# ANNEX P

## F/S - 1:
## Municipal SWM System Improvement Project

## Contents



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# P F/S-1: Municipal SWM System Improvement Project

## P.1 Outline of the Municipal SWM System Improvement Projects

### a. Target

The Municipal SWM System Improvement Project aims to improve the solid waste collection, haulage and disposal systems between 2001 and 2005 in order to attain the targets shown in Table P-1.

Table P-1: Targets of the Municipal Solid Waste Management System Improvement Project

| Item | Unit | 1996 (At the time of the Study) | 2001 | 2003 | 2005 |
|---|---|---|---|---|---|
| Population in Granada City | persons | 96,996 | 126,307 | 147,830 | 171,618 |
| Population within Study area | persons | 76,250 | 100,382 | 107,330 | 114,760 |
| Waste generation amount (A) | ton/day | 57.1 | 80.3 | 88.5 | 97.5 |
| Waste discharge amount (B) | ton/day | 43.2 | 62.8 | 70.1 | 78.2 |
| Waste collection amount (C) | ton/day | 35.4 | 56.5 | 63.1 | 70.4 |
| Coverage Rate (C/B) | % | 81.9 | 90 | 90 | 90 |
| Population served | persons | 48,037 | 89,083 | 96,249 | 101,843 |
| Street Sweeping | km | 35 | 35 | 37 | 40 |
| Final disposal | | | | | |
| Disposal amount | thousand $m^3$/year | 16.8 | 26.8 | 29.8 | 33.1 |
| Name of the disposal site | - | La Joya | SJV a new landfill site | | |
| Level of disposal method | - | Level 1 | Level 4 | | |

### b. Outline of Municipal SWM System Improvement Project

The outline of the project which is proposed to realize the targets in Table P-1 are shown in Table P-2.

Table P-2: Outline of Municipal SWM System Improvement Project

| | Contents |
|---|---|
| 1. Refuse Collection System Improvement Project | |
| 1.1 Refuse Collection System Improvement | Procurement of equipment:<br>General collection (street/point)<br>• $12m^3$ compactor truck: 5 in 2000, 1 in 2002, 1 in 2004<br>• Special collection service<br>• 1 of $10m^3$ tipper truck (2000),<br>• 1 of wheel loader (2000) |
| 1.2 Improvement of Street Sweeping | Procurement of equipment:<br>• 12 $m^3$ compactor trucks (included in the above)<br>• 30 Nos. of hand carts |

| | Contents |
|---|---|
| 1.3 Improvement of the Modulo de Operacion Workshop | • Renovation in 2000, Operation from 2001.<br>• Renovation works: operation yard, inspection pit, water tank, lighting, electrical system, etc.<br>• Procurement of equipment: tools, etc. |
| 2. SJV A New Municipal SW Disposal Site Development Project | • Construction in 2000, Operation from 2001.<br>• Level of Sanitary Landfill: level 4 (i.e., sanitary landfill with a leachate treatment facility)<br>• Total volume (till 2010): 436,700 $m^3$,<br>• Volume of F/S period (till 2005): 179,400 $m^3$<br>• Major facilities: One landfill section for 5 years (3.5 ha), regulation pond, facultative lagoon, maturation pond, access road, office, stormwater drainage system, etc.<br>• Procurement of landfill equipment: 1 bulldozer, 1 backhoe, 1 tipper truck, and 1 water tanker |
| 3. Improvement of Administrative System | • Strengthening of the UEMB (Urban Environmental Maintenance Bureau, and procurement of office equipment<br>• Improvement of organizational system |

**b. Field Investigation**

During the 3rd Study Work in Nicaragua, the field investigations necessary for the F/S of Municipal Solid Waste Management System Improvement Project (F/S-1) were carried out.

**c. Refuse Collection System Improvement Project**

A survey was carried out on "Modulo de Operacion" maintenance workshop, which maintains and repairs vehicles and heavy machinery, etc. owned by Granada Municipality at present, for the Refuse Collection System Improvement Project.

**d. A New Municipal SW Disposal Site Development Project**

The following surveys, necessary for formulating A New Municipal SW Disposal Site Development Project and its Environmental Impact Assessment (EIA), were conducted.

1. Topographical survey of the SJV site
2. Route survey from SJV to Tepetate sewage treatment plant
3. Geological survey of SJV
4. Environmental Baseline Survey of the SJV site:
   It comprises: water quality survey; air quality survey; hydrological survey; noise and vibration survey; traffic volume survey; odor survey; soil analysis; flora and fauna survey; economic activities survey; land use survey; water use survey; landscape analysis by photo-montage; cultural inheritance survey; borrow pit survey for cover soil and soil for an impermeable liner work.

# P.2 Preliminary Design of the Refuse Collection System Improvement Project

## P.2.1 Design Conditions

**a. Planned Waste Collection Amount**

Table P-3 shows the waste collection amount in 1996 and from 2001 to 2010.

Table P-3: Waste Generation, Discharge and Collection Amount

| Description | Unit | 1996 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Generation | t/day | 57.1 | 80.3 | 84.2 | 88.5 | 92.7 | 97.5 | 102.0 | 107.1 | 112.2 | 117.6 | 123.4 |
| Discharge | t/day | 43.2 | 62.8 | 66.2 | 70.1 | 73.9 | 78.2 | 82.3 | 86.9 | 91.7 | 96.7 | 102.0 |
| Collection | t/day | 35.4 | 56.5 | 59.6 | 63.1 | 66.5 | 70.4 | 82.3 | 86.9 | 91.7 | 96.7 | 102.0 |
| Coverage Rate (waste) | % | 82 | 90 | 90 | 90 | 90 | 90 | 100 | 100 | 100 | 100 | 100 |
| Total Population | Person | 97,078 | 100,382 | 103,798 | 107,330 | 110,983 | 114,760 | 118,568 | 122,502 | 126,567 | 130,767 | 135,106 |
| Served Population | Person | 61,159 | 89,083 | 92,115 | 95,249 | 98,491 | 101,843 | 118,568 | 122,502 | 126,567 | 130,767 | 135,106 |
| Coverage Rate (pop.) | % | 63 | 89 | 89 | 89 | 89 | 89 | 100 | 100 | 100 | 100 | 100 |

### b. Refuse Collection System

### b.1 Classification of Collection Service

The plan for the collection service shall be classified in consideration of the conditions in the areas and quality of services required. The classification of the areas is shown in Figure P-1. The collection service is classified into the 4 categories as follows:

1. Curb Collection Area A: CCA
   Urban Core Area with street sweeping services
2. Curb Collection Area B: CCB
   Urban Core Area/Semi-Urban Area without street sweeping services
3. Point Collection Area: PCA
   Urban Fringe/Semi-Urban Area without street sweeping services
4. Special Collection Service: SCS
   Special collection service to collect bulky waste and the large amount of garden waste etc., and removal of illegally dumped waste and sedimented soil.

Based on the classified collection service plan above, the waste collection amount and collection rate to be achieved during the F/S period are summarized in the following table. Moreover, besides, the municipal collection service, constructors which directly haul non-hazardous industrial waste, etc. were taken into account.

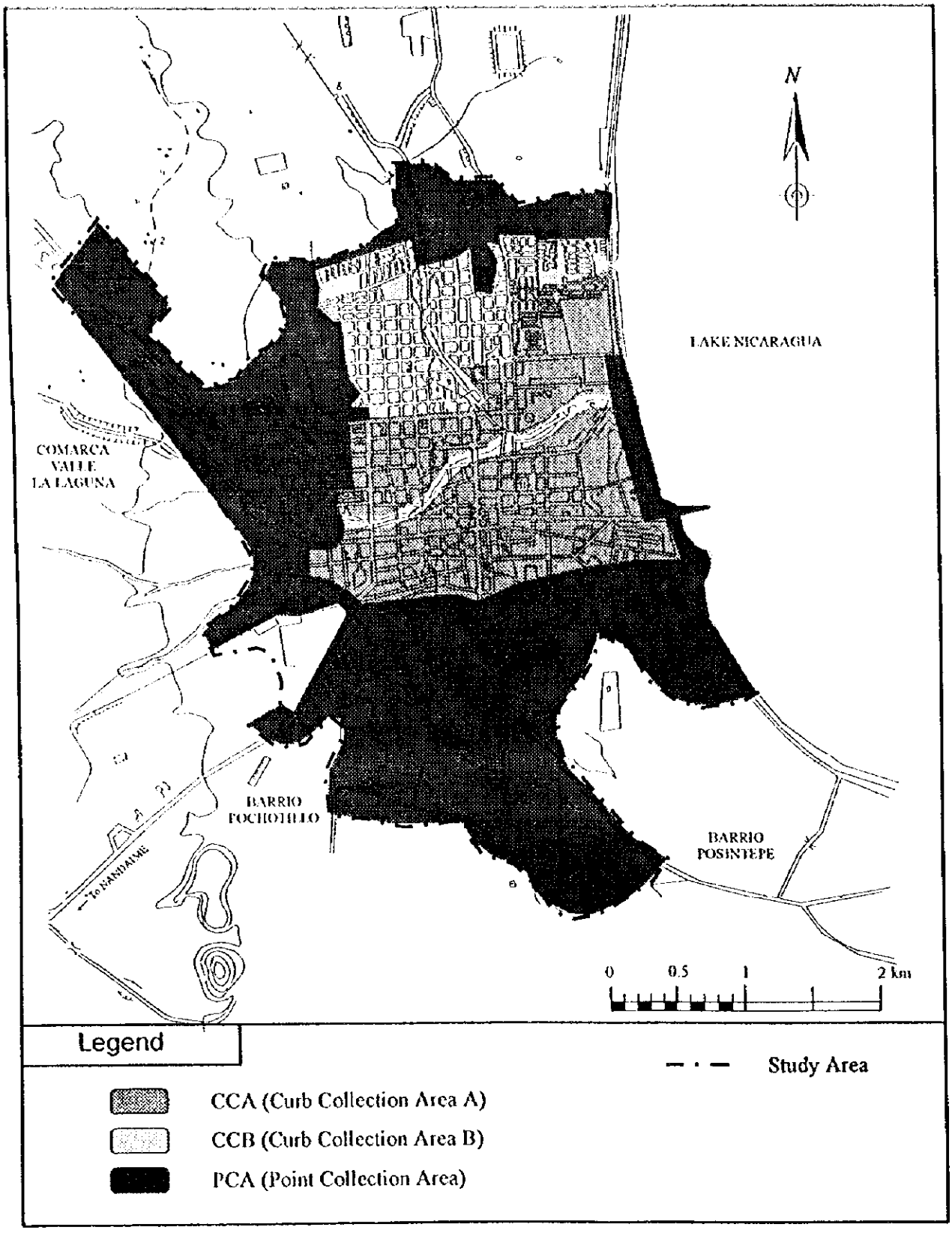



Figure P-1: Classification of Waste Collection Areas

Table P-4: Waste Collection Plan

| Item | code | Unit | 1996 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|
| Total generation amount | a+b+c | ton/day | 57.1 | 80.3 | 84.2 | 88.5 | 92.7 | 97.5 |
| Discharge amount (including street sweeping amount) | a | ton/day | 43.2 | 62.8 | 66.2 | 70.1 | 73.9 | 78.2 |
| Self disposal amount | b | ton/day | 8.9 | 10.5 | 10.6 | 10.7 | 10.7 | 10.8 |
| Recycling amount at generation | c | ton/day | 5.0 | 7.0 | 7.4 | 7.7 | 8.1 | 8.5 |
| Collection rate | (A/a) | % | 81.9 | 90.0 | 90.0 | 90.0 | 90.0 | 90.0 |
| Total collection amount (A) | A=e+h+j | population (person) | 48,037 | 89,083 | 92,115 | 95,249 | 98,491 | 101,843 |
| | | ton/day | 35.4 | 56.5 | 59.6 | 63.1 | 66.5 | 70.4 |
| Curb Collection Area A | | population (person) | -- | 35,633 | 36,845 | 38,099 | 39,397 | 40,737 |
| | General waste :d | ton/day | -- | 24.0 | 25.3 | 26.6 | 28.1 | 29.7 |
| | Street sweeping waste :e | ton/day | -- | 1.3 | 1.3 | 1.4 | 1.4 | 1.5 |
| Curb Collection Area B | | population (person) | -- | 26,725 | 27,635 | 28,575 | 29,547 | 30,553 |
| | f | ton/day | -- | 15.1 | 16.0 | 17.0 | 17.9 | 19.0 |
| Point Collection Area | | population (person) | -- | 26,725 | 27,635 | 28,575 | 29,547 | 30,553 |
| | g | ton/day | -- | 15.1 | 16.0 | 17.0 | 17.9 | 19.0 |
| Household waste (street sweeping amount not included) | h=d+f+g | ton/day | -- | 54.2 | 57.3 | 60.6 | 63.9 | 67.7 |
| Special Collection Service | Illegally dumped waste: i | ton/day | -- | 6.3 | 6.6 | 7.0 | 7.4 | 7.8 |
| | Bulky waste: j | ton/day | -- | 1.0 | 1.0 | 1.1 | 1.2 | 1.2 |
| Other Wastes (direct haulage) | k | ton/day | 2.0 | 2.2 | 2.2 | 2.2 | 2.3 | 2.3 |

### b.2 Waste Collection Frequency

The frequency of waste collection shall be as follows;

Curb Collection Area A: 4 times/week

Curb Collection Area B: 3 times/week

Point Collection Area: 2 times/week

## P.2.2 Planning the Collection and Transportation System

### a. Determination of Refuse Collection Vehicle Type

This section compares eight different waste collection vehicles in terms of unit collection cost.

### a.1 Equation for Required Number of Vehicles

The following equations were adopted for computing the number of vehicles required.

- Number of trips per day (Tr)

$$Tr = (t1-(t2+t3))/(D/V+t4+t5)$$

*where,*

Tr: Number of trips per day
D: Travel distance per trip (km)
V: Velocity (km/hr)
t1: Working hours per day (hr)
t2: Daily inspection and fueling time before working (hr)
t3: Daily inspection and washing time after working (hr)
t4: Loading (collection) time (hr)
t5: Unloading time (hr)

- Amount of waste carried(Qd)

$Qd = (q \times e) \times Tr / (1 + r) \times 0.5$

*where,*

Qd: Amount of waste carried(ton/day/truck)
q: Volume capacity of a vehicle ($m^3$)
e: Efficiency of loading capacity
r: Reserve rate of vehicle
ASG of waste (0.5)

- Number of vehicles (Nv)

$Nv = WCA \times 7 / Wd / Qd$

*where,*

Nv : Required number of vehicles
WCA : Waste collection amount(ton/day)
Wd : Working days per week (6 days)

### a.2 Cost Comparison

From a long term viewpoint, unit costs were calculated based on the collection amount in 2010 (102.0 ton/day). Table P-5shows the unit cost of each vehicle.

Table P-5: Cost Comparison by Vehicle Type

| Item | Unit | Compactor Truck | | | Tipper Truck | | Container Truck | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. Specification | | | | | | | | | |
| Capacity in weight | t | 4 | 6 | 8 | 4 | 6 | 4 | 6 | 8 |
| Capacity in volume | $m^3$ | 8 | 12 | 15 | 10 | 15 | 5 | 8 | 10 |
| Required number of trucks | Unit | 11 | 9 | 8 | 14 | 12 | 13 | 8 | 7 |
| Required containers | Unit | | | | | | 237 | 150 | 120 |
| 2. Investment | | | | | | | | | |
| Investment cost per waste (a) | C$/ton | 31 | 30 | 34 | 32 | 32 | 62 | 45 | 45 |
| 3. O&M cost | | | | | | | | | |
| Fuel cost per waste (b) | C$/ton | 9 | 9 | 12 | 11 | 12 | 24 | 19 | 25 |
| Labor cost per waste (c) | C$/ton | 19 | 15 | 13 | 24 | 20 | 14 | 9 | 8 |
| M&R cost per waste(d) | C$/ton | 6 | 6 | 7 | 6 | 6 | 12 | 9 | 9 |
| O&M cost per waste (b+c+d) | C$/ton | 34 | 30 | 32 | 41 | 38 | 50 | 37 | 42 |
| 4. Unit rate | | | | | | | | | |
| a + b + c + d | C$/ton | 65 | 60 | 66 | 73 | 70 | 112 | 82 | 87 |

### a.3 Type of Refuse Collection Vehicle

Taking the followings into consideration as well as cost comparison, the vehicles shown in Table P-6 were selected.

- Considerably high level of maintenance skills required the municipalities' workshop (Modulo), although the equipment is insufficient to conduct the work.

  This proves that introduction of vehicles which have complicated hydraulic system in some degree is possible.

- Waste on streets include a lot of soil and sand; waste in parks mainly consists of bulky waste, e.g., grass, leaves, woods and so on, and waste illegally dumped is often construction debris.

  These wastes are absolutely inappropriate to be collected by the compactor trucks which have more complicated hydraulic system than tipper trucks.

Table P-6: Waste Collection Vehicle Plan

| Collection Service | Type of Vehicle |
|---|---|
| General collection service areas<br>CCA<br>CCB<br>PCA | Compactor truck (12m$^3$) |
| Special collection service | Tipper truck (10m$^3$)<br>Wheel loader (75ps) |

### a.4 Waste Collection Vehicle

A compactor truck (12m$^3$) was selected as a street/point collection vehicle as it is more economical compared with a tipper truck. A tipper truck was selected as a vehicle for special collection services since it can drive through poor road conditions to collect bulky and illegally dumped wastes, that are often dumped into the riverside or close to the areas where road condition is poor.

Waste collection vehicles are planned per respective collection service as follows;.

Table P-7: Waste Collection Vehicle Plan

| Collection Service | Type of Vehicles | Code | Waste Collection Amount (ton/day) | | |
|---|---|---|---|---|---|
| | | | Year 2001 | Year 2003 | Year 2005 |
| General collection service areas<br>CCA<br>CCB<br>PCA | 12m$^3$ compactor truck | e + h | 55.5 | 62.0 | 69.2 |
| Special collection service | 10m$^3$ tipper truck<br>Wheel loader | i + j | 7.3 | 8.1 | 9.0 |
| Total | | | **62.8** | **70.1** | **69.2** |

### a.5 Number of Refuse Collection Vehicle Required

The number of equipment required are calculated and shown in the table below, based on the waste collection vehicle plan.

Table P-8: Waste Collection Equipment Plan

| Collection service | Type of vehicle | Number of Trips (times/day) | Amount of waste carried (ton/day/truck) | Number of Vehicles | | |
|---|---|---|---|---|---|---|
| | | | | 2001 | 2003 | 2005 |
| General collection service CCA CCB PCA | 12 $m^3$ compactor truck | 3 | 13.09 | 5 | 6 | 7 |
| Special collection service | 10 $m^3$ tipper truck Wheel loader | 4 | 14.55 | 1 | 1 | 1 |
| total | | | | 6 | 7 | 8 |

■ Compactor truck(12$m^3$)

- Number of trips per day (Tr)

*Tr = (t1- (t2 + t3))/(D/V + t4 + t5)*

*=(7.0- (0.5 +0.5))/(20/40 + 1.25 + 0.2)=3.08* ***Say 3trip***

Tr: Number of trips per day

| | | |
|---|---|---|
| D: | Travel distance per trip (km) | 20km |
| V: | Velocity (km/hr) | 40km/hr |
| t1: | Working hours per day (hr) | 7.0hr |
| t2: | Daily inspection and fueling time before working (hr) | 0.5hr |
| t3: | Daily inspection and washing time after working (hr) | 0.5hr |
| t4: | Loading (collection) time (hr) | 1.25hr |
| t5: | Unloading time (hr) | 0.2hr |

- Amount of waste carried(Qd)

*Qd =(q x e)xTr / (1 + r)x0.5*

*=(12x0.8)x3/(1+0.1)x0.5=13.09* ***Say 13.09(ton/day/truck)***

| | | |
|---|---|---|
| Qd: | Amount of waste carried(ton/day/truck) | |
| q: | Volume capacity of a vehicle ($m^3$) | 12$m^3$ |
| e: | Efficiency of loading capacity | 0.8 |
| r: | Reserve rate of vehicle | 0.1 |
| | ASG of waste | 0.5 |

- Number of vehicles (Nv)

*Nv = WCAx7/Wd/Qd*

Nv: Number of vehicles required

WCA: Waste collection amount(ton/day)

Wd: Working days per week (day) 6 days

-2001 Nv = 55.5x7/6/13.09=4.95 Say 5

-2003 *Nv = 62.0x7/6/13.09=5.50* ***Say 6***

-2005 *Nv = 69.2x7/6/13.09=6.15* ***Say 7***

■ Tipper truck($10m^3$)

*Tr = (t1- (t2 + t3))/(D/V + t4 + t5)*

*=(7.0- (0.5 +0.5))/(20/40 +1.2 + 0.2)=3.08* ***Say 4trip***

Tr: Number of trips per day

| | | | |
|---|---|---|---|
| D: | Travel distance per trip (km) | 20km | |
| V: | Velocity (km/hr) | 40km/hr | |
| t1: | Working hours per day (hr) | 7.0hr | |
| t2: | Daily inspection and fueling time before working (hr) | | 0.5hr |
| t3: | Daily inspection and washing time after working (hr) | | 0.5hr |
| t4: | Loading (collection) time (hr) | 1.2hr | |
| t5: | Unloading time (hr) | 0.2hr | |

- Amount of waste carried(Qd)

*Qd =(q x e)xTr / (1 + r)x0.5*

*=(10x0.8)*x4/(1+0.1)x0.5=14.55 Say 14.55(ton/day/truck)

| | | |
|---|---|---|
| Qd: | Amount of waste carried(ton/day/truck) | |
| q: | Volume capacity of a vehicle ($m^3$) | $10m^3$ |
| e: | Efficiency of loading capacity | 0.8 |
| r: | Reserve rate of vehicle | 0.1 |
| | ASG of waste | 0.5 |

- Number of vehicles (Nv)

*Nv = WCAx7/Wd/Qd*

Nv: Number of vehicles required

WCA: Waste collection amount(ton/day)

Wd: Working days per week (day) 6 days

-2001 Nv = 7.3x7/6/14.55=0.58 Say 1

-2003 *Nv = 8.1x7/6/14.55=0.65* ***Say 1***

-2005 *Nv = 9.0x7/6/14.55=0.72* ***Say1***

**b. Maintenance of Equipment**

The location and size of the maintenance shop and motor pool for the planned vehicles were examined in view of : distribution of each collection service area in Granada City; Granada's road infrastructure condition; disposal site location and collection/transport distance; and initial investment cost for the construction and its O&M cost. It is planned

to renovate Modulo de Operacion (MDO) in order for it to function as a maintenance shop and a motor pool. The maintenance of equipment could be carried out at MDO which is belong to Granada Municipality, so that it becomes unnecessary to spend a large amount of capital to procure new property and to newly construct a motor pool and a maintenance shop (see Figure 4-2: MDO Location Plan).

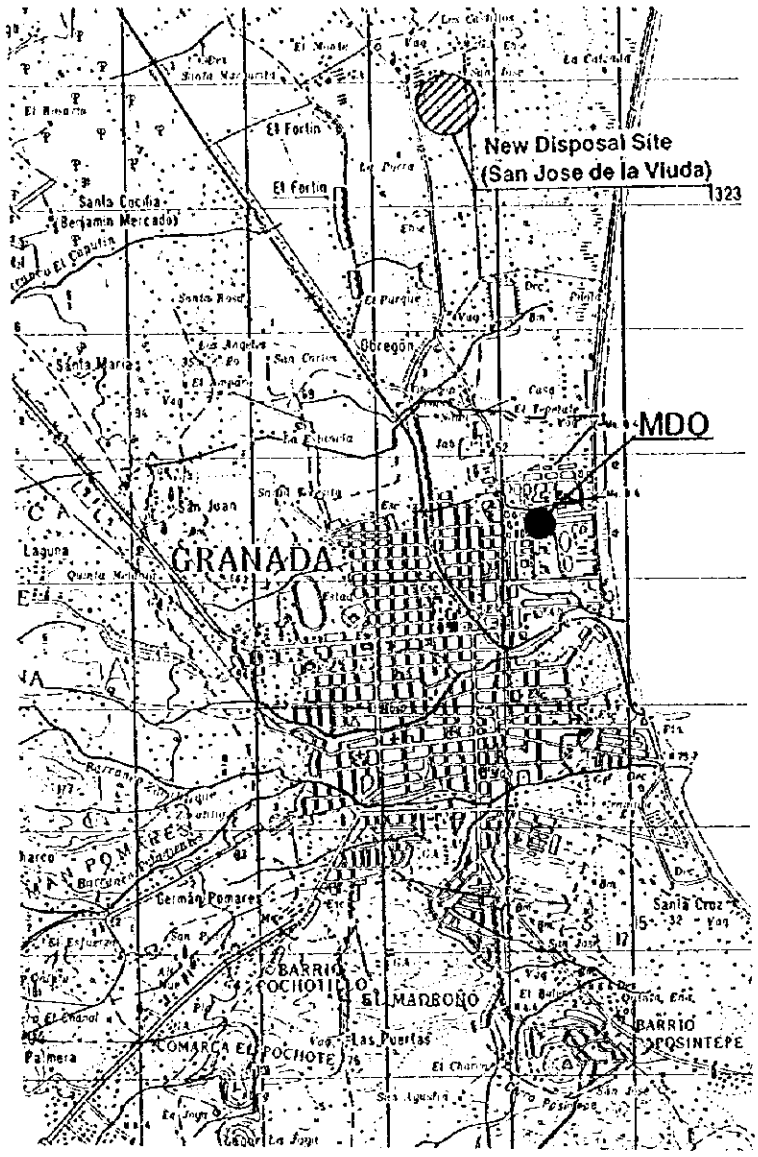



Figure P-2: MDO Location Plan

### e. Improvement of Street Sweeping

Street sweeping shall be carried out manually by using hand carts in Curb Collection Area A. The waste collected shall be placed along the roadside to be collected together with household waste in CCA by the Curb Collection Service. The improvement of the street sweeping till the year 2005 is outlined in Table P-9 below;

Table P-9: Improvement of Street Sweeping

| Item | Unit | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Length of streets to be sweept | km | 35 | 36 | 37 | 39 | 40 |
| Waste collection vehicle ($12m^3$ compactor truck) | units | 0*1 | 0*1 | 0*1 | 0*1 | 0*1 |
| Driver of waste collection vehicle | person | 0*1 | 0*1 | 0*1 | 0*1 | 0*1 |
| Hand cart | Nos | 30 | 30 | 30 | 30 | 30 |
| Sweeping worker | person | 30 | 30 | 30 | 30 | 30 |

Note: *1 : The street sweeping waste are calculated as required vehicles for general vollection service (see Table 4-5), it is not quantified.

### d. Improvement of the Modulo de Operacion (MDO) Workshop

Modulo de Operacion workshop, which is now used as the workshop for the trucks and machinery (e.g., motor grader and wheel loader) owned by Granada Municipality shall be renovated as shown in Figure P-3. It is planned that MDO will also have to serve as a workshop for the waste collection vehicles and disposal site equipment. The activities of the workshop shall be limited to routine and preventive maintenance and breakdown repair shall be commissioned to private workshop. As Granada Municipality owns the MDO, there is no need to acquire additional land for improvement. The main contents of the improvement are as follows.

#### Operation Yard

At present, the operation yard in front of the workshop building is not paved so that when it rains, the mud prevents vehicles from gaining access to the workshop. As a solution, the operation yard shall be paving in concrete and also a drainage ditch shall be installed in order to exclude stormwater. The outline of the operation yard improvement is shown in Table P-10.

Table P-10: Outline of Operation Yard Improvement

| Contents | | Quantity |
|---|---|---|
| Pavement | Concrete paving (t=20cm) | A=1,400$m^2$ |
| Drainage ditch | U -shaped side ditch (U300× 300) | L=40m |

#### Lighting Works

As slates are used for the roof of the present workshop building, the workshop interior is dark and not fully utilized. Therefore, a part of the present roof (approximately 180 $m^2$) shall be replaced with transparent roofing materials in order to improve the working environment of the workshop (Refer to Figure P-5: Roof Improvement Plan of MDO Workshop).

### Facilities and Tools for Maintenance

Although breakdown repairs are to be entrusted to private workshops, the present workshop is not sufficiently equipped even for routine and preventive maintenance of refuse collection vehicles and heavy machinery of the disposal site. Thus, the following facilities and tools shall be newly provided and electrical system shall be also improved for a larger capacity as shown in Table P-11 below.

Table P-11: Improvement of Facilities and Tools for Maintenance

| Contents | Quantity |
|---|---|
| For general maintenance and repair | One set |
| Tire repair equipment | One set |
| Battery equipment | One set |
| Inspection pit | One set |
| Parts and tool storage | One set |
| Electrical system | One set |

### Installation of Car Wash

Car wash shall be installed to prevent vehicles and heavy machinery from corrosion by waste that has accumulated during waste collection and landfill work. It will also make routine inspections of the vehicles easier, and to prolong service life of the vehicles.

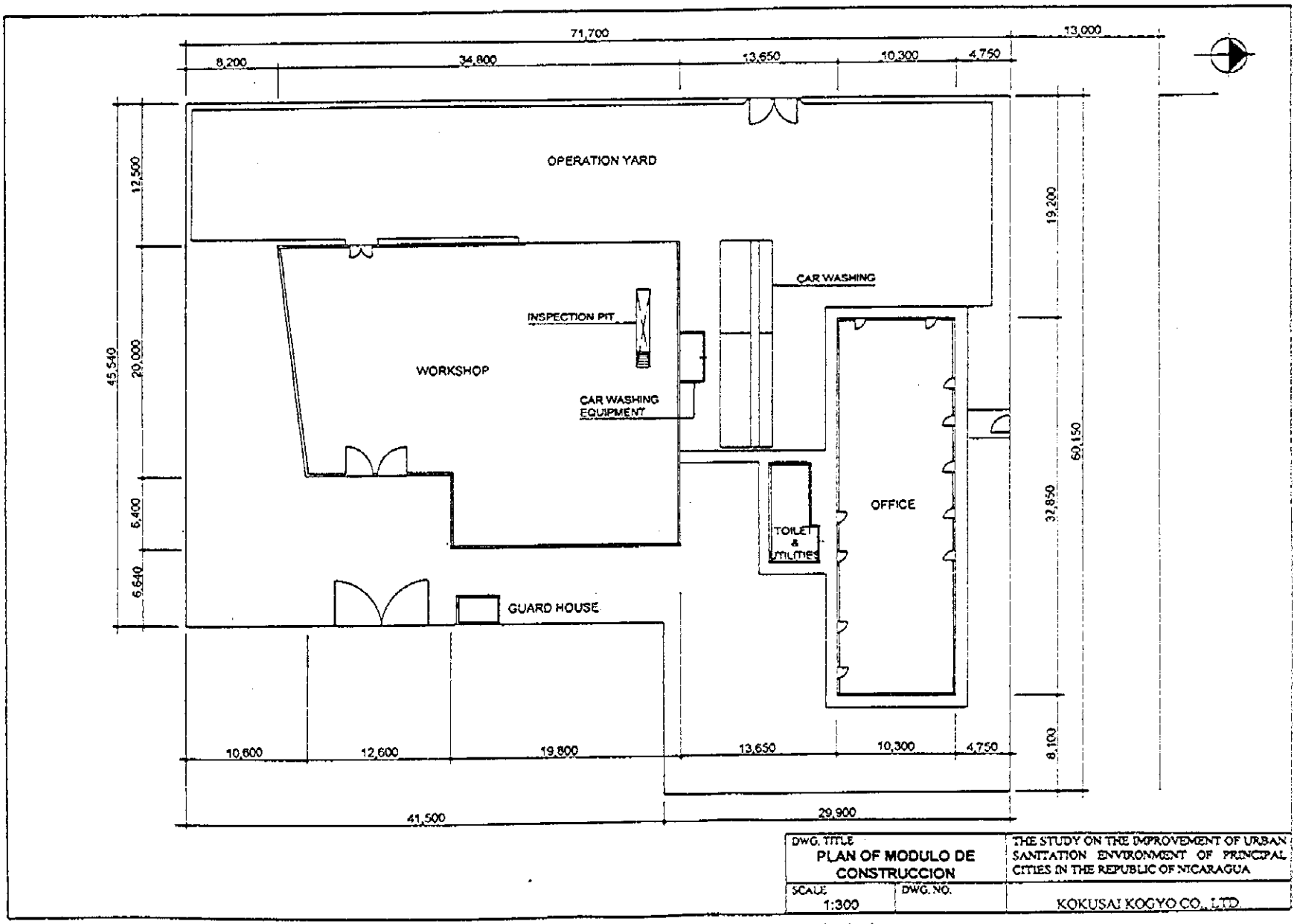



Figure P-3: Improvement of MDO Workshop

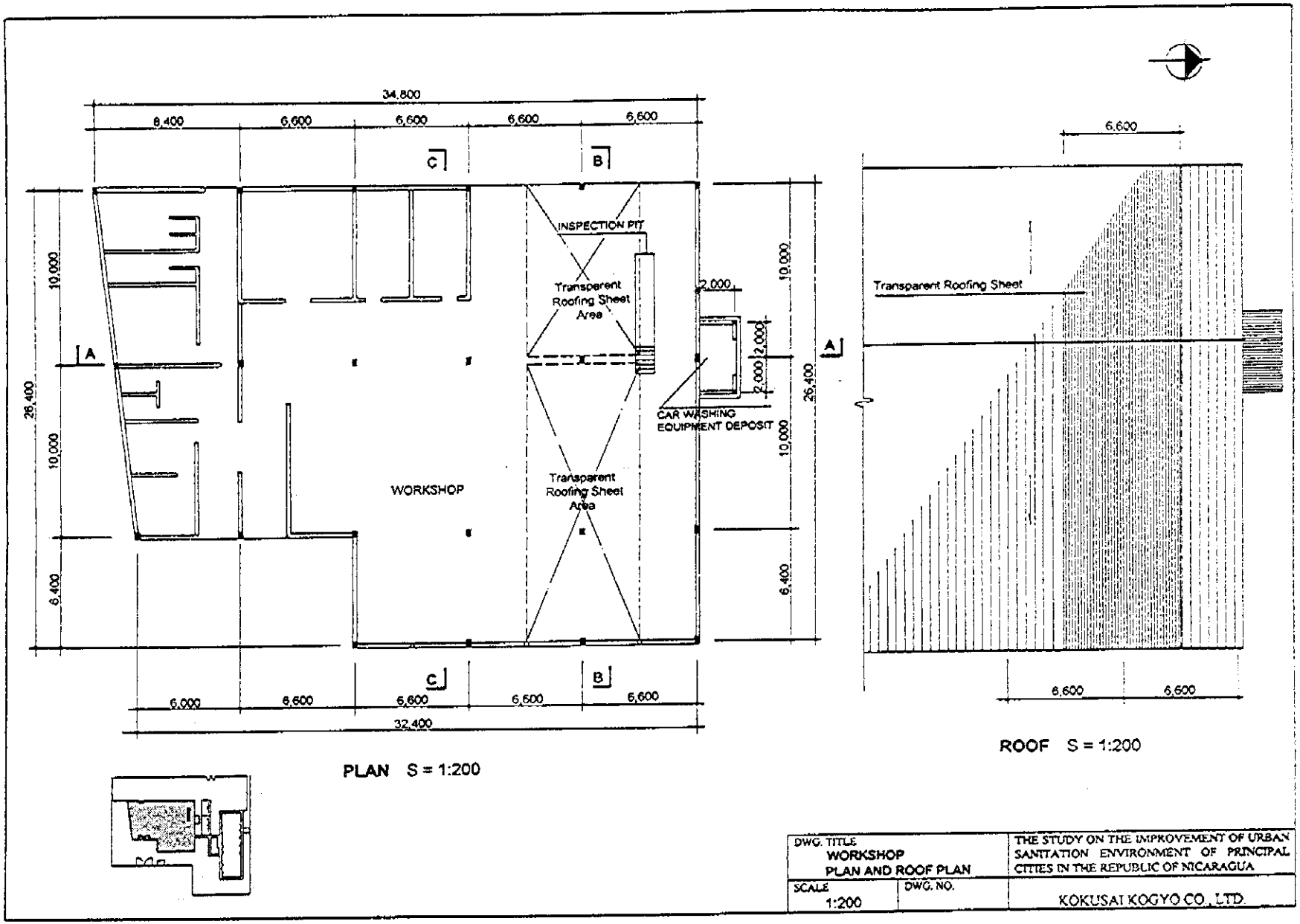



Figure P-4: MDO Workshop Improvement

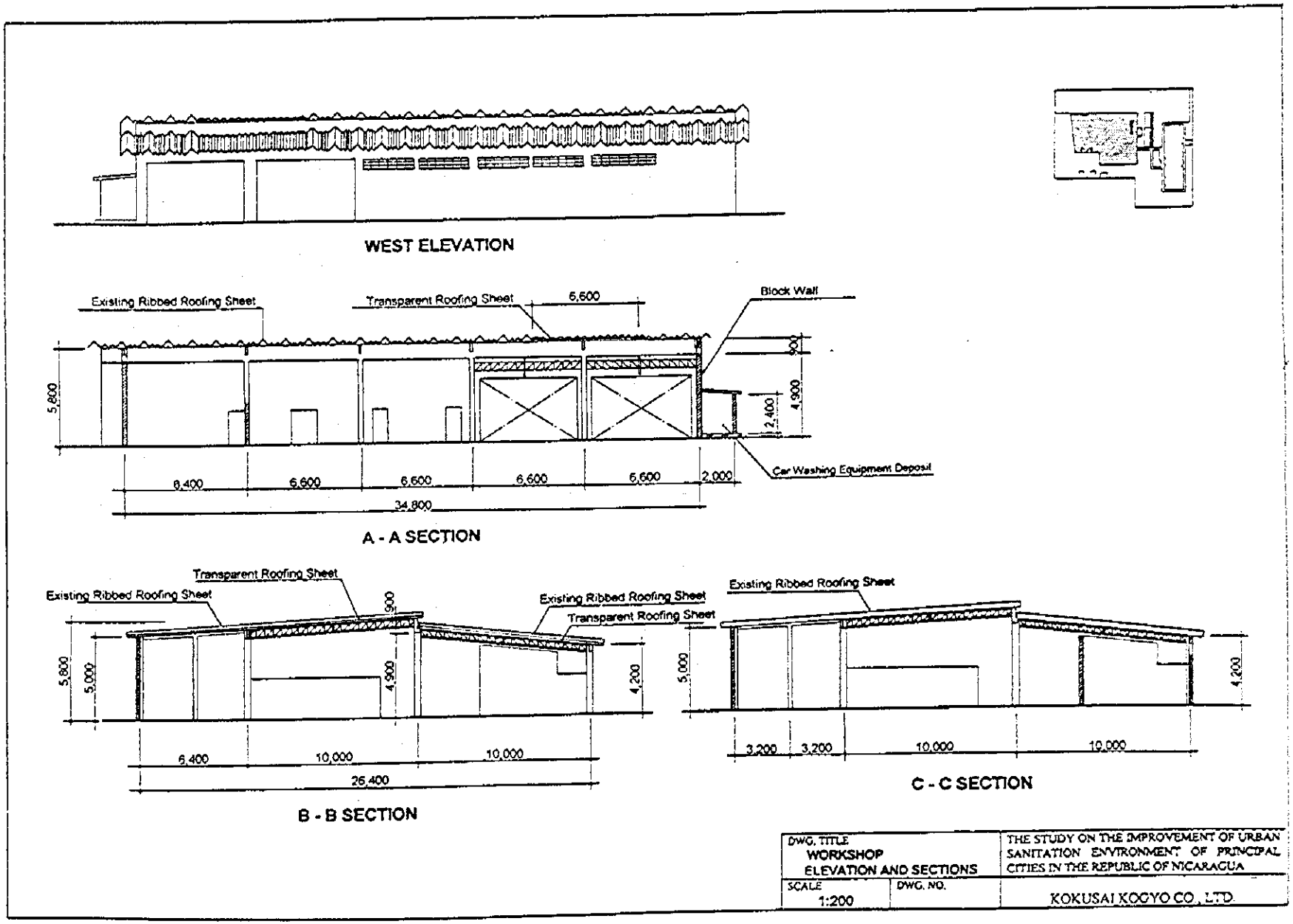



Figure P-5: Roof Improvement of MDO Workshop

# P.3 Preliminary Design of a New Municipal SW Disposal Site Development Project

## P.3.1 Design Conditions

### a. Introduction

The municipality has one landfill (La Joya) which is located 5 km southwest of the city center. The La Joya landfill is located to the south of a crater. It is feared that the lechate from the landfill may contaminate the groundwater because the crater is directly connected to the groundwater. To make matters worse, there are some tap water wells belonging to INAA downstream of the creater.

Therefore, it is strongly recommended to terminate the La Joya landfill's operation and to develop a new landfill. In this study, the work for selecting a site was conducted, where upon San Jose de la Viuda (SVV) was selected as the new MSW disposal site.

This chapter presents the preliminary design for the proposed new sanitary landfill at SJV. The main items considered and examined in this chapter are as follows:

- Current conditions of SJV.
- Waste composition and amount dealt with in the future.
- Instructions on the new disposal site development by the Nicaraguan authorities concerned.
- Appropriate sanitary level of the disposal site.
- Preliminary design.
- Operation.

### b. Location and Current Conditions

#### b.1 Location

The site "San Jose de la Viuda (SJV)", is located 5 km north from the center of Granada City, to the east of the highway (Granada-Santa Rosa), and 1 km from the shoreline of Lake Nicaragua. The coordinates of the site's center are approximately 11°58'20"N, 85°57'20"W. The altitude is around 35m to 45 meters above sea level. See Figure P-6.

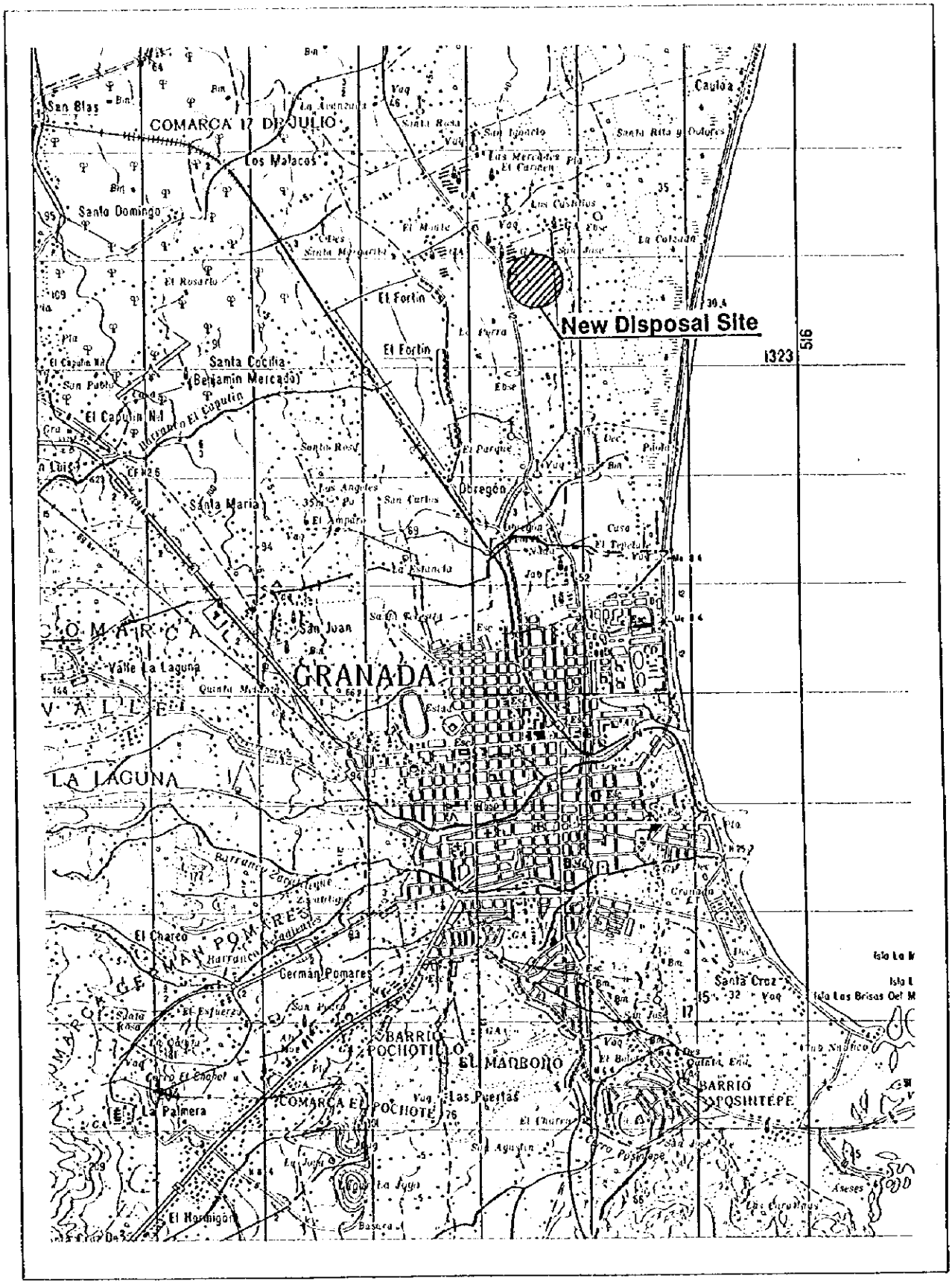
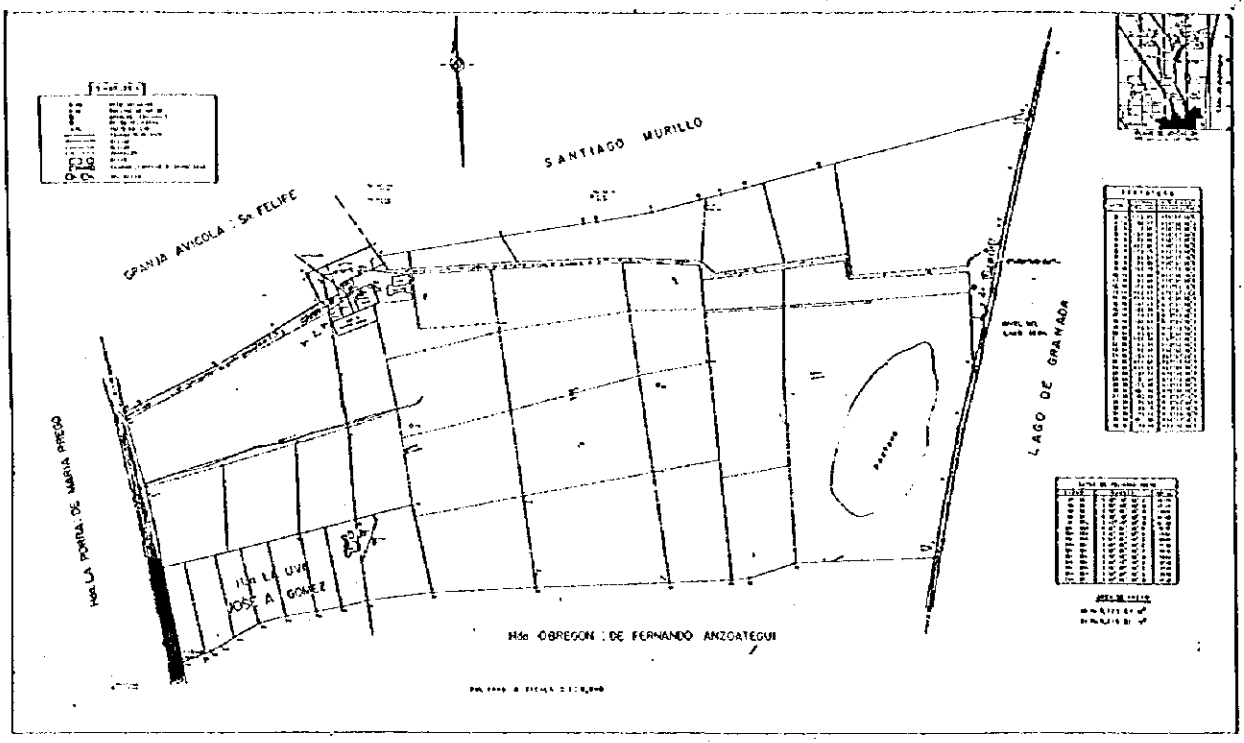



Figure P-6: Location Map of the New Disposal Site (San Jose de la Viuda)



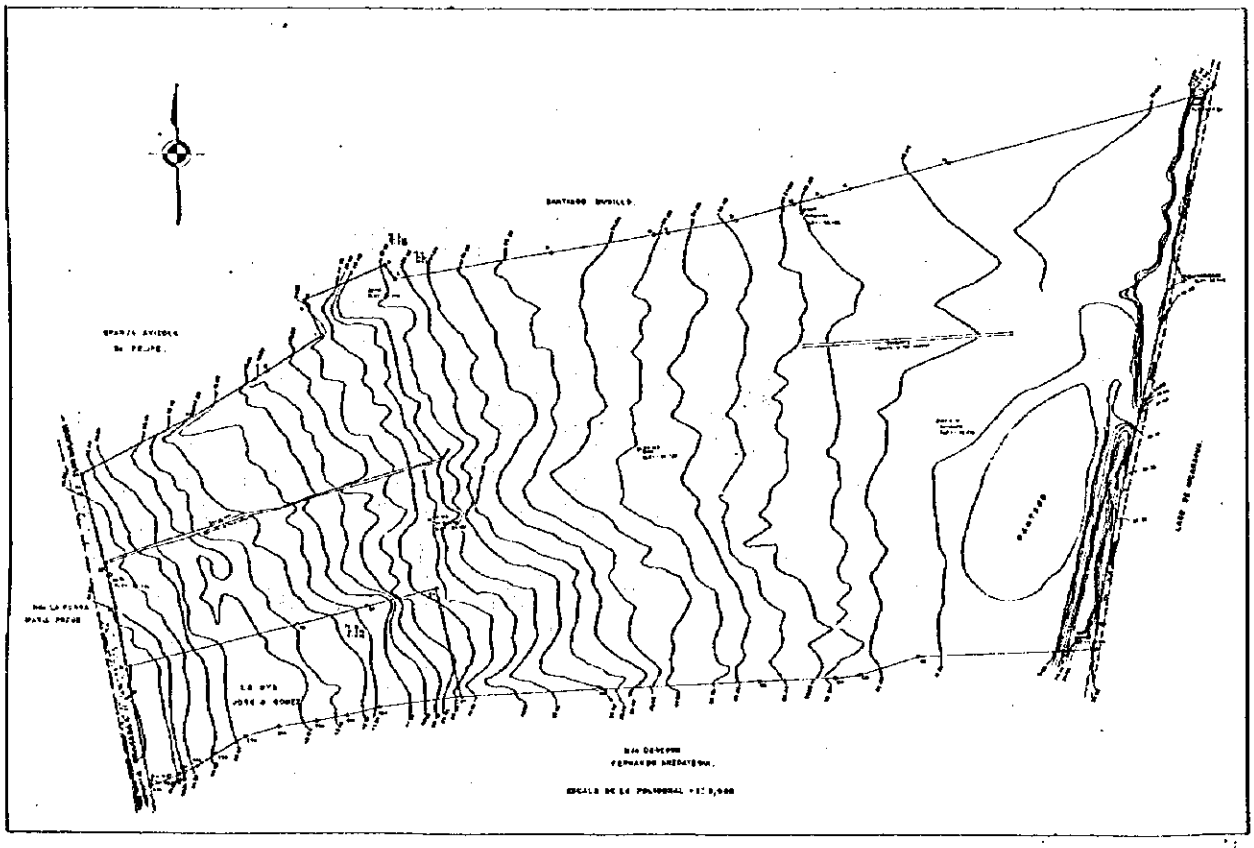



Figure P-7: Topographical Map of San Jose de la Viuda

### b.2 Land Use

The site used mainly for cattle breeding and partially for agricultural purposes. The surrounding areas are used in a similar way. There is swampy area across the woods to the east of the site. In addition, there is a poultry farm bordering in the north of the property.

### b.3 Weather Conditions

**Temperature, Precipitation and Evaporation**

The mean temperature is 26°C, the mean precipitation is 1,517 mm/year and the mean evaporation is 1,561 mm/year.[1]

### b.4 Geological Conditions

The study team conducted the borling survey in order to lean the hydrogeological conditions of the site in July and August in 1997.

The site expands at an elevation of 35 m to 45 m. The groundwater level exists around 2 to 10 m below the ground level.

The surface layer (0 to 1.5m) of the proposed SJV site is made up of clay and silt that overlies a layer of sandy silt and volcanic deposits that extends to depth. The surface layer is relatively permeable with a permeability coefficient ranging from 2.08E-5 to 7.0E-5 cm/sec.

### b.5. Road Condition to the Site

The road connecting the city and the site is enough for two-way traffic and the condition is substantial. The improvement works could only be grading of the existing one and laying of asphalt pavement.

### b.6 Public Utilities

The site and the surrounding areas have no access to tap water, sewage nor telephone service, meanwhile, electric service is available.

### b.7 Expected Life Span

The expected life span of the new disposal site is around 30 years. Although the site is a flatland, the use of the site as a landfill is limited by the groundwater level and the distance to the lake and to the poultry farm. Taking these factors into consideration, around 30 ha is planned for the new disposal site. This area is expected to operate for 30 years.

### c. Disposal Amount and Type of Waste

The landfill is expected to receive the following types of waste:

- Household waste (kitchen, garden waste)
- Commercial waste (restaurants, other shops)
- Institutional waste
- Market waste

[1] At the Masaya meteorological station, data by INETER.

- Street sweeping waste
- Parks and green areas cleansing waste
- Other waste (construction and demolition waste, non-hazardous industrial waste, non-infectious/non-hazardous hospital waste, etc.)

The waste expected to be disposed at the new landfill mostly consists of household waste, then, a substantial portion (around 80%) of organic matter.

Disposal of hazardous and chemical wastes shall be not allowed on the landfill. These types of waste must be treated to become inert and safe enough to be dealt with in the landfill before being disposed. The landfill will not receive the following types of waste:

- Hazardous and toxic waste from industries, commerce, institutions etc.
- Infectious waste, syringes, etc. from hospitals, clinics and dentists.
- Radioactive waste.
- Liquid waste

Table P-12 and Table P-13 shows future waste generation and disposal amount.

Table P-12: Forecast of Waste Generation Amount

Unit : ton/day

| Items | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| Household Waste | 72.0 | 75.6 | 79.3 | 83.1 | 87.4 | 91.4 | 95.9 | 100.5 | 105.4 | 110.5 |
| Restaurant | 1.0 | 1.0 | 1.1 | 1.1 | 1.2 | 1.2 | 1.3 | 1.4 | 1.4 | 1.5 |
| Other Shop Waste | 1.1 | 1.2 | 1.2 | 1.33 | 1.4 | 1.4 | 1.5 | 1.6 | 1.6 | 1.7 |
| Institutional Waste | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 |
| Market Waste | 3.7 | 3.9 | 4.1 | 4.3 | 4.5 | 4.8 | 5.0 | 5.2 | 5.5 | 5.8 |
| Street Sweeping Waste | 1.3 | 1.3 | 1.4 | 1.4 | 1.5 | 1.5 | 1.6 | 1.6 | 1.7 | 1.7 |
| Bulky Waste | 1.0 | 1.0 | 1.1 | 1.2 | 1.2 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 |
| Sub-total | 80.3 | 84.2 | 88.5 | 92.7 | 97.5 | 102.0 | 107.1 | 112.2 | 117.6 | 123.4 |
| Other Waste | 2.2 | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 | 2.5 |
| Total | 82.5 | 86.4 | 90.7 | 95.0 | 99.8 | 104.3 | 109.5 | 114.6 | 120.0 | 125.9 |

Table P-13 : Forecast of Waste Stream

Unit : ton/day

| Items | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| Waste Generation | 80.3 | 84.2 | 88.5 | 92.7 | 97.5 | 102.0 | 107.1 | 112.2 | 117.6 | 123.4 |
| Recycling at Generation | 7.0 | 7.4 | 7.7 | 8.1 | 8.5 | 8.9 | 9.4 | 9.8 | 10.3 | 10.8 |
| Waste Discharge | 62.8 | 66.2 | 70.1 | 73.9 | 78.2 | 82.3 | 86.9 | 91.7 | 96.7 | 102.0 |
| Self-disposal | 10.5 | 10.6 | 10.7 | 10.7 | 10.8 | 10.8 | 10.8 | 10.7 | 10.6 | 10.6 |
| Collection Amount | 56.5 | 59.6 | 63.1 | 66.5 | 70.4 | 82.3 | 86.9 | 91.7 | 96.7 | 102.0 |
| Illegal Dumping | 6.3 | 6.6 | 7.0 | 7.4 | 7.8 | 0 | 0 | 0 | 0 | 0 |
| Recycling at Disposal Site | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other Waste | 2.2 | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 | 2.5 |
| Final Disposal Amount | 58.7 | 61.8 | 65.3 | 68.8 | 72.7 | 84.6 | 89.3 | 94.1 | 99.1 | 104.5 |

### d. Landfill Volume

Table P-14 shows yearly and accumulated final disposal amount, based on the waste stream (see Table P-13).

Table P-14: Final Disposal Amount

| Items | Unit | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Final Disposal | 1000ton/year | 21.4 | 22.6 | 23.8 | 25.1 | 26.5 | 30.9 | 32.6 | 34.3 | 36.2 | 38.1 |
| | 1000m³/year | 26.8 | 28.3 | 29.8 | 31.4 | 33.1 | 38.6 | 40.8 | 42.9 | 45.3 | 47.6 |
| 2001-2010 | 1000ton | 21.4 | 44.0 | 67.8 | 92.9 | 119.4 | 150.3 | 182.9 | 217.2 | 253.4 | 291.5 |
| 2001-2010 | 1000m³ | 26.8 | 55.1 | 84.9 | 116.3 | 149.4 | 188.0 | 228.8 | 271.7 | 317.0 | 364.6 |
| Covering Soil | 1000m³/year | 5.4 | 5.7 | 6.0 | 6.3 | 6.6 | 7.7 | 8.2 | 8.6 | 9.1 | 9.5 |
| 2001-2010 | 1000m³ | 5.4 | 11.1 | 17.1 | 23.4 | 30.0 | 37.7 | 45.9 | 54.5 | 63.6 | 73.1 |
| Waste + Soil | 1000m³/year | 32.2 | 34.0 | 35.8 | 37.7 | 39.7 | 46.3 | 49.0 | 51.5 | 54.4 | 57.1 |
| 2001-2010 | 1000m³ | 32.2 | 66.2 | 102.0 | 139.7 | 179.4 | 225.7 | 274.7 | 326.2 | 380.6 | 437.7 |

Note: ASG of waste after compaction is 0.8ton/m³.
Covering soil is 20% to waste amount in volume.

As the landfill will be used for long term, around 30 years, the landfill capacity is set based on the waste disposed from 2001 to 2010.

Waste volume disposed is as follows:

2001 to 2005 : 179,400 m³ (inc. cover soil)

2006 to 2010 : 253,300 m³ (inc. cover soil)

Total : 437,700 m³

A lot (200 x 300m, 10m height) for 10 years operation has the capacity of 468,000 m³. As 5 years operation is subject to this preliminary design, a half lot, i.e., 150 x 200m, is set for 5 years operation.

### e. Other Conditions

At present, Nicaragua has no official technical guidelines necessary to plan a final disposal site for municipal solid wastes. Consequently, the Study Team, INIFOM and Granada Municipality held a discussion with MARENA concerning technical guidelines. Table P-15 shows the technical guidelines presented by MARENA, of which this plan is based on.

Table P-15 : Design Standards from MARENA

| PRAMETER | STANDARD | OBSERVATIONS |
|---|---|---|
| Minimum distance to a water body(Lake Nicaragua) | 500 meters | Downstream, with an intercepting marshland(it would have to consider pollution monitoring wells) |
| Minimum depth of phreatic line | 1.00 meter | With effective and sustainable impermeability (compacted clay or plastic membrane) |
| Concentration of $BOD_5$ in case of rupture of impervious layer | 100 mg/liter | Maximum concentration that could reach Lake Nicaragua |
| All of this can be applied under the following assumptions:<br>1. The impermeable layer ensures to contain infiltration throughout the period the land fill is in used.<br>2. No toxic materials should be disposed in the landfill.<br>3. No dangerous waste from hospitals should be brought into the landfill.<br>4. The standards have a pilot characteristic; they are subject to the appropriate officialization.<br>5. Appropriate evacuation of leachate accumulated over the impervious layer.<br>6. These standards are applied to this site only.<br>7. The environmental permit is subject to the corresponding EIA. | | |

### f. Appropriate Sanitary Level of the Disposal Site

Sanitary landfill levels are classified as follows:

Level 1: Controlled tipping

Level 2: Sanitary landfill without a bottom liner but with daily soil coverage of waste.

Level 3: Sanitary landfill with a bottom liner, leachate collection system and a regulation pond for recirculation/evaporation of leachate.

Level 4: Sanitary landfill with a bottom liner, leachate collection system and leachate treatment facilities.

To meet the technical guidelines presented by MARENA, the sanitary landfill level of the disposal site should be planned for either level 3 or 4. However, considering the annual precipitation in the proposed site, which is approximately 1,400mm/year, it would make leachate treatment by on-site leachate retention for evaporation difficult. Therefore, it is necessary to adopt the level 4 sanitary landfill for the final disposal site.

## P.3.2 Preliminary Design

### a. Access Road

Though the access road from the urban area to the site (Grenada - Santa Rosa) is in a rather good conditions, a part of it from the north of the urban area to the site will be paved to ensure an efficient transportation and to avoid additional dust impacts. The construction works do not need substantial earth movement works, just grading of present road and paving works will be sufficient for the road improvement.

Width of the pavement: 4.0 m
Length: approximately 3.0 km

### b. Enclosing Structure

An embankment surrounding the landfill will be built, with the purpose of defining the area, and to avoid the leachate efflux exit and the intrusion of surface runoff from its surrounding area. It will have a height of 3m, with a width at the top of 5 m and a slope with a gradient of 3 to 1.

### c. Drainage System

Elimination of possible entry of stormwater to the landfill site is of fundamental importance to avoid the increase of the leachate volume generated in the waste disposal area. For these pluvial currents an open ditch, 2 m wide, 0.5 m deep and 1,600 m long will be built. The collected waters will be disposed into the wetland.

Inactive cells for future landfill should be isolated with small dikes in order to prevent stormwater therein to flow in the active cell. Stormwater falls on inactive future cells will be collected through leachate collection pipelines therein and separately discharged to stormwater drainage system nearby, in order to minimize leachate generation by preventing the stormwater on inactive cells to flow into the active leachate collection system.

## d. Climate and Leachate Generation

### d.1 Precipitation

According to the 17 year precipitation record from 1969 to 1985 taken at Granada City, the average annual precipitation was 1,517 mm with a minimum of 1,022 mm in 1979 and a maximum of 1,932 mm in 1972. Similar to the areas of the Pacific coastal plain, the rainy season begins in May and ends in the beginning of November. More than 90 % of the annual precipitation occurs in the rainy season of May to October, and nearly 10 % in the remaining 6 months. The average monthly precipitation was the highest in September (309 mm) followed by October (276 mm) and June (236 mm). The maximum monthly rainfall in 17 years was 587 mm in May of 1982. The annual precipitation varies considerably by year, as shown in Figure P-8. The average monthly rainfall is given in Figure P-9, which is accompanied by the minimum and maximum monthly precipitation in the year 1969-1986. Monthly precipitation in the same years is tabulated in Table P-16.

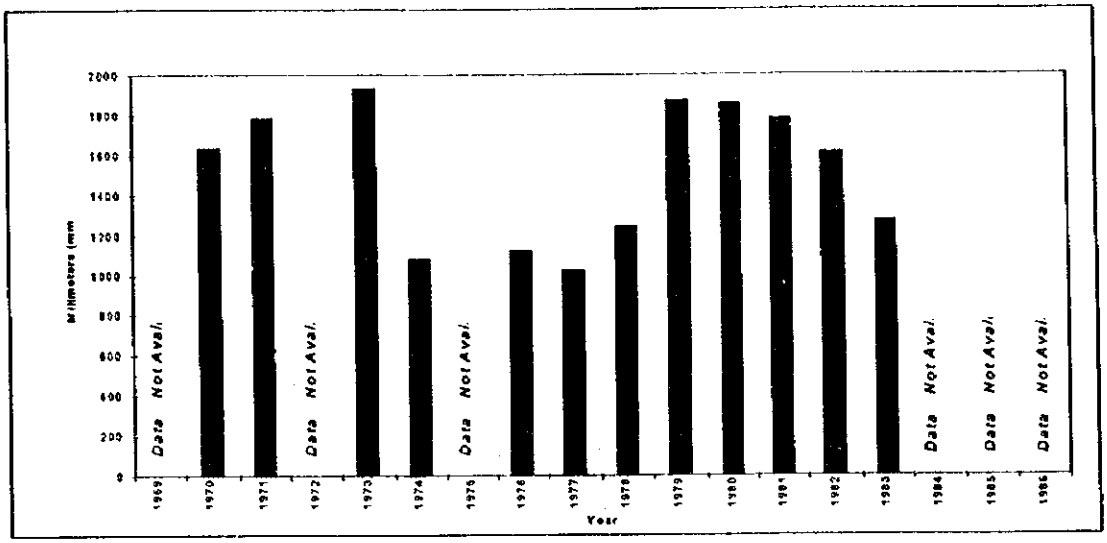



Figure P-8 : Fluctuation of the Annual Precipitation

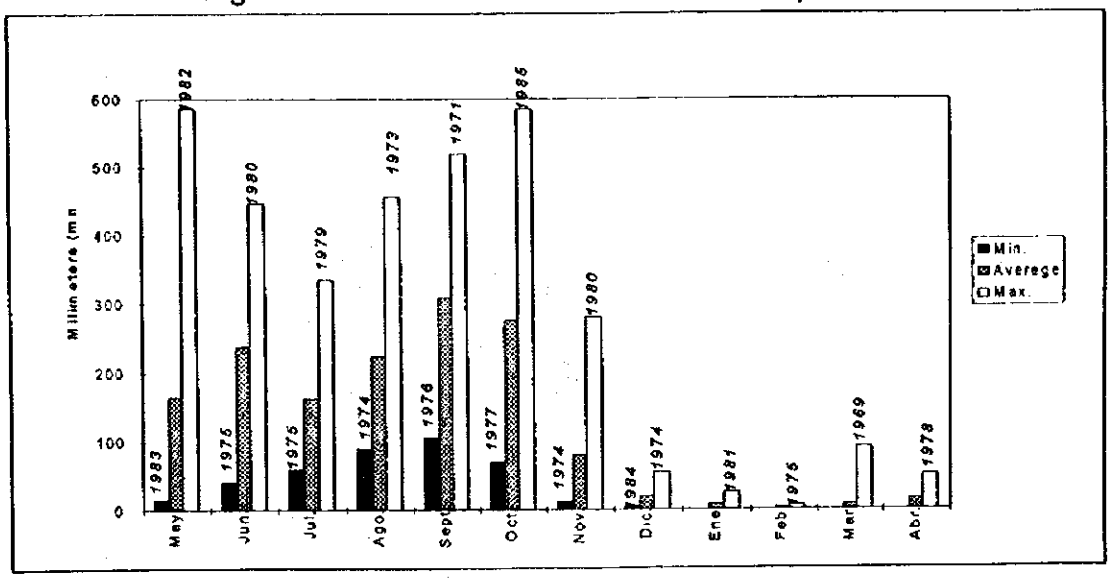



Figure P-9 : Monthly Average Precipitation, 17 Years(1969 to 1986)

Table P-16 : Monthly Precipitation (1969 to 1985)

| Year | May. | Jun. | Jul. | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1969 | -1 | 363 | 97 | 274 | 287 | 196 | 96 | 25 | -1 | -1 | 92 | 46 | |
| 1970 | 144 | 165 | 215 | 358 | 420 | 187 | 106 | 20 | 14 | 1 | 0 | 4 | 1634 |
| 1971 | 187 | 248 | 158 | 224 | 519 | 277 | 106 | 44 | 19 | 2 | 0 | 0 | 1784 |
| 1972 | 194 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 0 | 2 | 0 | 0 | |
| 1973 | 117 | 323 | 257 | 457 | 209 | 474 | 68 | 7 | 12 | 2 | 2 | 4 | 1932 |
| 1974 | 85 | 251 | 94 | 90 | 315 | 170 | 11 | 54 | 7 | 0 | 1 | 0 | 1078 |
| 1975 | 33 | 41 | 59 | 183 | 517 | 256 | 123 | -1 | 0 | 5 | 4 | 25 | |
| 1976 | 127 | 377 | 69 | 132 | 104 | 280 | 14 | 16 | 0 | 0 | 0 | 1 | 1120 |
| 1977 | 223 | 172 | 65 | 146 | 243 | 70 | 73 | 7 | 2 | 0 | 0 | 21 | 1022 |
| 1978 | 118 | 116 | 167 | 137 | 337 | 257 | 56 | 5 | 0 | 0 | 0 | 51 | 1244 |
| 1979 | 126 | 307 | 334 | 304 | 262 | 429 | 80 | 26 | 4 | 0 | 0 | 0 | 1872 |
| 1980 | 169 | 446 | 153 | 156 | 341 | 273 | 281 | 5 | 1 | 0 | 17 | 15 | 1857 |
| 1981 | 249 | 295 | 203 | 346 | 268 | 301 | 21 | 23 | 26 | 3 | 1 | 43 | 1779 |
| 1982 | 587 | 242 | 158 | 141 | 242 | 168 | 43 | 9 | 1 | 0 | 2 | 17 | 1610 |
| 1983 | 16 | 176 | 204 | 190 | 270 | 357 | 33 | 17 | 3 | 1 | 0 | 3 | 1270 |
| 1984 | 85 | 203 | 245 | 246 | 456 | 142 | 100 | 3 | 3 | 3 | 1 | -1 | |
| 1985 | -1 | 57 | 124 | 199 | 150 | 584 | 61 | 19 | -1 | -1 | -1 | -1 | |
| 1986 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | |
| **Average** | 164 | 236 | 163 | 224 | 309 | 276 | 80 | 19 | 6 | 1 | 8 | 15 | 1517 |
| **Standard Deviation** | 134 | 114 | 78 | 101 | 120 | 132 | 64 | 15 | 8 | 2 | 23 | 18 | 345 |
| **Min.** | 16 | 41 | 59 | 90 | 104 | 70 | 11 | 3 | 0 | 0 | 0 | 0 | 1022 |
| **Max.** | 587 | 446 | 334 | 457 | 519 | 584 | 281 | 54 | 26 | 5 | 92 | 51 | 1932 |
| **75 % (*)** | 141 | 203 | 140 | 192 | 265 | 237 | 68 | 16 | 5 | 1 | 6 | 13 | 1288 |
| **95 % (*)** | 76 | 157 | 74 | 141 | 268 | 215 | 18 | 1 | 0 | 0 | 0 | 1 | 950 |

Source : INETER (*) Probability Distribution : (Normal and Weibull), elaborated by ITS-LOTTI/LAMSA, -1 = No Data

### d.2 Temperature, Humidity and Evaporation

Since the data on various meteorologic conditions were not available at the rain gauging station in Granada, the data taken at the nearest station - the Masaya station at elevation of 210 m - was referred for estimation of Granada's condition. The mean monthly temperature averages 26.0 °C with a small monthly variation within a range of 24.8 - 28.3 °C. Monthly mean maximum temperature usually rises at the end of dry season from 32.8 °C in March to 34.2 °C in May. The highest temperature recorded in 1992 was 36.8 °C in May.

Monthly mean minimum temperature is relatively low in the dry season, ranging from 20.8 °C in January to 21.8 °C in December. In rainy season, it ranges from 21.8 °C to 23.6 °C in May. The minimum temperature recorded in 1992 was 18.0 °C in December. Since the mean elevation of Granada is 140 - 150 m lower than that of Masaya, the temperatures in Granada City are presumably slightly higher than the above mentioned ones. The difference in the highest and lowest temperature may be smaller than in Masaya, because Granada faces the vast waters of the Lake Nicaragua.

Monthly relative humidity in Masaya is considerably high throughout the year ranging from 64 % in April to 87 % in July. The period of high humidity, exceeding 80 %, lags one month behind the rainy season. Granada may follow a similar pattern influenced by the vast water area it faces. Regardless of the high humidity in Masaya, the potential of evaporation is quite high ranging from 65.0 mm in July to 245 mm in April. The

evaporation of 1992 totaled 1,561 mm, which was twice the precipitation of the same year. Granada's features cannot be extrapolated from the data in Masaya.

### d.3 Leachate Generation

Leachate results from waste moisture and stormwater infiltrating the waste disposed of in the landfill. Because the amount of leachate that would result from waste moisture itself is negligible, it is disregarded in this plan. On the other hand, leachate generation resulting from stormwater was calculated using the model illustrated in Figure P-10.

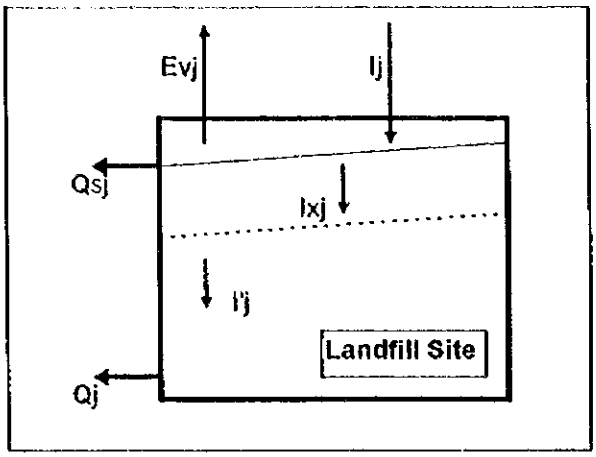



Figure P-10: Leachate Generation Mode

$$Qj = Q_{j-1}e^{-\frac{1}{R}} + \frac{A}{1000}\left\{I'_j - \left(I'_j - I'_{j-1}\right)R\left(1 - e^{-\frac{1}{R}}\right) - I'_{j-1}e^{-\frac{1}{R}}\right\} ----(1)$$

*where,*

*Qj : Daily Leachate Generation Amount ($m^3$/day)*

*R : Run-off Resistance*

*Ij : Daily Precipitation (mm/day)*

*A : Catchment Area ($m^2$)*

Leachate amount calculated according to equation (1) significantly varies according to the daily precipitation amount. If the leachate treatment facility is designed based on maximum daily precipitation, the facility needs to be extremely large. This will be more outstanding if the facility design is based on maximum daily precipitation in areas where precipitation in the rainy and dry seasons (almost 0 in the dry season) varies considerably as in Nicaragua. Therefore, the design daily leachate amount will have to be determined, on condition that leachate generated will be once stored in a regulation pond in order to accommodate the fluctuation of leachate generation caused by rainfall variances.

There is a correlation between the regulation pond capacity and the required daily leachate treatment amount. Supposing that a regulation pond is capable of storing the total leachate amount generated from the annual precipitation, the daily leachate treatment amount shall be set by dividing the total leachate amount generated from the annual precipitation by 365 days. The resulting figure would necessitate a huge regulation pond capacity.

Using the 10 year daily precipitation data from 1979 to 1995, the correlation of the regulation pond storage capacity and daily leachate treatment amount is simulated using a computer. The results are shown in Table P-17.

Table P-17: Regulation Pond Capacity and Leachate Treatment Amount

| Daily Leachate Treatment Amount ($m^3$/day) | Regulation Pond Capacity ($m^3$) |
|---|---|
| 100 | 18,389 |
| 150 | 12,994 |
| 170 | 10,994 |
| 180 | 9,994 |
| 190 | 8,994 |
| 200 | 7,994 |
| 210 | 7,234 |
| 220 | 6,934 |
| 230 | 6,634 |
| 240 | 6,335 |
| 250 | 6,045 |
| 260 | 5,755 |
| 270 | 5,465 |
| 280 | 5,175 |

Table P-18 indicates the daily leachate treatment amount and the regulation pond capacity determined, taking into account the simulation results in Table P-17 and the regulation pond layout conditions.

Table P-18: Leachate Treatment Amount and Regulation Pond Capacity

| Daily Leachate Treatment Amount ($m^3$/day) | Regulation Pond Capacity ($m^3$) |
|---|---|
| 250 | 6,000 |

**e. Liner and Leachate Collection**

**e.1 Liner**

The impermeable liner for the final disposal site shall be either made of synthetic material or clay, or the combination of both (composite liner). The selection of the liner material should be based on the material property on seepage control and the cost.

The liner proposed by MARENA for the project should be as such:

- the impermeable layer ensures to contain infiltration throughout the period the landfill is in use.

Other conditions required for the project include:

- the period that the landfill is in use is for 5 years from 2001 to 2005.

For the availability of clay materials:

- the results of the study conducted by the Team suggest that clayey soil after compaction with a permeability coefficient of 8-2 $\times$ $10^{-7}$ cm/sec can be acquired within 20 km from the proposed site.

From these conditions, the required thickness in case a clay liner will be used was calculated as: t=(8.2 × 10-7 (cm/sec) × 60 × 60 × 24 × 365) × 5 = 129.3 cm

However, in account of implementation accuracy, the design clay liner thickness was set at 150cm.

From an economic point of view, the haulage of clay materials even from a distance of 20km would curtail the costs, as shown in Table P-19.

Table P-19: Comparison of Liner System

Unit C$/m$^2$

| Synthetic Liner | Clay Liner(t=150cm) | Composite Liner |
|---|---|---|
| 220 | 200 | 420 |

From the above results, the adoption of a clay liner for the project was decided.

### e.2 Leachate Collection

#### e.2.1 Design Rainfall

The operation of the landfill will be completed (covered by intermediate cover soil) every 5 years. Therefore, the 5 year return period is appropriated.

A four (4) hour inundation in the landfill is allowed, so that, the time of flood concentration is set as 240 minutes.

From the figure mentioned above, the design rainfall intensity is 32.4 mm/hr.

$$I = \frac{A}{(T+B)^N}$$

where,

A: 370.68
T: 240 min.
B: 5
N: 0.443

I=32.4 mm/hr

#### e.2.1 Run-off coefficient

The run-off coefficient inside of the landfill is set as 0.7.

#### e.2.3 Design Flood Discharge

From the rational formula, the discharge amount becomes 0.063 m$^3$/sec/ha.

$$Q = \frac{1}{360} f \cdot \gamma \cdot A$$

where,

f: 0.7
$\gamma$: 32.4 mm/hr

A: 1 ha

$Q=0.063\ m^3/sec/ha$

### e.2.4 Distribution of Leachate Collection Pipes

Leachate collection pipes are spaced every 20m, so that, one pipe covers an area of around 0.3 ha. The discharge amount from 0.3 ha is 0.0189 $m^3$/sec (0.063 $m^3$/sec x 0.3 ha).

Meanwhile, the 200 mm pipes has a capacity of 0.0284 $m^3$/sec according to the following calculation.

$$V = \frac{1}{n} R^{\left(\frac{2}{3}\right)} \cdot I^{\left(\frac{1}{2}\right)}$$

$Q=A \cdot V$

where,

n: 0.010
A: $\pi \cdot 0.1^2$ (0.0314)
P: $2\pi \cdot 0.1$ (0.628)
R: A/P (0.05)
I: 1/100

V=1.260 m/sec

$Q=0.0427\ m^3/sec$

The capacity of a pipe, 0.0427 $m^3$/sec exceeds the discharge amount, 0.0189 $m^3$/sec. And the pipe can also act as an air distributor due to its sufficient capacity.

## f. Leachate Treatment

### f.1 Leachate Quality

Leachate quality varies according to type of waste disposed of at the landfill, landfill structure (aerobic, anaerobic, semi-aerobic), and climate conditions, e.g. ambient temperature. Determining leachate quality by referring to past examples is a non-objective practice. However, because the final disposal sites in Nicaragua are not equipped with leachate control structures (e.g., impermeable liners to block leachate from permeating the ground), examples form Japan and other countries were used to determine leachate quality. Biochemical Oxygen Demand (BODs) and Suspended Solid (SS) are used to determine leachate quality. Although MARENA only specified a permissible BOD level for the effluent discharged from the site, the project also used the SS in consideration of the facility design.

Table P-20: Comparison of Leachate Quality

| Constituent | Japan (combustible waste with a semi-aerobic structure) | USA(combustible waste with an an-aerobic structure) | Denmark (combustible waste with an an-aerobic structure) |
|---|---|---|---|
| BOD (5-day biochemical oxygen demand) (mg/l) | 250 to 2500 (typical 1,000) | 2,000 to 30,000 (typical 10,000) | 200 to 20,000 |
| S S (suspended solid) (mg/l) | 100 to 500 (typical 200) | 200 to 2,000 (typical 500) | not available |

As indicated in Table P-20, leachate quality is considerably better in semi-aerobic landfill structures than in anaerobic landfills.

An anaerobic landfill structure decomposes and stabilize the organic fraction in solid waste under anaerobic conditions, and utilizes combustible gases produced such as methane. This structure does not enhance aerobic decomposition of the waste but mainly causes methane fermentation. As a result, the organic fraction is high in the leachate from this landfill structure.

The semi-aerobic landfill structure maintains aerobic conditions in many parts of the waste layers mainly to enhance aerobic decomposition of the organic fraction in solid waste. The organic fraction in leachate that results from this landfill structure is considerably lower than in anaerobic landfill structures because the organic fraction in the semi-aerobic structure landfill has already been degraded to a certain degree within the waste layer under aerobic conditions.

This project adopted the semi-aerobic structure for the disposal site in order to maintain a lower load to the leachate treatment facilities and to immediately stabilize disposed waste in the landfill. Accordingly, the **BOD (1,000mg/l) and SS (200mg/l)** values of Japan for leachate quality were adopted for the design.

### f.2 Leachate Treatment Method

The Study Team held a discussion with the Nicaraguan side concerning feasibility of the design of the leachate treatment, in which leachate is diluted to the permissible concentration level and treated at Tepetate sewage treatment plant. The response was not clarified and declared by INAA at that time, as to whether diluted leachate is acceptable or not at Tepetate plant, in view of the limited capacity of the present plant. Consequently, it was mutually agreed that the two options below should be compared and examined during the 3rd Study Work in Japan by the Study Team. One of these two options was selected in order to carry out the F/S.

1) Leachate should be diluted to the permissible concentration level and to be treated at Tepetate sewage treatment plant.

2) Install an independent leachate treatment system at SJV site.

The problems of the two options above can be summarized as follows.

Table P-21: Comparative Study of Leachate Treatment System

| | Technical Problem | Institutional Problem |
|---|---|---|
| 1) Treat leachate at Tepetate Sewage Treatment Plant | 1)The amount of diluted leachate constitutes a significant increase in the influent of the sewage treatment plant in view of the capacity of the plant.<br>2)Therefore, the expansion of the sewage treatment plant becomes indispensable. | 1) INAA's procurement of finances for the expansion of the plant is still undecided.<br>2) It was decided that the expansion of Tepetate plant is not subject to the priority projects of the Study, because the landowner of the site did not permit the Team to enter the site for site investigation. Furthermore, INAA expected IDB funds for the expansion. |

| | Technical Problem | Institutional Problem |
|---|---|---|
| 2) Treat leachate at the disposal site | 1) Considerable increase in construction cost and operation and maintenance cost.<br>2) Whether or not the Municipality is technically capable of operating and managing the treatment facility.<br>1) Where to discharge the treated effluent. | 1) Operation and maintenance costs increase. |

First of all, the Study Team examined a closed system which does not require treatment outside the disposal site by recirculating leachate within the disposal site, except during heavy rains.

It was found that, even if a 6,000 $m^3$ regulation pond is designed for regulating the fluctuation of leachate generation, 250 $m^3$/day of raw leachate still needs to be treated outside of the disposal site everyday (based on the precipitation data and an assumption that an average BOD concentration of raw leachate generated is 1,000mg/l).

On the other hand, if the leachate is to be treated at Tepetate sewage treatment plant, it should be diluted to the permissible concentration level (i.e., BOD 400mg/l). In this case, the total amount of leachate to be treated reaches 625$m^3$/day (= 1000(mg/l)/400(mg/l)×250($m^3$/day)).

Therefore, it became clear that even if the treatment capacity of Tepetate plant is increased by installing an aerator, the marginal ability (i.e., 240$m^3$/day in 2005) of the plant is much smaller than what is required for the diluted leachate treatment.

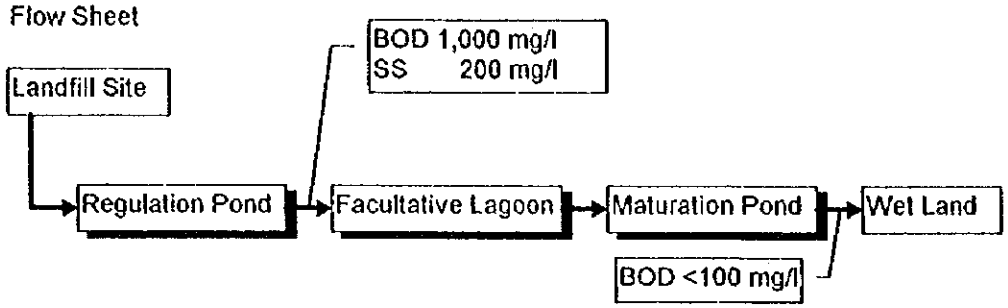
Accordingly, it also became clear that this case (i.e., leachate treatment at the sewage plant) inevitably requires the expansion of Tepetate sewage treatment plant which had been excluded from the priority projects in this Study with the reason stated in the table above.

In conclusion, leachate shall be treated within the SJV site in this project. The on-site leachate treatment shall be through a facultative lagoon and a maturation pond, which is basically the same treatment method used in the Tepetate sewage treatment plant. The outline of the treatment facility is summarized in the following table.

Table P-22: Outline of the Leachate Treatment facility

| | |
|---|---|
| Intake water quality | BOD: 1,000 mg/l, S S:200 mg/l |
| Treated water quality | BOD : <100 mg/l |
| Treatment capacity | 250 $m^3$/day |
| Treatment method | Facultative lagoon + Maturation pond |
| Facility volume | |
| Regulation pond | 6,000 $m^3$ |
| Facultative lagoon | 5,700 $m^2$ |
| Maturation pond | 1,250 $m^3$ |

Flow Sheet




### f.2.1 Engineering Calculation

#### f.2.1.1 BOD Removal Rate and Treated Water Quality

As can be seen from the figures in Table P-23, the BOD removal rate of the treatment system, consisting of a facultative lagoon and maturation pond, is found to vary according to the temperature of the water subject to the treatment.

Table P-23: BOD Removal Rate of Facultative Lagoon System[2]

| | Ambient Temperature (centigrade) | | |
|---|---|---|---|
| | 12 | 20 | 25 |
| Facultative lagoon | 75 % | 80 % | 84 % |
| Facultative + Maturation pond* | 86 % | 90 % | 93 % |

Note: * detention time : 5day

The temperature in the proposed site averages at about 26°C, and fluctuates somewhere around 24.8 to 28.3°C. Assuming a temperature of 25°C, the BOD concentration level of the treated effluent would be:

$$Q_f = 1{,}000(mg/l)-(1000\times 93\%)=70\ (mg/l)$$

#### f.2.1.2 Facultative Lagoon and Maturation Pond

The equation (1)[2] is used to represent the areal load of the facultative lagoon to calculate the required area.

$$\lambda s = 20T-60$$

[2] WORLD BANK TECHNICAL PAPER NUMBER 7, Notes on the Design and Operation of Waste Stabilization Pond in Warm Climates of Developing Countries, J.P.Arthur

where,

λs : BOD areal load rate (kg/ha/day)
T : Atmospheric temperature (centigrade)

The BOD inflow load is

$B_1$ = 1,000mg/l × 250m³/day = 250kg/day

Therefore, the required area for the facultative lagoon is:

A = 250(kg of $_{BOD}$)/day / 440(kg $_{BOD}$/ha/day)= 0.57 (hectare)

With a retention time of 5 days in the maturation pond (see Table P-23), the required volume was calculated as:

V = 250m³/day × 5 days = 1,250m³

**g. Environmental Protection Facilities**

**g.1 Fence**

The fence will restrict the access of the scavengers and animals to the site. The fence installed around the site will be of mesh type and will have a height of 2m and a length of about 2,600m. Scattering of waste from the landfill site will be prevented by mobile fences near the active cells and by tall trees planted as a buffer zone. Therefore, waste scattering beyond the buffer zone will be minimal. In addition to those measures, the fence around the project site will function as final barrier for flowing waste.

**g.2 Buffer Zone**

The planting of fast growing eucalyptus trees at the circumferrence of the landfill site, 20 meters wide, will also work to prevent the scattering of litter such as plastic bags and furthermore will function as a vegetation screen (visual shield) that will improve the aesthetic landscape view and avoid possible impact by offensive odor and noise.

**g.3 Gas removal**

To remove the landfill gases carefully from the landfill site, vertical chimneys will be installed with perforated concrete pipes, of 200 mm a diameter, every 40 m (pitch to both north-south and east-west directions). At its bottom, these will be connected to the leachate collection pipes, in order to achieve better ventilation of the gases.

**g.4 Monitoring Borehole**

To confirm whether leachate has contaminated groundwater resources, monitoring wells 35 deep with a diameter of 100mm will be installed in 4 areas (2 each to the west and east).

**h. Building and Accessories**

**h.1 Reception Area**

The reception area will be paved with asphalt, comprising a site office, a weighbridge, a tire washing pit and a gate, and furnished with electric lighting facilities.

### h.2 Asphalt Pavement

From the entrance, the road 30m long and 7.0m wide will be paved. And, the area in front of the site office (120m by 15.0m) will also be paved.

### h.3 Site Office

The site office (approximately 100m$^2$) shall have a control room and facilities for staff and management.

The control room shall be constructed and equipped with facilities, that enable easy control and registration of incoming vehicles. The computerized weighbridge system enables detailed registration, this is indispensable for appropriate SWM.

The facilities are as follows:

- a control room furnished with a computer for the weighbridge.
- a changing room.
- toilets and showers.
- cooking facilities.
- a storeroom.

### h.4 Weighbridge

A weighbridge shall be constructed on weighing cells in a concrete structure, 3 x 12m. The recorded weight of a full vehicle will be transmitted to the computer in the site office.

### h.5 Tire Washing Pit

The refuse collection vehicles should pass through the tire washing pit before leaving the site to avoid carrying the dirt back into the city. The pit should be of a concrete structure, 4 x 15m.

### h.6 Gate

A 8m wide gate should be installed at the entrance of the site.

### h.7 Parking and Washing Yard

The parking and washing yard should be mainly for heavy equipment for the landfill operation. A section of the yard should have a roof (7 x 15m). This yard should also be available for the refuse collection vehicles to park.

### h.8 Approach Road

For the refuse collection vehicles reaching the active filling area (waste disposal site), this approach road should be constructed. Its width should be 7.0m and 410m long, paved with gravel.

### h.9 Internal Access Road

This internal access road should be for maintenance of the enclosing structure, ditches, regulation pond, facultative lagoon and the maturation pond. Its width should be 3.0m, and 1,600m long, paved with gravel.

### i. Outline of the Disposal Site

The outline of the disposal site's layout is shown in Table P-24.

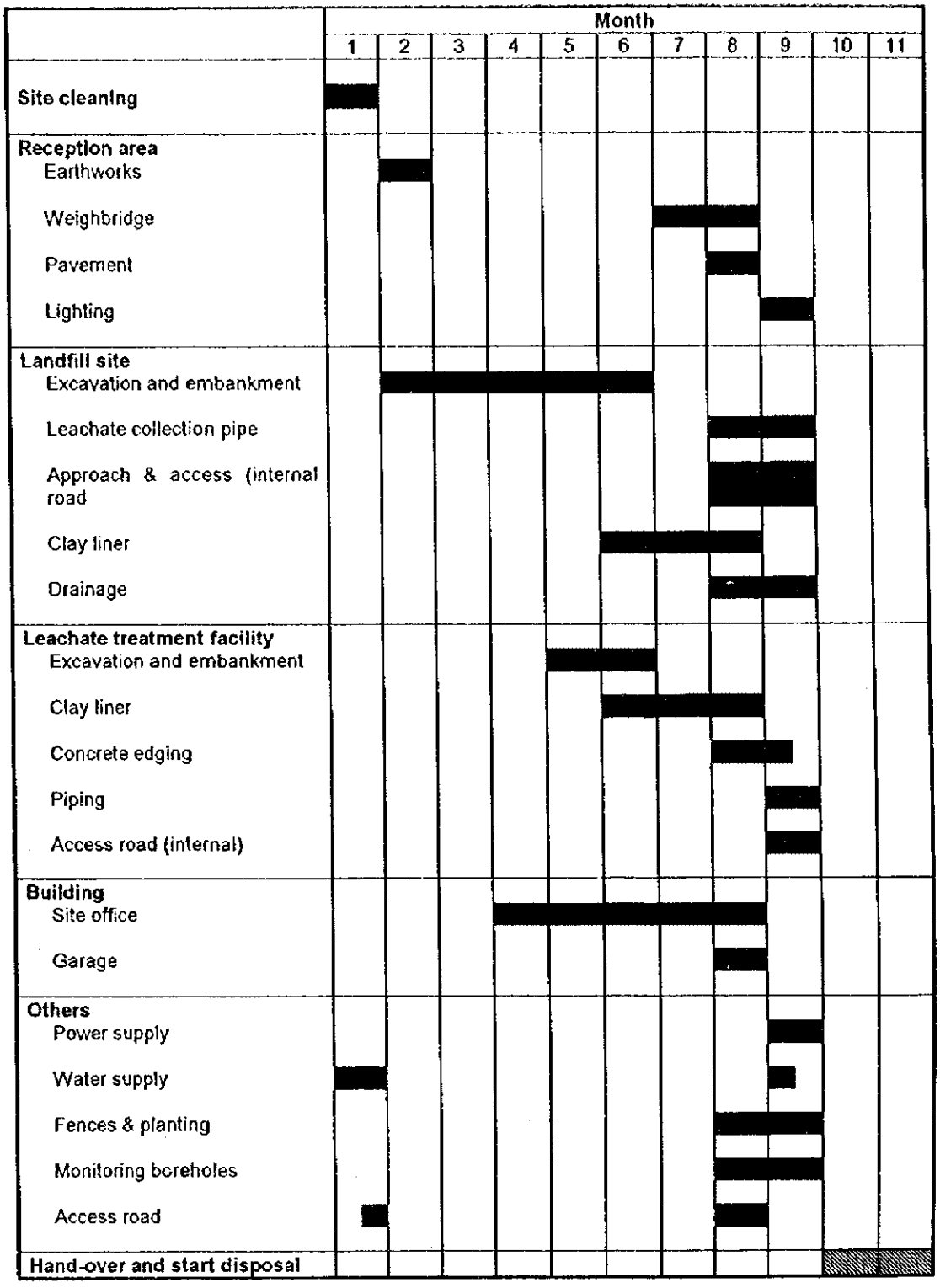
Table P-24: Outline of the Disposal Site

| Items | Description |
|---|---|
| Land Area | around 40 ha |
| Access road (from the city to the site) | asphalt paved: width 4.0m, length 3 km |
| Reception area | asphalt paved: width 7.0m, length 30m; width 15.0m, length 120m,<br>Site office: approximately 100 $m^2$<br>Weighbridge: 1 set: 3 x 12m<br>Tire washing pit: 1 set: 4 x 15m<br>8m wide gate: 1 set<br>electric lighting<br>water and power supply |
| Parking and washing yard | 600$m^2$, roof: 7 x 15m |
| Approach road (in the site) | gravel paved: width 7.0m, length 440m |
| Access road (internal) | gravel paved: width 3.0m, length 770m |
| Enclosing structure of landfill | width 10m, height 2m, length 700m |
| Landfill liner | clay liner: thickness 150cm; sand layer: thickness 60cm |
| Leachate collection | perforated PVC pipe: $\phi$200mm; open main ditch |
| Leachate treatment | regulation pond : 6,000 $m^3$, facultative lagoon : 5,700$m^2$, maturation pond : 1,250$m^3$ |
| Gas removal | perforated concrete pipe $\phi$200mm at 40m intervals |
| Surface drainage | vee type lined ditch: width 2m, length 1,600m |
| Fence | 2m height fence: length 2,600m |
| Planting (buffer zone) | eucalyptus nos. :3,000 |
| Monitoring borehole | 4 borehole: depth 35m |

### j. Time Schedule for Construction Works

The following time schedule provides a summary of the construction works.

## Table P-25: Time Schedule for Construction Works



## k. Operation of the Disposal Site

### k.1 Crew and Equipment Plan

The following personnel and equipment are required to operate the sanitary landfill.

Table P-26 : Required Clew and Equipment for the Sanitary Landfill

| Personnel and Equipment | Number | Remarks |
|---|---|---|
| Personnel | | |
| Site manager | 1 | |
| Waste controller | 1 | |
| Operator | 2 | |
| Driver | 2 | |
| Maintenance personnel | (1) | dispatched from the maintenance shop |
| Worker | 1 | |
| Security guard | 2 | |
| Total | 9 | |
| Equipment | | |
| Bulldozer (219Hp) | 1 | |
| Excavator (83Hp) | 1 | |
| Tipper truck (8 ton) | 1 | |
| Sprinkler truck (6-7 ton) | 1 | |
| Total | 4 | |

**A site manager:**

who has overall financial responsibilities and management duties, i.e.

- management and supervision of landfill operation, maintenance of landfill equipment, and performance of control procedures, e.g. registration of incoming waste and control of the groundwater.
- planning of the future extensions of the landfill, i.e. the construction of further landfill sections and preparation of new excavation areas for soil coverage.

**An incoming waste controller:**

who undertakes the task of controlling the incoming waste by using the weighbridge system.

**Equipment operators and truck drivers:**

for the operation of the sanitary landfill, one bulldozer for smoothing and compacting waste, one excavator for digging the daily cover soil, one tipper truck for transporting covering soil and one sprinkler truck for preventing waste and soil from scattering. Therefore, 2 operators and 2 drivers are required.

**Maintenance personnel for the equipment:**

conducts preventive maintenance of the equipment. However, they should be dispatched from the maintenance shop when required.

**A worker:**

to generally perform auxiliary functions.

**Two security guards:**

responsible for the security of the disposal site.

### k.2 Daily Operation

The sanitary landfill will operate Monday through Saturday, from 8:00 a.m. to 5:00 p.m.

#### k.2.1 Registration and Control at the Weighbridge

All vehicles will have to be registered upon arrival at the site office. The information recorded at the weighbridge will include:

- Registration number of the truck
- Type of waste
- Quantity of waste
- Origin of the waste (district, address of industry, institution etc.)

The staff of the site office will undertake control of the waste. Special attention will be paid to chemical and hazardous wastes that are not allowed on the sanitary landfill. These types of waste should be rejected on inspection and if there are suspicious cases, it should be further examined during the unloading at the filling area.

After registration, vehicles should go to the unloading area directly. While being unloaded, the waste should be checked again by the operators of the landfill equipment. If the waste is unsuitable for the landfill, the truck driver is obliged to remove the waste from the landfill area.

It is recommended that construction and demolition wastes is placed at an other area and stocked for construction of roads in the disposal site.

#### k.2.2 Waste Disposal and Daily Soil Coverage

The waste should be spread and compacted into 0.3m layers, optimum compaction at the filling area should be achieved by the bulldozer. This work should be continued repeatedly up to approximately 3m high. Each day's wastes should form one cell, and be covered with 10-15 cm soil at the end of a day. The cell dimension should be 9m length, 4m width and 3m height, and the slope of working face a gradient of 3 to 1.

The soil for daily coverage excavated from areas where further landfill sections will be constructed should be stocked close to the filling area.

### k.2.3 Treatment of Leachate

The operation and maintenance of leachate treatment facilities are classified into daily maintenance and periodical sampling and analysis of leachate.

Daily maintenance involves recording the volume of leachate flowing into the treatment facilities, recording the color of the influent and effluent of the lagoon, cleaning and mowing the surrounding areas of the lagoon, etc.

Periodical sampling and analysis of leachate will be carried out in conjunction with the groundwater quality monitoring works. The parameters used in the groundwater monitoring works will also be used to analyze sampled leachate. The sampling will be for raw leachate generated, facultative lagoon effluent, and maturation pond effluent.

## k.3 Control Procedures

To ensure that the landfill does not impose any negative impact on the surroundings, the sanitary landfill must be supervised regularly and monitored. Reports on the monitoring should be available at any time for inspection by authorities concerned.

The monitoring program should include issues described below.

### k.3.1 Waste Control

Ongoing monitoring of waste is to be conducted at the weighbridge. Monthly and annual reports based on the registration of waste should be prepared.

### k.3.2 Monitoring Program for Groundwater and Leachate

Monitoring should be carried out to closely watch for changes in the groundwater and leachate qualities.

The recommended monitoring program is described in Table P-27. The frequency and the parameters may be altered in accordance with the changes in the leachate qualities.

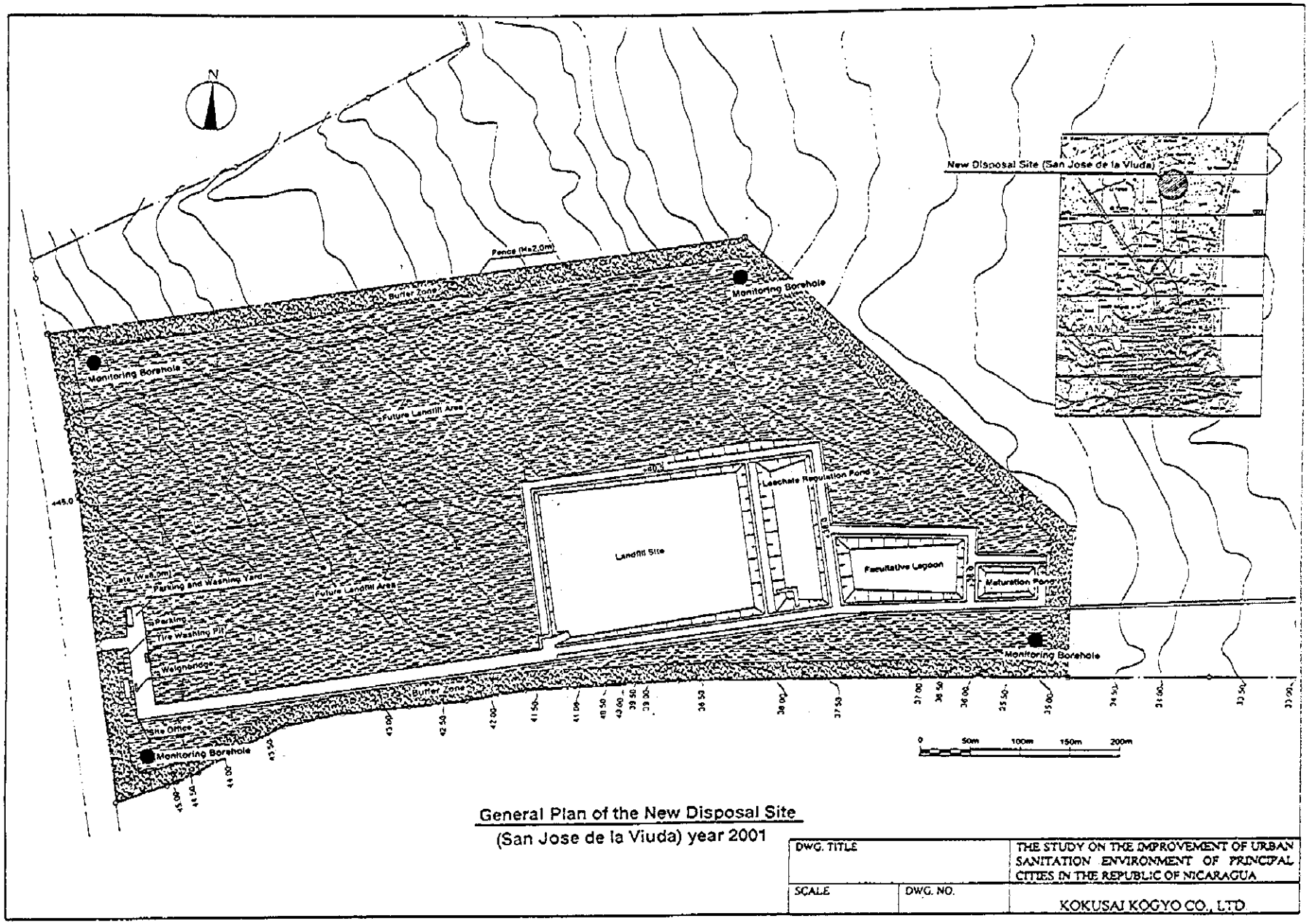
The groundwater must be analyzed before the opening of the landfill for later reference.

Table P-27: Monitoring Item and Frequency for Groundwater and Leachate

| | Groundwater | Leachate |
|---|---|---|
| Color | once per week | daily |
| pH | once per week | once per week |
| BOD | once per year | twice per year |
| COD | once per year | twice per year |
| SS | once per year | twice per year |
| Electric conductivity | once per week | once per week |
| $NH_4$-N | once per year | twice per year |
| $Cl^-$ | once per year | twice per year |
| $SO_4^{2-}$ | once per year | twice per year |
| Fe | once per year | twice per year |
| E-coliform | once per year | twice per year |

### l. Ultimate Use of the Site

After landfill operation is completed, a hill of about 5.5 to 8.5m height will be formed. An ecological park with an observatory will be constructed on the hill, which will be integrated with surrounding natural resources such as Lake Nicaragua, the wetlands and forests. The observatory could also provide views of the volcanic mountains and the Lake around Granada City.




General Plan of the New Disposal Site
(San Jose de la Viuda) year 2001

| | | |
|---|---|---|
| DWG. TITLE | | THE STUDY ON THE IMPROVEMENT OF URBAN SANITATION ENVIRONMENT OF PRINCIPAL CITIES IN THE REPUBLIC OF NICARAGUA |
| SCALE | DWG. NO. | KOKUSAI KOGYO CO., LTD |

Figure P-11 : General Plan of SVJ Landfill Site (Before Operation)

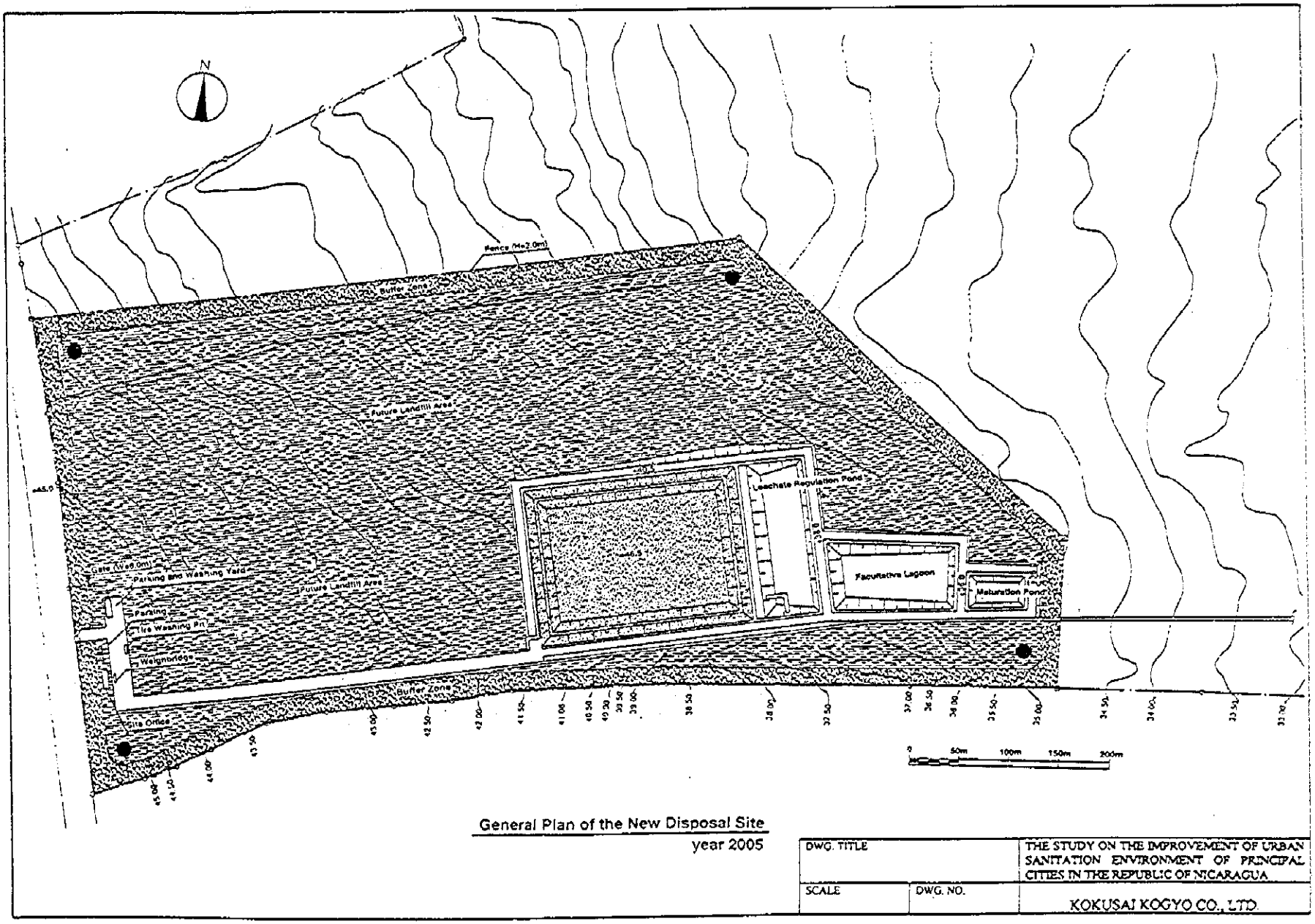



Figure P-12 : General Plan of SVJ Landfill Site (After Filled)

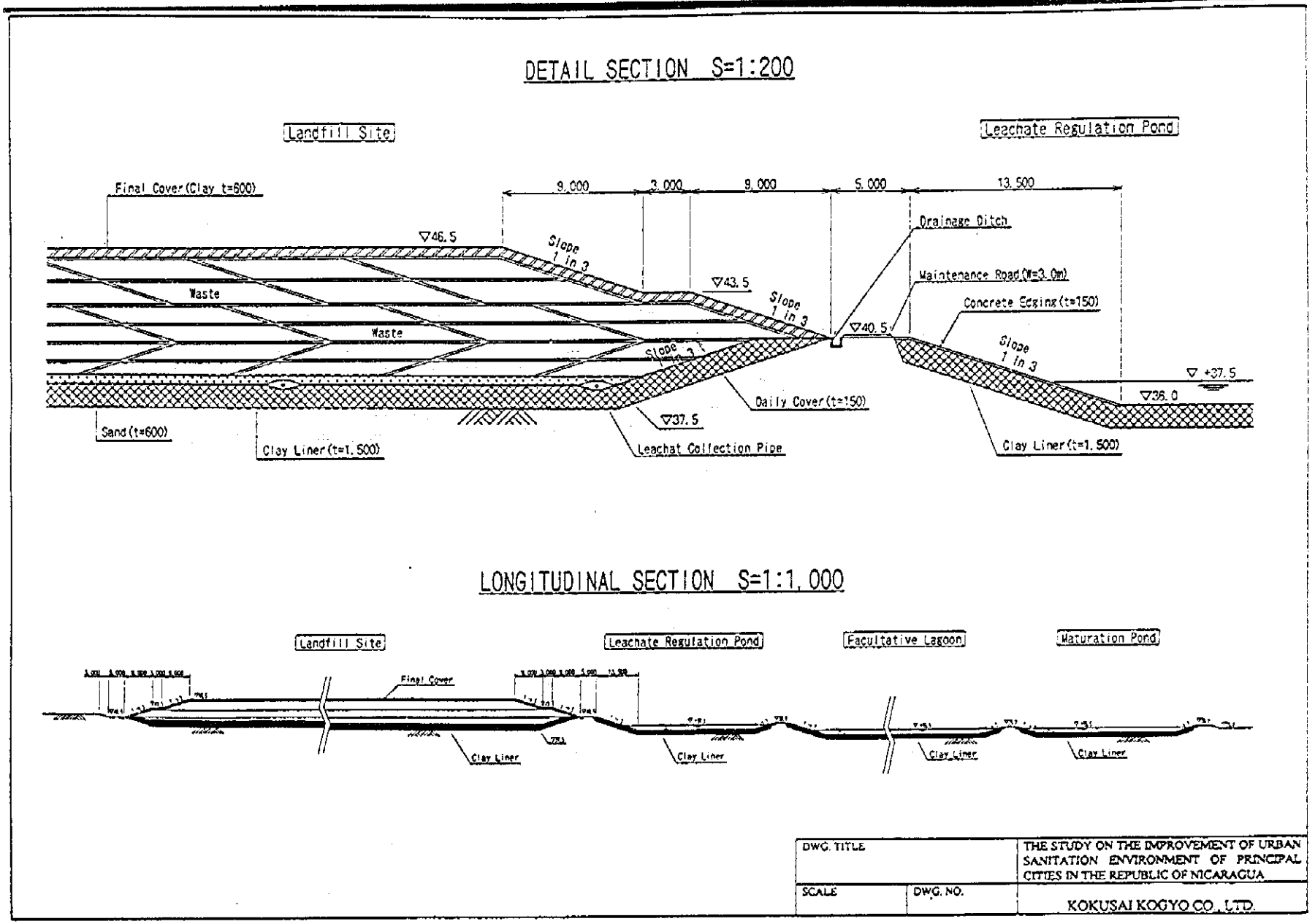



Figure P-13 : Detail and Longitudinal Section of SVJ Landfill Site

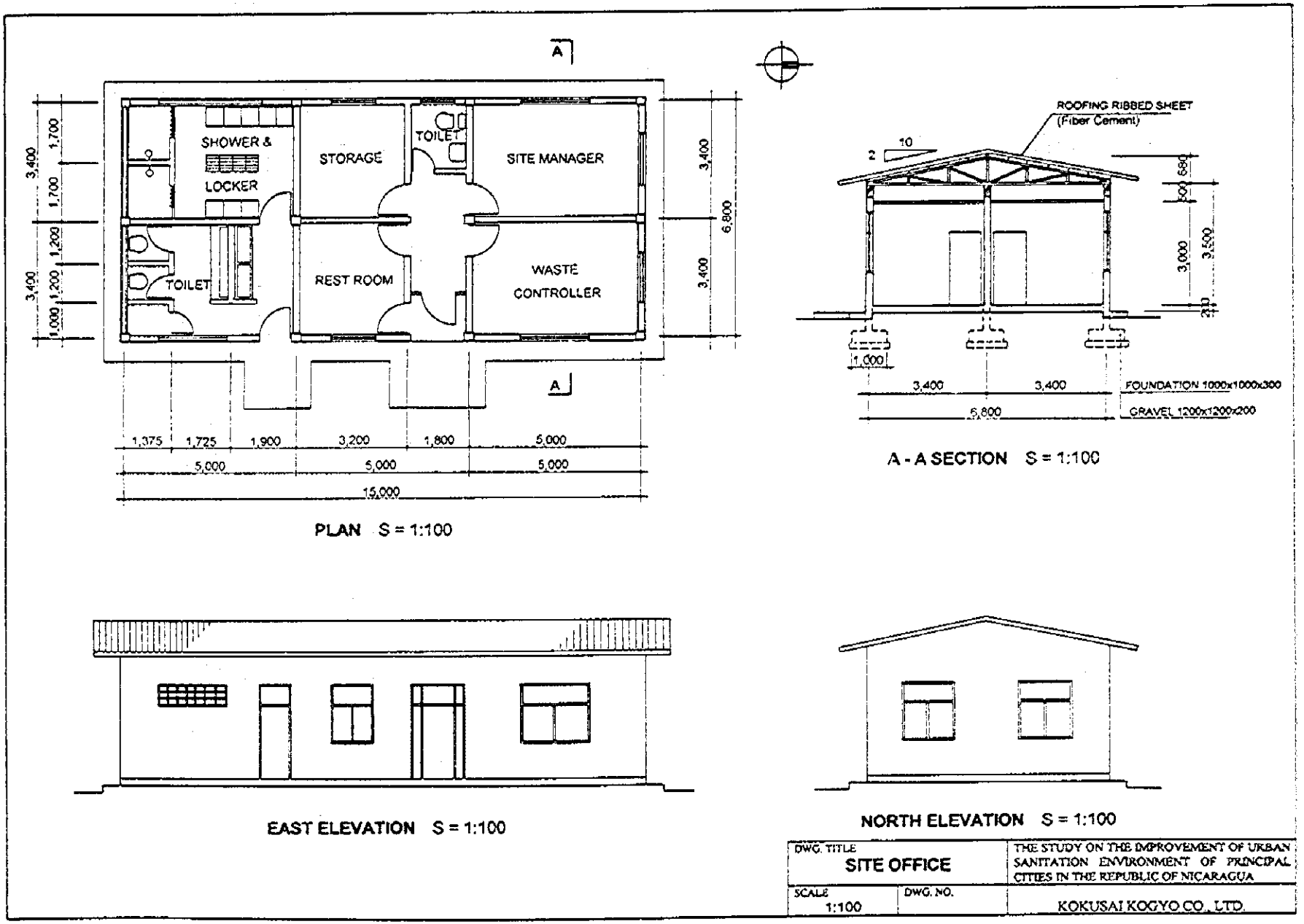
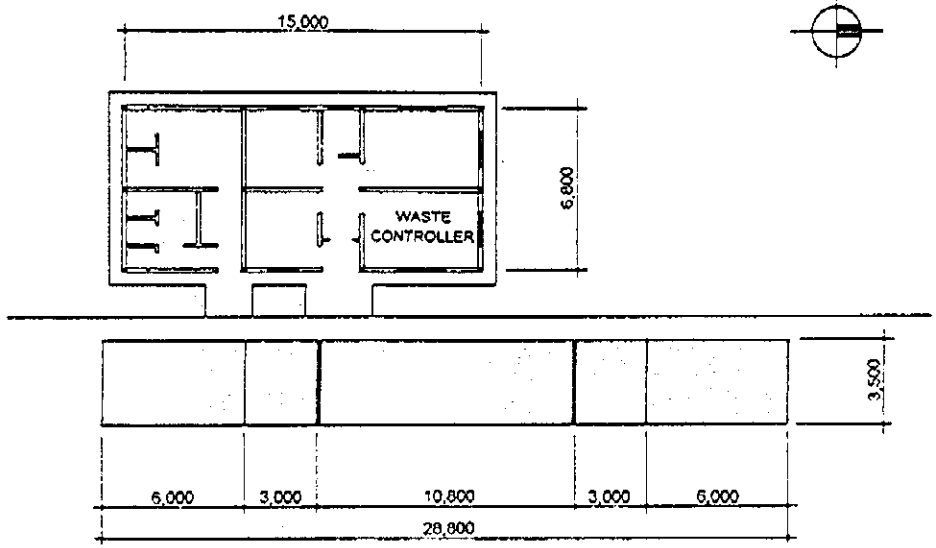
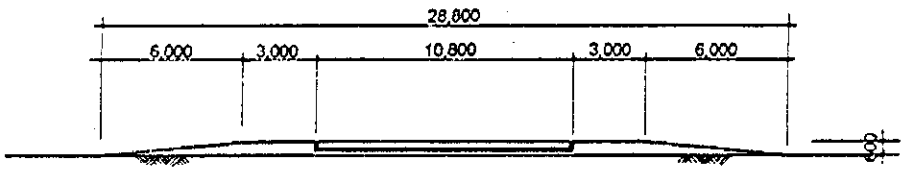



Figure P-14 : Detail Plan of Site Office



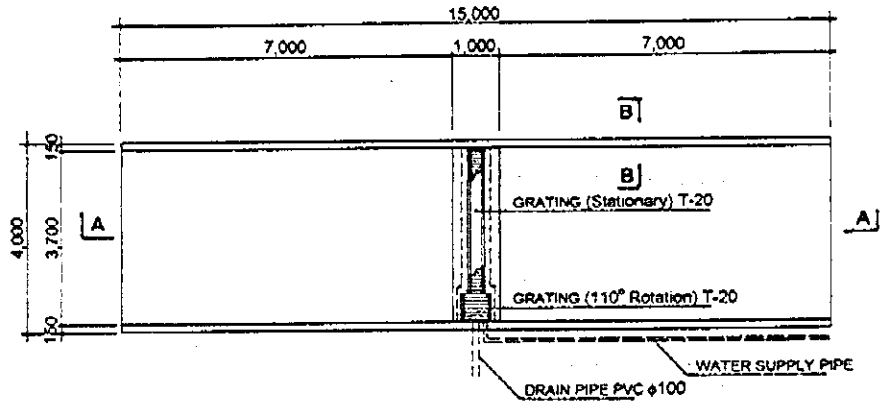

**PLAN** S = 1:200



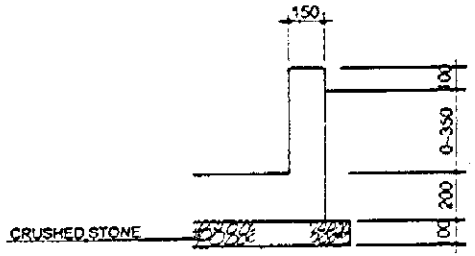

**PROFILE** S = 1:200

| DWG. TITLE | | THE STUDY ON THE IMPROVEMENT OF URBAN SANITATION ENVIRONMENT OF PRINCIPAL CITIES IN THE REPUBLIC OF NICARAGUA |
|---|---|---|
| **WEIGHTBRIDGE** | | |
| SCALE 1:200 | DWG. NO. | KOKUSAI KOGYO CO., LTD. |

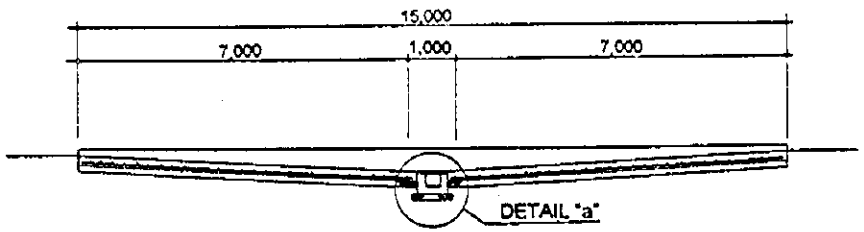
Figure P-15 : Weighbridge



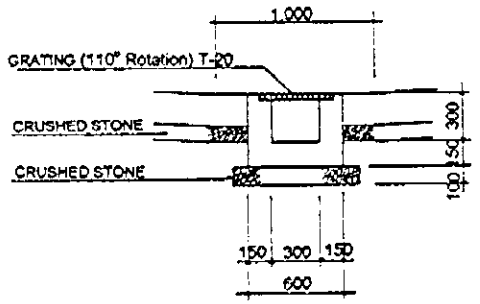

PLAN S = 1:100




B - B SECTION S = 1:20



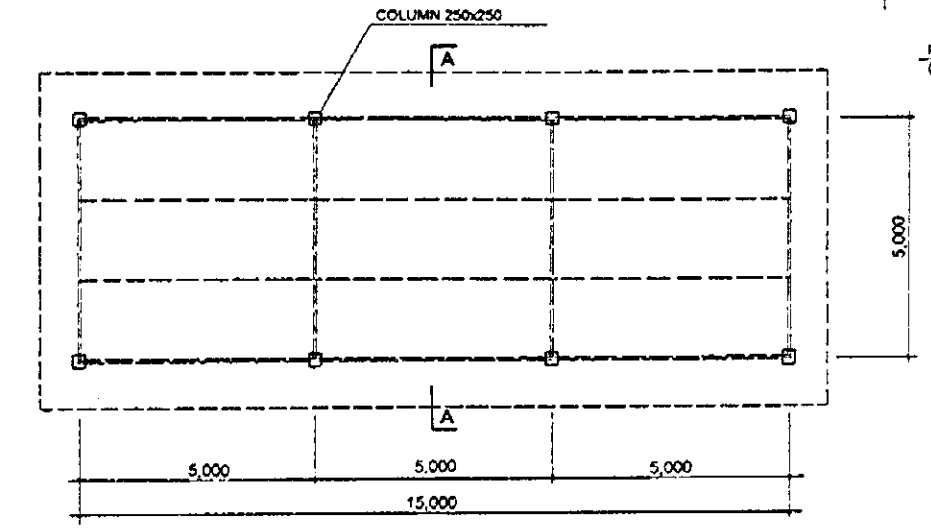

A - A SECTION S = 1:100



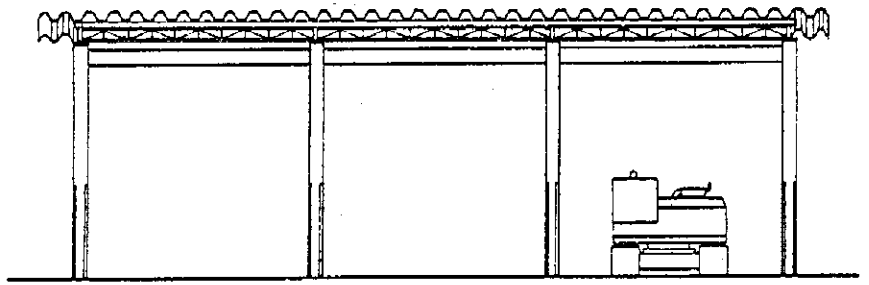

DETAIL "a" S = 1:30

| | | |
|---|---|---|
| DWG. TITLE<br>**TYRE WASHING PIT** | | THE STUDY ON THE IMPROVEMENT OF URBAN SANITATION ENVIRONMENT OF PRINCIPAL CITIES IN THE REPUBLIC OF NICARAGUA |
| SCALE<br>1:20, 1:30, 1:100 | DWG. NO. | KOKUSAI KOGYO CO., LTD |

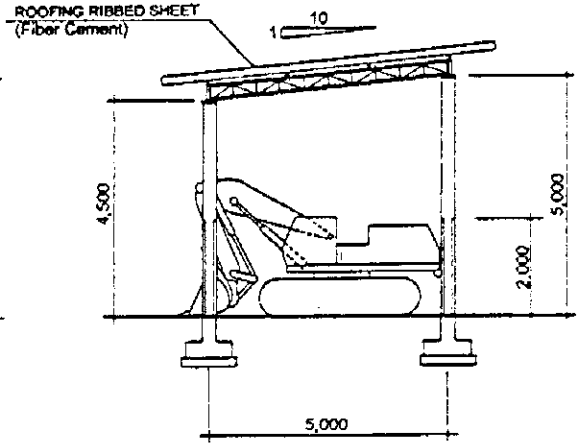
Figure P-16: Tire Washing Pit



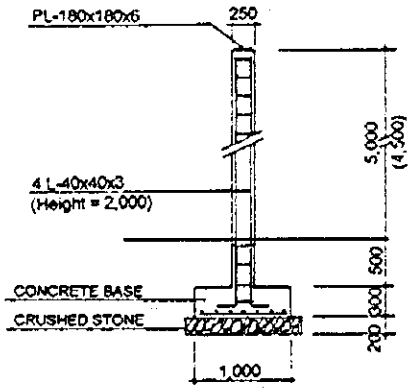

PLAN S = 1:100



EAST ELEVATION S = 1:100




A - A SECTION S = 1:100




COLUMN DETAIL S = 1:50

| | | |
|---|---|---|
| DWG. TITLE **PARKING YARD** | | THE STUDY ON THE IMPROVEMENT OF URBAN SANITATION ENVIRONMENT OF PRINCIPAL CITIES IN THE REPUBLIC OF NICARAGUA |
| SCALE 1:100, 1:50 | DWG. NO. | KOKUSAI KOGYO CO., LTD. |

Figure P-17: Parking Yard

# P.4 Cost Estimation

## P.4.1 Conditions of the Cost Estimate

Unit costs used in the preparation of the preliminary cost estimates were obtained from various sources, primarily, unit costs periodically published by the Ministry of Construction and Transport. Further data was obtained from Nicaraguan contractors and equipment suppliers, recent projects undertaken in the study area, and international sources.

An allowance of 10% of the basic cost estimate to cover physical contingency is reasonable, based on the degree of detail of the preliminary design. A further 25% is applied to cover over heads, and 10% for design and construction supervision.

Unit costs contained in the following table are those prevailing in September 1997; at the exchange rates, US$1 = ¥120 = C$9.6.

Table P-28: Unit Costs

| Description | Unit | Unit Cost (C$) |
|---|---|---|
| **Personnel** | | |
| manager | m.m | 4,000 |
| engineer, site manager | m.m | 10,000 |
| driver, operator, mechanic | m.m | 2,000 |
| accountant | m.m | 4,000 |
| secretary, clerk | m.m | 2,000 |
| collection worker, laborer, watchmen | m.m | 800 |
| **Earthwork** | | |
| machine excavation, 200 m transport, and stockpiling of soil | $m^3$ | 55 |
| construction of embankment, machine filling and compacting of soil | $m^3$ | 60 |
| s/t/p clay lining material in 150 mm layers | $m^3$ | 133 |
| **Drainage** | | |
| s/t/p open stone and mortar drain, d=0.75m, w=2.0m | m | 195 |
| s/t/p open concrete drain, d= 1.0m, w=0.5m+0.5m | m | 440 |
| s/t/p ϕ200 mm perforated PVC drain | m | 200 |
| s/t/p 0.70m x 0.70m x 1.20m concrete pit, wall t= 0.175m | Unit | 6,000 |
| **Concrete work** | | |
| s/t/p reinforced concrete paving (200mm) on prepared gravel base (300mm) and subgrade | $m^2$ | 210 |
| s/t/p reinforced concrete fc=180kg/cm², incl. formwork | $m^3$ | 750 |
| s/t/p premixed concrete 180 kg/cm² | $m^3$ | 650 |
| s/t/p premixed concrete 240 kg/cm² | $m^3$ | 730 |
| **Road work** | | |
| s/t/p concrete block paving and base preparation | $m^2$ | 120 |
| s/t/p hot-mix asphalt and base preparation | $m^2$ | 125 |
| s/t/p "piedra cantera" curb and channel | m | 50 |
| s/t/p gravel road (t=0.3m) and subgrade preparation | $m^2$ | 90 |
| **Miscellaneous** | | |
| s/t/p tubewell and submersible pump ϕ75mm, d=30m | Unit | 160,000 |
| s/t/plant trees 2 to 5 m in height | tree | 90 |
| s/t/p gabion, 1m x 1m x 1.5m | $m^3$ | 241 |
| s/t/p gas removal points, ϕ200mm perforated PVC, L=40m | point | 3,100 |
| s/t/p gas monitoring well, ϕ100mm, d=40m | point | 15,000 |
| s/t/p water supply pipeline, ϕ75mm | m | 100 |
| **Basic materials** | | |
| diesel oil | gal | 12 |
| gasoline | gal | 22 |
| crushed rock | $m^3$ | 165 |
| course aggregate | $m^3$ | 165 |
| fine aggregate | $m^3$ | 30 |
| sand | $m^3$ | 30 |
| reinforcing bar | ton | 7,170 |
| timber | $m^3$ | 4,600 |

Note : s: supply of materials, t: transport, p: placement

## P.4.2 Investment

### a. Final Disposal Site

### a.1 Construction Works

The following cost estimate is based on the preliminary design of the proposed Granada sanitary landfill carried out during the F/S. The basic difference between level 4 and level 2 is that the level 4 cost estimate is for a landfill with a clay lining layer and leachate treatment facilities. The level 2 landfill has no liner nor leachate treatment.

Table P-29: Investment Cost of Construction of Final Disposal Site

| Item | Unit | Unit cost (C$) | LEVEL 4 | | LEVEL 2 | |
|---|---|---|---|---|---|---|
| | | | quantity | cost | quantity | cost |
| **Access road from city to site** | | | | | | |
| asphalt paving | m² | 125 | 12,000 | 1,500,000 | 12,000 | 1,500,000 |
| **Site buildings and administration area** | | | | | | |
| site clearing | m² | 6 | 95,000 | 570,000 | 57,500 | 345,000 |
| entrance area, asphalt pavement | m² | 125 | 2,200 | 275,000 | 2,200 | 275,000 |
| site office | m² | 1,800 | 100 | 180,000 | 100 | 180,000 |
| weighbridge, 3 x 12m | wb | 660,000 | 1 | 660,000 | 1 | 660,000 |
| tire washing pit, 4 x 15m | pit | 8,000 | 1 | 8,000 | 1 | 8,000 |
| 8m wide gate | gate | 3,500 | 1 | 3,500 | 1 | 3,500 |
| power supply | | | | 15,000 | | 15,000 |
| water supply to site, tubewell and submersible pump, d=30m | | | | 160,000 | | - |
| water supply system | m | 100 | - | - | | 150,000 |
| parking, washing area, reinforced conc. pav. t=210mm | m² | 210 | 600 | 126,000 | 600 | 126,000 |
| approach road, within site, gravel road, w=15m, L=410m | m² | 90 | 8,880 | 799,500 | 8,880 | 799,000 |
| on site road, gravel road, w=3m, L=1600m | m² | 90 | 6,930 | 623,700 | 6,930 | 624,000 |
| 2m high fence | m | 100 | 2,600 | 260,000 | 2,600 | 260,000 |
| planting of buffer zones | tree | 90 | 3,000 | 270,000 | 3,000 | 270,000 |
| **Sanitary landfill** | | | | | | |
| construct embankment | m³ | 20 | 20,720 | 414,400 | 7,700 | 154,000 |
| construct embankment using imported soil | m³ | 60 | - | - | 13,020 | 781,200 |
| excavation of soil | m³ | 55 | 39,900 | 2,194,500 | 7,700 | 423,500 |
| landfill liner, 150cm compacted clay | m² | 200 | 31,300 | 6,260,000 | - | - |
| 60 cm compacted sand layer | m² | 33 | 26,000 | 858,000 | - | - |
| leachate collection drain, ϕ200 mm perforated PVC pipe | m | 200 | 1,600 | 320,000 | - | - |
| 0.70x0.70 concrete pit | pit | 6,000 | 7 | 42,000 | - | - |
| open concrete drain, double type | m | 440 | 230 | 101,200 | - | - |
| open concrete drain, single type | m | 300 | 850 | 255,000 | 1,080 | 324,000 |
| surface drainage, V type concrete lined drain | m | 170 | 170 | 272,000 | 1,600 | 272,000 |
| gas removal, perforated ϕ200mm, d=40m | point | 3,100 | 36 | 111,600 | 36 | 111,600 |
| monitoring borehole, ϕ100, 30m | point | 15,000 | 4 | 60,000 | 6 | 90,000 |
| **Leachate treatment** | | | | | | |
| construction of embankment | m³ | 60 | 10,400 | 624,000 | - | - |
| excavation of soil | m³ | 55 | 10,830 | 595,650 | - | - |
| clay liner, t=1500mm | m² | 200 | 21,660 | 4,332,000 | - | - |
| concrete lining of embankment, t=150mm | m² | 98 | 8,660 | 848,680 | - | - |
| SUB TOTAL | C$ | | | 22,739,430 | | 7,371,700 |
| PHYSICAL CONTINGENCY | C$ | | | 2,273,943 | | 737,170 |
| TOTAL DIRECT COST | C$ | | | 25,013,373 | | 8,108,870 |
| OVERHEAD | C$ | | | 6,251,838 | | 2,025,025 |
| TOTAL CONSTRUCTION COST | C$ | | | 31,265,211 | | 10,133,895 |
| DESIGN AND SUPERVISION | C$ | | | 3,126,521 | | 1,013,390 |
| TOTAL PROJECT COST | C$ | | | 34,391,732 | | 11,147,285 |
| LAND ACQUISITION COST | ha | 15,000 | 40 | 60,000 | 40 | 600,000 |
| TOTAL | | | | 34,991,732 | | 11,747,285 |

## a.2 Equipment

### a.2.1 Investment Schedule of Landfill Equipment

The landfill equipment procurement schedule, determined in previous sections, is summarized in Table P-29. From this table, the following investment schedule is made.

Table P-30: Procurement Schedule

| Items | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Bulldozer (219 Hp) | 1 | - | - | - | - | - |
| Excavator (83 Hp) | 1 | - | - | - | - | - |
| Tipper truck (8 ton) | 1 | - | - | - | - | - |
| Sprinkler truck (6-7 ton) | 1 | - | - | - | - | - |

Table P-31: Investment Schedule

Unit : C$ 1,000

| Items | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Bulldozer (219 Hp) | 1,639 | - | - | - | - | - |
| Excavator (83 Hp) | 979 | - | - | - | - | - |
| Tipper truck (8 ton) | 407 | - | - | - | - | - |
| Sprinkler truck (6-7 ton) | 572 | | | | | |
| Total | 3,597 | - | - | - | - | - |

## b. Collection System

### b.1 Workshop

The following cost estimate is based on the preliminary design of the proposed workshop improvement plan.

Table P-32: Investment Cost for Workshop

Unit : C$ 1,000

| Items | Cost |
|---|---|
| **Construction work** | |
| Improvement of existing building | 658 |
| Concrete pavement | 192 |
| Sub-total | 850 |
| Physical contingency | 85 |
| Total direct cost | 935 |
| Overhead | 233 |
| Total construction cost | 1,168 |
| Design and supervision | 117 |
| **Total construction works** | **1,285** |
| **Equipment and tools** | **1,444** |
| **Total** | **2,729** |

### b.2 Collection Vehicles

The vehicle procurement schedule, determined in previous sections, is summarized in Table P-33. From this table, the following investment schedule is made.

Table P-33: Procurement Schedule

| Items | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Compactor truck (12m³) | 5 | 1 | - | - | 1 | - |
| Tipper truck (12m³) | 1 | - | - | - | - | - |
| Handcart | 30 | - | - | 30 | - | - |
| Wheel loader(0.7m³) | 1 | - | - | - | - | - |

Table P-34: Investment Schedule

Unit : C$ 1,000

| Items | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Compactor truck (12m³) | 4,267 | 853 | - | - | 853 | - |
| Tipper truck (12m³) | 598 | - | - | - | - | - |
| Handcart | 67 | - | - | 67 | - | - |
| Wheel loader | 768 | - | - | - | - | - |
| TOTAL | 5,700 | 853 | - | 67 | 853 | - |

## P.4.3 Operation and Maintenance Costs

### a. Operation Costs

### a.1 Final Disposal Site

The operation costs consist of the cost of diesel fuel consumed by the landfill equipment (e.g., bulldozer, excavator, etc.) and labor: landfill equipment drivers, waste controller, workers, and supervisors.

The fuel costs were calculated assuming the equipment will operate for six (6) days a week, fifty two (52) weeks per year.

Table P-35: Required Operation Quantities of the Final Disposal Site

| Items | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Fuel | | | | | | |
| Diesel (C$1,000) | - | 108 | 116 | 120 | 126 | 135 |
| Labor | | | | | | |
| Site manager | - | 1 | 1 | 1 | 1 | 1 |
| Waste controller | - | 1 | 1 | 1 | 1 | 1 |
| Operator | - | 2 | 2 | 2 | 2 | 2 |
| Driver | - | 2 | 2 | 2 | 2 | 2 |
| Worker | - | 1 | 1 | 1 | 1 | 1 |
| Security guard | - | 2 | 2 | 2 | 2 | 2 |
| Total | - | 9 | 9 | 9 | 9 | 9 |

Table P-36: Required Operation Costs of the Final Disposal Site

Unit : C$ 1,000

| Items | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Fuel | - | 108 | 116 | 120 | 126 | 135 |
| Labor | - | 203 | 203 | 203 | 203 | 203 |
| TOTAL | - | 311 | 319 | 323 | 329 | 338 |

### a.2 Collection System

The operation costs consist of the cost of diesel fuel consumed by the collection vehicles and labor: collection vehicle drivers, collection workers, street sweepers and supervisors.

The fuel costs were calculated assuming the vehicles will operate for six (6) days a week, fifty two (52) weeks per year.

Table P-37: Required Operation Quantities of the Collection System

| Items | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| **Fuel** | | | | | | |
| Diesel (C$ 1,000) | - | 173 | 203 | 203 | 203 | 203 |
| **Labor** | | | | | | |
| Driver | - | 7 | 8 | 8 | 8 | 9 |
| Worker | - | 18 | 21 | 21 | 21 | 24 |
| Supervisor | - | 1 | 1 | 1 | 1 | 1 |
| Sweeper | - | 30 | 30 | 30 | 30 | 30 |

Table P-38: Required Operation Costs of the Collection System

Unit : C$ 1,000

| Items | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Fuel | - | 218 | 251 | 251 | 251 | 251 |
| Labor | - | 901 | 1,011 | 1,011 | 1,011 | 1,011 |
| TOTAL | - | 1,119 | 1,262 | 1,262 | 1,262 | 1,262 |

## b. Maintenance Costs

### b.1 Final Disposal Site

The maintenance costs for the final disposal site have been broken down into two costs: 1) landfill equipment maintenance costs; and 2) leachate treatment facility maintenance cost.

The landfill equipment maintenance cost is estimated to be 20% of the landfill equipment investment cost. This cost covers general operation costs (electricity, water supply, spare parts, lubricants, periodic building maintenance, etc.) of the landfill site.

The leachate treatment facility maintenance cost is estimated to be 1% of the leachate treatment facility investment cost. This cost covers general operation costs (monitoring

of intake and treated water quality, sludge management, etc.) of the leachate treatment facility.

Table P-39 : Required Maintenance Costs

Unit : C$ 1,000

| Items | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Landfill | - | 103 | 103 | 103 | 103 | 103 |
| Leachate treatment | - | 36 | 36 | 36 | 36 | 36 |
| TOTAL | - | 139 | 139 | 139 | 139 | 139 |

### b.2 Collection System

The maintenance costs for the solid waste collection vehicles have been broken down into two costs: 1) collection vehicle maintenance costs, and 2) maintenance workshop labor costs.

The collection vehicle maintenance cost is estimated to be 20% of the vehicle investment cost, and 5% of the handcart investment cost. This cost covers general operation costs (electricity, water supply, spare parts, lubricants, periodic building maintenance, etc.) of the maintenance workshop.

The workshop labor cost is the cost of employing a crew of mechanics, administrative staff, and watchmen, necessary for the day to day operation of the maintenance workshop.

Table P-40 : Maintenance Workshop Labor

| Position | Number | Pay (C$/month) | Pay/year |
|---|---|---|---|
| Manager | 1 | 4,000 | 48,000 |
| Assistant manager | 1 | 2,500 | 30,000 |
| Secretary | 1 | 2,500 | 30,000 |
| Mechanic | 2 | 3,000 | 72,000 |
| Assistant mechanic | 4 | 2,000 | 96,000 |
| Store manager | 1 | 2,000 | 24,000 |
| Watch man | 2 | 800 | 19,200 |
| TOTAL | | | 319,200 |

Table P-41: Required Maintenance Costs

Unit: C$1,000

| Items | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Collection vehicles | | 162 | 187 | 187 | 187 | 187 |
| Workshop labor | | 319 | 319 | 319 | 319 | 319 |
| TOTAL | | 481 | 506 | 506 | 506 | 506 |

## P.4.4 Administrative Cost

The total number of staff necessary for the day to day administration of the solid waste collection services has been described in the Institutional Plan. It is assumed that most of these positions will be filled with existing staff.

However, it is expected that a number of additional staff will be needed to fulfill the requirements of the Institutional Plan. The following table is an estimate of the number and qualifications of this additional staff.

Table P-42 : Cost of Additional Administrative Staff

| Profession | Level of Experience | Staff required | Monthly Remuneration | Annual Pay C$ |
|---|---|---|---|---|
| Engineer/ Architect | high | 1 | 10,000 | 120,000 |
| Engineer/Architect | medium | 1 | 4,000 | 48,000 |
| Economist | medium | 1 | 4,000 | 48,000 |
| Technician | medium | 3 | 2,000 | 72,000 |
| TOTAL | | | | 288,000 |

## P.4.5 Project Cost Summary

Table P-43 summarises the project cost schedule from 2000 to 2005 to implement the complete priority project.

Table P-43: Project Cost Summary

Unit : C$ 1,000

| Item | Category | Description | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | Total |
|---|---|---|---|---|---|---|---|---|---|
| Direct Cost | Collection System | Investment for equipment | 5,700 | 853 | - | 67 | 853 | - | 7,473 |
| | | Operation for labor | - | 695 | 805 | 805 | 805 | 915 | 4,025 |
| | | Operation for material & fuel | - | 218 | 251 | 251 | 251 | 283 | 1,254 |
| | | Maintenance | - | 162 | 187 | 187 | 187 | 211 | 934 |
| | | **sub-total** | 5,700 | 1,928 | 1,234 | 1,310 | 2,096 | 1,409 | 13,686 |
| | Street Sweeping | Investment for equipment | Inc. collection system | | | | | | |
| | | Operation for labor | - | 206 | 206 | 206 | 206 | 206 | 1,030 |
| | | Operation for material & fuel | Inc. collection system | | | | | | |
| | | Maintenance | Inc. collection system | | | | | | |
| | | **sub-total** | - | 206 | 206 | 206 | 206 | 206 | 1,030 |
| | Disposal Site | Investment for facilities (Inc. land acquisition cost) | 34,992 | - | - | - | - | - | 34,992 |
| | | Investment for equipment | 3,597 | - | - | - | - | - | 3,597 |
| | | Operation for labor | - | 203 | 203 | 203 | 203 | 203 | 1,015 |
| | | Operation for material & fuel | - | 108 | 116 | 120 | 126 | 135 | 605 |
| | | Maintenance | - | 139 | 139 | 139 | 139 | 139 | 695 |
| | | **sub-total** | 38,589 | 450 | 458 | 462 | 468 | 477 | 40,904 |
| | **Total Direct Cost** | | 44,289 | 2,584 | 1,907 | 1,978 | 2,770 | 2,092 | 55,620 |
| Indirect Cost | Maintenance Workshop and Vehicle Depot | Investment for facilities | 1,285 | - | - | - | - | - | 1,285 |
| | | Investment for equipment | 1,444 | - | - | - | - | - | 1,444 |
| | | Operation for labor | - | 319 | 319 | 319 | 319 | 319 | 1,595 |
| | | Operation for material | - | 5 | 5 | 5 | 5 | 5 | 25 |
| | | Maintenance | - | 5 | 5 | 5 | 5 | 5 | 25 |
| | | **sub-total** | 2,729 | 329 | 329 | 329 | 329 | 329 | 4,374 |
| | Administration | Investment for facilities | Inc. workshop & depot | | | | | | |
| | | Investment for equipment | Inc. workshop & depot | | | | | | |
| | | Operation for labor | - | 288 | 288 | 288 | 288 | 288 | 1,440 |
| | | Operation for material | Inc. workshop & depot | | | | | | |
| | | Maintenance | Inc. workshop & depot | | | | | | |
| | | **sub-total** | - | 288 | 288 | 288 | 288 | 288 | 1,440 |
| | **Total Indirect Cost** | | 2,729 | 617 | 617 | 617 | 617 | 617 | 5,814 |
| **Grand Total** | | | 47,018 | 3,201 | 2,524 | 2,595 | 3,387 | 2,709 | 61,434 |

# P.5 Financial and Economic Evaluation

## P.5.1 Financial Analysis

The objective of the financial analysis is to evaluate the municipal SWM system improvement project for Granada City and to select a financially sustainable plan.

### a. Methods and Conditions of the Analysis

The FIRR (Financial Internal Rate of Return) is calculated to evaluate the project in the following conditions.

| | |
|---|---|
| Project Life | 31 years, from 2000 until 2030 |
| Executing Organ | Granada Municipality will be the executing body, but a part of the services will be contracted out to private collection companies |
| Investment plan | The M/P proposes the construction of the San Jose de la Viuda (SJV) disposal site in the northern part of the city after the closure of the La Joya disposal site in 2001. the financial analysis was therefore carried out assuming that in 2000, Granada Municipality will purchase all vehicles required for the collection, haulage and disposal of wastes to the SJV final disposal site.<br>Additional investment of vehicles and replacement investment of plants and equipments were counted according to their economic life span. |
| Residual value | The residual value of the collection vehicles, facilities, landfill equipment in the year 2031 is considered as the minus investment costs. |
| Cut-off Rate | A cut-off rate of 8.5%, which is also equivalent to the prime rate of the Central Bank of Nicaragua in 1997, was assumed. The cost to be covered by the grant was excluded from the project cost items subject to the financial analysis. |

### b. Case Studies

Three case studies were established for the financial analysis.

- Financial Source: Financial source for a part of the project cost
- Revenue Source 1: Waste fee collection system
- Revenue Source 2: Total budget allocated for SWM services from municipal tax revenue

### b.1 Financial Source for a Part of the Project Cost

The following possibilities were considered for this case.

| | |
|---|---|
| Case A | To acquire a loan for the total investment amount |
| Case B | To acquire grant aid to cover 90% of the investment for the construction of the final disposal site, procurement equipment's and collection vehicles, and improvement of plants in 2000. |
| Case C | To acquire grant aid to cover the entire investment for the construction of the final disposal site, procurement equipment's and collection vehicles, and improvement of plants in 2000. |

### b.2 Waste Fee Collection System

Granada Municipality directly collects waste fees from service recipients, but because the present collection rate is extremely low, 16.3%, the system is not functioning at all. Furthermore, the tax reforms currently being promoted in the country deprives the municipality of the power to reinforce the direct fee collection system. As a result, the municipality made a plan to combine the collection of charges for household waste (ordinary households) with the water supply charges of INAA, who had a 96% collection rate in 1996. In view of the fact that discharge volume significantly varies by generation source, and that it is favorable to have dischargers shoulder the expenses for waste they generate, the municipality established charges according to discharge volume for wastes generated in commercial and business sectors. It is favorable to attach waste collection charges to taxes imposed in the municipality, such as that on sales and services

(the business tax), for effective collection. Thus, as before, waste collection charges will be collected through the municipal tax section.

### b.3 Total Budget Allocated for SWM Services from the Municipal Tax Revenue

The following possibilities were considered for this case.

| | |
|---|---|
| Case A | Very optimistic assumptions regarding increase in municipal tax revenue (6.7% per annum) and budget allocation for SWM (12% in the year 2005) |
| Case B | Assuming the present rate of increase in municipal tax revenue (5.4% per annum) and budget allocation for SWM (10% per anumm) |
| Case C | Very pessimistic assumptions regarding increase in municipal tax revenue (3.3% per annum) and budget allocation for SWM (8% in the year 2005) |

## c. Waste Fee Collection System

The following were the conditions established to determine the waste fee collection system.

### c.1 Household Waste

| | |
|---|---|
| Target Population | All households that will receive waste collection services |
| RCC | The refuse collection charges are set as follows, based on the service level:<br>- High service charge (CCA): C$15/household/month<br>- Ordinary service charge (CCB): C$10/household/month<br>- Low service charge (PCA): C$5/household/month |
| Collection Rate | 82% (attained by multiplying the waste supply collection rate of 96% with the water supply service expansion rate, in 2000, of 85%)<br>The area where the high service and the ordinary service are conducted is assumed to be included in the water supply service area. |
| Collection Cost rate | 5% (5% of the collection charge will be allocated to cover the INAA fee collection expenses and commission.) |

### c.2 Other Waste

| | |
|---|---|
| Target Population | Commercial and business institutions, as well as all municipal waste generators that will receive waste collection services |
| RCC's | The refuse collection charges are set according to waste volumes as shown below:<br>Collection services C$ 363/ton (will basically cover the cost for collection, haulage and final disposal services)<br>Direct haulage C$ 215/ton (will basically cover the final disposal services) |
| Collection Rate | 100% |
| Collection Cost rate | 0% (will be covered with other municipal tax) |

### c.3 Revenue of Waste Fee

The revenue of waste fee is calculated based on above mentioned conditions are shown in the following table.

Table P-44: Revenue of Waste Fee

Unit: C$ 1,000

| | | 2001 | 2002 | 2003 | 2004 | 2005 | 2001~ 2005 Total |
|---|---|---|---|---|---|---|---|
| Household | CCA | 806 | 892 | 987 | 1,093 | 1,210 | 4,988 |
| | CCB | 403 | 446 | 494 | 546 | 605 | 2,494 |
| | PCA | 100 | 111 | 123 | 137 | 151 | 622 |
| | Total | 1,309 | 1,449 | 1,604 | 1,776 | 1,966 | 8,104 |
| Other | Collection | 901 | 954 | 994 | 1,047 | 1,100 | 4,996 |
| | Direct haulage | 194 | 194 | 194 | 203 | 203 | 988 |
| | Total | 1,095 | 1,148 | 1,188 | 1,250 | 1,303 | 5,984 |
| Total | | 2,404 | 2,597 | 2,792 | 3,026 | 3,269 | 14,088 |

### d. Forecast Increase in Municipal Tax Revenue and SWM Budget

The total budget to be allocated for SWM from the municipal tax revenue was estimated according to the assumed increase in tax revenue and the budget rate for SWM services.

#### d.1 Forecast on Municipal Taxes

#### d.1.1 Municipal Taxes

The municipal tax revenue of Granada Municipality is broken down into 64% municipal tax and 13% municipal service charges.

The municipal imposed tax on sales and services (the business tax) make up 52% of the municipal tax. However, tax reforms proposed the lowering the tax rate to 1% in 2000 from the present rate of 2%. Accordingly, the municipality needs to fill up the deficit that would result from this proposal. Although nothing concrete has been decided, the municipality is currently reinforcing the collection system for real property tax, vehicle tax and service charges, to secure the funds required.

#### d.1.2 Forecast Tax Revenue Growth Rate

The tax revenue growth rate was estimated based on the following factors:

- effect of cuts in the business tax rate on actual revenue deductions (share of the business tax in annual revenues)
- maximum amount collectible for other municipal taxes (tax revenue potential growth rate and potential maximum collection rate)

#### d.1.3 Effects of Cuts in the Business Tax Rate

The business tax rate will be cut from the present rate of 2% to 1.5% in 1998, and to 1% in 2000, in order to stimulate economic growth and increase annual revenue as a result. The table below shows the possible scenarios that may result from the tax rate cuts.

| | |
|---|---|
| Case 1 | Hardly no impact; the same annual revenue rate can be expected in terms of GRDP |
| Case 2 | With tax rate cuts, an increase of about 75% in the present revenue rate can be expected in terms of GRDP |
| Case 3 | Tax rate cuts will have a direct impact; an increase of about 50% in the present revenue rate can be expected in terms of GRDP |

### d.1.4 Tax Revenue Potential Growth Rate

As long as the tax rate remains constant, the tax revenue potential growth rate is basically influenced by the municipal economic growth rate. Accordingly, the GRDP growth rate of Granada Municipality (6% from 1995-2000, 5% from 2001-2005) estimated by the Study Team was adopted as the potential growth rate of each tax revenue.

### d.1.5 Potential Maximum Collectible Rate for Tax Revenue

The study determined the potential collectible rate of tax revenues by taking the budget (B) as potential tax revenue and dividing it (A/B) by the actual tax revenue (A).

The potential maximum collectible rate of revenue from vehicle tax, property tax and service charges was estimated based on the data on annual revenues for the past 4 years, as shown in the table below.

| Municipal Tax | 1995 Annual Revenue Budget (A) | 1994-1997 Maximum Budget (B) | Collectible Rate (A/B) |
|---|---|---|---|
| Vehicle Tax | C$ 376,000 (2.9%) | C$ 1,105,000 | 0.34 |
| Property Tax | C$ 847,000 (6.5%) | C$ 5,488,000 | 0.15 |
| Service Charges | C$ 1,797,000 (15.5%) | C$ 2,043,000 | 0.88 |

Note: * figures in parentheses are contribution to municipal annual revenues

Because the potential rate specified in the previous section, the tax revenue growth rate is estimated by creating optimistic, moderate, and pessimistic scenarios as shown below.

| Municipal Tax | Tax Revenue Growth Rate | | | Maximum Collection Rate |
|---|---|---|---|---|
| | Optimistic Scenario | Moderate Scenario | Pessimistic Scenario | |
| The Business tax | 5.3% | 2.9% | -1.7% | 100% |
| Vehicle Tax | 13.7% | 12.9% | 12.1% | 70% |
| Property Tax | 16.3% | 15.5% | 14.6% | 70% |
| service Charges/Others | 5.4% | 5.4% | 5.4% | 90% |
| Average Service Changes in Total | 6.7% | 5.4% | 3.4% | 90% |

## d.2 Budget Allocation for SWM from Municipal Tax Revenue

As shown in the table below, the budget allocated for SWM services for the past 4 years ranges around 10%.

| | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|
| SWM Budget | 8.4% | 10.0% | 11.5% | 10.1% |

Taking this into account, the changes in the budget allocation rate for SWM services were estimated as shown below.

| Scenario | Budget Allocation Rate |
|---|---|
| Optimistic Scenario | To incur a 0.2 % per annual increase in the current budget allocation rate of 10%; the budget allocation rate for 2005 is estimated at 12% |
| Moderate Scenario | To maintain the current budget allocation rate; the budget allocation rate for 2005 is estimated at 10% |
| Pessimistic Scenario | To reduce a 0.2% per annual in the current budget allocation rate of 10%; the budget allocation rate for 2005 is estimated at 8%. |

### d.3 Budget Allocation for SWM as Revenue Source 2 (from Municipal Tax Resource)

The budget allocation for SWM as revenue source 2 is calculated based on the above mentioned conditions as shown in the following table.

Table P-45: Budget Allocation for SWM as Revenue Source 2

Unit: C$ 1,000

| | | 2001 | 2002 | 2003 | 2004 | 2005 | 2001~2005 Total |
|---|---|---|---|---|---|---|---|
| Optimistic Scenario | Case A | 2,333 | 2,488 | 2,653 | 2,828 | 3,014 | 13,316 |
| Moderate Scenario | Case B | 1,885 | 1,980 | 2,079 | 2,183 | 2,292 | 10,419 |
| Pessimistic Scenario | Case C | 1,290 | 1,330 | 1,369 | 1,410 | 1,450 | 6,849 |

### e. Project costs

The investment costs from 2000 until 2004 is set based on the cost estimation of the project. After 2005, the replacement investment costs are considered in the FIRR calculations. Concerning the replacement cost of the SJV disposal site, C$ 8,000,000 is assumed to be the cost in order to expand the disposal area, every 5 years.

The project costs used to calculate the FIRR are summarized in the following table.

Table P-46: Project costs for SWM

Unit: C$ 1,000

| | 2000 | 2001~2005 Total | 2006~2030 Total | Residual value in 2031 | Total |
|---|---|---|---|---|---|
| Investment | 47,018 | 9,773 | 81,203 | -8,355 | 129,639 |
| O&M costs | | 12,643 | 67,723 | | 83,230 |
| Fee collection cost | | 8405 | 2,457 | | 2,862 |

### f. FIRR

The FIRR was calculated for a total of 9 cases (3 x 3 = 9): a combination of the three cases for the acquisition of funds for the project costs (A: use of a loan to fully cover expenses; B: acquire grant aid to cover 90% of the investment for final disposal site construction, collection vehicles procurement and facility improvement; C: acquire grant aid to cover 100% of the investment for final disposal sit construction, collection vehicles procurement and plant improvement) and the three scenarios to forecast the budget allocation for SWM. The results are shown in the table below.

| Financial Source | Forecast Revenue | Case | FIRR (%) | R/E |
|---|---|---|---|---|
| By Loan | Optimistic | A-1 | n.a. | 0.7291 |
| (Full Investment Cost) | Moderate | A-2 | n.a. | 0.7046 |
| | Pessimistic | A-3 | n.a. | 0.5986 |
| Grant aid | Optimistic | B-1 | 16.4 | 1.2357 |
| (for 90% of the investment | Moderate | B-2 | 4.7 | 1.1280 |
| required in 2000) | Pessimistic | B-3 | -0.4 | 0.9875 |
| Grant aid | Optimistic | C-1 | 37.4 | 1.2938 |
| (for entire investment | Moderate | C-2 | 13.0 | 1.1766 |
| required in 2000) | Pessimistic | C-3 | 1.2 | 1.0391 |

#### d.4 Cash Flow

The cash flow and the statement of profit and loss for each case was carried out and shown in Chapter 7 of the Data Book: Volume V.

Case C-2, which proposes covering the total investment cost for 2000 by grant aid, the joint collection of waste fee and water supply charges, and the most appropriate tax revenue growth rate and budget allocation, shows positive results in profit and clearly indicates the capability to accumulate C$ 11 million to cover the investment cost after 2006.

#### e. Conclusion

1. If a loan is acquired to cover the entire project cost, the R/E(Revenue divided by Expenditure) would be less than 1 and the FIRR calculation indicates that the project would be financially unfeasible.
2. If grant aid is to be acquired for 90% of the investment required in 2000, only Case B-1, where the forecast revenue is optimistic, was calculated to incur an FIRR (16.4%) that is higher than the cut-off rate (8.5%).
3. If grant aid is to be acquired for the entire investment required in 2000, Case C-2 (where the forecast increase in municipal tax rate and SWM budget is most probable) was calculated to incur an FIRR (13%), higher than the cut-off rate. In this case, the profit and loss statement would be in the black and an internal reserve of C$ 11 million can be accumulated by 2005, enabling Granada Municipality to independently provide for the investment required after 2005.

### P.5.2 Economic Analysis

#### a. Methods and Major Assumptions

The economic evaluation on the municipal SWM system improvement project is conducted to investigate the necessity of the proposed project from the national economic view-points.

The EIRR(Economic Internal Rate of Return) is calculated to evaluate the project in the following conditions.

| | |
|---|---|
| Evaluation Term | 31 years, from 2000 till 2030 |
| Executing bodies | Granada Municipality with partial contracting-out of collection services to private companies |
| Investment plan | Construction of SJV disposal site, improvement of MDO workshop and purchase the necessary vehicles and equipment in 2000 in order to operate SWM services sufficiently in 2001.<br>Additional investment of vehicles and replacement investment of facilities and equipment were counted according to their life span. |
| Residual value | The residual value of facilities and equipment in 2031 is considered as the negative investment costs in 2031. |
| Opportunity cost of capital | The prime rate of BCN in 1997, that is 8.5%, is used as the cut-off rate. |

**b. Benefits**

According to the POS, the beneficiaries are only willing to pay an amount that is lower than the present fee regulated in July in 1997. In this study, the following three cases were set to calculate the EIRR.

- Only the willingness-to-pay, that is the average of all households in the three cities not receiving the services, is counted as the benefit of this project.
- The willingness-to-pay and some of the environmental effects are counted as the benefit.
- The payment based on the proposed tariff and the budget allocation from Granada Municipality in case of appropriate revenue growth and allocating rate (the case A2 analyzed in the above-mentioned Financial Evaluation) are counted as the benefit.

The environmental effects are calculated in the same way in the M/P study as the following items.

- effects of public health improvement
- effects of rise in real estate value
- effects of the increase in tourist consumption

The benefits of improvements in public health were calculated in consideration of the following factors.

- time wasted due to illness
- medical treatment costs
- loss in economic productivity due to death (life span shortened to 10 years)

The figures used in this study are as following table.

Table P-47: Benefits used in this analysis

| | | 2005 | 2001~2005 Total | 2006~ 2030 Total | 2001~ 2030 Total |
|---|---|---|---|---|---|
| willingness-to-pay | C$6.48/month | 1,361 | 5,610 | 34,023 | 39,633 |
| benefit of public health improvement | | 64 | 192 | 4,808 | 5,000 |
| benefit of rises of property value | | 2,016 | 8,352 | 208,800 | 217,152 |
| benefit of increase of tourism consumption | | 2,329 | 15,297 | 382,418 | 397,715 |
| payment and budget allocation | C$ 9.75/month 10% of appropriate revenue increase | 4,887 | 21,664 | 122,103 | 143,768 |

The benefit after 2006 is assumed to be equal to that of 2005.

### c. Conversion factors and Costs of the projects

In order to convert the market price to economic price, in order to evaluate the projects of the project economically, the following conversion factor was used based on those adopted in M/P study.

Table P-48: Conversion Factor used to evaluate the project

| Items | | Conversion rate |
|---|---|---|
| Investment | Civil | 0.840 |
| | Equipment | 0.820 |
| Operation & maintenance | Fuel | 1.5 |
| | Personnel cost | 0.458 |
| | Maintenance | 0.869 |

The economic costs of the project are summarized in the following table.

Table P-49: Economic costs of the project

| | 2000 | 2001~2005 Total | 2006~2030 Total | Residual value in 2031 | Total |
|---|---|---|---|---|---|
| Investment | 39,274 | 8,168 | 48,003 | -5,203 | 90,241 |
| O&M costs | | 8,433 | 45,685 | | 54,118 |

### d. EIRR

The EIRR in terms of benefits is as shown below.

| Benefits | Willingness-to-pay | EIRR | B/C (0 discount rate) |
|---|---|---|---|
| Willingness-to-pay only | C$ 6.48/month | n.a. | 0.2745 |
| Willingness-to-pay and environmental improvement | C$ 11.53/month | 2.5% | 1.1453 |
| Payment and budget allocation | C$ 9.75/month | 2.2% | 1.1179 |
| Payment, budget allocation and environmental improvement | C$ 17.34/month | 13.6% | 1.8667 |

### e. Sensitivity Analysis

This section shall deal with the conduct of a trial sensitivity analysis in case changes occur in the environmental improvement benefits and economic costs estimated in this F/S.

The sensitivity analysis of EIRR on municipal SWM are shown in the following table.

| | | Benefit of Urban Sanitary Improvement | | |
|---|---|---|---|---|
| | | -10% | 0% | +10% |
| Economic Cost | -10% | 3.0 | 4.4 | 5.7 |
| | 0% | 1.1 | 2.5 | 3.8 |
| | +10% | -0.7 | 0.8 | 2.1 |

There figures show the need to implement policies, e.g., use of a relatively large number of local equipment and materials, that would reduce the economic costs, and consider the conservation of energy.

### f. Conclusion

The economic evaluation was carried out using the Economic Internal Rate of Return(EIRR) as a basis. The EIRR was calculated using the overall project costs, which is converted in order to revise the irregularities in domestic market prices, and the overall project benefits, which took environmental benefits into account.

When only the willingness-to-pay of residents is assumed to be the benefit, it is difficult to calculate the EIRR because B/C is very low. Even with environmental considerations, this case would incur an EIRR of 2.5%, still less than the opportunity cost of the investment.

For the case A2 (see FIRR table), which proposes the acquisition of a loan to cover the entire project cost and the joint collection of water supply charges and a very appropriate tax revenue growth rate and SWM budget allocation, the EIRR was calculated at 2.2%.

The main reason why the EIRR's are so much lower than the cut-off rate is that the costs of the SJV disposal site is too high. Taking the case A2 with environmental consideration, it would incur an EIRR of 13.6%, more than the opportunity cost of the investment.

In this analysis, the effects of the SWM improvement project on the conservation of water quality Lake Nicaraguan could not be counted as benefits, because it was very difficult to quantify. In view of the various intangible benefits involved, such as the conservation of potential water supply resources for Managua and other areas, the implementation of the project based on this case is presumed to contribute to the national economic growth.