3.3.3 Formulation of Questionnaire

The questionnaires for households, factories, offices, universities/primary schools, markets/shops and hospitals were drafted by the team. Taking into account the comments from the counterpart and the experience of questionnaire surveys by the local sub contractor, which was contracted by the team for this survey, the draft questionnaires were amended and finalized.

3.3.4 Results of the Survey

The results are presented in the Data C of the Data Book.

3.3.5 Findings

3.3.5.1 Household

a. Waste Collection Services and Waste Discharge Behavior

a.1 Service Coverage

Almost all the interviewees, 99%, have the waste collection services. Five interviewees without the collection service live in Cuauhtemoc, Gustvo A. Madero (two interviewees), Iztapalapa and Venustiano Carranza.

Further questions asked to service recipients.

a.2 Service Satisfaction

Relatively high proportion (79%) of the service recipients express satisfaction with the waste collection service. The most major reason for satisfaction is that the frequency of collection is appropriate. The other minor reasons are that the service helps keep houses clean and that collection time is convenient for them. On the other hand, the most common reason for dissatisfaction is that the frequency of collection is very few. The less common reasons are the bad behavior of the collectors; too early, too late or irregular collection time and high tips. Far collection point was complained by a small number of interviewees, but their situation varies. One answers the current distance to the collection point is 15m and it should be five meters, while another answers the distance should be shortened from 500m to 200m.

In summary, the frequency is found to be the highly critical element for the satisfactory service.

a.3 Waste Containers/Bags

Plastic shopping bags are used by 47% of total interviewees to discharge their wastes, followed by large plastic bags (26%) and dustbins (24%).

b. Recycling

b.1 Recycling Practices of Bottles, Cans and Paper

Questions about the recycling practices of bottles, cans and paper, recycling of which is in general most commonly attempted, were asked.

The situation is similar in the cases of recycling bottles, cans and paper. About 40% of the interviewees currently separate those from other normal garbage.

Most of the separated materials are, however, simply given to the waste collectors (Table 3-16).

Table 3-16: Fate of Separated Materials

	Bottle		Cans		Newspaper		Cardboard	
Total effective interviewees who separate them	156	(%)	166	(%)	129	(%)	39	(%)
Give them to the waste collectors	105	(67)	56	(34)	43	(33)	23	(59)
Sell them	10	(6)	62	(37)	44	(34)	10	(26)
Give or donate them to somebody	13	(8)	31	(19)	24	(19)	3	(8)
Reuse	19	(12)	15	(9)	16	(12)	0	(0)
Others	9	(6)	2	(1)	2	(2)	3	(8)

Average selling prices of bottles, cans, newspaper and cardboard came to 0.73, 6.76, 1.79, and 1.14 pesos/kg.

Those who do not separate materials were asked the reason. The most common reason was that there is no reason or request to do so. In other words, they are not aware of the merit or necessity to separate waste and take the mixed discharge for granted. The other reasons include "It is troublesome", "The waste collectors do so", and "Lack of time or habit".

On the contrary, when they were asked if they would separate materials when required, the majority of them (about 90%) answered "Yes".

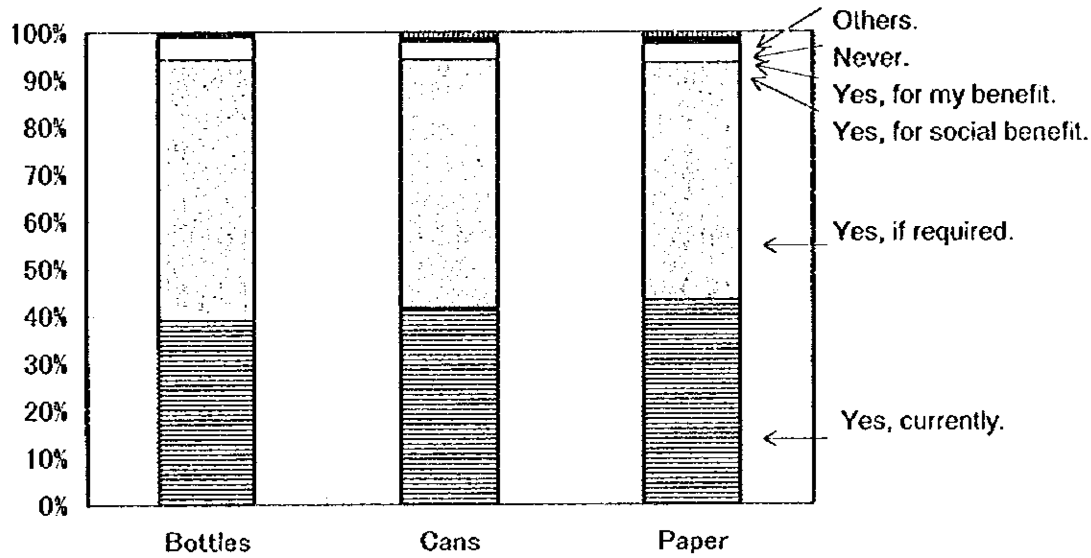

Figure 3-4: Cooperation for Source Separation

b.2 Kitchen Waste

Kitchen waste is separated by 61% of the interviewees. The main purposes for separating kitchen waste are making waste storage easy and clean, preventing odor, making compost and feeding animals. As seen in the cases of bottles, cans and paper, the interviewees who do not currently separate kitchen wastes have intention to do so: more than 90% of them answered yes to the question if they would cooperate in separating kitchen waste to make compost.

b.3 Support for Recycling

As high as 96% of total interviewees answered that they support the idea of recycling. This high rate of support well complies with the results shown in Figure 3-4.

c. Financial Matters

The majority (81%) of the interviewees pay tips to the waste collectors. Their average value is calculated at 28.3 pesos per month (median is 20 pesos).

Those who pay tips were then asked about the preference of tips or taxes. 80% of them prefer tips, and further asked which they would prefer, tips or taxes of the same amount with better service. 64% of them still prefer tips. The main reason for the preference of tips is related to the collectors: "The waste collectors can benefit" or "It makes the behavior of the waste collectors good". The economical reason is also common, such as "Tips would be cheaper than taxes", "I want pay what I can afford", and "There are many taxes already". On the other hand, the reasons for the preference of taxes include "The quality of the service will be improved", "I will not be required tips", "Tax would be fair" and "Tax would bring social benefit".

In spite of such reluctance to pay taxes within the majority, the amount of waste management taxes which people have the willingness to pay was asked. It averages 13.2 pesos/week (median is 10 pesos), which is about 80% more than the currently paid value.

3.3.5.2 Institutions

a. Waste Collection Services and Waste Discharge Behavior

(Restricted to municipal waste in case of factories and hospitals)

a.1 Service Coverage

Among 180 institutions interviewed, only one office does not receive the waste collection service. "Service provision" includes waste collection systems run by themselves, which are found in a few cases.

Further questions asked to service recipients.

a.2 Service Satisfaction

Relatively high proportion (80 to 95%) of the service recipients express satisfaction with the waste collection service in all the five types of institutions. Two major reasons for the satisfaction shown by 83% and 45% of the interviewees were the service frequency and the contribution of the service to keep the place clean, respectively. On the contrary, the most common reasons for dissatisfaction are less frequent collection and the irregularity of collection time.

In summary, the frequency is found to be the highly critical element for the satisfactory service, as in the case of households.

b. Recycling

b.1 Recycling Practices of Bottles, Cans and Paper

Questions about the recycling practices of bottles, cans and paper, recycling of which is most commonly attempted in general, were asked.

The rate of those who separate these items to all interviewees is 16%, 30% and 44% for bottles, cans, and paper (of any kind), respectively. It is to be noted that when excluding the cases where the interviewees have too little volume of those items to be recycled, the figures raise to 21%, 38%, and 44%, respectively.

Table 3-17 shows the result of the further questions about how they deal with the separated materials.

Table 3-17: Fate of Separated Materials

	Bottles		Cans		Paper			
					Newspaper		Cardboard	
Base: separating the item	26	(%)	48	(%)	18	(%)	48	(%)
Give them to waste collectors	19	(73)	17	(35)	4	(22)	11	(23)
Sell to waste collectors	0	(0)	5	(10)	1	(6)	7	(15)
Bring them somewhere to sell	2	(8)	15	(31)	9	(50)	10	(21)
Sell them to somebody	2	(8)	2	(4)	1	(6)	8	(17)
Give them to somebody	2	(8)	4	(8)	0	(0)	7	(15)
Reuse	2	(8)	6	(13)	2	(11)	2	(4)

Those who do not separate materials were asked the reasons. The most common reason was, as in the case of household, that there is no reason or request to do so. In other words, they do not separate wastes merely because they are not motivated to do. The other reasons include "It is troublesome", "It is the waste collectors who separate wastes", "Lack of time or habit, or "No staff for separation". For the final answer, it should be mentioned that separation is carried out by not the waste generators themselves but the cleaning staff of the institutions in most cases.

They were then asked stepped questions to examine their potential intention to cooperate in waste separation at source. The questions were same as used for households, and the result is summarized in Figure 3-5. It is revealed that the majority of them (about 80%) answered "Yes".

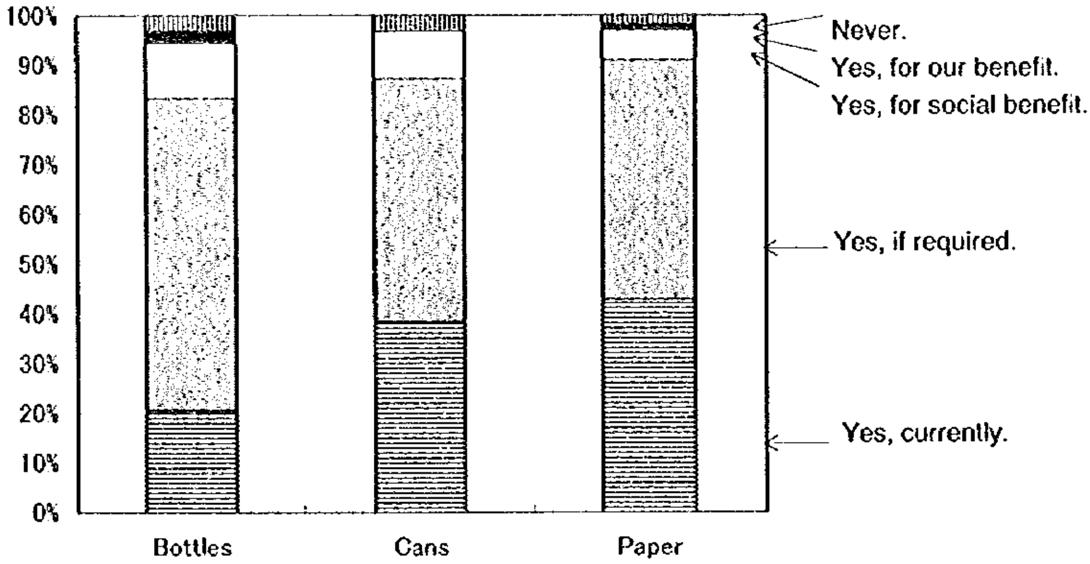

Figure 3-5: Cooperation for Source Separation

b.2 Organic Waste

The handling of organic waste is asked to markets/shops, universities/schools and hospitals.

There are only three markets/shops which utilize organic waste in some ways. Among those which do not utilize it at present, 64% stated that they would separate organic waste if required so (excluding those without organic waste). The reasons of the rest 36% for not willing to separate organic waste were such as "It is troublesome", "It is difficult to separate organic waste from others", and "The waste collectors do".

For the universities/schools and hospitals, the numbers of the answers of those which would separate organic waste if required were 6 out of 8 and 9 out of 10 of those which do not currently separate organic waste although they generate it, respectively.

c. Financial Matters

The table below shows summary of financial matters. If compared to households, it can be pointed out that firstly, tip payers account for smaller percentages of service recipients except factories, and second, both the paid tip and WTP are much lower. Influential factors are probably the following.

- Public institutions (schools and markets) consider that waste collection should be done by the concerned governmental bodies.
- Private institutions (offices and factories) considers that the tax already paid should cover the cost for SWM by the government.
- Waste amount of part of institutions is huge, thus the collection can be carried out with higher efficiency.
- Waste from institutions tends to include recyclable elements, from which the collectors can benefit.

Table 3-18: Payment for SWM by Institution

	School	Office	Market	Factory
Tip payers	14/38 (37%)	12/29 (41%)	11/33 (33%)	14/14 (100%)
Amount of Tip (pesos/kg)	0.458	012 (0.435 as fee for private collection)	0.51 (0.93 as fee for private collection)	0.018
WTP (pesos/kg)	0.033	0.047	0.024	0.016

In the question about the preference of tax and tips, it was observed that nearly half of institutions prefer paying tax to tip. Some of the rest answered that they prefer paying tax if the service would be improved. The sum of those two groups accounted for more than half of the interviewees. The result is illustrated in Figure 3-6.

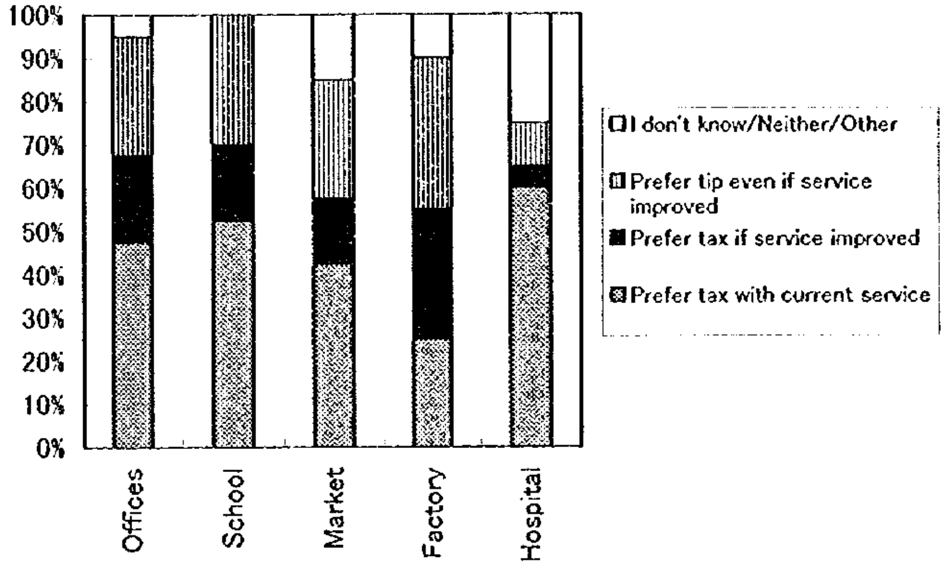

Figure 3-6: Preference of Tax and Tip

d. Cooperation for Waste Management

d.1 General View

Asked about the possibility of doing something for good waste management, 86% of institutions gave positive answers. Further, they answered that they can contribute to waste management by the following.

- Discharging waste neatly.
- Recycling wastes.
- Reusing wastes (factories).
- Separating wastes.
- Providing information to the public (hospitals, universities/schools).
- Raising the environmental awareness of the public/pupils (hospitals, universities/schools).

Different questions depending on the type of institutions and those results are described in Annex B.

3.4 Environment Survey

3.4.1 Objectives of the Survey

At the initial stage prior to the M/P, the team examined environmental aspects concerning the vertical expansion of the Bordo Poniente final disposal site. They included the current situation of waste disposal, the characteristics of the ground (i.e., the state of consolidation, ground strength, etc.), and the possible impact on the groundwater.

3.4.2 Methodology

a. Sites of Survey

The former landfill areas, Etapa I, II, and III at Bordo Poniente, were investigated.

b. Survey Items

Table 3-19 summarizes the conducted works. Figure 3-7 shows the locations of the electric prospecting survey lines and bore-holes.

Table 3-19: Work Quantity

Survey Items	Location	Survey Contents
Electric Prospecting	Etapa I	2 lines, total 2,000 meter (20 meter pitch)
	Etapa II	2 lines, total 2,100 meter (20 meter pitch)
	Etapa III	2 lines, total 3,200 meter (20 meter pitch)
Boring	Etapa I	2 Bore holes, 20 m deep
	Etapa II	2 Bore holes, 20 m deep
	Etapa III	2 Bore holes, 20 m deep
In-situ Test	6 bore holes	In-situ permeability test at each bore hole(6 in total)
	6 locations	In-situ permeability test at ground level (total 6 Nos.)
Laboratory Test	6 boring samples	Liquid and plastic limit test, unit weight test, consolidation test, grain size distribution, triaxial compression test (6 Nos. each)

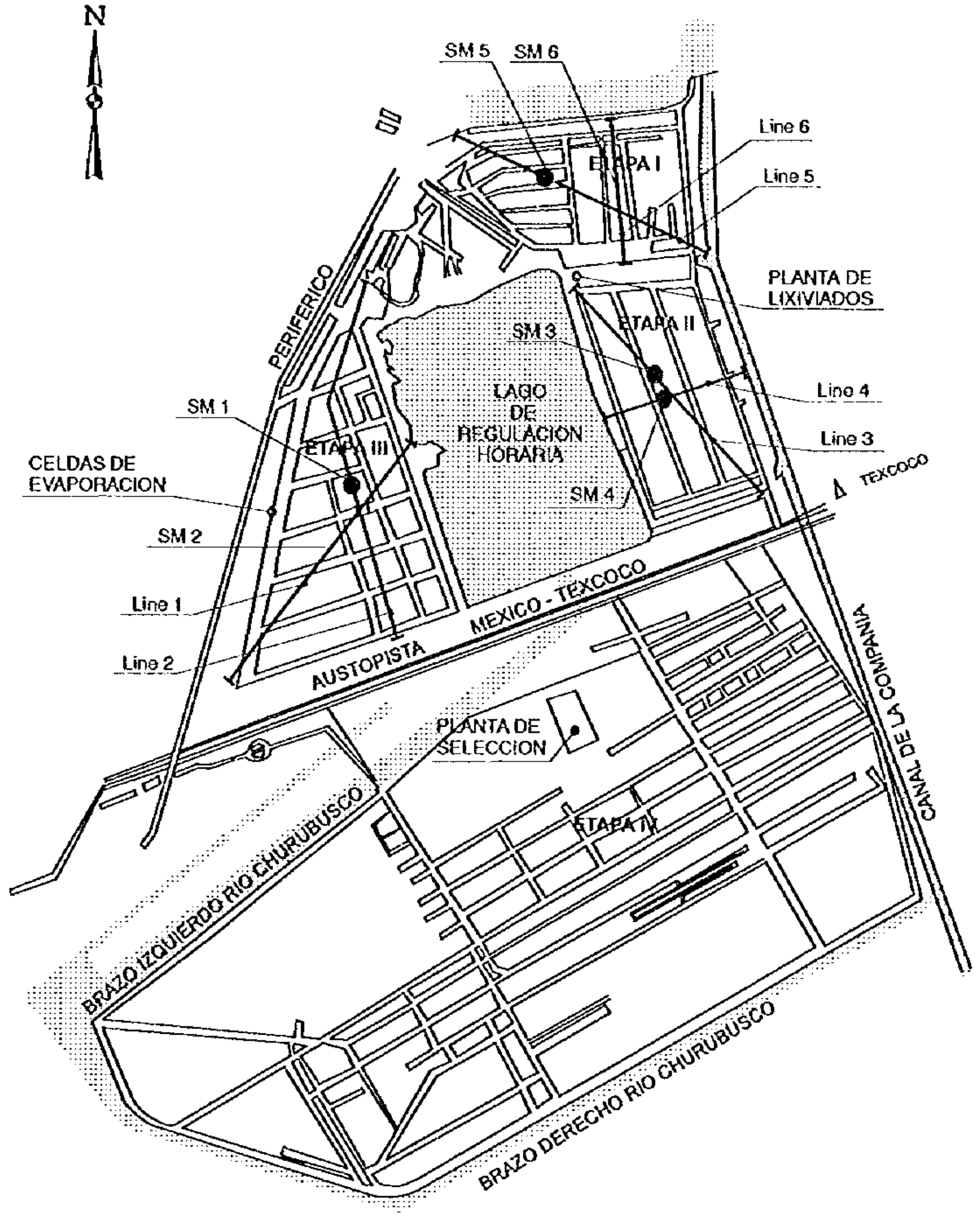

Figure 3-7: Location Map of Environmental Survey	Electric Prospecting Line Core Boring
	KOKUSAI KOGYO Co., Ltd.

3.4.3 Results of the Survey

Results of the survey are shown in Annex B.

3.4.4 Findings

a. Groundwater Level

In Etapa I, II and III where wastes were landfilled above the initial ground level, the groundwater level is high. It is about 2.0m from the surface according to the "Landfill Mining Survey" whereas groundwater tables in the bore holes in this survey range 0.8 to 1.2m from the surface. The groundwater level measured aside the landfills was also found at about 1.0m depth from the ground surface.

This phenomenon is backed by the two facts. First, there are no any leachate control mechanisms in landfills except part of Etapa III. Second, it is considered that substantial volume of rainwater seeps into the landfills from the facts that the permeability of cover soil is as high as an order of 10^{-4}(cm/sec) and that its layer depth is only 30cm.

Consequently, it can be concluded that groundwater level within the ex-landfills (Etapa I, II and III) has been raised to the level higher than the original ground surface by the rainwater seepage from the landfill surface and the groundwater intrusion from the landfill bottom by capillary force. This is illustrated in Figure 3-8.

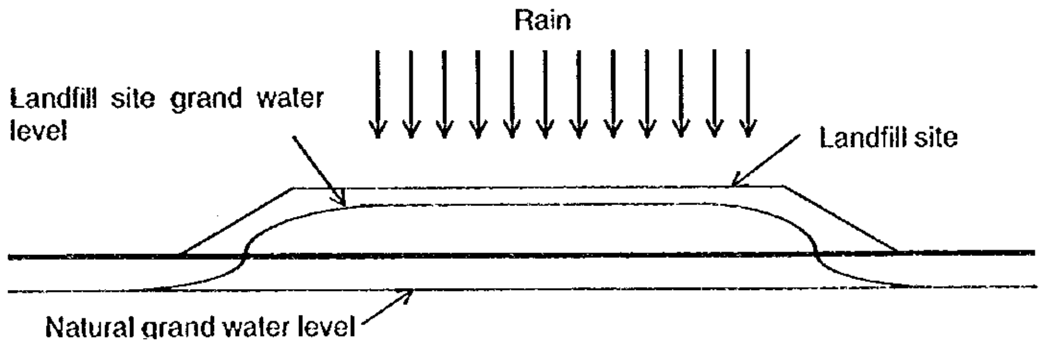

Figure 3-8: Image of Landfill Site Grand Water Level

b. Permeability

b.1 Cover Soil

As stated above, the permeability of cover soil is relatively high (at the order of 10^{-4}(cm/sec)) and its layer thickness is small (30cm). Hence considerable volume of rainwater infiltrates to the landfilled waste, encouraging leachate generation.

b.2 Foundation Soil

As the foundation soil is clayey with permeability at the order of 10^{-5}(cm/sec), some form of impermeabilization is necessary to sufficiently operate a municipal solid waste final disposal site which complies with the existing environmental norms. For this reason, high-density-polyethylene (HDPE) impermeable liners are laid in the present landfill in Etapa IV.

b.3 Conclusion

In conclusion, bottom impermeable liners have to be employed if vertical expansion of Etapa I, II and/or III is to be implemented, in order to prevent groundwater contamination with leachate.

c. Soil Mechanics

As an indicator of ground stability, cohesion and internal friction angle at about 10m depth (i.e., about 2m below the original surface under the bottom of buried wastes) were studied and those results are shown in Table 3-20.

Table 3-20: Cohesion and Internal Friction Angle

	Etapa I	Etapa II	Etapa III	*Etapa IV
Operation period	1985 - 1988	1989 - 1991	1991 -1993	1993 -
Cohesion (ton/m^2)	1.0	0.8	0.5	0.8
Internal Friction Angle (deg.)	3.0	0	0	1.8

* Etapa IV : existing data

Comparing the figures above and the geological data in Etapa IV before landfilling, the following findings were drawn.

- Both cohesion and internal friction angle have been relatively improved in Etapa I, where nearly 10 years have passed after landfilling. This implies the improvement of ground stability due to land compression.
- On the other hand, data taken in Etapa II and III are similar to or rather smaller than those in Etapa IV, thus major improvement of ground stability due to land compression is not seen.

Consequently, it is envisaged that it will require substantial time to improve ground stability by land compression.

3.5 Recycle Market Survey

3.5.1 Objectives

The surveys investigated present markets and potential demands for recycled materials, particularly compost and plastic that would be generated by the technical alternatives to be proposed in the M/P.

The size of the markets and the prices of reusable articles are the main survey items since they could largely influence the selection of alternatives. Information on items such as bottles, cans, plastic, compost, and heat and electricity was investigated by using statistics available and by interviewing authorities concerned with heat and electric energy, recycling company and recycling union.

3.5.2 Methodology

a. Targets of Survey

The survey targets are following companies.

- glass recyclers.
- aluminum and steel cans recyclers.
- plastics recyclers.
- compost companies.
- electricity companies.
- heat energies supplying companies.
- INARE.
- unions dealing recycling materials.
- informal recyclers.

b. Number of Samples

The survey carried out for 22 companies. Table 3-21 shows outline of surveyed companies.

Table 3-21: Outline of Surveyed Companies

c	Name of Company or Institution	Major Dealing Item
1	Sr. Fernando Rosales	Glass, steel, aluminum, cardboard, newspaper, paper
2	Vidrería México S.A. DE C.V.	
3	Jose González	Cardboard and paper
4	Bodega Tacubaya S.A.	Cardboard and paper
5	La bodeguita	Scrap metal, paper, cardboard, aluminum cans
6	Maria Pérez Gárcia.	Paper
7	Antonio Hérnandez	Cardboard and paper
8	José Vidal.	Plastic
9	José Luis Pineda.	Aluminum cans, "*chacharas*" (toys, shoes, cloths, etc.)
10	Angel Básilio Hérnandez	Glass
11	Comercializadora de fibras secundarias S.A. de C.V.	Paper and distribution of used fiber
12	Todo de cartón S.A de C.V.	Corrugated board
13	Procesadora y recicladora El Ancla S.A. de C.V.	Steel and non-ferrous metal

c	Name of Company or Institution	Major Dealing Item
14	Marco Antonio Rueda	Cardboard and paper
15	Vidriera Los Reyes	Glass
16	Sacarias Cepeda Guadarrama	Steel, copper, bronze, aluminum cans
17	José Silverio Escobar	Cardboard and cans
18	María de la Cruz Baéz Montes	Glass, tortilla, mattress
19	Comercial Carimex	Paper
20	Interamericana de Metales	Stainless alloyed steel, principally copper derivatives
21	Dirección General de Servicios Urbanos	Pruned branches, grass
22	Rubén Jiménez	Glass

c. Survey Item

The survey items are as follows.

- General information of company (number of employee, established year, working day, annual sales amount, etc.)
- Major activity (recycler, collector, sorting, brokerage, etc.)
- Profile of the major client (type of industry, sales price and amount, etc.)
- Profile of the major supplier (type of material, original cost, supply amount)
- Treatment and/or processing method
- Outline of treatment and/or processing equipment
- Major recycling item
- Transportation method
- Others

3.5.3 Results of the Survey

Results of survey are shown in Annex B.

3.5.4 Findings

a. Recycled Material

The market size for the recycled material is estimated to be as large as 5,000 million peso/year in 2010 (at 1998 price), assuming that there is no drop in sales prices of them. If the demand outside of the DF is considered in addition, the market size can be much larger.

Table 3-22: Estimated Recycled Material Market Size of the GDF in 2010

	Paper	Glass	Plastic	Aluminum	Total
Unit rate (pesos/ton)	250	700	3,600	7,000	-
Market size (1,000 ton/year)	2,000	5,400	100	60	-
Market size (1,000 pesos/year)	500,000	3,780,000	360,000	420,000	5,060,000

However, as more recycled material is supplied to the market, the sales prices tend to be declined eventually down to below zero where there is no longer benefit but cost to supply it. In order to avoid such an event, the following policy management will be required beside recycling promotion.

- Promotion of resource recovery industry
- Encouragement of the use of recycled material

b. Compost

As stated earlier in regard to compost, the major supplier is the GDF's compost plant, which produces only 10 to 20 tons in a month.

On the other hand, population are day by day settled near to the ex-landfill areas of Bordo Poniente I, II, and III (about 260 ha), where landscaping with a forested green area are awaited. However, the areas are in the ex-lake Texcoco area with high salinity in the soil, thus soil improvement will have to be needed in order to restore the green areas. Therefore, if soil conditioner of 30 cm thick is to be provided annually in these areas, compost demand of about 80,000 ton/year can be expected.

Furthermore, if composts are needed to be also applied in the other areas of ex-Lake Texcoco, its demand will become considerably large.

Besides, the existing studies showed the future demand size of about 1,750,000 to 5,980,000 ton/year, as mentioned before. This suggests that, if the quality of compost is satisfactory, large demand can be expected.

c. Electricity

On the other hand, the present electricity generation price is so low (0.273 pesos/kWh (1 US$= 9.1 pesos, 0.03US$/kWh)) that it can not be feasible to obtain electricity from incineration.

Therefore, material recycling is the promising area as a resource recovery method of municipal solid waste in the DF.

3.6 Bordo Poniente Landfill Mining Survey

3.6.1 Objective

The purpose of this work is to obtain physical and chemical characteristic data of buried waste in the Bordo Poniente disposal site (Etapa I, II and III), in view of examining possibility of landfill waste future reuse for such as: material recovery; compost or cover soil; and space obtainment for further landfilling.

3.6.2 Methodology

a. Site and Quantity of Survey

The closed landfill areas, Etapa I, II, and III at Bordo Poniente where landfilling have finished several years ago were investigated. The locations of the survey were selected where the waste depth is sufficiently thick, which was ascertained though electric prospecting and core boring of the Environmental Survey of the Bordo Poniente.

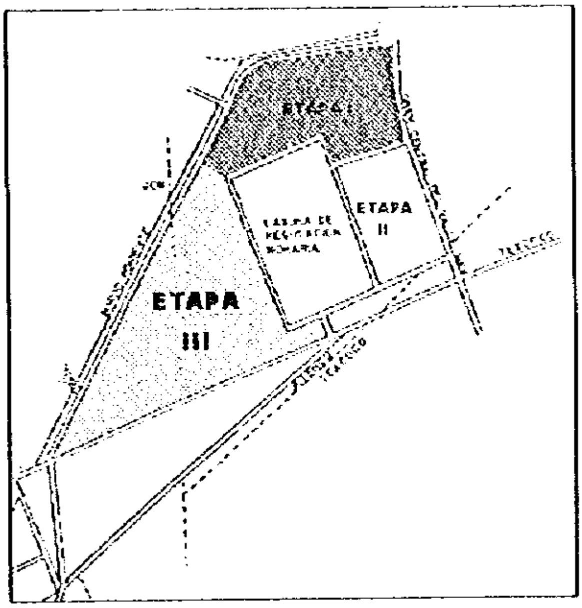

Figure 3-9: Location Map

The survey was carried out in six pits in total, namely two pits in the Etapa I, two pits in the Etapa II, and two pits in the Etapa III of the Bordo Poniente Final Disposal Site. The pit (2.0 to 2.5m length, 2.0 to 2.5m width and 4.0m depth) was excavated and later backfilled in each location.

b. Measurement of Excavated Volume and Weight in Stages

Volume and weight of total 4 stages (i.e., total 4 stages: 1 stage of top covering soil and 3 depth stages in buried waste) were measured.

- Volume of excavation was measured in each stage by inner dimension of excavation pit.
- Weight of excavated materials was measured in each stage by weigh-bridge.

c. Physical Composition Survey of Buried Waste Samples

Buried waste sample were taken at each depth stage of excavation. (i.e., 3 samples shall be taken from one excavation pit). Physical composition of sample were measured by dividing into:

- glass.
- aluminum.
- steel.
- combustible matters.
- and earth and sand matters.

Waste was measured respectively by portable weighing measures.

d. Laboratory Test for Chemical Analysis of Buried Waste Samples

Buried waste samples were taken at each depth stage of waste excavation. (i.e., 3 samples were taken from one excavation pit). Chemical analysis of sample were conducted at a laboratory. Chemical analysis were carried out for 14 items of:

- Carbon; Nitrogen; pH; Pb; Cd; Cr; Cu; Ni; Hg; Zn; As; Molybdenum; Selenium; and Polychlorinated-biphenyl (PCB)

referring to the US-EPA standard for agricultural use of sludge.

e. Backfilling of Excavated Pits

Backfilling of excavated pits were carried out as follows:

- firstly with excavated waste with sufficient compaction.
- secondly with excavated top covering soil with sufficient compaction.
- lastly with additional soil material (imported soil) with sufficient compaction.

Final shaping of the top of the backfilled pits was mounted with convex shape of about 40 cm higher in the middle than the surrounding existing ground level.

3.6.3 Results of the Survey

Results of the survey are shown in Annex B.

3.6.4 Findings

3.6.4.1 Shallow/Medium/Bottom Layers

a. Bulk Density

Comparing the bulk density of shallow, medium and bottom layers, it is found that the shallow layer has an average bulk density of about **1.1 ton/m^3**, and the medium and bottom layers have an average bulk density of about **1.8 ton/m^3**. It reveals that since the shallow part has slow decomposition of buried waste, its bulk density is close to that of buried waste (which normally can be estimated at around **0.8 ton/m^3**).

Meanwhile it is estimated that since the medium and bottom layers are under the groundwater table, anaerobic decomposition takes place to raise its bulk density as high as **1.8 tom/m^3**.

b. Physical Composition

b.1 Combustible and Soil Matters

Comparing the proportion of combustible matters of shallow, medium and bottom layers, it is found that **combustible matters** in average account for about **29.8%, 17.6% and 14.5%** respectively in the shallow, medium and bottom layers. It reveals that since the shallow part has slow decomposition of buried waste, proportion of combustible matters in the shallow layer was found to be larger than those in the medium and bottom layers.

Comparing the proportion of soil matters of the shallow, medium and bottom layers, it is found that **soil matters** in average account for about **48.6%, 51.6% and 56.6%** respectively in the shallow, medium and bottom layers. It reveals that since the shallow part has slow decomposition of buried waste, the proportion of soil matters in the shallow layer was smaller than those in medium and bottom layer.

Meanwhile it is estimated that since the medium and bottom layers are under the groundwater table, anaerobic decomposition of combustible matters takes place to reduce its proportion and turned them into soil matters.

b.2 Non-Decomposable Matters

Comparing the proportion of **non-decomposable matters (such as metals, glass, plastics)** of the shallow, medium and bottom layers, it is found that non-decomposable matters in average account for about **21.7%, 30.9% and 28.9%** respectively in the shallow, medium and bottom layers. It reveals that proportion of non-decomposable matters in the shallow layer was smaller than those in the medium and bottom layer. It is estimated that since the medium and bottom layers are under the groundwater table, anaerobic decomposition of combustible matters takes place to turn them into water, gasses and soil matters, which consequently reduces the proportion of combustible matters and comparatively increases the proportion of non-decomposable matters in the medium and bottom layers.

3.6.4.2 Old/Medium/New (Etapa I, II, and III)

a. Physical Composition

Comparing the proportion of combustible matters of Etapa I, II, and III, it is found that **combustible matters** in average account for about **16.5%, 23.4% and 21.9%** respectively in Etapa I, II, and III.

Comparing the proportion of non-decomposable matters of Etapa I, II, and III, it is found that **non-decomposable matters** in average account for about **34.0%, 26.1% and 21.4%** respectively in Etapa I, II, and III. It reveals that the proportion of non-decomposable matters in the older cells (Etapa I) was higher than those in the medium old cells (Etapa II) and newer cells (Etapa III). It is estimated that older cells are with longer time of decomposition of combustible matters. Decomposition takes place to turn the combustible matters into water (H_2O), landfill gases (CH_4 etc.) and soil matters, which consequently reduces proportion of combustible matters contents and comparatively increases the proportion of non-decomposable matters in the older cells.

3.6.4.3 Stabilization of Landfill

In view of the above results that the shallow layer or newly disposed part of landfills have slow decomposition, it will be suggested that **recirculation of leachate** will accelerate decomposition of buried waste and then to stabilize the landfill.

3.6.5 Conclusion

In general, landfill mining has two main objectives as follows:

- sub-products recovery.
- space recovery.

Meanwhile, the landfill mining will have a problem of

- **re-disposal of rejects** from landfill mining.

a. Sub-Products Recovery

Sub-products recovery can refer to:

- recovery of valuable materials (e.g., metals) or
- recovery of soil matters (such as compost, soil for landfill cover materials).

a.1 Recovery of Valuable Materials

The survey revealed that the proportion of valuable materials in buried wastes is substantially small (e.g., aluminum and iron matters recovered in the survey account for only less than 2% to the total). Therefore it can be concluded that recovery of valuable materials (such as metals) from landfill mining is not feasible nor practicable, in comparing:

- costly works of landfill excavation, sieving such as aluminum and irons, re-disposal of rejects, etc. and

- recycling works of aluminum and iron which are currently practiced by citizen, collectors and workers in S/Ps in the DF.

a.2 Recovery of Soil Matters

The survey revealed that the proportion of soil matters in buried wastes is substantially large (e.g., soil and mud accounts for more than 50% to the total).

Laboratory analysis of the samples revealed as follows.

- Average of 18 samples are within the permissible level of concentration in every parameter for the agricultural land use application. As for 7 parameters (Cd, Cr, Ni, Pb, As, Se, PCB) out of 11 parameters, all 18 samples are within the permissible levels. As for the rest 4 parameters (Cu, Mo, Zn, Hg), only one sample out of 18 exceeds the permissible level. Therefore the pollution level of soil matters in landfills are within the permissible level for its agricultural use.

- As for pH, all the samples range from 7 to 9. Therefore the soil is applicable for agricultural use in view of acidity or alkalinity.

- As for C/N ratio, it ranges widely from 11 to 400, its average being about 100. Samples with high C/N ratio are judged that their carbon contents still can be decomposable with much time. Meanwhile, in order to adjust C/N ratio to an appropriate level, nitrogen application might become necessary.

It will be needed to discuss whether the soil matters recoverable from the landfills in DF are applicable for agricultural use or only for non-agricultural use.

a.3 Soil Matters for Agricultural Use or Non-Agricultural Use

The US-EPA regulation (Sewage Sludge Use and Disposal Regulations: Part 503 Standards) specifies that:

- If a sludge meets the "high quality" metal concentration limits, it can be land applied provided that the application rate does not exceed "annual pollutant loading rates".

Therefore, the "annual pollution loading rates (kg/ha/day)" might give a restriction on the quantity of agricultural application in view of the size of land that should receive the soil matters from landfill mining.

Furthermore, if excreta or manure is used for nitrogen application in order to adjust C/N ratio, it is necessary to take measures for controlling bacteriological level (i.e., fecal coliforms level). Otherwise soil matters with high bacteriological level (more than 1,000 fecal coliforms per gram) should also have restriction on agricultural application as follows (Sewage Sludge Use and Disposal Regulations: Part 503 Standards):

- food crops that receive the sludge application cannot be harvested for periods ranging from 14 to 38 months afterwards, depending upon the type of crop grown and the method of application.
- pasture lands that receive the sludge cannot be grazed for 30 days.
- turf lands are not allowed to be harvested within 12 months of application.
- public lands that receive the sludge application will have access restricted for 30 days in low-exposure areas and up to 1 year for high-exposure areas.

Consequently, in view of samples quality, the soil matters from "landfill mining" are usable for **agricultural** purposes **with conditions** such as "annual pollution loading rates (kg/ha/day)" and "bacteriological level". Meanwhile, **additional cost of laboratory analysis** of soil sample will become necessary in order to verify that can be safely used as agricultural purposes.

Meanwhile, in case of non-agricultural uses, "soil matters from landfill mining" can be utilized as:

- cover soil of landfill; or
- soil conditioner for no-orchard afforestation or no-grazing vegetation.

without the **cost of laboratory analysis.**

a.4 Odor Control of Soil Matters

One major disadvantage of soil matters from "landfill mining" is the offensive odor, which was experienced during the field investigation works. Since the decomposition of buried wastes in the landfill takes place at anaerobic conditions, soil matters re-excavated through "landfill mining" have offensive odor. Therefore, some measures (such as aeration) to reduce offensive odor is required for the soil matters recovered from the landfill mining, after separating the rejects (such as plastics) and before applying as compost or cover soil for landfill.

b. Space Recovery

As mentioned above, proportion of soil matters in buried wastes is substantially large (e.g., soil and mud accounts for more than 50% to the total). Therefore, if the soil matters are removed to be used in some purposes (such as landfill soil cover or soil conditioner for green areas), about 50% of space recovery could be achieved by that.

Hypothetically comparing economic values of space recovered from:

- Bordo Poniente Etapa I, II, III landfills **(old landfills without impermeable liner)**
- Bordo Poniente Etapa IV and V **(new landfills with impermeable liner)**

a unit space recovered in **landfills with impermeable liner** will have much higher values than that in **landfills without impermeable liner.**

because, if a space recovered in **Etapa I, II, III** are to be used for future landfill, a new impermeable bottom liner should be installed in the area (Etapa I, II, III) in order to comply the existing environmental norms. Meanwhile, if a space recovered in Etapa IV and V are to be used for future landfill, a space recovered therein has an economic advantage that the space is already exempted with the cost of impermeabilization, because a liner already exist below the space recovered.

c. Re-Disposal of Rejects

On the other hand, after soil matters are recovered, the rejects such as plastics should again be disposed of. It will be anticipated that additional costs of rejects re-disposal become costly.

3.6.6 Recommendation and Concluding Remarks

In view of conclusions listed above, "landfill mining" is not workable today. However, the "landfill mining" in the future (maybe after the study's target year 2010) might possibly become workable and feasible.

The possible scenarios in the future might be:

- If a windrow composting facility is introduced as the new intermediate treatment of the DF in the near future, as proposed as one of F/S projects, its facility can be co-used by the landfill mining operation in the process of soil matters aeration, in order to remove offensive odor. It will also be another future possibility that landfill mining will be an auxiliary function of windrow compost production.

- Preparation of separate disposal of only organic waste from today might be another possible scenario, in order to minimize the future cost of re-disposal of rejects in the landfill mining; and

- When and if in the future landfill becomes much more costly than today, it will in turn make the landfill mining technology feasible in view of space recovery merits.