H.4 Examination of Technical System Components

H.4.1 Examination of Technical System Components

The components of technical sub-systems of SWM are so closely related to each other and have an impact in the people's lifestyle that it will be very difficult to replace an existing system with a new one, besides the fact that there are too many factors to be taken into account for the formulation of a different system.

a. Discharge and Storage

The existing technical sub-systems generally comply with the requirements of the study area. Curb collection is the most common system, using 80 to 100 liter nylon sacks as storage vessels for household waste in low and middle income residential areas receiving collection service. So far, it appears to function well.

Consequently, the examination is made only for applicability of various technology for areas receiving no collection service.

aa. Discharge

aaa. Discharge Method

The waste discharge method is divided into two categories; mixed discharge and separate discharge. The present technical sub-systems of discharge and storage in Managua by generation source is shown in Table H.4.1a. Mixed discharge is carried out in Managua City.

Table H.4.1a Present Discharge and Storage System

Generation Sources		Source Separation	Type of Containers	Discharge Points
Residential Area	Collection Area	None	Nylon sacks are used as waste containers in low and middle income areas. Plastic bags and drums are used as waste containers in high income areas	In front of premises (approximately half of residents use waste stands in high income area)
	Non–Collection Area	None	–	Self disposal outside or peripheral area of their premises
Commercial Area	Shops	None	Containers (0.83 m^3)/Drum cans	Open space in a commercial area
	Restaurants	None	Plastic bags/Drums	Open space near their premises
Markets		None	Containers (0.83 or 15 m^3)	Open space outside a market
Offices		None	Containers (0.83 m^3)	Open space outside an office
Hospitals		None (infectious waste is dis–charged with other waste)	Containers (0.83 m^3)	Open space in hospital grounds
Factories		None	Containers (factories with an agreement with the Municipality use containers (0.83 or 15 m^3))	Open space within factory grounds
Roads		None	Open dumping	Roadside or vacant areas
Parks and Green Areas		None	Open dumping	Roadside or vacant areas

i. Household waste

Collection service area is divided into two categories; collection area A and B. Collection area A is defined as the area where infrastructure is well established and the waste is discharged in front of premises and collected by the municipality.

Collection area B is defined as the area where road conditions are inadequate and low illegally drawn electric outlets prevent the entry of collection vehicles. The waste is discharged in illegal dumping sites registered by the municipality and collected using municipal wheel loaders and dump trucks. However, some houses do not receive collection service due to the shortage of collection facilities.

The following were confirmed by the Study Team in May 1994 by conducting a Public Opinion Survey (POS) in the Study Area.

(1) Approximately 40% of the residents do not discharge garden waste with other household refuse, and approximately 30% feed kitchen waste to their animals.
(2) There are no door to door collectors or purchasers of recycling materials. (based on the response of more than 80% of the residents and 95% shops).

The introduction of a separate discharge system in the future is recommended if the operation of a processing facility and/or recycling plant is feasible.

ii. Market, office and medical institution waste

These wastes are discharged into containers and some drum cans installed by the municipality. Regarding industrial waste, the municipality requests the contracted factories to segregate hazardous waste, glass, construction debris, etc., and not to discharge harmful waste into municipal collection vehicles. This has been emphasized in order to assure the safety of collection workers and the long economic life of the equipment. Unfortunately, however, these institutions do not abide by this regulation.

aab. Discharge points

Primarily, waste is discharged in front of the premises in collection area A, and is later gathered by collection vehicles. It was observed during the Time and Motion Survey that approximately 30% of the residents use waste stands as discharge points in high income areas. On the other hand, waste in collection area B is discarded in illegal dumping sites registered by the municipality.

The containers or drum cans for storage and discharge of waste used in commercial areas, markets, offices and hospitals are usually placed at any open space available outside the premises.

On the other hand, in non–collection areas, waste is self–disposed outside or in peripheral areas of the premises, such as roadsides and vacant areas. Street sweeping waste is also discarded on roadsides or registered illegal dump sites.

aac. Introduction of Separate Discharge System

The introduction of a separate discharge system will be recommendable in future, if the operation of a processing facility and/or recycling plant is economically feasible.

ab. Storage

aba. Type of Storage System

i. Residential Areas

Nylon sacks, with 80–100 liters capacity, is commonly used in low and middle income residential areas as a storage and discharge container. Sacks are reused after loading the waste onto collection vehicles. On the other hand, plastic bags and drum cans are commonly used as containers in high income areas.

ii. Commercial areas

In commercial areas, shops use $0.83m^3$ containers and drum cans for waste storage and discharge, while restaurants use plastic bags or drum cans.

iii. Markets, offices and large medical institutions

Markets, offices and large medical institutions use containers as a storage vessel. There are two types of containers; the $0.83m^3$ container, collected by a screw type collection truck with attachment, and the $15m^3$ container placed outside large waste generation sources and collected by roll–on roll–off trucks.

iv. Street sweeping

Street sweeping waste is generally not stored in containers but heaped in open spaces.

v. Industries

Factories with an agreement with the Municipality concerning waste collection use $0.83m^3$ or $15m^3$ containers.

ac. Capacity of Storage Equipment

Based upon the field survey conducted during Phase 1, the following results were obtained:

Waste generation	: 0.68kg/person/day
Average persons per family	: 6.7 persons
Average discharge weight/household/day	: 4.6kg/household/day
Household waste collection frequency	: 3 times/week
Average household waste volume (beginning of week)	: 55.2 liters/household
(4.6 kg x 3 days/0.25kg/liter (ASG))	
Average household waste volume (middle and end of week)	: 36.8 liters/household

N.B. ASG: Apparent Specific Gravity

During the field survey of Phase 1, households discharged an average of 60 liters of waste a day. The present 80-100 liter nylon sack is thereby considered to be suitable for households under the three times a week collection frequency.

ad. Sanitary Aspects of Storage Equipment

The following properties are required for waste storage equipment in terms of sanitary aspects:

- cover (to prevent leakage of odor)
- adequate capacity
- structurally safe
- easy to keep clean

ae. Conclusions

aea. Collection Area A

In order to improve collection efficiency and avoid littering due to animal scavenging, waste stands shall be installed, if considered feasible.

aeb. Collection Area B

From a sanitary point of view, the present discharge system shall be changed from self-disposal to collection of steel containers.

aec. Non-collection Area

i. Squat area with poor road conditions

From a sanitary point of view, the container discharge system employed in collection area B shall be introduced.

ii. Rural areas

When rural areas are urbanized in the future, the roads will be improved to allow access of collection vehicles. Municipal collection services will be implemented then. Collection services in collection area A will be extended to these areas.

aed. Commercial area, markets and industries

As the present system is adequate for the service required, improvement is not necessary in these areas.

aee. Medical institutions

The Ministry of Health is preoccupied with the improvement of clinical waste treatment measures with the financial support of the European Union (EU). Decisions concerning this improvement program is left entirely up to the Ministry.

b. Collection and Haulage

ba. Collection frequency

The collection frequency is determined by taking into account the sanitary conditions of the area and operation and maintenance cost involved. Although a six times a week collection frequency is desirable, a three times a week collection will be carried out in consideration of the operation and maintenance cost.

Organic waste should be collected more frequently than inorganic. The collection frequency should be determined by waste composition in case separate collection is introduced in the future.

bb. Mixed or Separate Collection

Separate collection requires public cooperation for source segregation whereas mixed collection requires none. However, separate collection can contribute towards effective recycling and resource recovery and is therefore recommended if the introduction of a recycling or processing facility is economically feasible. However, one must bear in mind that successful implementation of separate collection highly depends on public cooperation.

bc. Collection

bca. Type of Collection

The characteristics of these collection services are described as follows:

i. Curb Collection

Each household is responsible for placing the containers at the curb on collection day and for returning them when emptied to their storage location until the next collection.

ii. Door to Door Collection

(1) Set-out-set-back and Set-out Collection

Containers are set out from the premises and set back after being emptied by the additional crew that work in conjunction with the operators responsible for loading the collection vehicle.

(2) Set-out Collection

Set-out collection is essentially the same as set-out-set-back collection, except that residents are responsible for returning the containers to their storage location.

(3) Backyard Collection

The collection crew enters the premises and collects the wastes from their storage location.

iii. Bell Collection

The collector calls out to the residents to discharge their waste when a collection vehicle arrives at a given collection point.

iv. Public Container Collection

Residents discharge waste regardless of collection day. This collection method produces a high collection efficiency.

bcb. Selection of Collection Services

i. Existing system in collection areas

Curb collection with waste stands is common in high income residential areas, while nylon sacks are used in low and middle income areas. Markets, commercial areas, industries and medical institutions in a contract with the municipality are serviced by the public container system. The curb collection system with the use of nylon sacks without waste stands causes animal scavenging and littering, which create an unsanitary condition and ruin local sights. People frequently leave nylon sacks at the curb early in the morning of a collection day.

bcb. Selection of collection service in residential areas

Curb collection provides a high collection efficiency. Residents usually leave nylon sacks filled with wastes at the curb along the road for collection. This system of collection shall be continued in future.

bd. Collection Time

Traffic congestion is not observed in the downtown area. Night collection will not be required before 2010.

be. Collection Vehicles

There are three types of collection vehicles as shown in Figure H.4.1a and Table H.4.1b. A comparison is made in terms of advantages and disadvantages.

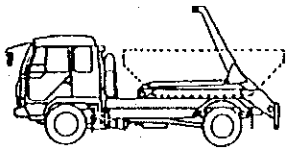
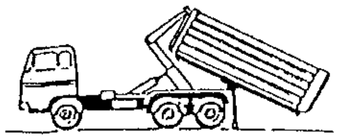
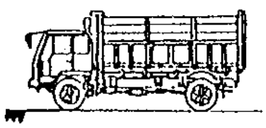
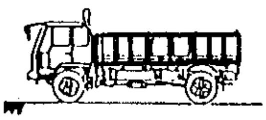
Type	Truck	
Compaction	Compactor Truck	
Detachable	Hoist Truck	
	Roll-on Roll-off Truck	
Standard	Dump Truck	
	Flat Bed Truck	

Figure H.4.1a Type of Waste Collection Vehicles

Table H.4.1b Comparison of Waste Collection Vehicles

Item	Compaction Type	Non-compaction Type	
	Compaction Type	Detachable Container Type	Standard Type
1. Waste Loading Factor	Good	Excellent	Poor
2. Waste Scattering During Transportation	None	Possible (in case of open type)	High possibility (in case of open type)
3. Discharge	Easy	Easy	Easy (if with dumping function)
4. Maintenance	Complicated	Relatively easy	Easy
5. Loading Bulky Waste	Impossible	Difficult	Possible
6. Purchase Cost	Higher	Highest due to a large number of containers required.	Lowest
7. Compatibility with Present Collection System	Compatible	Compatible	Compatible
8. Use for Other Purposes	Impossible	Impossible	Possible

bf. Haulage Method

bfa. Motor vehicle haulage

The motor vehicle is the most common transport method for solid wastes throughout the world.

Refuse trucks are classified into the following three categories:

- compaction
- detachable container
- standard

bfb. Railway Haulage

Since the railway operation was suspended in 1992, this system cannot be an alternative to the present haulage system.

bfc. Water Haulage

Waste is transported to transfer stations to be loaded onto boats and carried elsewhere. This method is frequently used for shipping and land reclamation.

Although there is a large lake (Lake Managua) in the Study Area, this system cannot be taken as an alternative due to the following reasons:

i. There is a good national road system along the shores of Lake Managua.
ii. The water haulage system requires loading and unloading facilities and transfer vehicles, thus needing a certain amount of capital.

Table H.4.1c General Evaluation of Water Haulage

	Advantage	Disadvantage
1. Haulage Capacity	Larger than other methods	–
2. Unit Haulage Cost	Cheaper than other methods	–
3. Transfer Station	–	Loading and unloading points are required
4. Operation in Harsh Weather Conditions	–	Difficult
5. Flexibility	–	Less

bfd. Pneumatic and Hydraulic System (via pipes)

Widespread use of these methods have not been conducted. A huge initial investment and O & M fees are required; use of this method should be limited to areas generating a large volume of waste. It is judged that these systems cannot be taken as an alternative.

bg. Transfer Station

Transfer and transport operations become a necessity when hauling distances to available disposal sites or intermediate treatment plants increase to the point that direct transport is no longer economically feasible. Transfer operations and the introduction of transfer stations are necessary in cases where the following are observed:

- location of disposal sites exceed 20 km
- use of small collection trucks (under 15 m^3)
- widespread use of medium-sized containers for commercial areas
- Use of hydraulic or pneumatic collection systems.

The distance from the core collection area to the proposed disposal sites in Santa Ana is more than 20 km. Therefore, it is indispensable to examine the introduction of the transfer system with motor vehicles.

bh. Conclusions

bha. Collection frequency

Basically, the present collection frequency, – everyday except sundays for commercial areas and three times a week for residential areas – shall be applied in the future.

bhb. Mixed or separate collection

The introduction of the separate collection system is advisable if a recycling or processing facility is economically feasible. Separation at sources should be promoted.

bhc. Collection service

Since the present curb collection is very efficient, it should be continued. However, container collection shall be introduced in collection area B and the squatter areas, where municipal collection service is not extended due to shortage of resources.

bhd. Collection vehicles

The appropriate vehicles are as follows:

i. Compactors–
waste from collection area A, commercial areas, markets, medical institutions and factories.

ii. Container trucks–
street sweeping waste and waste from collection area B.

iii. Standard trucks–
not applicable

bhe. Haulage method

The present motor vehicle haulage method shall be continued.

bhf. Transfer station

The introduction of the transfer system for motor vehicles shall be examined as an alternative for Santa Ana candidate disposal site.

c. Street Sweeping

ca. Introduction

The effect of street cleansing is one of the most visible of all government services. Consciously or not, residents allow the effectiveness of street cleansing programs to influence their feelings toward their municipalities and local officials. Visitors may instinctively rate municipalities on its cleanliness before they learn anything else; such opinions can help to shape a community's future. Street cleansing has been associated primarily with aesthetics.

The major goal of street cleansing programs has been to remove litter and dirt so that streets appear presentable and traffic will not create dust. In some areas particularly, regular street cleansing is necessary to prevent sewers from becoming clogged. Knowledgeable officials now recognize the pollution potential of particulate matter when washed into sewers.

Managua Municipality must balance the costs of adequate street cleansing and effective litter control programs, improved sewer operations, safety of pedestrians and vehicle occupants, reduction of air and water pollution, and economic development. Public education, however, will not eliminate all street litter. Debris also accumulates from air pollution fallout, carcasses, oil drippings, parts dropped from vehicles, spillage from solid waste collection, mud tracked onto pavements, etc..

cb. Manual Cleaning Methods

Manual street cleansing is by far the oldest method. And although it has been widely replaced by mechanical methods, certain advantages still remain.

The equipment required for manual sweeping is simple and inexpensive. Sweepers use stiff bristled brooms and wheeled carts carrying barrel-like containers, shovels, and possibly a few other tools for special tasks. Motor scooters have sometimes replaced push carts for certain manual cleansing assignments.

cbb. Mechanical Cleansing

Mechanical cleansing is a cleansing method utilizing various types of machinery.

cbc. Vacuum Cleansing

Vacuum street sweeping appears to be increasingly attractive because it minimizes water pollution by removing more of the fine dust on the street as well as the larger debris. The flicking action of the broom is not as effective on fine materials as is the vacuum. Mechanical sweepers were designed to remove the larger debris; they do so in commendable fashion when the operator is capable and conscientious.

Vacuum units can also pick up larger debris, ranging from cigarette ends to beer bottles at operating speeds of 25 miles per hour. Vacuum units also use gutter brooms to loosen and deflect debris so it can be picked up. They also have an additional broom to windrow the dirt; this devise may also be used additionally to pick up debris. This second broom loosens the street dirt and pushes it toward the vacuum nozzles where it is drawn into the storage compartment. A filter system traps the dust and confines it to the sweeper hopper.

cbd. Flushing

Street flushers hydraulically move debris from the street surface to the gutter. Since disposing of street dirt in sewers and catch basins is regarded with increasing disfavor because of its adverse effects, several municipalities now flush only to aid sweeping and not as the sole method of cleansing. Flushing before sweeping washes street dirt to the curb for collection by motorized sweepers. This type of flushing ordinarily employs smaller quantities of water and lower nozzle pressures, which also minimizes splashing pedestrians and vehicles, to keep the dirt from flowing into the inlets. The benefits of flushing after sweeping are that the entire pavement is made cleaner and that only small quantities of dirt are washed into inlets and catch basins.

cf. Conclusions

The introduction of a mechanical or vacuum cleansing machines seems to be attractive. However, it is judged that the present manual sweeping system is more suitable under the condition of high unemployment and underemployment ratio in the study area. Therefore, the present manual sweeping system shall be continued.

d. Intermediate Treatment (Processing and Recycling)

da. Intermediate Treatment System

The technical system of MSWM consists of 3 main technical sub-systems, i.e., collection and haulage, intermediate treatment and final disposal. The intermediate treatment system requires not only the most modern technology but also considerable amount of construction and O & M cost. In addition, the intermediate treatment system is not indispensable in MSWM, while the other two sub-systems are. The construction of an intermediate treatment facility is often the biggest investment project in a local government. It is, therefore, very important to carefully examine the introduction of an intermediate treatment facility to a local government.

As for the intermediate treatment technology, there are various processing and resource recovery (including recycling) facilities as shown in Figure H.4.1b. In this section, the following intermediate technologies are examined and primarily screened for the comparison of technical system alternatives.

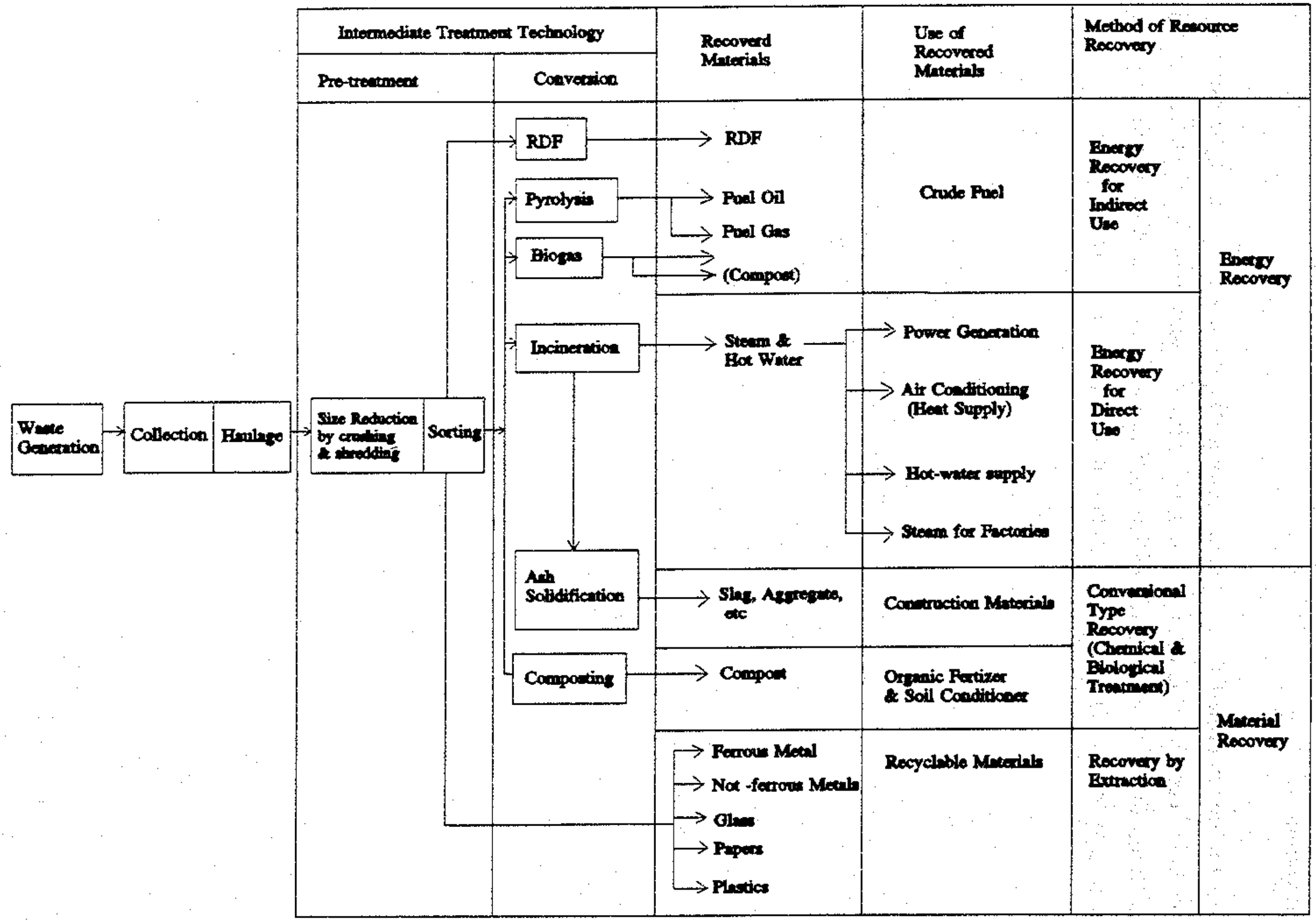


Figure H.4.1b Intermediate Treatment Technologies and Resource Recovery Methods

db. Incineration

dba. Introduction

Recently, incineration of municipal solid wastes is one of the most popular method for processing wastes in developed countries. Waste is converted mainly into stable gaseous oxides and some stable inorganic matters by combustion at high temperatures. Generally, incineration results in the biggest volume reduction among the various intermediate treatment technologies and it also achieves stabilization of putrescible organic wastes.

A general observation would indicate that incinerators may be feasible where land availability is scarce, expensive or very remote from the actual solid waste generation center.

Modern incineration and flue gas cleaning technology makes waste incineration an environmentally acceptable form of waste treatment and enables the construction of plants, even in densely populated areas.

dbb. Construction, maintenance and operating costs

A major factor contributing to the disfavor of incineration as an economical disposal solution is the high capital requirement. Total capital requirement per ton will generally decrease with increasing capacity, however, unit values are typically higher than other disposal alternatives, especially sanitary landfilling. Therefore, detailed cost evaluation has to be made on the construction cost, annual running and maintenance cost, versus expected income which could be obtained from the supply of electricity or heat.

dbc. Advantages and disadvantages

Basic advantages are:

i. Wide range of applicability and it is able to treat almost any kind of waste except bulky inert materials.
ii. High reduction in bulk volume and weight and transportation costs due to possible location near cities and landfill requirements.
iii. Hygienic way of treating waste.
iv. Revenue will be expected from the sale of surplus electricity by means of power generation in the plant (in case of high calorific value of waste).

Disadvantages of incineration include:

i. The system requires considerable investment, high operation and maintenance costs.
ii. Residues may have a higher concentration of heavy metals and other hazardous items.

dbb. Composting

i. Introduction

Waste composting is a method which achieves microbial degradation of organic matter, to produce fertilizers for use in gardens, parks, horticulture, etc..

Waste composting can be applied to household, kitchen and garden wastes including branches and litter.

Composting technology is divided into two main categories, i.e., on-site composting and composting plants.

ii. On-site composting

On-site composting is the simplest possible composting technique and is carried out at each generation source (mainly each household) and it requires:

- the sorting of organic wastes in the kitchen
- the provision of a standard model compost container for each household

Containers can be made of recycled plastics and constructed so as to allow a circulation of air via air inlets and outlets both at the top and bottom of the devise.

iii. Composting plants

(1) Windrow type

The existing composting plant at Acahualinca is manually operated. Numerous windrow type plants were constructed throughout the world during this century, in which several types of turners have been designed to turn windrows or compost stacked over a wide area. In the last two decades, windrow composting has gained acceptance in Europe, especially for making compost from garden wastes.

Windrow composting is the conventional process for treating unsorted or sorted and sieved organic wastes.

The process may be equipped with different pre-and post-treatment machinery devices to:

- prevent the input of undesirable metals, etc.
- break large components into smaller fragments to make it compostable
- sort incoming materials depending on density
- give a biological pre-treatment
- aerate the windrows
- sort the compost product, to recirculate larger fragments, or to send them for incineration
- fill up bags and sacks for sale

(2) high-rate composting type

High rate composting system consists of various equipment, devices, etc., (with a unit operation) in order to perform the function of composting treatment, regardless of its method or size. The main function of this system is to feed sorted and mixed wastes, shredding, and adjusting wastes in the equipment, fermenting, maturing and post-treating, and finally removing refined compost and residue in a continuous and smooth manner.

Composting operation must be kept in a controlled environment so that oxygen amount, temperature, moisture, and C/N ratio, etc., can be easily adjusted and secondary pollution, especially offensive odor, can be prevented. High-rate composting plants can be located in urban areas if environmental protection facilities such as fume removers are built.

(3) Modified landfill employing on-site composting

This process has been recommended as the lowest cost composting method yet available today. Essentially the process calls for pre-shredding of refuse and placing it in a sanitary landfill without cover. Composting may be conducted by the use of forced air blown through pre-laid, four inch corrugated polyethylene pipes which is low in cost. Pre-shredding can be accomplished either centrally or with a rotor shredder on site. The cost of the stabilized refuse is approximately the same as or slightly more than a sanitary landfill, but there are the advantages of; (1) no cover, (2) less water pollution, and (3) approximately one-third of the landfill area required due to hydrolysis and greater compaction. The end product can be dug out and sold if a market exists thus making room for more material.

iii. Value of organic matter, utilization and marketing.

Organic composts used as low-grade fertilizer or soil conditioner improve soil quality particularly heavy clays or loose sand where its usage can increase crop yield.

The need for organic matter in the soil can be summarized as follows:

- improvement of physical character of soil;
- increase of moisture retaining capacity;
- reduction of chemical fertilizer leaching especially nitrates and phosphates; and
- stimulation of healthy root growth.

dd. RDF (Refuse Derived Fuel)

RDF (Refuse Derived Fuel) is based on replacing a fuel e.g. coal in a conventional power or district heating plant by pellets made from waste.

de. Pyrolysis

Recently, considerable attention has been given to pyrolysis in providing means of recycling municipal solid wastes. Pyrolysis is a process whereby organic substances are decomposed under temperatures in the range of 700–1,200 °C, in the absence of oxygen or at oxygen levels insufficient for total combustion.

df. Ash Solidification

Besides increase in the quantity, refuse of today is diversified quality-wise. Even after complete incineration, there still remains a large quantity of substances which can not be treated such as ash and sludge from waste water treatment. For heavy metals, in particular, a fundamental solution is desired because the environmental problems it is associated with posses difficulty when acquiring land for disposal.

Ash solidification technology is developed so as to liquefy and solidify such substances at high temperatures or its conversion into solid concrete by using cements and other bonding agents.

dg. Biogas

Biogas is produced when organic material decomposes under anaerobic conditions. The energy will be bound in the hydrocarbon methane, which is the main compound in natural gas. Anaerobic degradation of organic matter, resulting in biogas production, is an efficient means of decomposing organic wastes, and making it hygienic. Anaerobic waste treatment is a well known process relating to treatment of farmyard manure, sewage sludge, industrial waste water, etc..

A biogas plant consists of reception, pre–treatment, process and post–treatment sectors including stock facilities. In the process area, the organic material is differentiated into carbohydrates, proteins, and fats by micro organisms. Firstly, the material is decomposed by catabolic bacteria to organic acids and carbon dioxide, after this process organic acids are broken down and the products include hydrogen and methane.

Biogas can be utilized both for heat and power production. The residues are compost and can be utilized as a soil improving agent.

It is possible to add the following wastes to biogas production plants:

- organic wastes from households, including meat and vegetables
- flowers, including herb wastes from gardens
- coffee grounds and tea leaves including paper filters
- fruit wastes
- paper kitchen towels and tissues
- organic sludge and waste water from industry, including the food factories
- sewage sludge

However, one should exclude waste water and wastes containing heavy metals, and those from some branches of the chemical industry.

This type of waste processing technology is rather new, therefore, it has been impossible to find plants which have been operating for more than a few years to provide the relevant information. On the other hand, plants for agricultural and industrial purposes are well documented and reliable.

dh. Size Reduction (Crushing and Shredding)

A size reduction facility, which normally has crushing and shredding functions, is generally used as a pre–treatment facility for an incineration plant, composting plant and other intermediate treatment facilities, and also used in order to improve sanitary landfill operation.

Shredding for sanitary landfill, is conducted to reduce the volume of waste pending final disposal at a site. The shredded waste, as compared with non-shredded ones, will be settled when tipped because of its high compaction ratio. They cause less damage to the landfill equipment and trucks for landfill work and there is less complaints from the neighbors about landfill operations as it is invigilated and is hygienic. In addition, fewer fires will break out during the landfill work. Fewer vermin will require less insecticides and rat poison.

The term "crush" has various meanings, i.e., shredding, milling, pulverizing, grinding, cutting, tearing, ripping, etc., for which appropriate machines are developed. For example, an ordinary hammer mill, with a swing hammer attached to the horizontal or vertical shaft, rotates very fast pulverizing any matter by sheer force of the cutting board.

The grindability depends upon the substances to be crushed, and the size required for the purpose of each treatment system. The pulverizing process will be accompanied with sieving, if necessary.

di. Sorting

dia. Introduction

An important point to be considered in both treatment and disposal is that a system for recovery of the resource such as paper, glass, metal, plastics, etc., must be provided in the early stage of planning. The most desirable method is a system which allows reclamation of as many kinds of waste possible at the lowest cost, and not causing any secondary environmental pollution.

The lay-out of sorting plants and the specific operational requirements vary accordingly, but the plants in general serve one of two purposes;

- Salvaging recyclable materials from the waste stream in order to increase the amount of recycling (positive sorting). Rejected materials are disposed of at a landfill or incinerated.

- Separating unwanted materials from the waste stream before further processing (recycling, incineration, composting etc.). (negative sorting).

Furthermore, as the incoming waste usually has to be separated at source, the plant will act as a control unit for the quality of the collection system and source separation.

Based on the above the following types of sorting plants are most relevant:

- sorting of source separated wastes
- sorting of waste before incineration
- sorting of waste before composting
- sorting of construction and demolition debris
- sorting of bottom ash from incineration

However, it shall be stressed that the market price for the output material together with the quality of the input material are the determining factors for the economic viability of the plant.

dib. Type of salvage process

The major purposes of the salvage process are to recover valuables. For iron and steel, nonferrous metals, papers, cardboards, glass, plastics, rags, leather, etc., to be recovered as valuables, a dry classifier which uses wind power, magnetic separator vibration, and manpower are mainly used in accordance with each characteristic of valuables. Dry classification is usually performed in air. In addition to this method, wet classification by means of excess liquid and the semi–wet classification by means of limited liquid are available. Both the dry and the wet classifier have a wide range of application in accordance with their characteristics. Various sorting methods are described in Table H.4.1d.

Table H.4.1d Sorting Methods

Sorting Method	Type of Differentiation	Classification	Sub–classification
Mechanical Sorting	Dry Classification	Mechanical Type	- Vibrating sieving - Trammel - Brush
		Wind Power Type	
		Magnetic Type	
		Electric Type	- Electrostatic Method (for non–ferrous metals)
		Optical Sorting (for glass)	
	Wet Classification	Mechanical Type (Semi–wet)	
		Water Power Type	
		Heavy Liquid Type	
Manual Sorting			

dj. Examination of Technical Sub-system Components of Intermediate Treatment

Generally, the possibility of introducing appropriate intermediate treatment facilities must be examined because the acquisition of new disposal sites is becoming increasingly difficult and that better environmental conservation measures should be introduced.

dja. Selection criteria for intermediate treatment

The following criteria are considered in the selection of possible intermediate treatment

i. Volume reduction of solid waste

The facility should be capable of reducing the waste volume for final disposal, thereby contributing to extend the life of disposal sites.

ii. Resource recovery

The facility should assist the recycling of resources.

There are two ways of resource recovery from solid waste. One is the extraction of economically usable materials from solid waste, and the other is the conversion of waste to useful energy.

iii. Prevention of environmental pollution

The facility should contribute to the improvement of environmental conditions.

djb. Possible intermediate treatment

In response to the above-mentioned criteria, the following intermediate treatment systems are discussed in this report:

- incineration
- composting
- RDF
- pyrolysis
- ash solidification
- biogas
- size reduction (crushing and shredding)

- sorting

Each system can be employed independently or jointly, and has advantages and disadvantages. It is, therefore, important to select an optimum system or an optimum combination of systems, taking the following points into account:

- construction, operation, maintenance and repair cost
- adaptability to various kinds of wastes
- volume reduction effects for final disposal
- marketability and price stability in markets of recovered materials
- ease in operation
- reliability and stability of treatment plants (degree of technical development and operation results, etc.)
- impact on surroundings and its intensity
- simplicity in design of plants (pre-treatment, back-end treatment, etc.)

Table H.4.1e shows the characteristics of possible intermediate treatment systems.

djc. Relationship between intermediate treatment systems and solid waste quality

The processing systems should be selected according to qualities of waste. Table H.4.1f shows the general characteristics of various kinds of solid wastes (percentage of organic materials, water content, inorganic materials and calorific value), and types of wastes most effectively treated by the respective processing plants.

The various intermediate treatment technologies and their respective characteristics are described below;

i. Incineration

Suited for a wide variety of waste except for incombustible bulky waste. Waste from medical institutions and carcasses are low in calorific values. However, they should be incinerated in a special furnace for sanitary purposes.

ii. Composting

Generally, suited for domestic waste (especially garden wastes), other similar types of waste and some kinds of commercial waste.

iii. RDF

Commercial waste especially rich in paper content might be processable.

iv. Pyrolysis

Limited only to waste with low moisture content and high calorific value.

v. Ash solidification

Suited for ash including inert materials.

Table H.4.1e Characteristics of Possible Intermediate Treatment System

ITT	Recovered Material	Main Target of System	Contribution to Landfill			Special Cautions								Remarks
			Volume reduction	Harm-less	Stabil-ization	Stabil-ity of Tech-nology	Pre-treat-ment	Post treatment	Rejected Sub-stances	Accepta-bility of Refuse Quality	Construc-tion Cost (US$/ton)	Marketa-bil-ity of recovered Material	Enviro-nmental Impact	
Incineration	Heat/or Electric Power	Volume Reduction & Energy Conversion	B	B	B	A	Not Necessary	Not Necessary	Noncom-bustibles	A	82,200*1)	(Electricity or Heat) C	B	-Initial/Running Cost -Possibility to find User of Heat
Composting	Compost	Converssation to Fertilizer	C	C	C	A	Necessary	Necessary	Glass, Stone, Plastic, etc.	C	46,000*2)	C	C (Odor)	-Stability of Market for Products
RDF	Solid Fuel	Converssation to Fuel	C	C	C	C	Necessary	Necessary	Noncom-bustibles	C	N.A.	?	C (Noise & Dust)	-Marketability of Prod-ucts
Pyrolysis	Gas or Oil		B	B	B	C	Necessary	Necessary	Noncom-bustibles & Carbon	C	N.A.	X	B	-Incompletion of Technology -Initial/Running Cost
Ash Solidifica-tion	Slag	Volume Reduction & Prevention of Water Pollution	A	A	A	C	Occasionally Necessary	Not Necessary	None	B	N.A.	?	B	-Large Consumption of Supplemental Fuel -Difficulty of Operation
Biogas	Gas & Compost	Converssation to Fuel & Fertilizer	C	C	C	C	Necessary	Necessary	Glass, Stone, Plastic, etc.	C	97,500*3)	C	B	-Stability of Market for Products
Crushing & Shredding	Ferrous etc.	Volume Re-duction of Bulky Waste	C	C	B	B	Extraction of Explosive Object	Necessary	discarded Material	C	N.A.	C	C (Noise & Dust)	-Large Consumption of Electricity -Much Expense for Maintenance -Possibility of Explosion
Sorting (Mechanical or Manual Sorting)	Ferrous, Glass, Paper, Plastic, etc.	Recycling	C	C	C	A	Occasionally Necessary	Necessary	Discarded Material	C	N.A. 46,000*4)	B	B	-Stability of Market for Salvaged Materials

Note: A: Excellent B: Good C: Fair or ( ) to be considered D: Poor and ( ) shows reason
ITT: Intermediate Treatment Technology
*1) : The cost for 30 ton/hour plant was estimated in the Study on the Solid Waste Management for Poznan City, May 1993 JICA (JICA Poland SWM Report)
*2) : The cost for 19,000 tons of garden waste per year from the JICA Poland SWM Report
*3) : The cost for 36,000 tons per year from the JICA Poland SWM Report
*4) : The cost from the JICA Poland SWM Report for 20,000 ton/year

Table H.4.1f Kinds of Waste and Technical Feasibility of Intermediate Treatment System

	3-Elements of Waste				Incineration	Composting	RDF	Pyrolysis	Ash Solidification*2)	Biogas	Crushing & Shredding	Sorting
	Organic Substances B	Moisture Contents W	Inorganic Substances A	Calorific Value of Waste								
Municipal Waste												
.Domestic Waste	Good	Fair	Less	Middle	A	A	B	A	A	A	B	A
.Commercial Waste (mainly from officers and shops)	Fair	Less	Fair	High	A	-	A	A	A	-	B	A
.Commercial Waste (mainly from markets)	Good	Good	Less	Low	A	A	-	-	A	A	B	-
.Carcasses	Good	Good	Low	Low	A	-	-	-	A	-	-	-
.Other Waste (Street Sweeping and public area cleaning wastes)	Fair	Fair	Less	Low	B	B*1)	-	-	A	-	-	-
Industrial Waste (Non-Toxic)	Less	Less	Fair	High	A	-	A	B	A	-	B	B
Bulky Waste												
Combustible Bulky Waste	Fair	Less	Less	High	A	-	B	B	A	-	A	B
Incombustible Bulky Waste	Low	Less	Good	-	-	-	-	-	B	-	A	A
Hospital Waste (Infectious)	Good	Good	Less	Low	A	-	-	-	A	-	-	-

Remarks :
A Suitable
B Processable
- Normally not for processing

Ranking System for 3-Elements of Waste:
.Good
.Fair
.Bad
.Poor

Ranking System for Calorific Values of Waste:
.High
.Middle
.Low

Note:
*1) : Only for garden wastes.
*2) : All evaluation is for the plant combined with an incineration.

vi. biogas

Limited only to organic wastes including paper and sewage sludge.

vii. size reduction (crushing & shredding)

An independent plant solely for bulky waste. However, crushing and shredding devices are necessary for other intermediate treatment systems.

viii. sorting

Suited for inert waste.

dk. Conclusion

Upon consideration of the examination of intermediate treatment systems and the present MSWM in the Study Area, the introduction of an intermediate treatment system is concluded to be unsuitable and is omitted from the alternative study.

dka. Incineration

i. The LCV (Lower Calorific Value) of the MSW is very low (1,215 kcal/kg) and it requires auxiliary fuel for combustion.
ii. The cost of incineration was estimated to be more than 26.3 US$/ton according to the JICA SWM study in Asuncion, Paraguay, where the LCV was 1,192 kcal/kg. The highest sanitary landfill cost in this study was estimated at 8.6 US$/ton which included the treatment cost of leachate.
iii. There are enough candidate sanitary landfill sites for future disposal operations.

dkb. Composting

i. The market for the compost product from municipal solid waste is very limited in the Study Area.
ii. Other competitive organic fertilizers derived from animal dung are easily obtained in the region.
iii. Due to high production cost, subsidies on the sale price will be necessary to make compost from municipal solid waste to compete in the fertilizer markets.
iv. High cost of transportation and labor for the utilization of compost.
v. Less volume reduction.

vi. Possibilities of hazardous heavy metals accumulating in the soil and secondary environmental pollution in the case of mixed collection system.

There is a pilot composting plant at Acahualinca under the technical assistance of a Dutch specialist. However, for the product to become a marketable commodity, a minimum of 5 years experience is required.

dkc. RDF

i. Waste which can be converted to RDF is very limited.
ii. The technology is in its developing stage.
iii. The market for RDF product is limited.

dkd. Pyrolysis

i. The waste quality is limited.
ii. The technology is under development.
iii. The operation of plant is very difficult.
iv. Large capital investment and high operational cost are required.

dke. Ash solidification

i. Large capital investment and high operational cost are required.
ii. The technology is in its developing stage.
iii. Land for final disposal is still available in the study area.
iv. Difficulty of operation.

dkf. Biogas

i. High investment cost.
ii. The technology is in its developing stage; only a few years operational experience regarding MSW.

dkg. Size reduction

i. Waste is limited to bulky waste and not much is produced.
ii. Bulky waste may be recycled manually.

dkh. Sorting

i. The present recycling system (manual recycling system) mainly established by private sectors functions well.

ii. The introduction of the sorting facility may cause a conflict with the present private sectors concerned with recycling activities (e.g. scavengers) because it may cost them their job.

iii. The prices of recyclable materials are not stable.

iv. The amount of recyclable materials in MSW is minimal.

v. The volume reduction by the introduction of a sorting facility is limited.

e. Final Disposal

ea. Possible Technical Sub-System Alternatives

Upon consideration of the possible technical sub-system alternatives of final disposal, the following aspects are to be considered:

- location and number of final disposal sites
- final disposal methods
- landfill structure
- recovery of methane gas
- level of sanitary landfill development and operation

eb. Location and Number of Final Disposal Sites

As for the location and number of final disposal sites for the Master Plan alternatives study, the following were confirmed:

i. Three sites were selected as candidate municipal disposal sites for the study of alternatives for the Master Plan.

ii. There are two sites located within Managua Municipality; Acahualinca and Esquipulas.

iii. There is one site located beyond the boundaries of Managua Municipality; Santa Ana.

ec. Final Disposal Methods

eca. Introduction

There are several final disposal methods, as listed below:

- open dumping

- controlled tipping
- sanitary landfill

Although the controlled tipping method is employed in Acahualinca landfill, open dumping prevails in the Study Area. These methods should not be tolerated in the future in view of their adverse effects on the landscape, public health and environment.

A sanitary landfill should be used for final disposal which is proven to be the most economical and acceptable method. The term sanitary landfill implies an operation in which the wastes to be disposed of are compacted and covered with a layer of soil at the end of each day. When the disposal site has reached its ultimate capacity i.e. after all the disposal operations have been completed, a final layer covering material (more than 60cm) is applied.

ecb. Advantages of Sanitary Landfills

The advantages of sanitary landfills are shown below.

- Where land is available, a sanitary landfill is usually the most economical method of solid waste disposal.

- Initial investment is low compared with other disposal methods, such as composting and incineration.

- A sanitary landfill is a complete or ultimate disposal method as compared to incineration and composting which require additional treatment or disposal operations for residue, quenching water, unusable materials, etc..

- A sanitary landfill can receive all types of solid wastes, eliminating the necessity of separate collections.

- A sanitary landfill is flexible; increased quantities of solid wastes can be disposed of with little need for additional personnel and equipment.

- Submerged land may be reclaimed for use as parking lots, playgrounds, golf courses, botanical garden, etc..

ed. Landfill Structure

There are five types of landfill structure, and they are as follows:

- anaerobic landfill
- anaerobic sanitary landfill
- improved anaerobic sanitary landfill
- semi-aerobic sanitary landfill
- aerobic sanitary landfill

Contribution towards mitigation of environmental pollution is improved in accordance with the above list. Figure H.4.1c shows the structure of each landfill type.

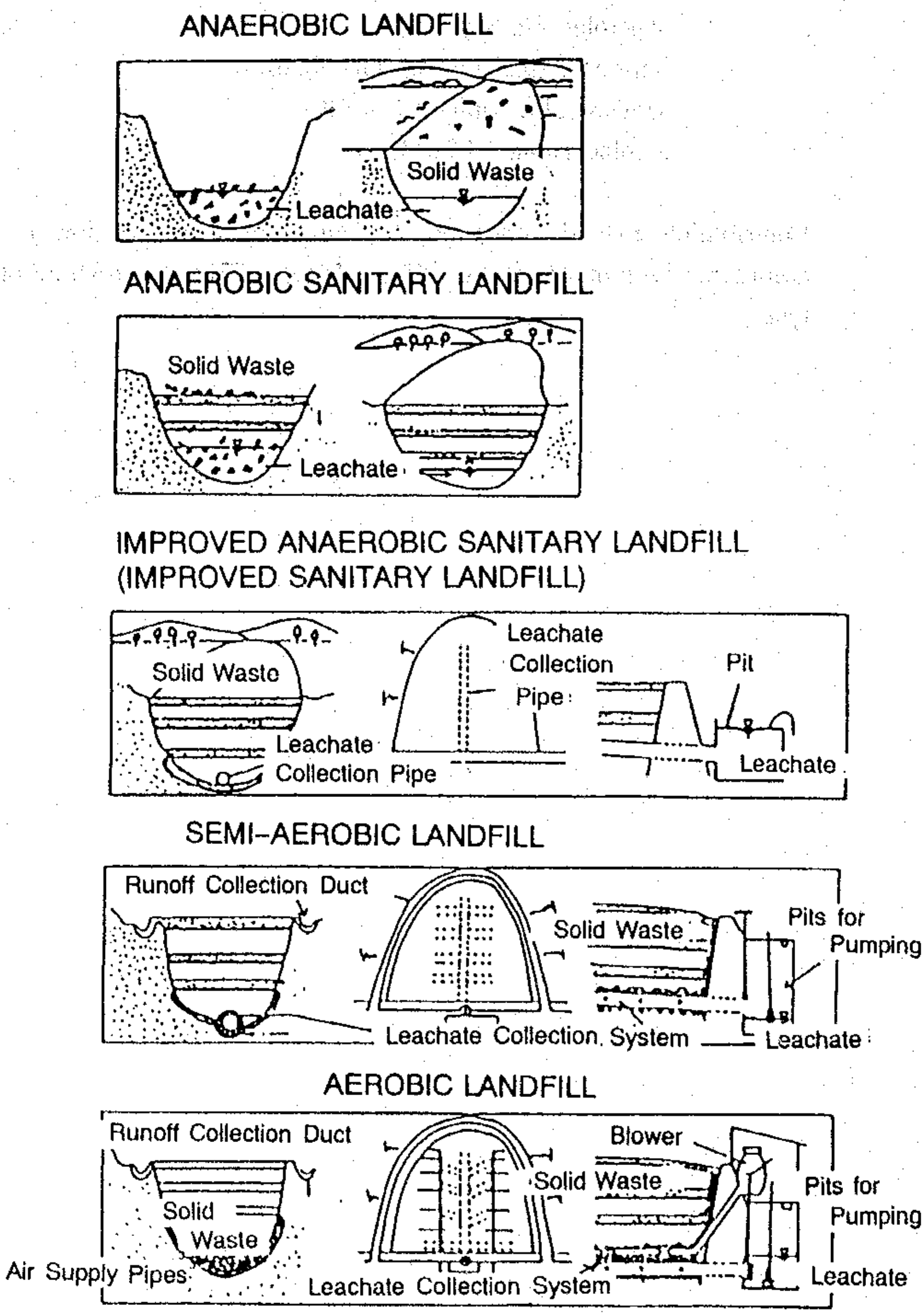


Figure H.4.1c Landfill Structures

eda. **Anaerobic Landfill**

As the leachate generated in the landfill layers is hardly drained, the landfill layers constantly maintain an anaerobic condition. The quality of the leachate is very poor, producing pungent fumes and the propagation of disease vectors and vermin.

edb. **Anaerobic Sanitary Landfill**

Covering soil is applied to each layer of waste. This covering soil restrains bad odors, incidental fires and the propagation of noxious insects to a certain extent. However the problems of leachate and gas generation remain. As in the case of anaerobic landfill, the disposed solid waste maintains anaerobic conditions.

edc. **Improved Anaerobic Sanitary Landfill**

In addition to covering soil, a drainage facility for the leachate is introduced at the bottom of the disposal site. The quality of the leachate is accordingly improved, although the anaerobic conditions are still maintained.

edd. **Semi-Aerobic Sanitary Landfill**

As the leachate is constantly drained by drainage pipes, the quality of the leachate is improved to a certain degree. These drainage pipes stimulate natural ventilation, achieving aerobic conditions in the landfill layers. As a result, the decomposition of the solid waste is accelerated.

ede. **Aerobic Sanitary Landfill**

In addition to the drainage pipes used in semi-aerobic landfill, air supply pipes are introduced for air injection to achieve aerobic conditions in the layers, thus accelerating the decomposition and stabilization of the solid waste and improving the leachate quality.

In view of the different types of landfill structure types mentioned above, it is planned that final disposal sites in the Master Plan will employ the semi-aerobic sanitary landfill structure with leachate drain pipes for sanitary landfill.

ee. **Recovery of Methane Gas**

eea. **Minimum conditions of methane gas recovery**

According to the " Instruction Manual for Recovery of Methane Gas from Sanitary

Landfill" prepared by the Technology Company For Environmental Sanitation (CETESB), Brazil, November 1982, the criteria to ascertain whether or not a sanitary landfill is promising for methane gas production is presented as follows:

Population:	200,000	people
Landfill Volume:	2,000,000	tons
Average Depth:	9	meters
Area:	12	ha
Daily Disposal Amount:	500	tons/day

eeb. Inference regarding methane gas recovery

According to the above-mentioned manual, the recovery of methane gas is possible at all proposed landfills. It is, however, not examined in this report. The reasons are:

- It requires 3 to 4 years landfill operation to clear the above-mentioned criteria. In addition, it also requires several years to obtain a reasonable amount of gas after the clearance for the production of gas.
- In order to examine the feasibility of gas production, it is necessary to investigate quantity and quality of gas, including a test boring which is not included in the Scope of the Study.
- In order to produce methane gas, the landfill should be anaerobic, which deteriorates the quality of leachate. For the improvement of the leachate, the landfill structure in the Master Plan is proposed as semi-aerobic with a liner.
- If the Nicaraguan side wishes to produce methane in future, they will be able to change the semi-aerobic to anaerobic condition by sealing gas ventilation facilities.
- Although the recovery of methane gas at the present Acahualinca landfill is possible, the efficiency of the recovery may be insufficient due to the very permeable bottom layers and lack of sealing measures for them.

eec. Requirements for the feasibility study

Although this Study does not examine the feasibility study of methane gas recovery at the present Acahualinca landfill, it may be necessary to check the following aspects if the Nicaraguan side intends to conduct the study by themselves.

- quantity and characteristics of generated gas by test boring(s)
- quantity and characteristics of the wastes disposed

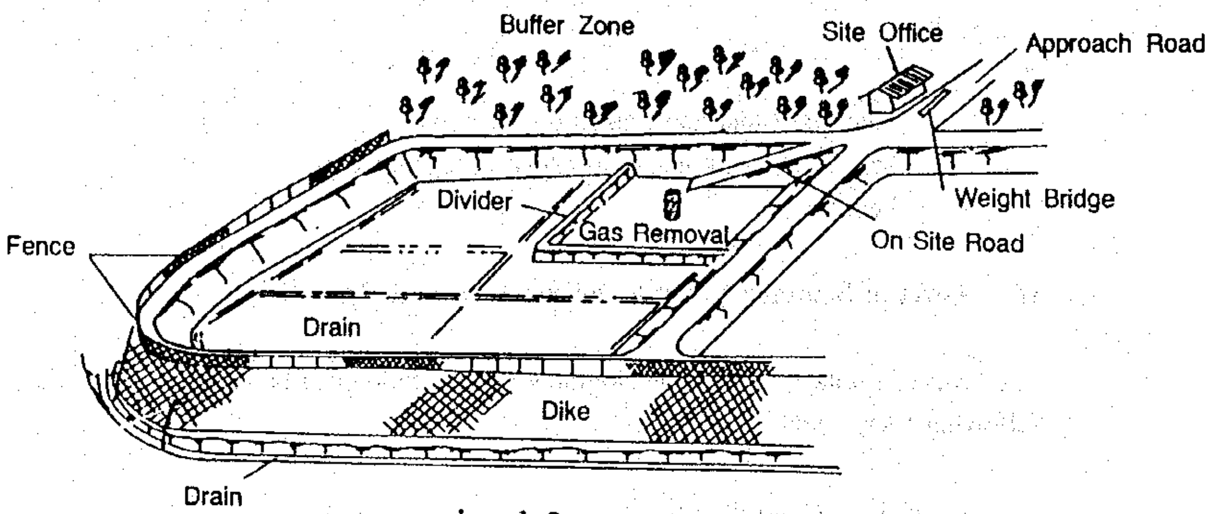
- potential users and utilization methods
- investment and operation and maintenance cost
- benefits

ef. Level of Sanitary Landfill Development and Operation

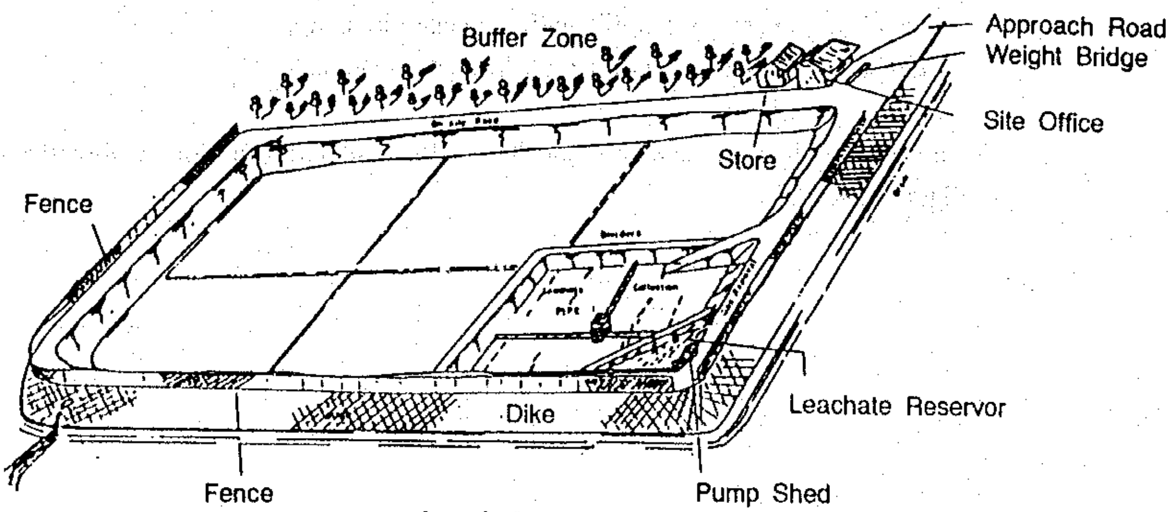
The level of sanitary landfill development and operation can be classified into the following four levels.

Level 1: Controlled tipping
Level 2: Sanitary landfill with a bund and daily soil covering
Level 3: Sanitary landfill with leachate circulation
Level 4: Sanitary landfill with leachate treatment

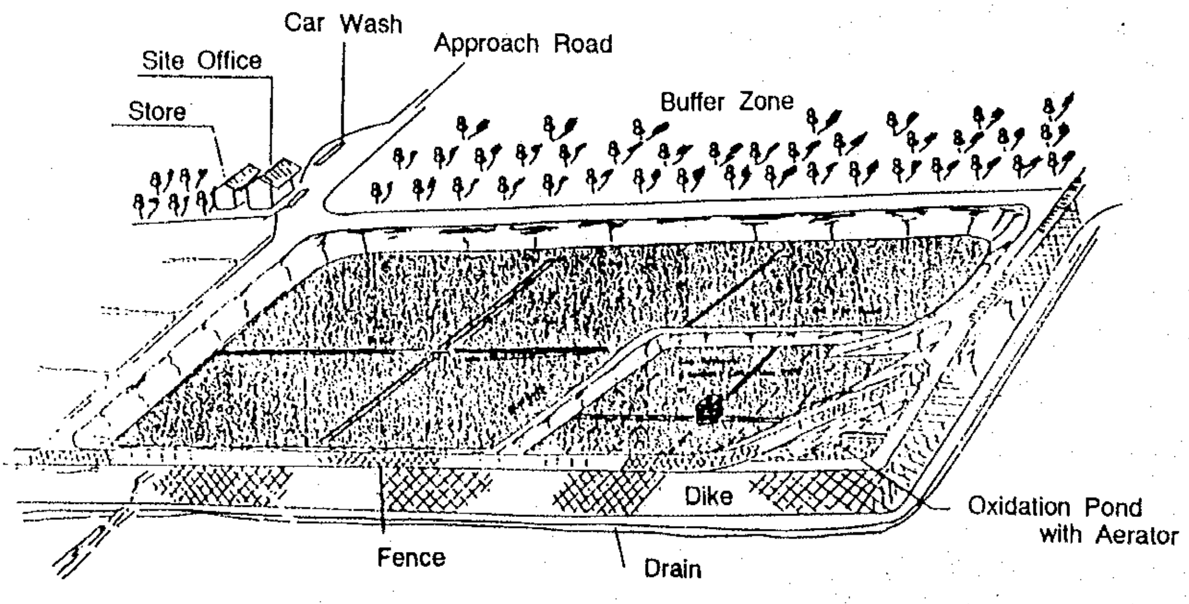
The prospective levels of sanitary landfill development and operation are illustrated in Figure H.4.1d.



Level 2



Level 3



Level 4

Figure H.4.1d Prospective Illustration of Sanitary Landfill Development and Operation in Level 2, 3 and 4

efa. Level 1; Controlled Tipping

Introduction of controlled tipping through:

- establishment of access to site
- provision of cover materials in order to prevent fire and dispersion of rank odor
- establishment of inspection, control and operational recording system of incoming waste

efb. Level 2; Sanitary Landfill with a Bund and Daily Soil Covering

Introduction of sanitary landfill through:

- establishment of site boundary in order to distinguish the disposal site and to eliminate scavenging
- execution of sufficient cover over waste disposed
- differentiation of a disposal area by the construction of an enclosing bund
- construction of a divider between present and future landfill areas
- establishment of a drainage system in order to divert storm water from surrounding areas and to reduce leachate
- construction of environmental protection facilities in order to abate direct impact on surroundings such as buffer zone, litter control and gas removal facilities
- installation of gas removal facilities to achieve the conditions of a semi-aerobic sanitary landfill
- introduction of amenities for staff

efc. Level 3; Sanitary Landfill with Leachate Circulation

Establishment of leachate control through:

- the installation of leachate collection, circulation and monitoring facilities
- the installation of liner to achieve seepage control
- construction of semi-aerobic sanitary landfill in order to facilitate the stabilization of waste disposed through the active decomposition in semi-aerobic condition
- introduction of dust prevention system by introducing water sprinkling

efd. Level 4; Sanitary Landfill with Leachate Treatment

Establishment of leachate treatment through:

- the installation of an oxidation pond

The above mentioned level of sanitary landfill development and operation are described and tabulated in Table H.4.1g. A comparison on the environmental standard to be achieved by each level of sanitary landfill development and operation is made and tabulated in Table H.4.2h.

Table H.4.1g Outline of Sanitary Landfill Development and Operation

Items	Level of Sanitary Landfill				Remarks
	1	2	3	4	
1. Site Development Works					
1.1 Main Facilities					
a. Enclosing Structure					
i. Enclosing Dike		A	A	A	
ii. Divider		B	A	A	- B: the dike is made from a mixture of waste and earth
b. Drainage System					
i. Surrounding Drain		A	A	A	
ii. On-site Drain (Surface Water)		A	A	A	- The drain is for the site which is not used for landfill
iii. On-site Drain (Underground Springs)		A	A	A	- If necessary
iv. Drain for Reclaimed Area		A	A	A	
c. Access					
i. Approach Road	A	A	A	A	
ii. On-site Road	A	A	A	A	
iii. Others	A	A	A	A	- Improvement of existing road network for accessing to the site
1.2 Environment Protection Facilities					
i. Buffer Zone		A	A	A	
ii. Litter Control Facilities		B	A	A	- Mobile fence,etc.
iii. Gas Removal Facilities		B	A	A	
iv. Leachate Collection Facilities			A	A	
v. Leachate Circulation Facilities			A	A	
vi. Seepage Control Facilities			B	A	
vii. Leachate Treatment Facilities				A	
1.3 Buildings and Accessories					
i. Site Office	B	A	A	A	
ii. Weigh Bridge	A	A	A	A	
iii. Storage Building			A	A	
iv. Safety Facilities		A	A	A	- Gate, fence, lights, etc.
v. Fire Prevention Facilities		B	A	A	- Water tank, fire extinguisher, etc.
vi. Monitoring Facilities			A	A	- Monitoring well, etc.
vii. Car Wash			A	A	
2 Equipment					
i. Landfill Equipment	A	A	A	A	
ii. Others			A	A	- Water truck, Inspection Vehicles, etc.
3 Operation and Maintenance					
3.1 Operation					
a. Personnel	A	A	A	A	
b. Cover Material	B	A	A	A	- B: insufficient operation
c. Utility					
i. Fuel	A	A	A	A	
ii. Water		A	A	A	
iii. Electricity	B	A	A	A	
d. Chemicals					
i. Insecticide	A	A	A	A	
ii. Monitoring Chemicals			A	A	
e. Others		A	A	A	- Divider, drain for reclaimed area, leachate collection pipes, etc.
3.2 Maintenance					
i. Main Facilities		A	A	A	
ii. Environment Protection Facilities		A	A	A	
iii. Building and Accessories	A	A	A	A	
iv. Equipment	A	A	A	A	

A means the facility is a necessity.
B means the facility is a necessity under a certain condition, or in case the budget is not enough, the facility might not be provided.

Table H.4.1h Comparison of Environment Level to be Achieved by Each Level of Sanitary Landfill Development and Operational

Items	Level of Sanitary Landfill Development and Operation			
	Level 1	Level 2	Level 3	Level 4
1. Landfill Structure				
1-1 Landfill Structure	- Anaerobic Sanitary Landfill	- Improved Anaerobic Sanitary Landfill.	- Semi-aerobic Sanitary Landfill	- Semi-aerobic Sanitary Landfill
1-2 Achieved Condition	- Leachate generated in solid waste layers is seldom drained but remains within, and always keeps landfill in an anaerobic state. Generally, the quality of leachate does not improve over a long time. - Because of inactive decomposition of wastes, prompt stabilization of a landfill is not achievable.	- Through gas removal facilities, the quality of leachate is slightly improved as compared with Level 1. Almost all of the solid waste, however, is still kept in an anaerobic state. - The rate of decomposition is also slightly improved.	- Leachate accumulated at the bottom of landfills is promptly discharged through drain pipes (leachate collection pipes). The pipes also permit natural ventilation. - This structure facilitates the decomposition of solid waste because of semi-aerobic condition by drain pipes. The quality of leachate is much improved and generation of offensive odor is further reduced. - Water content of solid wastes disposed is lower than Level 2.	- Same as Level 3.
2. Leachate and it's Impacts on Surroundings				
2-1 Leachate Generation Amount	- Leachate is freely discharged out from both landfilling and reclaimed areas because enclosing structure is not set up. - Rain water flows into the landfill from catchment area and it increases leachate amount.	- As for the reclaimed areas, surface water is drained and discharged out. - Rain water from the catchment area is diverted into surrounding drains. - A divider limits the area for leachate generation to the working area. - As mentioned above, since the area for leachate generation is limited, leachate amount is also limited to the precipitation on the certain area.	- Same as Level 2.	- Same as Level 2.
2-2 Leachate Control Facilities	- None	- Enclosing dike and divider prevents direct discharge of leachate.	- In addition to the facilities for Level 2, there are leachate cycling and monitoring facilities. - Leachate is discharged only during heavy rain from regulating pond. Leachate discharged is therefore, diluted.	- Same as Level 3 except for effluent which is constantly treated and discharged from oxidation pond.
2-3 Leachate Treatment Facilities	- None	- None	- Retention and regulation ponds may work as oxidation pond.	- Leachate is treated in an oxidation pond with aerator.

2-4	Leachate Quality	- Amount of leachate is high and it's quality is worse than any other levels. Besides that, there shall be little improvement on the quality even after a long period of time.	- Amount of leachate is limited because of dike and divider. However, the quality of leachate is not improved after a long period of time.	- Amount of leachate is limited as in Level 2. - The quality of leachate is improved more rapidly than Level 2 because of the semi-aerobic landfill condition. - Leachate circulation facilitates purification by the wastes disposed. - Since leachate is discharged only during heavy rain, it is therefore, diluted.	- Amount of leachate is limited as in Level 2 - The quality of leachate to be discharged will be treated in order to meet with an effluent standard.
2-5	Impacts by Leachate				
a.	Impacts on Underground water	- The impacts are dependent on the permeability of bottom soil. - If it is a permeable bottom soil, the impacts on underground water is very high because of high pressure head and large amount of leachate.	- The impacts are dependent on the permeability of bottom soil. - The amount of leachate is much less than Level 1. However, the impacts are still high in the case of permeable bottom soil.	- Liner is laid so as to prevent underground water from leachate seepage. - There is very little underground water contamination.	- Liner is laid so as to prevent underground water from leachate seepage. - There is very little underground water contamination.
b.	Impacts on Surface Water	- Because of free discharge of leachate from a landfill site, the impacts on to surrounding water area is very high.	- Discharged of leachate may occur when the divider is overflown and through seepage. - Although leachate amount is limited, impacts on to surrounding water area is still high because of uncontrolled and unimproved leachate.	- Discharge of leachate is made only during heavy rain. - Leachate can be monitored. In case leachate to be discharged would affect the surroundings, the construction of leachate treatment facility is encouraged.	- Effluent from landfill site will satisfy a required effluent standard.
3.	**Others**				
3-1	Vector control	- Great generation of flies, insects and rodents. - Great crow gathering. - Odors are constantly generated.	- Vector control is achieved and it is much improved compared to Level 1.	- Same as Level 2.	- Same as Level 2.
3-2	Odors and Gas Production	- Occasional fires occur due to spontaneous ignition.	- It is much better than Level 1. - No occurrence of fire	- Due to semi-aerobic landfill structure, it is better than Level 2.	- Same as Level 3.
3-3	Others	- Litter of wastes and dust. - Deterioration of Landscape. - Noise. - Existing of scavengers.	- It is improved in all aspects.	- In addition to the condition achieved at Level 2, dust problem is improved by a water sprinkler.	- Same as Level 3.

eg. Selection of Leachate Treatment Method

The treatment of leachate is an important factor in the study of the Master plan disposal site facilities because it contaminates groundwater. Accordingly, the results of the survey carried out by JICA in 1993 on groundwater development in

Managua city were reviewed and the following were confirmed:

- Groundwater is the only drinking water source of the 1 million population of Managua city.

- The groundwater source of Managua city and those that can be utilized originate from the mountain ranges that administratively divide the city, pass through the urban areas and flow north toward Managua Lake.

- Managua city is almost entirely volcanic in geology and covered by extremely permeable scoria layers. The rivers in the area are dry rocky watercourses, except during heavy rain.

Figure H.4.1e shows the relationship between groundwater flow and the disposal site candidates.

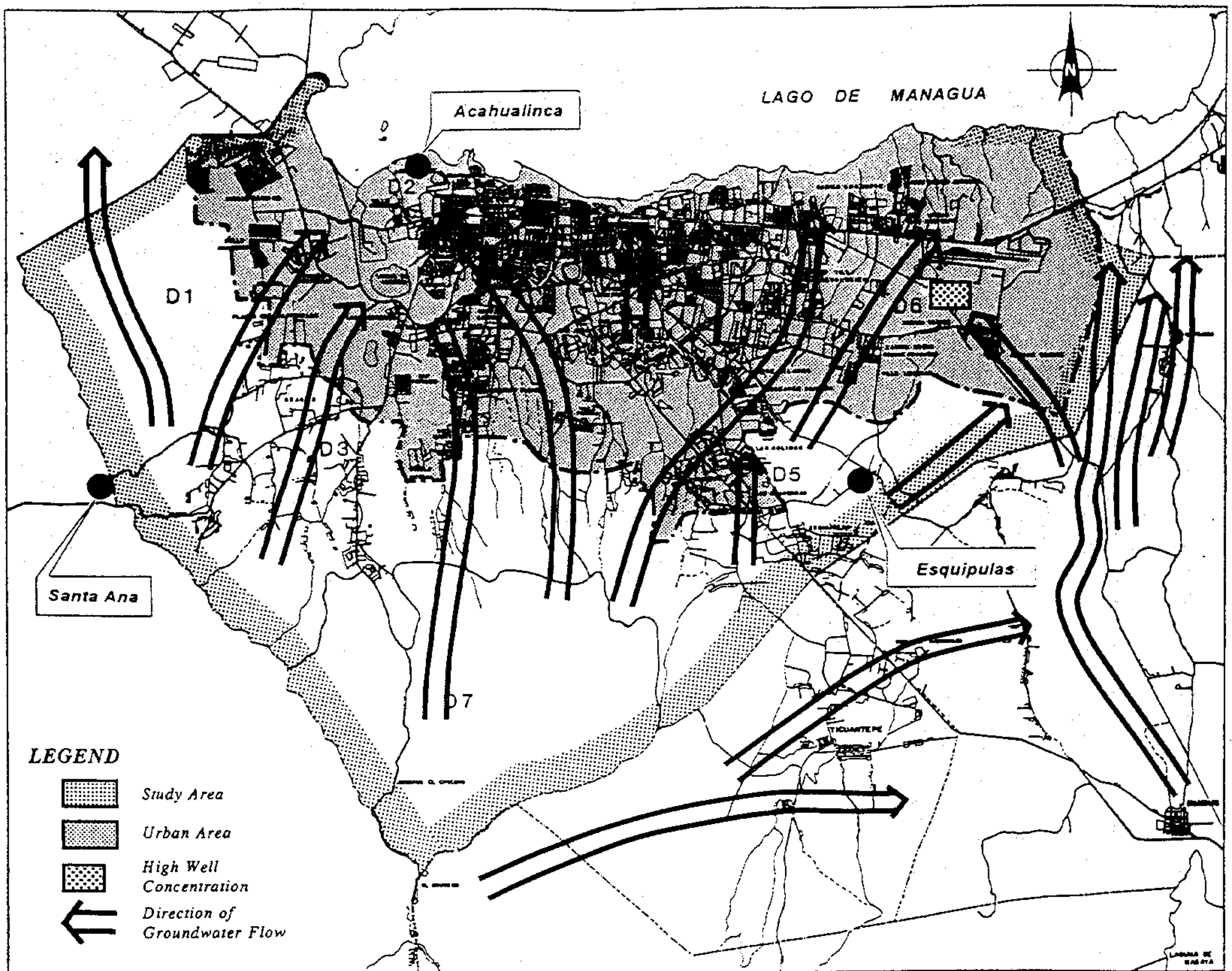
Based on the conditions stated above, it can be assumed that the leachate discharged by the candidate disposal sites, except for the Acahualinca disposal site, in the rainy season, could contaminate groundwater (drinking water source) through infiltration of the dry river beds.

Groundwater contamination is expected to occur if leachate from disposal sites is discharged without undergoing treatment. Even if leachate is diluted with rain water, the groundwater quality will not satisfy the standard quality for drinking water.

The installation of water treatment facilities should be considered, therefore, for the Esquipulas candidate disposal site which can possibly cause groundwater contamination, and the Santa Ana candidate disposal site outside the city, which has a diverse water system and an influence on the downstream basin.

On the one hand, the Acahualinca disposal site is considered to have no effect on groundwater as a drinking water source because it is located near Managua Lake, the final destination of groundwater flow. However, the quality of leachate from the existing Acahualinca disposal site is worse than the quality of Managua Lake, and is one of the factors that contaminate the waters of Lake Acahualinca. In consideration of this, the installation of water treatment facilities in the Acahualinca candidate disposal site, as a means of leachate control, would be desirable.

Given the above conditions, all candidate disposal sites for the Master Plan Study shall be incorporated with the leachate treatment facilities categorized under Level 4.



-THE STUDY ON THE IMPROVEMENT OF THE SOLID WASTE MANAGEMENT SYSTEM FOR THE CITY OF MANAGUA

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Figure 3.2.5c Candidate Disposal Site and Ground Water Flow

H.4.2 Examination of Technical System Component

a. Concept of the Alternatives

The alternatives, advantages, disadvantages and evaluation of technical components for each sub-system are shown in Table H.4.2a.

As for the components of each item, the location of final disposal sites and introduction of transfer station differ with each alternative. On the other hand, the components of discharge & storage, collection & haulage and street sweeping differ only slightly with each alternative, i.e. hauling distance, collection vehicle, etc..

Table H.4.2a Component of Technical System Alternatives (Discharge and Storage)

Technical Sub-system	Component	Advantages	Disadvantages	Evaluation	Conclusion
a. Source Separation	. Mixed discharge	. Present discharging system. . Lower cost.	Inappropriate for introduction of a processing facility and/or recycling plant and /or composting plant		
	. Separate discharge	Appropriate for the introduction of a processing facility or recycling plant and/or composting plant.	. High cost. . Public cooperation is required.	The introduction of the separate discharge system will be recommended in future, if the introduction of a processing and/or composting plant is feasible.	**Mixed discharge**
b. Type of Storage Equipment	. Bag/Sack	. The present system in residential areas. . Nylon sacks are cheap, easy to handle and reusable.	Littering due to animal scavenging.	Nylon sacks are suitable in residential areas as they are cheap, easy to handle and recyclable.	**Nylon sacks or plastic bags** Residential areas (collection area A)
	. Bucket	Recyclable.			**Public containers** Collection area B, large waste generation sources i.e. commercial area, markets, hospitals, etc., street sweeping and waste from park and green area cleansing.

Technical Sub-system	Component	Advantages	Disadvantages	Evaluation	Conclusion
b. Type of Storage Equipment	. Public container	. Appropriate when there is no access for the collection vehicles. . Appropriate for large waste generation sources due to high collection efficiency.	Public cooperation is required.	. Regarding non-collection service area (e.g. urban fringe area), due to the lack of access routes for the collection vehicle, the introduction of public containers shall be examined. . Regarding large waste generation sources, due to the requirement of increased collection efficiency, the introduction of public containers shall be examined. . Regarding public area cleansing, including street sweeping, the introduction of public containers shall be examined in order to maintain the cleanliness of public areas.	

Table H.4.2b Components of Technical System Alternatives (Collection and Haulage)

Technical Sub-system	Component	Advantages	Disadvantages	Evaluation	Conclusions
a. Collection Frequency				. The collection frequency shall be examined considering sanitary aspects and operation cost. . The collection frequency and route of the container system shall be examined using a truck scale.	The present frequency, i.e. three times a week for residential areas and every day except sundays for large waste generation sources.
b. Collection Method	. Mixed collection	. Present collection system. . Lower cost.	. Inappropriate for introduction of a processing facility and/or recycling plant and/or composting plant.		**Mixed collection**
	. Separate collection	. Appropriate for the introduction of a processing facility and/or recycling plant and/or composting plant.	. High cost. . Public cooperation required.	. The introduction of the separate collection system will be recommended in future, if the introduction of a processing facility and/or recycling plant and/or composting plant is feasible.	

Technical Sub-system	Component	Advantages	Disadvantages	Evaluation	Conclusions
c. Type of Collection Service	. Curb collection	. Present collection system in the residential area. . High collection frequency.	. Public cooperation is required. . For scheduled service, public cooperation is required. . Many spillage and littering problems.	. Present curb collection system, due to high collection efficiency and low cost is appropriate for the Study area. . However, public cooperation and scheduled service is necessary of the introduction of the curb collection to prevent unsanitary conditions initiated by animal scavenging and waste littering.	**Curb collection** in collection area A. **Container collection** in collection area B and large generation sources, i.e. commercial areas, markets, hospitals,etc., and waste from park and green area cleansing.
	. Door to door collection (i.e. set-out-set-back collection, set-out collection, backyard collection)	. Public cooperation is not required. . For scheduled service, public cooperation is not required. . No spillage and littering problems. . Unattractive to scavengers.	. Low collection efficiency. . Costs due to large crew and time requirements is high.		
	. Bell collection	. No spillage and littering problems. . Unattractive to scavengers. . High collection efficiency.	. Public cooperation is required. . For scheduled service, public cooperation is required.		
	. Public container collection	. High collection efficiency. . For residents, discharge time is not limited to collection days.	. Public cooperation is required. . Attractive to scavengers. . Spillage and littering problems.		

Technical sub-system	Component	Advantages	Disadvantages	Evaluation	Conclusion
d. Collection Time	. Day collection	. If there is no traffic congestion, the collection efficiency is high.	. If the traffic is highly congested, the collection efficiency is low and dangerous for the workers.	. Under the existing conditions, it is deemed that heavy traffic conditions will not disturb the efficiency of waste collection work.	**Day collection**
	. Night collection	. If there is traffic congestion during the day, the collection efficiency is high. Collection work is safe at night when there is little traffic.	. If there is no traffic congestion during the day, the collection efficiency is low at night.		
e. Type of Collection Vehicle	. Compaction type	. High waste loading factor. . No waste scattering during transportation. . Easy to unload.	. Complicated maintenance procedure. . Expensive. . Incapable of loading bulky waste.	. Compaction type ($15m^3$) is common in the residential areas of collection area A.	**The compactor type** is recommended for residential areas in collection area A.

Technical sub-system	Component	Advantages	Disadvantages	Evaluation	Conclusion
f. Type of Collection Vehicle	. Detachable container truck	. Maintenance is relatively facile. . Easy to unload. . Container can be used as a collection vessel. . High collection and haulage efficiency.	. High purchase cost due to number of containers required. . Possibility of waste scattering during transportation, if the open loading type is used. . Difficult to load bulky waste.	. Regarding non-collection areas (e.g. urban fringes), due to the lack of access routes for the collection vehicles, the introduction of detachable container trucks shall be examined. . Regarding large waste generation sources, due to the requirement of increased collection efficiency, the introduction of detachable container trucks shall be examined. . Regarding public cleansing including street sweeping, the introduction of detachable container trucks shall be examined in order to maintain the cleanliness of public areas.	**The detachable container type** is suitable due to the efficiency of collection and loading work for collection area B, large generation sources and public areas.
	. Standard truck	. Maintenance is facile. . Operation is facile. . Capable of collecting bulky waste. . Compatible with present collection system and relatively simple to operate. . Multi-purpose.	. Low waste loading factor. . High possibility of waste scattering during transportation, if the open tipper is employed. . Possibility of being used for other purposes		

Technical system	Component	Advantages	Disadvantages	Evaluation	Conclusions
g. Haulage system	. Motor vehicle haulage	. Present haulage method. . Flexibility . Transfer station is not required if the location of the disposal site is near the collection area.	. Small hauling capacity.		**Motor vehicle haulage**
	. Railway haulage	. Large haulage capacity. . Low haulage cost per km.	. Two transfer stations are needed, both at loading and unloading points. . Limited flexibility.	There are no railways in the Study area and there is a good national road system along the shores of Lake Managua. These systems require loading and unloading facilities and transfer vehi–cles, thus, a certain amount of capital investment is re–quired.	
	. Water Haulage	. Large haulage capacity. . Low haulage cost per km. . Less flexibility.	. Two transfer stations area needed, both at loading and unloading points. . Unsuitable under bad weather conditions.		
h. Transfer Station	. Necessity			. If the distance from the main generation source to the disposal site exceeds 20 km, the introduction of a transfer station shall be examined.	. For Santa Ana candidate disposal site, the intro–duction of a transfer station will be examined.

Table H.4.2c Components of Technical System Alternatives (Street Sweeping)

Technical Sub-system	Component	Advantage	Disadvantage	Evaluation	Conclusion
a. Cleansing Method	. Manual street sweeping	. Creation of many jobs. . Low capital cost. . Operation is flexible. . Applicable to where debris accumulate frequently. . Ability to clean areas under parked vehicles. . Ability to clean under harsh weather conditions. . Low operation noise.	. High labor cost. . Supervision is not facile. . Dangerous under heavy traffic conditions.	. The present system is more suitable under the condition of high unemployment ratio in the Study area.	**Manual street cleaning.**
	. Mechanical cleaning	. High productivity. . Low manpower. . Operation is safe for workers.	. High capital cost. . Low flexibility of operation. . Operation in narrow areas is difficult. . Operation produces a lot of noise. . Operation under heavy traffic conditions is difficult.	Unsuitable.	Not viable.
	. Vacuum cleaning	. High cleaning capability. . Sewage pipes are unharmed by dust accumulation. . Less dust.	. High capital cost. . Low flexibility of operation. . Operation in narrow areas is difficult. . Operation produces a lot of noise. . Operation under heavy traffic conditions is difficult.	Unsuitable.	Not viable.
	. Flushing	. No dust.	. A large amount of water is required. . May lead to clogging of sewage pipes. . Dangerous in winter. . Low flexibility of operation. . Operation in narrow areas difficult. . Operation under heavy traffic is difficult.	Unsuitable.	Not viable.

Table H.4.2d Components of Alternatives (Intermediate Treatment)

Technical Sub-system	Component	Advantages	Disadvantages	Evaluation	Conclusion
		Examination of intermediate treatment technologies and type of waste and availability of technical system is shown in Tables 3.2.4b and 3.2.4c respectively.	Examination of intermediate treatment technologies and type of waste and availability of technical system is shown in Tables 3.2.4b and 3.2.4c respectively.	Upon consideration of different intermediate treatment systems and the present MSWM in the Study area, these intermediate treatment systems were omitted for the following reasons.	
a. Incineration				. The LCV of the MSW is very low (1,215kcal/kg) and it requires auxiliary fuel for combustion. . The cost was estimated to be more than 26.3 US$/ton. The highest sanitary landfill cost in this study was estimated at 8.6 US$/ton which included the treatment of leachate. . There are enough candidate sanitary landfill sites for future disposal operations	Not viable.

Technical Sub–system	Component	Advantages	Disadvantages	Evaluation	Conclusion
b. Composting				. The market for compost from municipal solid waste is very limited in the Study area. . Other competent fertilizers derived from animal excrement are easily obtained in the region. . Due to high production cost, subsidies o the sale price will be necessary to make compost from municipal solid waste competitive in fertilizer markets. . High cost of transportation and labor for the utilization of compost. . Less volume reduction. . Possibilities of toxic heavy metals and secondary pollution in case of mixed collection.	Not viable.
c. RDF				. Waste which can be converted to RDF is very limited. . The technology is in its developing stage. . The market for RDF products are limited.	Not viable.
d. Pyrolysis				. The waste quality is limited. . The technology is under development. . The operation of the plant is very difficult. . Large capital investment and high operational cost are required.	Not viable.

Technical Sub-system	Component	Advantages	Disadvantages	Evaluation	Conclusion
		Examination of intermediate treatment technologies and type of waste and availability of intermediate technical system is shown in Tables 3.2.4b and 3.2.4c respectively.	Examination of intermediate treatment technologies and type of waste and availability of intermediate technical system is shown in Tables 3.2.4b and 3.2.4c respectively.		
e. Ash Solidification				. Large capital investment and high operation cost are required. . The technology is in its developing stage. . Land for final disposal is still available in the Study area. . Operation is difficult.	Not viable.
f. Biogas				. High investment cost. . The technology is in its developing stage; only a few years operational experience regarding MSW.	Not viable.
g. Size Reduction (Crushing and Shredding)				. Waste is limited to bulky waste and its production is minimal. . Bulky waste can be recycled manually.	Not viable.

Technical Sub-system	Component	Advantages	Disadvantages	Evaluation	Conclusion
h. Sorting				. The present recycling system (manual recycling system), mainly established in the private sector, functions well. . The introduction of the sorting facility may cause conflict with the present private sectors concerned with recycling activities (e.g. scavengers) because it may reduce their job. . Prices of recyclable materials are unstable. . The amount of recyclable materials in MSW is minimal. . Volume reduction of a sorting facility is minimal.	Not viable.

Table H.4.2e Components of Technical System Alternatives (Final Disposal)

Technical Sub-system	Component	Advantages	Disadvantages	Evaluation	Conclusion
a. Location and Number of Final Disposal Sites				. Acahualinca, Santa Ana and Esquipulas were selected as candidate disposal sites by the Coordination Committee. . Both centralized and separate disposal systems are considered for candidate alternatives.	**Acahualinca** **Santa Ana** **Esquipulas**
	. Centralized disposal	. Low construction cost of the disposal site. . Low operation and maintenance cost of the disposal site.	. High transportation costs.	. Both centralized and separate disposal system are considered as a component of the alternative.	. Centralized disposal system: Acahualinca Santa Ana . Separate disposal system: Santa Ana + Esquipulas
	. Separate disposal	. Transport cost is low.	. Construction and operation & maintenance cost is high.		
	. Level of sanitary landfill development and operation.	. Outline of sanitary landfill development and operation and comparison of environmental level to be achieved during each landfill level are shown in Tables 3.2.5a and 3.2.5b respectively.	. Outline of sanitary landfill development and operation and comparison of environmental level to be achieved during each landfill level are shown in Tables 3.2.5a and 3.2.5b respectively.	. Leachate should be treated to avoid contaminating groundwater which is used for drinking.	**Level 4:** Sanitary landfill with leachate treatment.

b. Candidate Alternatives

Candidate alternatives, a combination of technical system components selected in section 3.2 and summarized in H.4.1, were formulated. The concept of candidate alternatives are composed of the system components as shown in Table H.4.2f in addition to the components of collection, haulage and street sweeping which do not differ greatly in each alternative.

Table H.4.2f Candidate Alternatives for Master Plan Study

System Component		Candidate Alternatives				
		A-1	A-2	A-3	A-4	A-5
Location of Sanitary Landfill Site	Acahualinca	x				
	Santa Ana		x	x		x
	Esquipulas				x	x
Transfer System				x		

Note: Each candidate alternative consists of "x" systems.

H.5 Examination of Technical System Alternatives

H.5.1 Concept of Each Alternative

H.5.1.1 Concept

a. Technical System Component of Alternatives

The concept of alternatives are summarized in Table H.5.1a.

Table H.5.1a Concept of Technical System Alternatives

Disposal	Site	Transfer System	Alternative No.
Centralized Disposal	Acahualinca	Without	A-1
	Santa Ana	Without	A-2
		With	A-3
	Esquipulas	Without	A-4
Separate Disposal	Santa Ana & Esquipulas	Without	A-5

aa. Type of system in terms of final disposal site location

Centralized disposal system and separate disposal system, two types of MSWM alternatives, are considered for candidate alternatives.

In a centralized disposal system, the wastes collected from the Study area are hauled to one disposal site to reduce construction, operation and maintenance costs.

In a separate disposal system, the wastes collected from each area are hauled to the nearest disposal site to reduce transportation cost.

ab. Candidate site

Acahualinca, Santa Ana and Esquipulas were selected as candidate disposal sites by the Coordinating Committee of Managua Municipality. The centralized disposal system is considered for alternatives A-1,2,3 and 4, while the separate disposal system is considered for Santa Ana and Esquipulas candidate disposal sites in Alternative A-5.

ac. Transfer system

In order to examine the most appropriate haulage system, the alternatives with and without the transfer station were formulated for examination. In the case of distance exceeding 20 km from the collection area to the disposal site, the introduction of a transfer station should be examined to reduce haulage cost. When considering Santa Ana candidate disposal site, the wastes collected from Districts 4, 5, and 6, which exceed a transportation distance of 20 km, will be hauled to the transfer station primarily, then to the final disposal site.

H.5.1.2 Concept of Each Alternative

a. Alternative A-1: Acahualinca Disposal Site without a Transfer Station

Alternative A-1 is presented as an extended disposal system providing sanitary landfill operation at the existing Acahualinca disposal site. All waste collected from the Study Area will be hauled directly to the disposal site without a transfer station nor processing facilities. The alternative is illustrated in Figure H.5.1a.

b. Alternative A-2: Santa Ana Disposal Site without a Transfer Station

Alternative A-2 is presented as a disposal system providing sanitary landfill operation at Santa Ana disposal site. All waste collected from the Study area will be hauled directly to the disposal site without a transfer station nor processing facilities. The alternative is illustrated in Figure H.5.1b.

c. Alternative A-3: Santa Ana Disposal Site with a Transfer Station

Alternative A-3 is presented as a disposal system providing sanitary landfill operation at Santa Ana disposal site. The waste collected from areas within 20 km from the disposal site, i.e. districts 1 to 3 will be hauled directly to the disposal site without a transfer station. However, the waste collected from areas outside the 20 km radius, i.e. districts 4 to 6 will be carried to the disposal site via a transfer station. The alternative is illustrated in Figure H.5.1c.

d. Alternative A-4: Esquipulas Disposal Site without a Transfer Station

Alternative A-4 is presented as a disposal system providing sanitary landfill operation at Esquipulas disposal site. All waste collected from the Study Area will be hauled directly to the disposal site without a transfer station nor processing facilities. The alternative is illustrated in Figure H.5.1d.

e. Alternative A-5: Santa Ana and Esquipulas Disposal Sites without a Transfer Station

Alternative A-5 is presented as a separate disposal system providing sanitary landfill operation at Santa Ana and Esquipulas disposal sites. The waste collected from districts 1 to 3 will be hauled to Santa Ana disposal site. On the other hand, the waste collected from districts 4 to 6 will be hauled to Esquipulas disposal site. All wastes will be hauled directly to the disposal site without a transfer system nor processing facilities. The alternative is illustrated in Figure H.5.1e.

Alternative A-1:

Centralized Sanitary Landfill at Acahualinca without a transfer station

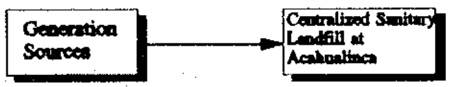

Figure H.5.1a Concept Flow for Alternative A-1

Alternative A-2:

Centralized sanitary landfill at Santa Ana without a transfer station

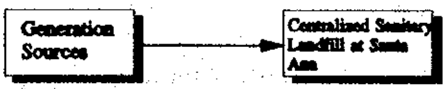

Figure H.5.1b Concept Flow for Alternative A-2

Alternative A-3:

Centralized sanitary landfill at Santa Ana with a transfer station

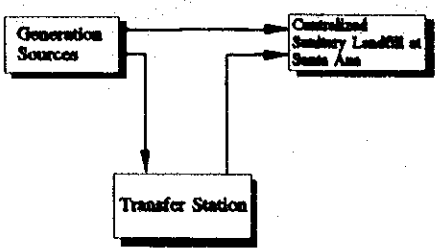

Figure H.5.1c Concept Flow for Alternative A-3

Alternative A-4

Centralized sanitary landfill at Esquipulas without a transfer station

Figure H.5.1d Concept Flow for Alternative A-4

Alternative A-5:

Separate sanitary landfill at Santa Ana and Esquipulas without a transfer station

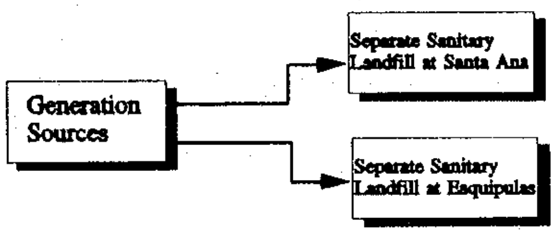

Figure H.5.1e Concept Flow for Alternative A-5

H.5.2 Conceptual Design and Cost Estimation

First of all, it should be noted that the purpose of the conceptual design and cost estimation is to compare the cost of each technical system alternative. The design and estimation work is simplified as much as possible and a more detailed design including modification of the conceptual design and cost estimation will be done at the Feasibility Study stage.

H.5.2.1 Premises

a. Objectives

Based on the results of the examination of the system component (refer to Section 3.2), this section presents the conceptual design and estimates for the following MSWM systems and facilities in Managua:

- –storage and collection system
- –haulage system
- –system for street sweeping
- –sanitary landfill

b. Key Assumptions

ba. For design

baa. Key assumptions for design

The conceptual design of this report were made based on the following key assumptions:

Table H.5.2a Key Assumptions for Design

Design Items	Applied Figure	Unit	Remarks
1. Storage and Collection			
1-1 ASG of Waste in Compactor	0.44	ton/m^3	
1-2 ASG of Waste in Container	0.22	ton/m^3	
1-3 Operation Rate of Vehicles	0.9		
2. Haulage			
2-1 ASG of Waste in Transfer Vehicle (Non-compaction Type)	0.3	ton/m^3	
3. Street Sweeping			
3-1 ASG of Waste in Compactor	0.44		
3-2 ASG of Waste in Container	0.22	ton/m^3	
4. Final Disposal			
4-1 ASG of MSW	1.0	ton/m^3	After compaction

Table H.5.2b Distance Table for Alternatives

Alternative	A-1	A-2	A-3			A-4	A-5	
Distance (km)	8.3 from genera-tion to disposal site	18.0 from genera-tion to disposal site	15.8 districts 1-3 to disposal site	5.0 districts 4-6 to transfer station	16.9 transfer station to disposal site	11.0 from genera-tion to disposal site	15.8 districts 1-3 to disposal site	10.0 districts 4-6 to disposal site
Waste collec-tion Amount (ton/day)	1,483	1,483	593	890		1,483	593	890

bab. Waste stream

In order to carry out the conceptual design and cost estimation, the waste streams in the year 2010 for each alternative are presented in Table H.5.2c.

Table H.5.2c Waste Stream for MSW in Managua in the Year 2010

Alternatives	Unit	A-1	A-2	A-3	A-4	A-5
a. Generation	ton/day	2265.2	2265.2	2265.2	2265.2	2265.2
b. Self Disposal	ton/day	223.5	223.5	223.5	223.5	223.5
c. Recycling at Generation	ton/day	47.0	47.0	47.0	47.0	47.0
d. Collection Amount	ton/day	1,483	1,483	1,483	1,483	1,483
e. Street Sweeping	ton/day	20	20	20	20	20
f. Waste amount at T/S	ton/day	0	0	890	0	0
g. Recycling	ton/day	37.0	37.0	37.0	37.0	37.0
h. Amount of Direct Haul Waste	ton/day	512.3	512.3	512.3	512.3	512.3
i. Waste amount at Final Disposal Site per day	ton/day	1958	1958	1958	1958	1958
j. Waste amount at Final Disposal Site per year (i x 365)	ton/year	714,560	714,560	714,560	714,560	714,560

bb. Location of facilities

The location of the candidate disposal sites and transfer station area shown in Figure H.5.2a.

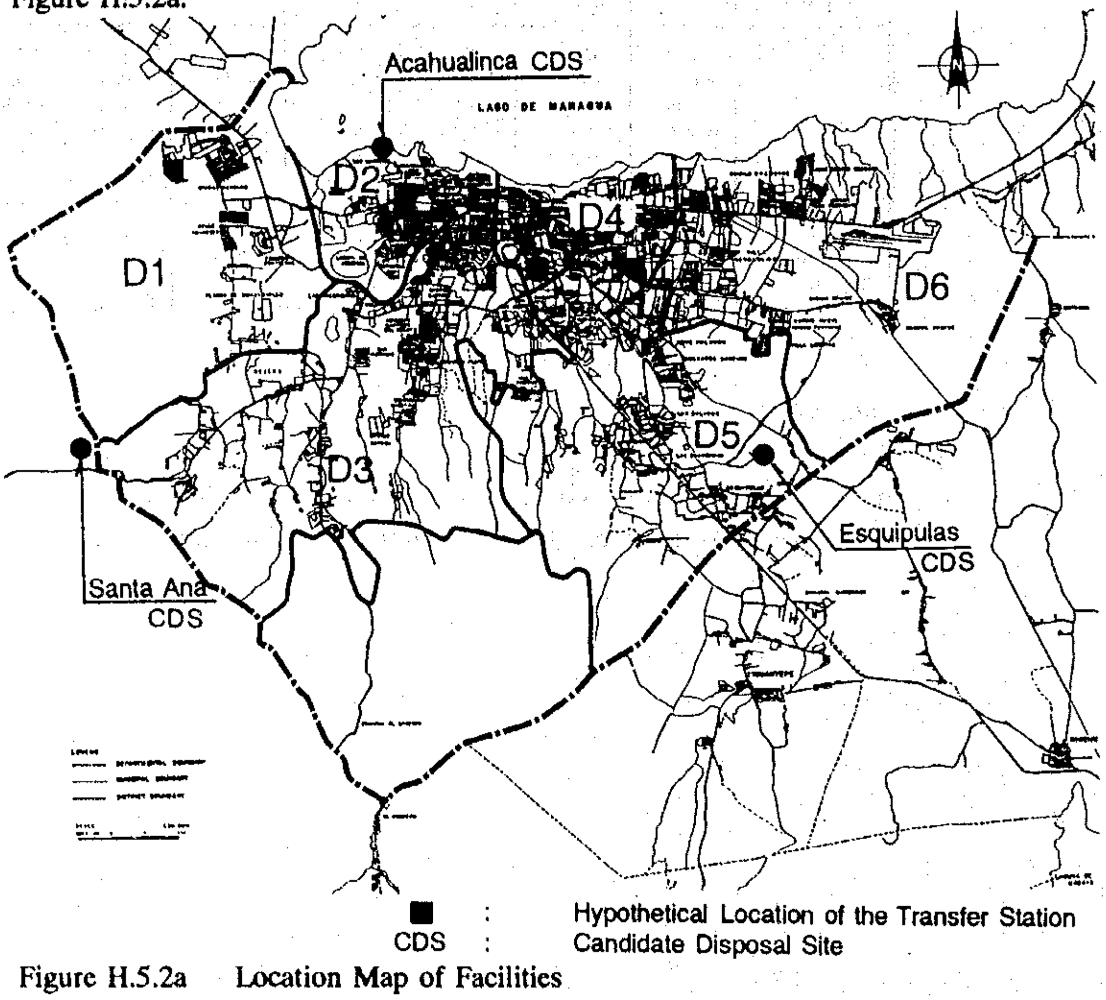

Figure H.5.2a Location Map of Facilities

bc. For cost estimation

bca. Basic consideration

The cost of each technical system alternative is used to represent the annual MSWM cost in 2010. Consequently, the following assumptions were made for cost estimation:

i. The executing body of MSWM will be the Municipality.

ii. Cost comparison is carried out by means of the O & M (Operation and Maintenance) cost in the year 2010 which includes the depreciation cost of all facilities and equipment related to MSWM.

iii. Cost estimation is conducted based on the price in June 1994. The exchange rate is US$1=C$6.62.

iv. The estimated cost does not include interest or tax. Although the actual cost should include them, they were excluded because the purpose of the cost comparison is to select the optimum alternative. The actual cost will be estimated at the Feasibility Study stage.

bcb. Annual working days and working efficiency

The annual working days are determined as follows;

- Total days per year	:	365
- Sundays	:	53
- Public holidays	:	15
Total working days	:	**297 days/year**

Equipment is assumed to be operated for 8 hours per day. The operation rate of equipment is assumed at **0.9**.

bcc. Life span of equipment and facilities

	Life Span (years)
Containers	5
Trucks and Heavy Equipment	7
Machineries	15
Buildings and Civil Works	30

Note: The life span of other facilities for the disposal site depends on the period of its operation.

H.5.2.2 Storage and Collection System

a. Wastes and Collection Amount

aa. Wastes

The objective wastes for the storage, collection and haulage plan are as follows;

- household waste (Area A & B)
- commercial waste (restaurant, others)
- market waste
- institutional waste
- hospital waste
- street sweeping waste
- park and green area waste
- industrial waste

ab. Collection amount

The waste collection amount of each collection system in 2010 is shown in Table H.5.2d.

Table H.5.2d Waste Collection Amount in 2010 unit : ton/day

Collection System	Type of Waste	1994	2010
Compactor (15.3m^3)	Household (Area A)	299.4	864
	Commercial (Restaurant)	23.6	47
	Sub-total	323.0	911
Compactor (15m^3) & Container (1.0m^3)	Commercial (Others)	11.2	22
	Institutional	2.4	5
	Hospital	5.0	10
	Street Sweeping	(16.3)	20
	Industrial	11.2	17
	Sub-total	46.1	74
Hoist Truck & and Container (7.0m^3)	Household (Area B)	(47.0)	465
	Market	14.2	28
	Park & Green Area	(1.8)	5
	Sub-total	63.0	498
Total		432.1	1,483

* The figure in parentheses indicates the waste collection amount from a combination of wheel loaders and dump trucks.
* At present, market waste is collected using Roll-on Roll-off trucks and 15m^{3}containers.

b. Storage system

ba. Assumptions

A storage system assumed for MSW in this section is summarized in Table H.5.2e.

Table H.5.2e Assumed Storage System

Category of Wastes	Storage System
Household Waste (Area A)	Nylon Sacks or Plastic Bags
Household Waste (Area B)	7.0m^3 Container
Commercial Waste (restaurant)	Plastic Bags
Commercial Waste (others)	1.0m^3 Container
Market Waste	7.0m^3 Container
Institutional Waste	1.0m^3 Container
Hospital Waste	1.0m^3 Container
Street Sweeping Waste	1.0m^3 Container
Park and Green Area Waste	7.0m^3 Container
Industrial Waste	1.0m^3 Container

bb. Required number of containers

The number of containers required is calculated by the following formula;

$$Qc = Qw \times 7/Qd/E/ASG/C \text{ (unit)}$$

Qc : Number of containers required (unit)
Qw : Waste collection amount (ton/day)
Qd : Number of working days per week = 6 (day)
E : Rate of efficiency = 0.8
ASG : Apparent Specific Gravity
C : Capacity of Container (m^3)

Consequently, the number of required containers is as follows:

Table H.5.2f Required Number of Containers ($1.0m^3$)

Type of Container	For D1 - 3	For D4 - 6	Total
1.0 m^3 Container	143	215	358
7.0 m^3 Container	187	280	467

Note: D1 - 3 : Districts 1 - 3
D4 - 6 : Districts 4 - 6

c. Collection system

ca. Assumptions

The collection system assumed in this section is as follows:

Table H.5.2g Collection System

Category of Wastes	Collection vehicle	Type of Vessel
Household (Area A) Commercial (Restaurant)	Compactor ($15.3m^3$)	Nylon Sacks or Plastic bags
Commercial (Others) Institutional Hospital Street Sweeping Industrial	Compactor ($15.3m^3$)	Public Container ($1.0m^3$)
Household (Area B) Market Waste Park & Green Area	Hoist Truck	Public Container ($7.0m^3$)

cb. Estimation of required number of collection vehicles

The required number of collection vehicles according to the alternatives was calculated based on the following conditions and procedures:

i. Most of the present collection vehicles in the Study Area were donated in 1993. However, as the Master Plan is for 2010, which is in 17 years time, the required number of vehicles cannot be calculated based on the present number of vehicles.

ii. As described in the previous section, it is assumed that vehicles will be utilized 297 days/year and operate for 8 hrs/day, with a operation ratio of 0.9.

iii. The required time for the collection work differs with the area. Since the rear loading 15.3m^3 compaction truck is the most common collection vehicle for the city of Managua, the work efficiency of this type of vehicle is applied to the estimation of the required number of collection vehicles.

iv. According to the data observed by the truck scale at the Acahualinca disposal site from July 11th to 16th, 1994, the average collection amount of a 15m^3 compactor was 5.86 tons/trip.

v. The collection work consists of the following works:

- collection
- haulage
- dumping
- miscellaneous

The required time for collection work differs with the method. The collection system, i.e. compactor (15.3m^3), compactor (15.3m^3) + container and hoist truck + container (7.0m^3) will be established by 2010. Therefore, the time share of each operation was summarized in Table H.5.2.2f based on the Time and Motion (T&M) Survey conducted from May 16th to 21st, 1994.

Table H.5.2h Time share of Each Collection Work Observed by the Time& Motion Survey

Collection System	Compactor (15.3m^3)	Compactor(15.3m^3) + Container (1.0m^3)	Hoist Truck + Container (7m^3)
Collection	140 (62%)	70 (45%)	10 (14%)
Haulage	40 (18%)	40 (26%)	40 (55%)
Dumping	15 (7%)	15 (10%)	15 (20%)
Miscellaneous	30 (13%)	30 (19%)	8 (11%)
Total	225 (100%)	155 (100%)	73 (100%)

v. Based on the applied time for one cycle of collection work, the required number of collection vehicles was calculated; i.e. the required time for collection, haulage and discharge will differ in accordance with alternatives.

With the above-mentioned procedures, the required number of collection vehicles for each alternative is calculated and tabulated in Table H.5.2.2f.

Table H.5.2i Required Number of Collection Vehicles

	A-1	A-2	A-3	A-4	A-5
Compactor Trucks ($15.3m^3$)	86	108	89	92	95
Compactor Trucks ($15.3m^3$) with Container Lifter	6	7	6	6	7
Hoist Truck	72	124	79	87	95

d. Cost estimate

da. Method

The collection cost in 2010 of each alternative was estimated in accordance with the following methods:

- By 2010, all the equipment being used at present is assumed to have exceeded its economic lifespan and will have been replaced by this time. Therefore the depreciation costs are calculated based on the price of equipment recommended in this plan in 1994 and life span.

- At the time of cost estimation for the personnel expenses, the disposition of the staff for the collection work are assumed as follows.

Collection System	Driver	Workers
Compactor $15.3m^3$	1	3
Compactor $15.3m^3$+Container($1.0m^3$)	1	2
Hoist Truck+Container($7.0m^3$)	1	1

- The cost of fuel and lubricant for the collection works is calculated according to the running distance obtained in the Time and Motion Survey.

Collection system	Running Distance (km)
Compactor $15.3m^3$	12
Compactor $15.3m^3$ + Container ($1.0m^3$)	16
Hoist Truck + Container ($7.0m^3$)	0.86 (hypothetical distance)

- Based on the market price of diesel etc., the unit cost of fuel and lubricant is assumed to be 0.82 C$/km.

db. Unit cost

According to the above mentioned method, the unit collection cost for each alternative was calculated and tabulated in Table H.5.2j.

Table H.5.2j Unit Collection Cost for Each Alternative

		A-1	A-2	A-3	A-4	A-5
Depreciation Fuel & Lubricant O & M	C$/ton C$/ton C$/ton	40.78 1.27 22.24	51.16 1.27 29.62	42.38 1.27 23.24	43.38 1.27 24.33	45.29 1.27 20.60
Total Unit Cost	C$/ton	64.29	82.05	66.89	69.44	67.16
Collection Amount	ton/day	1,458	1,458	1,458	1,458	1,458
Total Cost	mill C$	34.2	43.7	35.6	37.0	35.7

H.5.2.3 Haulage System

a. Consideration for Planning

Haulage activities are divided into two categories; primary haulage and secondary haulage. Primary haulage is the transportation of waste from the collection area to the final disposal site (direct haulage) or transfer station by the collection vehicles. Secondary haulage is the transportation of the waste hauled by the collection vehicle from the transfer station to the final disposal site. A trailer truck is used to efficiently carry out secondary haulage. Secondary haulage is considered only for Alternative 5.

aa. Haulage amount

The haulage amount for each alternative is shown in Table H.5.2k.

Table H.5.2k Haulage Amount of Each Alternative

(unit: ton/day)

	A-1	A-2	A-3		A-4	A-5
			without T/S	with T/S		
Primary Haulage	1,483	1483	593	890	1483	1483
Secondary Haulage	-	-	-	890	-	-

Waste to be collected for secondary haulage will be those discharged in Districts 4 to 6, areas furthest from the disposal site.

ab. Haulage distance

The haulage distance of each alternative are shown in Table H.5.2b.

b. Primary haulage

It is difficult to divide collection and haulage because the same vehicles are used in both works. Therefore, fuel and lubricant costs were included in the primary haulage cost to examine cost variation according to the distance from the collection area to the disposal site.

The depreciation costs of the equipment and personnel expenses are included in the collection costs estimated in the foregoing paragraph.

c. Secondary haulage

ca. Location of the Transfer Station

The location of the transfer station was examined by using a map on a scale of 1 to 10,000 taking into consideration the nearest point from Districts 4, 5 and 6 to Santa Ana, the proposed final disposal site, and accessibility. The map states that the most suitable location for the transfer station is located near the junction between Ruben Ave. and Pista de la Municipalidad Ave. This place was selected temporarily as it is deemed advantageous for the comparison study of alternatives for the Master Plan.

cb. Type of transfer station

There are two types of transfer station: the direct re-loading type and the indirect re-loading type. The latter has a waste compactor. This study adopted the former because it is cheaper and easier to operate and maintain due to its simple structure.

cc. Type of transfer vehicles

A transfer vehicle should be as big as possible for efficient haulage. Therefore a 70 m^3 trailer truck was selected for the secondary haulage. This model is the biggest transfer vehicle found in the Central and South American region.

cd. Required number of vehicles

The required number of vehicles for secondary haulage was estimated as follows:

- Loading capacity
  70 m^3 x 0.3 ton/m^3 = 21.0 tons/vehicle
- Time share of transfer cycle
  Loading = 40 min
  Hauling = 51 min (16.9 km/one way)
  Dumping = 20 min
  Miscellaneous = 15 min
  Total = 126 min

- Haulage amount per vehicle
  21.0 tons/v x 60 min x 8 hr/126 min x 0.9 = 72 tons/day

- Required number of vehicles
  890 tons/day x 7 days/ 6 days/72 tons = 15

ce. Basic design of transfer station

The facilities for the transfer station are shown in Table H.5.2l taking into consideration the estimated transfer amount and number of vehicles, etc.. The layout plan of the transfer station is shown in Figure H.5.2b.

Table H.5.2l Facilities of Transfer Station

Facilities	Quantities
Required Area	5,000 m^2
Building (inc. Office)	500 m^2
Approach Road	50 m
Truck Scale	2 sets
Refuse Hopper	4 sets
Crane	1 sets
Container Truck (70m^3)	15 vehicles
Water Tank Truck	2 vehicles

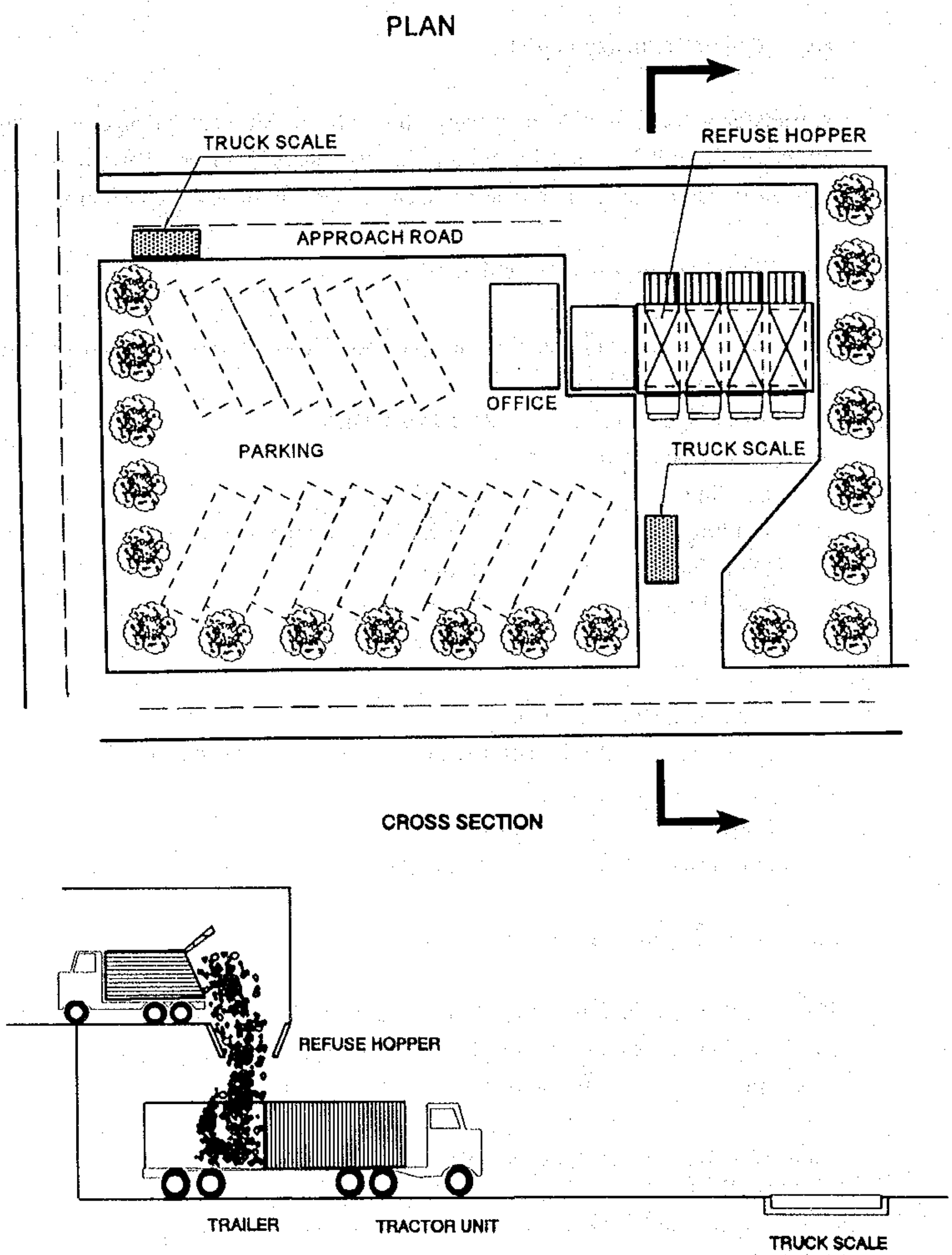

Figure H.5.2b Layout Plan of Transfer Station

d. Cost Estimate

da. Method

The haulage cost in 2010 of each alternative was estimated in accordance with the following methods:

daa. Primary haulage

- Since the depreciation cost and personnel expenses of primary haulage is included in the collection cost estimate, they were omitted in this estimate.
- The cost of fuel and lubricant represent primary haulage.
- Hauling velocity is estimated to be the same as the collection velocity, i.e. 20 km/hr.
- The unit cost of fuel and lubricant was set at 0.82 C$/km.
- The cost of primary haulage was estimated by the number of transfer cycles, hauling distance per cycle and the unit cost of fuel and lubricant.

dab. Secondary haulage

- The depreciation cost was estimated by dividing the life span of the facilities by their price.
- Construction cost of the transfer station was estimated by using the quantities indicated in Table H.5.21 and the unit cost described in Chapter 2.
- Hauling velocity is taken as 40 km/hr.
- Hauling distance is taken as 16.9 km one way.

db. Haulage cost

According to the method mentioned above, the haulage costs were estimated as follows:

Table H.5.2m Haulage Cost

unit: million C$ (C$/ton)

	A-1	A-2	A-3	A-4	A-5
Primary Haulage	2.56 (4.81)	5.55 (10.43)	2.87 (5.40)	3.39 (6.37)	3.80 (7.73)
Secondary Haulage	-	-	4.13 (12.7)	-	-
Total	2.56 (4.81)	5.55 (10.43)	7.00 (13.15)	3.39 (6.37)	3.80 (7.73)

H.5.2.4 Street Sweeping System

a. Consideration for Planning

Street sweeping is carried out by each district. According to the institutional recommendations in the progress report, this examination was executed under the premise that street sweeping is to be carried out by the Public Cleansing Office.

b. Objective Waste and Collection Amount

The objective waste is street sweeping waste and the amount of waste collected by this service in 2010 was estimated at 20.4 tons per day.

c. Street Sweeping System

ca. Sweeping system

The present manual sweeping system is to be continued due to the following reasons:

- high unemployment ratio in the Study area
- poor road conditions such as relatively narrow streets, low asphalt and concrete pavement rate, poor condition of storm water drains and curb stones, lack of parking areas, etc.

cb. Storage system

As for the storage system of swept waste, the 1.0 m^3 public container is proposed.

cc. Required number of containers

The number of containers required for the storage of swept waste is calculated by the following formula;

$$Qc = Qw \times 7/Qd/E/ASG \text{ (unit)}$$

Qc : Number of containers required (unit)
Qw : Waste collection amount (ton/day)
Qd : Number of working days per week = 6 (day)

E : Rate of efficiency = 0.8
ASG : Apparent Specific Gravity = 0.22

Consequently, the number of required containers is estimated as follows:

Table H.5.2n Required Number of Containers ($1.0m^3$) for Street Sweeping

Alternative	A-1	A-2	A-3	A-4	A-5
Number of Containers	133	133	134	133	134

cd. Collection system

The proposed collection system for street swept waste is the one using the $15.3m^3$ compaction truck with the $1.0m^3$ public containers.

ce. Estimation of required number of collection vehicles

The required number of collection vehicles was calculated based on the conditions and procedures described in Section H.5.2.2, Collection System. The required number of collection vehicles for street sweeping is calculated and tabulated in Table H.5.2o.

Table H.5.2o Required Number of Collection Vehicles for Street Sweeping

Type of Vehicles	A-1	A-2	A-3	A-4	A-5
Compactor Truck $15.3m^3$	2	2	2	2	2

d. Cost Estimate

da. Method

The street sweeping service cost in 2010 for each alternative was estimated in accordance with the following methods:

- The total street sweeping service cost in 1994, assuming that the O & M expense includes depreciation cost of equipment, was calculated based on the 1993 figures.
- The unit cost of street sweeping service work (C$/ton) was calculated by dividing the total collection cost by the total collection amount of swept waste obtained from the truck scale.

- Since the present street sweeping service cost includes depreciation cost of equipment, which is negligible, the depreciation cost was calculated and added based on the price in 1994 and life span of the equipment. The depreciation cost of collection vehicles includes some spare vehicles by means of the rate of their operations (0.9).
- The street sweeping cost obtained by the above-mentioned methods is divided into street sweeping (manual) cost and collection (by 1.0m^3 public container) cost.
- The unit street sweeping cost (manual) is simply calculated by subtracting the unit collection cost from the unit street sweeping service cost.
- Upon consideration of haulage distance, work efficiencies, etc., the time share of each work item (collection, haulage, discharge and miscellaneous) for each alternative was estimated based on the present time share of collection work by the 15.3m^3 compactor.
- Unit collection cost (C$/ton) for each alternative was calculated based on collection time and collection amount of one cycle.

db. Street sweeping cost

According to the above mentioned method, the unit street sweeping service cost for each alternative was calculated and tabulated in Table H.5.2p.

Table H.5.2p Street Sweeping Cost

Costs	Unit	A-1	A-2	A-3	A-4	A-5
Street Sweeping Services	C$/ton mill.C$	689.26 5.03	689.26 5.03	689.26 5.03	689.26 5.03	689.26 5.03
Collection & Haulage	C$/ton mill.C$	110.74 0.81	113.36 0.83	111.01 0.81	111.47 0.81	111.83 0.82
Total Street Sweeping	C$/ton mill.C$	800.00 5.84	802.62 5.86	800.27 5.84	800.73 5.84	801.09 5.85

H.5.2.5 Park and Green Area Cleansing System

a. Consideration for Planning

The park and green area cleansing services are carried out by the Beautification Head Office in the Municipality. According to the institutional recommendations the examination was executed under the premise that park and green area cleansing is to be carried out by the Public Cleansing Office.

b. Objective Waste and Collection Amount

The objective waste and its amount, i.e. from park and green areas, in 2010 was estimated at 4.9 tons per day.

c. System of Park and Green Area Cleansing

ca. Cleansing system

The present manual cleansing system is planned to be continued due to the following reasons:

- high unemployment ratio in the Study area
- these areas can only incorporate manual cleaning methods

cb. Storage system

As for the storage system, the 7.0 m^3 public container is proposed.

cc. Required number of containers

The number of containers required for the storage of waste is calculated in the same manner as the street sweeping system. The number of required containers is estimated as follows:

Table H.5.2q Required Number of Container (7.0m^3) for Park and Green Area Cleansing

Alternative	A-1 to A-5
Number of Containers	10

cd. Collection system

The proposed collection system is the one using hoist trucks with 7.0m^3 public containers.

ce. Estimation of required number of collection vehicles

The required number of collection vehicles was calculated based on the conditions and procedures described in Section H.5.2.2, Collection System. The required number of collection vehicles for park and green area cleansing is calculated and tabulated in Table H.5.2r.

Table H.5.2r Required Number of Collection Vehicles for Park and Green Area Cleansing

Type of Vehicles	A-1	A-2	A-3	A-4	A-5
Hoist Truck	1	2	2	1	2

d. Cost Estimate

da. Method

The service cost of park and green area cleansing in 2010 for each alternative was estimated in accordance with the following methods:

- The total service cost in 1994, assuming that the O & M expense includes depreciation cost of equipment, was estimated as 20% of the total expenses of the Beautification Head Office in 1993.
- The unit cost of park and green area cleansing service work (C$/ton) was calculated by dividing the total collection cost by the total collection amount of swept waste obtained from the truck scale.
- Since the present service cost includes depreciation cost of equipment which is almost negligible, the depreciation cost was calculated and added based on the price in 1994 and life span of equipment. The depreciation cost of collection vehicles includes some spare vehicles by means of their operation rate (0.9).
- The park and green area cleansing cost obtained by the above-mentioned methods is divided into cleansing (manual) cost and collection (by 7.0m^3 public container) cost.
- The unit cleansing service cost (manual) is simply calculated by subtracting the unit collection cost from the unit service cost.
- Upon consideration of haulage distance, work efficiencies, etc., the time share of each work item (collection, haulage, discharge and miscellaneous) for each alternative was estimated based on the present time share of collection work by the hoist truck and 7m^3 container.
- Unit collection cost (C$/ton) for each alternative was calculated based