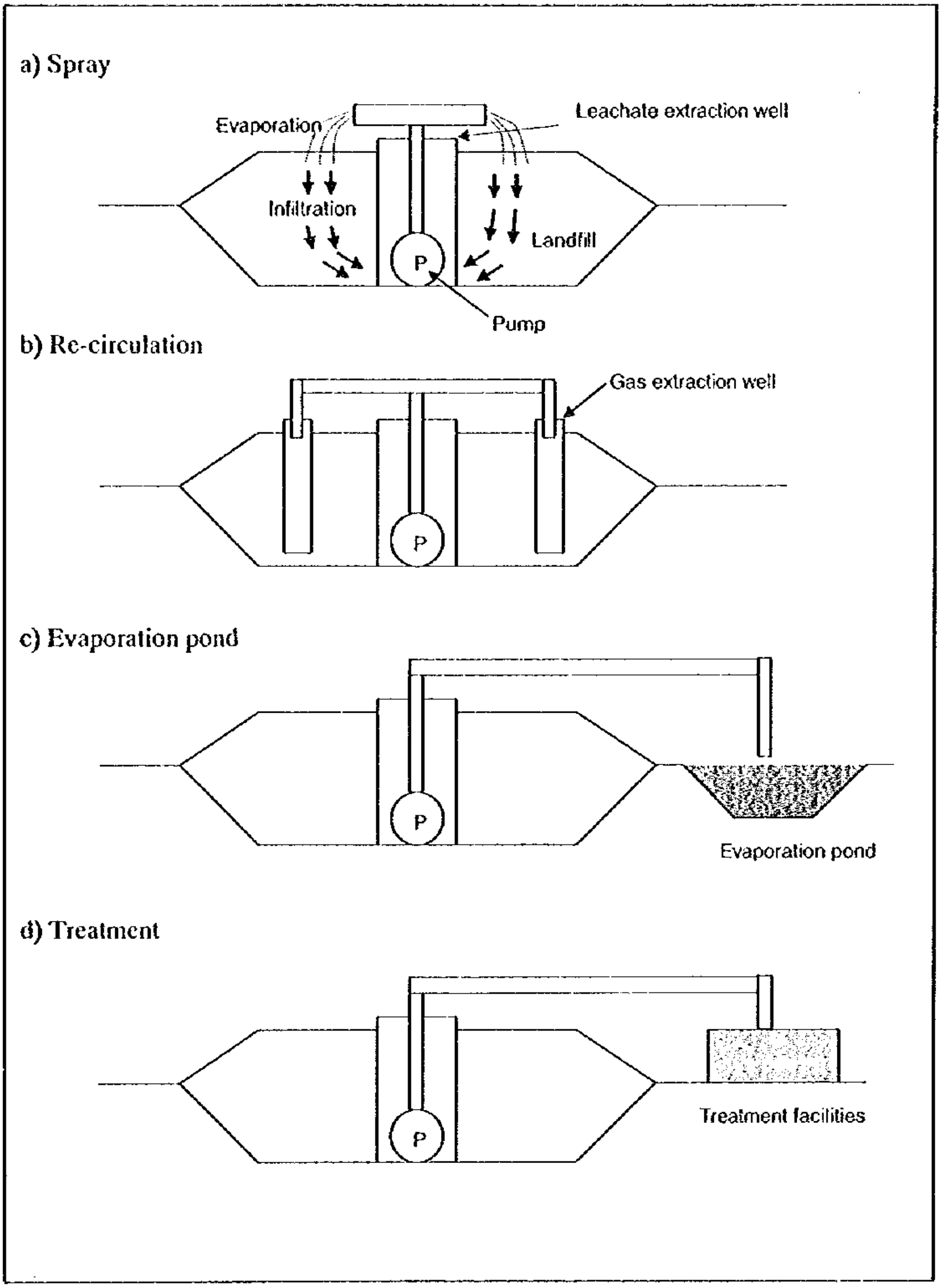

Figure H-13: Leachate Disposal Alternatives

b.4 Landfill Gas Disposal

Landfill gas is generated through decomposition of biodegradable material. It is composed of several constituents. The principal gases are methane (CH_4) and carbon dioxide (CO_2) produced through the anaerobic decomposition.

Ways of controlling landfill gas can be classified as passive and active. The passive control uses pressure of landfill gas generated in the landfill to extract it through gas vents. On the other hand, the active control uses energy to pull it out. Therefore, the active control is generally more costly than the passive one. When gas energy recovery is preferable, or circumstances require strict landfill gas control, the active control may be taken.

As previously stated, the spray method is the recommended manner for leachate disposal. The manner does not encourage landfill gas generation so much as the re-circulation method. Also, there are no residential or commercial areas around the landfill like the surroundings of the Montana landfill which is equipped with modern biogas extraction facilities. Therefore, **the passive control is recommendable for the Etapa IV landfill.**

c. Conceptual Design and Cost Estimates

Outline of the conceptual design for the Vertical Expansion Plan is presented in Table H-35.

Table H-35: Outline of the Conceptual Design for the Vertical Expansion Plan

Items	Facilities
Landfill capacity	25,849,000m^3(20,679,000ton) is available for waste disposal.
Access	at 0m elevation outer road: 8,285m (existing) inner road: 26,675m (existing) at 8m elevation outer road: 7,075m inner road: 19,623m at 16m elevation outer road: 5,160m inner road: 6,453m
Leachate management	Leachate extraction wells concrete pipes with 600mm diameter: 24 nos. Leachate extraction pumps: 24 nos. Leachate collection lines at 0m elevation: 26,675m at 8m elevation: 26,708m at 16m elevation: 11,613m
Landfill gas management	Gas extraction wells concrete pipes with 600mm diameter: 198nos. Gas extraction pipes - PVC200 at 8m elevation: 141 nos. at 16m elevation: 102 nos.
Surface water management	Daily/intermediate soil cover: 30cm (Compost is also usable.)
Monitoring	Monitoring items: -settlement of the landfill -leachate quality -landfill gas quality

Items	Facilities
Aesthetic design	Mobile screen Daily/intermediate soil cover: 30cm (Compost is also usable.)
Closure and post-closure	Final soil cover: 60cm Greening by seeding the final cover with grass
Landfill equipment	Bulldozers (300hp class): 4 nos. Sprinkler trucks (15,000liter class): 2 nos. Excavators (85hp class): 2 nos.

c.1 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
- exchange rate: US$ 1.00 = 9.1pesos
- daily (intermediate) soil cover: 30cm
- final landfill elevation: 24m

c.2 Landfill Capacity

Capacity of the vertical expansion in the part of 8 to 24m elevation is to be 26,926,000m^3. Of the capacity, 25,849,000m^3 will be occupied with waste and 1,077,000 m^3 with soil (See Table H-37 and Figure H-14).

All the waste disposed of in 2001, 2005 and 2006, and part of waste in 2009 are to be placed in the lift of 8-16m elevation. The rest of waste in 2009 and all waste in 2010 are to be disposed of in the lift of 16-24m elevation. The remaining capacity of the landfill after 2010 will be 4,368,000m^3 for waste disposal, i.e., 3,494,000 ton of waste (See Table H-36).

It should be noted that the calculation of landfill capacity does not take the settlement of subsoil and waste into account.

Table H-36: Waste Disposal Amount in Etapa IV

Unit: 1,000m^3

Elevation	Landfill capacity	Waste disposal amount						Remaining capacity
		2001	2005	2006	2009	2010	Total	
8-16m	16,447	4,845	4,216	4,198	3,188		16,447	0
16-24m	9,402				937	4,098	5,035	4,367
Total	25,849	4,845	4,216	4,198	4,125	4,098	21,482	4,367

Table H-37: Landfill Capacity of Etapa IV

Unit: 1,000m^3

Height (m)	Total Volume	Waste Volume	Soil Volume
8	0	0	0
9	2,225	2,136	89
10	4,426	4,249	177
11	6,603	6,339	264
12	8,755	8,405	350
13	10,885	10,450	435
14	12,991	12,471	520
15	15,072	14,469	603
16	17,132	16,447	685
17	18,408	17,672	736
18	19,669	18,882	787
19	20,915	20,078	837
20	22,146	21,260	886
21	23,363	22,428	935
22	24,564	23,581	983
23	25,752	24,722	1,030
24	26,926	25,849	1,077

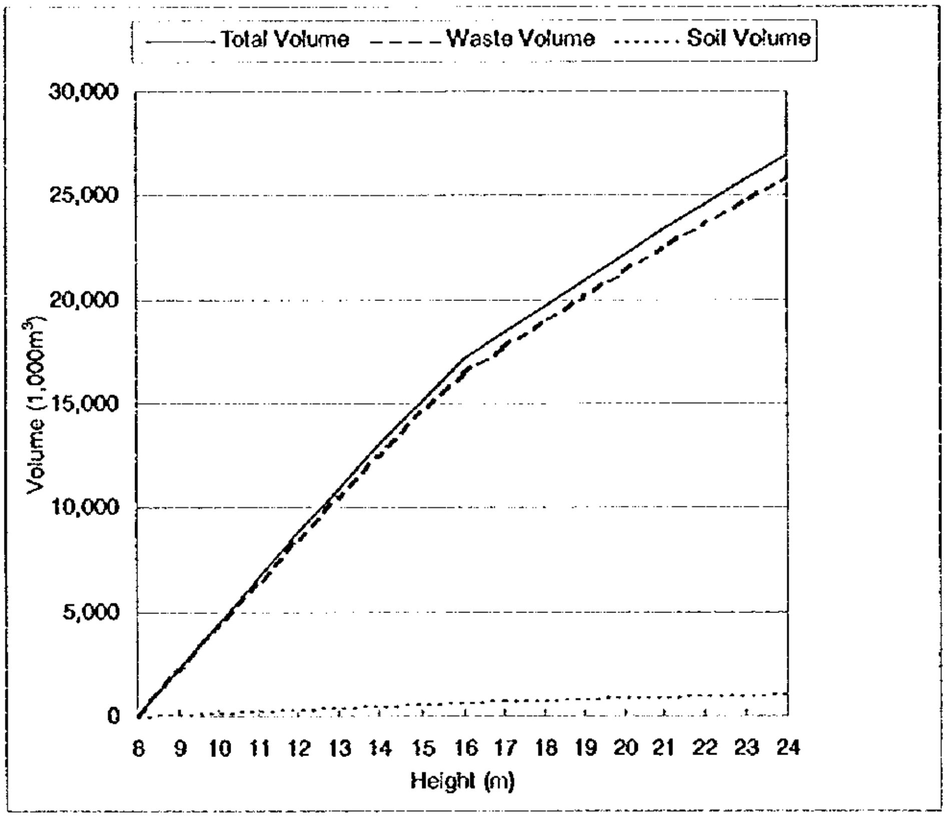

Figure H-14: Height - Volume Curve (Etapa IV)

c.3 Access

In order to secure accessibility to waste unloading areas, outer roads and inner roads will be constructed on the 8m and 16m elevation respectively. The outer roads are to be used for monitoring and maintenance roads after completion of waste placement. The dimensions of roads are shown below.

- Carriage width: 9.0m
- Shoulder width: 0.5m at both sides
- Pavement: volcanic porous rocks or equivalent material

c.4 Leachate Management

The daily (intermediate) cover, whether using native soil or compost, must properly be conducted 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. This results in 331,000m^3/year of leachate generation in total. This amount of leachate will be extracted and sprayed by the 24 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.

c.5 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 installed along the ring road and the outer roads, and concrete pipes with 600mm diameter will be in the inner part of the landfill. Some of the concrete pipes are also to be used as leachate extraction wells.

c.6 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 recommendable.

c.7 Monitoring

Leachate quality and landfill gas have been monitored, and this should be continued. Recommendations on the present monitoring manner are:

- sample for leachate quality analysis should be taken from a leachate extraction well to be installed.

- the sampling manner of landfill gas should be improved not to mix the gas with air outside the landfill.

And monitoring of landfill elevation should be conducted in order to know:

- condition of waste decomposition.
- progress of waste and subsoil settlement.

c.8 Aesthetic Design Consideration

To avoid waste to be blown to the surroundings, use of mobile screens near the operating area is recommendable. Proper daily (intermediate) soil cover should be practiced in order to control birds, pests and vectors as well as to avoid wind-blown wastes.

c.9 Closure and Post-closure Care

The final cover of 60 cm thickness 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 the landfill surface is to be effective to encourage evapotranspiration on the surface, and this results in reduction of leachate generation. It will also have an effect on improving the appearance of the site.

c.10 Landfill Equipment

Equipment recommended for the sanitary landfill comprises:

- four (4) bulldozers (300hp class) for spreading and compacting both waste and cover material.
- two (2) sprinkler trucks (15,000liters class) for dust control.
- 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. The number of bulldozers were calculated as follows.

i. Productivity of Bulldozer (300hp class)

Probable cycle time (Cm)

Forward: 20m / 60m/min	=0.33 min
Reverse: 20m / 80m/min	=0.25 min
Others (loading and shifting gears)	=0.32 min
Total cycle time	=0.90 min

Output

$$Qh = \frac{60 \times q \times f \times E}{Cm}$$

Qh: Output per hour (m^3/h)

q: Capacity of blade	(m^3)	
f: Conversion factor of waste	1.0	
E: Operation efficiency	0.6	

Hence, Qh is 320 m^3/h.

ii. Required Number of Bulldozers

Weight of waste disposed of per day:	10,000 ton/day	
Volume of waste disposed of per day:	10,000 / 0.8 = 12,500 m^3/day	
(0.8: bulk density of waste)		
Operation hours of a bulldozer	:10 hours	
Volume of waste disposed of per hour	:12,500/10 = 1,250 m^3/day	
Required number of bulldozers	:1,250/320=3.91	say 4 units

c.11 Operation

The 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., and such manner should be continued. 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 the Vertical Expansion.

c.12 Sequence of BP-IV Vertical Expansion

At present, leachate is seeping out at cell's slope bottom on to the surrounding road. **It creates the problem of the operation today and the near future that the road condition is being deteriorated especially when it rains.**

In order to implement the "Vertical Expansion of BP-IV", the following components should be carried out in an appropriate sequential manner:

a. Bottom impermeabilization of roads part (0.0 meter elevation)
b. Provision of horizontal leachate collection system (0.0 meter elevation)
c. Approach road (from 0.0 meter to 8.0 meter elevation) construction
d. Roads (on 8.0 meter elevation) construction
e. Vertical shaft (for leachate collection/pump-up, biogas removal) construction
f. Filling of valleys on roads (0.0 to 8.0 meter elevation)
g. Leachate pump-up and spray (and/or impound) at 8.0 meter elevation

h. Landfilling (8.0 to 16.0 meter elevation)
b'. Provision of horizontal leachate collection system (on 8.0 meter elevation roads)
c'. Approach road (from 8.0 meter to 16.0 meter elevation) construction
d'. Roads (on 16.0 meter elevation) construction
e'. Expansion of vertical shaft (from 8.0 to 16.0 meter elevation)
f'. Filling of valleys on roads (8.0 to 16.0 meter elevation)
g'. Leachate pump-up and spray (and/or impound) for drying at 16.0 meter elevation

h'. Landfilling (16.0 to 24.0 meter elevation)
b". Provision of horizontal leachate collection system (on 16.0 meter elevation roads)
c". Approach road (from 16.0 meter to 24.0 meter elevation) construction
d". Roads (on 24.0 meter elevation) construction
e". Expansion of vertical shaft (from 16.0 to 24.0 meter elevation)
f". Filling of valleys on roads (16.0 to 24.0 meter elevation)
g". Leachate pump-up and spray (and/or impound) for drying at 24.0 meter elevation.

a. Impermeabilization of 0.0 Meter Elevation Roads

Although all the cells have a bottom impermeable liner, roads do not have the bottom impermeable liner. Therefore, impermeable lining on roads part should be carried out in order to attain the holistic impermeability of the BP-IV site as a total.

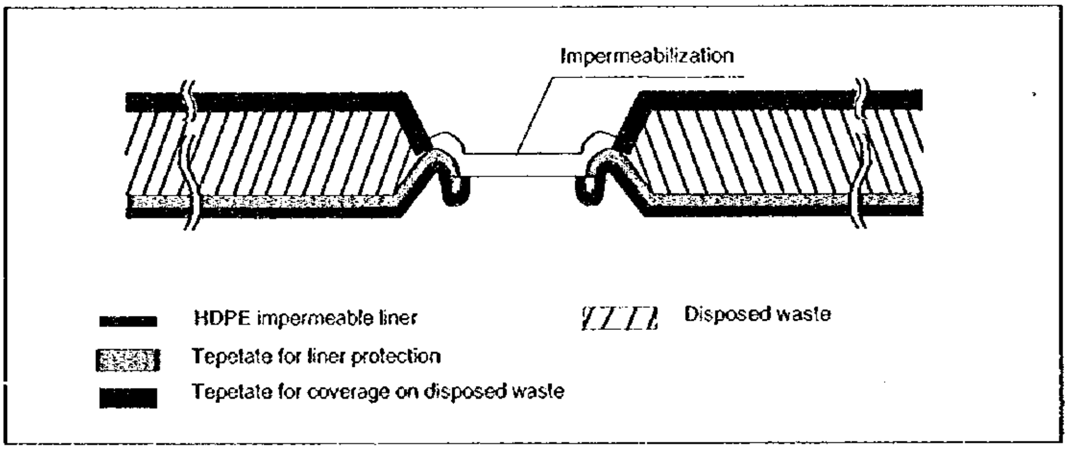

Figure H-15: Impermeabilization of 0.0 Meter Elevation Roads

b. Leachate Collection and Drainage Lines on 0.0 Meter Elevation Inner Roads

After impermeable lining on 0.0 meter elevation inner roads is carried out, tepetate should be laid on the impermeable liner for its protection. Above the tepetate, leachate collection and drainage lines by porous volcanic rocks should be installed.

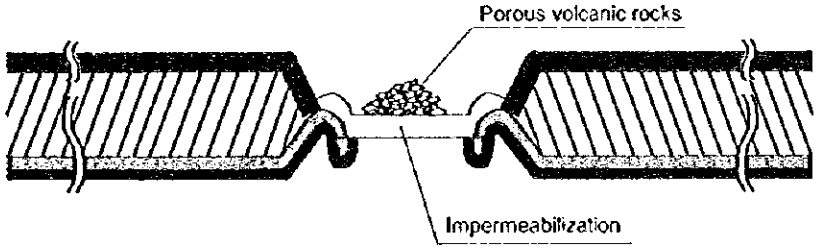

Figure H-16: Leachate Collection and Drainage Lines

b.1 Outer Roads on 0.0 Meter Elevation

The outer ring roads on 0.0 meter elevation should be maintained as "monitoring and maintenance" roads for BP-IV.

c. Approach Road to 8.0 Meter Elevation

An approach road (ramp) to the 8.0 meter elevation should be firstly planned.

As the trailers pass the weighbridge located in the entrance of the BP-IV site, the ramp is recommended to be located at the No. 19 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.

Meanwhile, the area between the No. 19 Cell and the S/P will possibly be subject to the future landfill, therefore the ramp should have a bottom impermeable liner before its construction.

The width of this ramp **(5% slope)** should be wide enough only to have **one-way** traffic of trailers. When the valley (on 0.0 meter road) filling operations are carried out, the traffic volume on the ramp should be small enough to maintain alternate traffic on one-way width ramp. When the landfilling operation of 8.0 to 16.0 meter elevation takes place, traffic volume on the ramp becomes large, therefore, 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.

d. Roads on 8.0 Meter Elevation

When the BP-IV 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 as shown in Figure H-17.

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 road construction material, and it will later work as a 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.

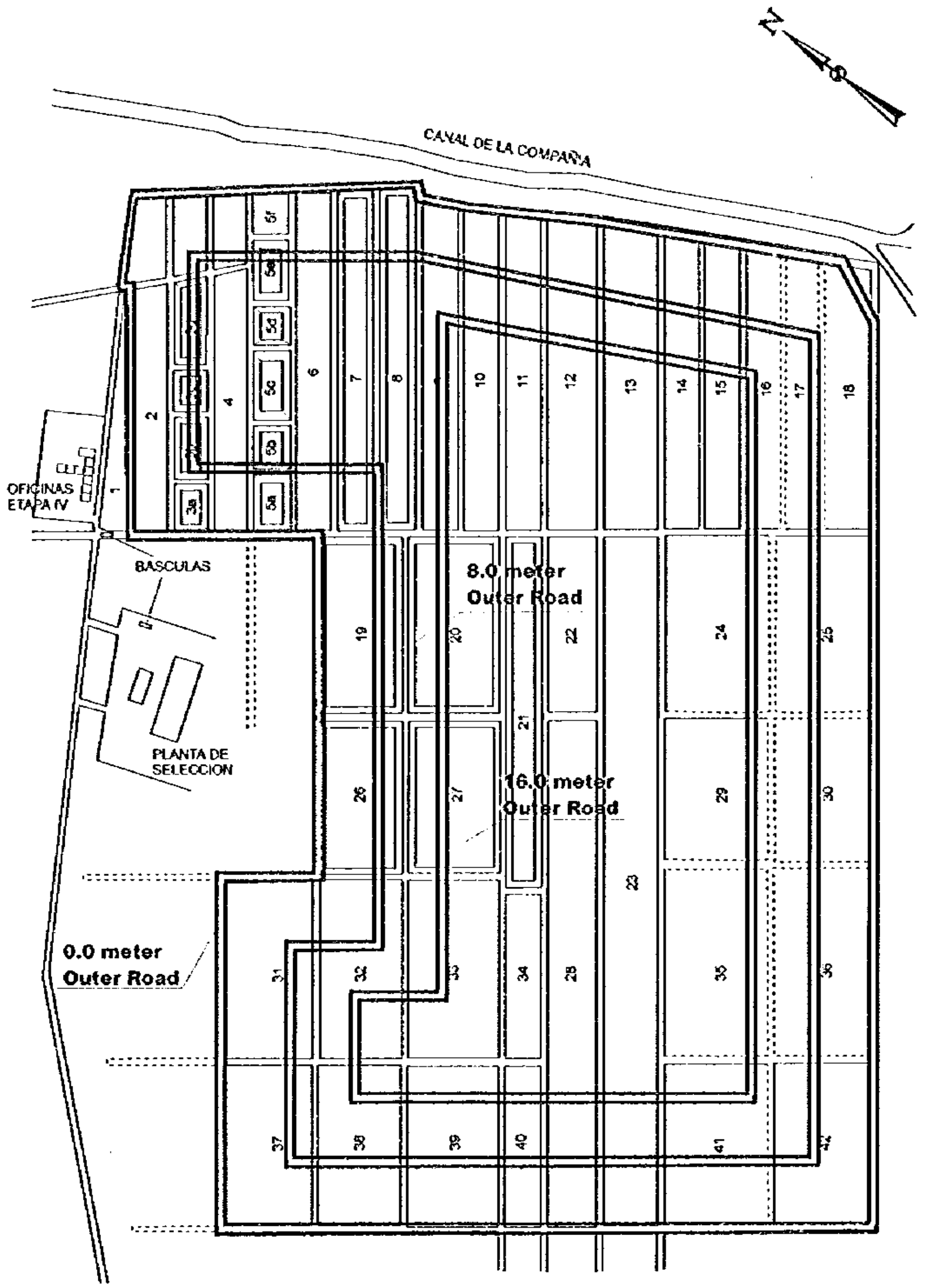

Figure H-17:

Outer Roads on 0.0, 8.0 and 16.0 meter Elevation

Scale 1 : 150,000

KOKUSAI KOGYO Co., Ltd.

e. Vertical Shaft (for Leachate Collection/Pump-Up, Biogas Removal) on 0.0 Meter Elevation Inner Roads

As the BP-IV site is located on a flat plain area, the leachate collection system can not employ gravity draining to a treatment facility (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 0.0 meter elevation roads with an appropriate interval with each other. As all **inner roads** on 0.0 meter elevation will be utilized as draining lines, the suction pits should be installed at all junctions of inner roads. The interval of the suction pits are recommended to be about **100 meter**, as the vertical shafts for pumping up leachate can also be utilized as biogas removal facilities (i.e., chimneys). It gives a total of **222** Nos. of suction pits with vertical shaft.

The estimated leachate generation of **101** mm/year requires 24 pumps (with a nominal capacity of $0.11m^3/min$) running 12 hours during the day. Therefore, **24** shafts should have functions of leachate pump-up and biogas removal shafts, while other **198** shafts should regularly work as biogas removal and occasionally as pump-up shaft when maintenance, inspection or repair is required for the regular pump-up shafts.

The vertical shafts (of leachate pump-up and biogas removal) should initially be constructed up to the 8.0 meter elevation or a little higher before filling the gap (valley on roads).

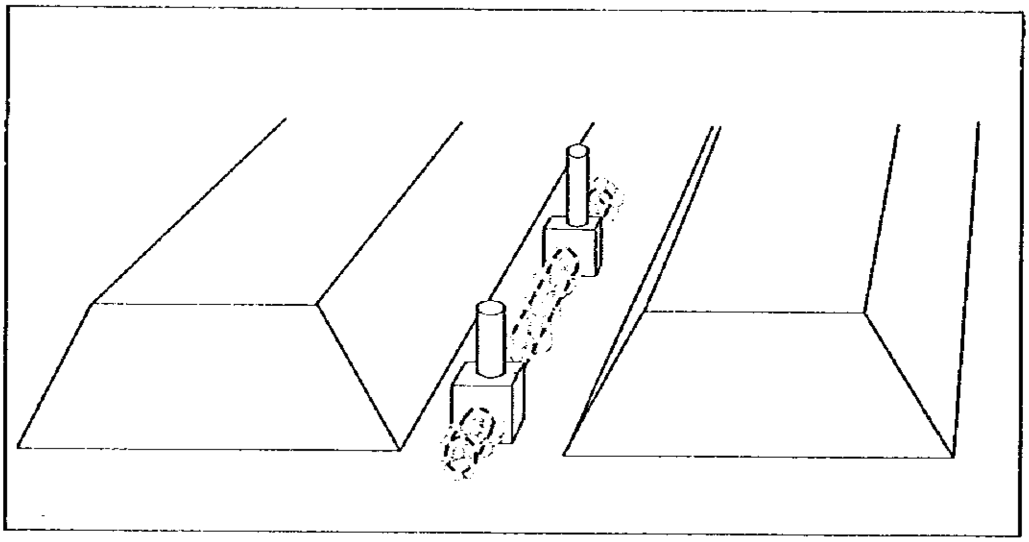

Figure H-18: Vertical Shaft (for Leachate Collection/Pump-Up, Biogas Removal)

f. Filling the Gaps between 2 Cells to 8.0 Meter Elevation

The gaps on roads (between cells) should be filled with wastes to be disposed of from the 8.0 meter elevation road, and be compacted and covered with soil to the 8.0 meter elevation.

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

When the gaps are 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.

h. 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 the outer area 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 a better trafficability on 16.0 meter elevation roads in the future, the cell which receives the 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 to the south from the ramp (0.0 to 8.0 meter) on No. 19 Cell.

Table II-38 shows the concept of construction schedule for valley filling for the vertical expansion works.

Table H-38: Concept of Construction Schedule for Valley Filling

	Valley No.*																													
		c	c	c																										
		South Extension																												
			d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d											
1	19-20	a	b	e	f																									
2	20-21		a	b	e	f																								
3	21-22			a	b	e	f																							
4	22-23				a	b	e	f																						
5	20-27					a	b	e	f																					
6	27-21						a	b	e	f																				
7	21-28							a	b	e	f																			
8	22-28								a	b	e	f																		
9	28-23									a	b	e	f																	
10	21-34										a	b	e	f																
11	20-10											a	b	e	f															
12	21-11												a	b	e	f														
13	22-12													a	b	e	f													
14	11-12														a	b	e	f												
15	12-13															a	b	e	f											
16	23-13																a	b	e	f										
						East Extension																								
								d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d						
17	19-6						a	b	e	f																				
18	19-7							a	b	e	f																			
19	19-8								a	b	e	f																		
20	20-8									a	b	e	f																	
21	20-9										a	b	e	f																
22	7-6											a	b	e	f															
23	7-8												a	b	e	f														
24	6-5													a	b	e	f													
25	8-9														a	b	e	f												
26	5-5															a	b	e	f											
27	9-10																a	b	e	f										
28	5-4																	a	b	e	f									
29	10-11																		a	b	e	f								
30	4-3																			a	b	e	f							
31	3-3																				a	b	e	f						
32	3-2																					a	b	e	f					
												West Extension																		
													d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	
33	19-26											a	b	e	f															
34	26-27												a	b	e	f														
35	26-32													a	b	e	f													
36	27-33														a	b	e	f												
37	32-31															a	b	e	f											
38	32-33																a	b	e	f										
39	33-34																	a	b	e	f									
40	34-28																		a	b	e	f								
41	32-38																			a	b	e	f							
42	33-39																				a	b	e	f						
43	34-40																					a	b	e	f					
44	31-37																						a	b	e	f				
45	38-37																							a	b	e	f			
46	38-39																								a	b	e	f		
47	39-40																									a	b	e	f	
48	40-28																										a	b	e	f

Note: * Valley No. e.g. 19-20 represents the valley between the Cell No. 19 and the Cell No. 20.

c.13 Cost Estimates

Two cases are set for operation of the landfill as follows:

- Case 1: Investment and operation by the DGSU.
- Case 2: Investment by the DGSU and contracting out operation.

This makes cost estimates for this Vertical Expansion Plan different, so that the estimates are carried out in Case 1 and Case 2 respectively.

Difference between Case 1 and Case 2 is whether the landfill operation is conducted by the DGSU directly or by private company(s) under the DGSU's supervision. From a viewpoint of disbursement, the difference reflects payment for the landfill equipment. That is, the payment for landfill equipment in Case 1 has peaks in 2000 and 2007 due to procurement. Such peaks will not appear in Case 2, because the equipment will be delivered by the private company(s) under a contract.

i. Case 1

Construction

Construction costs of US$ 17,316,000 until 2010 was estimated as shown in Table H-39. Table H-40 explains construction costs until the closure of the landfill. Table H-41 presents initial installment costs of pumps for leachate disposal of which disbursement is to be required in 2000.

Table H-39: Construction Costs for the Vertical Expansion until 2010

				Unit construction costs per ton of waste (US$/ton)				8-16m	16-24m
								0.5582	0.4660
Year	Waste amount (1000 ton)			Costs for landfill construction (US$ 1,000)					
				Design and supervision	Initial construction	Construction while operation		Pumps for leachate	Total
	8-16m	16-24m	Total			8-16m	16-24m		
1999-2000			-	19					19
2000			-	173	7,752			150	8,075
2001	3,876		3,876			2,164	0		2,164
2005	3,373		3,373			1,883	0		1,883
2006	3,358		3,358			1,874	0		1,874
2009	2,551	749	3,300			1,424	349		1,773
2010		3,278	3,278			0	1,528		1,528
Total	13,158	4,027	17,185	192	7,752	7,345	1,877	150	17,316

Table H-40: Construction Costs for the Vertical Expansion until Closure

No.	Description	Quantity	Unit	Exchange rate, $1.00=9.1 pesos				
				Unit rate	Currency	Amount		
						Domestic		Foreign
						1,000 peso	1,000 US$	1,000 US$
1	0-8 Elevation							
1.1	leachate collection (along inner road)	26,675	m	300	peso	8,003	879	
1.1.1	leachate & gas extraction well	222	nos	8,000	peso	1,776	195	
	sub-total						1,074	
	Miscellaneous	10	%				107	
Direct cost							1,181	
General expenses and overhead		30	%				354	
Total construction costs							1,535	
Physical contingency		10	%				154	
IVA		15	%				230	
Total cost (inc. conti. & tax)							1,919	
Design and supervision		10	%		of construction costs		154	
Physical contingency		10	%				15	
IVA		15	%				23	
Total cost (inc. conti. & tax)							192	
1.2	Bottom liner & others							
1.2.1	bottom lliner							
a	HDPE (1mm)	533,500	m^2	1.70	US$			907
b	HDPE (1mm) installation	533,500	m^2	3	peso	1,601	176	
c	protective soil (inc. installation)	160,050	m^3	30	peso	4,802	528	
1.2.2	cover soil (0.3m)	592,185	m^3	22	peso	13,028	1,432	
1.2.3	pump (50mm, H=30m)					See pump		
1.2.4	electric work	1	unit	2,000,000	peso	2,000	220	
	sub-total						2,356	907
	Miscellaneous	10	%				236	91
Direct cost							2,592	998
General expenses and overhead		30	%				778	299
Total construction costs							3,370	1,297
Physical contingency		10	%				337	130
IVA		15	%				506	195
Total cost (inc. conti. & tax)							4,213	1,622
Total cost (domestic+foreign)							5,835	
(Unit cost, $/ton of waste)		-		th.ton				
2	8-16 Elevation							
2.1	outer road	7,075	m	550	peso	3,891	428	
2.2	inner road	19,633	m	550	peso	10,798	1,187	
2.3	leachate collection (along outer road)	7,075	m	210	peso	1,486	163	
2.4	leachate collection (along inner road)	19,633	m	300	peso	5,890	647	
2.5	gas extraction (along ring road)	141	nos	200	peso	28	3	
2.6	leachate & gas extraction well	152	nos	8,000	peso	1,216	134	
2.7	cover soil (0.3m)	639,930	m^3	22	peso	14,078	1,547	
	sub-total						4,109	0
	Miscellaneous	10	%				411	0
Direct cost							4,520	0
General expenses and overhead		30	%				1,356	0
Total construction costs							5,876	0
Physical contingency		10	%				588	0
IVA		15	%				881	0
Total cost (inc. conti. & tax)							7,345	0
Total cost (domestic+foreign)							7,345	
(Unit cost, $/ton of waste)		13,158		th.ton			0.5582	
3	16-24 Elevation							
3.1	outer road	5,160	m	550	peso	2,838	312	
3.2	inner road	6,453	m	550	peso	3,549	390	
3.3	leachate collection (along outer road)	5,160	m	210	peso	1,084	119	
3.4	leachate collection (along inner road)	6,453	m	300	peso	1,936	213	
3.5	gas extraction (along ring road)	102	nos	200	peso	20	2	

No.	Description	Quantity	Unit	Unit rate	Currency	Exchange rate, $1.00=9.1 pesos Amount Domestic 1,000 peso	Domestic 1,000 US$	Foreign 1,000 US$
3.6	leachate & gas extraction well	89	nos	8,000	peso	712	78	
3.7	cover soil (0.3m)	350,250	m^3	22	peso	7,706	847	
	sub-total						1,961	0
	Miscellaneous	10	%				196	0
	Direct cost						2,157	0
	General expenses and overhead	30	%				647	0
	Total construction costs						2,804	0
	Physical contingency	10	%				280	0
	IVA	15	%				421	0
	Total cost (inc. conti. & tax)						3,505	0
	Total cost (domestic+foreign)						3,505	
	(Unit cost, $/ton of waste)	7,522	th.ton				0.4660	
4	Final cover (t=0.6)	1,640,000	m^3	22	peso	36,080	3,965	
	sub-total						3,965	0
	Miscellaneous	10	%				397	0
	Direct cost						4,362	0
	General expenses and overhead	30	%				1,309	0
	Total construction costs						5,671	0
	Physical contingency	10	%				567	0
	IVA	15	%				851	0
	Total cost (inc. conti. & tax)						7,089	0
	Total cost (domestic+foreign)						7,089	
	(Unit cost, $/ton of waste)	-	th.ton					
	Total construction cost (exc. conti. & tax)						19,256	1,297
	Physical contingency	10	%				1,926	130
	IVA	15	%				2,888	195
	Total construction cost (inc. conti. & tax)						24,070	1,622
	Total construction cost (domestic+foreign)						25,692	
	Design and supervision (exc. conti. & tax)						154	0
	Physical contingency	10	%				15	0
	IVA	15	%				23	0
	Design and supervision (inc. conti. & tax)						192	0
	Design and supervision (domestic+foreign)						192	
	Total cost (inc. conti. & tax)						24,262	1,622
	Total cost (domestic+foreign)						25,884	
	(Unit cost, $/ton of waste)	20,679	th.ton				1.2517	

Note: 10% of the cost for design and supervision will be used for basic design, 50% for detailed design and 40% for supervision.

IVA: tax on value added

Table H-41: Initial Installment Costs of Pumps for Leachate Disposal

Description		Exchange rate, $1.00= 9.1 Pesos Quantity	Unit	Unit rate	Currency	Amount (US$ 1,000)
1	Pump (50mm, 3.7kw)	24	unit	5,000	US$	120
Physical contingency		10	%			12
IVA		15	%			18
Total						150

Landfill Equipment

Table H-42 shows costs for procurement of the landfill equipment in Case 1. The disbursement is to be required in 2000. The equipment will not only be used in Etapa IV but also in Etapa V alternately.

Table H-42: Costs for Landfill Equipment (Case 1)

	Description	Exchange rate, $1.00= 9.1 pesos				
		Quantity	Unit	Unit rate	Currency	Amount (US$ 1,000)
1	Bulldozer (300hp)	4	nos	400,000	US$	1,600
2	Excavator (85hp)	2	nos	110,000	US$	220
3	Sprinkler truck (15000litre)	2	nos	100,000	US$	200
	sub-total					2,020
	spare parts	10	%			202
Equipment cost (exc. conti.& tax)						2,222
Physical contingency		10	%			222
IVA		15	%			333
Equipment cost (inc. conti.& tax)						2,777
Design and supervision (exc. conti.& tax)		10	%			111
Physical contingency		10	%			11
IVA		15	%			17
Design and supervision (inc. conti.& tax)						139
Total cost (inc. tax&conti.)						2,916

Note:

- 10% of design and supervision will be used for basic design, 50% for detailed design and 40% for supervision.
- Lifetime of equipment is expected to be 7 years.

Operation and Maintenance

It is estimated that US$ 707,000 of O&M costs will annually be required for landfilling (See Table H-43), US$ 90,000 for replacement of pumps for leachate disposal every 2 years (See Table H-44), and US$ 21,000 for operation of the pumps annually (See Table H-45).

Table H-43: O&M Costs for Landfilling (Case 1)

	Description	Quantity	Unit	Exchange rate, $1.00=9.1 pesos				
				Unit rate	Currency	Amount		
						Domestic		Foreign
						1,000 peso	1,000 US$	1,000 US$
1	Bulldozer (300hp)							
1.1	Fuel cost							
	consumption	35	l/h	4	peso	2,044	225	
	cost (inc. 10% lubricant)					2,248	247	
1.2	Labor							
	Operator	4	person	155	peso	226	25	
	cost					226	25	
1.3	Maintenance							
	cost (15% of procurement)	15	%					24
Sub-total							272	24
2	Excavator (85hp)							
2.1	Fuel cost							
	consumption	10	l/h	4	peso	292	32	
	cost (inc. 10% lubricant)					321	35	
2.2	Labor							
	Operator	2	person	155	peso	113	12	
	cost					113	12	
2.3	Maintenance							
	cost (15% of procurement)	15	%					33
Sub-total							47	33

	Description	Quantity	Unit	Exchange rate, $1.00=9.1 pesos		Amount		
				Unit rate	Currency	Domestic		Foreign
						1,000 peso	1,000 US$	1,000 US$
3	Sprinkler truck (15000litre)							
3.1	Fuel cost							
	consumption	12	l/h	4	peso	350	38	
	cost (inc. 10% lubricant)					385	42	
3.2	Labor							
	Operator	2	person	155	peso	113	12	
	cost					113	12	
3.3	Maintenance							
	cost (15% of procurement)	15	%					30
Sub-total							54	30
4	Other personnel							
	Chief supervisor	1	person	350	peso	128	14	
	Supervisors	3	person	290	peso	318	35	
	Workers	20	person	70	peso	511	56	
Sub-total							105	
Total (O&M, annual, exc. tax)							478	87
Physical contingency		10	%				48	9
IVA		15	%				72	13
Total (O&M, annual, inc. tax)							598	109
Total (domestic+foreign)							707	

Note: Operation time of each equipment is expected to be 10 hours/day.

Table H-44: Replacement Costs for Leachate Disposal Pumps

	Description	Quantity	Unit	Exchange rate, $1.00= 9.1 Pesos		
				Unit rate	Currency	Amount (US$ 1,000)
1	Pump (50mm, 3.7kw)	24	unit	3,000	US$	72
Physical contingency		10	%			7
IVA		15	%			11
Total						90

Note: Pump's lifetime is expected to be 2 years.

Table H-45: Operation Cost for Leachate Disposal Pumps

	Description	Quantity	Unit	Exchange rate, $1.00= 9.1 Pesos		Amount	
				Unit rate	Currency	(1,000 peso)	(US$ 1,000)
1	Electricity consumption	194,500	kWh	0.83	peso	161	18
IVA		15	%			24	3
Total							21

Land Rental Fee

The site has been lent from CNA. The DGSU has been expending a certain amount of money for some works, such as road maintenance, as compensation. Land Rental Fee means such expenditure. It costs US$ 425,000 annually.

Table H-46: Land Rental Fee

	Description	Quantity	Unit	Exchange rate, $1.00= 9.1 Pesos			
				Unit rate	Currency	Amount	
						(1,000 peso)	(US$ 1,000)
1	Land rental fee	472	ha	8,200	peso	3,870	425

ii. Case 2

Construction

Costs of construction is the same as Case 1, i.e., US$ 17,316,000 until 2010 (See Table H-39).

Landfill Equipment

Table H-47 shows costs for landfill equipment in Case 2. The costs for each equipment are estimated on the basis of rental fee in Mexico City and amount which the DGSU are presently paying to the sub-contractors. It is also assumed that the same amount of expenditure as the amount of design and supervision in Case 1 will be required for contracting out.

Table H-47: Costs for Landfill Equipment (Case 2)

	Description	Quantity	Unit	Exchange rate, $1.00= 9.1 Pesos			
				Unit rate	Currency	Amount	
						(1,000 peso)	(US$ 1,000)
1	Bulldozer (300hp)	4	nos	1,277,500	peso	5,110	562
2	Excavator (85hp)	2	nos	365,000	peso	730	80
3	Sprinkler truck (15000litre)	2	nos	360,000	peso	720	79
Rental fee (exc. Conti.& tax)							721
Physical contingency		10	%				72
IVA		15	%				108
Rental fee (inc. conti.& tax)							901

Table H-48: Costs for Design and Supervision of Equipment

Description	Quantity	Unit	Exchange rate, $1.00= 9.1 Pesos		
			Unit rate	Currency	Amount
					(US$ 1,000)
Design and supervision (exc. conti.& tax)					111
Physical contingency					11
IVA					17
Design and supervision (inc. conti.& tax)					139

Operation and Maintenance

O&M costs for landfilling is different from Case 1. Maintenance cost of the equipment is not taken into account, as the rental fee includes such maintenance cost. The costs amount to US$ 598,000 annually (Table H-49), while the operation costs for leachate disposal is the same as those of Case 1 (See Table H-44 and Table H-45).

Table H-49: O&M for Landfilling (Case 2)

Description		Quantity	Unit	Exchange rate, $1.00= 9.1 Pesos			
				Unit rate	Currency	Amount	
						(1,000 peso)	(US$ 1,000)
1	Bulldozer (300hp)						
1.1	Fuel cost						
	consumption	35	l/h	4	peso	2,044	225
	cost (inc. 10% lubricant)					2,248	247
1.2	Labor						
	Operator	4	person	155	peso	226	25
	cost					226	25
Sub-total							272
2	Excavator (85hp)						
2.1	Fuel cost						
	consumption	10	l/h	4	peso	292	32
	cost (inc. 10% lubricant)					321	35
2.2	Labor						
	Operator	2	person	155	peso	113	12
	cost					113	12
Sub-total							47
3	Sprinkler truck (15000liter)						
3.1	Fuel cost						
	consumption	12	l/h	4	peso	350	38
	cost (inc. 10% lubricant)					385	42
3.2	Labor						
	Operator	2	person	155	peso	113	12
	cost					113	12
Sub-total							54
4	Other personnel						
	Chief supervisor	1	person	350	peso	128	14
	Supervisors	3	person	290	peso	318	35
	Workers	20	person	70	peso	511	56
Sub-total							105
Total (O&M, annual, exc. tax)							478
Physical contingency		10	%				48
IVA		15	%				72
Total (O&M, annual, inc. tax)							598

Land Rental Fee

Land rental fee is the same as that of Case 1 (See Table H-46).

iii. Summary of costs

Table H-50 and Table H-51 summarize the costs for the Vertical Expansion Plan. The costs estimated for Case 1 was US$ 28,677,000, and Case 2 was US$ 29,860,000.

Table H-50: Summary of Costs for the Vertical Expansion Plan (Case 1)

Unit: US$ 1,000

Year	B/D	D/D	Con. (Ini.)	Con(Rec)	Equip.	O&M	Land fee	Total
1999	33							33
2000		298	7,902		2,777			10,977
2001				2,164		728	425	3,317
2002						111	425	536
2003						21	425	446
2004						111	425	536
2005				1,883		728	425	3,036
2006				1,874		818	425	3,117
2007						21	425	446
2008						111	425	536
2009				1,773		728	425	2,926
2010				1,528		818	425	2,771
Total	33	298	7,902	9,122	2,777	4,195	4,250	28,677

B/D: Basic design for construction and equipment.
D/D: Detailed design for construction and equipment. The amount complies costs for supervision as well.
Con. (Ini.): Initial investment cost for construction
Con(Rec): Recurrent cost for construction
Equip.: Landfill equipment
O&M: Operation and maintenance
Land fee: Land rental fee

Table H-51: Summary of Costs for the Vertical Expansion Plan (Case 2)

Unit: US$ 1,000

Year	B/D	D/D	Con. (Ini.)	Con(Rec)	Equip.	O&M	Land fee	Total
1999	33							33
2000		298	7,902					8,200
2001				2,164	901	619	425	4,109
2002						111	425	536
2003						21	425	446
2004						111	425	536
2005				1,883	901	619	425	3,828
2006				1,874	901	709	425	3,909
2007						21	425	446
2008						111	425	536
2009				1,773	901	619	425	3,718
2010				1,528	901	709	425	3,563
Total	33	298	7,902	9,222	4,505	3,650	4,250	29,860

B/D: Basic design for construction.
D/D: Detailed design for construction. The amount complies costs for supervision as well.
Con. (Ini.): Initial investment cost for construction
Con(Rec): Recurrent cost for construction
Equip.: Landfill equipment
O&M: Operation and maintenance
Land fee: Land rental fee

H.2.2.2 New Landfill Development (Etapa V)

The capacity of the vertically expanded part of Etapa IV is not enough to receive waste to be disposed of until 2010. Therefore, the development of a new landfill is crucial to sustain the sound waste disposal in the study area. After the Mexican side specified a candidate site for a landfill, surveys, i.e., soil, aerial and environmental survey, which are necessary for landfill planing were conducted during the 2nd study work in Mexico. In this section, followings are to be presented.

- examination of design conditions.
- examination of technical alternatives.
- conceptual design and cost estimates.

a. Examination of Design Conditions

As mentioned previously, there is a norm NOM-083-ECOL-1996 which is one of the Mexican Official Norms to establish the requirements to be applied to new landfill development of municipal solid waste. The new landfill development at Etapa V has to follow this norm.

In this section, design conditions are examined basically according to the norm. In addition, other conditions, such as location and area are presented.

a.1 Location and Area

The site for Etapa V is located in the ex-Texcoco lake as well as Etapa IV, the latter being about 6km south-west of the former. The site has an area of 256 ha and its coordinates are 19°29'N (latitude 19 degrees 29 minutes north) and 98°58'W (longitude 98 degrees 58 minutes west). The nearest residential area is located at 2.2km away from the west border of the site. The Mexico City International Airport is situated about 10 km south-west of the site. The location of the site is shown in Figure H-19.

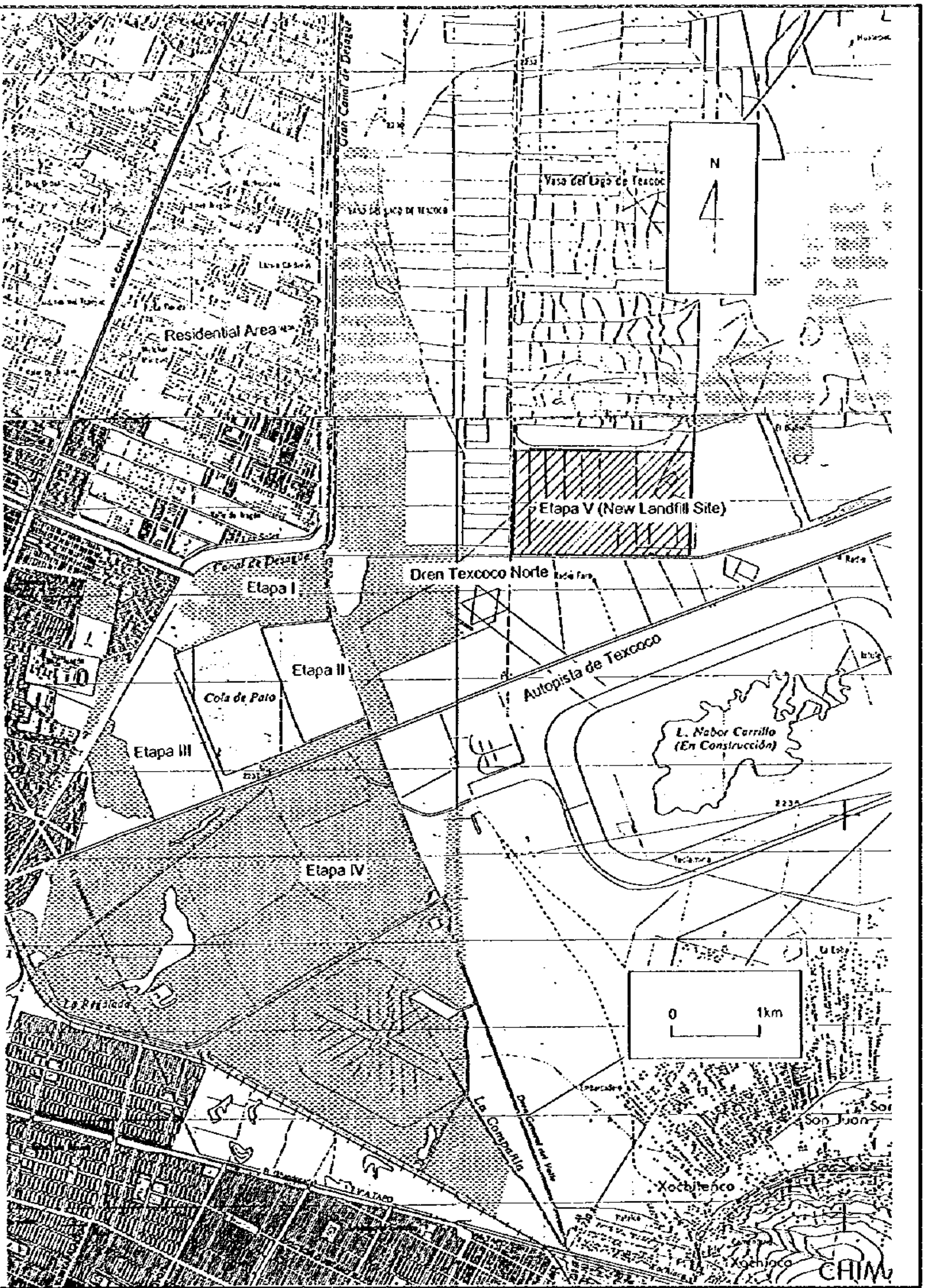

Figure H-19:

Location of the New Site (Etapa V)

KOKUSAI KOGYO Co., Ltd.