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SECTION H

FINAL DISPOSAL

THE STUDY ON SOLID WASTE MANAGEMENT IN NAIROBI CITY IN THE REPUBLIC OF KENYA

FINAL REPORT

SECTION II

FINAL DISPOSAL

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FINAL DISPOSAL

1. PRESENT CONDITION OF FINAL DISPOSAL SYSTEM

1.1 Former Dump Site

The Nairobi City Council (NCC) has been using seven (7) landfill sites since 1968 for the disposal of solid waste. The locations are as shown in **Figure H.1-1** and some details are in **Table H.1-1**. Of the 7 landfill sites, 6 sites are located on a quarry of a construction factory and the other site is located on a swampy land formed by land erosion. One of the sites is located in the western area of the city and the others are in the eastern area. Haulage distance to these sites is 15 km at most, which contributed to economical waste haulage.

All the former sites were selected from the topographical viewpoint with inadequate environmental consideration. Therefore, there were many local residents who complained about contamination of groundwater, as well as foul odour and smoke from the sites.

All former landfill sites are now used for other purposes, as shown in **Table H.1-2**. Since not all of the land has completely stabilised, some countermeasures are required for their appropriate land-use.

The proposed countermeasures for each former dump site are as shown in **Table H.1-3**. Keeping these sites in a sanitary and clean condition will be appreciated by residents. A favorable response by residents will help in promoting the construction of any future landfill site.

Table H.1-1 Details on Former Dump Site

No	Name	Location	Period	Old Topography	Landowner
1	Industrial area off Enterprise Road	4.0 km southeast of NRS*	1972 ~ 1980	Quarry	Central Government
2	Githurai off Thika Road	14 km southeast of NRS	1980 ~ 1981	Quarry	Private
3	Mathare North	5.5 km northeast of NRS	1972 ~ 1977	Quarry	Central Government
4	Kariobangi North near the bridge	7.2 km northeast of NRS	1968 ~ 1976	Quarry	Private
5	Kibera near Otiendo Estate	6.5 km southwest of NRS	1978 ~ 1989	Quarry	Central Government
6	Dandora Area I	7.5 km northeast of NRS	1980 ~ 1986	Quarry	Private
7	Dandora Area VI	8.0 km northeast of NRS	1986 ~ 1995	Gently sloping area	Private

* NRS: Nairobi Railway Station

Table H.1-2 Current Condition of Former Dump Site

No	Name	Current Condition
1	Industrial area off Enterprise Road	• Ground is not stable, drainage is not good, plastic films are scattered. • No recycling company and slums • Land uses are school ground and grassland
2	Githurai off Thika Road	• Ground is not stable, plastic films are scattered • Recycling company collects plastics, paper, glass, steel • No slum area • Land use is vegetable field
3	Mathare North	• There are slums on the old quarry filled with garbage. • Settlement of the ground still continues, therefore the slum housing condition becomes bad every year.
4	Kariobangi North near the bridge	• Recycling companies collect plastics, paper, steel, glass. • Recycling company produces simple steel goods. • Ground is not stable, plastic films are scattered. • Land uses are vegetable field and grassland
5	Kibera near Otiende Estate	• There is a slum area. • Land use is vegetable field.
6	Dandora Area I	• Ground is not stable, plastic films are scattered, foul odour is strong. • Surface water make a pond at quarry site. • There is a slum area. • Land uses are open space and housing
7	Dandora Area VI	• Ground is not stable, illegal dumping continues, bad conditions. • Land use are open space and housing.

Table H.1-3 Countermeasures for Former Dump Site

No.	Name	Countermeasures
1	Industrial area off Enterprise Road	• Access road to school, cover soil (fine sand) for school ground, drainage system around the school area. • Open space can be used for green space and park after cover soil becomes more than three meters.
2	Githurai off Thika Road	• Land reclamation for surrounding area by using cover soil. • Land can be used continuously for vegetable field.
3	Mathare North	• Conditions for slum area are critical, especially, quarry slope is not stable. • Redevelopment is needed.
4	Kariobangi North near the bridge	• Cover soil (fine sand) should be more than two meters.
5	Kibera near Otiende Estate	• Land can be used continuously for vegetable field.
6	Dandora Area I	• Redevelopment is needed.
7	Dandora Area VI	• Prohibition of illegal dumping. • Cleaning of the nearby road area.

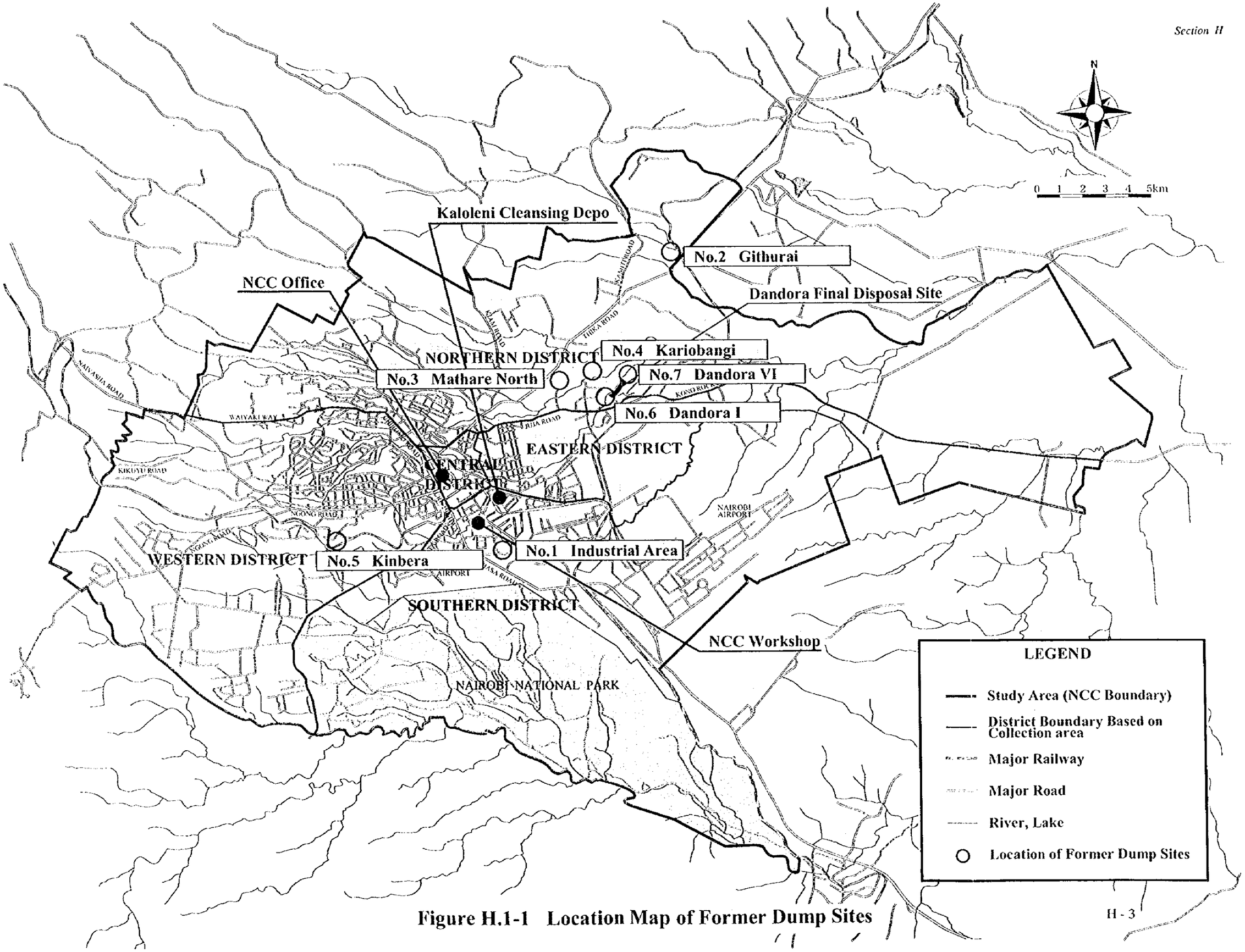

Figure H.1-1 Location Map of Former Dump Sites

1.2 Existing Dump Site

In Nairobi, there is, at present, only one landfill site, which is located in Dandora. It is 7.5 km southeast of the centre of Nairobi. The site map is shown in **Figure H.1-2.** The area is about 26.5 ha. The site is filled with approximately 1.3 million cubic meters (mcm) of waste at present.

The site can be used for several years more, if NCC will load up waste a few meters more. However, the site is a privately owned land and the landowner has requested the return of the land completely after reclamation.

NCC also has decided to stop the dumping of waste and return the land to the owner as soon as possible. Therefore, NCC should promote the construction of a new site as soon as possible.

The construction of new sanitary landfill site(s) is an urgent matter for NCC's solid waste management. The present condition of the existing dumping site is as follows.

1.2.1 Environmental Condition of Dandora Dumping Site

Adjacent to the Dandora site is the Dandora Housing Estate. However, no facilities are provided to prevent secondary pollution. There is a high risk of environmental pollution which may affect the health of residents in the following ways:

(1) Smoke, odor and rodents are generated, which may affect the health of people living near the site. The problem may become more serious because the dumping operation area is moving towards the housing area; and

(2) There is a considerably high risk that leachate generated from the waste deposits will contaminate surface and groundwater on the Nairobi riverside.

1.2.2 Management Condition of the Dandora Dumpsite

Management of the Dandora Dumpsite is described as follows:

(1) There is no strict control to prevent toxic and hasardous waste from being brought into the site.

(2) Landfill is not operated in a systematic and planned manner. Tipping method and area are decided by drivers of vehicles.

(3) The site office is so far from the dumping place; therefore, site controllers cannot give appropriate instructions to truck drivers as to waste dumping place.

(4) There is no heavy equipment to manage the daily land-filling work; therefore, the wastes are compacted and removed to a suitable tipping area.

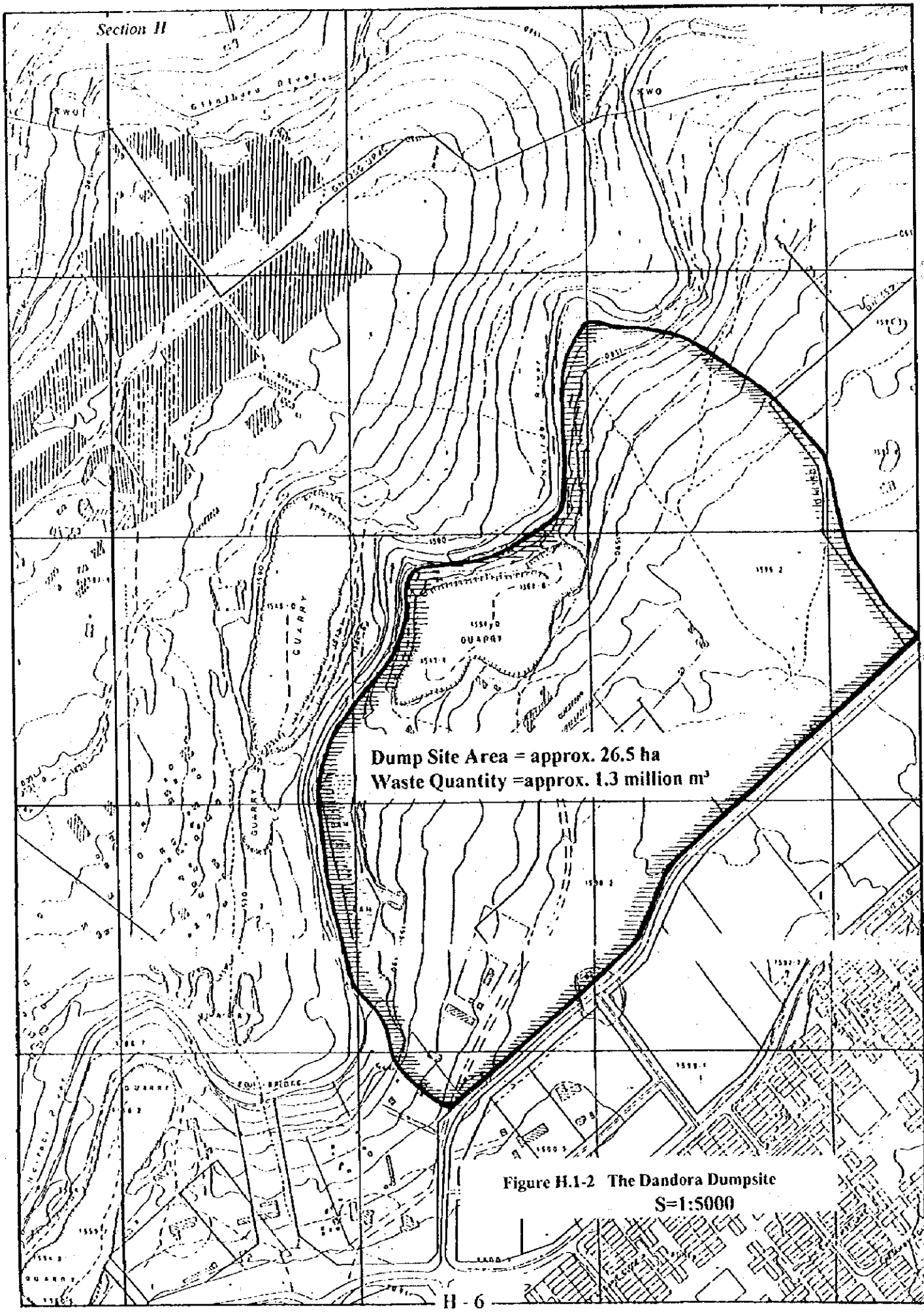

Figure H.1-2 The Dandora Dumpsite
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1.3 Evaluation of Current Conditions and Urgent Activities Required

1.3.1 Evaluation of Current Conditions

As shown by the present environmental and management situations at the existing dump site the final disposal system of NCC is considered to be in a very critical condition. It is proposed that NCC should improve the existing site conditions and also make efforts to ensure the construction of a new sanitary landfill site(s).

1.3.2 Urgent Improvement Plan for the Final Disposal System

(1) Preparatory Actions

Preparatory actions means self-endeavouring actions without a large capital investment to improve current conditions.

(a) Introduction of Minimum Number of Heavy Equipment

The condition of the Dandora Dumpsite should be improved and sustained by ensuring that the access road and dumping points are kept constantly clear, and that periodical land-filling and land reclamation of the existing dumping area is carried out.

(b) Strengthening of Operational Management of Dandora Dumpsite

DoE has to separate disposal from collection and street cleansing services and establish a Disposal Section. A new Disposal Manager has to be appointed and DoE has to strengthen the operational management of the Dandora Dumpsite.

(i) Increase in Number of Inspectors at the Site

The Dandora Dumpsite is managed by a Site Manager with a few inspectors at present. The few inspectors cannot issue proper instructions to drivers of collection vehicles, because there are many dumping points in the wide dumping site. The following site management organisation is thus proposed.

Table H.1-4 Management Organisation Proposed for the Dandora Dumpsite

Title	Responsibilities	Proper number*
Site Manager	• To manage all activities at the site	1
Site Inspector A	• To record and collect charges on collection vehicles • To check the quantity and quality of waste	6
Site Inspector B	• To give directions to the proper dumping points	10
Site Inspector C	• To inspect the environmental conditions at the site	1
Chief Operator	• To decide and allocate the daily dumping points	1
Operator	• To compact and bed the wastes	4
Total		23

* Excluding members on standby.

(ii) Introduction of Controlled Dumping

Controlled dumping is very important to improve and sustain the conditions at the site. The dump should be divided into zones for hospital waste, industrial waste and others.

Dumping of hospital wastes, especially, has to be controlled to a specific zone to maintain the health condition of site workers and scavengers. The hospital waste area should be regularly covered with cover soil.

(iii) Records-keeping on Dumped Volume of Solid Waste, and Comparison between Collection and Dumped Records

The data should be reported as daily, monthly and annual reports, and submitted to the Disposal Manager.

(iv) Monthly Monitoring of Surrounding Environmental Conditions

The result of the monitoring should be reported to the Director of the DoE. The report will be very effective to understand the current conditions of the site and to consider countermeasures to environmental pollution.

(v) Prohibition of Dumping at Night

DoE has to issue instructions to private companies on the regulations on dumping at the Dandora Dumpsite.

Site inspectors work at the site only from 8 A.M. to 5 P.M., therefore, DoE has to prohibit dumping outside of the working time. At nighttime, waste has often been dumped on public roads.

(c) Preparation Work for New Disposal Site

The construction of a new disposal site(s) is a very urgent matter for NCC. Therefore, NCC should take steps to realise a new disposal system.

The following actions are required:

(i) To acquire land for a new disposal site(s); and

(ii) To obtain consent of neighboring residents through EIA to the construction of a new disposal site.

(2) Urgent Improvement Plan of Final Disposal Site

NCC has to use the existing dumpsite until a new site(s) is constructed. Therefore, NCC should strive to improve and sustain the condition of the Dandora Dumpsite.

The DoE introduced three (3) units of bulldozers to the site around the end of October 1997 (2 units hired and 1 repaired) to clean the public road and ensure access from the road to the dumping points. Although the two bulldozers were hired from a private company for only one month, the activities demonstrated that the use of heavy equipment is the most effective way to improve the site conditions.

Accordingly, the DoE has to maintain the repaired bulldozer very well and has to make efforts to introduce and operate a reasonable number of heavy equipment at the site permanently. The reasonable number of heavy equipment for daily management is considered to be 3 bulldozers and 1 excavator, according to the calculation below. If land reclamation of old dumping areas is necessary to improve the present site conditions, NCC has to introduce more number of heavy equipment to the site.

(Heavy equipment for daily management: 1998 to 1999 Collection Ratio was about 20%, almost the same as the existing condition.)

• Waste amount	:	200 ~ 300 t/day (400 ~ 1,000 m^3/day)
• Bulldozer Capacity (15t class)	:	50 m^3/hour (300 ~ 400 m^3/day)
• Required number of Bulldozers	:	3
• Required number of Excavators	:	1 (for bedding assistance)

2. INTRODUCTION OF SANITARY LANDFILL

2.1 Establishment of Landfill Disposal Concept

The aim of solid waste disposal is to remove solid waste from the urban community immediately and to reduce its volume, making it stable and hygienic. In choosing the process of proper treatment and disposal, not only the geographical area should be considered but also the financial situation and the level of technology within the organisation responsible for solid waste management. This management process can usually be divided into three processes: collection/transport, intermediate treatment and final disposal. Basically, the landfill disposal process finally restores solid wastes to nature.

The purpose of landfill disposal is to stabilise the solid waste and to make it hygienic through proper dumping of waste and use of natural metabolic function. Therefore, it is important to have a practical method of disposal which can be decided upon by regional condition and organisational situation. In making this decision, it is important to take into account the type, form, composition of waste, location of landfill site, regional, hydrological and climatic conditions.

In planning the final disposal system, it is necessary to determine the types and volumes of waste for landfill and to formulate an effective master plan for solid waste management based on actual needs of the region. The final disposal plan should also be formulated in such a manner as to be organic with the collection or hauling plan and the intermediate treatment plan.

2.2 Adoption of Sanitary Landfill

Though open dumping as currently practiced by NCC is the cheapest method of disposal, it causes environmental pollution and can potentially affect the health of local residents living near the disposal site. Therefore, it is necessary for Nairobi City to adopt the sanitary landfill method. Sanitary landfill of the highest environmental standard is still much more economical than other intermediate treatments.

Complete landfill system requires a large amount of capital investment. Taking into consideration the size of the NCC's annual budget and its financial situation, various problems are expected with regard to the funding of a complete landfill system.

It is thus unrealistic at the moment to adopt a complete landfill system. It is also important at the same time to consider the need to achieve a balanced urban infrastructure improvement and aspects of urban environmental preservation.

The basic landfill structure is to be planned through the decision on sanitary level in Nairobi City.

2.3 Selection and Evaluation of Candidate Final Disposal Sites

2.3.1 Outline of Landfill Site Selection Criteria

In selecting a sanitary landfill site, it is necessary to ensure that the site has a sufficient capacity to accept the planned landfill volume. In addition, the following aspects should also be jointly considered:

(a) Landfill area is of sufficient size
(b) Efficiency of collection and transport
(c) Surrounding conditions
(d) Topography and geological conditions
(e) Safety against disaster
(f) Ultimate land-use plan
(g) Availability of cover soil

Details on "The Selection Criteria of Landfill Sites" are given in **Section 8.3 of Data Book (1)**.

2.3.2 Selection and Evaluation of Candidate Final Disposal Sites

The selection and evaluation of a disposal site(s) was carried out based on the nine (9) candidate sites shown in **Figure H.2-1**. Every site was checked as to necessity of Initial Environmental Examination (IEE) and Environmental Impact Assessment (EIA) for screening and scoping. The results suggest that every site need IEE and EIA prior to implementation of the project. The details of IEE are described in **Section 2.9, Volume 2, Main Report, Master Plan Study**.

In the selection of candidate final disposal sites, the major constraints are as given in **Table H.2-1** below. The process of evaluation of the nine (9) candidate sites in compliance with the selection criteria for landfill sites is shown in **Table H.2-2**.

Table H.2-1 Major Constraints to the Selection of Candidate Final Disposal Sites

(1) Safety against disaster (Fire risk)	Ngong Road Forest Dagoretti Forest Karura Forest
(2) Surrounding condition (Close to Sports facilities)	Kasarani Area
(3) Geological condition (Hard rock is distributed)	Ongata Rongai
(4) Suitable Area for Landfill Site	Ruai Area* Industrial Area* Ruiru Town Athi River Area

* Cover soil in the site is not sufficient.

The results of evaluation indicate that four (4) sites have higher feasibility to be developed for landfill site; namely, the Ruai Area, the Industrial Area, Ruiru Town and the Athi River Area. Following the first screening on 9 sites, environmental and technical evaluation of the 4 sites was made, as summarised in **Table H.2-3**. This table shows that the results of each approach give different priority.

NCC has selected the Ruai and Ngong Road Forest areas for the feasibility study, taking the possibility of land acquisition into consideration. The selection of Ruai Area was given high evaluation, because ensuring a new landfill site is an urgent matter for NCC's solid waste management. The Ruai Area belong to NCC, therefore NCC will be able to start the construction of a new final disposal site without long land acquisition proceedings.

The Ngong Road Forest Area has not satisfied the condition of pre-qualification; hence, the Kenyan authorities have strongly recommended carrying out of Environmental Impact Assessment(EIA) for both sites. The reason why the Ngong Road Forest Area was selected was not only the high possibility of land acquisition but also the distance from the centre of the city. Its advanced point can reduce the transportation cost compared with the case of only the Ruai Area as final disposal site. Therefore, the necessary investigations required for EIA and facility planning were carried out for both sites in the second field study stage.

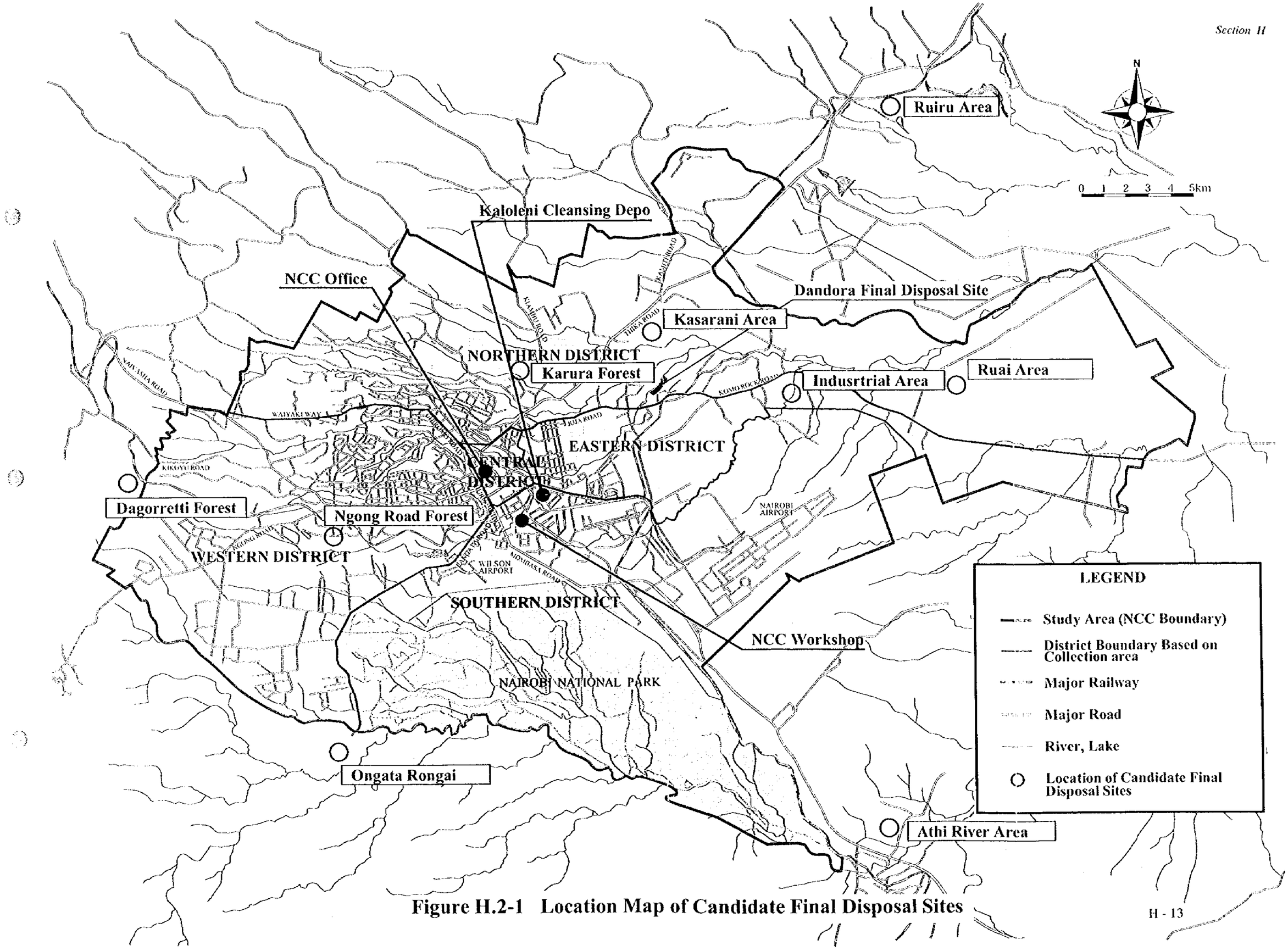

Figure H.2-1 Location Map of Candidate Final Disposal Sites

TableH.2-2 (1/2) Evaluation of Candidate Final Disposal Sites (Western Zone)

Site Conditions	Ngong Road Forest	Dagorretti Forest	Ongata Rongai	Karura Forest
(1) Landfill area is of sufficient area	- 20 ha(grass-land) **Excellent** - Include a part of forest **Unsatisfactory**	- 20 ha(grass-land, bush and forest) **Excellent** - Include a part of forest **Unsatisfactory**	- 16 ha (grassland) **Good**	- 20 ha (grassland and bush) **Excellent** - Include a part of forest **Unsatisfactory**
(2) Efficiency of collection and transport	- 10 km **Excellent** - 200m new access road should be constructed in forest **Unsatisfactory**	- 15 km **Excellent** - 300m new access road should be constructed. **Good**	- 23km **Good** - There is no pavement at a part of main access road. **Good**	- 12 km **Excellent** - 300 m access road should be constructed in forest **Unsatisfactory**
(3) Surrounding Conditions	- Gasetted under the forest act **Unsatisfactory** - Forest makes natural buffer zone **Excellent**	- Gasetted under the forest act **Unsatisfactory** - Forest makes natural buffer zone **Excellent**	- Open area **Good**	- Gasetted under the forest act **Unsatisfactory** - Forest makes natural buffer zone **Excellent**
(4) Topography and geological conditions	- T: Flat land **Excellent** - G: Topsoil (sandy/loam) distributes 50 cm. Base rock is tuff. **Good**	- T: Undulations **Excellent** - G: Topsoil (loam) distributes more than 1 m. **Excellent**	- T: Flat land **Excellent** - G: Topsoil (loam) distributes less than 10 cm. Base rock is hard volcanic rock. **Good**	- T: Undulations **Excellent** - G: Topsoil (loam) distributes more than 1 m. **Excellent**
(5) Safety against disaster	- Fire risk **Unsatisfactory**	- Fire risk **Unsatisfactory**	- No problem **Excellent**	- Fire risk **Unsatisfactory**
(6) Ultimate land-use	- Forest **Excellent**	- Forest **Excellent**	- Grass land **Excellent**	- Forest **Excellent**
(7) Availability of cover soil	- Available (by excavation), not enough **Good**	- Available (by excavation) **Excellent**	- Non-available **Unsatisfactory**	- Available (by excavation) **Excellent**
(8) Land owner	- Central Government **Excellent**	- Central Government **Excellent**	- Private **Unsatisfactory**	- Central Government **Excellent**
Evaluation (Against points)	**Unsuitable** 1. Gasetted forest 2. Fire risk 3. Cover soil is not enough	**Unsuitable** 1. Gasetted forest 2. Fire risk 3. Out of Nairobi City	Unsuitable 1. Main access road is not paved. 2. Cover soil is not available 3. Excavation work is difficult	**Unsuitable** 1. Gassetted forest 2. Fire risk

T: topography; G: geological conditions

Table H.2-2 (2/2) Evaluation of Candidate Final Disposal Sites (Eastern Zone)

Site Condition	Kasarani Area	Ruai Area	Industrial Area Oxygenation Ponds	Area towards Ruiru Town	Athi River Area
(1) Landfill area is of sufficient area	- 16 ha (grassland) **Good**	- 20 ha (grassland) **Excellent**	- 16 ha (oxygenation pond, grassland) **Good**	- 16 ha (grassland) **Good**	- 20 ha (grassland) **Excellent**
(2) Efficiency of collection and transport	- 12 km **Excellent** - Close to main road **Excellent**	- 30 km **Unsatisfactory** - 500m new access road should be constructed **Good**	- 19.5 km **Excellent** - Close to main road **Excellent**	- 22 km **Good** - Close to main road **Excellent**	- 27 km **Good** - 200 m new access road should be constructed **Excellent**
(3) Surrounding condition	- Close to sports facilities - Electric power line is located in the site centre **Unsatisfactory**	- No problem **Excellent**	- No problem **Excellent**	- Close to new settlements **Good**	- No problem **Excellent**
(4) Topography and geological conditions	- T: gently slope to the river **Excellent** - G: Topsoil distributes less than 1 m **Good**	- T: swampy flat land **Excellent** - G: Alluvium deposit **Good**	- T: Flat land **Excellent** - G: Topsoil distributes less than 0.5 m. **Good**	- T: Flat land **Excellent** - G: Topsoil distributes more than 1 m **Excellent**	- T: Flat land **Excellent** - G: Topsoil distributes more than 1 m **Excellent**
(5) Safety against disaster	- No problem **Excellent**	- Flood risk **Unsatisfactory**	- No problem **Excellent**	- No problem **Excellent**	- No problem **Excellent**
(6) Ultimate Land-use plan	- Park, grassland **Excellent**	- Grassland **Excellent**	- Grassland **Excellent**	- Grassland **Excellent**	- Grassland **Excellent**
(7) Availability of cover soil	- Available (by excavation), not enough **Good**	- Available (by excavation), not enough **Good**	- Available (by excavation), not enough **Good**	- Available **Excellent**	- Available **Excellent**
(8) Landowner	- NCC	- NCC	- Private	- Private	- Private
Evaluation (Demerits)	**Unsuitable** 1. Surrounding conditions (close to sports facilities, electric power line)	**Suitable** 1. Transportation 2. Cover soil is not sufficient.	**Suitable** 1. Sewerage sludge should be disposed. 2. Intake and effluent facility of the ponds should be taken to pieces. 3. Cover soil is not enough	**Suitable** 1. Out of Nairobi City	**Suitable** 1. Out of Nairobi City

T: topography; G: geological conditions

Table H.2-3 Summary of Evaluation for the Candidate Final Disposal Sites

Site Name	Environmental Approach		Technical Approach		Priority
	Evaluation (Merits)	Priority	Evaluation (Demerits)	Priority	
Ruai Area	• Available large land • No significant socio-economic activities	1	• Transportation • High construction unit cost	3	3
Industrial area Oxygenation Ponds	• Mitigation measures of landfill site will improve the site conditions	3	• Sewerage sludge should be treated and disposed • Small capacity • High construction unit cost • Private land	4	4
Area towards Ruiru Town	• Limited settlement • Available large land	2	• Out of Nairobi City • Private land	2	2
Athi River Area	• Limited settlement • Available large land	2	• Out of Nairobi City • Private land	1	1

3. FINAL DISPOSAL AND FACILITY PLAN

3.1 Action Plan for NCC's Final Disposal System

To formulate the final disposal system for NCC, the study should include not only the Master Plan but also the Urgent Improvement Plan. The master plan is divided into three (3) stages according to the target of a total SWM system, and the urgent improvement plan is also needed. Hence, the final disposal system is composed of four (4) plans, and the major contents and schedule are as discussed below.

(1) Urgent Improvement Plan (1998~1999)

The Urgent Improvement Plan is as described in **Supporting Report 1.3.2.** The main objectives are (a) to improve and sustain the conditions at the existing Dandora dump site and (b) to make preparations for the construction of a new disposal site(s).

(2) Master Plan (1999~2008)

The Master Plan is divided into three (3) stages according to the target of a total SWM system, as presented below:

(a) First Implementation Stage (1999~2003)

The major target of the First Implementation Stage is the construction of a new sanitary landfill site(s), as follows:

Table H.3-1 Activities in the First Implementation Stage of Master Plan

Year	Activities
1999	• Basic Design, Detail Design
2000	• Construction of new Disposal Site(s), 1st Area
2001	• Construction of new Disposal Site(s), 2nd Area • Landfilling at 1st Area • Closure Work on Existing Dandora Dumpsite
2002 ~ 2003	• Well maintenance and operation of new landfill site(s)

(b) Second Implementation Stage (2003~ 2007)

The major activities in the Second Implementation Stage are the well maintenance and operation of landfill site(s) and the preparation work for the construction of a new landfill site(s).

(c) Third Implementation Stage (2007~2008)

The major activities in the Third Implementation Stage are the well maintenance and operation of the landfill site(s) and preparation work for the construction of a new landfill site(s).

3.2 Disposal Site Capacity Requirement

An attempt was made to estimate the capacity of the site(s) needed for future landfill from 2001 to 2008 based on 100% collection volume of waste in future as shown in **Table H.3-2** below.

Table H.3-2 Disposal Site Capacity Requirement (100% Collection)

Year	(1) Landfill Waste Amount (t/d)	(2) Landfill Waste Amount (m^3/d) (2) / 1.0*	(3) Landfill Waste Amount (m^3/year) (3) × 365	(4) Total Waste Amount (m^3)
1998	1,509	1,509	550,785	550,785
1999	1,587	1,587	579,255	1,130,040
2000	1,667	1,667	608,455	1,738,495
2001	1,758	1,758	641,670	641,670
2002	1,855	1,855	677,075	1,318,745
2003	1,959	1,959	715,035	2,033,780
2004	2,077	2,077	758,105	2,791,885
2005	2,190	2,190	799,350	3,591,235
2006	2,316	2,316	845,340	4,436,575
2007	2,451	2,451	894,615	5,331,190
2008	2,594	2,594	946,810	6,278,000
Total	-	-		8,016,495

* Bulk density of waste at the site is from 0.7 to 1.4 (or 1.0).

3.3 Suitable Sanitary Level of Landfill System for Nairobi City

A complete landfill system requires a large amount of capital investment. Taking into consideration the size of the local government's annual budget and its financial

situation, it is expected that various problems with regard to funding a complete landfill system will ensue. It is thus more realistic at the moment to have a complete landfill system in stages. It is also important at the same time to consider the need to achieve a balanced urban infrastructure improvement and the aspects of urban environmental preservation.

The sanitary level of landfill system can be classified into four (4) as tabulated below. The primary target of the Landfill System Improvement Plan for Kenya should be Level 3 plus simple leachate treatment ponds, according to the EIA.

Table H.3-3 Classification of Sanitary Level of Landfill System

Level 1	Controlled tipping
Level 2	With a bund and daily cover soil
Level 3	Effluent control of leachate
Level 4	Leachate treatment system

There are two sites for feasibility study, one is the Ngong Road Forest Area and the other is the Ruai Area. Effluent leachate of both sites flow into the Nairobi River which is main river in the city, and NCC has to make efforts to improve the discharged water quality. Therefore, simple leachate treatment ponds that can be managed with low maintenance costs are considered for both site facility plans.

The Ruai Area is located near the sewerage wastewater treatment pond; hence, the pond cannot received the leachate from the disposal site because the present system has not considered treating the leachate and also, the pond's capacity is limited. Should there be an expansion plan for the treatment pond, it should consider the quantity and quality of leachate from the disposal site.

The sanitary level of landfill system, its target and so on, are as further summarised below:

(1) Level 1

(a) Target

- Introduction of controlled tipping

(b) Achievement Level

- Establishment of access to site
- Introduction of cover material in order to prevent fire, littering of wastes and odour
- Introduction of inspection, control and operational records of incoming wastes

(c) Further Improvement to Next Level

- Establishment of site boundary
- Introduction of environmental protection facilities

- Introduction of amenities for the staff such as sanitary facilities and locker room
- Introduction of a semi-aerobic landfill

(d) Environmental Issue

In this level, environmental protection measures are not established except the provision of cover material. Impact of landfill operations on the surroundings is great and may include the following:

- Surface and groundwater pollution by leachate
- Littering and dust
- Breeding of insects and rodents
- Unpleasant view of landfill
- Noise
- Odour

(2) Level 2

(a) Target

- With a bund and daily cover soil

(b) Achievement Level

- Establishment of site boundary to distinguish the disposal site and to eliminate scavenging
- Application of sufficient cover to disposed waste
- Establishment of disposal site by construction of enclosing bund
- Introduction of divider for unloading areas and working place
- Establishment of drainage system to divert storm water and seepage from surrounding areas and to reduce leachate
- Introduction of environmental protection facilities to lessen direct impact on surroundings, such as buffer zone, litter control and gas removal facilities
- Introduction of semi-aerobic landfill through the installation of gas removal facilities
- Introduction of amenities for staff

(c) Further Improvement to Next Level

- Improvement of semi-aerobic landfill
- Establishment of leachate control
- Establishment of leachate treatment

(d) Environmental Issue

In this level, since the disposal site and drainage system are already established, landfill operations can be controlled efficiently. Furthermore, with the application of sufficient cover and introduction of some environmental protection facilities, impacts from landfill operations are much reduced than Level 1. Besides, the installation of gas removal facilities introduces a semi-aerobic landfill system. However, leachate is still not controlled and a monitoring system has yet to be established.

(3) Level 3

(a) Target

- Effluent control of leachate

(b) Achievement Level

- Establishment of leachate control by the installation of effluent collection, storage and monitoring facilities

(c) Further Improvement to Next Level

- Introduction of leachate treatment system
- Establishment of semi-aerobic landfill

(d) Environmental Issue

Leachate accumulated at the bottom of landfill is discharged through drainpipes, i.e., leachate collection pipes. These pipes also permit the natural inflow of air to promote semi-aerobic condition for the decomposition of waste. To achieve favorable improvement, the monitoring and control of leachate levels and checking for malfunctioning of leachate collection pipes are essential.

(4) Level 4

(a) Target

- Leachate treatment

(b) Achieved Level

- Establishment of leachate treatment by the installation of oxidation pond, etc.
- Establishment of seepage control
- Establishment of semi-aerobic landfill

(c) Further Improvement to Next Stage

- Establishment of high-level treatment system
- Introduction of service system to the surrounding residents

(d) Environmental Issue

The installation of seepage control facilities and oxygenation pond with aerator for the leachate treatment would achieve the landfill sanitary level.

3.4 Facility Plan of New Landfill Site

3.4.1 Geological Investigation Results

Geological conditions of the candidate site are key elements for the design of the final disposal site. Details of the investigation result are shown in **Section 8.2 of Data Book (1)**. This section summarises the important results.

(1) Ruai Area

The site is a relatively flat, poorly drained zone with grass and sisal vegetation. The location map of boring points and the geological cross sections of the site are given in the **Geological Survey Report**.

(a) Geological Structure

Overburden generally comprises dark gray clay which vary in depth of between 0.8 and 1.5 m in thickness.

The dominant bedrock material comprises agglomeritic and slightly agglomeritic Tuff varying in color from yellow-brown to gray depending on weathering grade. This material is frequently inter-bedded with an ashy Tuff of light green color particularly in Borehole 2 where the ashy tuff reaches a maximum thickness of 12.15 meters.

Within Borehole 2 a layer of Sand is encountered between 27.75 and 29.55 m. In Borehole 4 the tuffs are inter-bedded with both clay and ash of between 22.55 and 28.35 m. The clay layers probably represent completely weathered tuffs.

Typically the weathering grade of the tuff varies from Grade I to III, however, they can be as low as Grade IV at depths greater than 13.0 m. This is seen in Boreholes 1 and 4.

(b) Field Permeability Test

Falling head in-situ permeability tests were undertaken at typically 5 m intervals in each borehole. The test results are shown in **Table H.3-4.**

The results suggests that tuff has a 1×10-8~10-9 m/sec order of permeability which is evaluated as low.

Table H.3-4 Results of Field Permeability Test at Ruai Area

Unit: m/sec

Borehole No	-5m	-10m	-15m	-20m	-25m	-30m
No. 1	5.2×10-8	2.8×10-8	2.0×10-8	-	-	-
No. 2	2.6×10-8	2.7×10-8	-	1.4×10-8	3.9×10-9	6.7×10-9
No. 3	6.7×10-8	3.5×10-8	1.8×10-8	-	-	-
No. 4	-	-	-	-	-	8.3×10-9
No. 5	2.2×10-8	1.5×10-8	9.9×10-9	-	-	-
No. 6	5.3×10-8	1.8×10-8	8.0×10-8			
No. 7	-	-	1.4×10-8	-	-	-

(c) Laboratory Test

The top dark gray soil is called black cotton soil. The soil charactereristics are shown in **Table H.3-5** based on laboratory analysis. Compaction test results are shown in **Table H.3-6**.

The black cotton soil consists of more than 90% fine material, e.g., clay and silt, and natural moisture content is approx.30%. According to the compaction test, the optimum moisture content of black cotton soil is approx. 10%. The test results suggest that the soil has a difficult characteristic for earth works especially in the rainy season.

Table H.3-5 Physical Characteristics of the Black Cotton Soil at Ruai Area

Sampling Point (Borehole No.)	Depth (m)	Moisture Content (%)	Specific Gravity	Density	Particle Size		
					Clay >0.005 mm	Silt 0.005 - 0.075	Sand <0.075 mm
No. 1	0 - 0.8	24.9	2.53	1.92	50.0	40.8	9.2
No. 2	0 - 1.0	34.0	2.48	1.98	52.0	46.0	2.0
No. 3	0 - 1.0	35.8	2.55	2.00	54.0	44.2	1.8
No. 4	0 - 0.9	30.1	2.47	1.99	68.0	22.1	9.9
No. 5	0 - 1.0	31.6	2.54	1.93	66.0	31.7	2.3
No. 6	0 - 1.0	38.4	2.47	2.01	44.0	50.9	5.1
No. 7	0 - 1.0	36.9	2.56	2.05	54.0	43.9	2.1

Table H.3-6 Compaction Test Results of Black Cotton Soil at Ruai Area

Borehole No.	Depth	Optimum Moisture Content (%)	Maximum Dry Density (g/cm^3)
No. 1	Topsoil	-	-
No. 2	Topsoil	9.0	1.27
No. 3	Topsoil	11.6	1.31
No. 4	Topsoil	11.0	1.30
No. 5	Topsoil	-	-
No. 6	Topsoil	11.9	1.27
No. 6	Topsoil	5.6	1.31

Data for Borehole No. 1 and No. 5 were disregarded because the samples of black cotton soil from the site gave erratic results during the compaction test.

The topsoil includes higher than 90% of fine material, i.e., clay and silt, and optimum moisture content is about 10%. The results indicate that treatment of the black cotton soil has to be taken carefully especially in the rainy season.

(2) Ngong Road Forest Area

The Ngong Road Forest Area is in a forested area with a relatively good drainage. The location map of boring points and the geological cross sections of the site are given in the **Geological Survey Report.**

(a) Geological Structure

Overburden generally comprises stiff to hard reddish-brown, silty clay which vary in depth, between 1 and 6.7 m in thickness. In Borehole No. 2, No. 3 and No. 5, this overlay a medium dense to very dense lateritic gravel of 1.45 m maximum thickness.

The dominant bedrock material comprises agglomeritic tuff varying in color from reddish-brown, reddish-gray, to cream whitish gray. In Borehole No. 1, No. 2 and No. 3, the tuff is highly weathered to a depth of 2.3 m below the overburden material.

Within the boreholes, the tuff appears to be generally slightly and faintly weathered with depth. However in Borehole No. 1 below 14.65 m, the material is highly and completely weathered. Frequently within this weathered sequence there are interbedded layers of reddish brown clay, silt and sand. These are probably completely weathered bands of tuff. A further clay band of 2.35 m in thickness is encountered in Borehole No. 6, between 25.45 to 27.80 m.

(b) Field Permeability Test

Falling head in-situ permeability tests were undertaken typically at 5 m intervals in each borehole. The test results are shown in **Table H.3-7.**

The results suggest that the tuff has a 1×10-7~10-10 m/sec order of permeability, which is evaluated as low.

Table H.3-7 Results of Field Permeability Test at Ngong Road Forest Area

Unit: m/sec

Borehole No	-5m	-10m	-15m	-20m	-25m	-30m
No. 1	6.2×10-7	1.9×10-8	9.8×10-9	4.3×10-9	1.3×10-9	9.8×10-10
No. 2	2.1×10-6	6.8×10-9	6.0×10-9	-	-	-
No. 3	4.0×10-8	7.2×10-9	4.5×10-9	-	-	-
No. 4	5.1×10-9	3.2×10-9	1.6×10-9	-	-	-
No. 5	4.6×10-8	1.4×10-8	-	-	-	-
No. 6	3.4×10-6	1.1×10-7	2.4×10-8	8.0×10-9	1.6×10-9-	4.8×10-9-

(c) Laboratory Test

The top red soil characteristics are as shown in **Table H.3-8** based on laboratory analysis. The compaction test results are as shown in **Table H.3-9**.

The test results show that the red clay can be used as cover material for sanitary landfill.

Table H.3-8 Physical Characteristics of the Red Clay at Ngong Road Forest Area

Sampling Point (Borehole No.)	Depth (m)	Moisture Content (%)	Specific Gravity	Density	Particle Size		
					Clay >0.005 mm	Silt 0.005 - 0.075mm	Sand <0.075 mm
No. 1	0.0 - 1.0	49.83	2.72	1.91	64.0	31.7	4.3
	1.0 - 2.0	56.43	2.86	1.90	62.0	36.3	1.7
	2.0 - 3.0	50.99	2.79	1.86			
	3.0 - 4.0	46.63	2.80	2.02	62.0	15.3	22.7
	4.0 - 5.0	45.69	2.74	1.82	64.0	21.9	14.1
No .2	0.0 - 1.0	39.03	2.69	1.97	73.0	21.0	6.0
	1.0 - 2.0	51.15	2.72	1.86	67.0	26.3	6.7
	2.0 - 3.0	51.35	2.73	1.83	85.0	9.9	5.1
	3.0 - 4.0	46.25	2.79	1.76	71.0	24.6	4.4
	4.0 - 5.0	52.83	2.83	1.63	71.0	22.3	6.7
No. 3	0.0 - 1.0	47.50	2.75	1.98	52.0	24.1	23.9
	1.0 - 2.0	42.20	2.88	2.06	38.0	20.4	41.6
No. 4	0.0 - 1.0	54.65	2.65	2.07	90.0	7.0	3.0
No. 5	0.0 - 1.0	30.45	2.67	1.90	39.0	26.4	34.6
	1.0 - 2.0	27.32	2.73	2.04	40.0	29.3	30.7
	2.0 - 3.0	35.33	2.69	2.23	60.0	26.9	13.1
No. 6	0.0 - 0.1	38.70	2.60	1.98	42.0	50.6	7.4
	1.0 - 2.0	52.20	2.73	1.89	62.0	30.6	7.4
	2.0 - 3.0	50.00	2.75	2.02	86.0	-	-
	3.0 - 4.0	47.2	2.76	1.91	76.0	17.1	6.9
	4.0 - 5.0	52.80	2.78	1.98	84.0	12.0	4.0

Table H.3-9 Compaction Test Results of Red Clay at Ngong Road Forest Area

Borehole No.	Depth	Optimum Moisture Content (%)	Maximum Dry Density (g/cm^3)
No. 1	Topsoil	32.4	1.32
No. 2	Topsoil	33.0	1.28
No. 3	Topsoil	29.2	1.31
No. 4	Topsoil	-	-
No. 5	Topsoil	29.6	1.36
No. 6	Topsoil	33.5	1.29

Data for Borehole No. 1 and No. 5 were disregarded because the samples of black cotton soil from the site gave erratic results during the compaction test.

3.4.2 Facilities Plan and Design Calculation

(1) Alternative Plans

The decision on final disposal system has to consider the collection and transportation system. Therefore, total evaluation is done on a total combination of the SWM system.

Alternative plans of final disposal system are considered, as follows:

Case A-1: Two (2) sites (Ruai Area: 20ha; Ngong Road Forest Area: 27ha)

Case A-1-1: Two (2) sites; total site capacity: $5,300 \times 10^3$ m^3

Case A-1-2: Two (2) sites; total site capacity: $3,300 \times 10^3$ m^3

Case A-2: 1 site (Ruai: 40ha)

Case A-2-1: Ruai; total site capacity: $5,300 \times 10^3$ m^3

Case A-2-2: Ruai; total site capacity: $3,300 \times 10^3$ m^3

These cases are numbered from Case 1 to Case 6, as summarised in **Table H.3-10**. The design and cost estimation for each case were carried out based on Sanitary Level 4 (Level 3 pulse simple leachate treatment ponds).

Table H.3-10 Alternative Design Cases of Facilities Plan

Design Case	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Site	Ruai				Ngong Road Forest	
Area	20 ha		40 ha		27 ha	
Site and Waste Amount Condition	Case A-1		Case A-2		Case A-1	
	Case A-1-1	Case A-1-2	Case A-2-1	Case A-2-2	Case A-1-1	Case A-1-2
Minimum Landfill Capacity*	2,700 x 10^3m^3	1,700 x 10^3m^3	5,300 x 10^3m^3	3,300 x 10^3m^3	2,600 x 10^3m^3	1,600 x 10^3m^3

* Minimum Landfill Capacity means the volume of landfilled solid waste with cover material since 2001 to 2008.

(2) Structure and Function of Facility

(a) Access Road

The planned access road will provide the shortest access to the existing road. Therefore, the roads planned for each new disposal site will access the following existing roads:

- Ruai site: The access road to the existing Sewerage Treatment Plant (Cases 1,2,3 and 4)
- Ngong site: Ngong Road (Cases 5 and 6)

The bearing capacity of the access road is planned to be 10 tons of axle load. The design width of the access road is 6 m.

(b) Dike

The landfill area is planned to be placed within the area enclosed by dikes which are classified into two types by their location, namely:

(i) Enclosure dike
(ii) Divider dike

Dikes should be constructed before the landfill operation starts in order to prepare the landfill area for the first year operation. Then the construction is carried out two times (Cases 1, 2, 5 and 6) or three times (Cases 3 and 4) according to the staged plan. The whole landfill area is divided into two (2) zones by a divider dike placed on the boundary of the partition to separate hospital wastes from general solid wastes. The dike is planned to be of trapezoidal section with the following basic dimensions:

- Width of top: 5 m (Enclosure dike) or 1 m (Divider dike)
- Gradient of exterior slope: 1:1.5
- Gradient of interior slope: 1:1.5

Material of dike should be selected to ensure stability at low cost. From this viewpoint, it is desirable that materials should be acquired from the landfill site. In these cases the excavated clay and tuffs are unsuitable to use as dike material. Therefore, these soils are mainly adopted as cover material.

It is not necessary to provide a lining to the facility works to prevent or reduce contamination of public water and underground water by leachate, because the soils of the Ruai site and the Ngong road forest site have high impermeability.

(c) Leachate Collection Facility and Gas Exhaust Equipment

The leachate collection facility and the gas exhaust equipment have the following functions:

(i) To supply air into the garbage layer to facilitate aerobic decomposition.

(ii) To discharge gaseous substances generated in the garbage layer.

(iii) To collect and take out leachate from the garbage layer to the leachate reservoir by the horizontal and vertical drain network.

To perform there functions, vertical gas exhaust equipment and horizontal underdrains will be installed beside the network. The gas exhaust equipment and underdrains are composed of porous materials such as crushed stone and porous PVC pipes. In this case the gas exhaust equipment consists of crushed stone installed in wire baskets. Underdrains consist of porous PVC pipes made in Kenya.

The diameter of collection and drain pipes for leachate are as determined below.

(i) **Condition**

<u>Discharge Rate of Leachate (Q)</u>

The discharge rate of leachate is derived from the following equation (Rational Formula):

$$Q = (1/3{,}600) \times C \times I \times A \quad (m^3/sec)$$

Where,

C : Seepage coefficient = 0.5
I : Rainfall intensity = 41 mm/hr

(This rainfall intensity was used as the average intensity in the Nairobi Master Plan for Sewer, Sanitation and Drainage.)

A : Landfill area = 15.9ha (Case 1 and Case 2);
33.3ha (Case 3 and Case 4); 20.0ha (Case 5 and Case 6)

<u>Flow Capacity (Q')</u>

Flow capacity is derived from the following equation (Manning's formula):

$$Q' = (1/n) \times R^{2/3} \times T^{1/2} \times A \quad (1)$$

Where,

n : Roughness coefficient = 0.009 for PVC pipe
R : Hydraulic radius (m)
T : Pipe slope
A : Cross sectional area of the pipe (m^2)
v : Channel flow velocity (m/sec)

When effective cross section area ratio of the pipe is 100%, Equation (1) is derived from the following equation:

$$Q' = (1/0.009) \times (D/4)^{2/3} \times I^{1/2} \times (D^2 \times 3.14) / 4$$

Where, D : Diameter of pipe (mm)

(ii) Consideration Results

Pipe diameter (D) is determined as Q × P (where P is the number of pipes per line), assuming that the flow capacity (Q') is more than the discharge rate of leachate (Q). It is assumed that the diameter of the PVC pipe made in Kenya is less than 400 mm. The consideration results are shown in **Table H.3-11** below.

Table H.3-11 Diameter of Leachate Collection Pipe

		Q (m^3/sec)	P (lines)	I (-)	D (mm)	Number of pipes per line (pipes/line)	Q' (m^3/sec)
Case1	Main	0.905	3	0.006	400	2	1.405
Case2	Branch		18	0.002	300	1	1.134
Case3	Main	1.896	3	0.005	400	3	1.923
Case4	Branch		38	0.0015	300	1	2.072
Case5	Main-1	1.139	3	0.006	400	2	1.405
Case6	Main-2			0.025		1	2.868
	Branch		33	0.002	300	1	2.078

(c) Retention Pond and Leachate Treatment Facility

(i) Quantity of Leachate

The retention and the treatment ponds are designed to confine leachate water. These equipment are expected to confine the leachate even in rainy season. Therefore, their sizes should be determined to have enough capacity to contain the leachate without discharging the untreated leachate.

The characteristics of precipitation and evaporation in Nairobi are summarised in **Table H.3-12** and **Table H.3-13**, respectively. The quantity of leachate is related to the meteorological parameters, as derived from the following equations:

$$Q_0 = 0$$

$$Q_n = \{(C_0 \times A_0 + C_1 \times A_1) \times I_n - A_0 \times E_n\}/1000 + Q_{n-1}$$

Where,

n : n-th month from the beginning of rainy season (March)

Q_n: Quantity of confined leachate in ponds at the end of the n-th month

I_n : Precipitation intensity during the n-th month

E_n : Evaporation intensity during the n-th month

A_0: Area of retention pond and treatment pond, set at 15,000 m^2 (Cases 1 and 2); 28,000 m^2 (Cases 3 and 4); 18,000 m^2 (Cases 5 and 6)

A_1: Landfilling duration area, set at 159,000 m^2 (Cases 1 and 2); 330,000 m^2 (Cases 3 and 4); 200,000 m^2 (Cases 5 and 6)

C_0: Leachate production rate out of rainfall at pond area, set at 1.0

C_1: Leachate production rate out of rainfall at landfilling duration area, set at 0.5 according to **Table H.3-14**

Table H.3-12 Precipitation in Nairobi

Month	NAIROBI J KIA (1959～90)		WILSON MET. STATION (1951～90)		NAIROBI (D.CORNER) (1954～90)		NAIROBI NATIONAL LAB. (1923～80)		KABETE UNIV. STAT. (1972～90)		MAB	RUIRU SUKARI RANCH	Total Mean Precipi-tation	Total Mean Precipi-tation ÷7	Mean Days of Precipi-tation in month
	Mean Precipi-tation (mm/mon.)	Days of Precipi-tation in month	Mean Precipi-tation (mm/mon.)	Days of Precipi-tation in month	Mean Precipi-tation (mm/mon.)	Days of Precipi-tation in month	Mean Precipi-tation (mm/mon.)	Days of Precipi-tation in month	Mean Precipi-tation (mm/mon.)	Days of Precipi-tation in month	Mean Precipi-tation (mm/mon.)	Mean Precipi-tation (mm/mon.)		(mm/mon.)	
Jan.	49	4	55	3	62	4	53	6	48.3	3.8	44.5	37.7	349.5	50	4
Feb.	48	4	50	5	55	5	48	5	56.4	4.3	41.3	40.5	339.2	48	5
Mar.	73	8	81	9	95	9	102	9	95.2	8.6	79.0	81.6	606.8	87	9
Apr.	153	13	190	15	227	16	219	17	228.2	15.9	183.0	170.8	1,371.0	196	15
May	116	8	157	12	185	13	174	16	194.7	13.7	136.7	4.4	967.8	138	13
Jun.	24	3	36	3	35	5	43	4	36.2	5.4	38.1	28.9	241.2	34	4
Jul.	11	1	16	3	18	3	19	4	24.0	4.6	16.7	14.0	118.7	17	3
Aug.	15	3	19	4	23	4	26	5	21.9	3.5	28.8	15.3	149.0	21	4
Sep.	18	3	25	3	32	4	24	2	36.9	4.7	26.3	18.0	180.2	26	3
Oct.	42	5	49	5	54	7	55	6	62.7	7.3	52.7	50.1	365.5	52	6
Nov.	118	12	126	14	148	15	135	15	128.7	14.7	122.9	139.0	917.6	131	14
Dec.	83	7	85	8	102	8	83	7	91.9	8.4	77.0	67.1	589.0	84	8
Total	750	71	889	84	1,036	93	981	96	1,025.1	94.9	847.0	667.4		885	88

Table H.3-13 Evaporation in Nairobi

(Unit: mm/month)

Month	Nairobi J Kia	Nairobi (D. Corner)	Kabete University Station	Total	Mean
Jan.	222	184	160	566	189
Feb.	224	183	157	564	188
Mar.	248	192	181	621	207
Apr.	177	145	140	462	154
May	138	120	144	402	134
Jun.	117	99	132	348	116
Jul.	117	91	137	345	115
Aug.	126	102	150	378	126
Sep.	171	138	152	461	154
Oct.	210	163	155	528	176
Nov.	169	139	146	454	151
Dec.	196	156	167	519	173
Total	2,115	1,712	1,821	-	1,883

Table H.3-14 Leachate Production Rate out of Rainfall

Month	Temperature				Leachate Production Rate out of Rainfall in Tokyo*	
	TOKYO MEAN		NAIROBI MEAN			
	MAX	MIN	MAX	MIN	C1	C2
Jan.	10.1	2.9			0.52	0.31
Feb.	10.4	3.1			0.50	0.30
Mar.	13.0	5.6			0.51	0.31
Apr.	18.6	10.6			0.49	0.29
May	22.4	15.0			0.50	0.30
Jun.	25.4	19.1			0.63	0.38
Jul.	28.8	22.7			0.39	0.23
Aug.	30.8	24.3			0.58	0.35
Sep.	26.9	21.0			0.70	0.42
Oct.	21.6	15.4			0.76	0.46
Nov.	17.0	9.8			0.66	0.40
Dec.	12.8	5.2			0.57	0.34
Year			24.2	12.7		

Note: C1: Rate of landfilling duration area; C2: Rate of landfilled area

* According to the Design Guideline of Final Disposal Site of Japan

Under these circumstances, the leachate volume confined in the pond is connected to the meteorological data and the sizes of ponds mentioned above. The sizes of ponds are given in due consideration of the share of each component facility. With these sizes of ponds, the peak quantity of untreated leachate appears to be 55,294 m^3, 117,888 m^3, and 70,418 m^3, according to the monthly fluctuation of precipitation and evaporation, as shown in **Tables H.3-15, H.3-16 and H.3-17** below.

Table H.3-15 Quantity of Leachate Production and Capacity of Leachate Treatment (Case 1 and Case 2)

No.	Month	Days in month	Precipitation (mm/mo.)	Days of Precipitation in month	Evaporation (mm/mo.)	Quantity of Leachate (m^3)	Quantity of Untreated Leachate [Tc=100] (m^3)	Quantity of Untreated Leachate [Tc=200] (m^3)
1	Mar.	31	87	9	207	5,117	2,017	0
2	Apr.	30	196	15	154	21,329	15,229	10,212
3	May	31	138	13	134	32,360	23,160	15,043
4	Jun.	30	34	4	116	33,833	21,633	10,516
5	Jul.	31	17	3	115	33,714	18,414	4,197
6	Aug.	31	21	4	126	33,809	15,409	0
7	Sep.	30	26	3	154	33,956	12,556	0
8	Oct.	31	52	6	176	36,230	11,730	0
9	Nov.	30	131	14	151	46,345	18,845	4,115
10	Dec.	31	84	8	173	51,688	21,088	3,258
11	Jan.	31	50	4	189	53,578	19,878	0
12	Feb.	28	48	5	188	55,294	18,794	0
	Total	365	884	88	1,506	55,294	18,794	0

Table H.3-16 Quantity of Leachate Production and Capacity of Leachate Treatment (Case 3 and Case 4)

No.	Month	Days in month	Precipitation (mm/mo.)	Days of Precipitation in month	Evaporation (mm/mo.)	Quantity of Leachate (m^3)	Quantity of Untreated Leachate [Tc=300] (m^3)	Quantity of Untreated Leachate [Tc=400] (m^3)
1	Mar.	31	87	9	207	10,995	1,695	0
2	Apr.	30	196	15	154	44,511	26,211	21,516
3	May	31	138	13	134	67,393	39,793	31,998
4	Jun.	30	34	4	116	70,707	34,107	23,312
5	Jul.	31	17	3	115	70,768	24,868	10,973
6	Aug.	31	21	4	126	71,293	16,093	0
7	Sep.	30	26	3	154	71,999	7,799	0
8	Oct.	31	52	6	176	77,107	3,607	0
9	Nov.	30	131	14	151	98,162	15,662	9,055
10	Dec.	31	84	8	173	109,530	17,730	8,023
11	Jan.	31	50	4	189	113,888	12,788	0
12	Feb.	28	48	5	188	117,888	8,388	0
	Total	365	884	88	1,506	117,888	8,388	0

Table H.3-17 Quantity of Leachate Production and Capacity of Leachate Treatment (Case 5 and Case 6)

No.	Month	Days in month	Precipi-tation (mm/mo.)	Days of Precipi-tation in month	Evapo-ration (mm/mo.)	Quantity of Leachate (m^3)	Quantity of Untreated Leachate [Tc=100] (m^3)	Quantity of Untreated Leachate [Tc=200] (m^3)
1	Mar.	31	87	9	207	6,540	3,440	340
2	Apr.	30	196	15	154	26,896	20,796	14,696
3	May	31	138	13	134	40,768	31,568	22,368
4	Jun.	30	34	4	116	42,692	30,492	18,292
5	Jul.	31	17	3	115	42,628	27,328	12,028
6	Aug.	31	21	4	126	42,838	24,438	6,038
7	Sep.	30	26	3	154	43,134	21,734	334
8	Oct.	31	52	6	176	46,102	21,602	0
9	Nov.	30	131	14	151	58,842	31,342	6,740
10	Dec.	31	84	8	173	65,640	35,040	7,338
11	Jan.	31	50	4	189	68,138	34,438	3,636
12	Feb.	28	48	5	188	70,418	33,918	316
	Total	365	884	88	1,506	70,418	33,918	0

(ii) Capacity of Treatment Pond

Cases 1 and 2

The capacity of treatment ponds is determined to keep the quantity of untreated leachate at zero within a year. Minimum treatment capacity is as shown in the following equation:

$$Tc\ min = Qle_0 / 365days = 55{,}294 / 365 = 151\ m^3/day$$

Where, Tc min. is the minimum treatment capacity (m^3/day); and Qle_0 is the quantity of leachate, which is 55,294 m^3 according to **Table H.3-15.**

According to the above equation, the capacity of treatment ponds is determined at 200 m^3/day(>151 m^3/day).

Cases 3 and 4

Capacity of treatment ponds is determined to keep the quantity of untreated leachate at zero within a year. Minimum treatment capacity is as shown in the following equation:

$$Tc\ min = Qle_0 / 365days = 117{,}888 / 365 = 323\ m^3/day$$

Where, Tc min. is the minimum treatment capacity (m^3/day); and Qle_0 is the quantity of leachate, which is 117,888 m^3 according to **Table H.3-16.**

According to the above equation, the capacity of treatment ponds is determined at 400 m^3/day(>323 m^3/day).

Cases 5 and 6

Capacity of treatment ponds is determined to keep the quantity of untreated leachate at zero within a year. Minimum treatment capacity is as shown in the following equation:

$$Tc\ min = Qle_0 / 365days = 70,418 / 365 = 193\ m^3/day$$

Where, Tc min. is the minimum treatment capacity (unit; m^3/day); and Qle_0 is the quantity of leachate, which is 70,418 m^3 according to **Table H.3-17.**

According to the above equation, the capacity of treatment ponds is determined at 200 m^3/day(>193 m^3/day).

(iii) Volume of Retention Pond

The volume of retention pond should be determined to have enough capacity to contain the leachate without discharging the untreated leachate in case of the following:

- *Target month*: May, which has maximum untreated leachate according to **Tables H.3-15, H.3-16 and H.3-17.**
- *Pattern of rainfall*: It rains 10.6mm/day everyday from 1st to 13th of May.

[10.6mm/day = Total precipitation in May / Days of precipitation in May = 138mm/month) / 13days]

The volume of retention pond (Rc) is calculated by the following equation, as given below:

$$Rc = Qle_{Case\ n}\ May + Tc \times (31days \cdot 13days)$$

Where, $Qle_{Case\ n}$ May is the quantity of untreated leachate at the end of May in Case n of treatment capacity (cf. **Tables H.1-6, H.1-7 and H.1-8).**

Cases 1 and 2: $15,043 + 200 \times (31 \cdot 13) = 19,000\ m^3$

Cases 3 and 4: $31,998 + 400 \times (31 \cdot 13) = 40,000\ m^3$

Cases 5 and 6: $22,368 + 200 \times (31 \cdot 13) = 26,000\ m^3$

(iv) Volume of Treatment Pond

Volume of treatment ponds is determined to have enough capacity to satisfy the following items.

- Flow rate (Capacity of treatment): 200 m^3/day
- Influent BOD_5 (Quality of leachate): 5,000 g/ m^3
- Effluent BOD_5 (Quality of discharge): 30 g/ m^3

Treatment ponds should consist of anaerobic ponds, facultative ponds and maturation ponds in order to satisfy above items. Anaerobic ponds are designed to receive such a high organic loading that they are completely devoid of dissolved oxygen. Facultative ponds normally receive raw sewage that has received only preliminary treatment; however, they are generally used to treat the effluent from anaerobic pretreatment ponds for high organic loading. Maturation ponds are used as a second stage to facultative ponds. Their main function is the destruction of pathogens.

The specification and dimension of these ponds are as shown in **Table H.3-18.**

Table H.3-18 Specification and Dimension of Treatment Pond

Pond	Depth (m)	Retention Time (day)	Influent BOD_5 (g/m^3)	Effluent BOD_5 (g/m^3)	Removal rate of BOD_5 (%)
Anaerobic pond	3.0	5	5,000	-	70
Facultative pond	1.5	-	-	60	-
Maturation pond	1.0	7	Less than 75	Less than 30	-

The quality of discharge 30 Effluent BOD_5 g/m^3 is not contained in the Kenyan Standard for Discharge into Public Water Course. However, the item is not a problem because:

- The Japanese Standard for Discharge into Public Water Course for the item is 160 Effluent BOD_5 g/m^3.
- It is necessary to install an aerator and the capital and maintenance cost will be expensive.
- It is difficult to operate the leachate treatment system.

Volumes of treatment ponds are determined as shown **Tables H.3-19 and H.3-20** in order to satisfy the above specifications/dimensions.

Table H.3-19 Volumes of Treatment Pond (Cases 1, 2, 5 and 6)

		Area (m^2)	Depth (m)	Volume (m^3)	Retention time (days)	Influent BOD (g/m^3)	Effluent BOD (g/m^3)
Retention pond		6,400 or 8,700	3.0	19,000 or 26,000	-	-	-
Treatment pond	Anaerobic	340 × 3 =1,020	3.0	1,000 × 3 =3,000	5 × 3 =15	5,000	450
	Facultative	3,200	1.5	4,800	24	450	60
	Maturation	1,400 × 2 =2,800	1.0	1,400 × 2 =2,800	7 × 2 = 14	60	30
Total		13,400 or 15,700	-	36,600	53	-	-

Table H.3-20 Volumes of Treatment Pond (Cases 3 and 4)

		Area (m^2)	Depth (m)	Volume (m^3)	Retention time (days)	Influent BOD (g/m^3)	Effluent BOD (g/m^3)
Retention pond		13,400	3.0	40,000			
Treatment pond	Anaerobic	670 × 3 =2,010	3.0	2,000 × 3 =6,000	5 × 3 =15	5,000	450
	Facultative	6,400	1.5	9,600	24	450	60
	Maturation	1,400 × 2 =2,800	1.0	1,400 × 2 =2,800	7 × 2 = 14	60	30
Total		24,600	-	36,600	53	-	-

(d) Rainwater Drainage

(i) Condition

Rainwater Runoff (Q)

Rainwater runoff is derived from the following equation (Rational formula):

$$Q = (1/360) \times C \times I \times A \quad (m^3/sec)$$

Where,

C : Runoff coefficient = 0.3

(Leachate production rate out of rainfall at landfilled area which is set at 0.3 according to **Table H.3-14.**)

I : Rainfall intensity (mm/hr)

(The rainfall intensity curve for Wilson Airport is presented in the Nairobi Master Plan for Sewer, Sanitation and Drainage.)

t = Rainfall duration (min) = t1 + (L/v) × (1/60)
t1 = Inlet time (from rainfall point to the channel) = 7min
L = Channel length (refer to **Tables H.3-21, H.3-22 and H.3-23)**
v = Average flow velocity (m/sec) (refer to **Subsection 3.4.2(2)(c)(i))**
A : Drainage area (ha) (refer to **Tables H.3-21, H.3-22 and H.3-23)**

Table H.3-21 Drainage Area and Channel Length (Cases 1 and 2)

Channel Section	Section Length (m)	Cumulative Channel Length (m)	Drainage Area (ha)
a-1	400	400	5
a-2	533	933	10
a-3	400	1,333	10
b-1	470	470	5
b-b-1	397	397	5
b-2	63	533	10
c-1	330	1,663	20

Table H.3-22 Drainage Area and Channel Length (Cases 3 and 4)

Channel Section	Section Length (m)	Cumulative Channel Length (m)	Drainage area (ha)
a-1	400	400	10
a-2	1,055	1,455	20
a-3	400	1,855	20
b-1	947	947	10
b-b-1	397	397	10
b-2	55	1,497	20
c-1	315	2,170	40

Table H.3-23 Drainage Area and Channel Length (Cases 5 and 6)

Channel Section	Section Length (m)	Cumulative Channel Length (m)	Drainage area (ha)
a-1	185	185	1
a-2	1,060	1,245	14.5
a-a-1	225	255	1
a-3	220	1,465	15.5
b-1	1,015	1,015	13.5
b-2	140	1,155	17
c-1	150	1,615	32.5

Flow Capacity (Q')

Flow capacity is derived from the following equation (Manning formula):

$$Q' = (1/n) \times R^{2/3} \times T^{1/2} \times A = v \times A'$$

Where, n : Roughness coefficient = 0.013 for mortal open channel
R : Hydraulic radius (m)
T : Channel slope
A : Cross sectional area of the channel (m^2)
v : Channel flow velocity (m/sec)

(ii) Consideration Result

The size of channel is determined by comparing Flow Capacity (Q') to Rainwater Runoff (Q). The Flow Capacity (Q') of the channel must be larger than the Rainwater Runoff (Q). The consideration result is as shown in **Tables H.3-24, H.3-25 and H.3-26.**

Table H.3-24 Dimensions of Gutter (Cases 1 and 2)

Channel Section	Width of Gutter (mm)	Depth of Gutter (mm)
a-1	700	600
a-2	800	800
a-3	1,400	1,400
b-1	600	500
b-b-1	1,200	900
b-2	1,400	1,400
c-1	1,500	1,500

Table H.3-25 Dimensions of Gutter (Cases 3 and 4)

Channel Section	Width of Gutter (mm)	Depth of Gutter (mm)
a-1	800	800
a-2	1,200	900
a-3	2,100	1,400
b-1	800	800
b-b-1	1,600	1,200
b-2	2,200	1,400
c-1	2,200	1,500

Table H.3-26 Dimensions of Gutter (Cases 5 and 6)

Channel Section	Width of Gutter (mm)	Depth of Gutter (mm)
a-1	700	600
a-2	700	600
a-a-1	700	600
a-3	2,000	1,400
b-1	700	600
b-2	2,200	1,400
c-1	1,500	1,500

3.4.3 Management of Landfill System

The detail of the management of landfill system is described in **Section 8.5 of Data Book (1), "Operation and Maintenance Manual of Sanitary Landfill".**

The functions of the landfill system will only be realised if appropriately managed. Therefore, the management of a sanitary landfill system must be thoroughly examined. In principle, the planning must consider the following points:

(1) Strict adherence to the technical standards set up for maintenance and control of landfill system.

(2) Recording and storing of data on the volume of solid waste dumped, volume of cover material used and the condition of the landfill site in order to correctly control the volume of solid waste dumped into the site and for the planning of efficient operations.

(3) The arrangement of proper organisation for the site is a very important point to sustain the sanitary landfill system. The proposed organisation is as shown in **Table H.3-27.** The number of operators will depend on the transported waste amount.

Table II.3-27 Operational Organisation

Staffing	Responsibility
Site Manager	• all the responsibility of handling the site, and contact and reporting to NCC
Secretary	• controls and regulates the schedule of Site Manager, register income and outlay daily management
Chief of engineering section	• responsible for all engineering matters, planning and conduct suitable landfill operation method
Truck scale engineer	• operates truck scale to measure the waste quantity and quality, and directs to designated landfill area
Site inspector	• inspects the safety against disaster of the site and illegal dumping
Chief operator	• controls daily operator's work and directs trucks to the designated landfill area in site
Operator	• landfills the waste

(4) Monitoring of the environment during the landfilling process as well as after completion. **Table II.3-28** shows an outline of the proposed monitoring.

Table II.3-28 Monitoring Items

Monitoring Items	Monitoring Facility	Inspection Item	Frequency
Groundwater	Groundwater monitoring well	PH, CN, Pb, T-Hg, Cd, BOD, COD, SS, MPN, Color	1/month
Gas	Gas outlet pipe	Temperature and humidity of original air, Temperature and volume of gas , component analysis (CH4, CO2)	4/year
Settlement	Ground surface settlement board	Settlement of ground level	1/month
Odour	-	Item should be selected by surrounding conditions	2/year
Leachate	Leachate reservoir pond	PH, CN, Pb, T-Hg, Cd, BOD, COD, SS, MPN, Color	1/month
Effluent water from leachate treatment facility	-	PH, CN ,Pb, T-Hg, Cd, BOD, COD, SS, MPN, Color	1/month

(5) Inspection and maintenance of each facility in the landfill system should be done periodically and after a heavy downpour or the occurrence of a natural disaster.

(6) Rational management taking into account of the prevailing social atmosphere in the region and the actual condition and technical level of the cleansing operators.

3.4.4 Landfill Operation

The detail of the landfill operation is described in **Section 8.5 of Data Book (1), "Operation and Maintenance Manual of Sanitary Landfill".**

(1) Application of Cover Soil

Dumped waste should be covered with soil everyday. Daily application of cover soil is required to:

- reduce smoke and odour.
- reduce the number of insects and rodents.
- accelerate waste decomposition.

(2) Bedding and Compaction

Solid waste must be sufficiently compacted so as to stabilise the landfill foundation and to prolong use period of landfill. A layer of cover soil must be systematically placed after landfilling each layer of solid waste.

The wastes are unloaded at the toe of the earth dike and spread and compacted on the slope of the dike in a series of layers that vary in depth from 30 to 60 cm. The recommended slope of these layers is 1 is to 3.

At the end of each day's operation, a 15 cm to 30 cm layer of cover soil is placed over the day's completed fill. This one day's completed fill including the cover soil requires about 10 to 20% of daily waste quantity. Therefore, the daily cover soil should be prepared and stocked by excavation work or selection of suitable construction work.

The cell method is recommended for sanitary landfill in view of the large area of landfill, and uphill method is recommended for bedding and compaction. Daily covering by soil should be done. The method is as illustrated in **Figures H.3-1** to **H.3-4.**

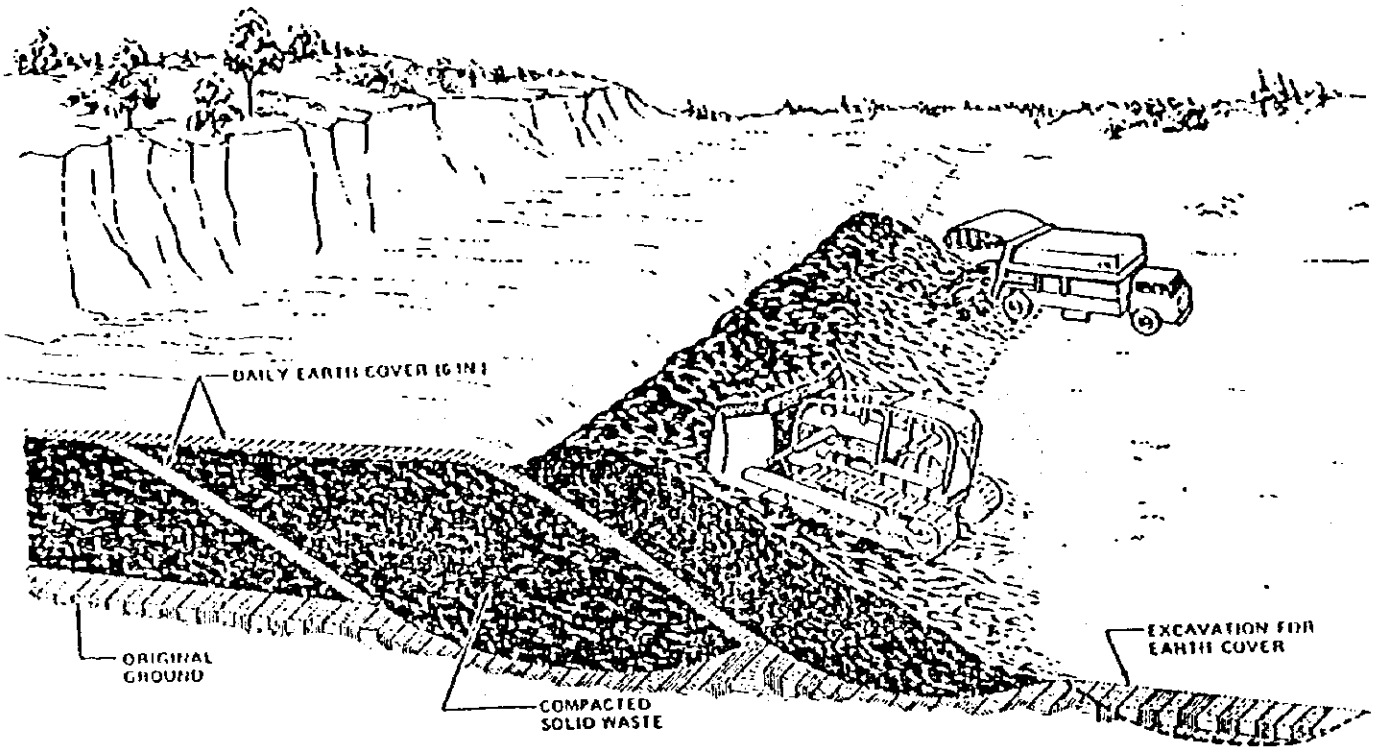

Figure H.3-1 Landfill Method

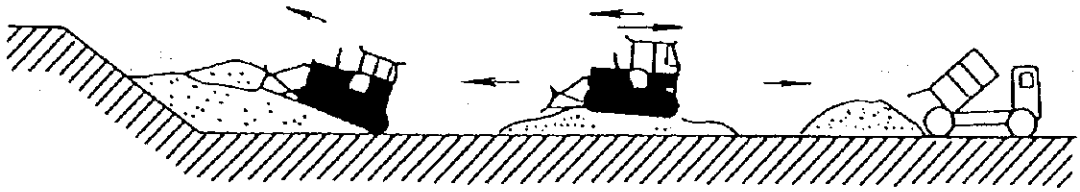

Figure H.3-2 Preparation of a Unit of Cell with the Up-fill Method

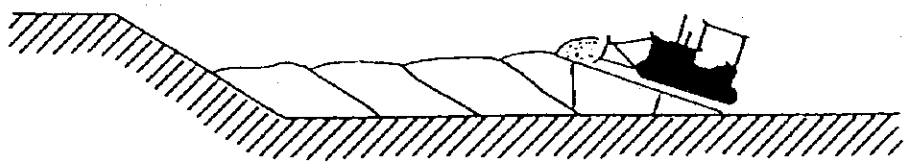

Figure H.3-3 Preparation of Cells with the Up-fill Method

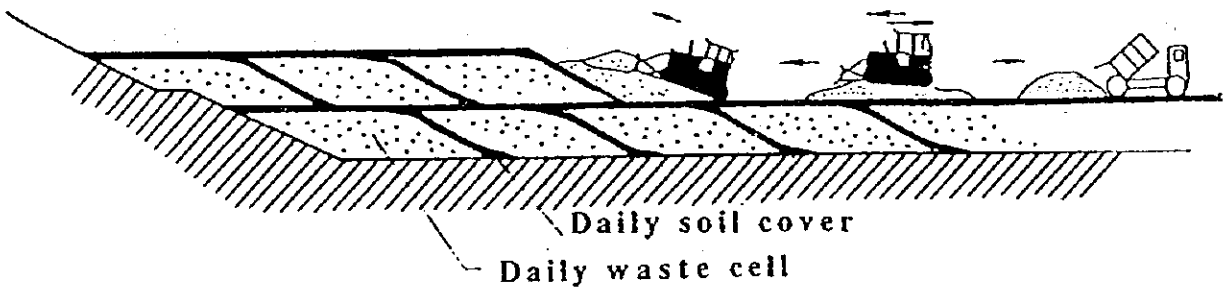

Figure H.3-4 Typical Landfill by Cell Method

3.4.5 Safety and Sanitary Control

A landfill system should be designed by considering safety and sanitary conditions for workers.

Work at a sanitary landfill system is mainly done outdoors. Workers will be affected by dust, odour and gas emission. In addition, they have some contact with chemicals. Working environment requirements then need to be considered.

(1) Safety and Sanitary Control for Workers

In order to ensure health and safety for workers at a landfill site, it is necessary to consider the working conditions and examine the following items:

(a) Dust from landfill operations
(b) Gas formation
(c) Use of chemicals
(d) Accidents such as falls
(e) Vectors and animals
(f) Others

(2) Welfare Facilities and Health Check

Health care for workers should be one aspect of the overall sanitary landfill system plan. Particular consideration should be given to the following points for safety and ease of work.

(a) Canteen, welfare and rest facilities
(b) Regular health checks
(c) Maintenance of first-aid kits

3.4.6 Cost Estimation

(1) Construction Schedule

It is necessary to prepare the new landfill site before the existing landfill site is exhausted. All the facilities of sanitary landfill site will be constructedin 2 or 3 years at least case by case, but it is not necessary to construct all the facilities before the beginning of landfill operation. The construction should be continued even after the commencement of the landfill operation according to the annual landfill amount expected in the successive years. The construction plan of each case is shown in **Figure H.3-5**. Therefore, it is possible for the landfill operation to begin in the second stage of construction.

Case	Site	Area	Year			
			1st	2nd	3rd	4th
Case1	Ruai	20 ha	1st Stage	2nd Stage		
Case 2				Beginning	Operation	
Case 3		40 ha	1st Stage	2nd Stage	3rd Stage	
Case 4				Beginning	Operation	
Case 5	Ngong Road Forest	27 ha	1st Stage	2nd Stage		
Case 6				Beginning	Operation	

Figure H.3-5 Construction Stage Plan for Each Case

(2) Construction Cost

The construction cost is estimated for each case and each construction stage. Especially, the facility estimation for Case 1, Case 3 and Case 5 is carried out for each sanitary landfill level. The results of facility estimation is summarised in **Table H.3-29**. The detail results are shown from **Table 8-7-1** to **Table 8-7-15** in **Data Book (1)**. Construction cost estimation cases are also shown in **Table H.3-29** below.

Table H.3-29 Summarised Facility Estimation Results

(1000 Kshs)

Site	Case			Construction Cost			
				1st year	2nd year	3rd year	
Ruai	A-1	A-1(1)	Case 1	519,853	306,744	-	826,597
		A-1(2)	Case 2	519,477	306,219	-	825,696
	A-2	A-2(1)	Case 3	667,857	338,007	405,100	1,410,964
		A-2(2)	Case 4	667,549	337,263	404,544	1,409,356
Ngong	A-1	A-1(1)	Case 5	412,260	366,964	-	918,174
		A-1(2)	Case 6	548,596	367,842	-	916,438

(3) Selection of Alternative Plans

The Ngong Road Forest Area, one of the candidate sites, is disregarded through the EIA, especially, the social impact assessment. Therefore, in this section, the annual disposal expenditure is described based on the cases where only the Ruai site is constructed (Ruai: 40 ha, Design Cases 3 and 4).

(4) Annual Disposal Expenditure of Alternative Plan

The annual disposal expenditure for each alternative plan which consist of design cost, heavy machines purchase cost, construction cost and O/M cost (engineering cost, fuel, electricity, water, spear parts) is shown in **Section 8.6, Cost Estimation, Data Book (1).**

The disposal site capacity requirement is decided by the collection plan.

Case	Site	Area	Year			
			1st	2nd	3rd	4th
Case1	Ruai	20 ha	1st Stage	2nd Stage		
Case 2				Beginning	Operation	
Case 3		40 ha	1st Stage	2nd Stage	3rd Stage	
Case 4				Beginning	Operation	
Case 5	Ngong Road Forest	27 ha	1st Stage	2nd Stage		
Case 6				Beginning	Operation	

Figure II.3-5 Construction Stage Plan for Each Case

(2) Construction Cost

The construction cost is estimated for each case and each construction stage. Especially, the facility estimation for Case 1, Case 3 and Case 5 is carried out for each sanitary landfill level. The results of facility estimation is summarised in **Table II.3-29**. The detail results are shown from **Table 8-7-1** to **Table 8-7-15 in Data Book (1)**. Construction cost estimation cases are also shown in **Table II.3-29** below.

Table II.3-29 Summarised Facility Estimation Results

(1000 Kshs)

Site	Case			Construction Cost			
				1st year	2nd year	3rd year	
Ruai	A-1	A-1(1)	Case 1	519,853	306,744	-	826,597
		A-1(2)	Case 2	519,477	306,219	-	825,696
	A-2	A-2(1)	Case 3	667,857	338,007	405,100	1,410,964
		A-2(2)	Case 4	667,549	337,263	404,544	1,409,356
Ngong	A-1	A-1(1)	Case 5	412,260	366,964	-	918,174
		A-1(2)	Case 6	548,596	367,842		916,438

(3) Selection of Alternative Plans

The Ngong Road Forest Area, one of the candidate sites, is disregarded through the EIA, especially, the social impact assessment. Therefore, in this section, the annual disposal expenditure is described based on the cases where only the Ruai site is constructed (Ruai: 40 ha, Design Cases 3 and 4).

(4) Annual Disposal Expenditure of Alternative Plan

The annual disposal expenditure for each alternative plan which consist of design cost, heavy machines purchase cost, construction cost and O/M cost (engineering cost, fuel, electricity, water, spear parts) is shown in **Section 8.6, Cost Estimation, Data Book (1).**

The disposal site capacity requirement is decided by the collection plan.

(a) Case 3: Ruai, 40ha (Collection Rate is 2000-2003 60%; 2004-2007 80%; 2008 100%)

(i) Waste Amount

Table H.3-30 Disposal Site Capacity Requirement Case 3)

Year	(1) Landfill Waste Amount (t/d)	(2) (1)x60%	(2) Landfill Waste Amount (m^3/d) (2)/*1.0	(3) Landfill Waste Amount (m^3/year) (3)x365	(4) Total Waste Amount (m^3)
1998	1,509	905	905	330,325	330,325
1999	1,587	952	952	347,480	677,805
2000	1,667	1,000	1,000	365,000	1,042,805
2001	1,758	1,055	1,055	385,075	385,075
2002	1,855	1,113	1,113	406,245	791,320
2003	1,959	1,175	1,175	428,875	1,220,195
2004	2,077	1,662	1,662	606,630	1,826,825
2005	2,190	1,752	1,752	639,480	2,466,305
2006	2,316	1,853	1,853	676,345	3,142,650
2007	2,451	1,961	1,961	715,765	3,860,415
2008	2,594	2,594	2,594	946,810	4,807,225
Total	-		-		5,849,030

* Bulk density of waste in the site is from 0.7to 1.4 (1.0)

(ii) Annual Disposal Expenditure

Table H.3-31 Annual Disposal Expenditure (Case 3)

Year	Waste Amount	Cost (x10^3 Kshs)				
		Design*	Construction	Heavy equipment	O.M Cost	Total Cost
1999		70,548				70,548
2000			667,857	152,300		820,157
2001	385,075		338,007 (227,000)		22,950	746,032 (227,000)
2002	406,245		405,100		24,212	973,032
2003	428,875			78,300	25,561	532,736
2004	606,630				35,306	641,936
2005	639,480				37,218	676,698
2006	676,345				39,363	715,708
2007	715,765			63,200	41,658	820,623
2008	946,810				53,211	1,000,021
Total	4,805,225	70,548	1,410,964 (227,000)	293,800	279,479	6,860,016 (227,000)

* Design cost is 5% of construction cost.
( ) is closure work of Dandora site.

(b) Case 4: Ruai 40ha (Collection Rate is 2000- 2003 40%; 2004-2007 50%; 2008 60%)

(i) Waste Amount

Table H.3-32 Disposal Site Capacity Requirement (Case 4)

Year	(1) Landfill Waste Amount (t/d)	(2) (1)x40% x50% x60%	(2) Landfill Waste Amount (m^3/d) (2)/*1.0	(3) Landfill Waste Amount (m^3/year) (3)x365	(4) Total Waste Amount (m^3)
1998	1,509	604	604	220,460	220,460
1999	1,587	635	635	231,775	452,235
2000	1,667	667	667	243,455	695,690
2001	1,758	703	703	256,595	256,595
2002	1,855	742	742	270,830	527,425
2003	1,959	784	784	286,160	813,585
2004	2,077	1,039	1,039	379,235	1,192,820
2005	2,190	1,095	1,095	399,675	1,592,495
2006	2,316	1,158	1,158	422,670	2,015,165
2007	2,451	1,226	1,226	447,490	2,462,655
2008	2,594	1,556	1,556	567,940	3,030,595
Total	-		-		3,726,285

* Bulk density of waste in the site is from 0.7 to 1.4 (1.0)

(ii) Annual Disposal Expenditure

Table H.3-33 Annual Disposal Expenditures (Case 4)

Year	Waste Amount	Cost (x10^3 Kshs)				
		Design*	Construction	Heavy equipment	O.M Cost	Total Cost
1999		70,468				70,468
2000			667,549	122,900		790,449
2001	256,595		337,263 (227,000)		16,756	354,019 (227,000)
2002	270,830		404,544		17,685	422,229
2003	286,160			29,400	18,686	48,086
2004	379,235				23,475	23,475
2005	399,675				24,740	24,740
2006	422,670				26,163	26,163
2007	447,490			34,200	27,700	61,900
2008	567,940				33,849	33,849
Total	3,030,595	70,468	1,409,356 (227,000)	186,500	189,054	1,855,378 (227,000)

* Design cost is 5% of construction cost.
( ) is closure work of Dandora site.

4. CLOSURE PLAN OF DANDORA DUMPSITE

4.1 Closure Plan

The Dandora Dumpsite should be closed when a new site(s) is constructed. There is a plan that the area will be developed as a residential area by a private company. However, if the area will not be used for any other purpose and leave it as it is, the site will generate many environmental problems in the future. Therefore, NCC has to consider the closure plan and another post-closure land-use plan.

The site is an uncontrolled dumping site, so that it is very difficult to make improvements or to quickly restore the same to its original ground condition. The

following closure work has to be be done and it will need more than ten years for the ground to stabilise.

(1) Scattered waste have to be got together to the northern part of the site. The work will reduce the waste distributed area. Cleaned-up original ground area in front of public road can be used for any land-use immediately.

(2) The waste distributed area should be covered with soil material completely. The thickness of cover soil should at least be 50 cm.

(3) Gas outlet equipment and leachate collection pipes should be installed in the waste distributed area to promote stabilisation of the waste layer.

(4) Rainwater drainage ditch should be constructed around the site area.

(5) Periodical monitoring is required to check the progress of stabilisation.

(6) The waste distributed area has to use the open space area, i.e., football ground or park until the waste layer has stabilised|completely.

Closure work of Dandora site is as shown in **Figure H.4-1.**

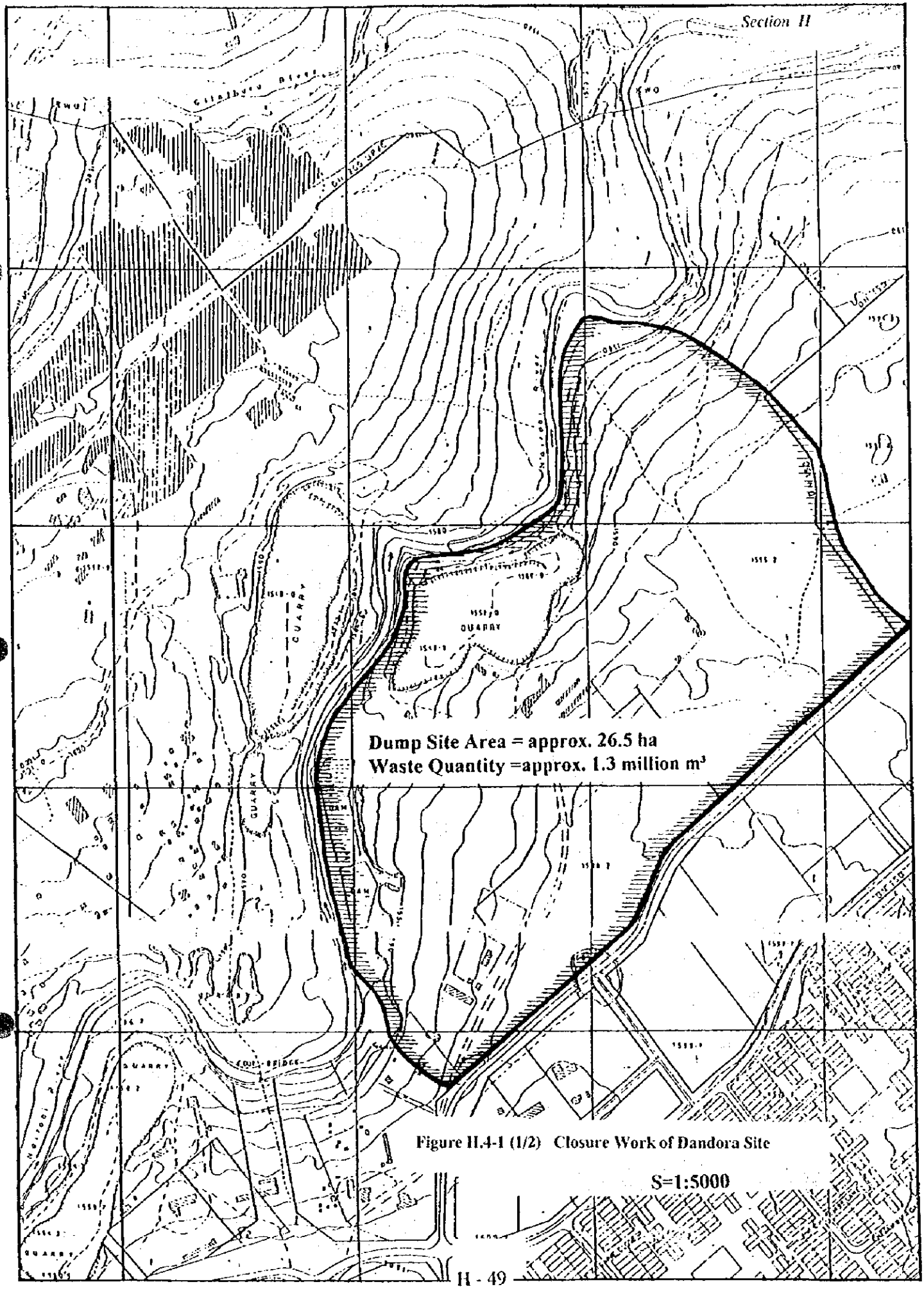

Figure II.4-1 (1/2) Closure Work of Dandora Site

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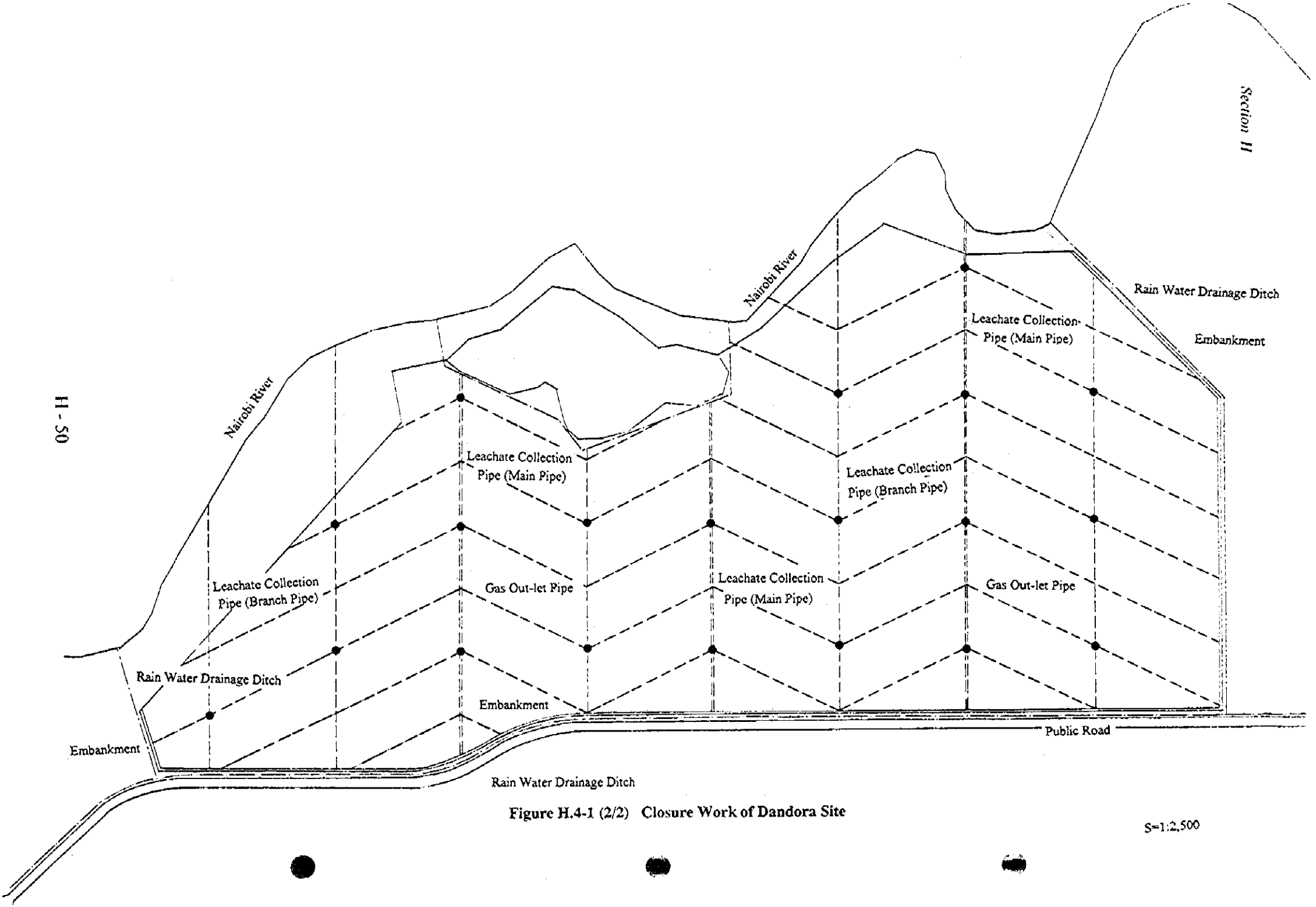

Figure H.4-1 (2/2) Closure Work of Dandora Site

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4.2 Cost Estimation of Closure Work for the Existing Dump Site

The existing Dandora Dumpsite should be closed when the new site is constructed. The main closure work consists of land reclamation and soil cover work. The closure work is as shown in **Figure H.4-1**. The quantity of complete closure work and cost estimation is described in **Table H.4-1**. The table shows that the work requires an approximate amount of 302 million Kshs for a one year period. Even if NCC could not assure enough budget for a complete closure work, NCC has to carry out a minimum closure work as shown in **Table H.4-2**. The work requires an approximate amount of 227 million Kshs for a half-year period.

Post-closure land-use plan of landfill site is as described in the following **Section 4.3**.

Table H.4-1 Cost Estimate for Complete Closure Work of Dandora

Items	Unit Cost (m^3/Kshs)	Quantity (m^3)	Cost (x 1000 Kshs)	Remarks
1. Land Reclamation	105	90,000	9,450	30.0 ha x 0.3m= 90,000m^3
2. Loading and Compaction	64	123,750	7,920	24.75ha x 0.5m= 123,750m^3
3. Cover Soil Material	1,221	123,750	151,099	Same as above
4. Enbankment	1,285	5,260	6,759	1,315m x 4m^3/m
5. Rainwater drainage ditch	6,500	1,910	12,415	
6. Leachate Collection Work				
6.1 Material & Installation Work (Main Pipe)	12,182	930	11,329	
6.2 Material & Installation Work (Branch Pipe)	3,441	6,500	22,367	
7. Gas Outlet Equipment	128,600	20	2,572	
Sub-Total	-	-	223,911	-
Overhead Cost	-	-	78,089	Sub-Total x Approx. 35%
Total	-	-	302,000	-

Table H.4-2 Cost Estimate for Minimum Closure Work of Dandora

Items	Unit Cost (m^3/Kshs)	Quantity (m^3)	Cost (1000 Kshs)	Remarks
1. Land Reclamation	105	90,000	9,450	30 ha x 0.3m= 90,000m^3
2. Loading & Compaction	64	123,750	7,920	24.75ha x 0.5m= 123,750m^3
3. Cover Soil Material	1,221	123,750	151,099	Same as above
Sub-Total	-	-	168,469	-
Overhead Cost	-	-	58,531	Sub Total x Approx. 35%
Total	-	-	227,000	-

4.3 Post-Closure Land-Use Plan

The landfill process will finally result in the formation of a useful land area. Therefore, it is desirable that the completed filled-up area should be utilised as early as possible and, in the meantime, it should be easily manageable. The post-closure land-use plan aims at reclaiming a piece of land with value-added.

In an urban area where most of the natural environment has been destroyed by development, the filled-up site can be transformed into urban woods or other

community facility such as a haven against natural disaster or fire. The planning which can reconcile solid waste management with the improvement of the living and urban environments should be the final goal and strategy of the cleansing operators.

On the other hand, the following points should be considered before starting the post closure land-use:

(a) Rate of subsidence
(b) Leachate quality
(c) Quality and quantity of gaseous products
(d) Internal temperature of landfill

Very often, the problems caused by subsidence and gas emission affect the post-closure land-use plan. In controlling the land-use, it is necessary to continuously measure these indicators so as to decide when the site can be duly utilised.

Even though many studies are still being made on the evaluation of landfill stability, it would be better to utilise the landfill site immediately by adopting temporary measures to counteract land subsidence, corrosion caused by leachate and emission gases.

Figure H-4-2 shows the general flowchart for preparing the land reclamation for a post-closure use. When reclamation works at the landfill site are completed, records on the finished land-form, type and volume of solid waste buried, etc., must be properly kept. It is necessary to clearly identify the responsible person after action has been taken to close up the landfill. Furthermore, between the time of completion of land-filling to the post-closure usage of the reclamation land, preparations must be made at each stage shown in **Figure H.4-2** to harmonise the finished land-form with the surrounding environment and to enable the ground to support the structures to be built on it.

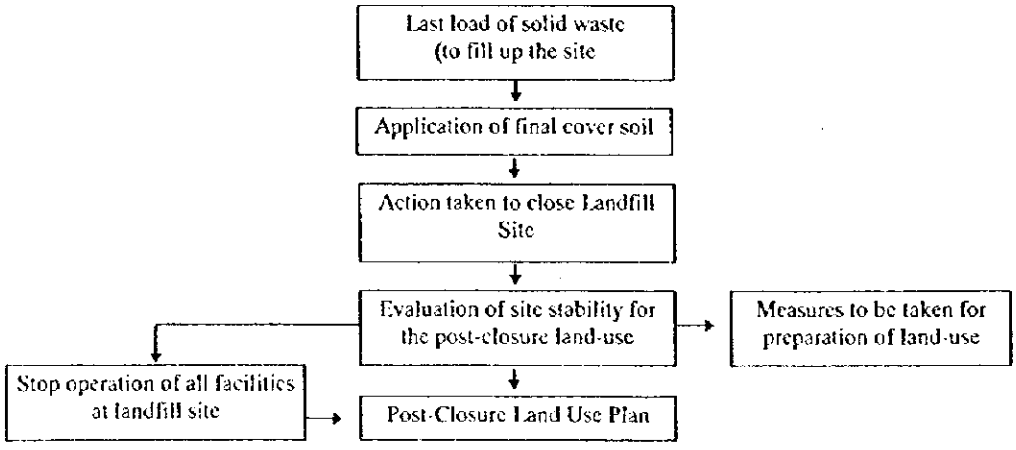


Figure H-4-2 Flow Chart for Preparation of Post-Closure Land-Use Plan

In the past, post closure land-use planning was never included in the improvement planning stage; the emphasis of the improvement plan was rather on how much solid waste can be buried or the economic aspects, etc. This is because the pressing problem was how to dispose of the increasing volume and types of solid waste in a safe and efficient manner. As a result, the completed filled-up site often experience problems

relating to poor soil condition, emission of combustible gases or offensive odor, land subsidence, weak foundation, etc.

In considering the ultimate usage of landfill site, the period required for the completed landfill to stabilise depends on the types and volume of filled-up solid waste, types and volume (thickness) of cover material applied, whether intermediate treatment processes such as crushing and compaction are adopted, or weather heavy machinery such as bulldozers are used to crush and compact the filled-up waste. All these and the factors relating to land-form will in return affect the type of land-use to be adopted.

The following conditions of the landfill site are prerequisites to post-closure land-use planning;

(1) The filled-up site has little subsidence; the consolidation period is relatively short;

(2) The ground foundation should as far as possible be load bearing;

(3) Slope failure should not occur;

(4) Emission of combustible gas and offensive odour should not occur;

(5) Contamination of groundwater should not occur;

(6) The filled-up site should not affect the load bearing capacity of ground foundation for structures; and

(7) The filled-up site should be suitable for vegetation growth.

If all the above mentioned conditions are met, the filled-up site should have a quality as good as any piece of land for high value development. Even if all these conditions are not fully satisfied, it is possible to utilise the landfill site by proper selection of land-use and protective measures.

In general, closed sites are used for agriculture, public park, sports ground, forest and so on.

(1) Agricultural Area

Final cover soil should be more than 1 m thick and the soil should be suitable for crops. Gas generated from filled-up waste will give an adverse impact to crops. Therefore, proper arrangement of gas outlet pipes should be installed in the area.

(2) Public Park and Sports Ground

These facilities are only open spaces, therefore, the management of facilities is easier than the land-use for agriculture. However, the management of a gas outlet facility has to be done carefully, so that many people will get together and use the facility.

(3) Construction Area for Residential Houses and Buildings

Ground subsidence will continue for 10 to 50 years depending on thickness of filled-up waste. The area should be checked for rate of subsidence, quality and quantity of gaseous products and internal temperature of waste layer.

5. PILOT PROJECT OF EXPERIMENTAL SANITARY LANDFILL AND CLOSURE WORK

5.1 Outline of the Pilot Project

The objective of this work was to show the effects of introducing sanitary landfill into the existing final disposal site where presently open dumping is prevailing, as well as to collect design data and produce an educational video.

The work was from 10 November to 19 December 1997. The Pilot Project Schedule is as shown in **Table H.5-1**.

Table H.5-1 The Pilot Project Schedule

Step	Date	Work Item	Activities
First Step	10th, November ~ 19th, November	Preparation Work for the Pilot Project	• Internal meeting • Organised NCC Team • Inspection of the site • Selection of the site • Planning of the schedule • Organised site security system • Contract for hired heavy equipment
Second Step	20th, November ~ 26th, November	Ensure the access road to the project area	• Introduction of heavy equipment • Access road construction work
Third Step	27th, November ~ 7th, December	land reclamation of the project area	• Land reclamation of the project area (1) • Land reclamation of the project area (2)
Fourth Step	8th, December ~ 10th, December	Experimental landfill work	• Preparation of landfill work • Demonstration
Fifth Step	11th, December ~ 14th, December	Experimental closure work	• Preparation of closure work • Demonstration
Sixth Step	15th, December ~ 19th, December	Experimental landfill work by NCC	• Experimental landfill work • Experimental closure work

The pilot project was composed of six (6) steps, namely:

(1) Preparation work (1st Step)
(2) Reclamation and access road to the pilot project area (2nd Step)
(3) Land reclamation for the pilot project area (3rd Step)
(4) Experimental sanitary landfill (4th Step)
(5) Experimental closure work (5th Step)
(6) Experimental sanitary landfill by NCC (6th Step)

The JICA Study Team and the NCC Project Team had carried out the project. The composition of the Project Team is as shown in **Table H.5-2**. The Pilot Project Team consisted of 18 personnel, from MOLG, NCC and hired operators.

Table H.5-2 The Members of the Pilot Project Team

Title	Name	Office
Team Leader/Adviser	Takashi Goto	JICA Study Team
Project Coordinator	N. N. Nyariki	MOLG, Counterpart
Project Coordinator	S. W. Opiyo	NCC (DoE), Counterpart
Project Manager	P. Wamwiri	NCC (DoE), Kaloreni Depo.
Project A- Manager	R. Onyango	NCC (DoE), Counterpart
Project Site Manager	A. Akufata	NCC (DoE), Dandora office
Operator	4 persons	NCC (DoE), Kaloreni Depot
Operator	2. persons	Operator hired from local firm
Security Guards	6 persons	Private company
Total	18 persons	-

5.2 Project Activities

(1) Location of the Project Site

In Nairobi, there is, at present, only one dumping site, which is located in Dandora. It is 7.5 km southeast of the centre of Nairobi. The area is about 26.5 ha. The site is filled with approximately 1.3 million cubic meters (mcm) of waste at present.

The pilot project area was selected within the Dandora dumping site. The first area selected was 1200 m^2 and located near the old quarry. However, it was very difficult to ensure the access road from the public road to the area due to continuous bad weather conditions. Therefore, the another area near the public road was selected. The pilot project area is as shown in **Figure H.5-1**.

(2) The Project Area

The project area was 1200 m^2. Half of the area was for this pilot project and other half was for NCC's experimental landfill area. The area is enclosed by 1.5 m height of embankment. Total capacity of the experimental landfill area was approximately 1800 m^3. The landfill plan is as shown in **Figure H.5-2**.

(3) Explanation of Landfill Method

The solid waste must be sufficiently compacted so as to stabilise the landfill foundation and to prolong the life span of the landfill. A layer of cover soil must be systematically placed after each layer of solid waste.

The method and order of landfilling must be carefully selected so as to improve stabilisation of the landfill, create a physically strong foundation, improve the usability of the completed landfill site, etc. At the same time, proper landfill equipment must be used to sufficiently compact the filled-up waste.

In this pilot project, the "cell method" was used for compaction and filling of waste.

The recommended and implemented landfill method is as shown in **Figure H.5-3.**

The waste were unloaded at the toe of the earth dike and then spread and compacted on the slope of the dike in a series of layers that varied in depth from 30 to 60 cm. The recommended slope of these layers was 1 is to 3.

At the end of each day's operation, a 15 to 30 cm layer of cover soil was placed over the day's completed fill. This one day's completed fill including the cover soil is called a cell.

(4) Demonstration of Sanitary Landfill

Demonstration of sanitary landfill was carried out at the project area on the 10th and 11th of December. The project was informed to NCC staff concerned in Solid Waste Management by means of a poster, and also introduced at the general workshop on the 9th of December. The poster is as shown in **Figure H.5-4.**

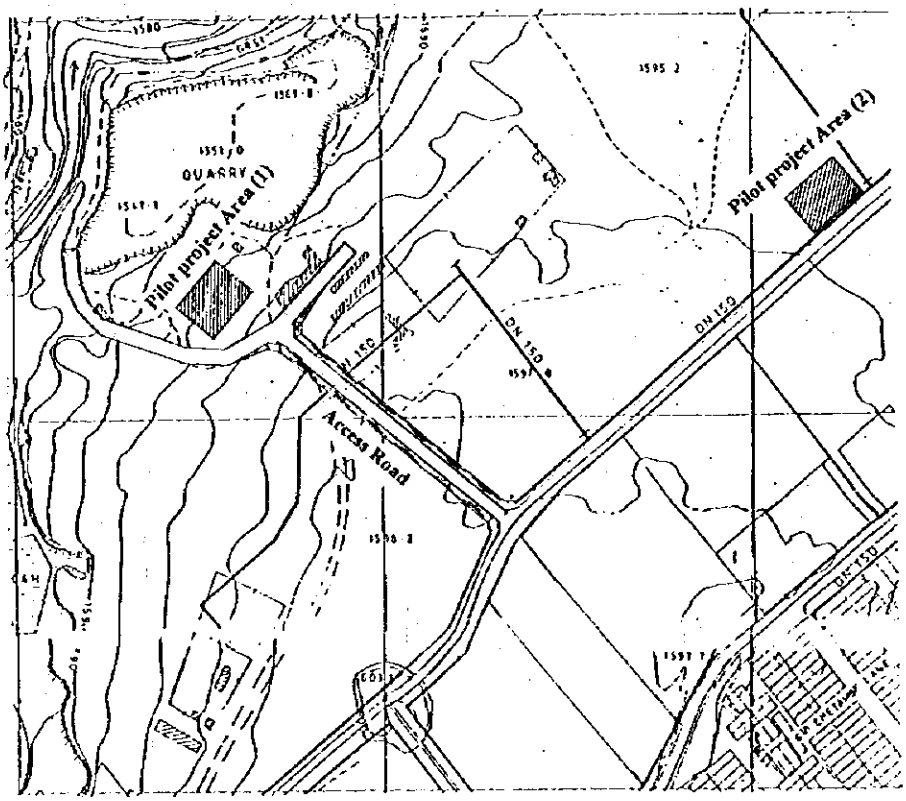
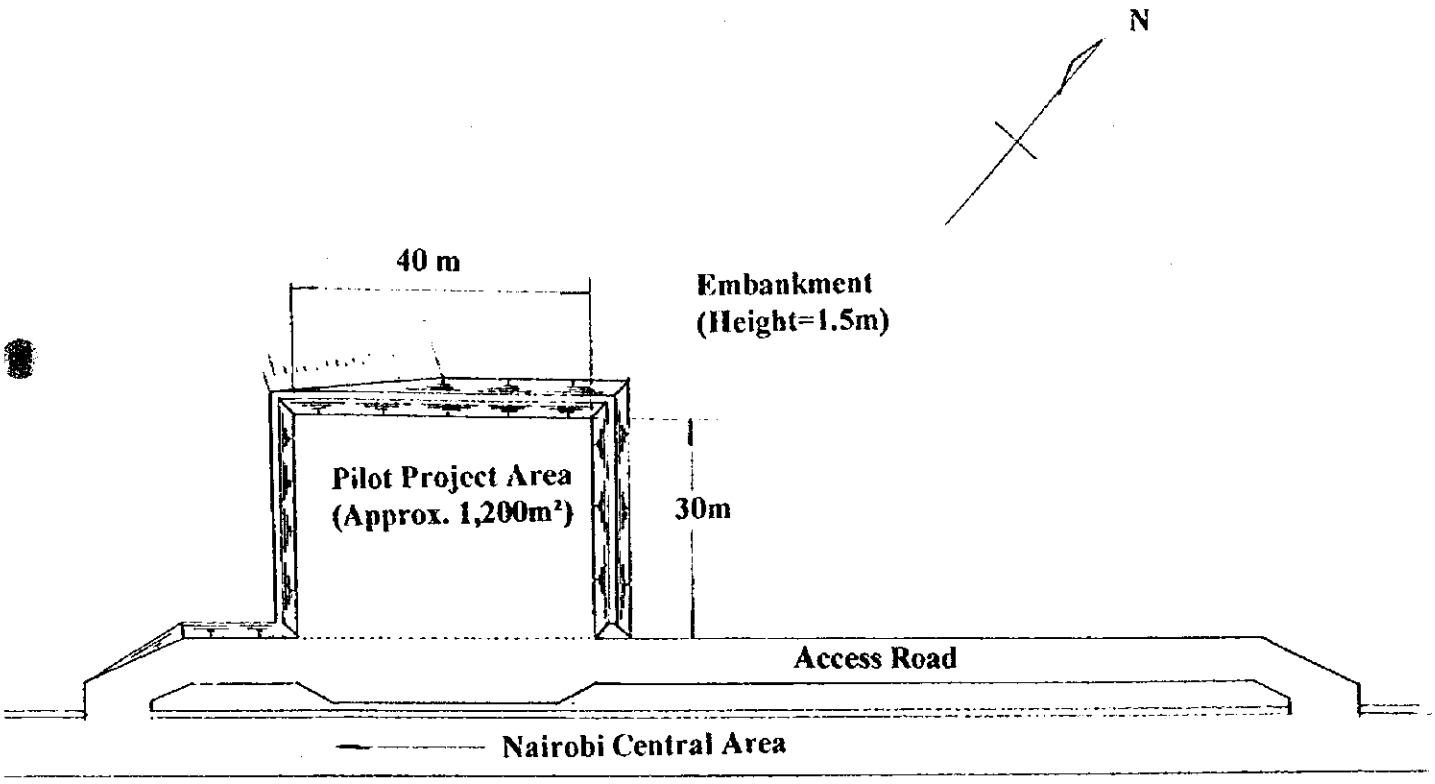


Figure H.5-1 Location Map of the Pilot Project Area



Relation between Public Road and Project Area (2)
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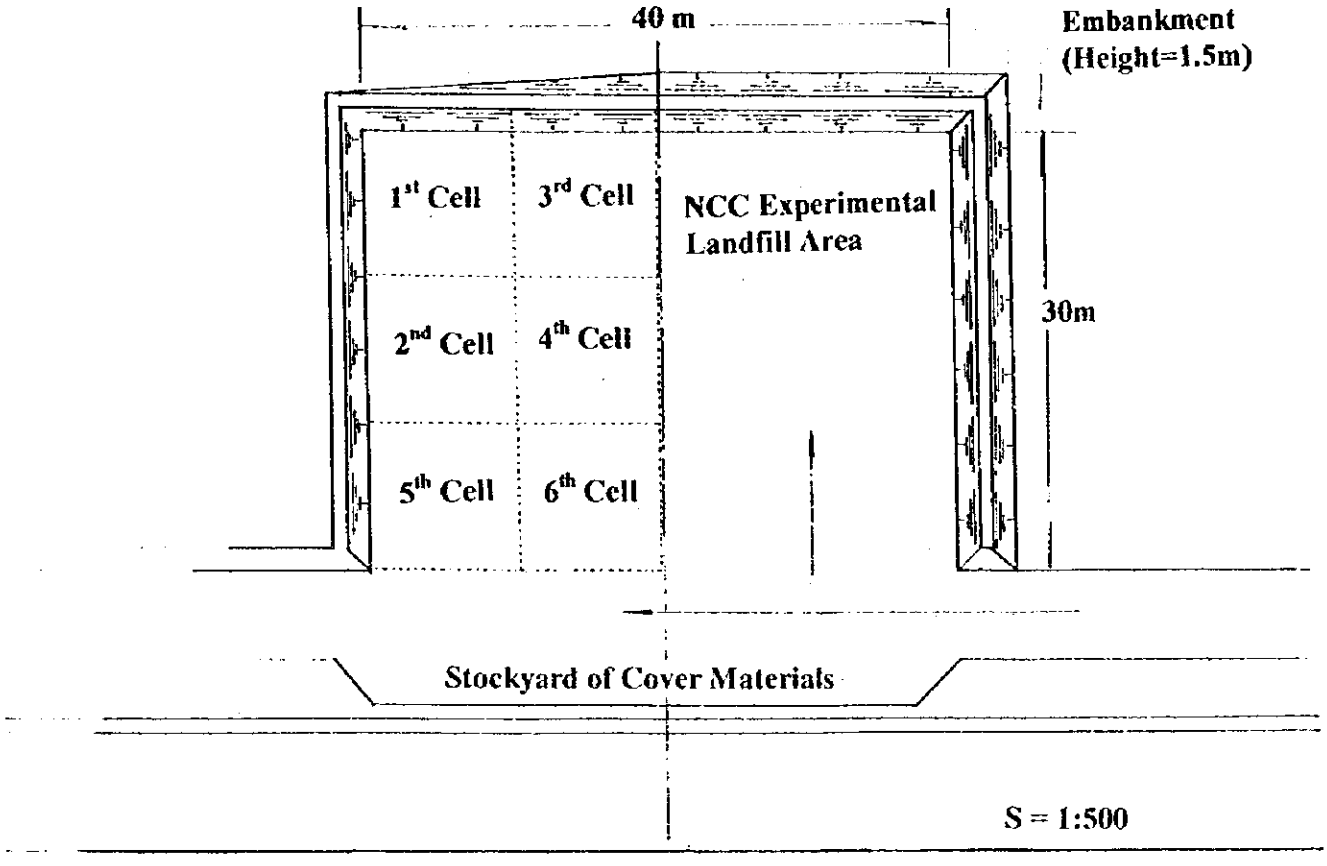

Figure II.5-2 The Landfill Plan of the Pilot Project

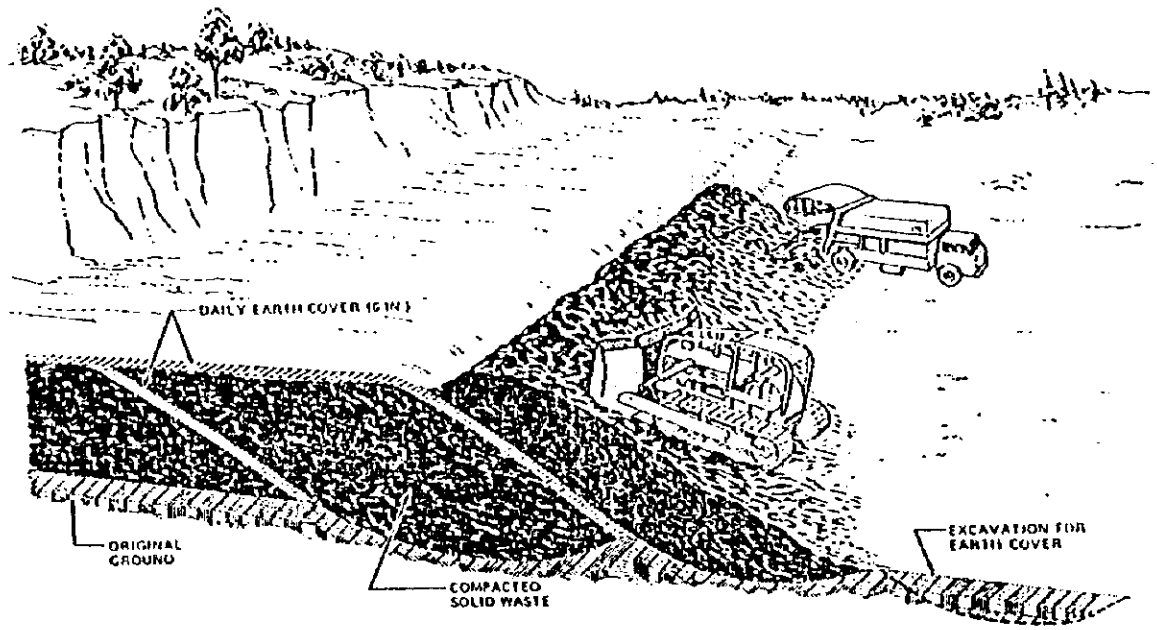

Figure H.5-3 The Experimental Landfill Method

Demonstration of Sanitary Landfill
in Dandora Dumping Site

The JICA Study Team and the NCC counterpart team will carry out the EXPERIMENTAL CLOSURE WORK AND SANITARY LANDFILL at Dandora dumping site.

We will answer the question of "**What is a sanitary landfill and why is it necessary?**" through the demonstration.

We welcome individuals and all organisations concerned in Solid Waste Management and protection of the environment.

Note:

Experimental Sanitary Landfill
Date: 10th, 11th December
Time: a.m. 10:00 to 12:00
p.m. 02:00 to 4:00
Place: Dandora dumpsite

Experimental Closure Work
Date: 11th December, 1997
Time: p.m. 02:00 to 4:00

Place: Dandora dumpsite

Figure II.5-4 The Poster for the Demonstration of the Project

5.3 Evaluation of the Pilot Project

The purposes of the pilot project were not only to confirm the effectiveness of sanitary landfill but also to effect transfer of technology on operation and maintenance of a sanitary landfill.

The effectiveness of sanitary landfill was demonstrated very clearly; the filled-up area by the cell method was like original ground. The NCC participants concerned in Solid Waste Management were able to understand the importance of a sanitary landfill easily.

NCC operators tried to spread and compact the solid waste, to do reclamation of cells using cover soil material under instructions of the JICA expert. The NCC operators studied the process of sanitary landfill and its necessity through the pilot project. After the demonstration, the NCC operators continued to do the experimental sanitary landfill at the other half of the project area.

NCC had evaluated that the project was a very significant activity for Nairobi City, because the systematic sanitary landfill itself was the first of its kind in the country. The recorded video tape should be used for training site officers and operators of new sanitary landfills.

On the other hand, the project ensured the access road to the inner dumping points, and cleaned up the public road in front of the Dandora dumping site. The activities contributed to improve the current condition of the existing site.

SECTION I

ENVIRONMENTAL IMPACT ASSESSMENT

THE STUDY ON SOLID WASTE MANAGEMENT IN NAIROBI CITY IN THE REPUBLIC OF KENYA

FINAL REPORT

SECTION 1

ENVIRONMENTAL IMPACT ASSESSMENT

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SECTION 1

ENVIRONMENTAL IMPACT ASSESSMENT

1. INTRODUCTION

1.1 Objectives of Environmental Impact Assessment (EIA)

An environmental impact assessment is required as a part of the feasibility study to delineate the characteristics of the project and to forecast potential impacts on the natural and social environments resulting from project implementation. The EIA will propose a suitable approach to identify significant impacts and impact sources, and proper measures are suggested to mitigate the adverse effects of the project.

1.2 Project Selected for EIA

One of the priority projects selected in the Master Plan is the construction of a new landfill site as a part of the solid waste management improvement program of Nairobi City. For this project, Initial Environmental Examination (IEE) was conducted on candidate sites and then a detailed EIA was executed on the two candidate sites (Ruai Area and Ngong Forest Area) chosen for the proposed project by the Kenyan authorities to prevent or mitigate negative impacts on the environment that may emerge from project implementation.

1.3 Procedure for EIA

The EIA on the two candidate sites was carried out by a local consultant under the supervision of the JICA Study Team based on the Terms of Reference. The technical specification of the Terms of Reference for EIA was prepared in accordance with the findings of the Initial Environmental Examination (IEE), while the administrative procedure was prepared taking the following guidelines into account:

(a) JICA Environmental Guidelines for Infrastructure Projects, VI Solid Waste Management, 1992

(b) Guidelines of OECF, Waste Disposal Sector, 1996

(c) Environmental Assessment Source Book, Sectoral Guidelines, World Bank

(d) Guidelines for EIA in the Republic of Kenya, Draft Report, 1996

The assessment of impacts was made, taking the existing regulations related to environment in Kenya and international standards into account.

The Terms of Reference for EIA and the IEE report on natural conditions for both candidate sites can be found in **Sections 9.1 and 9.2 of Data Book (1).**

1.4 Legislative and Regulatory Framework

1.4.1 General

The Government of Kenya has recently formulated the National Policy Guidelines on Environment and Development whose primary goal is sustainable development. In the past, the Environmental Impact Assessment (EIA) has been conducted for some development proposals, usually at the initiation of funding agencies.

In 1996, an intersectoral environmental committee composed of representatives from government ministries and departments, parastatals, non-governmental organisations (NGOs) and the private sector, prepared a draft on guidelines and administrative procedures for EIA for approval by the Parliament.

1.4.2 Existing Laws Related to EIA

The existing laws are sectoral and are not specific for conducting EIA. The mentioned sectoral laws which shall be used, when applicable, in the EIA process are described below.

(1) Laws Related to Water

(a) The Water Act, Cap. 372

Provisions are given for the conservation, control, apportionment and use of water resources in Kenya. The Act also prohibits water pollution. The Act allows local authorities to identify pollution problems and enact bylaws to set standards and impose penalties.

The Nairobi City Council had adopted a criteria of quality for drinking water.

(b) Local Government Act

The Act gives power to undertake sewerage, drainage, and water supply works to local authorities such as city commission, and municipal, town, urban and county councils.

(c) The Public Health Act

The Act has provisions for maintaining and securing health. Section 129 of the Act states that local authorities are responsible for taking the necessary measures to prevent any pollution dangerous to health of any supply of water which the public within its district has the right to use.

(2) Laws Related to Air

(a) The Traffic Act, Cap. 403

The Traffic Act empowers police officers to stop and remove from the road vehicles producing noxious emissions or to charge their owners in a

court of law. Under the Traffic Rule, every motor vehicle shall be constructed, maintained and used in such that no avoidable smoke or visible vapour is emitted therefrom. At present no standard is available to enforce this Act.

(b) The Penal Code, Cap. 63

The Penal Code was enacted in 1930 and contains a chapter entitled "Offenses Against Health and Convenience". The Code strictly prohibits releasing of foul air which affects the health of other persons. Any person who voluntarily violates the atmosphere at any place, to make it noxious to health of persons in general dwelling or carrying on business in the neighborhood or passing along public ways is guilty of a misdemeanor, i.e., imprisonment not exceeding two years with no option of a fine. Under this code any person who for the purposes of trade or otherwise makes loud noise or offensive or awful smells in such places and circumstances as to annoy any considerable number of persons in the exercise of their rights, commits an offense and is liable to be punished for a common nuisance, i.e., imprisonment not exceeding one year with no option of a fine. At present, no standard is available in order to enforce this Code under the Chapter already mentioned.

(a) Local Government Act

The Act empowers local authorities to control or prohibit all businesses, factories and workshops which by reason of smoke, fumes, chemical, gases, dust, smell, noise or vibration or other cause may be a source of danger, discomfort or annoyance to the neighborhood and to prescribe the conditions subject to which business, factories and workshops shall be carried on. At present, no standard is available on this subject.

(3) Laws Related to Soil

The Law on Chemical Substances deals with the use and disposal of chemical substances.

(4) Laws Related to Public Health

(a) The Public Health Act

This Act contains directives regarding regulations of activities that affect human health. There exist provisions within the Act to deal, in a general way, with water, air and noise. An environmental nuisance is defined and includes the emission from premises of waste waters, gases, smoke which could be regarded as injurious to health. At present, no standard is available regarding air and noise pollution.

(b) The Factories Act, Cap. 514

Environmental health and safety requirements within a functioning factory facility are regulated by this Act. A factory must be registered with the Chief Inspector of Factories. The Act requires that work areas be of an appropriate standard, well ventilated, with suitable lighting. Sanitary areas and drinking and washing areas should be provided, and safety provisions are described in the Act.

(5) Laws Related to Forest

- The Forest Act
- The Wildlife Conservation and Management Act

(6) Laws Related to Land Use

- The Land Planning Act

2. EXECUTION OF EIA

2.1 General

The environmental impact study was started on November 13, 1997 by Billtech Environmental Consultants Ltd., a selected local consulting firm, under the supervision of JICA Study Team. The study was conducted to become aware of the present condition of each candidate area, and it consisted of the analysis of natural environment and social environmental aspects. The analytical data and information obtained from the study were used to prepare the environmental management plan as well as the monitoring plan to prevent or mitigate possible negative impacts to the environment.

As for the natural environmental study, sampling points were selected taking into account existing resources, facilities and representative places of the candidate sites for environmental analysis, i.e., rivers, wells, drinking pipelines, etc. The laboratory owned by the Kenyatta University conducted the analysis of water and sediment while the laboratory owned by the University of Nairobi (Nuclear Science Institute) conducted the analysis of soil and sludge. As for pesticides in water, the Kenya Agricultural Research Institute was in charge of the analysis. Offensive odour, noise and traffic survey were surveyed in-situ by the Consultant.

As for water analysis, immediately after in-situ examinations were carried out for specific items, the samples were taken to the laboratory in a sealed container. On the other hand, the social environmental study was conducted by means of questionnaire and direct interview to people to be affected by the project. Besides, public awareness survey was conducted on people who will benefit from the project and on people living near the candidate sites, to evaluate their willingness to cooperate for a better management of solid waste and also to measure public concern about the improvement of sanitary environment.

Based on the study on the present conditions, further study was carried out to forecast potential impacts and impact sources during construction, operation, closure and post-closure stage of the landfill site. Potential impacts may have negative or positive effects to the environment. Mitigation or preventive measures were proposed for each stage of the Project when negative impacts were predicted to appear. Finally, the environmental management plan and monitoring plan were prepared to implement and evaluate the efficiency of the mitigation measures proposed to reduce the effects of significant impacts to be generated by the project.

2.2 Candidate A (Ngong Road Forest Area)

2.2.1 Brief Description of the Site

The place is located at about 10 km west of Nairobi City on a flat land (refer to **Figure I.2-1**). The area of approximately 33.2 ha available for the disposal site is composed of grassland (about 7 ha), indigenous forest (about 0.8 ha) and Eucalyptus plantation (about 25.4 ha).

Figure I.2-2 shows the study area for EIA, the candidate site area and sampling points, respectively. The area is unfenced and is owned by the Central Government.



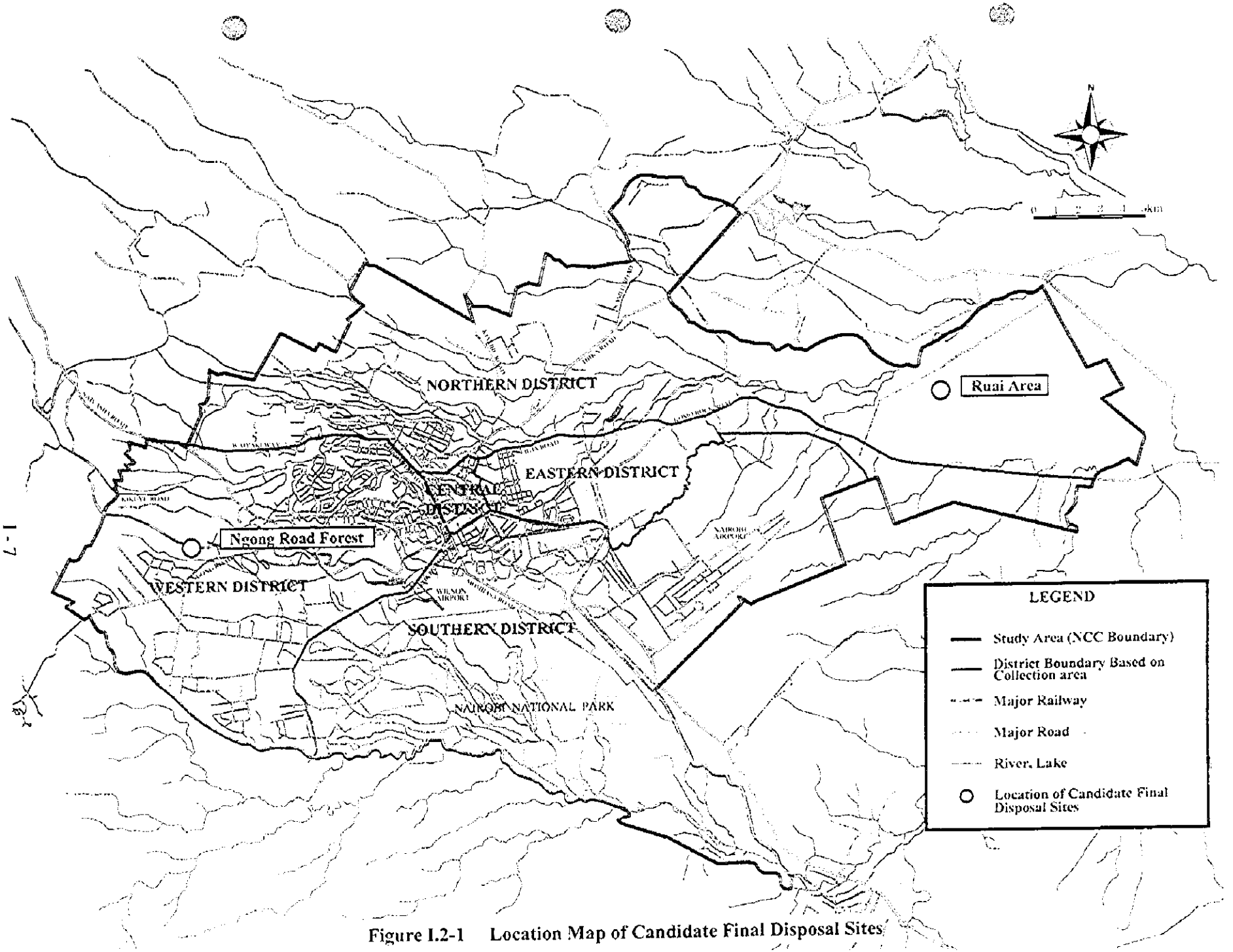

Figure I.2-1 Location Map of Candidate Final Disposal Sites

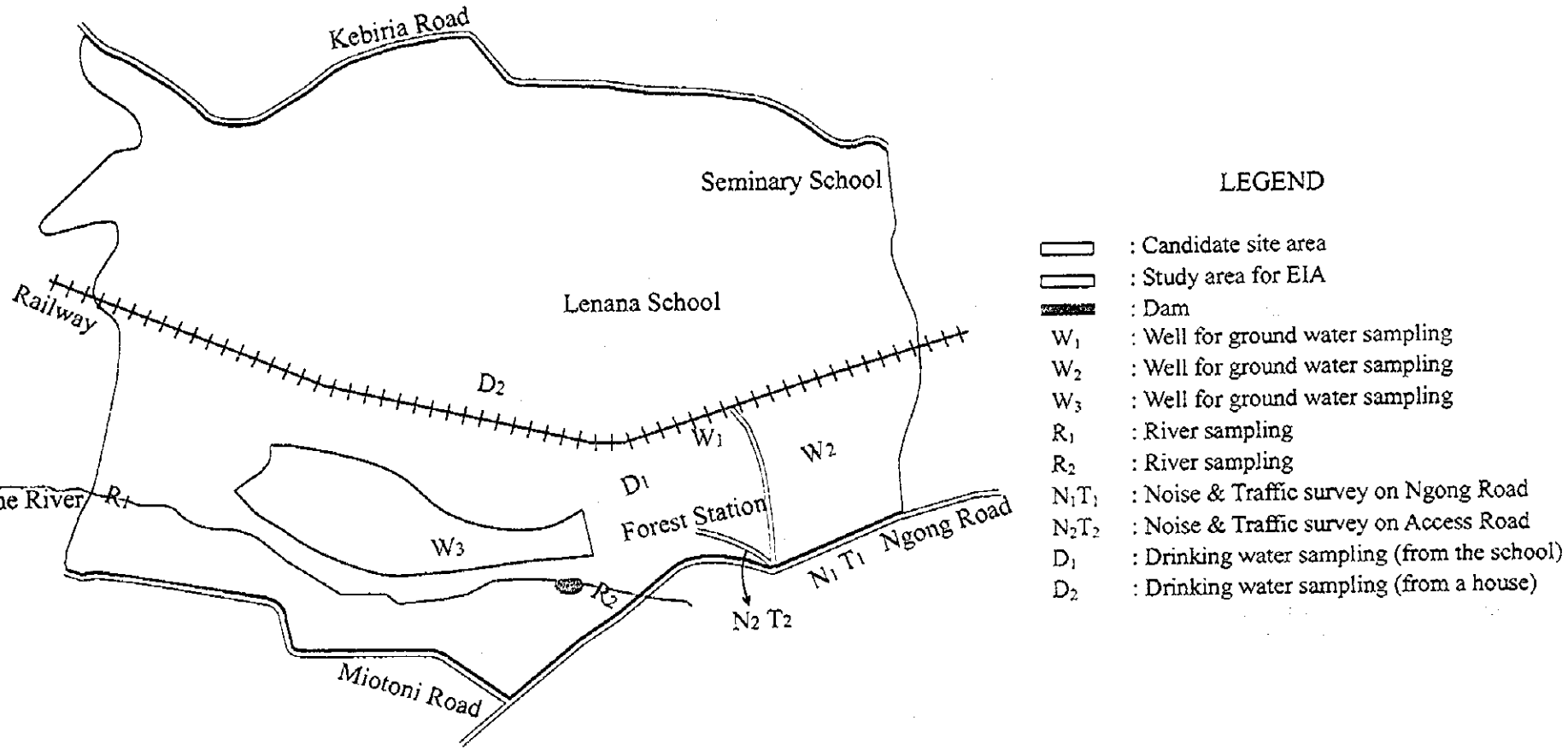

Figure I.2-2 Locations of Sampling Points for EIA in the Ngong Road Forest Area