Part IV

Feasibility Study

on the Priority Projects

Chapter 10

Dang Kor Disposal Site Development Project

10 Dang Kor Disposal Site Development Project

As mentioned in 7.6, the Dang Kor Disposal Site development project was selected as one of three priority projects according to its urgency and indispensability. In this chapter, the result of the feasibility study of the Dang Kor Disposal Site development plan is shown.

In conformity with Cambodian laws and regulations, the EIA survey was conducted. During the EIA survey, however, the development plan had to be modified because the increase in land price by speculation after the disclosure of information on the development plan made it impossible for MPP to afford the land along R. 303.

The EIA report was submitted to MOE through MPP on May 26, 2004. (The EIA report is attached as Appendix 15 of the Supporting Report. The analysis of alternatives including the location of the disposal site is described in the EIA report.) After exchanging opinions and comments with the team and visiting the project sites accompanied by the team, MOE approved the development plan on July 15, 2004.

10.1 Development Concept

a. Need for a Sanitary Landfill

It is generally recognized that a sanitary landfill is the basic element of modern SWM (solid waste management). Thus, it is acknowledged that the majority of waste has to be disposed of even if efforts are made to the 3Rs (reduce, reuse and recycle). As a priority step towards modern SMW, the Municipality of Phnom Penh is recommended to strengthen the final disposal service which minimizes environmental impact.

b. The New Disposal Site in Dang Kor

This section presents the preliminary design and cost estimates for a new final disposal site in Dang Kor, which has been selected by the MPP to be its future landfill. The distance from the city center of Phnom Penh to the disposal site is approximately 10 km and the site comprises an area of approximately 31 ha (for Phase 1), as shown in the following figure.

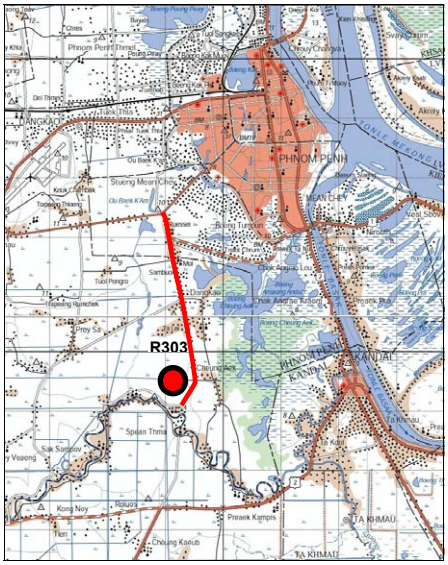


Figure 10-1: Location of Dang Kor Disposal Site

c. Natural Environment of the Dang Kor Disposal Site

c.1 Climate

The climate of this area and most of the Mekong river basin is characterized by two monsoons from the southwest and northeast, and occasional periods of cold weather caused by winds from Siberia and China. The hottest month is April with a maximum mean temperature of around 35 °C, and the coldest month is January with a minimum mean temperature of around 22 °C. The average relative humidity varies from around 73 % during the dry season to 85 % during the rainy season. The yearly average precipitation in the area is about 1,700 mm. Over 70 % of the annual rainfall is received from May to October. The yearly average precipitation in the area is about 1,700 mm.

c.2 Topography

The picture shows that the topography of the area is flat, containing mainly rice fields with some palm trees and ponds. There are not many roads in the area, the biggest one being road 303. No residence stays in a 1km radius from the center of the project area. See the picture below.

Several ponds are located in and around the project area. However almost all exist only in the rainy season except one pond, which is located northwest of the proposed disposal site. It is an irrigational regulation pond and irrigation canals are located from west to east and south to north. The Prek Thnot river, a tributary of the Bassac river, also runs through the South of the proposed disposal site. Ground aquifer exists and the people who live in the study area drink the groundwater. The people who live on Prek Thnot river use the river water for drinking purposes. The site and its surroundings consist of silty clay from the ground surface to a depth of 10-15 meters.

c.3 Fauna and Flora

As there are not so many green trees in the proposed disposal site, the natural environment of the site is typical but not abundant in flora and fauna. The majority of the site is used as agricultural land.

d. Design Concept of the Dang Kor Disposal Site

The JICA study team recommended that an area of 31 ha, including the land possessed by MPP, be secured for Phase 1 development of the new disposal site. Furthermore, the disposal site is to be expanded to approximately 100 ha in total in future. According to the development plan, the 100 ha site will be developed in four phases and each phase will be 25 ha.

The facilities of Dang Kor Disposal Site to be constructed in Phase 1 include PPWM's head office, the landfill area, a leachate treatment system (pond), a compost plant, a vehicle depot, and a maintenance workshop. The site comprises an area of approximately 31 ha, as shown in the figure below. The conceptual design of the site is presented in the following table.

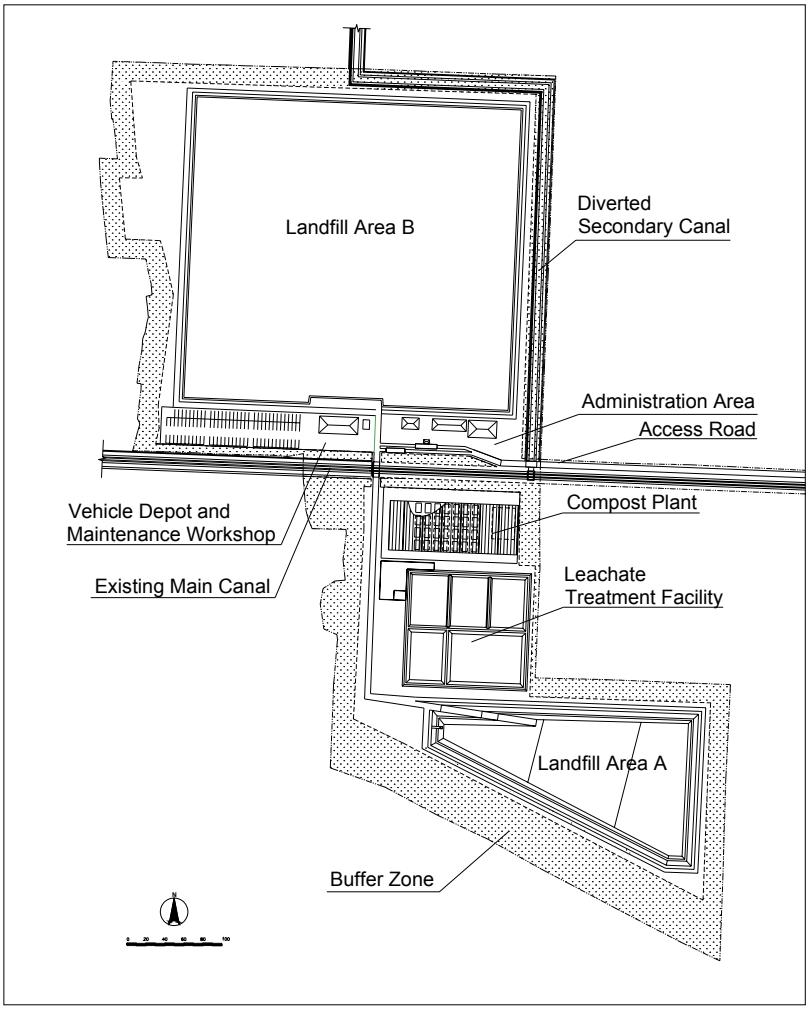


Figure 10-2: Layout Plan of Dang Kor Disposal Site (Phase1)

Table 10-1: Design Concept of the Dang Kor Disposal Site (Phase1)

Item		unit	Qty
Total area of disposal site		ha	approx.31.4
Administration area			
Area		ha	approx. 0.7
PPWM head office		L.S..	1
Weighbridge house		no.	1
Security and safety facility	Gate	no.	1
	Fence (Fixed type)	L.S.	1

Landfill and leachate treatment facilities			
Area		ha	approx. 17.0
Landfill Capacity	Total	m^3	2,270,000
	Landfill area A	m^3	43,400
	Landfill area B	m^3	183,600
Life span		years	6
Level	Top of the enclosing bank	m (Altitude)	10.2
	Level of Landfill bottom from top of enclosing bank	m	-10
	Level of Landfill top from top of enclosing bank	m	+10
Gradient of Slope	Enclosing bank (inside)	---	1:1
	Enclosing bank (outside)	---	1:3
	Landfilled waste	---	1:3
Sanitary waste disposal facility	Main access road (asphalt paved)	L.S.	1
	Main On-site road (gravel)	L.S.	1
	Secondary On-site road (gravel)	L.S.	1
	Fence (Movable type)	L.S.	1
Leachate collection facility -Perforated reinforced concrete pipe with rubble stone -Bottom layer as natural liner instead of artificial liner		L.S.	1
Leachate treatment facility -Wetland ponds + evaporation ponds + Reservoir ponds + Recirculation facilities		L.S.	1
Rain water drainage	U-shape concrete drain along the waste filling slope	L.S.	1
	Earth drain along the road	L.S.	1
Gas ventilation facility –Perforated steel pipe with rubble stone		L.S.	1
Monitoring well		L.S.	1
Buffer zone (Green belt etc.)		L.S.	1
Compost facility			
Area		ha	approx.1.1
Capacity		ton/day	20
Type		---	Windrow

10.2 Preliminary Design of the Dang Kor New Disposal Site

10.2.1 Administration Section

a. Conceptual Design

PPWM's head office is to be located in the administration area.

The administration section is to consist of the following buildings and accessories:

- Buildings and accessories
  - Entrance area (common use)
  - PPWM head office
  - Weighbridge house
  - Safety facilities (common use): gates, fences, handrail and street lights
  - Others: parking lot, etc.

b. Layout

The Administration section is to be designed in the Dang Kor Disposal Site. The area is approximately 0.7 hectares.

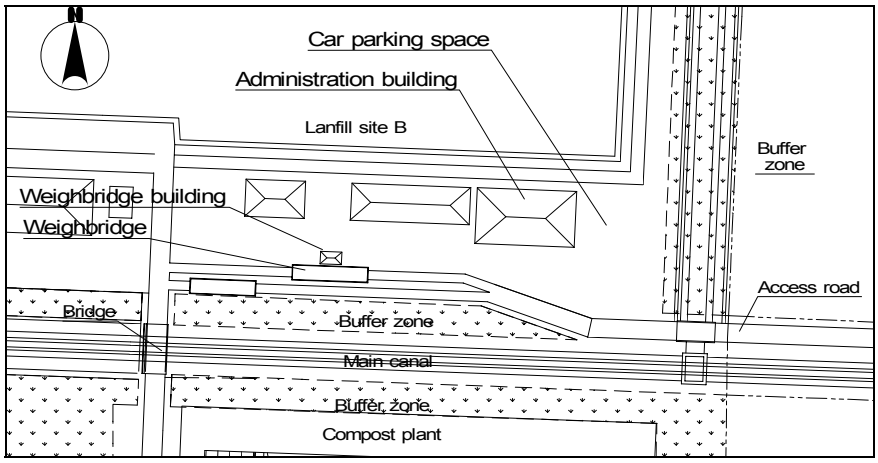


Figure 10-3: Layout of the Administration Section

10.2.2 Disposal Section

a. Conceptual Design

The basic concept of the disposal site design is to arrange the necessary facilities and equipment while taking into consideration the environmental impact on the surrounding area. For sustainable management, it is preferable to keep the unit cost of waste disposal (the construction cost per 1 ton of waste) as low as possible.

The features of the proposed disposal site plan are as follows:

The investigation conducted on the soil of the disposal site area revealed that the permeability of the natural soil (stiff clay) is low. The study team concluded that the existing ground could be used as a natural liner to control leakage, so it is possible to avoid the high cost of installing a plastic or rubber liner.

However, the site investigation also indicated that part of the site has a permeable stratum at a shallow underground site, so it is necessary to shield the stratum with stiff clay of low permeability to keep out rainwater from the outside area, while preventing leachate from leaving the landfill and entering the environment. In addition, a well of around 5m in depth will be installed just beside the landfill area in order to monitor water quality.

The height of the bank of the landfill area was designed to be 10.2m, considering the highest level of flood in the past (10.0m), as a flood protection measure.

In order to maintain the landscape of the surrounding area, the height of the landfill is to be no higher than 11m. The final height of the landfill was determined considering the experience at SMCDS and landslide protection. The slope of the completed fill was designed to be 1:3, and grass will be planted for the prevention of land erosion. Soil will be excavated to a depth of about 9 m in order to secure a low permeable soil layer with a thickness of more than 2 m at the bottom of the disposal site. The excavated soil can be used as cover material for landfilled sections and the extra soil can be sold.

The new disposal site will be equipped with a leachate treatment system (wetland ponds and evaporation method), which will not discharge treated waste water outside the disposal site, so that it is possible to prevent environmental degradation of the surrounding area. In addition, the treatment systems include a pumping system that returns the excess leachate back to the landfill section in the event that the rainfall exceeds the expected maximum capacity of the ponds. In addition, if heavy rain exceeds the capacity of the pump, it is necessary to consider storing the leachate inside the disposal site.

The landfill areas are divided into two parts: South and North. On the south part, there is one landfill section, while there are four landfill sections on the north part. The landfill section on the south part will be developed first. In the next stage, PPWM is supposed to develop the four landfill areas according to the operation plan. An important issue of this plan is to minimize the initial investment cost and the volume of the leachate to be treated. The peripheral road of the disposal site will also be constructed in the first phase.

The five main features of the proposed disposal site are mentioned above, and the landfill area is to be developed in accordance with the basic concept of mitigating the impact on the surrounding environment as much as possible.

b. Design Conditions

b.1 Target Operation Level of Land filling

- Target Level: Level 4
- Requirement of Level 4

The requirements for operation of a Level 4 landfill are as follows:

- to prevent infiltration of leachate;
- to cover waste with soil daily;
- to screen working areas from outsiders;
- to release gas promptly;
- to minimize the leachate quantity to be discharged outside;
- to have an adequate drainage system;
- to have a proper access road; and
- to have a leachate collection and evaporation system.

Commencement of Sanitary Landfill Operation

The operation of the new sanitary landfill is planned to commence at the beginning of 2007.

Estimated Amount of Waste Disposal in the Dang Kor Disposal Site

The proposed landfill in Dang Kor Disposal Site is designed to receive waste discharged from the following 7 Khans. The type of waste to be received will include MSW and general waste from medical institutions and factories.

Urban Area	Chamkar Mon
	Daun Penh
	Prampir Makara
	Toul Kork
Rural Area	Dang Kor
	Mean Chey
	Russei Keo

Table 10-2: Estimated Daily Amount of Waste Disposal in the Dang Kor Disposal site

Year	All Phnom Penh (Total) (ton/day)	Description			
		MSW		Medical Waste (general waste) (ton/day)	Industrial waste (general waste) (ton/day)
		Urban area (ton/day)	Rural area (ton/day)		
2007	923.7	548.8	325.1	12.3	37.5
2008	990.0	577.3	359.7	13.1	39.9
2009	1,064.7	606.6	401.6	13.9	42.6
2010	1,140.6	636.7	443.6	14.9	45.4
2011	1,205.0	659.7	481.8	15.7	47.8
2012	1,301.2	683.1	551.1	16.5	50.5
2013	1,367.0	705.9	590.6	17.4	53.1
2014	1,437.5	728.3	635.0	18.3	55.9
2015	1,539.7	751.4	710.0	19.3	59.0

c. Matters to be Examined

Basic matters necessary for the design of the landfill section such as the required capacity for disposing waste for the project period and the nature of the soil are examined.

c.1 Basic Ideas to Calculate Required Landfill Capacity

The weight and volume of waste generated at households and business establishments change with the progress of the SWM system from the stage of generation to final disposal. Here is an approach to calculate the required landfill capacity considering the waste reduction both in weight and volume.

c.1.1. Waste Weight and Unit Weight

At each stage of the SWM system, it is necessary to know the required capacity to treat waste properly, as shown in the table below. In order to obtain the required capacity, waste amount (weight) and unit weight are necessary.

Table 10-3: Required Capacity at Each Stage of SWM System

Stage	Items that require the calculation of capacity
Discharge	Storage/discharge container
Collection	Public container, collection vehicle volume
Just after the final disposal	Final disposal site
Half a year after the final disposal	Final disposal site
After the closure of the disposal site	Final disposal site

c.1.2. Calculation of Required Landfill Capacity

It is necessary obtain the waste amount (weight) and unit weight at each stage in order to calculate the required landfill capacity. A method to calculate the waste weight and unit weight half a year after the final disposal is shown.

i. Conditions for Calculation

1) The properties of waste just after discharge are based on the data obtained from the WACS.

   Water content: 68.3% (0.683 kg/1kg of waste)
   Degradable content (dry weight): 24.2% (0.242 kg/1kg of waste)
   Undegradable content (dry weight): 7.5% (0.075 kg/1 kg of waste)

2) The water content of waste and the decomposition rate of organic matters at each stage were assumed, referring to the result of the survey on the pilot project in SMCDS[1].

Table 10-4: Water Content and Decomposition rate of Organic Matter

Stage	Waste Content (wt%)	Decomposition Rate of Organic Matter (wt%)
Collection	65	---
Final disposal	60	---
Half a year after final disposal	50	10
A year after final disposal	45	15

ii. Change in Weight

[1] The changes in water content and apparent density of disposed waste a certain period (2, 6 and 9 months) after the landfill operation were measured at the SMC disposal site. The details are shown in Appendix 19 and 20 of the Supporting Report.

The team expected that half a year after final disposal the composition of waste changes as follows.

Water content:	50.0%
Degradable content (dry weight):	37.2%
Nondegradable content (dry weight):	12.8%

Because of the decrease in the water and degradable content, the waste weight (WW) changes from 1kg to 0.586kg half a year after being landfilled, as shown below.

WW = 0.293 + 0.218 + 0.075 = 0.586 kg/1kg of waste

Degradable:	0.242kg x (1-0.1) = 0.218kg (10% is decomposed)
Nondegradable:	0.075kg (no change in weight)
Water:	(0.218+0.075) x 0.5/(1-0.5) = 0.293kg

iii. Change in unit weight

The unit weight also changes as the stage of waste management system progresses from generation and storage to disposal. The estimated changes are shown in the table below. The unite weight shown below is smaller than the actual measurement conducted in the pilot project at SMCDS, so it is necessary to adjust the unit weight in order to avoid a large error.

Table 10-5: Unit Weight at each Stage

Step		Unit Weight (ton/m^3)
Discharge	UWw	0.25
Collection (compactor or container)	UWc	0.35
Final disposal	UWd	0.50
Half a year after final disposal	UWd6m	0.80
A year after final disposal	UWd1y	1.20

iv. Waste Weight and Weight per Unit Volume

The calculated waste weight and unit weight are shown in the table below.

Table 10-6: Waste Weight and Waste Weight per Unit Volume at each Stage

Stage	Three components			Unit weight (ton/m^3)	Volume to One ton of Waste Discharge (m^3)
	Composition	(wt%)	Weight to One ton of Waste Discharge (ton/ton)		
Discharge	Water	68.3	0.683	UWw 0.25	4.00
	Decomposable matter (dry weight)	24.2	0.242		
	Non-decomposable matter (dry weight)	7.5	0.075		
	Total	100.0	1.000		
Collection	Water	65.0	0.589	UWc = 0.35	2.59
	Decomposable matter (dry weight)	26.7	0.242		
	Non-decomposable matter (dry weight)	8.3	0.075		
	Total	100.0	0.906		
Just after landfill	Water	60.0	0.476	UWd = 0.50	1.59
	Decomposable matter (dry weight)	30.5	0.242		
	Non-decomposable matter (dry weight)	9.5	0.075		
	Total	100.0	0.793		
Half a year after landfill	Water	50.0	0.293	UWd6m = 0.80	0.73
	Decomposable matter (dry weight)	37.2	0.218		
	Non-decomposable matter (dry weight)	12.8	0.075		
	Total	100.0	0.586		
A year after landfill	Water	45.0	0.230	UWd1y = 1.20	0.43
	Decomposable matter (dry weight)	17.9	0.206		
	Non-decomposable matter (dry weight)	37.1	0.075		
	Total	100.0	0.511		

c.1.3. Calculation of Required Landfill Capacity

The volume of waste becomes smaller as water evaporates and organic matter decomposes. The volume of 1 ton of waste discharged can be estimated based on the following equation. One ton of discharged waste has a volume of 0.73m^3 half a year after landfilled.

$$WV6m = \frac{WW}{UWd6m} = \frac{0.568}{0.8} = 0.73m^3$$

WW (Waste Weight): 0.586 ton
Uwd6m (Unit Weight half a year after landfill): 0.8 ton/m^3

Based on the 1 ton of discharged waste, the apparent density of waste half a year after disposal is obtained as follows.

$$Apparent Density = \frac{1 ton of discharged waste}{0.73m^3} = 1.37 ton/m^3$$

Therefore, the volume of waste half a year after disposal can be calculated based on the weight of discharged waste according to the following equation.

$$Volume of\ waste half\ a year after the disposal = \frac{Weight of discharged waste}{1.37(ton/m^3)}$$

This equation is used to assume the required landfill capacity of the new disposal site. The necessary amount of soil for daily covering is determined based on the volume of waste just disposed of.

c.1.4. Required Capacity of Landfill Section

The final disposal site in phase 1 is designed to receive waste for a period of six years from 2007 to 2012.

The required capacity of the landfill was determined by the following equation.

V= V2 + V3
V2=V1 x 0.1
V : required volume
V1 : volume of waste to be dumped (apparent density=0.5 ton/m^3)
V2 : volume of soil required for covering waste dumped
V3 : volume of waste in a stable state (apparent density = 0.8ton/m^3)

In order to calculate the required capacity of the landfill sections, the following assumptions are made.

- The required amount of soil for covering the waste dumped daily is 10 % of the waste dumped in volume, including it for final cover.
- The unit weight of the waste just after dumped in a landfill is 0.5 tons/m^3.
- The unit weight of waste in a stable state after filling is 0.8 tons/m^3.
- The water content of waste when discharged is 68.3wt% (according to the WACS study), the content of decomposable matter is 24.2wt%, non-decomposable matter is 7.5wt% and when in a stable state it is 50wt%
- The decomposition rate of organic material in a stable state is 10%.
- Therefore, if the weight of the waste just after discharged in a landfill is 1 ton, the waste weight after half a year, calculated in accordance with the above mentioned conditions, is 0.586 tons.

The required capacity of landfill sections are presented in the following table.

Table 10-7: Required Capacity of Landfill

Year	Weight of Discharged Waste	V1	V2	Waste Weight in Stable State	V3	V	Accumulated Volume	Required Capacity
		Volume of Waste Just Dumped	Cover Soil		Waste Volume in Stable State	Total Volume		
	Wd	V1= Wd / 0.5	V2= V1 x 0.1	Ws= Wd x 0.586	V3= Ws/0.8	V=V2+V3		
	ton/year	m^3/year	m^3/year	ton/year	m^3/year	m^3/year	m^3	m^3
2007	337,151	674,302	67,430	197,570	246,963	314,393	314,393	
2008	361,350	722,700	72,270	211,751	264,689	336,959	651,352	
2009	388,616	777,232	77,723	227,729	284,661	362,384	1,013,736	Phase 1
2010	416,319	832,638	83,264	243,963	304,954	388,218	1,401,954	2,270,000
2011	439,825	879,650	87,965	257,737	322,171	410,136	1,812,090	
2012	474,938	949,876	94,988	278,314	347,893	442,881	2,254,971	

c.1.5. Impact of Increased Disposal Amount based on Population Projection by National Institute of Statistics

The population projected by the National Institute of Statistics (NIS) is shown below along with population projection estimated by the team.

The expected waste amount disposed of at the DKDS based on the population projection by the NIS was turned out to be larger than that based on the study team's projection by 4.5%. The difference in waste amount during phase 1 operation is equivalent to the disposal amount for 3.3 months (approx. 1.0m increase in landfill height). Therefore, this gap would little impact on the whole landfill plan.

Table 10-8: Waste Amount Disposed of at DKDS

	Based on population projection by the team*		Based on population projection by NIS**		Increase amount	Increase rate
	Population	Disposal amount	Population	Disposal amount		
		ton/year		ton/year	ton/year	%
		A		B	C=B-A	D=C/A
2007	1,371,981	337,151	1,493,000	349,906	12,755	3.8%
2008	1,416,445	361,350	1,546,000	375,741	14,391	4.0%
2009	1,462,946	388,616	1,600,000	404,698	16,082	4.1%
2010	1,511,602	416,319	1,656,000	434,165	17,846	4.3%
2011	1,545,581	439,825	1,714,000	461,499	21,674	4.9%
2012	1,581,432	474,938	1,767,000	501,720	26,782	5.6%
Accumulate Amount	---	2,418,199	---	2,527,729	109,530	4.5%

Remark: * Study on Transport Master Plan in the Phnom Penh (Nov. 2001 JICA)
** National Institute of Statistics (NIS)

c.2 Result of Soil Test

The study team conducted the soil test at five locations in the DKDS as shown below.

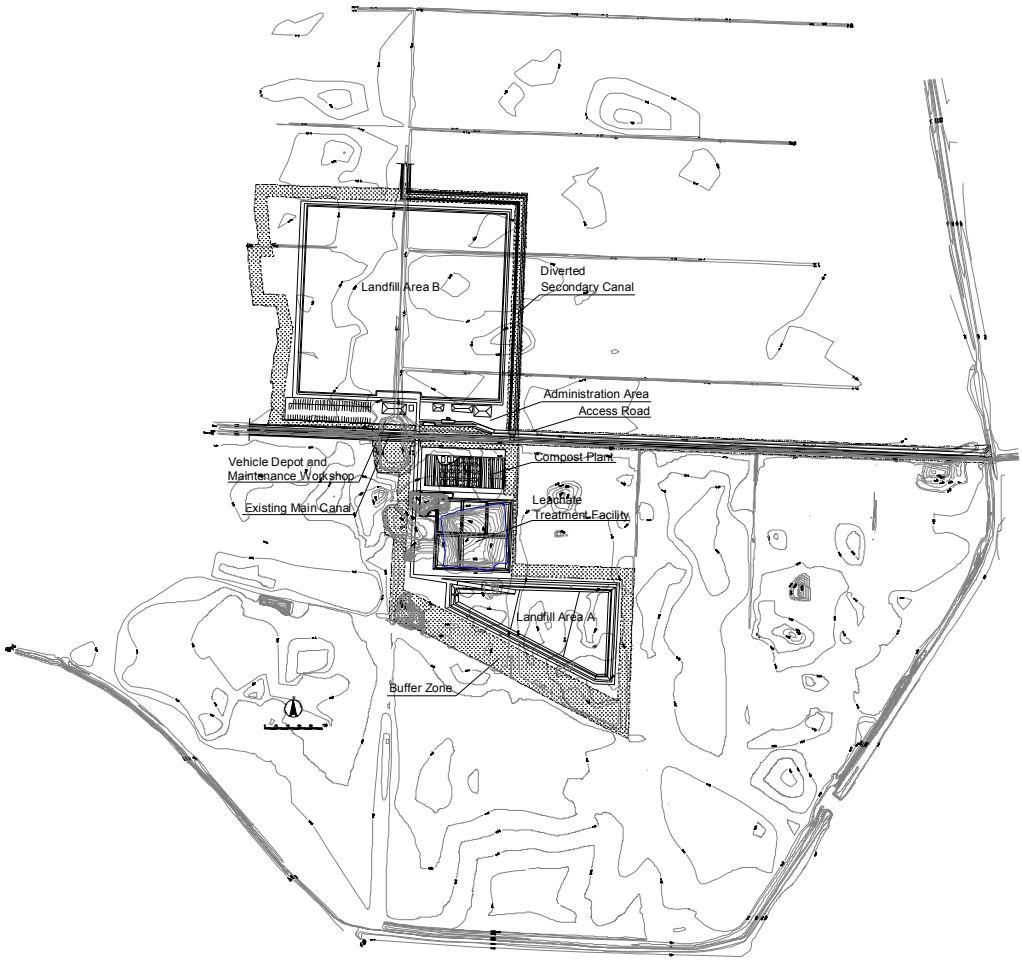


Figure 10-4: Locations of Soil Test

The result of the permeability is shown in the following table[2]. The comparison of the column diagram is shown in Figure 10-5.

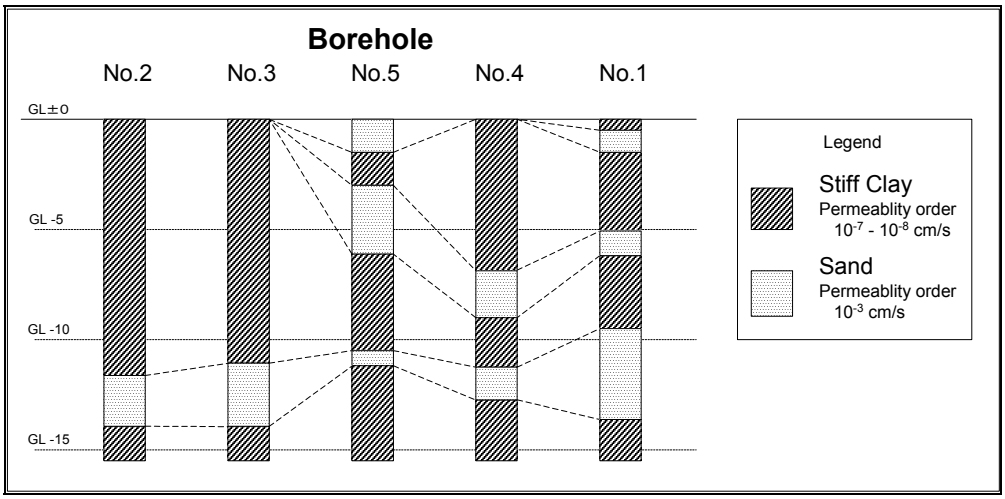


Figure 10-5: Column Diagram (Borehole No.1 – No.5)

[2] The detailed result of the soil test is shown in Databook.

The results of boreholes No.2, No.3, and No.5 show the soil quality of the DKDS. The results are summarized below.

- The geological stratum until 11m in depth is mostly stiff clay strata, whose permeability is on the scale of 10^{-8}cm/s. smaller than 10^{-7}cm/s.
- Each borehole shows that there is a sand stratum of 0.5-4m in thickness between 11-15m in depth. The permeability of the sand strata is on the order of 10^{-3}cm/s.
- The borehole No.5 shows that there is a sand stratum between 3.0-6.2m in depth. The borehole No.1 and No.4 also show the sand strata, while there is no sand strata in this depth. Therefore it is expected that the sand strata spread to the east, but there is not enough data to determine the starting point of the strata.

Because of the small permeability, the original ground of the DKDS has a high water barrier effect. The team drew the conclusion that an artificial liner is not necessary to enhance the effect of water barrier.

Because of the sand strata located at 11m in depth, the bottom of the landfill area is set at 9m in the depth, so that the landfill area has a layer of low permeability of more than 2.0 m in thickness.

Regarding the sand strata found in borehole No.5, it is necessary to enhance its water barrier effect by covering the section of the sand strata with clay of low permeability after excavation. Since there is not enough information on the extent and thickness of the sand strata, it is necessary to pay attention to the sand strata and to decide a proper method to enhance the water barrier effect.

The results of the soil test did not show any other issues of concern.

Table 10-9: Results of Soil Test（permeability）

Borehole 1

SAMPLE No	DEPTH From (m)	DEPTH to (m)	DESCRIPTION OF STRATA	Lab. Permeability K Cm/s
-	0.00	0.5	Farm soil	-
1	0.5	1.5	Stiff lean clay with sand	-
2				
3	1.50	2.6	Medium stiff lean clay	7.10^{-8}
4				
5	2.60	4.3	Loose sandy silt	$1.5.10^{-7}$
6				
7	4.3	5.1	Medium dense sandy silty clay	7.10^{-8}
8				
9	5.1	5.9	Loose clayey silty fine sand	-
10	5.9	6.3	Medium dense clayey fine sand	$4.8.10^{-3}$
11				
12				
13	6.3	8.5	Very stiff fat clay	4.10^{-8}
14				
15				
16	8.5	9.5	Very stiff sandy silty clay	-
17				
18	9.5	10.3	Loose coarse sand	$6.6.10^{-3}$
19				
20	10.3	13.7	Medium dense coarse sand	$3.7.10^{-3}$
21				
22	13.7	1 5.45	Very stiff sandy clay	-
23				

Borehole 2

SAMPLE No	DEPTH From (m)	DEPTH to (m)	DESCRIPTION OF STRATA	Lab. Permeability K Cm/s	Field Permeability K Cm/s
-	0.00	0.5	Farm soil		
1	0.5	1.1	Very stiff sitly clay		
2					
3	1.10	2.6	Very stiff lean clay	$4.7.10^{-8}$	
4					
5	2.60	4.5	Medium stiff lean clay	9.10^{-9}	9.10^{-7}
6					
7	4.5	5.25	Very stiff silty clay with gravel	$3.6.10^{-8}$	
8					
9	5.25	7.5	Stiff sandy fat clay	$1.7.10^{-8}$	
10					
11	7.5	10.6	Very stiff sandy lean clay	-	
12					
13	10.6	11.7	Very stiff fat clay with latrite	-	
14					
15	11.7	13.9	Medium dense clayey silty medium sand	-	
16					
17	13.9	15.45	Hard elastic silt	-	
18					

Borehole 3

SAMPLE No	DEPTH From (m)	DEPTH to (m)	DESCRIPTION OF STRATA	Lab. Permeability K Cm/s
1	0.0	2.3	Stiff sitly clay	5.10^{-8}
2				
3	2.30	3.8	Very stiff lean clay	5.10^{-8}
4				
5	3.80	5.8	Hard lean clay	5.10^{-8}
6				
7	5.8	7.50	stiff lean clay	-
8				
9	7.50	10.3	Medium stiff silty clay	-
10				
11	10.3	11.3	Stiff silty clay	-
12				
13	11.3	12.7	Medium dense silty fine sand	5.10^{-3}
14				
15	12.7	13.8	Very dense silty fine sand	-
16	13.8	15.50	Hard lean clay	-

Borehole 4

SAMPLE No	DEPTH From (m)	DEPTH to (m)	DESCRIPTION OF STRATA	Lab. Permeability K Cm/s
1	0.0	1.8	Very stiff sandy sitly clay	-
2				
3	1.80	3.0	Stiff sandy lean clay	4.10^{-8}
4				
5 6 7 8 9 10	3.00	6.8	Medium stiff sandy silty	1.10^{-7}
7	6.8	9.00	Medium dense clayey fine sand	1.10^{-3}
8				
9	9.00	9.5	Very dense clayey coarse sand	-
10	9.5	10.5	dense sandy silty clay	-
11	10.5	11.4	Hard lean clay	-
12	11.4	13.0	Very dense silty coarse sand	5.10^{-3}
13				
14	13.0	15.5	Dense silty fine sand	-
15				

Borehole 5

SAMPLE No	DEPTH From (m)	DEPTH to (m)	DESCRIPTION OF STRATA	Lab. Permeability K Cm/s
1	0.0	1.5	medium stiff lean clay with sand	-
2				
3	1.50	3.0	Very stiff sandy lean clay	4.10^{-8}
4				
5	3.00	3.50	Medium dense clayey fine sand	-
6 7	3.50	6.2	Loose silty fine sand	-
8 9	6.20	7.5	Medium stiff fat clay	-
10 11	7.5	9.20	Stiff lean clay	-
12				
13 14 15	9.2	10.5	Stiff sandy lean clay	-
16	10.5	11.3	Dense silty coarse sand	-
17	11.3	12.6	Medium dense clayey silty medium sand	-
18	12.6	14.2	Very stiff sandy silty clay	-
19	14.2	15.5	Dense clayey medium sand	-

d. Preliminary Design

d.1 Landfill Capacity

The landfill capacity of the proposed landfill site is designed to be 2,270,000 m3 as waste to be processed at this site in 2007.

Table 10-10: Landfill Capacity of DKDS

Area	Landfill capacity (m^3)	Landfill area (m^2)
Landfill area A	43,400	30,000
Landfill area B	183,600	110,400
Total	2,270,000	140,400

d.2 Working Time

The work schedule of the site is as follows.

- The proposed plant operates 365 days a year.
- Mondays - Sundays 4:00 - 22:00 (18 hours/day)

e. Design of Facilities of Landfill

e.1 Main facilities of landfill facilities

The proposed landfill site is designed to be composed of the following facilities. The landfill section comprises an area of approximately 14 ha (South section : 3.0 ha, North section : 11.0 ha).

- Main Facilities
  - Enclosing structure:
    enclosing bank and divider
  - Drainage system:
    open side drain, etc.
  - Access:
    main access road, on-site road

- Environmental protection facilities
  - Buffer zone
  - Litter scattering prevention facilities
  - Gas removal facilities
  - Leachate collection facilities
  - Wetland facilities and leachate evaporation facilities
  - Monitoring well

e.1.1. Enclosing Bank Structure

The role of the enclosing bank provided, which is banked with earth around the filling area, is to prevent the seepage of rainwater and leachate and to store dumped waste stably. The dimensions of the enclosing structure are set as follows.

- Gradient of slope: 1 in 3.0 for outside the site
  1 in 1.0 for inside the site
- Crest of bank: 2.0m
- Height of bank: 1.0m
- Material of bank structure: Laterite and Soil

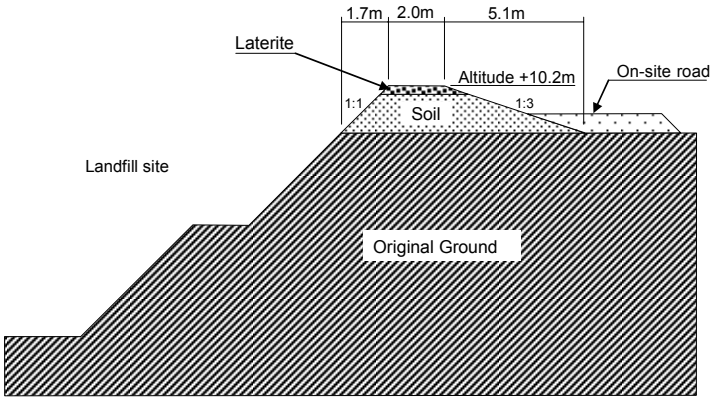


Figure 10-6: Enclosing Bank Structure

e.1.2. Divider

The role of the divider, which is made of soil (original ground) and provided inside an enclosing dike, is to reduce the quantity of leachate by blocking rain water and to separate the working face for landfill work. The dimensions of the divider are set as follows.

- Gradient of slope: 1 in 1.5
- Crest of dike: 1.5m
- Height of dike: 1.5m
- Material of dike structure: Original Ground

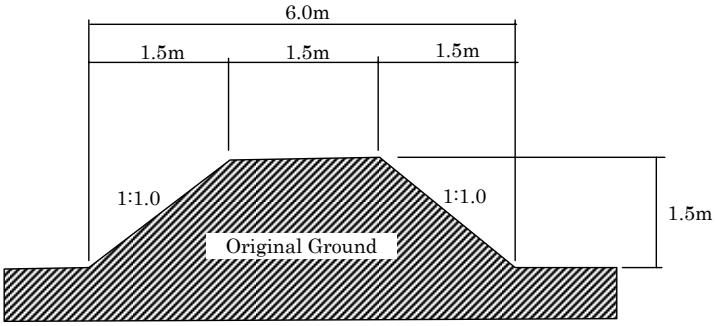


Figure 10-7: Structure of Divider

e.1.3. Drainage System (Open side drain)

The drainage system has a very important role in maintaining the site and peripheral roads in good condition and also to minimize the influx of rainwater to leachate control facilities.

The side drain is generally provided around the landfill to intercept all the runoff water from the landfill area and to remove the fluid from the site. The dimensions of the side drain are as follows.

- Top Width: 2.0m
- Bottom width: 1.0m
- Gradicnt of slope: 1 in 1.0
- Depth: 0.5m
- Surface of drain: Original Ground (No lining)

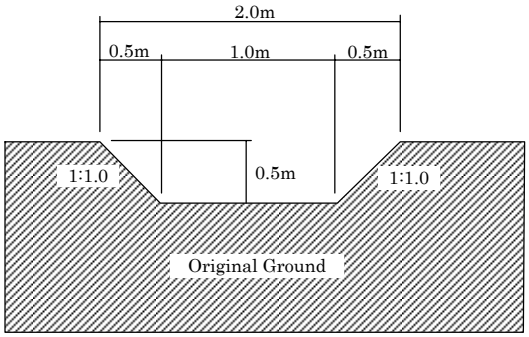


Figure 10-8: Structure of Drain

e.1.4. Access road and On-site road

Access road

The asphalt-paved road is constructed between National Road 303 and the entrance of the landfill site so that the waste collection vehicles can access the disposal site easily. The access road will be constructed on the north side of the main canal, as shown in the figure below.

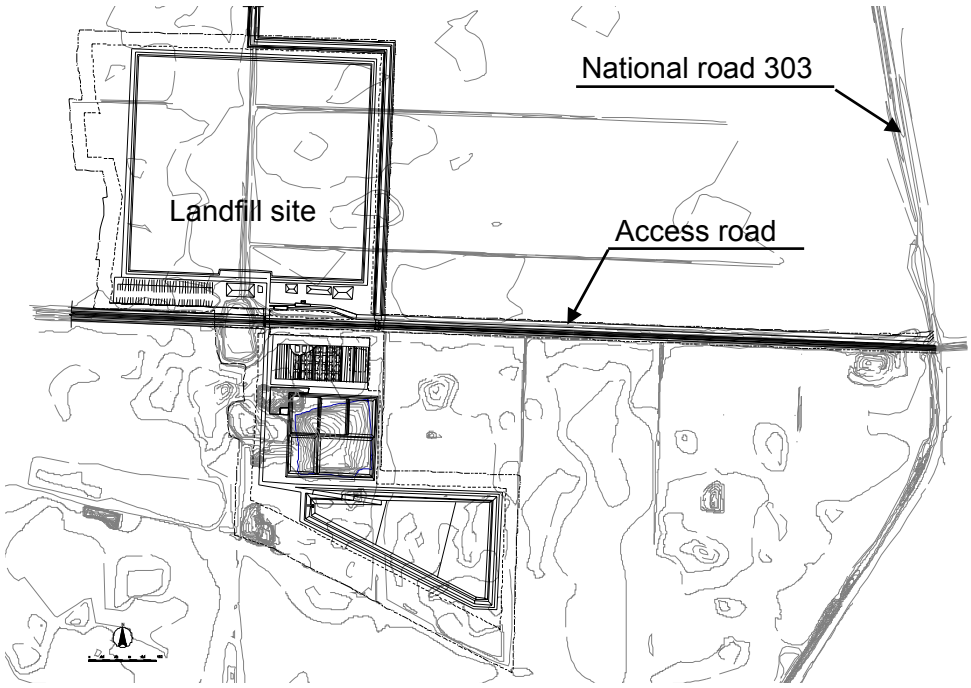


Figure 10-9: Location of Access Road

The dimensions of the approach roads are shown below.

- Carriageway width: 6.0m
- Shoulder width: 1.5m both sides
- 3 paved layer in the carriage way

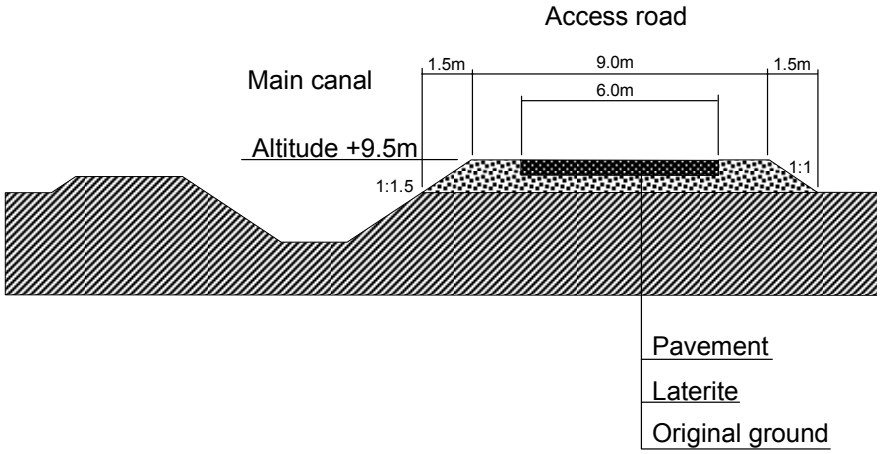


Figure 10-10: Structure of Access road

Main On-site Road

The asphalt-paved road is constructed at the entrance of the landfill site so that the waste collection vehicles can enter and leave the site without disturbing the public traffic. In addition, the road from the entrance of the Dang Kor Disposal Site to the landfill section is to be paved with asphalt because this segment of the road is expected to be used for more than 20 years. The dimensions of the main on-site roads are shown below.

- Carriageway width: 6.0m
- Shoulder width: 0.75m both sides
- 3 paved layer in the carriage way

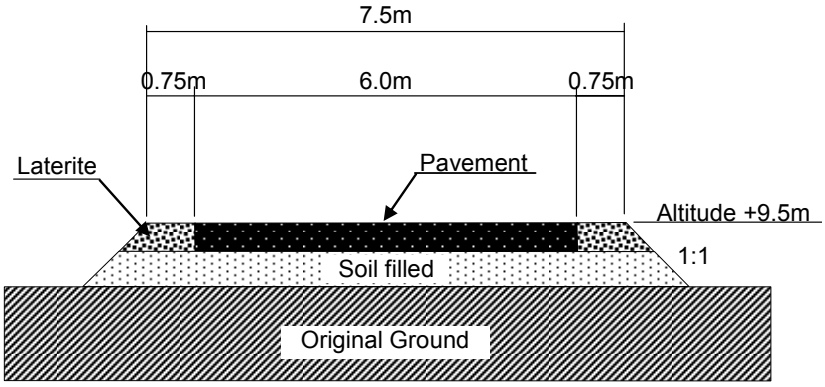


Figure 10-11: Structure of Main On-site Road

Secondary On-site Road

On-site roads are the roads for landfill works provided on the site. The dimensions of on-site roads are shown below.

- Thickness of paved road: 0.5m
- Width of paved road: 6.0m and 4.0m
- Shoulder width 0.75m
- Material: Crushed stone 0-40mm

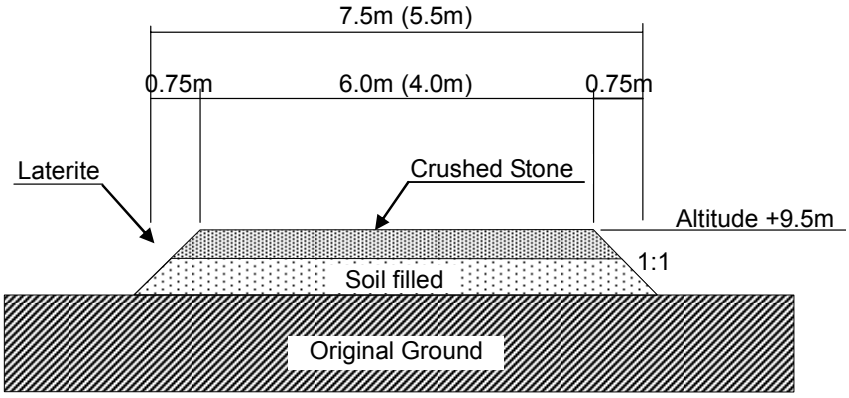


Figure 10-12: Structure of Secondary On-site Road

e.1.5. Environmental Protection Facilities

The environmental protection facilities are provided to prevent primary and secondary pollution outbreaks during and after completion of landfill operations.

e.1.6. Buffer Zone (Green belts, etc.)

A buffer zone with trees is constructed between the disposal site and outside areas for the purpose of;

- screening the landfill site from outside;
- reducing the noise and vibrations emitted during landfilling operation; and
- balancing the site with the natural surroundings in a harmonious fashion.

Basically, the width of the buffer zone is 20-50m, but the buffer zone which is located east of leachate treatment facilities is only 9m due to the layout of facilities. Adjacent to the residential area, a buffer zone with a width of 50m will be constructed. The side that is to be expanded in the future will have a 20 m buffer zone. The density of trees should be approximately 285 trees per hector.

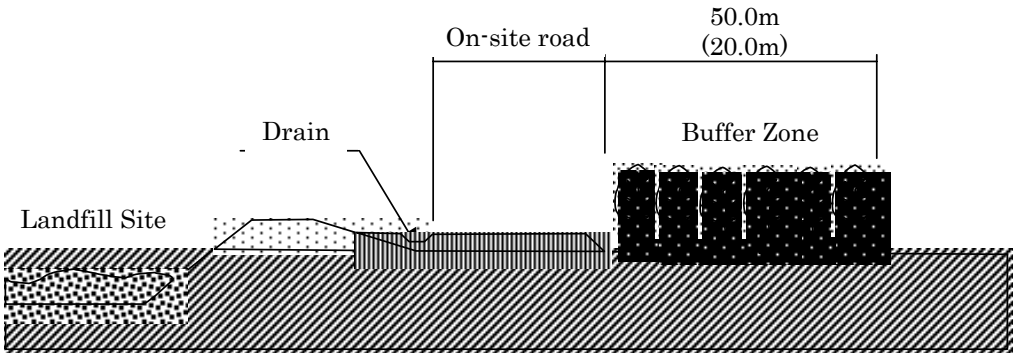


Figure 10-13: Structure of Buffer Zone

e.1.7. Litter Scattering Prevention Facilities

Litter scattering during landfill operation, before the waste is covered with soil, will be inevitable. Therefore, as a means of prevention, a temporary fence made of materials available locally like wood, and with nets to catch flying litter are constructed.

- Height: 2.0m
- Material of post: Steel pile
- Distribution density: The landfill working face shall closed with nets

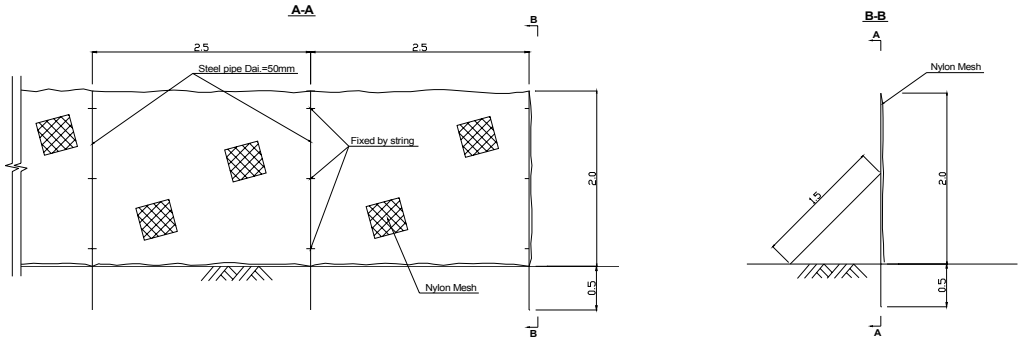


Figure 10-14: Temporary Fence

e.1.8. Gas Removal Facilities

For the organic matter present during landfill operations, microbial decomposition occurs and results in the production of water, gas and inorganic chlorides. If the landfill structure houses aerobic matters, this gives rise to aerobic bacterial activity. Therefore, decomposition is fast; carbon dioxide, water, ammonia etc. are produced, without a problem. On the other hand, if the structure houses anaerobic matter, this gives rise to anaerobic bacterial activity with slow decomposition; thus, odors and combustible gases, such as methane, carbon dioxide, hydrogen sulfide and ammonia, badly affect the environment.

Generally, outbreaks of gas in landfill sites are common at weak points on the boundary surface between the landfill site and surrounding structures. Disaster prevention measures, which are represented by gas removal facilities, are necessary at points where gas pockets burst unexpectedly and thus produce fires, odors, etc.

As for gas removal facilities, there are three types under consideration: by evacuation, by pumping, and by ventilation. Within these designs, the most economical gas removal facility, by evacuation, has been selected.

The completed landfill site gas removal facilities have been designed at 1 position per 1,000m^2. As for disaster prevention measures, the gas removal facilities make counteraction quite possible. However, the covering material is the most important factor, as it is necessary to not leave waste exposed over a long time.

Vertical Gas Removal

Before starting the filling of waste, 5 meters of the vertical gas removal system is constructed and is extended as the waste is filled. After completion of filling the waste the vertical gas removal pipe extends above ground to vent the gas. The structure is shown below.

Horizontal Gas Removal

Before starting the filling of waste, the horizontal gas removal system is constructed. A cap is installed at the top of the gas collection pipe in order to prevent rainwater from entering the pipe. The vertical removal pipe will be extended upward as the landfill operation makes progress.

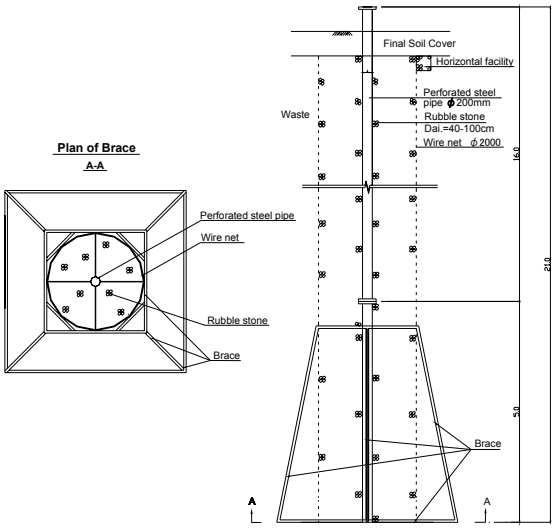


Figure 10-15: Structure of Vertical Gas Removal Pipe

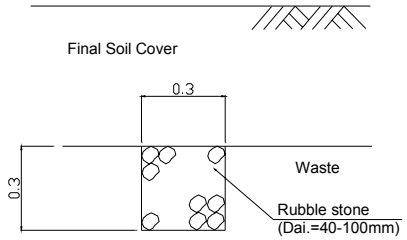


Figure 10-16: Structure of Horizontal Gas Removal Pipe

e.1.9. Leachate Collection Facilities

The purpose of leachate collection facilities is to collect only water contaminated with waste and decomposed polluted water, and carry it to the leachate treatment facilities without allowing it to infiltrate the ground.

The facility ordinary consists of the following components.

- A low permeable bottom liner
- A leachate collection pipe network

Low permeability of bottom liner

The permeability of the bottom liner must be sufficiently low in order to protect groundwater from contamination by infiltration of leachate, while preventing groundwater from penetrating the landfill site. However, the provision of an artificial liner is always the biggest factor in increasing the construction cost. The best solution is, therefore, the full utilization of the natural conditions. In order to examine whether the natural ground can be utilized as the low permeable layer for the landfill site, a geological survey was conducted at the site from October to December 2003 in the Study. The result of geological survey is as follows. (refer to Appendix)

1) Although the 4 m section directly below the ground surface contains a fine sand layer with a thickness of 0.8 m- 3.2 m, the ground generally consists of stiff clay soil with a permeability of 10-7 -10-8 m/sec..

2) The deeper section contains a sand layer at a depth of approximately 11 m.

Although the 4m layer directly below the ground surface has the required permeability for the landfill site, it may crack due to the construction work. Therefore, the underlying section should be used as the impermeable layer of the site. However, the upper sand layer needs to be covered with bottom clay soil of low permeability as shown in the diagram. An additional geological survey is necessary in order to make sure of the effect of this measure. In addition, at the time of construction, it is important to examine the most appropriate method considering the conditions of permeable stratum.

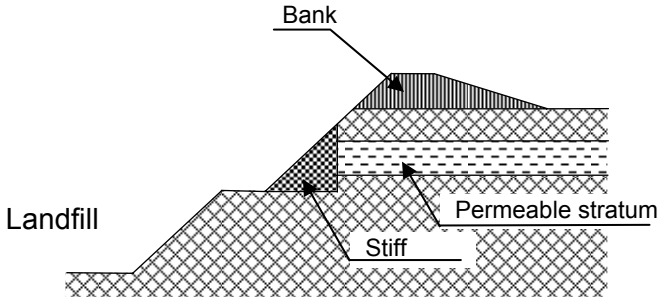
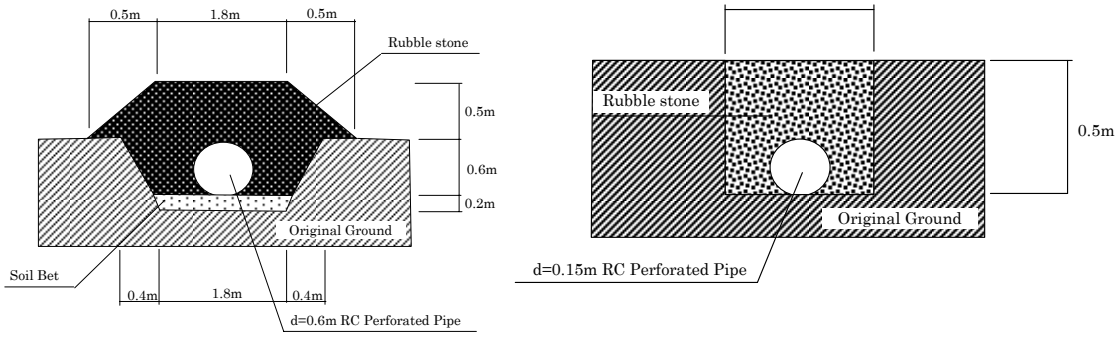


Figure 10-17: Structure of Soil condition

Leachate collection pipe net work

- Horizontal leachate collection

The purpose of a horizontal leachate collection facility, which is installed on the bottom of a disposal site, is to collect leachate and to drain it out quickly. In this plan, two types of horizontal leachate collection facilities were adopted depending on the flow capacity.



<for Main> <for Branch>

Figure 10-18: Structure of Leachate Collection Pipe

- Vertical leachate collection

The purpose of a vertical leachate collection facility is to quickly drain contaminated water contained in the waste layer downwards. In this plan, the vertical gas removal facility is also utilized as the vertical leachate collection facility.

e.1.10. Monitoring Well

To confirm whether leachate is contaminating groundwater resources, monitoring wells approximately 15m in depth with a diameter of more than 100mm will be installed in the site. In addition, other monitoring wells of 5m in depth will be constructed in the lower part of the groundwater under Landfill Area A and B in order to monitor the impact of the highly permeable stratum on water quality.

e.1.11. Final Soil Cover

After waste filling is completed, the top of the landfill should be covered with a layer of soil of a certain thickness so that the land can be utilized for other purposes without any impact by waste dumped. Although the required thickness of the final soil cover depends on the ultimate use, in this design the thickness of the final cover of soil was assumed to be 50 cm.

Soil for coverage was planned to be obtained within the Dang Kor Disposal Site.

e.2 Building and Accessories

These facilities include a PPWM head office, a weighbridge, safety facilities, fire prevention facilities, a storage building, monitoring facilities, a car wash, etc.

The facilities are to be shared by the maintenance work shop and compost facility.

e.2.1. Entrance area

The entrance area starts from the Access road to the PPWM head office. It has an area of 0.7 ha and is paved with asphalt.

e.2.2. Site Office

The site office shall have a weighbridge control house and facilities for staff and management.

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

The facilities are as follows:

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

e.2.3. Weighbridge

A weighbridge shall be constructed on weighing cells in a concrete structure. The recorded weight of a full vehicle will be transmitted to the computer in the site office. The capacity of the weighbridge shall be 60tons.

e.2.4. Tire Washing Pit

The waste collection vehicles should pass the tire washing pit before leaving the site to avoid carrying the dirt back into the city. The pit should be of a concrete structure.

e.2.5. Gate

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

e.2.6. Fence

Fencing is necessary to control the disposal site properly for the following reasons:

- to control waste pickers, outsiders, etc.
- to protect the equipment, spare parts, etc.
- to protect the disposal site from illegal dumping

The dimension of the proposed fence is as follows:

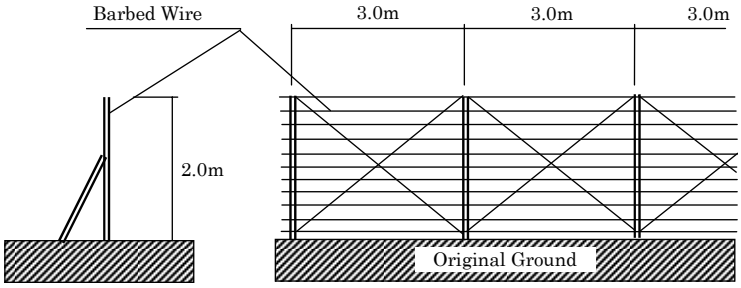


Figure 10-19: Structure of Fence

e.2.7. Parking area

A parking lot for the disposal site staff will be arranged. A parking space for heavy vehicles such as landfill vehicles and collection vehicles will be prepared in the workshop section, next to the parking lot.

e.2.8. Power supply and water supply

A power supply should be installed at the entrance area, site office, weighbridge, maintenance workshop, compost plant, etc. Well are to be constructed on-site to supply water. A water supply should be installed at the site office, maintenance workshop, compost pant, tire washing pit, etc.

e.3 Design and supervision

Prior to the commencement of constructing the disposal site, a detailed design study including investigation of site conditions has to be carried out. During construction of the site, supervision work has to be carried out to maintain the required quality of work.

f. Operation and Maintenance Plan

f.1 Landfill Plan

f.1.1. Basic Policy

The following basic policies were sustained for the preparation of the landfill plan:

- to spread and compact solid waste sufficiently;
- to minimize scattering of solid waste;
- to minimize the diffusion of offensive odor; and
- to stabilize wastes as early as possible.

Compaction of solid waste is necessary to prolong the service life of the landfill site, and is also helpful in reducing settlement after the completion of the landfill. Furthermore, the prevention of solid wastes scattering and diffusion of offensive odor is required in order to conserve the surrounding environment. In order to use the completed landfill site for other purposes, such as recreational or agricultural, early stabilization is necessary during landfill operation.

f.1.2. Landfill Structure

The improved semi-aerobic sanitary landfill method was adopted for the landfill structure.

f.1.3. Landfill Method

The landfill methods are divided into three types; open dumping, sandwich and cell method. The open dumping method cannot abate offensive odors, the generation of disease vectors and noxious insects and does not compact waste well either.

With the sandwich method, soil is spread to cover solid wastes filled horizontally. If the landfill site is narrow, this method is effective, but if the site is big, solid waste is left uncovered for a couple days, resulting in the generation of offensive odors, etc.

With the cell method, soil is spread daily to cover solid waste dumped. Through this method, a highly compacted landfill can be obtained and this prevents the scattering of solid waste, the generation of offensive odor and the breeding of disease vectors and noxious insects. Therefore, the cell method should be applied.

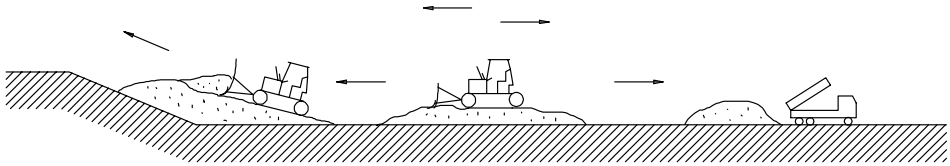


Figure 10-20: Conception of Landfill Operation

The outline of the landfill plan is summarized below.

- Step 1: Stage 1 is constructed by excavating the ground and the landfill operation starts at Stage 1. A part of the excavated soil is used as covering soil.
- Step 2: While the landfill operation is conducted at Stage 1, the excavation work starts at Stage 2 and the landfill section and the divider (bank) are constructed. A part of the excavated soil is used as covering soil and the rest is sold.
- Step 3: After the completion of the landfill operation at Stage 1, the landfill operation at Stage 2 starts.
- Step 4: The landfill operation continues by extending the landfill block of Stage 1 to Stage 2.
- Step 5: By the repetition of works from step 1 to step 4, the landfill block takes the form shown in the figure below.

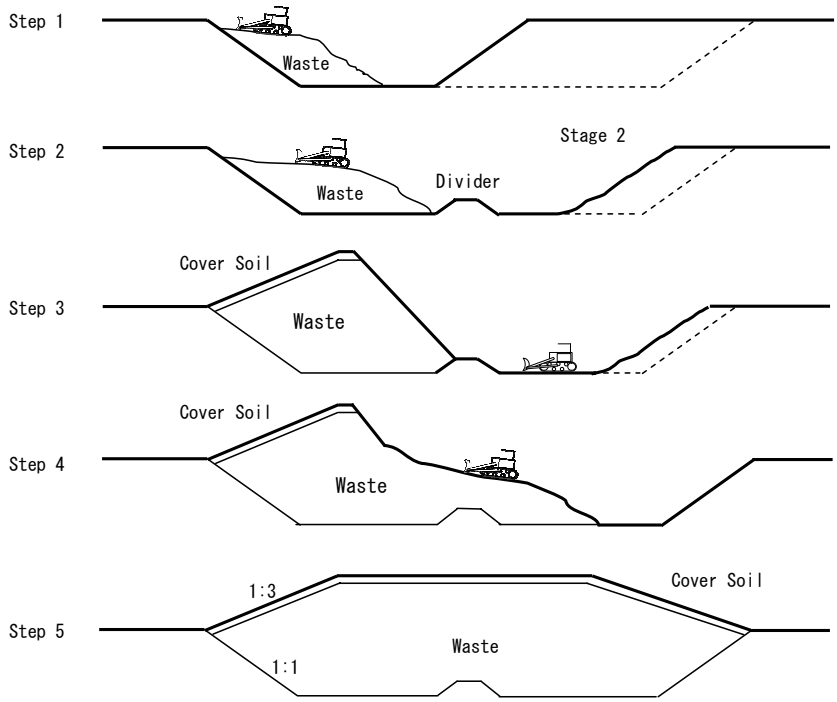


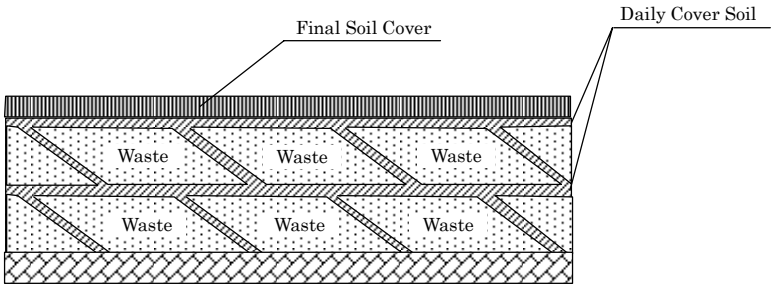
Figure 10-21: Each Step of Landfill Operation

f.1.4. Cover Soil

Cover soil is to be placed as in the method shown above and the thickness of each layer is as follows:

- daily cover soil : 15 cm
- intermediate cover soil : 30 cm
- final cover soil : 50 cm

Accordingly, the ratio of cover soil to waste disposal volume will be 10 %, including final cover soil. The cover soil is to be obtained within the Dang Kor Disposal site because its area is large enough.



f.2 Equipment Planning

f.2.1. Planning Conditions

It is essential to consider the following conditions to plan the landfill equipment to be acquired.

- Equipment which can work well on poor ground.
- Equipment with sufficient capacity to crush and compact combustibles and non-combustibles.
- Equipment which can carry out daily soil covering.

- Equipment with a high capacity for compaction is necessary not only for the ultimate use of the site when completed, but also for the preservation of sanitary conditions as well as the lengthening of the life span of the disposal site.

f.2.2. Equipment Selection

The following equipment was selected for the operation and maintenance of the landfill.

Table 10-11: Equipment for Landfill Operation and Maintenance

	Equipment	Specification	Quantity	Unit
1	Bulldozer	21 ton	4	nos
2	Wheel loader	1.2m^3	1	nos
3	Water Tank truck	6,000 liter	1	nos
4	Dump truck	11 ton	2	nos
5	Pickup truck	4WD	2	nos
6	Excavator	0.7m^3	2	nos

f.3 Personnel Plan

f.3.1. Organization structure

The organization structure for the operation of the Dang Kor Disposal Site in 2007 is proposed as shown in following table.

Table 10-12: Organization Structure of Landfill Operation section in 2007

Landfill Operation section	Section chief	1	person
	Engineer	1	person
	Clerk (include Weighbridge staff)	5	person
	Supervisor	4	person
	Operator	22	person
	Worker	12	person
Total		45	person

10.2.3 Leachate Treatment Section

g. Examination of Technical Alternative

g.1 Leachate Treatment Process

The selection of the most suitable leachate treatment system for the site is very important in project planning because there are many available systems which have different advantages and disadvantages. The following two points are mainly considered in the selection of the system.

- Required operation and maintenance cost
- Required technical skill for the operation

The leachate treatment methods are compared in the following table.

As already mentioned, the team estimated that a combination of the evaporation method with the recirculation method is the most suitable system for the Dong Kor Disposal Site because of its low operation and maintenance cost and easiness of operation. During the rainy season, the recirculation method along with wetland will be used in order to ensure leachate does not leak into surface water.

Table 10-13: Comparison of Leachate Treatment Method for the Dang Kor Disposal Site

	Activated Sludge system	Aerobic Pond Systems	Rotating Disk Contactor System	Recirculation System	Evaporation System and wetland
Description	The activated process is a continuous-flow, aerobic biological process for the treatment of domestic and biodegradable industrial wastewaters. The process provides a high-quality effluent and is characterized by the suspension of microorganisms, which are maintained in a relatively homogeneous state with the wastewater by mixing induced by the aeration system. The overall treatment process will include preliminary, and often primary, treatment before the aeration basin(s). The mixed liquor is discharged to a secondary clarifier where the microorganisms settle out and are recycled to the aeration basin. Excess sludge is piped to separate sludge-handling processes. The clarifier overflow proceeds to disinfection and final discharge or to supplemental treatment, if required.	Historically, aerobic wastewater stabilization pond systems have been a principal biological treatment method for a variety of wastewaters ranging from residential domestic to complex industrial. They may be used alone or in combination with other treatment processes. The advent of aeration via mechanical sources added yet a broader use of pond systems. The three principle types of aerobic ponds are 1. Aerobic 2. Facultative 3. Aerated Furthermore, pond systems are characterized hydraulically as discharge, controlled discharge or retention (no discharge to surface waters).	A rotating biological contactor (RBC) is an attached-growth process wherein the media are rotated through a basin of wastewater. The microorganisms are attached to large-diameter synthetic mounted on a horizontal shaft and placed at about 40% submergence in a contoured-bottom tank. Generally, the media are some 10 to 12 ft (3-3.5 m) in diameter and rotate at a peripheral velocity of 60 ft/min (0.3 m/s). The preferred temperature range for an RBC system is 55 to 90°F (13 to 32°C). Thus, in colder climates the units are enclosed for climatic control.	The process of recirculation is as follows. 1. Leachate collection by perforated pipe at the landfill site 2. Retention of leachate at a pond 3. Pumping up leachate for landfill site 4. Distribution of leachate at the landfill site The leachate is treated by contacting with waste and evaporated through the recirculation process. Advantages: 1. The process of landfill stabilisation is accelerated 2. The constituents of the leachate are attenuated by biological, chemical and physical changes occurring with the landfill. Disadvantages: 1. Not applicable for the area having low evaporation 2. Poor operation makes the disposal area muddy and inaccessible.	This system is adopted in areas with high evapotranspiration and relatively little rainfall. The greatest feature of the evaporation method is that waste water is not generated、However, treatment by evaporation requires a large land area and is not effective in projects with small sites. In regard to technical aspects, to use the site effectively, it is necessary to consider the distribution of drainage. To improve the efficiency of wetland treatment, the treated water can be recirculated. When adopting the wetland system, it is also necessary to conduct thorough studies on vegetation in the area surrounding the facilities. The wetland method can be easily combined with the evaporation method. The BOD and TSS in the waste water is treated by the wetland method、and the treated water is treated by evaporation.
Required technical skill for operation	High degree of technical skill required.	A simple technical skill required.	A simple technical skill is required.	A simple technical skill is required.	A very simple technical skill required.
O&M cost	Very expensive	Cheap	Expensive (material can not obtain in Sri Lanka)	Cheap	Cheap
Area	Enough for the facility.	Enough for the facility.	Enough for the facility.	Enough for the facility.	Enough for the facility.
Evaluation of treatment	It is too difficult for PPWM to operate the treatment facility with a high degree of technical skill due to lack of engineer. In addition the required O&M cost is too expensive	To maintain aerobic ponds, it is necessary to construct an aeration device, which increases the O&M cost.	It is difficult for PPWM to maintain the treatment facility because rotated disk can not obtained in Cambodia, when it is required to replace.	Recirculation system is suitable at Dang Kor due to quite high evaporation and low precipitation.	O&M cost is very cheap and operation technology is simple. Therefore it is easy to operate and maintained the system with technical knowledge.
Result	Not suitable	Not suitable	Not suitable	Suitable	Very suitable

g.2 Description of Proposed Leachate Treatment Process

All the leachate from Dang Kor Disposal Site is evaporated or circulated inside the facilities after treated on site. Therefore, leachate will not be discharged outside the site. However, if there is unexpected heavy rain and the main canal exceeds the level of the bank, leachate could be leaked from the landfill site.

The leachate treatment processes in the dry and rainy season are different, as described below.

Dry season : Leachate is collected in a regulation pond and treated in subsurface flow wetland ponds. After treated, a part of the leachate is evaporated in the evaporation pond, while the rest is evaporated after returned and sprinkled on active and completed fill. Any overflow of treated leachate is to be returned to the regulation pond by recirculation pump.

Wet season : Since there is a lot of rainfall, treated leachate is returned to the landfill area from the overflow pit. Leachate will be kept in evaporation ponds and within the landfill area.

The flow sheet of the leachate treatment facilities is shown in the following diagram.

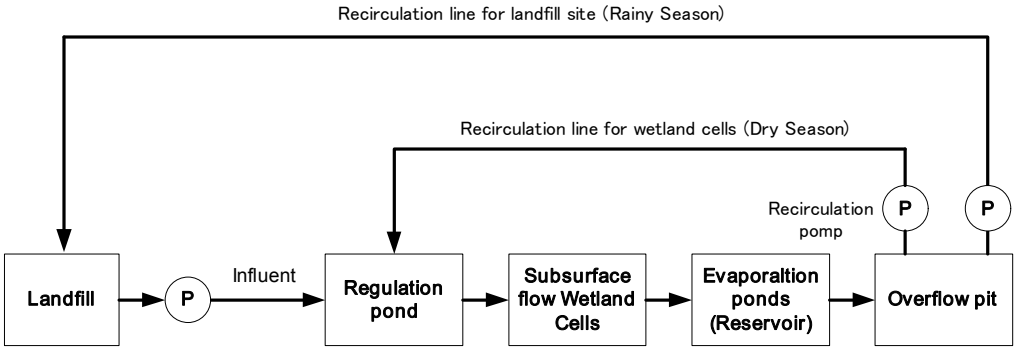


Figure 10-22: Flow sheet of Leachate Treatment Facilities

h. Preliminary Design

h.1 Layout

The leachate treatment facility is to be designed at the Dang Kor Disposal Site. The area is approximately 1.7 hectares.

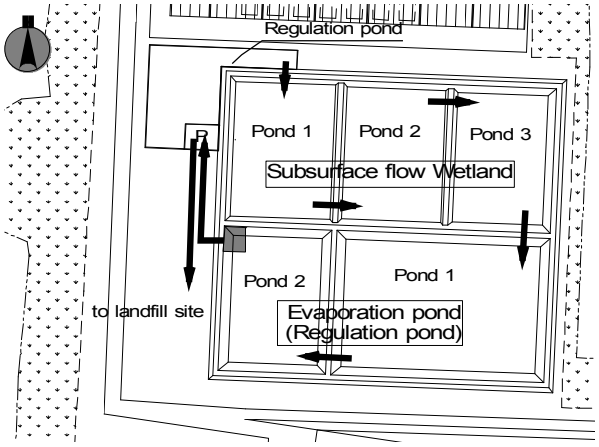


Figure 10-23: Layout of the Leachate Treatment Facility

h.2 Precipitation and Evaporation

The following table presents the data on monthly average precipitation and evaporation. At the sanitary landfill, the annual mean precipitation and evaporation is 1,531 mm/year and 1,560 mm/year, respectively.

Table 10-14: Average Precipitation and Evaporation

unit : mm/month

month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average Precipitation	32.7	2.2	67.5	69.1	134.8	178.0	183.0	171.8	228.3	288.8	82.8	92.1	1,531.1
Average Evaporation	126	146	179	177	146	131	115	108	100	96	110	126	1560
Precipitation - Evaporation	-93.3	-143.8	-111.5	-107.9	-11.2	47	68	63.8	128.3	192.8	-27.2	-33.9	-28.9

Source: Department of Meteorology, Office of Climate, Station Pochentong

h.3 Predicting leachate generation

Leachate generation rates depend on the amount of liquid originally in the waste and the quantity of precipitation that enters the landfill through the cover or falls directly on the waste. A way of estimating the total leachate generation amount is described below.

h.3.1. Leachate amount originating from rainfall

The leachate amount originating from rainfall is estimated according the following equation, which is widely used in Japan. The equation estimates the amount of rainwater likely to percolate through the landfill cover.

$$Q = 1/1000 \times I \times (C_1A_1 + C_2A_2) \quad \text{..... (1)}$$

Q : daily leachate generation (m^3/day)
I : dairy precipitation (mm/day)
C_1 : percolation rate at the active working fill (-)
C_2 : percolation rate at the completed fill (-)
A_1 : area of the active working fill (m^2)
A_2 : area of the completed fill (m^2)

h.3.2. Leachate amount estimation

(1) Preconditions

① There is no inflow from outside of the disposal site.

② Data on precipitation and evaporation is obtained from the Pochentong station.

Table 10-15: Meteorology data

Item		Year
1. Precipitation	Monthly	2000 - 2003
	Daily	2002
2. Evaporation	Monthly	1990 - 1999

(2) Percolation rate

The percolation rate was determined based on an assumption that the actual evaporation amount is 70% of the possible daily evaporation amount, as shown below. If the percolation rate is found to be less than 0, it is regarded as 0.

$$C_1 = 1 - (E \times 0.7) / I$$

$$C_2 = C1 \times 0.6$$

C_1: percolation rate at the active working fill (-)
C_2: percolation rate at the completed fill (-)
E: Possible evaporation amount (mm/day)
I: Daily precipitation (mm/day)

The estimated percolation rate in each month is shown below.

Table 10-16: Estimated percolation rate

month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
SC*	C1	0.00	0.00	0.00	0.00	0.24	0.48	0.56	0.56	0.69	0.77	0.07	0.04	0.29
	C2	0.00	0.00	0.00	0.00	0.14	0.29	0.34	0.34	0.41	0.46	0.04	0.02	0.17

* SC, Seepage coefficient
Source: Department of Meteorology, Office of Climate, Station Pochentong

h.3.3. Projected leachate generation (design daily treatment capacity of leachate treatment facilities

(1) Preconditions

The leachate generation amount will reach a peak when the final section (4th section) is land-filled at Stage 5 of Phase 1, and this maximum leachate generation amount is estimated on the following conditions.

① Site A of the landfill is completed
② All the area of Site B of the landfill is completed except the final one-sixteenth.

(2) Precipitation

The following information can be obtained from the monthly precipitation data.

Annual mean daily precipitation = 4.19 mm/day
Average daily precipitation of the largest precipitation month = 9.32 mm/day

According to the data of the past four years, the largest monthly precipitation amount was 442.5 mm/month (October 2004), and the average daily precipitation of the month was 14.27mm/day.

(3) Predicting Leachate Generation Amount

① Ratio of completed fill to active working fill

Area of completed fill : 133,500m^2 [Landfill Area A: 30,000m^2, Landfill Area B: 103,500m^2]

Area of active working fill: 6,900m^2 [Landfill Area B, Stage 5, 4th section]

② Leachate generation amount

The leachate generation amount at its peak was obtained by substituting C_1 and C_2 in Table 10-16 and A_1 = 6,900m^2 and A2 = 133,500m^2 for the equation (1). The result is shown in the table below.

Table 10-17: Leachate generation amount originating from rainfall

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Leachate amount	m^3/month	0	0	0	0	2,743	7,481	9,013	8,462	13,583	19,270	482	271
	m^3/day	0	0	0	0	88	249	291	273	453	622	16	9

② Annual mean daily leachate generation amount

The average daily leachate generation amount at its peak was estimated by substituting I = 4.19mm/day, C_1 = 0.29, C_2 = 0.17, A_1 = 6,900m^2 and A_2 = 133,500m^2 for the equation.

$Q = 1/1000 \times I \times (C_1A_1 + C_2A_2)$

$= 1/1000 \times 4.19 \times (0.29 \times 6900 + 0.17 \times 133500)$

$= 103.5$ m^3/day

③ Maximum leachate generation amount

The maximum daily leachate generation amount was estimated by substituting I = 9.32mm/day, C_1 = 0.77, C_2 = 0.46, A_1 = 6,900m^2 and A_2 = 133,500m^2 for the equation.

$Q = 1/1000 \times I \times (C_1A_1 + C_2A_2)$

$= 1/1000 \times 9.32 \times (0.77 \times 6900 + 0.46 \times 133500)$

$= 621.9$ m^3/day

According to the data of the past four years, the largest monthly precipitation is 442.5 mm/month (October, 2004) and the average daily precipitation of that month is 14.27mm/day. The leachate generation amount of that month is estimated as follows.

$Q = 1/1000 \times I \times (C_1A_1 + C_2A_2)$

$= 1/1000 \times 14.27 \times (0.77 \times 6900 + 0.46 \times 133500)$

$= 952.1$ m^3/day

The largest daily precipitation in 2002 is 110.8mm/day (on October 4). The leachate generation amount of that day is estimated as follows.

$Q = 1/1000 \times I \times (C_1A_1 + C_2A_2)$

$= 1/1000 \times 110.8 \times (0.77 \times 6900 + 0.46 \times 133500)$

$= 7392.9$ m^3/day

④ Leachate generation amount at the time of landfill completion

The average leachate generation amount after the completion of landfill operation is estimated by substituting I = 4.19mm/day, C_1 = 0.29, C_2 = 0.17, A_1 = 140,400m^2, A_2 = 0m^2 for the equation.

$Q = 1/1000 \times I \times (C_1A_1 + C_2A_2)$

$= 1/1000 \times 4.19 \times (0.29 \times 0 + 0.17 \times 140400)$

$= 100.0$ m^3/day

h.3.4. Leachate generation amount originating from disposed waste

Regarding the leachate generation amount originating from disposed waste, the projection in 2012, when the landfill of Stage 5 is used as an active working fill, is made.

(1) Preconditions

1) Amount of collected waste: 1,301.2 tons/day [in 2012]
2) Water content of collected waste: 60% [actually measured at SMCDS[3]]

[3] Refer to Appendix 19 of the Supporting Report

3) Solid amount of waste: 520.5 kg-DS/day [= 1301.2 x (1-0.6)]

4) Water content of disposed waste (2 months later)l: 45% [measured at SMCDS]

5) Ratio of water content to solid amount of collected waste: 1.50 kg-H_2O [= 0.6 / (1 – 0.6)]

6) Ratio of water content to solid amount of disposed waste (2 months later) : 0.82 kg-H_2O [= 0.45 /(1 – 0.45)]

7) Water amount which is used for organic decomposition: 0.165kg-H_2O/kg-degradable organics[4].

8) Content of degradable organics of waste: 56.9% [projected based on the result of the WACS. Kitchen waste, trees and plants are classified as degradable organics.]

9) Loss by evaporation: estimated in the section of leachate treatment capacity.

10) Leachate generated from disposed waste is supposed to flow out without delay.

(2) Estimation of leachate generation amount originating from disposed waste

1) Leachate amount generated from disposed waste

The leachate amount generated from disposed waste can be traced as the difference in water amount between waste just brought to the disposal site and disposed waste. Since the daily solid amount of waste in 2012 is 520.5ton-DS/day, the leachate generated from disposed waste is estimated as follows.

Leachate amount generated from disposed waste: Wg = 520.5 x (1.5 – 0.82) = 353.9 tons/day

2) Water consumption amount used for organic decomposition

Water consumption amount: We = (520.5 x 0.569) x 0.165 = 48.9 tons/day

3) Leachate amount generated from collected waste

Leachate amount generated from collected waste = Wg – We = 353.9 – 48.9 = 305.0 tons/day

h.3.5. Total leachate generation amount

The total leachate generation amount by month is shown in the table below.

Table 10-18: Total leachate generation amount

unit: m^3/day

Generation source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	0	0	0	0	88	249	291	265	463	622	20	9
Waste	305	305	305	305	305	305	305	305	305	305	305	305
Total	305	305	305	305	393	554	596	570	768	927	325	314

h.3.6. Estimated daily leachate generation

The estimated daily leachate generation is the sum of the daily average leachate generation originating from rainfall and from disposed waste as shown below. The largest daily leachate

[4] Integrated Solid Waste Management, Irwin/McGraw-Hill, 1993

generation is estimated as 927 tons/day in October (obtained from the monthly data in the past four years) or 1,257 tons/day (obtained from the daily data in the past four years).

Estimated daily leachate generation = 103 + 305 = 408 tons/day

h.4 Leachate treatment capacity

Leachate will be treated in the following ways.

- Evaporation treatment at the active working fill
- Evaporation treatment at the completed fill

The following shows how to estimate the treatment capacities of the two methods.

h.4.1. Evaporation method at active working fill

(1) Outline

Leachate is returned from the leachate treatment ponds to layers of disposed waste through gas removal pipes. The decomposition reaction of organics and the heat of its reaction evaporate the leachate.

(2) Preconditions

1) Landfill gas generation from gas removal pipes: 8,800kg/day [measured at SMCDS]
2) Landfill gas temperature: 40℃ [measured at SMCDS]
3) Saturated humidity: 0.0506 kg/kg' [at gas temperature of 40℃]
4) Number of gas removal pipes: 189 [in total in the year 2012, excluding active working fill]

(3) Estimated evaporation amount

The evaporation amount is estimated as follows:

Evaporation amount = 8800/(1 + 0.0506)/1000 ton-gas/pipe・day x 0.0506 x 189

= 80 ton/day

h.4.2. Evaporation treatment at the completed fill

(1) Outline

Leachate is returned from the leachate treatment ponds and sprinkled over the final cover and evaporated. Sprinkling leachate has another function of watering turf.

(2) Preconditions

1) Area of completed fill: 136,000m^2
[the gross area in 2012 excluding active working fill]
2) Water volume for sprinkling: 0.0075 m^3/m^2
[the sum of evaporation from soil and turf, average in the dry season]

(3) Estimated evaporation amount from the completed fill

The evaporation amount is estimated as follows:

Evaporation amount = 136,000 x 0.0075

= 1,020 tons/day

The evaporation method is effective during the dry season. Judging from the precipitation data, it is possible to apply this method in Phnom Penh for seven months annually. The annual average daily evaporation amount is estimated as shown below.

Daily evaporation volume = 1020 /12 x 7 = 595 ton/day

h.4.3. Summary

The total daily evaporation amount is estimated as 675 tons/day [= 80 + 595], which is larger than the estimated daily leachate generation of 408 tons/day. Therefore, it can be said that evaporation treatment method is applicable and effective as a leachate treatment method. However, leachate generation greatly fluctuates yearly or seasonally, and the maximum daily leachate generation in the last four years is estimated as 1,275 tons/day. It is necessary to install leachate adjustment facilities in order to deal with this fluctuation.

h.5 Volume of leachate adjustment facilities (Vmax)

h.5.1. Precipitation data

Regarding the precipitation data, the climatic data in 2002 is used, since information on daily precipitation is available. The annual precipitation in 2002 was 1,323mm/year.

h.5.2. Daily leachate generation (Qj)

Daily leachate generation is estimated by the following equation.

$$Qj = 1/1000 \times Ij \times (C_1A_1 + C_2A_2)$$

Qj: Daily leachate generation (m^3/day)
Ij: Daily precipitation from January 1, 2002 to December 31, 2002 (mm/day)
C_1, C_2: Percolation rate of the active working and completed fill
A_1, A_2: Area of active working fill and completed fill (m^2)

h.5.3. Percolation rate of the project site

The percolation rate in Table 10-16 is used as the percolation coefficient.

h.5.4. Maximum volume of leachate adjustment (Evaporation pond) Vmax

The maximum volume of leachate adjustment (an evaporation pond) is determined for each amount of leachate evaporation treatment, as shown in the table below.

Since the precipitation data used for this estimation is smaller than the annual average, it is necessary to increase the regulation amount by 15%.

Table 10-19: Maximum volume of evaporation pond (Vmax)

Evaporation Treatment Amount Q (ton/day)	Adjustment volume Vmax (m^3)	Leachate left in the ponds on December 31 (m^3)
400	18,516	12,721
450	15,576	6,721
500	12,825	867
550	10,825	0

h.6 Leachate treatment facilities and the capacity of leachate regulation facilities (evaporation pond)

It is better to store some of the leachate in an evaporation pond even during the dry season. The capacity of the evaporation pond was designed to store the volume of leachate of four months. The result is shown in the table below.

Table 10-20: Capacity of leachate treatment facilities and evaporation pond

Capacity of leachate treatment facilities: Q	450 tons/day
Capacity of evaporation pond: V	22,000 m^3 (= 15,579 x 1.15 x 1.2*)

*1.2 is safety factor

The accumulated volume of leachate in the evaporation pond is shown in Figure 10-24. The change in leachate volume of the evaporation pond for each capacity of evaporation treatment is shown in Figure 10-25.

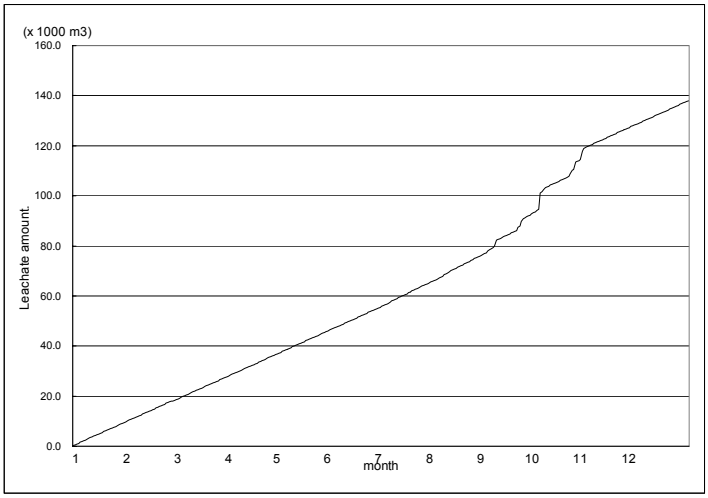


Figure 10-24: Accumulated leachate

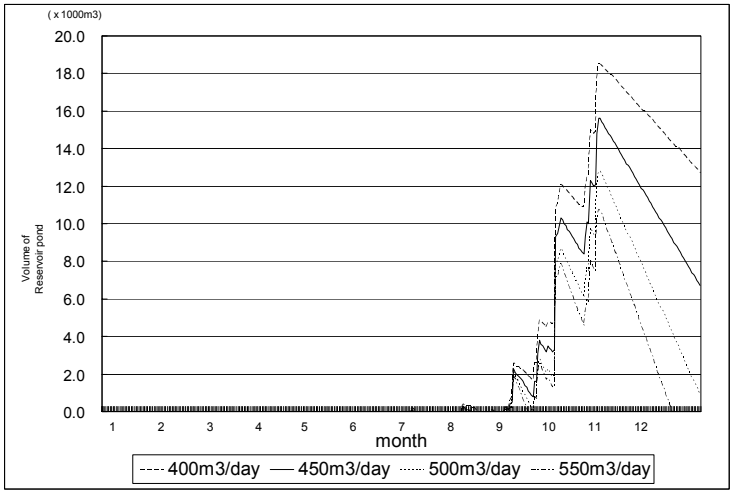


Figure 10-25: Change in leachate volume of evaporation pond

h.7 Leachate Evaporation Facilities

The Dang Kor Disposal site will be equipped with a leachate treatment system that does not discharge treated waste outside the site. All leachate is to be collected in a regulation pond

and conveyed to evaporation ponds for treatment. In case the rainfall exceeds the expected amount, a pump system will be installed to return the leachate to the evaporation ponds.

The leachate evaporation system consists of:

- A regulation pond

This is to hold leachate temporarily. The leachate quantity fluctuates, depending highly on rainfall; the capacity of the pond should be big enough to hold 7 days worth of liquid during the wettest month.

- Evaporation ponds (include wetland method)

The leachate from the regulation pond is to be conveyed to the evaporation ponds through drains placed in several locations. The sludge that accumulates in the regulation pond and evaporation ponds is to be removed in the dry season.

- A recirculation system

The recirculation system consists of a water pump and pipe for returning leachate to the landfill section in times of heavy rainfall.

h.8 Necessary consideration for the design of leachate treatment systems

The estimated daily leachate generation, which was obtained based on the annual mean daily precipitation, is 408 tons/day, while the maximum leachate generation calculated from the maximum daily precipitation in the past four years reaches 1,257tons/day. In addition, the operation systems in the dry and rainy seasons are different. Therefore, it is necessary to consider the following issues for the facility design.

- It is necessary to take measures such as decreasing the volume of leachate at the evaporation pond before the rainy season starts in order to operate and manage the system properly.
- At the start of the operation, since there is no completed landfill area where leachate evaporation treatment can be conducted, it is necessary to install tentative reservoir ponds along with the permanent evaporation pond at Landfill B.
- In times of heavy rain, there will be cases in which excess leachate has to be discharged outside if water quality is better than a certain level. It is necessary to establish the standards for emergency leachate discharge, as well as the monitoring system.
- It is important to select pumps of enough power to remove leachate from the landfill area quickly and return the leachate to the landfill area smoothly. In addition, a system in which a spare pump can be utilized along with active pumps should be prepared.
- It is important to control the volume of leachate that is retuned to the landfill area. During the dry season, leachate in a uniform volume is sprinkled; returning leachate is stopped during the rainy season.
- It is necessary to install equipment to sprinkle leachate over the completed fill effectively.
- Sludge left on the bottom of the evaporation pond has to be removed during the dry season and disposed of at the landfill.

- The effect of the evaporation treatment depends on the weather, and there could be cases in which leachate generation is larger than expected. Therefore, it is important to construct an evaporation pond as soon as possible under the expansion plan of the second phase.

10.2.4 Compost Plant

a. Conceptual Design of the Compost Plant

a.1 Examination of Technical Alternative

a.1.1. Composition of Compostable Waste

Based on the result of the WACS, the composition of compostable waste applied to the plant design is assumed as shown in the table below.

- Foreign material (non-compostable waste) in the compostable waste accounts for 10%.
- According to the result of the WACS, the moisture content of market waste was 64.4 %. Therefore, the moisture content of the market waste for this plan was assumed to be 65%.

Table 10-21: Composition of the Compostable Waste

Composition		Market Waste Composition (%)	Compost material (%)
Compostable	Kitchen	66.4	82.0
	Grass	6.5	8.0
	Sub-total	72.9	90.0
Non-Compostable	Paper	8.0	3.0
	Textile	0.9	0.3
	Plastic	11.6	4.4
	Leather	0.1	0.0
	Metal	0.0	0.0
	Glass	2.0	0.7
	Stone	1.2	0.4
	Others	3.3	1.2
	Sub-total	27.1	10.0
Total		100.0	100.0

a.1.2. Compost Process

There are basically two types of composting processes for the organic fraction of municipal solid wastes: the “aerobic process” (the so-called compost plant) and the “anaerobic process” (in general terms, a biogas plant). The following table shows the comparison of the two processes.

Table 10-22: Comparison of Aerobic and Anaerobic Composting for Organic Fraction of MSW

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

Source: Integrated Solid Waste Management, McGraw-Hill

As the compost plant is selected as one of the priority projects in the Study with the prime objective of "recovery of organic waste, especially market waste", the aerobic process is selected for the design of this project.

Aerobic composting can be operated by windrow composting, static pile composting or in-vessel composting. Furthermore, there are two types of windrow composting: minimal technology windrow and high-rate windrow.

a.1.3. Selection of Composting System

The team recommends that the new compost plant adopt the windrow system of minimal technology for the following reasons:

- The construction and operation cost is low.
- Both the two existing compost plants in MPP adopted this system, which proves the acceptability of this system.

Four composting methods are compared in Table 10-23

Table 10-23: Comparison of Composting Method

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

a.1.4. Non-compostable Material Mixed in the Raw Materials

It is proposed that the following pre-treatment system be adapted, based on the analysis of the COMPED plant and the production process of the windrow system.

The pre-treatment system of the proposed compost plant is to remove non-compostable materials manually. There is no need to install large-scale machines for the purpose of size reduction and size separation. In addition, at the time of turning waste, some non-compostable material such as plastic and large-sized paper can be removed manually.

The only machine used to remove non-compostable material is a trommel, which is installed at the production stage. The trommel is indispensable to increase the quality of compost.

a.1.5. Size Reduction

The compostable waste discharged from markets contains hardly any large-sized items mixed in such as general household yard waste. PPWM will also instruct all shops at markets to reduce the size of waste when separating it for collection. For such reasons, large sized items can be sorted out manually and the installation of machines for size reduction will not be necessary.

a.1.6. Pre-treatment Process

The proposed composting plant needs a pre-treatment process for the following reasons:

- The raw materials separated at the source as compostable can still contain non-compostable materials. To prevent product quality deterioration, they should be removed. The removal method may allow material recovery from the removed materials.
- Size reduction will result in a larger surface area of waste fractions. The larger the surface area is, the more oxygen can be supplied, and aerobic decomposition is facilitated.

a.1.7. Screening Section

The proposed compost plant is planned to be equipped with the following separators:

- trommel screen (size separation for raw compost and mature compost)
- ballistic inertial separator (density separation for small glass cullet and gravel)

a.2 Preliminary Design

a.2.1. Location

The compost plant is to be designed in the Dang Kor Disposal Site. The area is about 1.1 hectares.

a.2.2. Treatment Capacity

The treatment capacity of the proposed compost plant is designed to be 20 tons/day as the compostable wastes to be processed at this plant in 2007, the target year of the F/S, is projected at 43,435 tons/year (market waste : 119.0 tons/day).

a.2.3. Working Hours

The work schedule of the plant is as follows:

- The proposed plant operates : 350 days a year.
- Monday - Sunday : 7:00 - 16:00 (9 hours/day).
- National holidays : Closed

- Waste receiving time : 7 hours/day
- Equipment operation hours : 8 hours/day

a.2.4. Main Process Components of the Plant

The main components of the proposed plant operation are as follows:

- pre-treatment process
- composting process
- maturating process
- screening process

For the purpose of the preliminary design, the process times are assumed to be 28 days for composting and 60 days for maturation. Auxiliary facilities of the plant comprise the following:

- weighbridge (for common use)
- waste reception areas
- temporary storage areas
- compost product storage areas
- water supply facility
- drainage facility
- machine/equipment maintenance workshop (for common use)
- site office and laboratory (for common use)

a.3 Compost Plant Design Parameters

a.3.1. Design Principals

- The plant capacity is calculated to be 20 tons/day by assuming that about 17% of market waste in all of Phnom Penh city will be separately collected and that the plant operates 350 days a year.
- The compost plant is to start operating in the year 2007.
- The compost plant will be constructed at the Dang Kor Disposal Site, among the landfill area and maintenance workshop. The site will be surrounded by a buffer zone (green belt).
- The composting area is to be covered, and every effort will be made to prohibit the generation of leachate. The area will be equipped with side trenches to collect leachate generated from the piles, which will be treated at the leachate treatment facilities.

a.3.2. Design Assumption

The design assumptions made for the preliminary design are described below.

- **Composting Period**: In general practice, the composting period is in the order of 20 to 30 days. This preliminary design proposes a period of 28 days including a margin of safety that allows adjustment for variations in moisture content of the raw materials.
- **Turning Frequency**: Five turnings in total are carried out during the 28-day composting period, with an interval between turnings of 5 or 6 days. Transferring the raw compost to the maturation area on the 28th day is counted as the 5th turning. The initial temperature of the static piles should be maintained at 55-60 ºC, which is the determinant of the timing of turning.

- **Maturation Period**: This is generally in the order of 30 to 90 days. The preliminary design assumes a 60 day period in order to provide sufficient maturation time.
- **Bulk Density and C/N ratio**: Bulk density and the C/N ratio obtained by the WACS by the JICA study team are employed as the figures for the raw material. Meanwhile, the corresponding figures for the raw compost and mature compost are derived from empirical values obtained in Japan.
- **Moisture Content**: According to the result of the WACS, the moisture content of market waste was 64.4 %. Therefore the moisture content of the market waste for this plan was assumed to be 65%.
- **Compostable Content**: The compostable content in the raw material is assumed to be 90%. Therefore, the foreign material (non-compostable wastes) in the raw material accounts for 10%.

a.3.3. Summary of Design Parameters

The table below summarises the design parameters based on the design assumptions established above.

Table 10-24: Design Parameters of Compost Plant

Composting Section					
	Type	High-rate Windrow			
	Raw Material	Amount	20	tons/day	
	(Compostable Waste)	Compostable Content	27.4	% by dry weight	*1
		Moisture Content	65	%	
		Apparent Specific Gravity (ASG)	250	kg/m^3	
	Operation		350	days/year	
			8	hours/day	
	Treatment Capacity		20	tons/day	
	Composting Period		28	days	
	Pile Temperature		> 55	^oC	
Maturation (Curing) Section					
	Operation		350	days/year	
			8	hours/day	
	Treatment Capacity	Mature compost product	~ 3.8	tons/day	
		Moisture Content	~ 40	%	
		Apparent Specific Gravity (ASG)	600	kg/m^3	
	Maturation Period		60	day	
Final Separation Section					
	Type	Trommel screen			
	Operation		350	days/year	
			8	hours/day	
	Treatment Capacity	Fine compost product	~ 3.5	tons/day	
		Coarse compost product	~ 0.3	ton/day	
		Moisture Content	~ 40	%	
		Apparent Specific Gravity (ASG)	400 ~ 700	kg/m^3	

*1 : Obtained from WACS (composition of kitchen waste and grass/wood)

a.4 Quantity and Quality of Compost Product

Table 10-25 shows the target quality and quantity of the compost product in the preliminary design.

Table 10-25: Quantity and Quality of Compost Product

Quantity	Fine Compost	~ 3.5 tons/day
		~ 1,225 tons/year
Quality	Moisture Content	40 %
	Apparent Specific Gravity (ASG)	400 ~ 700 kg/m^3
	C/N ratio	< 25

a.5 Flow of Compost Plant Process

The figure below shows the flow of the proposed compost plant process.

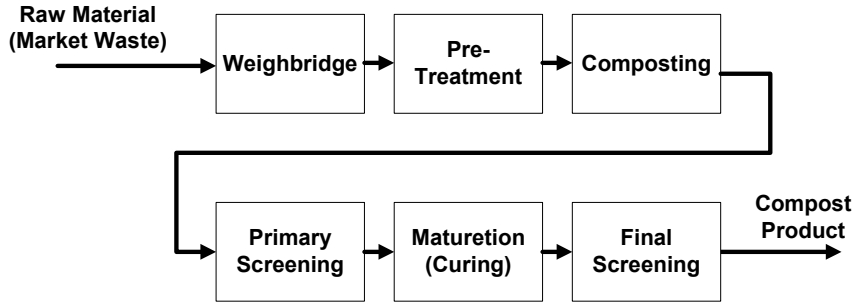


Figure 10-26: Process Flow Diagram of the Compost Plant in Dang Kor Disposal Site

a.6 Material Balance

The figure below shows the material balance in the proposed plant process in the case of 65 % moisture content.

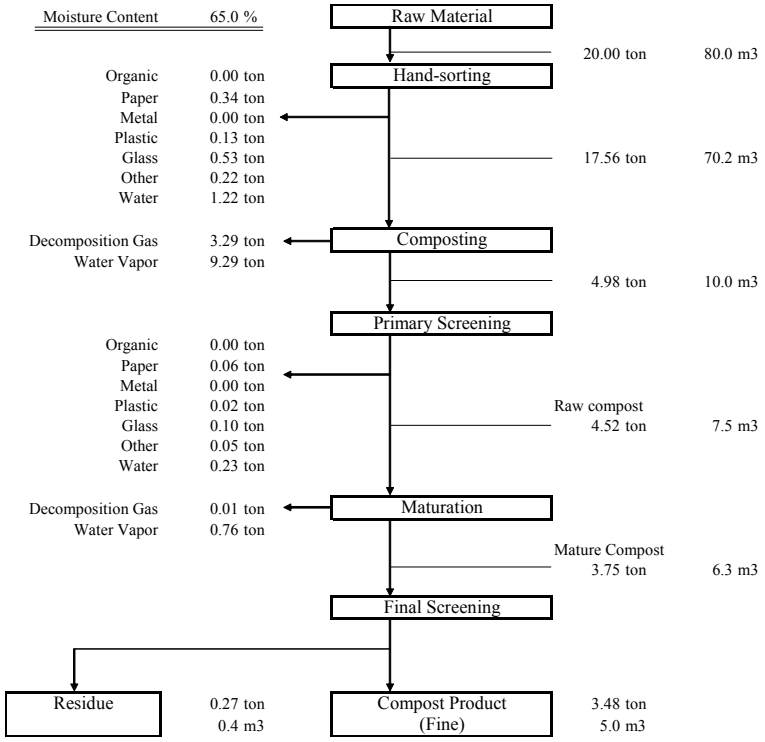


Figure 10-27: Material Balance of the Compost Plant in Dang Kor Disposal Site

a.7 Layout of Proposed Compost Plant

Figure 10-28: shows the proposed layout of the compost plant.

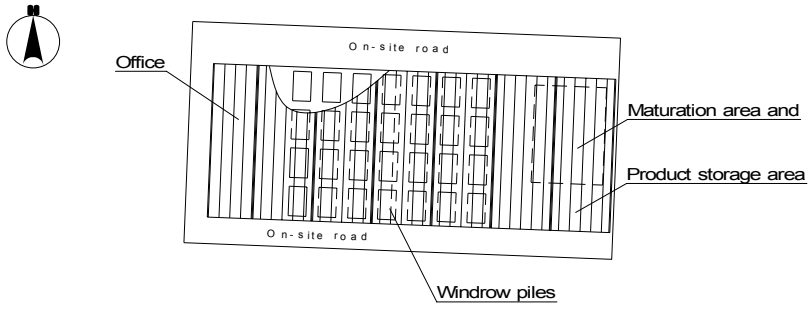


Figure 10-28: Layout of Proposed Compost Plant in Dang Kor Disposal Site

a.8 Equipment Planning

The following equipment was selected for the operation and maintenance of composting operation.

Table 10-26: Equipment plan of Compost Plant

	Equipment	Specification	Quantity	Unit
1	Wheel loader (Fork lift type)	Capacity 0.7 m^3	1	nos
2	Trommel	1 ton/hour with hopper and conveyer	1	nos

a.9 Personnel Plan

The proposed organization for operation of the compost plant in 2007 is shown in the following table.

Table 10-27: Organizational Structure of Compost Plant in 2007

Compost section	Section chief	1	person
	Clerk	1	person
	Supervisor	2	person
	Operator	2	person
	Worker	25	person
Total		31	person

a.10 Staff and Job Descriptions

Table 10-32 shows the staff allocation schedule for the proposed compost plant. The number of operators and manual workers is derived from the volume of materials to be processed and plant operation capacity.

a.10.1. Administration

The section chief is in charge of administrative work and overall management of the plant.

a.10.2. Operation

The plant is divided into two sections, the pre-treatment section and the composting section, each of which is headed by one supervisor for one shift. The sections are described below.

i. Pre-treatment

Waste Reception Section

Compostable wastes is received by this section and transferred to the pre-treatment space. The section has workers who reject wastes unsuitable for the process and a wheel loader operator who feeds the other wastes to the windrow. These works are controlled by the

reception supervisor.

Facility Operation Section

The facility operators, under the supervisor, operate the wheel loader and pile windrow.

This section is in a key position coordinating the preceding waste reception section. The capability to assess the entire pre-treatment section is required.

ii. Composting

Windrow Section

The supervisor of this section directs the loader operators to pile pre-treated materials in an appropriate place. He/she is responsible for the maintenance of the aerobic environment in the piles by wheel loader to be turning. Furthermore, he/she gives instructions to the workers about turning and water supply to the piles.

Screening Section

There are two stages of screening: primary screening for raw compost and final screening for mature compost. The primary screening line and the final screening line is operated alternately by the same operators and workers. They also operate the packaging machine of the final compost product.

Maturation Section

The screened raw compost from the screening section is matured in this section. Although it is usual to mature the materials to ensure stabilisation, market demand for the screened raw compost without maturation may rise. On such occasions, the section chief has to give necessary instructions to the supervisor and the workers of this section.

Table 10-28: Staff Allocation Schedule in the Compost plant

Position		person
ADMINISTRATION OF COMPOST SECTION		
	Section chief	1
	Clerk	1
	sub-total	2
OPERATION		
	Pre-treatment section	
	Supervisor	1
	Reception section	
	Loader operator	1
	Worker	5
	sub-total	7
	Composting section	
	Supervisor	1
	Windrow section	
	Loader operator	1
	Worker	10
	Separate section	
	Worker	5
	Curing section	
	Worker	5
	sub-total	22
	Total	31

10.2.5 Maintenance Workshop

a. Maintenance Facilities

At present, PPWM does not have a maintenance workshop or data management system for equipment.

Establishment of a maintenance and minor repair service will contribute to the effective use of the collection vehicles and landfill equipment. Therefore, a maintenance workshop is to be constructed in the compound of the new landfill site. The major components of the building are as follows:

Building
- main building
- storage for washing equipment

b. Maintenance Equipment

Equipment and tools will be furnished for the maintenance and minor repair of the vehicles and heavy equipment, thereby ensuring the availability of equipment. It is desirable that maintenance and repair work at an appropriate interval be carried out using those equipment and tools.

Basically , the maintenance and repair of vehicles and heavy equipment can be largely done with ordinary tools. Particular consideration is given to those which can be used to disassemble and assemble and major component parts of the engine and power train. In addition, portable type equipment and tools are selected to assure the convenience of the works.

Consequently, the following equipment is planned for the maintenance of collection and landfill equipment.

i . Periodical maintenance /repair
- general hand tools for both vehicle and heavy equipment
- hydraulic garage jack
- axle adjusting tool
- nozzle tester
- others

ii . Tire / welding works
- air compressor
- arc/gas welding machine
- tire pressure gage
- service tool set for tire and welding
- others

iii . Battery works
- quick battery charger
- booster cable
- battery tester
- others

iv . Store
- tool and parts rack
- computer
- others

v . Spare parts and data control works
- computer

vi . Washing and inspection pit

- steam combination washer

vii. Washing equipment storage

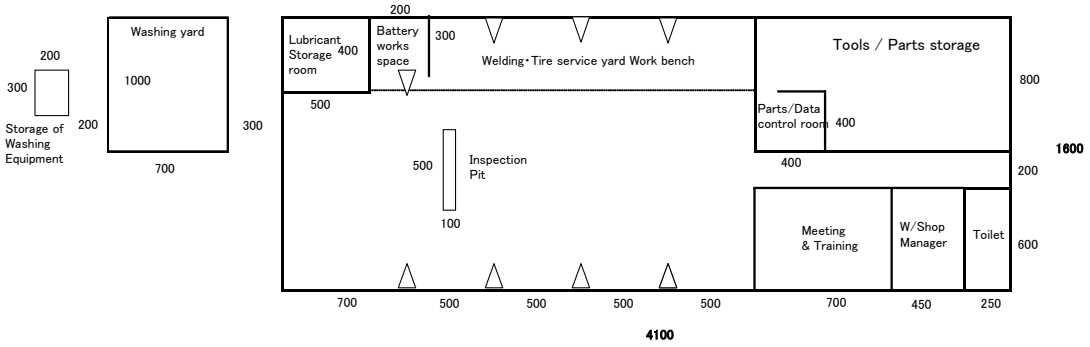


Figure 10-29: Proposed Layout Plan of the Maintenance Workshop at the Dang Kor Disposal Site

10.3 Operational Plan

10.3.1 Final Disposal Site

a. Fundamental Issues

This operational plan shall be applied for the proposed disposal site in DKDS.

b. Working Hours

The work schedule of the site is as followings.

- The proposed plant operates : 365 days a year.
- Mondays – Sundays, : 4:00 - 22:00 (18 hours/day).

c. Types of Solid Wastes

The disposal site will receive the following types of wastes.

- Mixed municipal solid waste such as households and commercial enterprises.
- Rejected waste from the Compost plant.
- Other wastes (general waste from factories and medical institutions)

d. Preliminary Design

The outline of the preliminary design for the proposed disposal site is shown in Table 10-29.

Table 10-29: Outline of the DK disposal Site

Items	Description
Land Area and Proposed Land Use	Total Area : 23.5ha Stage 1:Landfill Area (South section) : 3.0 ha Stage 2:Landfill Area (North section) : 2.76 ha Stage 3:Landfill Area (North section) : 2.76 ha Stage 4:Landfill Area (North section) : 2.76 ha Stage 5:Landfill Area (North section) : 2.76 ha

Landfill Volume	Stage	Capacity	Disposal Period
	Stage 1	434,000 m^3	2007-2008
	Stage 2	459,000 m^3	2008-2009
	Stage 3	459,000 m^3	2009-2010
	Stage 4	459,000 m^3	2010-2011
	Stage 5	459,000 m^3	2011-2012
	Total	2,270,000 m^3	2007-2012

e. Personnel and Heavy Vehicle Plan

The following personnel and heavy vehicles are required to operate the landfill site.

Table 10-30: Organization Structure of Landfill Operation section in 2007

Personnel	Director		1	Person
	Section chief		1	Person
	Engineer		1	person
	Clerk (include weighbridge staff)		5	persons
	Supervisor		4	persons
	Operator		22	persons
	Worker		12	persons
	Total		45	persons
Equipment	Bulldozer	21 tons	4	nos.
	Wheel loader	1.2 m^3	1	nos.
	Water Tank truck	6,000 liters	1	nos.
	Dump truck	11 tons	2	nos.
	Pickup truck	4WD	2	nos.
	Excavator	0.7 m^3	2	nos.

f. Operation Plan

f.1 Weighbridge

The final disposal site and compost plant, which are to be sited in the same land plot, will share one weighbridge.

The weighbridge will be used to measure the following.

- MSW directly delivered to the landfill.
- General waste from medical institutions and factories directly delivered to the landfill.
- Compostable wastes from market.
- Compost and residue from the compost plant.
- Soil from landfill site

f.2 Operation at Landfill Area

f.2.1. Landfill Method

With the cell method, soil is spread daily to cover solid wastes dumped. Through this method, a highly compacted landfill can be obtained and this prevents scattering of solid waste, generation of offensive odour and the breeding of disease vectors and noxious insects. Therefore, the cell method should be applied.

f.2.2. Cover Soil

Cover soil will be placed, and the thickness of each layer is as follows.

- daily covering soil : 15 cm

- intermediate cover soil : 30 cm
- final covering soil : 50 cm

The ratio of cover soil to the disposal volume of waste will be 10 %, excluding final covering soil.

f.2.3. Landfill Procedure

The landfill operations are outlined below.

1) Wastes are dumped directed by the collection vehicle driver with landfill operation staff.
2) The dumped waste is spread, crushed, leveled and compacted by bulldozers.
3) After the landfill operations, the covering operations will be performed daily or weekly using the cell method.
4) A second layer will be laid on the first in the same manner, extending to the divider.
5) Covering material will be laid on top of the second layer of landfill.
6) A divider as well as gas and leachate removal facilities will be constructed in the adjacent area for the next landfill operations.

According to the landfill plan, while the landfill operation is conducted at Stage 1, the ground is excavated at Stage 2 to construct the next landfill section. This combination of work continues at Stage 2, 3, and 4 in turn, and when the landfill operation advances to Section 5, Stage 1 of the phase 2 is constructed.

g. Conditions of Landfill Site at Each Stage

Conditions of landfill site at final cover stage are as follows.

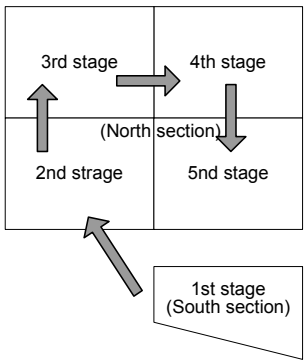


Figure 10-30: The Condition of Proposed Landfill Site at Each Stage

10.3.2 Maintenance Plan of Landfill Equipment

The maintenance plan for landfill equipment is described in sections 11.3 and 11.4 with the maintenance of the waste collection vehicles

10.3.3 Compost Plant Operation

a. Fundamental Issues

This operational plan is designed for the compost plant proposed for the DKDS. It covers the process from waste reception to final product storage.

a.1 Working Hours

The work schedule of the plant is as follows.

- The proposed plant operates : 350 days a year.
- Mondays – Sundays : 7:00 - 16:00 (9 hours/day).
- National holidays : Closed
- Waste received time : 7 hours/day
- Equipment operation hours : 8 hour/day

a.2 Types of Solid Wastes

The compost plant will receive the following types of wastes.

- Compostable waste separated at the source such as markets

a.3 Main Design Parameters

The table below summarises the design parameters taking the above design assumptions into account.

Table 10-31: Design Parameters of the Compost Plant in DKDS

Composting Section					
	Type	High-rate Windrow			
	Raw Material (Compostable Waste)	Amount	20	tons/day	
		Compostable Content	27.4	% by Dry weight	*1
		Moisture Content	65	%	
		Apparent Specific Gravity (ASG)	250	kg/m^3	
	Operation		350	days/year	
			8	hours/day	
	Treatment Capacity		20	tons/day	
	Composting Period		28	days	
	Pile Temperature		> 55	^{o}C	
Maturation (Curing) Section					
	Operation		350	days/year	
			8	hours/day	
	Treatment Capacity	Mature compost product	~ 3.8	tons/day	
		Moisture Content	~ 40	%	
		Apparent Specific Gravity (ASG)	600	kg/m^3	
	Maturation Period		60	day	
Final Separation Section					
	Type	Trommel screen			
	Operation Time		350	days/year	
			8	hours/day	
	Treatment Capacity	Fine compost product	~ 3.5	tons/day	
		Coarse compost product	~ 0.3	tons/day	
		Moisture Content	~ 40	%	
		Apparent Specific Gravity (ASG)	400 ~ 700	kg/m^3	

a.4 Process Flow of the Plant

The process flow of the compost plant is presented in following figure.

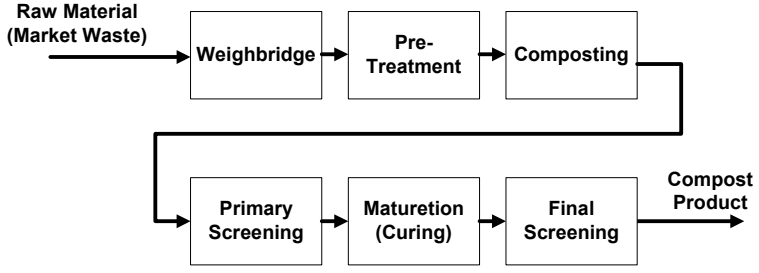


Figure 10-31: Process Flow of the Compost Plant in DKDS

b. Staff and Job Descriptions

Table 10-32 shows the staff allocation schedule for the proposed compost plant. The number of operators and manual workers is derived from the volume of materials to be processed and plant operation capacity.

Table 10-32: Staff Allocation Schedule in the Compost Plant

Position		person
ADMINISTRATION OF COMPOST SECTION		
	Section chief	1
	Clerk	1
	sub-total	2
OPERATION		
	Pre-treatment section	
	Supervisor	1
	Reception section	
	Loader operator	1
	Worker	5
	sub-total	7
	Composting section	
	Supervisor	1
	Windrow section	
	Loader operator	1
	Worker	10
	Separate section	
	Worker	5
	Curing section	
	Worker	5
	sub-total	22
Total		31

b.1 Administration

The section chief is in charge of administrative work and overall management of the plant.

b.2 Operation

Operation is divided into two sections, the pre-treatment section and composting section, each of which is headed by one supervisor for one shift. The sections are described below.

b.2.1. Pre-treatment

i. Waste Reception Section

Compostable waste is received by this section and transferred to pre-treatment space. The section has workers who reject wastes unsuitable for process and a wheel loader operator who feeds the other wastes to windrow. These works are controlled by the reception supervisor.

ii. Facility Operation Section

The facility operators, under the supervisor, operate wheel loader and pile windrow.

This section is in a key position coordinating the preceding waste reception section. The capability to assess the entire pre-treatment section is required.

b.2.2. Composting

i. Windrow Section

The supervisor of this section directs the loader operators to pile pre-treated materials onto an appropriate place. He/she is responsible for the maintenance of the aerobic environment in

the piles by wheel loader to be turning. Furthermore, he/she gives instructions to the workers about turning and water supply to the piles.

ii. Screening Section

There are two stages of screening: primary screening for raw compost and final screening for mature compost. The primary screening line and the final screening line is operated alternately by the same operators and workers. They also operate the packaging machine of the final compost product.

iii. Maturation Section

The screened raw compost from the screening section is matured in this section. Although it is usual to mature the materials to ensure stabilisation, market demand for the screened raw compost without maturation may rise. In such occasion, the section chief has to give necessary instructions to the supervisor and the workers of this section.

10.3.4 Monitoring Plan

a. Monitoring Plan

Monitoring items and frequency

In the monitoring system, the measurement of hazardous chemical substances such as heavy metals is very important. However, these measurements are very costly and the budget and human resources of MPP/PPWM are quite limited.

Therefore, in the monitoring system of DKDS, only limited analytical parameters such as pH, EC and chloride were set for water quality. These parameters are inexpensive and easy to measure, and can monitor the leachate leakage. As for the frequency of monitoring, the same matters mentioned above had to be considered and the frequency was set as monthly.

If the results of monitoring change significantly, it means that leachate may have leaked to the outside area so full-scale measurement parameters, including heavy metals, shall be measured and the frequency of monitoring increased.

As with water quality monitoring, practicable measurements for air quality monitoring are also limited. Therefore, CH4, CO2, H2O and temperature, which can be measured by portable meter, as well as landfill fire and offensive odor, which can monitored by visual check, are the set measurement parameters for air quality.

In case of heavy rain, the leachate treatment facility may be flooded and cause serious damage to the surrounding area. Therefore, “Overflow” is added as a monitoring item. (See the table below)

Table 10-33: Monitoring plan of the Dang Kor Disposal Site

Items	Facility and equipment	Measuring Items	Stage		
			construction	Operation	Closure
Underground Water	Monitoring well	Electric conductivity, Cl^-, pH		√	√
Surface Water	Water sampling	Electric conductivity, Cl^-, pH		√	√
Landfill gas	Gas removal pipe	CH_4, CO_2, H_2O, Temperature		√	√
Noise	Noise level meter	Odor, Noise	√	√	

Settlement	Settlement board	Settlement level		√	√
Landfill fire	Personal check,	Landfill fire		√	√
Offensive odor	Personal check,	Offensive odor		√	√
Overflow	Personal check,	Overflow of the leachate treatment facolity		√	√

The matters mentioned above shall be considered in the detailed design of DKDS. However, it should be noted that if the situation concerning the budget and human resources of MPP/PPWM improves, measurement parameters and frequency of monitoring must be re-considered immediately.

The monitoring locations are shown in the following figure.

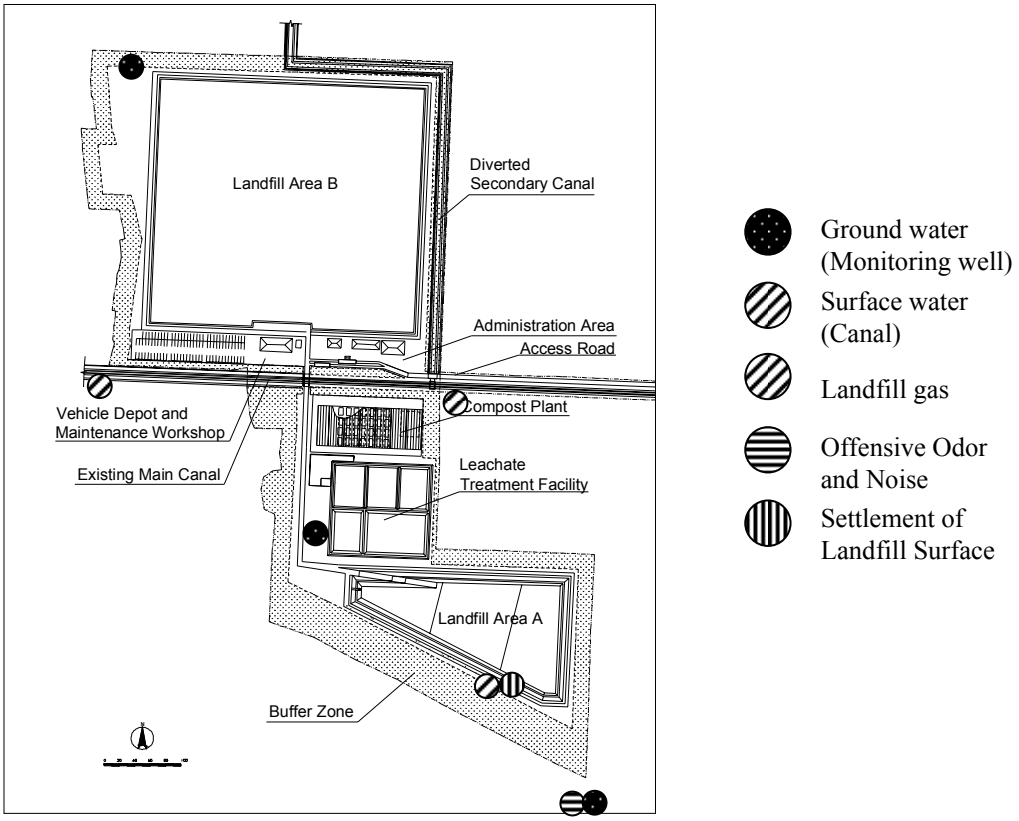


Figure 10-32: Location of Monitoring Plan

b. Opening of Information

The result of the regular monitoring will be opened to local residents through the monitoring committee, while other citizens will be able to access the data through the web site of MPP.

10.3.5 Monitoring committee

In order to strengthen a monitoring system, a monitoring committee for the Project is proposed. The monitoring committee will have the following function.

- The committee members shall join in the monitoring and observe the environmental condition of the site and its surroundings.
- If the operation is suspected of having an effect on environmental conditions, the committee members shall be able to request a survey for it and be able to join on-site inspection.
- In order to proper operation of the disposal site, the committee and PPWM shall hold discussions whenever necessary.

The committee may include:

- MPP
- MoE
- DoE
- NGOs
- Representatives from local authorities and residents

10.4 Cost Estimation

10.4.1 Administration Facilities

The investment cost and schedule for the administration section are shown in Table 10-34 and Table 10-35 respectively. The cost includes the following components: facility construction and operational equipment. It should be noted that the cost for land preparation is not included.

Table 10-34: Investment Cost of the Landfill Section

Item	Cost (US$)
Facility Construction of Administration section	1,589,000
Total cost	1,589,000

Table 10-35: Investment Schedule of the Administration Section (2005-2015)

unit : US$ 1,000

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
D/D	95	64	---	---	---	---	4	3	---	---	---	166
Civil	---	1,589	---	---	---	---	---	72	---	---	---	1,661
O&M	---	---	132	132	132	132	137	134	192	139	139	1,269
Total	95	1,653	132	132	132	132	141	209	192	139	139	3,096

Note: D/D : Detailed design, Civil : Civil works, Machine :Machinery

10.4.2 Disposal Facilities

The investment cost and schedule for the landfill section are shown in Table 10-36 and Table 10-37 respectively. The cost has two components: facility construction and operational equipment. It should be noted that the cost for land preparation is not included. The table also includes the cost of leachate treatment facilities which are mentioned in the next section.

Table 10-36: Investment Cost of the Landfill section

Item	Cost (US$)
Facility Construction of Landfill Section	5,274,000
Equipment (Machine and V&E)	1,341,000
Total cost	6,615,000

Note: V&E : Vehicles and Equipment

Table 10-37: Investment Schedule of the Disposal Facilities (2005-2015)

unit : US$ 1,000

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
D/D	316	211	0	0	0	0	193	129	0	0	0	849
Civil	0	5,274	0	0	0	0	0	3,220	0	0	0	8,494
V&E	0	1,341	0	0	0	175	0	0	1,724	0	0	3,240
O&M	0	0	486	468	468	468	508	498	506	521	632	4,555
Total	316	6,826	486	468	468	643	701	3,847	2,230	521	632	17,138

Note: D/D : Detailed design, Civil : Civil works, Machine :Machinery
V&E : Vehicles and Equipment, O&M : Operation and maintenance

10.4.3 Compost Plant

The investment cost and schedule for the compost plant are shown in Table 10-38 and Table 10-39 respectively. The cost has two components: facility construction and operational equipment. It should be noted that the cost for land preparation is not included.

Table 10-38: Investment Cost of the Compost Plant

Item	Cost (US$)
Facilities Construction of Compost Plant	985,000
Equipment Machine	10,000
V&E	100,000
Total cost	1,095,000

Note: Machine : Machinery, V&E : Vehicles and Equipment

Table 10-39: Investment Schedule of the Compost Plant (2005-2015)

unit : US$ 1,000

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
D/D	59	40	---	---	---	---	---	---	---	---	---	99
Civil	---	985	---	---	---	---	---	---	---	---	---	985
Machine	---	10	---	---	---	---	---	---	10	---	---	20
V&E	---	100	---	---	---	---	---	---	100	---	---	200
O&M	---	---	56	56	56	56	62	58	61	63	63	531
Total	59	1,135	56	56	56	56	62	58	171	63	63	1,835

Note: D/D : Detailed design, Civil : Civil works, Machine :Machinery
V&E : Vehicles and Equipment, O&M : Operation and maintenance

10.4.4 Maintenance Workshop

The investment cost is estimated as below table. The cost has two components: facility construction and maintenance equipment.

Table 10-40: Investment Cost of the Maintenance Workshop

Item	Cost (US$)
Facilities construction of maintenance workshop	1,393,000
Maintenance equipment	181,000
Total cost	1,574,000

Note: Machine : Machinery, V&E : Vehicles and Equipment

Table 10-41: Investment Schedule of the Compost Plant (2005-2015)

unit : US$ 1,000

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
D/D	76	51	0	0	0	0	0	0	0	0	0	127
Civil	0	1,266	0	0	0	0	0	0	0	0	0	1,266
E	0	181	0	0	0	0	0	0	0	0	0	181
O&M	0	0	121	121	121	121	137	130	138	148	148	1,185
Total	76	1,498	121	121	121	121	137	130	138	148	148	2,759

Note: D/D : Detailed design, Civil : Civil works, E : Maintenance equipment,
O&M : Operation and maintenance

10.5 Project Evaluation

10.5.1 Technical Evaluation

The result of soil tests revealed that the soil of the planned disposal site consists of clay strata whose permeability is low enough to stop leachate from penetrating into underground water. The development plan makes the best use of these national conditions and has succeeded in minimizing the project cost. In addition, the leachate treatment systems combined with the evaporation method, wetland method, and circulation method keep leachate from discharging into areas outside the disposal site.

The landfill section is to be excavated to a depth of 9m to maximize the landfill capacity and to minimize the landfill operation cost by selling soil.

It is indispensable for PPWM to acquire the know-how of landfill operation through the improvement of the SMCDS in order to operate and manage the DKDS properly.

10.5.2 Social Evaluation

The social impacts that the new disposal site could have are summarized below.

Negative Impact

Loss of the source of income for some farmers
Loss of the source of income for waste pickers
Division of a local community by the disposal site
A rise in collection fee

Positive Impact

Improvement of environmental and hygienic conditions around the SMCDS
Promotion of investment and tourism
A hike in land prices

As a countermeasure to the loss of the source of income of some farmers, the new disposal site could provide them with jobs such as work at the landfill section and the compost plant.

The team has a plan to change the route of the existing road that goes through the planned disposal site in order to minimize the impact.

In order to minimize the rise in collection fee, the team proposed to sell the excavated soil. In addition, the team suggests that the system for determining the collection fee be changed by charging more to business establishments. This could ease the burden of households.

The countermeasures to the loss of the source of waste pickers are described in Chap. 12, Closure of the SMC disposal site,

10.5.3 Environmental Evaluation

The team conducted an EIA survey based on the IEE, which was approved by MOE on July 16, 2003. The team analyzed environment resources, the environment impact, the result of pubic hearings, environment conservation measures, alternative plans, the environment management plan and institutional capability, and drew the conclusion that the development plan will have little environment impact. On the other hand, the implementation of the development plan could bring about benefits to the people in Phnom Penh and contribute to environment conservation in Phnom Penh.

The details of the EIA survey results are shown in the following section in the main report and in Annex 15 of the supporting report.

Please note that special consideration will be needed for water quality. At present, surrounding water sources such as the river, groundwater, canals and ponds are used for drinking, irrigation or domestic use. Therefore, proper operation and monitoring is essential for water quality control.

As for the construction period, as turbidity may occur due to earthwork, massive earthwork activities should be undertaken during the dry season.

As for the operational period, overflow of leachate must be prevented to protect the quality of surface waters such as canals and ponds. In order to prevent contamination to the groundwater, proper regular monitoring must be carried out. Once monitoring indicates a contamination of leachate, detailed water quality survey must be conducted with countermeasures. Hg and Pb also must be included in the analysis parameters as they were found in the baseline survey of the site and are very toxic.

10.5.4 Financial and Economic Evaluation

a. Outline of the Project

The Stung Mean Chay disposal site, which is currently used for final disposal of MSW collected in Phnom Penh, is going to end its life shortly. A new final disposal landfill needs to be developed within the coming few years.

Responding to this, the M/P formulates the project on the development and operation of a new final disposal site with 100ha of land in Khan Dang Kor for 20 years from 2007. The Study here analyzes the financial and economic viability of the 31.4 ha of development project as a first phase of this new final disposal site.

b. Financial Appraisal

b.1 Preconditions of financial appraisal

The financial appraisal here is made based on the following preconditions.

Table 10-42: Preconditions of the Project for Financial Appraisal

Project Implementation Body	Phnom Penh Waste Management Authority (PPWM)
Project Period	11 years from 2005 to 2015 (The period of landfill operation itself is set at 20 years.)
Project Income	• Collection of tipping fees on weight-based rate system from the service users from 2007 to 2015 (Fee collection efficiency is set at

Project Implementation Body	Phnom Penh Waste Management Authority (PPWM)
	100%.). • Income from selling the excavated soil (The average annual income of 279,000 US dollars is assumed to be earned during its operation period from 2007 to 2015.). • Income from selling compost materials produced in the compost plant at the rate of 200 riels per kilogram (The average annual income of 61,250 US dollars is assumed during its operation period from 2007 to 2015.).
Investment Cost	The following initial investment will be made from 2005 to 2006. 2004: Land purchase (31.4ha) 2005 and 2006: Design and construction of the landfill and compost plant Phase II development of landfill will start in 2012 for its operation from 2013.
O/M cost	The O/M cost is estimated for each year from 2007 to 2015 based on the determined unit cost and amount. Disposal site and compost plant are included.
Depreciation	The site development and building for common use including road, administration building, leachate treatment facility, compost plant and so forth in the final disposal landfill are completely depreciated in 20 years while the landfill area developed in Phase I is completely depreciated in 6 years while 3 years' depreciation will also be counted for the landfill developed in Phase II. Compost plant in the landfill area is completely depreciated in 15 years while the vehicles and equipment used in landfill are depreciated in 7 years with a scrap value of 10%.
Price	All the cost is estimated based on the current price of 2004. No price escalation is included.
Discount rate	10% (same as the MSW collection and haulage project above)

Remark:
1. Durable period of landfill area is equivalent with the number of years it can be used for waste disposal.
2. The remaining value of common facilities after 15 years is included as the scrap value of project assets.

c. Financial Appraisal

The financial appraisal is made for two (2) cases, namely the case with no grant assistance and the case with grant assistance.

i) Case with no grant assistance

Assuming that the FIRR of the project to be financially feasible is set at 10%, the Study estimated the required tipping fee per ton of waste disposed. The result of the estimation is shown in the table below.

Table 10-43: Financial Viability and Tipping Fee Rates

Tipping Fee Rate (US$/ton)	Net Present Value (NPV) (US$)	Financial Internal Rate of Return (FIRR) (%)
1	-10,002,234	-13.15
2	-7,967,689	-7.81
3	-5,933,143	-2.83
4	-3,898,598	1.82
5	-1,864,053	6.20
6	170,493	10.34

Remark: Discount rate is set at 10%.

As shown in the table above, the tipping fee rate needs to be set at 5.92 dollars per ton of waste disposed to achieve the minimum required FIRR of 10%. Considering that the current operation cost of SMC disposal landfill is less than 1 dollar per ton and PPWM currently only charges to CINTRI for tipping fee at the rate of 0.56 dollar per ton of waste received, the required fee rate reaches about eleven-fold of the current fee rates. This means

that the proposed new final disposal landfill will not be financially viable as a general public investment with no grant assistance.

ii) Case with grant assistance

The Study here analyzes the required tipping fee rate to make the project financially feasible in the case of providing grant assistance to cover the initial investment made in 2005 and 2006.

Financial viability of the project in this case is secured if it earns enough income to cover the whole project cost including depreciation, additional equipment investment and operational expenses arising during the project period without any shortage of the fund.

The figure below illustrates the trend of project cost on a depreciation basis[5] as well as an actual expenditure basis in the case with grant assistance.

As indicated above, the required cost of the project increases between 2011 and 2013, when the second phase development of landfill site will be carried out. Although the increase of project cost is comparatively moderate on a depreciation cost basis due to equal allocation of the cost among durable years of investment assets based on the fixed installment method, the project needs to accumulate enough fund from its income to cover the investment and operation cost arising in 2012 and 2013 on an actual expenditure basis.

Thus, the income from the project is required to comply with the following conditions so that it can be financially viable:

- Single year income always exceeds the project cost estimated on a depreciation basis; and
- Reserved fund (accumulated income) of the project always exceeds the project cost estimated on an actual expenditure basis.

The result of analysis shows that the required tipping fee to comply with the conditions above is approximately 4.40 US dollars per ton of waste disposal.

The required tipping fee of 4.40 US dollars per ton of waste disposal is still about eight-fold of the disposal cost in 2002. Both PPWM and CINTRI are required to cover this cost based on the amount of waste they dispose at the new landfill. An increase of the tipping fee affects collection fee for the service provided by PPWM and CINTRI.

d. Economic Appraisal

The Study here made the following economic appraisals of Dang Kor Final Disposal Landfill Project.

- Quantitative cost-benefit analysis of the compost plant operation in Dang Kor Final Disposal Site
- Qualitative assessment of the economic cost and benefit of Dang Kor Final Disposal Site Project

Although it is preferable to assess the economic cost and benefit of the project on a quantitative basis, the major benefits of Dang Kor Final Disposal Site (i.e. improvement of human health and sanitation in the nearby area and avoidance of air and surface/ground water pollution) are difficult to quantify accurately in terms of their economic value with reliable

[5] The project cost in each year on depreciation basis consist of depreciation expense, O/M cost, and additional equipment investment cost, while the project cost on expenditure basis indicates an actual expenditure in each year.

data and methodologies. Taking this into account, the Study only makes a qualitative assessment of the economic benefits obtained from the project.

d.1 Quantitative cost-benefit analysis of the compost plant operation in Dang Kor Final Disposal Landfill

i) Preconditions for cost-benefit analysis of the compost plant operation

In making a cost-benefit analysis of the compost plant operation in Dang Kor Final Disposal Site, the Study established the following preconditions:

Table 10-44: Preconditions of Compost Plant Project

Project Implementation Body	Phnom Penh Waste Management Authority (PPWM)
Project Period	11 years from 2005 to 2015.
Project Income	• Income from selling compost materials produced in the compost plant. 1,225 tons of compost is annually produced while the its sales price is established by cases in the range from 100 to 500 riels per kg. • Reduction of final disposal cost by compost production Reduction of final disposal cost is estimated as the result of multiplying the annual compost production of 1,225 tons by the final disposal cost per ton of waste required to reach FIRR of 10% in the case with no grant assistance, which is 5.26 US dollars per ton of waste disposal. Accordingly, the annual reduction of final disposal cost is estimated as 6,643.5 US dollars.
Investment Cost	The following initial investment will be made from 2005 to 2006. Plant design: 70,000 US dollars Plant construction: 698,000 US dollars Machinery and Equipment: 110,000 US dollars
O/M cost	The O/M cost is estimated for each year from 2007 to 2015 based on the determined unit cost and amount.
Depreciation	The plant is completely depreciated in 15 years while the machinery and equipment is depreciated in 7 years with a scrap value of 10%. Machinery and equipment will be replaced in the 7th year of plant operation.
Price	All the cost is estimated based on the current price of 2004. No price escalation is included.

ii) Result of Economic Cost-Benefit Analysis

Based on the preconditions established above, the Study estimates the economic internal rate of return of the project for each of the cases set for sales price of compost ranging from 100 to 500 riels per kg. The table below shows the result of analysis.

Table 10-45: EIRR of Compost Plant Project by Cases

Sales Price of Compost (riel/kg)	Annual Income (US dollar/year)	EIRR (%)
100	37,628	-10.51
200	67,893	-5.85
300	98,518	-1.36
400	129,143	2.98
500	159,768	7.18

As shown in the table above, the required sales price of compost is more than 300 riels per kg to obtain positive EIRR. The EIRR of the project will reach 3 % with the sales price of compost at 400 riels (0.1 US dollar) per kg.

d.2 Qualitative assessment of economic cost and benefit of Dang Kor Final Disposal Landfill Project

In addition to the benefit obtained from operation of the compost plant above, the development and operation of Dang Kor Final Disposal Site is expected to provide the following benefits, although it is difficult to accurately quantify their economic values.

- **Avoidance of negative impacts upon the surrounding environment due to the delay of the closure of SMC disposal site**

If the new disposal site is not developed as scheduled in the M/P, the amount of waste disposal by landfill will exceed the landfill capacity of SMC disposal site. Considering the current insufficient operation of SMC disposal site, such excessive disposal of waste will cause collapse of waste landfill, spill over of waste to the surroundings, and further leakage of leachate into surface and ground water. As a result, not only the safety and sanitation of the landfill area, but also the health of residents and economic activities such as agriculture in the nearby areas will be seriously disturbed. Development and operation of Dang Kor Final Disposal Site will prevent such risks from arising in the near future.

- **Avoidance of illegal dumping**

The delay of a new disposal landfill may also encourage the illegal dumping of waste having no proper destination for its final disposal. Such improper dumping of waste, as already found in some areas in Phnom Penh, causes various negative impacts upon the living environment e.g. flood due to blockage of water flow by dumped waste, river pollution, aggravation of urban sanitation, damage to urban landscape (disfigurement), and so forth. Development and operation of a new disposal site will prevent an increase of such illegal dumping of waste.

- **Improvement of the impression of Phnom Penh City through realization of clean urban environment**

Proper disposal of MSW at the new final disposal site in Dang Kor will improve the urban environment and aesthetic value of the City of Phnom Penh, as the capital city of Cambodia. A well-managed urban environment and infrastructure is the key to vitalizing economic activities such as foreign capital investment, tourism, and so forth in the City of Phnom Penh. Proper disposal of MSW is an important part of the well-managed urban environment and infrastructure.

- **Inducement of growth in the relevant economic activities**

The Dang Kor Disposal Site Development Project offers not only proper disposal of MSW by sanitary landfill, but also other environmentally friendly waste management activities such as production of compost materials from MSW. Although such new activities require additional investment, they also provide the opportunities of developing the technologies (e.g. methane capture from landfill), know-how, and human skills in the relevant sectors. Such opportunities are expected to vitalize economic activities in the City of Phnom Penh.

Although the benefits mentioned above are difficult to quantify in terms of their economic value, they are estimated to be large enough to meet the cost required.

10.6 EIA

The EIA survey was conducted according to Cambodian laws and regulations. In this section, the summary of the EIA report that was submitted to MOE along with the EIA system in Cambodia is shown.

10.6.1 The EIA system in Cambodia

a. General

Based on the IEE implemented in advance, the EIA for the Disposal Site Development Project, which includes the construction of a final disposal site, compost plant, and maintenance workshops, was carried out to assess the impacts of the project on the following:

economic activity, traffic and public facilities, cultural property, public health, the socially vulnerable, hydrological conditions, fauna and flora, landscape, air pollution, water pollution, soil contamination, noise and vibration, offensive odour.

Consequently, the implementation of the plan is expected to bring about various positive and negative impacts. The adverse impacts may be mitigated through the various countermeasures to be taken at the time of implementation. Accordingly, it has been concluded that the allowable limit can be maintained by preparing suitable countermeasures based on the results of the EIA.

b. Legal System

b.1 Law on Environmental Protection and Natural Resource Management

Cambodia's "Law on Environmental Protection and Natural Resource Management (LEPNRM)", which was enacted in 1996, is the supreme legal instrument for the environmental management. It codifies the following frameworks for environmental protection and natural resource management:

- Formulation of national and regional environmental plans;
- Execution of environmental impact assessments for new investment projects;
- Natural resource management;
- Protection of the environment from public nuisance;
- Monitoring, record-keeping and inspections;
- Establishment of an environmental endowment fund; and
- Penalties against violation.

Based on the LEPNRM the following Sub-decrees were prepared:

- **Sub-decree on the Environmental Impact Assessment Process (enacted in August 1999);**
- Sub-decree on Water Pollution Control (enacted in April 1999);
- Sub-decree on Solid Waste Management (enacted in April 1999); and
- Sub-decree on Air and Noise Pollution Control (drafted in July 2000).

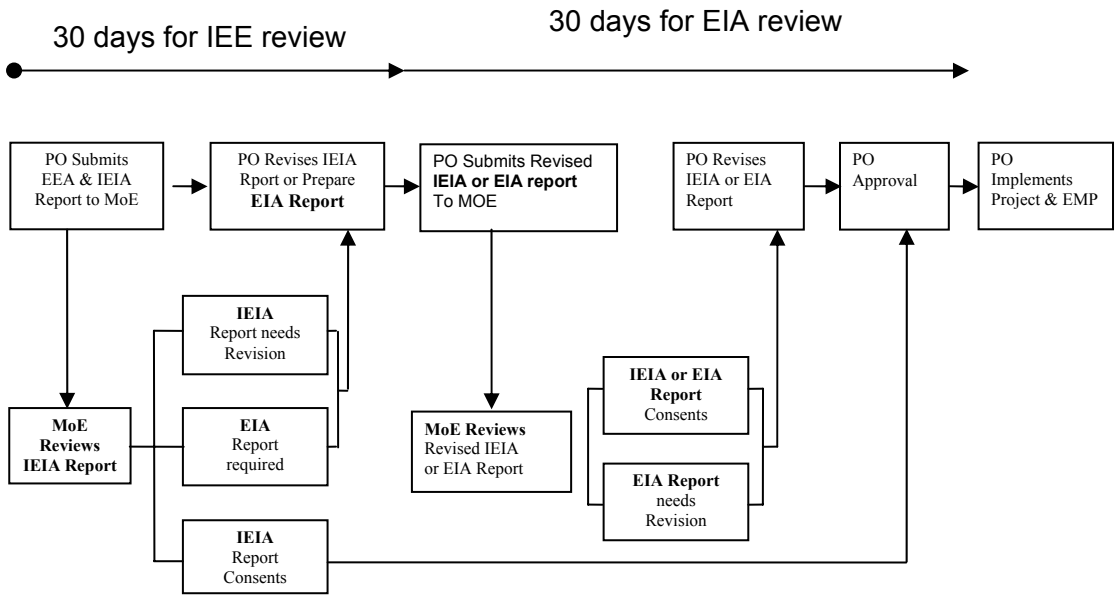
b.2 Sub-decree on the Environmental Impact Assessment Process

Based on the LEPNRM, the Sub-decree on the Environmental Impact Assessment Process was prepared and came into effect in August 1999. This Sub-decree requires an IEE/EIA for the following projects including all proposed and existing activities, either publicly or privately owned.

A. Industrial
- A-1 Foods, drinks, tobacco
- A-2 Leather tanning, garment and textile
- A-3 Wooden production
- A-4 Paper
- A-5 Plastic, rubber and chemical

B. Agriculture
C. Tourism
D. Infrastructure

The waste disposal site is listed in the D. Infrastructure in the event that the disposed population is more than 200,000. Since the Project correnponded to this category D, IEE/EIA was conducted. The procedures for IEE/EIA are shown in below.



Note: PO: Project Owner
IEIA: Initial EIA (same as IEE)
EMP: Environmental Management Plan
EEA: Environmental Examination Application

Figure 10-33: IEE/EIA process for proposed project

The Project's owner must prepare and submit the EEA and IEIA reports to the MOE. The MOE reviews the IEIA report and gives comments and suggestions to the project owner within 30 working days counting from the IEIA report submission day. If MOE concludes that the environmental impact of the proposed project is acceptable and a full EIA is not necessary, MOE gives approval for implementation to the project owner. If MOE concludes that the IEIA report is insufficient or the project will have a serious environmental impact, MOE requires an EIA. The project owner must revise the IEIA report or prepare a full EIA report, and submit it. MOE reviews the revised IEIA report or the full EIA report, and gives comments and suggestions to the project owner within 30 working days counting from the revised IEIA report or the full EIA report submission day. The project owner reviews the revised IEIA report or the full EIA report, and then the project is approved for implementation.

The draft guideline for EIA is prepared by MOE, pending approval by the Cambodian cabinet. As for the IEE report, there is no guideline in Cambodia as of yet.

10.6.2 Results of EIA survey

The results of impact assessments and mitigation measures proposed in the EIA report are summarized as follows.

a. Economic activities

a.1 Environmental impact analysis

Alternative jobs for landowners of the site should be proposed from the project owner. This request was also pointed out by local people at the 1st public hearing. Therefore, countermeasures were planned.

Based on the social environment survey to waste pickers, more than 90% of them do not want to move to the Dong Kor disposal site to continue to work there. Therefore, alternative jobs should be created for the waste pickers.

a.2 Mitigation Measures

The project owner of the proposed disposal site shall give priority to the landowners when hiring staff. For example, the composting plant, one of facilities at the disposal site, will need many workers. The project owner, MPP, shall provide the landowners a chance for employment in order to compensate for their loss in agricultural income. Therefore, this issue will be covered.

In accordance with the M/P, PPWM shall organize the waste pickers by the time of the disposal site closure in 2007 and make them work according to rules. Furthermore, PPWM shall encourage waste pickers to become primary or secondary waste collectors. Therefore, the waste pickers will have new job opportunities.

b. Traffic and public facilities

b.1 Environmental impact analysis

The number of trips made by collection vehicles is not large. However, the current road conditions are not sufficient, as most roads are unpaved. Therefore, improvement of national road 303 is needed. Moreover, based on the field survey for public facilities around the study area, there are five schools and one health center along the road 303. This makes improvement of road 303 essential.

b.2 Mitigation Measures

National road 303 is to be improved with ADB funding by 2007, by paving it until the entrance to the Killing Fields Memorial. The section of the road from there to the entrance of the proposed disposal site is also to be improved in the Dang Kor Disposal Site Development Project. Therefore, traffic jams are not expected and the impact on traffic conditions will be negligible.

c. Cultural Property

c.1 Environmental impact analysis

According to the Ministry of Cultural Affairs, there is no legal protection of pagodas so far, and there is no cultural property in the proposed disposal site area. However, the Killing Fields Memorial, which is the most important cultural property in Cambodia, is located near the study area. Between 20,000 and 30,000 people a year visit this genocide memorial and this number might become bigger after road 303 is rehabilitated. Once the disposal site is constructed, it will be visible from near the entrance to the memorial site. Therefore, countermeasures should be taken to avoid disturbing the visitors to the killing field.

c.2 Mitigation Measures

A buffer zone will be installed around the disposal site to conceal the facilities and protect the view. Moreover, in order to maintain the scenic landscape, the height of the landfill is to be 11 m. Soil will be excavated to a depth of about 9 m in order to secure a layer of low permeable soil of more than 2 m at the bottom of the disposal site.

d. Public health

d.1 Environmental impact analysis

- The waste disposal site is expected to promote growth in the population of vectors and vermin, which will have a negative impact on the study area.
- Leachate from the disposal site may have an impact on public health.
- Landfill fires may also have an impact on public health.
- Moreover, the following was pointed out at the public hearing by the local residents.
- Litter along national road 303, which is used by waste collection vehicles.
- Therefore, the above should be considered.

d.2 Mitigation Measures

- Daily soil covering work will be carried out at the disposal site, which will minimise the growth in the population of vectors and vermin. Landfill fires will also be controlled by cover soil. Therefore, there will be very few opportunities for landfill fires.
- All the leachate from the disposal site is to be treated on site year-round and will not be discharged outside the site. Therefore, leachate will not affect public health. The leachate treatment process will vary in the wet and dry seasons as described below. The systems are comprised of the same facilities although referred to by different names.

  Dry season: When the leachate quantity is small, it is to be treated with subsurface flow wetland ponds and evaporation ponds. Any overflow of treated leachate is to be returned to the regulation pond by recirculation pump.

  Wet season: If the quantity of leachate exceeds the capacity of the wetland ponds, the wetland ponds and evaporation ponds are to be used as reservoir ponds. In case the leachate exceeds the expected amount, an emergency line is to be constructed to return excess leachate to the landfill site via the overflow pit.
- In order to prevent the waste collection vehicles of littering along national road 303, which is the access road from the center of Phnom Penh to the disposal site, enclosed waste collection vehicles shall be used. In the case of open top trucks, cloth tarps shall be used to cover them.

e. Air pollution

e.1 Environmental impact analysis

-Prevention of dust generation from the construction activities

-Consideration for landfill gas in the operational stage

-Prevention of landfill fires

-Prevention of dust generation from the collection vehicles

-Consideration for landfill gas in the closure stage

e.2 Mitigation Measures

- As for dust from construction vehicles, regular watering shall be done to minimise dust generation during the dry season.
- Gas removal facilities shall be installed for ventilation of landfill gas as follows:
- Soil cover shall be applied daily. This practice will help to minimise the possibility of any spontaneous fires breaking out, which can produce large quantities of smoke and environmentally harmful gases. Moreover, if a fire does break out, it shall be extinguished immediately with water.
- As for dust from collection vehicles, National road 303 is to be improved with ADB funding by 2007 by paving it up to the entrance of the Killing Fields Memorial. The section from there to the entrance of the proposed disposal site shall be improved in the Dang Kor Disposal Site Development Project. Therefore, dust from collection vehicles is not expected and the impact on air pollution will be negligible.
- Landfill gas shall be monitored regularly after the site is closed to mitigate air pollution in the study area. The details of the monitoring program are mentioned in the section, “Description of the Project”.

f. Water quality

f.1 Environmental impact analysis

- Treatment of leachate from the landfill site in the operational stage
- Treatment of leachate from the compost plant
- Treatment of wastewater from the maintenance workshop
- Treatment of leachate from the landfill site in the closure stage

f.2 Mitigation Measures

- - All the leachate from the landfill site and compost plant is to be treated on site year-round and will not be discharged outside the site. Therefore, leachate will not affect the river water. The leachate treatment process will vary in the wet and dry seasons as described below. The systems are comprised of the same facilities although referred to by different names.

  Dry season: When the leachate quantity is small, it is to be treated with subsurface flow wetland ponds and evaporation ponds. Any overflow of treated leachate is to be returned to the regulation pond by recirculation pump.

  Wet season: If the quantity of leachate exceeds the capacity of the wetland ponds, the wetland ponds and evaporation ponds are to be used as reservoir ponds. In case the leachate exceeds the expected amount, an emergency line is to be constructed to return excess leachate to the landfill site via the overflow pit.
- - As for the infiltration into groundwater, the geological survey on the soil of the disposal site area revealed that the permeability of the natural soil is low. Therefore,

it can be said that the existing ground can be used as a natural liner to control leakage.

- - The wastewater from the maintenance workshop is to be treated. As the wastewater contains oils such as grease or lubricant oil, an oil trap shall be installed in the drain to recover the oil content.

- The leachate treatment facilities shall continue to be used after closure of the disposal site although the production rate of leachate will diminish with time. Moreover, leachate shall be monitored regularly after closure to protect the water quality of public water areas.

g. Hydrological situation

The environmental impact analysis and mitigation measures are same as "water quality".

h. Soil Contamination

h.1 Environmental impact analysis

-Prevention of contamination from infectionous and hazardous waste.

h.2 Mitigation Measures

In order to prevent soil contamination, Dang Kor disposal site shall be designed to receive only MSW and general waste from medical institutions and factories.

i. Noise

i.1 Environmental impact analysis

-Noise from waste collection vehicles.

i.2 Mitigation Measures

National road 303 is to be improved with ADB funding by 2007 by paving it up to the entrance of the Killing Fields Memorial. Then section from there to the entrance of the proposed disposal site is also to be improved in the Dang Kor Disposal Site Development Project. Therefore, traffic jams are not expected and the impact on noise will be negligible.

Generally, noise generated from vehicles is affected by the manner of driving. Therefore, all the drivers of collection vehicles shall undergo training to improve their manner of driving.

j. Offensive odor

j.1 Environmental impact analysis

-Offensive odor from the landfill site

-Offensive odor from the compost plant

j.2 Mitigation Measures

In order to reduce the offensive odor from the landfill site, soil cover shall be done daily.

In order to reduce the offensive odor from compost plant, the aerobic bio-decomposition method for composting shall be adopted. Moreover, composting works shall be done indoors.

k. Fauna and flora

k.1 Environmental impact analysis

- Leachate and landfill gas at the closure stage

k.2 Mitigation Measures

Leachate and landfill gas shall be monitored regularly after the disposal site is closed to protect the natural environment.

l. Landscape

l.1 Environmental impact analysis

- Harmonization of the disposal site and the surrounding landscape

l.2 Mitigation Measures

A buffer zone shall be installed around the disposal site to conceal the facilities and maintain the view of the surrounding area.

In order to maintain the scenic landscape, the height of the landfill shall be 11 m. Therefore, the impact will be limited.

10.6.3 Review of Data Surveyed

a. Air Pollution data

a.1 Review of the air pollution survey for baseline data

The air quality survey for baseline data of the project site was closely reviewed, including coordination of the effective digits of the values in the results tables. Table 15-53 in the supporting report was modified as follows.

Table 10-46: Air quality standard and monitoring results.

		NO_2 $\mu g/m^3$	SO_2 $\mu g/m^3$	CO mg/m^3	TSP mg/m^3	Pb $\mu g/m^3$
Standard	Cambodia	100	300	20	0.33	5
Station	Date					
A1	24/10/03	9.7	9.6	0.16	0.090	< 0.04
	25/10/03	10	7.0	0.26	0.15	< 0.04
	27/10/03	4.6	1.2	0.31	0.40	< 0.04
	30/10/03	3.9	1.5	0.16	0.071	< 0.04
	04/11/03	13	7.6	0.21	0.15	< 0.04
	05/11/03	3.1	1.3	0.31	0.31	< 0.04
	06/11/03	4.3	2.4	0.21	0.67	< 0.04
A2	24/10/03	3.0	8.7	0.63	5.2*	0.21
	27/10/03	12	7.0	1.0	1.2	0.070
	28/10/03	16	10	0.73	0.44	0.080
	29/10/03	8.6	4.3	1.1	0.47	0.040
	30/10/03	15	12	0.94	0.14	0.080
	31/10/03	6.9	5.6	0.63	4.4*	0.070
	05/11/03	18	6.0	0.78	14*	1.5
A3	28/10/03	5.7	11	0.94	2.8	0.71
	29/10/03	18	10	0.78	2.7	0.050
	30/10/03	26	4.6	1.5	0.18	0.96
	31/10/03	15	5.1	1.0	1.3	0.73
	04/11/03	21	17	1.5	3.1*	0.68
	05/11/03	14	4.7	1.6	2.9*	0.13
	06/11/03	28	5.3	1.6	13*	0.13

* Data is questionable

a.2 Re-survey of TSP

The results of TSP in samples from A2 and A3, located along national road 303, are generally higher than those of A1, located almost in the center of the proposed site and at a distance

from road 303. This is because of the traffic volume on road 303, as mentioned in "section 15.4.3 a. Air pollution" in the main report. However, some of the data (marked with a *) were higher than expected.

Accurate results of the air pollution survey are quite essential as baseline data, so the re-survey mentioned above must be carried out before commencement of the project operation.

b. Water Quality Data

The water quality survey for baseline data of the project site was closely reviewed and some points were rectified including coordination of the effective digits of the values in the results tables. Table 15-54 to -56 in the supporting report were modified as follows.

Table 10-47: Groundwater analysis results

Date			18/11/2003	18/11/2003	18/11/2003	18/11/2003	18/11/2003	18/11/2003	18/11/2003
Station Name			Landfill 1	Landfill 2	Anlong Kong Cha	Bakou 1	Bakou 2	Khvav	Rolous
Station Code			GW1	GW2	GW3	GW4	GW5	GW6	GW7
GPS position			N 11°28'46.2"	N 11°28'38.5"	N 11°28'27.4"	N 11°28'16.3"	N 11°28'16.9"	N 11°30'24.3"	N 11°28'56.9"
			E 104°53'25.8"	E 104°53'53.2"	E 104°52'14.9"	E 104°53'28.5"	E 104°53'40.1"	E 104°53'59.1"	E 104°54'06.0"
Parameters	Unit	MoE Standard							
Temperature	(°C)		31.8	31.6	30.6	30.1	29.8	29.7	29.3
pH		6.5-8.5	6.8	7.2	7.8	6.8	6.8	6.8	7.2
Turbidity		NTU	160	2.1	1.9	57	1.6	1.5	1.1
Color		Pt/Co	160	7.0	11	19	29	13	8.0
Electric Conductivity	(us/cm)		573	533	831	425	985	471	1700
DO	(mg/L)		2.8	2.8	1.7	0.98	1.2	1.2	1.2
Alkalinity (as CaCO3)	(mg/L)		181	248	399	186	202	144	594
Oil content	(mg/L)		< 5	< 5	< 5	< 5	< 5	< 5	< 5
Total Coliforms	(#/100 mL)	<5000	0	160	0	0	0	0	0
BOD5	(mg/L)	1-10	6.5	1.5	0.9	5.4	2.0	0.82	1.1
COD	(mg/L)		2.0	1.3	0.92	0.80	1.1	0.72	0.92
SS (TSS)	(mg/L)	25-100	470*	16	2.0	270*	4.0	11	4.0
Ammonium - N (NH4-N)	(mg/L)		0.073	0.023	0.014	0.039	0.063	0.028	0.012
Na+	(mg/L)		5.0	4.4	7.7	3.4	4.8	3.5	11
K+	(mg/L)		0.59	0.060	0.056	0.026	0.041	0.046	0.014
SO42-	(mg/L)		75	15	26	16	190	22	120
Cl-	(mg/L)		0.29	0.33	0.29	0.37	0.70	0.33	0.21
Tot-P	(mg/L)		3.4	0.028	0.0089	0.28	0.015	0.011	0.024

Date			18/11/2003	18/11/2003	18/11/2003	18/11/2003	18/11/2003	18/11/2003	18/11/2003
Cd	(ug/L)	<1	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Pb	(ug/L)	<10	14*	< 5.0	< 5.0	7.0	< 5.0	< 5.0	< 5.0
Cr total	(ug/L)		29	< 2.0	< 2.0	9.6	< 2.0	< 2.0	< 2.0
Cr6+	(ug/L)	<50	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15
Cu	(ug/L)		12	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Zn	(mg/L)		< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Fe	(mg/L)		5.4	0.5	0.11	6.3	0.56	0.29	0.12
Mn	(mg/L)		< 0.10	0.93	< 0.10	0.49	1.0	0.83	0.54
As	(mg/L)	<0.01	0.0046	0.0005	< 0,0003	< 0,0003	< 0,0003	< 0,0003	0.0008
Tot-N	(mg/L)		0.57	0.071	0.050	0.064	0.17	0.12	0.17
HCO3-	(mg/L)		346	486	277	138	381	312	832
CN-	(ug/L)	<0.005**	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Hg	(mg/L)	<0.0005	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
PCB 28	(ug/L)	0	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
PCB 52	(ug/L)		< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
PCB 101	(ug/L)		< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
PCB 138	(ug/L)		< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
PCB 153	(ug/L)		< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
PCB 180	(ug/L)		< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003

* Data are suspected or even minimum quantitative limits are higher than the standard of Cambodia

**Cambodian standard should be reviewed (more than 1,000 times higher than the Japanese drinking standard)

Table 10-48: Surface water analysis results (1/2)

Date			18/11/2003	18/11/2003	18/11/2003	28/10/2003	28/10/2003
Station Name			**Boeng 1**	**Boeng 2**	**Boeng 3**	**River**	**Canal**
Station Code			**SW1**	**SW2**	**SW3**	**SW4**	**SW5**
GPS position			N 11°28'46.8"	N 11°28'42.9"	N 11°28'51.4"	-	-
			E 104°53'27.0"	E 104°53'17.1"	E 104°53'23.2"	-	-
Parameters	**Unit**	**MoE Standard**					
Temperature	**(°C)**		34.7	32	32.6	26.5	30.0
pH		**6.5-8.5**	7.7	7.2	7.0	6.87	6.95
Turbidity	**NTU**		980	16	150	42.10	117
Color	**Pt/Co**		850	58	470	400	470
Electric Conductivity	**(us/cm)**		97.6	98.9	82.9	39.0	35.0
DO	**(mg/L)**		5.8	4.5	3.7	-	-
Alkalinity (as CaCO3)	**(mg/L)**		128	219	144	8.85	9.84
Oil content	**(mg/L)**		< 5	< 5	< 5	2	3
Total Coliforms	**(#/100 mL)**	**<5000**	1900	900	1600	130	510
BOD_5	**(mg/L)**	**1-10**	6.1	5.3	4.5	14	9.6
COD	**(mg/L)**		4.6	6.4	6.2	27*	24*
SS (as TSS)	**(mg/L)**	**25-100**	1900*	24	180*	110	99
Ammonium - N	**(mg/L)**		0.072	0.017	0.031	<1	<1
Na^+	**(mg/L)**		1.5	0.50	0.55	<0.05	0.05
K^+	**(mg/L)**		0.063	0.020	0.023	<0.1	<0.1
$SO4^{2-}$	**(mg/L)**		25	3.3	3.4	8.3	6.0
Cl^-	**(mg/L)**		0.57	0.37	1.3	5.4	6.9
Tot-P	**(mg/L)**		0.20	0.043	0.19	0.80	1.4
Cd	**(ug/L)**	**<1**	0.63	< 0.50	< 0.50	<50*	<50*
Pb	**(ug/L)**	**<10**	47*	< 5.0	14*	<1,000*	<1,000*
Cr total	**(ug/L)**		190	< 2.0	13	<200	<200
Cr6+	**(ug/L)**	**<50**	0.29	< 0.15	< 0.15	<5	<5
Cu	**(ug/L)**		60	< 5,0	5.4	<200	<200
Zn	**(mg/L)**		0.19	< 0,10	< 0,10	0.27	0.24
Fe	**(mg/L)**		64	1.2	6.7	0.62	1.0
Mn	**(mg/L)**		0.16	0.89	0.12	<0.1	<0.1
As	**(mg/L)**	**<0.01**	0.0042	< 0,0003	< 0,0003	<0.01	<0.01
Tot-N	**(mg/L)**		1.7	0.85	0.24	1.5	2.3
HCO3-	**(mg/L)**		311	173	104	63.9	65.1
CN-	**(ug/L)**	**<0.005****	< 2	< 2	< 2	< 1	<1
Hg	**(mg/L)**	**<0.0005**	< 0,0001	< 0,0001	< 0,0001	<0.005*	<0.005*
PCB 28	**(ug/L)**		< 0.006	< 0.006	< 0.006		
PCB 52	**(ug/L)**		< 0.006	< 0.006	< 0.006		
PCB 101	**(ug/L)**	**0**	< 0.006	< 0.006	< 0.006	<0.2	<0.2
PCB 138	**(ug/L)**		< 0.003	< 0.003	< 0.003		
PCB 153	**(ug/L)**		< 0.006	< 0.006	< 0.006		
PCB 180	**(ug/L)**		< 0.003	< 0.003	< 0.003		

* Data are suspected or even minimum quantitative limits are higher than the standard of Cambodia
**Cambodian standard should be reviewed (more than 1,000 times higher than the Japanese drinking standard)

Table 10-49: Surface water analysis results (2/2)

No.	Parameters	Unit	Standard for in public	Sample No			
				SW4		SW5	
				Dry season	Rainy season	Dry season	Rainy season
1	Temperature	^{o}C		24.5	26.5	25.5	30.0
2	pH		6.5-8.5	7.00	6.87	7.00	6.95
3	Electric Conductivity	μ S/cm		83.0	39.0	153	35.0
4	Turbidity	NTU		20	42.10	410	117
5	Color	Pt/Co		440	400	24,000	470
6	Alkalinity	mg/l		22.0	8.85	104	9.84
7	Oil Content	mg/l		<1	2	<1	3
8	Total Coliform	MPN/100ml	<5000	150	130	430	510
9	BOD_5	mg/l	1-10	1.7*	14	<1	9.6
10	COD	mg/l		15*	27*	19*	24*
11	SS	mg/l	25-100	360	110	5,600	99
12	Ammonium-N	mg/l		19*	<1	6.5	<1
13	Na^+	mg/l		<0.1	<0.05	4.6	0.05
14	K^+	mg/l		17	<0.1	2.8	<0.1
15	SO_4^-	mg/l		46	8.3	530	6.0
16	Cl^-	mg/l		9.9	5.4	79	6.9
17	HCO_3^-	mg/l		21.7	63.9	59.9	65.1
18	Total Phosphorus	mg/l		0.32	0.80	0.13	1.4
19	Cadmium	μg/l	<1	<100*	<50*	<100*	<50*
20	Cyanide	μg/l	<0.005**	6	<1	<1	<1
21	Lead	μg/l	<10	<1000*	<1000*	<1000*	<1000*
22	Total Chromium	mg/l		<0.1	<0.2	<0.1	<0.2
23	Hexavalent Chromium	μg/l	<50	<5	<5	<5	<5
24	Arsenic	μg/l	<10	<10	<10	<10	<10
25	Copper	mg/l		<0.1	<0.2	0.13	<0.2
26	Zinc	mg/l		<0.1	0.27	<0.1	0.24
27	Iron	mg/l		14	0.62	<0.3	1.0
28	Manganese	mg/l		<0.1	<0.1	0.38	<0.1
29	Total Nitrogen	mg/l		2.2	1.5	6.5	2.3
30	Total Mercury	μg/l	<0.5	2*	<5*	12*	<5*
31	PCB	μg/l	0	<0.2	<0.2	<0.2	<0.2

* Data are suspected or even minimum quantitative limits are higher than the standard of Cambodia
**Cambodian standard should be reviewed (more than 1,000 times higher than the Japanese drinking standard)

10.6.4 Public Hearing

As a part of the EIA survey, public hearings were organized three times. The outline of these public hearings is summarized as follows.

a. Outline of public hearings

a.1 Main Objective

The main purpose of the public hearings was to build a consensus with all the stakeholders.

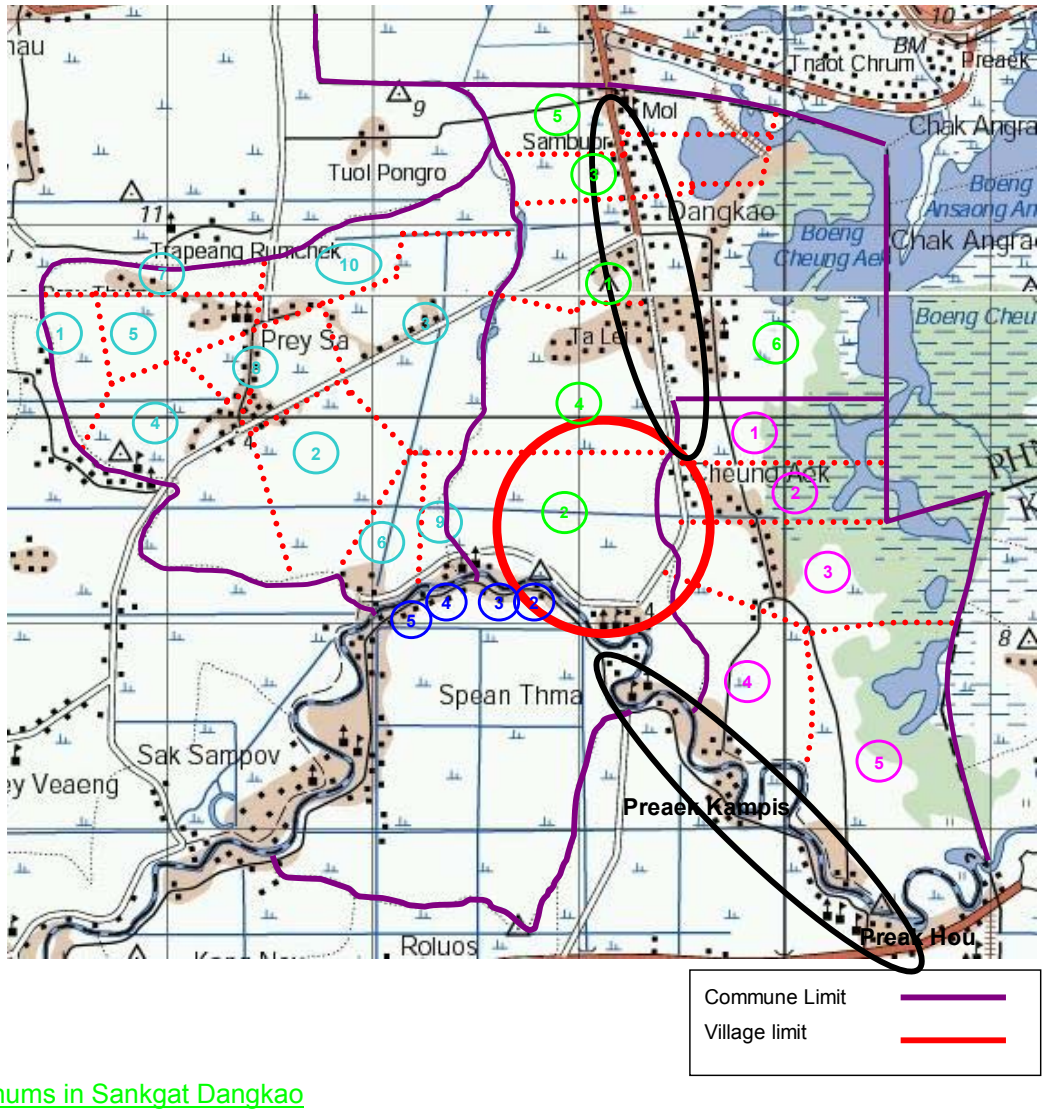
The first hearing was arranged before the start of the EIA survey. To reflect the opinions and comments from participants in the EIA survey plan and the final development plan was also an important objective.

a.2 Main target areas and participants of public hearings

The following three areas were selected as possibly most affected areas: the area within a radius of 1km from the center of the planned disposal site (within the red circle on the map shown below), along National Road 303 (in the black oval), and along the middle part of the Prek Thnot river basin (in the other black oval). (In the lowest reaches of the river, river

water is not utilized for drinking or living water.) In the area within a radius of 1km from the planned disposal site, all the households were regarded as stakeholders, while only local authorities were invited from the two other areas.

From the first public hearing, all the households located inside the circle were supposed to be invited to the public hearings. However, C/P insisted on the importance of informing all the Sangkats and Phums in Khan Dang Kor first and that they should be invited to the first public hearing. In the end, all the Sangkats and Phums were invited, while only representatives (leaders of housing group) of local residents, not all the households, were invited due to the limited space of the place of meeting.



Phums in Sankgat Dangkao
1: Thmey; 2: Bakou; 3: Sambour; 4: Ta Ley; 5: Mol; 6: Khva
Phums in Sangkat Cheung Aek
1: Choeung Ek; 2: Rolous; 3: Sroc Chek; 4: Prey Pranak; 5: Prek Thloeung
Phums in Khum Spean Thma (in Kandal Province)
1: Preaek Chrey; 2: Doung; 3: Ha; 4: Svay Mean Leak; 5: Spean Thma;
6: Meun Tra; 7: Anhchanh; 8: Kouk Ovloek
Khum Preaek Kampis (in Kandal Province)
Khum Preak Hou (Kandal Province)

Figure 10-34: Possibly most affected areas by the new disposal site

Waste pickers working at the SMC disposal site were not invited to the public hearings because it was almost impossible to organize them due to the lack of representative organizations. Instead, the social environmental survey in the first phase tried to obtain their opinion and future plan after the closure of the disposal site. In addition, PPWM and the team organized a meeting inviting NGOs and community leaders that were actively involved in waste picker issues, to exchange opinions on how to support waste pickers in finding alternative jobs. It is necessary for MPP/PPWM to arrange this kind of meeting regularly from now on and to establish a mechanism through which waste pickers can contact PPWM easily.

a.3 Follow-up survey

Although the question and answer sessions at each public hearing were active, it was expected that many of the local authorities and residents had difficulties in understanding the content of the presentations due to their limited knowledge on solid waste management, and that some participants hesitated to express opinions in front of authorities. Therefore, the team conducted a follow-up survey after each public hearing in order to check their level of understanding of the presentations and to obtain their opinions and comments on the development plan.

In the following sections, three public hearings and the result of the follow-up surveys are summarized. The details are shown in Annex 15 (1st and 2nd hearing) and Annex 18 (3rd hearing) of the Supporting Report.

b. Result of public hearings

b.1 First public hearing

b.1.1. Public hearing

Objective

The first public hearing was organized before the EIA survey started. The main purpose of the first public hearing was to inform all the stakeholders of the development plan and its EIA survey plan. Since it is expected that many of participants were not familiar with solid waste management, the basic idea of solid waste management and its current conditions in Phnom Penh were presented before the explanation of the development plan.

Another main objective was to reflect the results of the first public hearing in the EIA survey plan as well as in the proposed disposal site development plan.

Schedule

Date: December 25, 2003
Time: From 8:00 a.m. to 11:00 a.m.
Location: Thom Matray Pgoda, Commune Pray Sor

The location was decided considering the convenience of local residents.

Attendants

The attendants of the first public hearing were as follows:

Project owner side:
PPWM: Heng Lay Orn (governor)

Leng Simen (vice governor)

Representative of Khan Dang Kor
Deputy Governor Mey Mon

Local Participants
Sangkat and Phum representative
Local residents (mainly leaders of housing groups)
NGO: 1 (Pour un Sourire d'Enfant)

JICA side
JICA study team

Regarding local authorities and residents, a total of 95 people (including 8 local police officers) from 12 Phums participated in the hearing. Among them, 52 people were from the possibly most affected areas.

Table 10-50: Local Participants

Commune	Village	Local Authority (Commune/ Village)	Housing Group Leader	Others	Remarks
Dang Kor	Ta ley	3	4	17	'Others' included 14 farmers
	Thmey	4	4	0	
	Bakou	3	0	0	
	Khvar	2	0	0	
Cheung Aek	Rolous	4	5	3	'Others' included 1 farmer
	Preak Pranak	1	2	0	
Prey Sa	Prey Sor East	3	4	0	
	Anlong Kong	4	9	1	'Others' was a teacher
	Prey Sor West	1	0	0	
	Pra Kar	2	9	0	
	Tituy	1	0	0	
	Peam	0	0	0	
Others (NGO)			0	1	
Total		28	37	22	87

Plus: 7 police officers from Prey Sor East and 1 from Pream (for security)

Program

The 1st public hearing was done as follows:

1	Registration		7:30 - 8:00
2	Opening Remark	by Mr. Mey Mon (Deputy Governor of Commune Dang Kor)	8:00 - 8:15
		by Mr. Anai (Leader of the JICA Study Team)	
3	Presentation of the Dong Kor disposal site development plan and the EIA survey plan		
	3-1 Current situation of waste management in MPP	by Mr. Kani (JICA Study Team)	8:15 - 8:45
	3-2 Outline of the proposed Dang Kor new disposal site	by Mr.Anai (JICA Study Team)	8:45 - 9:15
	3-3 Outline of EIA survey plan	by Mr. Higo (JICA Study Team)	9:15 - 9:45
4	Q&A	Facilitator: Mr. Makathy	9:45 - 10:15
5	Closing Remark	by Mr. Heng Lay Orn	10:15 - 10:45

by Mr. Mey Mon

Facilitator: Mr. Makathy and Ms. Kani
Interpreter: Mr. Makathy

Q&A

There were several questions. It seemed that many of the attendants already knew something about the problems caused by disposal sites from their experience of the SMCDS, and that they are concerned that the same things will happen in the proposed disposal site.

The Q&A session is summarized below.

Question or Comment	Answer
It will cause a problem without improving R303.	ADB has a plan to improve R303.
I am very concerned about the possibility of water contamination by leachate from the new disposal site, because local residents here use underground and river water as drinking and domestic water.	The JICA Study Team is now conducting a geological survey and will design the disposal site based on the result of the survey. This will prevent water contamination as much as possible.
How will farmers be able to make a living after they sell their land? How far from the disposal site can people settle?	The new disposal site will create some jobs such as workers. Landowners who sell the land will be given a priority to get these jobs. We have a plan to construct a "Green Belt" of 50m in width to separate the disposal site from the surrounding areas, so they can settle in the area adjacent to this buffer zone.
Why you are not considering an incinerator?	Because an incinerator is too expensive and Cambodia cannot afford it. It costs approximately US$ 300 per ton to incinerate waste, while at present PPWM spends only US$ 0.6 for the landfill operation (open dumping).

b.1.2. Follow-up survey

Objective

A follow-up survey was arranged to check how much the participants of the first public hearing understood the explanations and what they thought about the new disposal site plan and the EIA survey plan.

The approach to the second public hearing was modified based on the result of the first public hearing and the follow-up survey.

Method

Survey Method: Interview Survey

Selection of Interviewees:

Interviewees were selected based on the attendant list of the public hearing. Residents in villages which are far away from the new disposal site were eliminated from the selection list.

Implementation of the survey

The survey was conducted from October 27 - 28.

Findings

The findings are summarized below.

- Although the majority of the respondents replied that they understand waste disposal issues, the extent of their understanding is questionable. Their limited knowledge on waste management issues may have lead them to believe that they understand these issues better than they actually do. PPWM and the team need to make more effort to ensure a greater understanding of these issues.
- Moreover, all the respondents agree with the new disposal site plan, but it would be better to analyze these data carefully. They may have made their decisions based on their limited knowledge and on unscientific grounds such as the remarks of local authorities. In order to achieve a real consensus with local residents, it is necessary for MPP/PPWM to deepen the knowledge of local residents on waste management issues and to establish a mutual (two-way) relationship between MPP/PPWM and local residents.
- On the other hand, few respondents recognized PPWM as either the project owner or the responsible organization of the EIA survey. Its presence at the first public hearing was not visible enough for the local residents. Therefore, it is vital for PPWM to take a leading role in the second public hearing and to guarantee that they themselves will take all the necessary measures to prevent serious environment problems as the responsible organization.

b.2 Second Public Hearing

b.2.1. Public Hearing

The Draft Final of the Dang Kor disposal site development plan was made based on the first public hearing, and the EIA survey was conducted according to the Draft Final. The second public hearing was organized at the end of December 2003, after the EIA survey was completed.

Objective

The main objectives of the second public hearing were to inform the result of the EIA survey and to discuss about it.

Since the result of the follow-up survey revealed that many of local participants were not clear about the responsible organizations of the development plan and the new disposal site's operation, the roles and responsibilities of institutions were clarified at the second hearing. In addition, the importance of public participation in the Dang Kor development project was emphasized.

Schedule

Date: December 25, 2003
Time: From 8:00 a.m. to 11:00 a.m.
Location: Thom Matray Pgoda, Commune Pray Sor

The location was decided considering the convenience of local residents.

Attendants

Unlike the first public hearing, the target participants were narrowed down to those who are living in the three possible most affected areas. In particular, all the households located within a radius of 1km from the project site were invited, though a third of them did not attended the hearing.

Project owner side

MPP: Mr. Sok Leakhena (Deputy chief of Cabinet)

PPWM: Heng Lay Orn (governor)
Ms. Nay Ratha (Staff)
Ms. Hem Visal (Staff)

Others

Sangkat and Phum officials (near the project site and along R303 and the Thnot River)
Local residents (mainly coming from near the project site)
NGOs: 4 (Pour un Sourire d'Enfant, Urban Resource Center Cambodia and so on)
MOE: Mr. Sarun Smbo (Department of Pollution Control)

JICA side

JICA Cambodia office
JICA study team

Table 10-51: Number of local participants (both officials and residents)

Location	Note	Number of Attendants
The area within a 1km radius from the center of the proposed disposal site (A part of Bakou, Cheung Aek, Rolous, Ha and Doung)	Both local authorities and residents	214
Along National Road 303 from the proposed disposal site until the bridge which is located at the north edge of Dang Kor Commune)	All the participants were local authorities	6
Along the downstream area of the Prek Thnot River which is located to the south of the proposed disposal site (from the south of the proposed disposal site until the bridge of National Road 2)	All the participants were local authorities	5
Other areas in Dang Kor		148
NGOs		6
Total		379

Program

The second public hearing was done as follows:

1	Registration		7:30 - 8:00
2	Opening Remark	by Heng Lay Orn (Governor)	8:00 - 8:15
3	Presentation of the draft final development plan for the Dong Kor disposal site and the EIA survey results		
	3-1 Background of the proposed disposal site development plan	by Mr. Sok Leakhena (Deputy Chief of Cabinet)	8:15 – 8:45
	3-2 Outline of EIA survey results	by Mr. Higo (JICA Study Team)	8:45 - 9:15
	3-3 Draft final plan of the Dang Kor disposal site development project	by Mr. Shimura (Vice Team Leader of JICA Study Team)	9:15 – 10:30
4	Q&A	Facilitator: Mr. Makathy	10:30 – 10:45

Q&A

It seemed that many of the attendants already knew something about the problems caused by disposal sites from their experience with the SMCDS, and that they are concerned that the same things would happen in the proposed disposal site.

The Q&A session is summarized below.

Question or Comment	Answer
In order to make sure of avoiding environmental problems, unlike the two existing disposal sites, I would like to make the following two requests.	
1. Please complete all the construction work before starting waste disposal at the proposed site.	1. This is a matter of course. We will complete all the construction work before starting waste disposal at the proposed site.
2. According to the explanation today, the MOE is	2. Monitoring is essential to ensure proper

responsible for controlling and monitoring the operation. If the operation will not be implemented according to the plan, we will take action to oppose the project.	operation of the disposal site. All the people and parties concerned must check whether it is causing problems or not. Furthermore, we would like you to keep watch of the site to make sure it is being properly operated.
We are concerned about the effect of the construction and operation of the disposal site. We understand mitigation measures are already considered. Still I have two questions. 1. When will the disposal site start operation? 2. Please complete all the construction work before the start of operations at the new disposal site.	1. Operation of the site is to start from 2008. However, it may change depending on the schedule of the request or implementation.

b.2.2. Follow-up Survey

Objective

The main purpose of the follow-up survey was to determine how well the participants of the public hearing understood the explanation of the development project and the result of the Environment Impact Assessment survey, and to obtain their opinions on the development project.

Since the result of the previous follow-up survey showed that questions with three or four choices did not reflect the actual situation well, in the follow-up survey of the second public hearing more free-answer questions were used in order to analyze more precisely.

Method

Survey Method: Questionnaire survey at the house of interviewees (for local residents)
Questionnaire survey by mail (for NGOs)

Selection of Interviewees:

- The targets of the interview survey were participants who were from the three target areas. Those who were from other areas were eliminated from the samples.
- All the local authorities and NGOs were selected as samples.
- As for the sampling of ordinary people, housing group was used as a basic sampling unit. From each housing group, one housing group leader and 1 or 2 ordinary people were selected as samples. Ordinary people were selected randomly by interviewers at the time of the interview survey, considering the balance in terms of sex and age. In the event that the housing group leader did not attend the hearing, 2-3 ordinary people were selected as samples.

Implementation of the survey

The survey was conducted from January 6 – 14, 2004.

Findings

- More than half of the respondents replied that they understood well why Dang Kor was selected as the new disposal site, and all of them agreed with the development plan either without condition or on condition. However, judging from the result of the free-answer questions, it seems that the level of understanding is not high. In particular, most respondents did not understand the responsible organizations of the development plan and the new disposal site's operation. It is necessary for MPP and PPWM to take every opportunity to open information to local residents and to make them understand the development plan further.

- The result of the interview survey revealed that many of the respondents are interested in a monitoring system. It is important to establish a reliable monitoring system to build a real consensus with local residents.

b.3 Third Public Hearing

As mentioned above, the development plan had to be modified due to the increase in land price by speculation after the disclosure of information on the development plan. The third public hearing was organized to explain the modified development plan and the result of the EIA survey based on the modified plan.

Since the follow-up surveys of the previous two public hearings showed that many of participants did not understand the responsible organizations correctly, at the third public hearing MPP and PPWM took initiative roles as project owners and answered all the questions but the technical issues.

b.3.1. Public hearing

Objective

The third public hearing was conducted with the following objectives:

- To explain the background of the 3rd public hearing
- To report the results of the EIA review
- To respond to the comments from MOE on the EIA report and from attendants of the 1st and 2nd public hearings.
- To explain the change of the development plan and to explain the development plan.

Schedule

Date:	15th of July 2004
Time:	8:00 ～ 11:00 am
Venue:	Thom Matray Pagoda, Prey Sor Sangkat（Same as previous）

Attendants

At the third public hearing, most of the local participants were from the three most affected sites. More local authorities from Kandal province attended the hearing.

Project owner side:

MPP	Mr. Heng Vantha	Deputy Chief of Cabinet
PPWM	Mr. Sao Kuchhon	Governor
	Mr. Leng Simen	Deputy Governor

Representative of Khan Dang Kor

Khan Dang Kor	Mr. Krouch Phan	Governor

JICA side

JICA Study Team
JICA Cambodia office

Others

MOE	Mr. Oung Vuthy	Department of EIA
DOE	Ms. Kuon Kinny	Deputy Director

Local authorities and residents

Category of attendant	Number
Local authorities and residents (from within a 1km radius from the center of the proposed disposal site)	303 persons
Local authorities (along National Road 303 and along the downstream of the Prek Thnot River)	21 persons
NGOs	9 persons
Press	11 persons

It is calculated that 83.7% of the total number of target households attended the 3rd public hearing in comparison to 51.3% in the 2nd public hearing.

Program

1	Registration		7:30-8:00
2	Opening remark	Mr. Heng Vantha , Deputy Chief of Cabinet, MPP	8:00-8:15
3	Presentation		
3-1	Background of the 3rd public hearing and answers to the comments of attendants at the 1st and 2nd public hearings	Mr. Sao Kuchhon, Governor, PPWM	8:15-8:45
3-2	The results of EIA review	Mr. Oung Vuthy, Department of EIA, MOE	8:45-9:15
3-3	The Dang Kor development site development plan and its modification	Nr. Takeshi Higo, JICA Study Team	9:15-9:45
3-4	Evaluation of the modified development plan	Ms. Kuon Kinny, Deputy Director, DOE	9:45-10:15
4	Q&A		10:15-10:45
5	Closing remarks	Mr. Krouch Phan, Governor, Dang Kor Khan	10:45-11:00
6	Press tour		11:30-12:30

Q&A

The Q&A session is summarized below.

Question or Comment	Answer
(by local authority of Phum Spean Thmor, Srok Kandal Stung, Kandal province) There are many households in Kandal province along the lower part of the Preak Thnot River and we use river water as drinking water. So I am worry about water contamination by leachate. I also requested the MPP/PPWM to complete all construction work before starting disposal of the waste at the proposed dump site. Lastly, when will the construction start and end?	(by PPWM Governor) As mentioned in the presentation by the JICA Study Team and DOE, the bottom of the landfill is a layer of clay about two meters in depth; and the sand layer will be secured by an impermeable clay layer. Therefore, it is able to conserve ground water quality. For countermeasures against flooding, the enclosing bank will be installed higher than the flood level. As a result, floodwater will not flow into the landfill so waste water generated in the landfill cannot spread to the outside area. PPWM is responsible for DKDS, and PPWM will respect the technical instructions of the JICA Study Team, monitoring from DOE and MOE as well as the observation from the local people. This means that this project is the responsibility of all concerned agencies. Local people and authorities will make objections against this operation if there are any faults. Regarding the construction period, at earliest, it will start in January 2006 and will finish in December 2006.
(by PSE) Does MPP have any solutions or measures for the waste pickers who work at SMCDS?	(by PPWM governor) DKDS will operate differently from SMCDS. All waste except market waste will be immediately covered by soil at the landfill area. This means

Question or Comment	Answer
Second question: For the DKDS, are waste pickers allowed to enter the landfill or not? If allowed, how many waste pickers will be allowed to enter the DKDS?" How many waste pickers will be chosen to work in the composting plant at the DKDS? Because there are a lot of waste-picker families working at SMCDS.	that waste pickers at the SMCDS will lose their jobs. In order for them to earn a living, PPWM is planning to employ some of the waste pickers as workers for primary waste collection or for the composting plant. If they do not want to work as mentioned above, they can change their jobs. Based on the plan, we will not be able to employ all waste pickers to work for the DKDS. MPP and other NGOs have been discussing how to help them. I noticed that JFPR which works closely with poor people is considering this as well.
(by CCC) There are 3 questions: • What is the total area of the DKDS? How many years can we dispose of waste at the DKDS? • What type of wastes can be disposed of? Can industrial, hospital and hazardous waste be disposed of at this landfill? • How can you secure soil for daily soil covering?	(by DOE) • The total area of DKDS is 30 ha. • This landfill receives only municipal solid waste, not industrial, hospital and hazardous waste, because we have a place where industrial and hazardous waste can be discharged in Kandal province. • The soil for soil covering will be taken from the DKDS. (by JICA Study Team) The lifespan of DKDS is six years. This is the image of the landfill operation in Thailand. Daily soil to cover the waste will be taken from the reservation area of the landfill. When we start operation, we have to consider the future operation of the landfill. For Dang Kor dumpsite, first we will operate landfill area A; therefore, the soil for covering the waste will be taken from landfill area B. The hole generated by soil excavation will be filled with waste.
(by World Vision) • As PPWM mentioned before, PPWM is planning to employ waste pickers to work as primary waste collectors and composting plant workers. How many workers will be required for Dang Kor dumpsite? • How many waste pickers (percentage) who work at SMCDS are ensured to be chosen by PPWM to work for new disposal site?	(by JICA study team) As PPWM mentioned, waste pickers will not be allowed to pick through waste at the DKDS. PPWM is planning to employ waste pickers who work at SMCDS to work as primary collection workers. PPWM will also expand the collection service to un-serviced areas so PPWM will employ waste pickers who can work with PPWM

b.3.2. Follow-up survey

Objective

At the third public hearings, several participants asked questions and there were vigorous discussions on the environmental and socio-economic impacts of the disposal site. However, most of the questions were asked by participants from NGOs. As with the two previous public hearings, a follow-up survey was conducted after the third public hearing in order to grasp how well the local authorities and residents understood the content of the presentations and what they thought of the proposed development plan.

Method

Survey Method: Questionnaire survey at the house of interviewees
Team assistants visited the houses of selected participants and conducted an interview with them based on the questionnaire.

Targets of survey

The targets of the follow-up survey were local authorities and residents that attended the third public hearing. Regarding the local authorities, all the participants (in total 30) were selected as interviewees, while samples of ordinary people were selected randomly from participants.

Sampling method

All the resident participants were divided by the housing group they belong to. The number of samples allocated to housing groups was decided according to the number of participants, and samples are randomly selected from each housing group. The number of participants of the third public hearing and samples of the follow-up survey by Sangkat are shown below.

Table 10-52: Number of participants by Sangkat

Sangkat	Sangkat Chief	Phum chief	Local Residents
Cheung Ek		7	113
Dangkor	1	7	165
Prey Sor		2	0
Spen Thmomey	2	1	25
Prek Hou	2		0
Total	5	17	303

Table 10-53: Samples for interview survey by Sangkat

Sangkat	Sangkat Chief	Phum chief	Local Residents		total
			Housing Group Leader	Ordinary people	
Cheung Ek		7		22	29
Dangkor	1	7	1	33	42
Prey Sor		2			2
Spen Thmomey	2	1		8	11
Prek Hou	2				2
total	5	17	1	63	86

Survey Period

The interview survey was conducted from August 12 to 14, 2004.

Contents of Questions

The questions were divided into the following four categories:

- First and second public hearings
- Outline of the third public hearing
- Level of understanding about the development plan
- Comments and opinions about the development plan

The result of the follow-up surveys after the first and second public hearings revealed that it is very difficult to evaluate the level of understanding of local people about the development plan by questions with 3-4 choices. Therefore, in this survey, free-answer questions were used as much as possible

Findings

The findings are summarized below.

- Even though this was the third public hearing, it could be said that the local authorities and residents understood the development plan roughly but their knowledge was still fragmented. Since their knowledge of waste management is so limited, it is necessary for MPP and PPWM to take further measures to ensure they have a good understanding of the development plan, possible risks and countermeasures.
- The development of visual educational materials about waste management for beginners is one possible measure. (A sample of educational material to explain

what kind of place final disposal sites are has already been developed.) The presentation method and style should be also improved. One possible idea is for PPWM and MPP staff to visit each village and organize a small meeting to provide necessary information with developed educational materials before the development plan is finalized. It is very important for MPP and PPWM to make a continuous effort to keep in touch with local authorities and residents and to make sure they understand the development plan well.

- At this time, those who were against the development plan appeared for the first time. It is likely that as more people deepen their knowledge on waste management issues, more people will be against the plan. It is necessary for MPP and PPWM to promote dialogue with local authorities and residents and to establish a relationship of mutual trust.

10.6.5 Conclusion

Based on the careful examination of the project, the environmental resources, the environmental impact analysis, the results of public participation, the environmental mitigation measures, analysis of alternatives, the environmental management plan and institutional capacity, it is expected that the negative impact of this development project on the environment can be controlled to be negligible. The conclusion for each aspect is as follows.

a. Project

The Project is for the development of a new disposal site in Phnom Penh and the project owner is MPP. The Project is essential for proper SWM in Phnom Penh and to continue to provide SWM services to the citizens as the existing disposal site, SMCDS, will be closed by the end of 2007. The implementation of the project will provide public benefit to Phnom Penh citizens and contribute to SWM and environmental conservation in Phnom Penh.

The Project covers all stages of development, i.e. the construction stage, operational stage and closure stage, with environmental consideration. The site location, size, and disposal methods were also determined giving adequate consideration to the environment. The environmental management plan is also well considered. In addition to countermeasures, the setting up of a monitoring committee for the Project and training for staff are also planned.

b. EIA Procedure

The Project is subject to an EIA in accordance with the Sub-decree on the Environmental Impact Assessment Process in Cambodia. As required in this Sub-decree, first an IEE was conducted and submitted to MOE.

The EIA of the Project was carried out based on the result of the IEE, which covered the environmental items that had been authorized by MOE on July 16, 2003.

c. Review of the standard in Cambodia

The parameters of the water quality standard in Cambodia in public areas such as cyanide and PCB should be reviewed. The standard of 0.005 μ g/l for cyanide seems to be too low compared with that of developed countries such as Japan, and the 0 μ g/l of PCB is not a suitable value as a standard.

d. Strengthening of MOE laboratory work

Firstly, the MOE laboratory should consider raising the analytical level and strengthen measurement data management. The role of the analytical laboratory is to produce measurement-based information that is technically valid and of known quality. Raising the analytical level and strengthen measurement data management are essential to provide precise and accurate laboratory data. Therefore, training to develop the skill of analysts and installation of data assurance systems such as QA/QC systems are required.

Secondary, the MOE laboratory should install advanced measurement systems to meet the Cambodian standard is needed. For example, the minimum quantitative limit of cadmium and lead were higher than the standard in Cambodia in public areas. This is because the analysis methods are basic and cannot reach the level of the standards. So far, there has been no other choice for the MOE laboratory as they do not have advanced equipment which can detect levels lower than the Cambodian standard. However, environmental monitoring is an essential part of their work, so the installation of advanced equipment to apply new techniques is indispensable.

The concentrations in COD were too high in comparison to other parameters such as BOD. This is because "5220 C Closed Reflux Titrimetric", the method for measuring COD in the MOE laboratory, is for higher concentrations of COD such as 40-400 mg/l.

The MOE laboratory should install advanced equipment and establish an advanced monitoring system.

e. Re-survey of mercury and others

The concentrations of mercury in samples from SW4 and SW5, the Prek Thot River and the irrigation canal at Choeung Eak commune, located in and around DKDS exceeded the standard for public water areas in Cambodia. Although they were not in excess in the rainy season, they should be re-surveyed because mercury is very toxic and can accumulate in the aquatic food chain in the case of organic mercury. As mentioned in the section 15.4.3 b.3 Surface water analysis results, there is a possibility of contamination by pesticide. If so, the possibility of organic mercury is very high.

Therefore, not only total mercury but also organic mercury must be re-surveyed for confirmation before the operation of DKDS. The measurements of total and organic mercury are very sensitive and the concentrations are expected to be very low, so the measurements should be done by agencies which have advanced techniques such as Thai or Japanese laboratories.

Other parameters should also be re-measured before implementation of the project such as the COD in samples from SW4 and SW5, the cyanide in samples from SW4 and SW5, the SS in samples from GW1, GW4, SW1 and SW3, the lead in samples from GW1, SW1, SW3, SW4 and SW5, and the cadmium in samples from SW4 and SW5.

Accurate results of the water quality survey are quite essential as baseline data so the re-survey mentioned above must be carried out before commencement of the project operation.

f. Public participation

In the EIA process, public participation and the publicizing of information were seriously considered.

As mentioned in the previous sub-section, three public hearings were arranged in order to build consensus with the stakeholders and reflect their comments and questions in the project plan. Public hearings provided opportunities for both the project owners and local authorities and residents to exchange opinions, but due to the limited knowledge of local authorities, residents and NGOs on solid waste management, some participants could not fully understand the presentations at the public hearings, as shown in the result of the follow-up surveys after each of three public hearings. It is necessary for MPP/PPWM to continue to take an effort to deepen their knowledge on solid waste management and understanding on the development plan.

As for the opening of information, all the development plans and contents of the public hearings including the questions and answers were presented on a web site.

g. Capacity of the project owners

The owner of the project is MPP. PPWM and DOE under MPP are responsible for operation and for control and monitoring of the Project respectively. As the C/P in the Study on Solid Waste Management in the Municipality of Phnom Penh implemented by JICA, the staff of PPWM and MOE are undergoing training to enhance their skills through the pilot project for the improvement of SMCDS.

h. Items that require special consideration

As a result, the impact of the Project on the surrounding environment is expected to be negligible, or diminished through mitigation measures and other projects that are expected to be implemented. However, special consideration will be needed for the following items.

i. Proper implementation

Even if the plan, design and construction of the proposed landfill will be completed as a sanitary landfill, monitoring is the key to securing environmentally sound landfill operation. Therefore, during the construction, operation and closure stage, regular monitoring is essential. The following table shows the environmental items to be seriously considered for proper implementation.

Parameter	Adverse impact
Water quality	The disposal site will generate leachate and if it is discharged into the river or canal or infiltrates into the groundwater, it will cause contamination. Leachate will continue to be generated after termination of the landfill operation, although the generation rate will diminish with time
Offensive odors	Organic waste disposed of at the site will generate offensive odor.
	The compost plant in the site will also generate offensive odor.
Landfill fires	Landfill fires may occur and generate harmful smoke at the landfill site.

In order to establish a monitoring system, a monitoring committee for the Project is proposed. The committee members shall participate in the monitoring and observe the environmental conditions of the site and its surroundings.

The committee may include:

- MPP
- MoE
- DoE
- NGOs
- Representatives from local authorities and residents

As for the frequency of monitoring, internal monitoring by PPWM shall be done every month, and monitoring by the monitoring committee shall be carried out twice a year.

j. Road improvement

Based on the waste collection and transportation system in the M/P, the collection vehicles will make a total of 322 trips per day in 2007. So the number of trips made by collection vehicles is not so large. However, the current road conditions are bad, as the road is not paved. The following environmental items would be seriously affected.

- -Noise
- -Traffic jams
- -Air pollution

The most effective countermeasure is to pave the road. The ADB will implement the "Mekong Tourism Development Project". In this project, national road 303 will be paved in order to create better access from the center of Phnom Penh to the Killing Field Memorial. The section of the road from there to the entrance of the proposed disposal site is also to be paved in the Project. Therefore, noise, traffic jams and air pollution will be negligible.

k. Alternative jobs

When the existing disposal site in SMC is closed at the end of 2006, a large number of waste pickers working there will lose their jobs. In addition, the land owners of the site for the new landfill in Dang Kor will lose agricultural income as the proposed site, which will be bought by the project owner, is mainly rice fields. It is very important to consider alternative jobs for them. The details are described in 12.7, Project Evaluation of "Closure Plan of the SMC disposal site".

Chapter 11

Waste Collection Service Expansion Project

11 Waste Collection Service Expansion Project

11.1 Design Concept

According to the collection system proposed in the M/P, MPP/PPWM will eliminate the unserviced area and insufficiently serviced area in the city in collaboration with the private sector. What MPP has to do is to provide the waste collection service to the areas in the three rural Khans that are not covered by CINTRI because it is economically unfeasible. This project is to establish a required waste collection system for PPWM, which is the implementing agency of waste management in MPP, to expand its collection service to such unserviced areas.

11.2 Preliminary Design of Collection System

11.2.1 Design Conditions

a. Target Year

The collection service by PPWM is to begin in 2007.

b. Target Areas of the Collection Service

PPWM will provide the waste collection service to areas that the private sector cannot cover in the three rural Khans. The service area will be settled based on negotiations between MPP and the private sector, but they have not reached an agreement as of the end of February, 2005. Therefore, the Study team will prepare the waste collection service expansion project based on the planned collection amount estimated below, without identifying the area.

c. Waste Amount

c.1 Issues to be consider for providing collection service

Conditions within the proposed collection area include several general patterns of development and land-use densities. These can be summarized as follows:

Designation	Conditions
High to medium density planned development	Mixed residential/commercial land use with standard planned road grid including paved primary roads, with paved or un-paved secondary and tertiary roads. This pattern provides easy access for larger collection vehicles
High to medium density unplanned areas with moderate road access	Primarily residential land use with some small business. Most areas have an un-planned road network. Roads are generally passable, but maybe unsurfaced, narrow or subject to flooding. Also an important factor for planning of a waste collection system, many of these areas have low overhead wires or low hanging trees.
Generally high to medium density unplanned areas with little or no road access.	Primarily residential land use with some small businesses. Areas are without a suitable road network. Access is generally by footpaths, alleyways and small bridges. These areas are inaccessible for normal collection trucks.
Medium to low density unplanned areas with moderate road access	These areas are generally on the fringe of development and may be undergoing conversion from agricultural to residential land use.
Low density rural areas	These areas are outside the developed areas and produce negligible waste. These areas have not been included in this waste management plan.

A mixed collection system with several types of collection vehicles and collection methods is proposed to meet the specific needs of each area. As with any waste collection system, the participation and cooperation of the residents and waste generators in the service area will be essential for the success of the collection service and improvement of sanitary conditions within the area.

A key factor in fostering the participation and cooperation of residents will be a public education campaign aimed at raising understanding and awareness of the environment and waste collection issues. This will require collaboration between the waste collection service providers (PPWM and CINTRI) and the agency tasked with developing and conducting educational campaigns and activities.

The required public response should be clearly defined for each area and each type of collection service. For example, in areas with curbside collection service, the public should place their waste at the curbside on the appropriate day and time only. In areas with stationary collection service (communal collection points), residents will be required to bring their own waste to the collection point and place it into the containers provided. These messages must be tailored to each area. All areas will require general campaigns aimed at educating the public to stop littering and illegal dumping. Special campaigns will also need to be developed to educate specific types of waste producers about proper waste disposal methods relating to their activities, such as street vendors and construction companies.

When the specific public response has been defined, the key messages and dissemination approach should be identified. The use of several communication methods should be encouraged in any public education campaigns. This can include broadcasting (radio, TV), public visual communication (posters, banners), print media (booklets, hand-outs with monthly billings), and direct communication (meetings and discussions). Other methods are also possible. The message to be communicated should be clearly presented in an interesting and innovative way to catch and hold people's interest.

In order to ensure public cooperation and compliance, a set of discharge rules should be adopted in addition to the public campaigns mentioned above. The following rules are proposed to control waste discharge.

Table 11-1: Waste Discharge Rules

Waste Discharge Rules

To meet the needs of the mixed collection approach used in the Master Plan for the period 2007-2015, the following discharge rules are proposed for all household and small waste generators:

- The Sangkat authorities should ensure that all residents are informed about the collection schedule and discharge rules for their areas.
- To avoid scattering, all loose waste (such as household, commercial and office waste) must be placed in plastic bags (with the top tied closed) or placed in an appropriate waste container (made from bamboo, plastic or metal) with a cover.
- Containers used for curbside collection must be no larger than 120 liters and not weigh more than 30 kg (container plus waste).
- All larger waste (such as garden waste, wood, construction materials, etc.) should be cut into pieces not longer than 1.2 meters and securely tied with cord or wire into bundles weighing not more than 30 kg.

- Where the separate collection service is provided, residents must separate their waste into the appropriate categories and discharge it in separate bags or containers.
- Waste must be stored at the customer's premises until the scheduled collection day. At the designated date and time, the waste should be placed at the curbside for collection.
- In areas with the container collection system, waste should be placed inside the container. Waste must never be placed on the ground or discharged in a place not designated for that purpose. If containers are full, waste should be stored at the customer's premises until containers are available.

All waste producers regularly discharging more than $1m^3$ or 300 kg of waste per day are required to discharge waste in standard "skip" type containers for mechanized collection. To insure high collection efficiency and standardization of equipment, waste producers are required to lease the appropriate container from PPWM. Non-PPWM containers are not permitted.

c.2 Planned Collection Amount

The Study team estimated the planned collection amount for PPWM based on the results of site reconnaissance and analysis of the weighbridge data of SMC disposal site and the following assumptions:

- The daily collection amount in 2004 of the private sector is the mean of the daily waste amount brought in the SMC disposal site during October and November, 2005.
- The waste amount collected by the private sector in the three rural Khans will increase 10% annually after 2004.
- The planned waste amount to be collected by PPWM is the difference between the waste collection amount proposed in the M/P and that of the private sector.

Table 11-2: Planned Collection Amount (unit: ton/day)

Collection amount	2007	2008	2009	2010	2011	2012	2013	2014	2015
Households	82.6	100.2	116.7	132	145.9	158.5	188.2	216.2	242.1
Commercial-Restaurants	8.1	8.5	9.3	9.9	9.9	13.3	13.5	13.6	17.5
Commercial-Others	20.6	22.1	24.5	26.5	26.7	36.3	37.2	38.1	49.1
Markets	14.1	15	16.5	17.8	17.9	24.2	24.7	25.2	32.4
Hotels	0.4	0.5	0.5	0.6	0.6	0.8	0.8	0.8	1
Offices	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4
Schools	1.4	1.4	1.6	1.7	1.7	2.3	2.3	2.3	3
Factories	15.9	16.5	17.9	19	18.8	25.1	25.4	25.6	32.8
Hospitals	2.7	2.8	3	3.2	3.1	4.2	4.3	4.3	5.5
Slaughter House	1.9	2	2.1	2.2	2.2	2.9	2.9	2.9	3.7
Unidentified source	8.4	9.2	10	10.9	11.8	12.7	13.7	15	16.2
Street Sweeping	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.7
TOTAL	156.5	178.7	202.7	224.4	239.2	281.1	313.8	344.8	404.4

11.2.2 Collection and Transport System

a. Collection Method

A mixed collection system is planned to meet the needs of the various conditions within the collection area. Two basic collection systems will be used. These are curbside collection and skip container collection.

Curbside collection will be divided into categories:

- Collection with 15 m^3 compactor trucks in areas with good road access
- Collection with 8 m^3 compactor trucks in areas with moderate road access

Skip container collection will be divided into four categories:

- Stationary collection in public parks and areas with poor access
- Stationary collection linked with primary collection service (with pushcarts) where residents choose this extra service
- Stationary collection inside recycling centers with a primary collection service where residents choose this extra service and suitable government land for construction of recycling centers exists
- Leased containers for use by large waste generators

In addition to the above, a single dump truck will be used for collection of street sweeping waste.

b. Equipment Plan

The equipment necessary for the collection service shall be utilized in combination based on the optimal technical system proposed in the M/P. The combination of equipment is shown in Table 11-3.

Table 11-3: Combination of Equipment

Generation Source		Collection Method	Equipment	Fr. of collection
Household	Areas with difficult road access	Primary collection + Container collection	SL, Container (5 m^3), Recycling Center, Push Cart	3 times per week
		Container collection	SL, Container, (5m3)	3 times per week
	Areas with road access	Curbside/Bell collection	Compactor Truck (4, 8, 15m^3)	3 times per week
Business Establishments	Small scale	Curbside/Bell collection	Compactor Truck (4, 8, 15m^3)	Every day
	Large Scale	Container collection (Lease)	SL, Container (5 m^3)	Anytime available
	Others	Container collection	SL, Container (5 m^3)	Anytime available
Road Sweeping		Curbside Collection	Dump Truck	Twice a week
Public Park		Container Collection	SL, Container (5 m^3)	Twice a week

b.1 Required Collection Equipment

The number of vehicles and other equipment required for operations is shown in the following table.

Table 11-4: Required Collection Equipment

Equipment	2007	2008	2009	2010	2011	2012	2013	2014	2015
Compactor truck 15m3	8	9	10	12	12	14	16	17	19
Compactor truck 8m3	3	3	3	3	4	4	5	5	6
Compactor truck 4m3	3	4	4	5	5	5	6	7	8
Skip loader truck	5	6	7	7	7	8	9	10	11
Container（5m3）	37	45	51	51	52	61	67	74	86
Dump truck	1	1	1	1	1	1	1	1	1
Wheel loader	1	1	1	1	1	1	1	1	1
Pick-up truck	2	2	2	2	2	2	2	2	2

b.2 Depreciation period of equipment

The useful life of vehicles and equipment has been calculated as follows:

Table 11-5: Useful Life of Vehicles

ITEM	USEFUL LIFE (years)
Equipment	
Compactor Truck - 8m^3	7
Compactor Truck – 8m^3	7
Compactor Truck – 15m^3	7
Dump truck	7
Skip Vehicle	7
Skip Container	7
Wheel Loader	7
Pushcarts	3
Pick-up Truck	7
Other	
Container Station	20
Recycling Center	20

11.3 Plan of Maintenance System

11.3.1 Periodical Maintenance

In order to perform maintenance for effective operations, problems that may occur during periodic checks should be analyzed and equipment should be repaired. At present, maintenance work by PPWM is not being done effectively due to lack of facilities (work shop) and personnel (skilled labor). PPWM should conduct periodical maintenance of equipment and miner repair work only. Heavy maintenance should be done by an authorized dealer or private workshop, especially for heavy equipment.

The periodical maintenance schedule and works is as follows.

a. General services

a.1 Collection and light duty vehicles

Skip loader, compactor truck, dump truck water tanker, and pick-up truck
- Maintenance every 3,000km or monthly
- Maintenance every 10000km or 3 months

- Maintenance every 18,000km or 6 months
- Maintenance every 36,000km or yearly

Table 11-6: Light and Heavy Duty vehicle

	3000km/month	10000km/3month	18000km/6month	36,000km/year
Engine oil	●	●	●	●
Oil filter	●	●	●	●
Fuel filter	●	●	●	●
Air element		▲	▲	●
Gear oil				●
Grease	▲	▲	▲	▲
Hydraulic oil				▲
Coolant				●

● : Change ▲ : Lubricant or Chang

a.2 Landfill Heavy Equipment

Bulldozer, wheel loader, and excavator
- Every 100hr
- Maintenance every 250hr or monthly
- Maintenance every 500hr or 3 months
- Maintenance every 1000hr or 6 months
- Maintenance every 2000hr or yearly

Table 11-7: Heavy Equipment

	Initial 100hr/month	Initial 250hr	250hr/month	500hr/3month	1000hr/ 6month	2000hr/1year
Engine oil	●		●	●	●	●
Oil filter	●		●	●	●	●
Fuel filter	●			●	●	●
Grease	▲	▲	▲	▲	▲	▲
Hydraulic oil						●
Hydraulic filter						●
Swing drive oil		●			●	
Final drive oil		●				

● : Change▲ : Lubricant or Change

Other preventive maintenance works are summarized below.

Table 11-8: Other preventive maintenance works

Equipment	Preventive maintenance
Collection equipment Light and heavy duty trucks	・Clutch overhaul, Propeller shaft repair works, Brake overhaul, miner axle repair works etc ・Battery charges & change, miner wiring works etc ・All tire repair works.
Landfill equipment Heavy equipment-tractor, wheel loader, excavator	・Track ,clutch, brake adjustment ,fuel nozzle adjustment ・Miner track repair works such as track adjustment. ・Battery charges & change, miner wiring works, etc

11.3.2 Heavy maintenance

At present, there are some authorized dealers that have a sufficient work system, skilled labor, and reliable spare parts for heavy maintenance works in the country. In addition, considering that the investment of special facilities or tools such as track undercarriage tools are high costing, PPWM owns less than 15 units of heavy equipment. Therefore, heavy maintenance for all major systems and overhaul works should be done by authorized dealers or suitable private workshops.

Recommended maintenance works to be done by private workshops are as follow.

Table 11-9: Recommended Duties

Equipment	Heavy maintenance
Collection equipment Light and heavy duty trucks	・Overhaul works (Engine, Transmission, Differential, Injection pump, Generator, Steering gear box,) ・Heavy Electric works（Generator ,Starter over hauls） ・Heavy Body works
Landfill equipment Heavy equipment-tractor, wheel loader, excavator	・Overhaul works (Engine, Transmission, Differential, Brake, Clutch, Hydraulic pump etc.) ・Radiator repair ・Track undercarriage repair and rebuild services (Sprocket, shoe, roller, etc) ・Heavy Electric works

11.4 Operation Plan

11.4.1 Staffing

The staff required for scenario 2 and 1 are shown in the following table respectively.

Table11-10：Personnel required for collection service (Scenario 2)

	2007	2008	2009	2010	2011	2012	2013	2014	2015
Section Chief	1	1	1	1	1	1	1	1	1
Collection Engineer	1	1	1	1	1	1	1	1	1
Supervisor	2	2	2	2	2	3	3	3	3
Cleck	3	3	3	3	3	4	4	4	5
Driver	22	25	27	30	31	34	39	42	47
Operator	1	1	1	1	1	1	1	1	1
Worker	43	49	53	59	61	69	78	84	95
Worker in Center	5	5	5	5	5	5	5	5	5
Sweeper	25	32	32	38	38	44	44	50	50
TOTAL	103	119	125	140	143	162	176	191	208

11.4.2 Public Participation

In order to ensure effective public participation in SWM the collection service provider must form a partnership with another agency such as the Municipal Department of Environment (DOE) to educate the public on SWM issues, especially waste handling, storage and discharge.

PPWM, CINTRI, and donors should work with DOE to develop the capacity to formulate and carry-out effective education campaigns and programs which convey the required information, build public understanding of the issues, and encourage residents of the city to follow established discharge rules and guidelines.

To be effective, all education campaigns and programs must be adapted to the needs of each area as collection methods may vary according to local conditions. Service providers should first develop a collection plan for each area and identify what specific participation will be required from the public in that area. An Education Planning Team should then be set-up from the main stakeholders to plan the approach to be used to convey the required information to the public. The planning process should include observation of existing waste discharge conditions to understand how proposed changes will effect peoples lives and

what habit changes are required by the public. Public input should be sought through interviews, public meetings and focus groups in-order to make the education activities as effective as possible. Draft discharge rules should be discussed to ensure that they are realistic and appropriate to conditions.

All education programs and campaigns should include baseline data collection and follow-up surveys to gauge the impact of the campaigns. The resulting information should be analyzed by the Education Planning Team to assess the effectiveness of various education approaches. The results of the analysis should be used to improve and up-date the educational approach in an on-going process to obtain the maximum result.

11.4.3 Fee Collection, Customer Data Management and Monitoring System

As shown in the table below, in the fee collection system, PPWM prepares monthly bills through its customer management system, which was developed based on collection service agreements made with customers. The Sangkat delivers the bills to the customers, collects payments, and sends the payments to PPWM. The Sangkat receives a commission for its service.

As for customer data management, the Sangkat notes any resident shifts at the time it collects the monthly payments and reports any changes to PPWM. Based on that information, PPWM exchanges service agreements and updates the customer database.

As with customer data management, the Sangkat monitors the collection service provided by PPWM when it collects the monthly fees by listening to complaints and suggestions for improvement from customers, and reports them to PPWM and DOE. PPWM formulates a suitable improvement plan to deal with the complaints and implements it based on DOE approval. If PPWM has not submitted an improvement plan after two weeks, DOE will push PPWM to submit one and inform MPP.

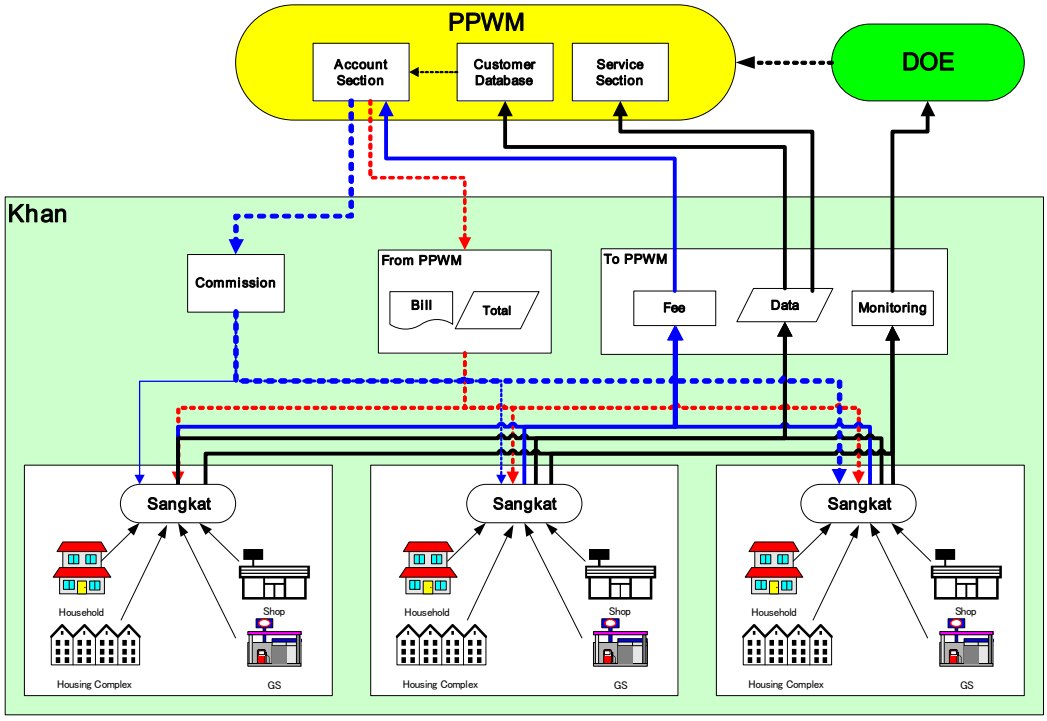


Figure 11-1: Fee Collection System

11.4.4 Maintenance plan

Proper maintenance (including general, preventive, and back-up services) will increase the actual economic life and operation efficiency of waste collection vehicles and landfill equipment. In order to solve the current problems shown below, the study team proposed to improve the maintenance system as shown in the table below.

Management system
- Responsibilities and roles are not clearly defined
- Poor data management (equipment ledger, each inspection sheet, etc.)

Technical system
- No maintenance facilities or tools
- No technical staff in the field
- No proper periodical maintenance is done

Table 11-11: Phased Improvement Plan for the Maintenance

	Immediate (2004-2007)	Target year (2008-2015)
Objective	・ Preparation of effective organization ・ Preparation of preventive maintenance system	・ Effective organization is established ・ Preventive maintenance system is established
Organization	・ Maintenance organization should be established	・ Maintenance organization is established
Facilities	・ Temporary w/shop for collection & landfill equipment maintenance is established in existing SMCDS. ・ Preparation of preventive maintenance tools and equipment	・ New w/shop at new disposal site for Collection & landfill equipment maintenance ・ General & Middle range of w/shop tools and equipment are prepared
Personnel	・ Preparation of w/shop personnel	・Skilled worker are prepared
Duties	・ All periodical maintenance for collection equipment and maintenance every 6-month period for heavy equipment ・ Back-up services (site duties) & normal repair work ・ Normal repair work ・ Heavy repairs, overhauls are made by private w/shop ・ Preparation of each working sheet	・ All periodical maintenance for both collection and landfill equipment ・ Back-up service ・ Normal repair works ・ Heavy repair ,overhauls are made by private w/shop ・ All working sheets are prepared and filled properly
Record System	・ Preparation of preventive maintenance record ・ Preparation of equipment record ・ Spare parts and Materials management record	・ All necessary systems are established -Preventive maintenance -Recording -Store stock management
Training	・ Management training for engineers and technicians ・ Technical training for mechanics ・ Training for operators and drivers ・ Office management training	・ Own preventive maintenance training system is established ・ Skilled drivers and operators are prepared ・ Skilled office management staff are prepared
Other	・ Establishment of material security system	・Material security system is established

a. Objective/Organization

Effective organization and the preparation of a preventive maintenance system is to ease monitoring and the preparation of an economical operation schedule of the collection and landfill equipment. PPWM shall be reviewed and the need for improvement and enhancement of their roles shall be identified. This will also help sustainable SWM in general.

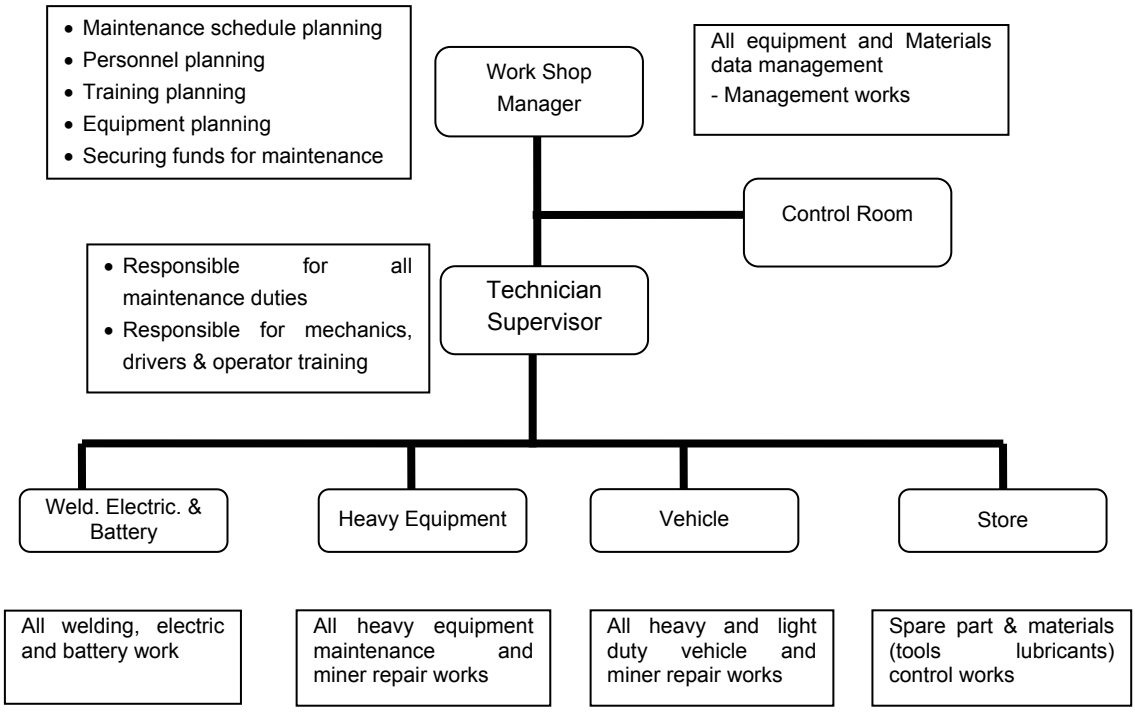


Figure 11-2: Proposed Organization for the Maintenance

b. Facilities

PPWM's present operational capability is very limited because its maintenance section does not have a maintenance workshop. PPWM should prepare space and facilities for a w/shop and equipment such as general tools and a washing machine as soon as possible. As for the immediate plan, a permanent w/shop is not necessary; construction of a temporary w/shop and parking yard somewhere in the existing disposal site will be sufficient. Small-scale hand tools and equipment will be furnished.

b.1 Workshop

In order to conduct proper maintenance works, a proper facility such as a maintenance workshop is indispensable. The workshop will consist of several service shops, a maintenance yard, a tire/welding shop, a battery shop, parts/material storage, tool storage and management office for both collection and heavy equipment.

Table 11-12: Proposed Maintenance Facilities for Temporary Workshop

Facilities
Heavy equipment maintenance yard
Vehicle maintenance yard
Spare & data control room
Spare & tool storage room
Manager & meeting room
Lubricant storage room
Washing yard
Washing equipment storage

b.2 Equipment

Equipment and tools will be furnished for the maintenance and miner repair of the vehicles and heavy equipment. Portable type equipment and tools should be selected to assure the convenience of the works.

c. Personnel

PPWM should arrange experienced and skilled personnel for its maintenance section as soon as possible. At minimum, an engineer, a technician (or supervisor), mechanics and office clerks (including store keeper) are required. The recommended personnel qualifications and numbers are as follows:

Table 11-13: Required staff for Maintenance System

Stuff	Immediate	2007	2012	2015
Engineer/Workshop manager	1	1	1	1
Technician/Supervisor	1	2	2	2
Mechanics	4	6	8	9
Store keeper/Office clerk	1	3	3	3
Total	7	12	14	15

Table 11-14: Qualification of Staff

Personnel	Qualification
Engineer	More than 10 years experience in w/shop management, both heavy and light duty equipment. Applied mechanical engineer by recognized authorities.
Technician/Supervisor	More than 15 years experience in site duties, both heavy and light duty equipment. Applied technician by recognized authorities.
Mechanic	More than 5 years experience in site duties, both heavy and light duty equipment.
Store keeper	More than 7 years experience in store management. Knowledge of computers is necessary.
Clerks(control room)	More than 3 years experience in office duties. Knowledge of computers is necessary.

d. Duties

The actual economic life and operation efficiency of waste collection and landfill equipment depend on the degree of maintenance. PPWM's maintenance section will carry out periodical maintenance (all periodical maintenance for vehicles and every 6-month period for heavy equipment in the immediate plan and all periodical maintenance in the target plan) and daily minor repair works in the initial stage (immediate stage). According to an investigation, authorized dealers have adequate technical support capability and work systems. Heavy repairs and overhauls shall be done by those workshops or other suitable institutions. Drivers and operators are required to obtain proper instruction of their daily duties. The personnel duties are as follows.

d.1 Mechanical section (incl. technicians and mechanics)

Type of Equipment	Duties
Medium equipment maintenance work (Skip loaders, dump trucks, compactor trucks, etc.)	・All periodical service ・Daily maintenance ・Repair works (except engine and transmission Differential, fuel pump overhauling) ・Tire and welding services ・Other miner works
Heavy equipment maintenance work (Bulldozer, wheel loader, excavator, etc.)	・All periodical service* ・Daily miner repair works ・Other miner works

*1-6 month periodical maintenance in an immediate plan

d.2 Operator and Drivers

Operators /Drivers	・Daily before and after check ・Entry of daily log book ・Safety and prevention of equipment failure ・Secure of own equipment

d.3 Store section

Daily	・Daily materials in-out management ・Order and purchase of materials
Monthly	・Monthly stock taking of materials
Yearly	・Yearly stock taking of materials

e. Recording Systems

Preparation of a recording system is to ease monitoring and the assessment of present equipment conditions. The following records are necessary.

Equipment management system	・Equipment ledger ・Repair history record
Preventive maintenance system	・Periodical service ledger ・Daily, weekly, and monthly inspection sheet ・Spare parts, lubricant and material ledger ・Numbering systems (vehicle, equipment, spare parts) ・Equipment log book

f. Training

Staffs trained have improved their equipment operation and maintenance capabilities. It is important to enhance skills, which might contribute to the improvement of the PPWM equipment and maintenance system in general.

Establishment of the training system is to improve the basic knowledge of the PPWM equipment maintenance personnel, including not only mechanics but also operators, drivers, and office clerks. In the initial stage of the plan, it is necessary to take consideration of technical cooperation such as the dispatch of experts.

Table 11-15: Training required

	Management	Technical	Data control	Record keeping
Engineer	●		●	●
Technician	▲	●		●
Mechanic		●		●
Store keeper			●	●
Office clerk			●	●
Driver		●		●
Operator		●		●

Proper planning is one of the key factors behind the conduct of smooth and effective works. The engineer or sometimes the technician needs skills in maintenance schedule planning, personnel management, parts and materials schedule planning, etc. For such training, they can be assigned to suitable agencies or authorized dealers.

Technical:

The mechanic or technician can be assigned to a local equipment dealer or authority to gain experience by working with their experienced staff. On their return, they can provide on-the-job training for other mechanics.

Operators and drivers will execute daily maintenance by themselves so they will be trained in appropriate maintenance methods using maintenance manuals or by on-the-the job training with the technician or supervisor.

Data control

Basic knowledge of computers can help and improve data control abilities. The staff can be sent to a training agency or suitable institution.

Record keeping

All responsible persons should be trained how to keep proper records or work sheets of maintenance/repairs and equipment in the workshop. On-the-job training is a common training method.

g. Security management

The quality of maintenance and materials will affect the life and efficiency of equipment. The materials used for maintenance, such as spare parts or lubricants, are expensive in Cambodia compared with the labor costs. Theft is often seen during working hours in developing countries. Prevention of this problem is also an important factor in equipment management. PPWM should make an effective plan.

	Point to notice	Measure to be taken
W/shop(including store)	・W/shop tools ・Spare parts	-Daily checking and numbering -Preparation of weekly check sheet -Preparation of daily issue voucher -Monthly store stock taking
Vehicle and Equipment (middle of work)	・Spare part ・Materials(Fuel)	-Keeping log book -Preparation of daily equipment check sheet -Before and after working equipment check sheet -Marking after general maintenance -Daily fuel record

11.5 Cost Estimation

11.5.1 Procurement Schedule

Based on the above data on vehicle and equipment requirements, the procurement schedule can be summarized as shown below.

Table 11-16: Equipment purchase schedule

Purchase Summary	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Totals
Equipment											
Compactor Truck - 4m3	3	1	0	1	0	0	1	4	2	0	12
Compactor Truck - 8m3	3	0	0	0	1	0	1	3	1	0	9
Compactor Truck - 15m3	8	1	1	2	0	2	2	9	3	1	29
Dump truck	1	0	0	0	0	0	0	1	0	0	2
Skip Vehicle	5	1	1	0	0	1	1	6	2	1	18
Skip Container	37	8	6	0	1	9	6	44	20	6	137
Wheel Loader	1	0	0	0	0	0	0	1	0	0	2
Pick-up Truck	2	0	0	0	0	0	0	2	0	0	4
Pushcarts	12	3	1	15	3	4	18	7	7	18	88
Other											
Container Station	11	3	1	2	1	1	3	4	2	0	28
Recycling Center	1	0	0	0	0	0	0	0	0	0	1

11.5.2 Investment Schedule

The investment cost necessary to procure collection equipment from 2005 to 2015 is shown in Table 11-17.

Table 11-17: Required Investment to Expand Collection Service (US$1,000)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Collection Equipment	1,746	193	140	195	59	219	320	1,601	521	144
Construction of facilities	58	2	1	2	1	1	2	3	2	-
Total	1,804	195	141	197	60	220	322	1,604	523	144

Note: Facilities include container bases, waste recycling centre.

11.5.3 O&M Cost

The O&M (operation and maintenance) cost consists of the expense for fuel, personnel, spare parts, uniforms and so on. Regarding the O&M cost of the maintenance workshop, the personnel and facility maintenance cost are summed up.

Table 11-18: Operation and Maintenance Cost (US$1,000)

	2007	2008	2009	2010	2011	2012	2013	2014	2015
Fuel	169	191	207	220	225	248	275	298	332
Personnel	83	94	99	110	112	127	138	149	163
Other (uniform etc.)	3	3	4	4	4	5	5	5	6
Maintenance	61	71	77	83	86	97	108	118	133
TOTAL ($US)	316	359	387	417	427	477	526	570	634

11.5.4 Waste Collection Cost

Table 11-19: Waste Collection Cost（1,000 US$）

	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014***	**2015**	**Total**
O&M Cost	286	325	352	379	390	434	485	524	588	3,763
Depreciation	178	203	221	245	253	281	322	210	369	2,281
Total Cost	464	528	573	624	643	715	807	734	957	6,044

The waste collection cost per 1 ton of waste from 2007 to 2015 is expected as follows. The average unit cost is 7.74 (US$/ton).

Table 11-20: Unit Cost

	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014 ***	**2015**	**Total**
Daily Collection Amount (ton/day)	156.2	178.4	202.3	224.0	238.8	280.6	313.3	344.3	403.7	
Yearly Collection Amount (ton/ year)	57,017	65,120	73,850	81,760	87,169	102,430	114,358	125,673	147,358	854,735
Unit Collection Cost ($US/ton)	8.14	8.10	7.76	7.64	7.37	6.98	7.05	5.84	6.50	7.07

* Depreciation costs in 2014 were off set by sale of scrap vehicles, resulting in a significant reduction of unit costs for that year

11.5.5 Summary of Public Cleansing Costs

Public cleansing consists of street sweeping and the collection of waste from public parks. For the period from 2007 to 2015, the streets targeted for sweeping will start at 4 to 8 km in the scenario2 area. Labor inputs for sweeping are summarized in the table below.

Table 11-21: Inputs for Public Cleaning

		2007	2008	2009	2010	2011	2012	2013	2014	2015
Road Cleaning *	km	4.00	5.00	5.00	6.00	6.00	7.00	7.00	8.00	8.00
Labor input**	pers/km	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25
Sweepers Required	pers	25	32	32	38	38	44	44	50	50
Waste Generation	kg/km/day	53.37	53.37	53.37	53.37	53.37	53.37	53.37	53.37	53.37
Waste Amount	ton/day	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4

* Figures shown are daily sweeping requirements based on cleaning all streets twice per week with a 6-day per week work schedule

** Based on data from CINTRI (350 sweepers / 56km = 6.25pers/km)

In addition to sweeper inputs, this section will have one dump truck with one driver and one worker for collection of the swept waste.

11.6 Project Evaluation

11.6.1 Technical Evaluation

The collection system is based on the following systems, and the improvement of the collection service cannot be achieved without the improvement of these systems.

1. Storage/Discharge System
2. Collection/Transportation System
3. Equipment Maintenance System

a. Storage/Discharge System

It is almost impossible to make the collection system work without proper storage and discharge practices by generators. Therefore, public cooperation and participation in the waste management system is indispensable to improve the collection system.

Therefore it is necessary for PPWM to make discharge rules and to make these rules understood widely through education programs and campaigns.

b. Collection/Transportation System

The collection efficiency of compactor truck collection is higher than that of container collection. However, compactor trucks can be utilized effectively only if the condition of roads is good. Therefore, compactor trucks are usable only in limited areas in the three Rural Khans.

Regarding household waste, the plan sets the ratio of curbside collection to the container collection in 2007 and 2015 at 1:1 and 6:4 respectively. On the other hand, business establishments are generally located along the street and the team expects that business wastes can be collected by compactor truck. In addition, the team proposes that a container be

leased to large quantity waste generators.

The proposed collection equipment is the same type of equipment that PPWM owns at present, and the number of types is limited to four. This simplifies the maintenance work.

c. Operation and Maintenance of Equipment

It is necessary to establish an equipment maintenance system in order to provide the collection service constantly. The maintenance workshop is to be constructed at the new disposal site in order to provide regular inspection and repair services. As long as the maintenance workshop is well maintained, the equipment necessary for collection and landfill work can be kept in good condition.

11.6.2 Social Evaluation

To establish the collection system proposed in the M/P, 267 personnel are necessary. The number of PPWM staff is 101, while the rest, 198, are temporary cleansing or sweeping workers. The team recommends that PPWM hire waste pickers as temporary workers.

When PPWM hires waste pickers as temporary workers, it is necessary for PPWM to use the waste picker database, which was developed under the pilot project, in order to keep the selection process transparent and fair.

11.6.3 Environmental Evaluation

a. Traffic jams, air pollution and noise by collection vehicles

Based on the waste collection and transportation system in the M/P, the collection vehicles will make a total of 557 trips per day in 2015. The number of trips made by collection vehicles is not large. However, the current road conditions are not sufficient because most roads are unpaved. Therefore, improvement of national road 303 is needed. Moreover, based on the field survey on public facilities around the study area, there are five schools and one health center along road 303. This makes improvement of road 303 essential.
National road 303 is to be improved with ADB funding by 2007, by paving it until the entrance to the Killing Fields Memorial. The section of the road from there to the entrance of the proposed disposal site is also to be improved in the Dang Kor Disposal Site Development Project. Therefore, traffic jams, air pollution and noise are not expected. Moreover, generally noise generated from vehicles is affected by the manner of driving. All the drivers of collection vehicles shall undergo training to improve their manner of driving. Therefore, air pollution and noise are not expected.

b. Prevention of waste scattering

In Phnom Penh, even in the central part where the collection service is adequately provided, garbage heaps and scattered waste are ubiquitous, not only causing a decline in the urban sanitary environment but also having a negative impact on the tourist industry due to the spoiled scenery. The beauty of Phnom Penh is maintained by street cleaning services, which are carried out somewhat to excess.
In order to solve this environmental problem, the following measures are recommended.

- In order to eliminate waste heaps and scattered waste, the collection service providers (PPWM and CINTRI) should establish the waste discharge rules proposed in the M/P in accordance with area features. The discharge rules should clearly provide information such as the disposal containers, times, days, and place, and should be

adequately publicized to the residents to obtain their cooperation. Furthermore, the collection service should be reliable and provided according to schedule.

- The administrative side (MPP) should raise public awareness by educating the residents (the beneficiaries of the service) about the need for public sanitation and environmental conservation so that they strictly adhere to the rules. The public education should include the required programs to eliminate the scattering of waste and littering. If such practices are stopped, the cost required for street cleaning can be reduced. As long as the high unemployment rate and cheap labor cost continue, the street cleaning service should be conducted manually.
- In order to prevent the litter falling from waste collection vehicles along national road 303, which is the access road from the center of Phnom Penh to the disposal site, enclosed waste collection vehicles shall be used. In the case of open top trucks, cloth tarps shall be used to cover them.

c. Wastewater from the maintenance workshop

The maintenance workshop located in Dang Kor disposal site will use a large volume of water for washing vehicles. This wastewater contains oils such as grease or lubricant oil. Therefore, countermeasures are needed.
The wastewater from the maintenance workshop is to be treated. As the wastewater contains oils such as grease or lubricant oil, an oil trap shall be installed in the drain to recover the oil content.

11.6.4 Financial and Economic Evaluation

a. Outline of the Project

The master plan formulated in this Study recommends that CINTRI, the private MSW collection and haulage company, should provide the service in the four urban Khans, where it seems to be financially feasible in terms of private business, and PPWM, the public sector, and CINTRI share the area in the three semi- urban Khans, where the service may not be financially feasible. Consequently, the basic public services will be provided equally to all the people in Phnom Penh.

The financial and economic appraisal made here targets the MSW collection and haulage services in the area where PPWM will provide the collection service.

b. Financial Appraisal

The financial appraisal here is made for 2 (two) cases, namely the case with no grant assistance and the case with grant assistance.

b.1 Preconditions of financial appraisal

The preconditions shown in the table below are common to the two scenarios.

Table 11-22: Preconditions of the Project for Financial Appraisal

Project Implementation Body	Phnom Penh Waste Management Authority (PPWM)
Project Period	10 years from 2006 to 2015
Project Income	Collection of user fees from the service users (households and business establishments) from 2007 to 2015. The fee collection efficiency is set at 80% for household users and for business establishments while the double fee rate of households

	is applied to businesses on a tonnage basis.
Investment Cost	Initial investment is made in 2006 for the following purposes. (Vehicles) ・ Compactor Truck (loading capacity of 4m3, 8m3 and 15m3) ・ Skip Loader Truck ・ Communal Containers (5m3) ・ Wheel Loader ・ Pushcarts ・ Pick-up Trucks ・ Dump truck (Facilities) ・ Container Stations ・ Recycling Center ・ Vehicles Maintenance Workshop Collection and haulage vehicles will be purchased in accordance with the increase in the number of service users and expansion of the service areas while the end-of-life vehicles and equipment will also be replaced.
O/M cost	The O/M cost is estimated for each year from 2007 to 2015 based on the determined unit cost and amount.
Depreciation	Depreciation periods of 20, 15 and 7 years are set for buildings, equipment and vehicles respectively. The scrap value is set at 10% for all vehicles and equipment while the buildings are assumed completely depreciated.
Price	All costs are estimated based on the current price of 2004. No price escalation is included.
Discount rate	10% (same as the case of Dang Kor Final Disposal Landfill Project)

b.2 Financial Appraisal

i) Case with no grant assistance

Assuming that FIRR of the project to be financially feasible is set at 10%, the Study estimated the required MSW collection fee per ton of waste. The result of the estimation is shown in the table below.

Table 11-23: Financial Viability and Fee rates

Fee Rate	Net Present Value	FIRR
10	- 1,370,578	- 5.08
11	- 1,022,691	- 1.06
12	- 674,807	2.83
13	- 326,920	6.59
14	20,968	10.22
15	368,854	13.72

Remark: Discount rate is set at 10%.

As shown in the table above, the fee rate needs to be set at above 13.94 US dollars per ton of waste collected to reach an IRR of 10%, the minimum required level of financial profitability of the project. In the case of applying this fee rate, the average monthly fee of MSW collection for household will be as shown in the table below.

Table 11-24: Estimated Fee Rate of MSW Collection for Household

	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015
Amount of MSW collected	Kg/month/ household	102	107	113	118	124	113	119	125	113
Fee rate	US$/month/ household	1.42	1.49	1.58	1.64	1.73	1.58	1.66	1.74	1.58

Remark: The decrease of the MSW collection amount in 2012 and 2015 comes from the increase in the reduction of MSW generation at the source by recycling, etc., which is assumed in the M/P.

As shown in the table above, the fee rate of MSW collection for household ranges from 1.42 to 1.74 US dollars per month per household during the project period. This estimated fee rate is between 1.7 to 2.0 fold of the current fee rate of 0.8 to 1.0 US dollar. Taking into account the current willingness and affordability to pay of the households in the three semi-urban Khans, this increase in fee rate is difficult to accept.

ii) Case with grant assistance

The Study here analyzes the fee rate of MSW collection in the case of providing grant assistance to fully cover the initial investment cost arising in 2005 and 2006. The financial feasibility of the project in this case is secured if it earns enough income to cover the whole project cost including depreciation, additional equipment investment and operational expenses arising during the project period.

Thus, the income from the project is required to comply with the following conditions so that it can be financially viable:

- Single year income always exceeds the project cost estimated on depreciation basis; and
- Reserved fund (accumulated income) of the project always exceeds the project cost estimated on actual investment basis.

The result of analysis shows that the required fee rate for MSW collection to comply with the conditions above is 11.61 US dollars per ton of waste collected.

The fee rate of 11.61 US dollars per ton of waste is 1.6 to 1.7 fold of the current collection fee rate of 7 US dollars in 2002 and 2003. However, the fee rate is reduced by 17 % by obtaining grant assistance.

Table 11-25: Estimated Fee Rate of MSW Collection for Household

	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015
Amount of MSW collected	Kg/month/ household	102	107	113	118	124	113	119	125	113
Fee rate	US$/month/ household	1.18	1.24	1.31	1.37	1.44	1.31	1.38	1.45	1.31

As shown in the table above, the monthly household fee rate of MSW collection ranges from 1.18 to 1.45, which is about 1.2 to 1.5 fold of the current fee rate of 0.8 to 1.0 US dollars per household per month. Although the unit cost is reduced by introducing grant assistance, measures for further reduction of the household fee rate should be developed.

c. Economic Appraisal

The MSW collection service provided by PPWM, which is currently proposed in the M/P, aims at providing the fundamental public service to un-services areas in Phnom Penh. Although it requires additional investment, it is the basic obligation of Phnom Penh City to provide equal MSW collection service to all the people living in Phnom Penh.

The current plan of MSW collection service in the three rural Khans is the result of examining the most cost efficient MSW collection and haulage methods by the Study; therefore, the incremental cost arising from the project is minimized as much as possible.

On the other hand, provision of MSW services to the three rural Khans is expected to create the following benefits although it is difficult to quantify in terms of their economic values.

- **Improvement of health, sanitation and environment for the citizen**

The waste is being dumped in the river and streets as well as open burned in the unserviced area. The serious threats caused by these waste affects human health, sanitation and living environment not only in the unserviced area but also whole city. Implementation of the project will prevent such pollution and improve the living environment of the city.

- **Promotion of socio-economic development**

Improvement of the health, sanitation and living environment will increase their value as the base of living and economic activities and vitalize socio-economic activities. Although there is currently a large economic gap between the four urban Khans and three rural Khans, the improvement of public services such as MSW collection will increase the potential of the three rural Khans as an alternative area of urban and economic development in the City of Phnom Penh.

- **Raising public awareness of the environment**

Although the pay service of MSW collection may cause adverse reaction of the people living in the three rural Khans, it may also raise their awareness on the environment if they properly understand the risk of the uncontrolled dumping of waste and the importance of environmental management in terms of protecting their health and living environment. An increase of public environmental awareness is also expected to encourage the efforts of waste reduction at sources, such as segregation, reuse, and recycling.

All of these expected effects of the project above will provide enough benefits to cover the cost required for its implementation.

Chapter 12

SMCDS Closure Project

12 Closure of the SMC Disposal Site

12.1 Design Concept

The SMCDS is approaching its capacity limit, and it will cease landfill operations in three years. It is necessary for PPWM to formulate a closure plan in order to demonstrate the operation and management of landfill work by its closure and the management of the disposal site after closure. In this chapter, matters that PPWM has to implement are summarized.

The key elements for the formulation of the closure plan of the SMCDS are shown in the following table.

Table 12-1: Key Elements of the SMCDS Closure Plan

Item	Unit	Qty
Total area of disposal site	ha	11.1
PPWM's own land (Existing area)	ha	7.5
Private land (Expansion area)	ha	3.6
Landfill Operation Period	3 years	(2004 - 12/2006)
Amount of Disposed Waste (accumulation)	ton	844,000
2004	ton	262,012
2005	ton	280,685
2006	ton	301,928

12.2 Preliminary Design of Closure

When the new final disposal site starts landfill operations, the existing SMC disposal site will be closed. The closure plan will be prepared to minimize the environmental impact and to examine technical and financial appropriateness as well as future land use.

12.2.1 Basic Requirements for Environmentally Sound Closure

The issues that PPWM should consider to carry out the closure plan properly are summarized below.

(1) Smooth transition from the old disposal site to the new disposal site
(2) Closure plan
(3) Future land use plan
(4) Monitoring plan

12.2.2 Smooth Transition from the Old Disposal Site to the New Disposal Site

a. Establishment of PPWM Management Systems

It is necessary for PPWM to establish a management system for the landfill section, compost plant, and maintenance workshop section of the DKDS before the start of operations. At present, however, PPWM does not have a management system for the SMCDS; hence, it is urgent for PPWM to establish the following management systems before the transition to the DKDS.

a.1 Personnel Plan

a.1.1. Present Management System

PPWM has the following facilities but it does not own any heavy vehicles necessary for the landfill operation.

- Administrative office (a simple tentative office constructed by the team under the pilot project
- Weighbridge facilities (constructed by the team in June, 2003)
- Landfill plots
- Septage sludge treatment ponds

The only work that PPWM actually does at the SMCDS is the weighing of waste and sludge brought into the disposal site. All operational works are conducted by a private contractor, which owns bulldozers, employs bulldozer operators and a guide for collection vehicles, and conducts maintenance. Regarding the septage sludge treatment ponds, PPWM just directs the dumping place. It does not clean the ponds periodically, which is one of the most important elements of the management of treatment ponds.

The current management system is shown in the table below.

Table 12-2: Management System of SMCDS

Organization	Roles
PPWM	General management (Supervision and instruction of landfill operation and so on)
	Measurement of waste amount brought to SMCDS
	Management of septage sludge treatment ponds
Private company for heavy vehicles	Management of bulldozer operation
	Maintenance of bulldozer
	Instruction of dumping work to collection vehicles
	Landfill work such as compaction and leveling
CONPED (NGO)	Management of compost plant
CINTRI (private company)	Management of collection vehicles

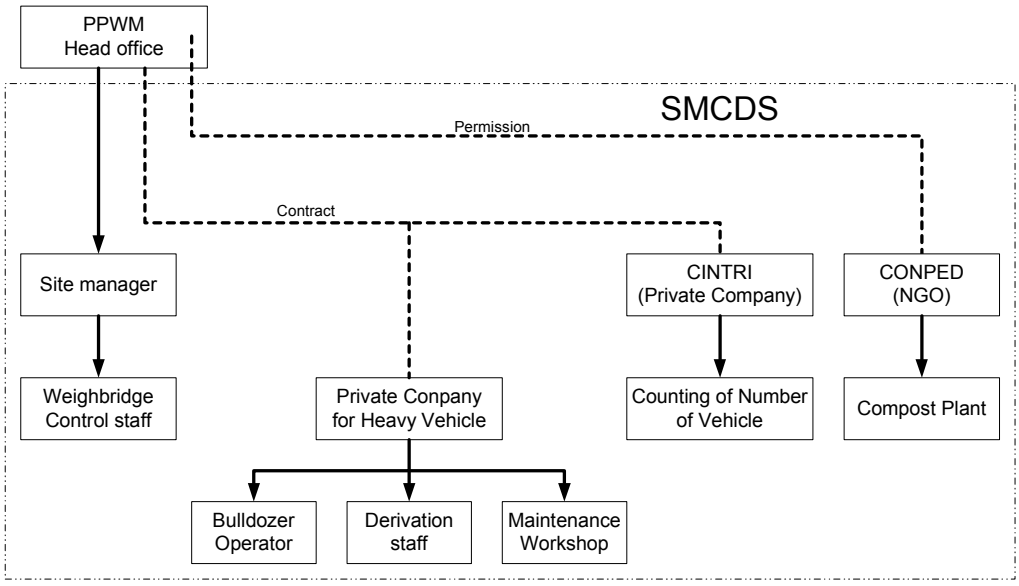


Figure 12-1: Management System of SMCDS

There is a compost plant at the SMCDS, and the NGO, COMPED, is in charge of its operation and management. PPWM has nothing to do with its management. On the other hand, CINTRI stations two staff members at the gate in order to check the collection vehicles for its own operation, and submits a report on the number of collection vehicles to PPWM

periodically. PPWM neither controls the entrance of waste pickers nor their improper activities.

a.1.2. Management System until the Transition

It is necessary for PPWM to reconsider the current management system of the SMCDS in order to close the disposal site properly. The management system proposed by the team to PPWM is summarized here. Regarding some heavy vehicles such as bulldozers, it is possible to extend the contract with the current private company in order to arrange bulldozers and their operators, rather than to buy bulldozers and employ operators.

PPWM should establish the management system of the DKDS based on the proposed management system of the SMCDS. In addition, PPWM should provide a practical training program at the SMCDS for the staff that will be in charge of operation and management of the DKDS.

As for the control of waste pickers, the most critical work is to control their entrance. PPWM should start to check the ID cards at the gates, while making a considerable effort to inform all waste pickers of the waste picking rules soon after the completion of the enclosing bank and fence.

On the other hand, MPP already decided to exclude waste pickers from the new disposal site in Dang Kor. It is necessary for MPP to examine alternative jobs for them, while making the future plan for both SMCDS and DKDS known to all the waste pickers. It is critical for MPP to work in close cooperation with other government organizations and NGOs that were actively involved in projects to support waste pickers.

Table 12-3: Personnel of SMCDS (by closure)

Position	nos.	Roles and Responsibility
1. Section chief	1	to be in charge of general management
2. Engineer	1	to formulate the operation plan from the technical point of view
3. Weighbridge operator	3	to manage the reception of waste
4. Supervisor	2	to manage the landfill operation
5. Operator	4	to operate heavy vehicles such as bulldozers (either PPWM staff or a private contractor)
6. Guard	12	to control waste pickers in order to realize working area separation

a.1.3. Management System after the Transition to DKDS

After the DKDS starts operations, the staff of the DKDS will be in charge of maintaining the SMCDS by regular inspection of the exterior of the disposal site, leachate treatment facilities and septage sludge treatment ponds. If large-scale repair work or measuring work is necessary, PPWM should arrange its engineers and heavy vehicles stationed at DKDS. It is necessary for PPWM to continue the regular inspection for a certain period, probably around 15 years, until the ground of the landfill area becomes stable and the water quality of leachate reaches an acceptable level.

At DKDS, with the progress of the landfill operation, it will be possible to construct septage sludge treatment ponds in a plot where the landfill work is completed. Therefore, the DKDS will be able to receive septage sludge from 2009, while the current treatment ponds in the SMCDS continue their operation in the first two years.

a.2 Equipment Plan

a.2.1. Current Maintenance System

At present, the only maintenance work PPWM is carrying out is the maintenance of weighbridge facilities and the cleansing of drains. The maintenance of bulldozers is done by the private contractor.

PPWM should carry out the following maintenance work, but it is impossible for PPWM to do so with the current personnel and equipment.

- To maintain the steel plates (to relocate steel plates) which were laid on the surface of the secondary road and working face
- To maintain the working face (to separate working areas such as the waste unloading area, waste picking area and waste compaction area)
- To form the landfill block and maintain drainage

a.2.2. Maintenance System until the Transition

The equipment PPWM needs for the proper operation and management of the SMCDS are shown in the table below. Since a large budget is necessary for PPWM to arrange this equipment and personnel, PPWM should make a purchase plan to arrange this equipment in order of priority. It is necessary for PPWM to consider financial assistance from donor countries or international organizations in order to reduce its financial burden.

Table 12-4: Necessary Equipment at the SMCDS

	Equipment	Specification	Quantity	unit
1	Bulldozer	21 tons	3	nos
2	Wheel loader	1.2 m^3	1	nos
3	Water tank truck	6,000 liters	1	nos
4	Dump truck	11 tons	2	nos
5	Excavator	0.7 m^3	1	nos

The study team proposed to give priority to the following equipment. A wheel loader is given the highest priority. Since it is possible to extend the contract to lease bulldozers, its priority is low.

(1) Wheel loader: 1
(2) Excavator: 1
(3) Bulldozer: 1
(4) Dump truck: 1

b. Completion of the construction of the Access Road to the New Disposal Site

The construction plan of the access road should be linked to the improvement plan of Route 303, which will be implemented by ADB. MMP should take responsibility to control the work schedule in order to ensure that the improvement plan is completed before the start of the new disposal site operation.

c. Formulation of Transition Plan

The smooth transition from the SMCDS to the DKDS is one of the top priorities.

PPWM should make all the staff understand the DKDS management plan and provide a training program for its operators and workers so that they can learn the landfill operation.

The team set a period of one month for the smooth transition so that all the PPWM staff and collection vehicle drivers can start the operation at the new disposal site without confusion. It might take a few more months before the complete transition of work.

12.2.3 Closure Plan

a. Landfill Operation Plan until the Closure

a.1 Basic Idea

The area of the SMCDS consists of municipal land (the existing area) and private land (the expansion area). Therefore, the closure plan should be formulated considering the content of the lease.

The lease has two important clauses shown below.

(1) The term of the lease is two years
(2) The height of the landfill area is lower than 4m above the road

Therefore, at first PPWM will conduct the landfill operation in the expansion area, and then move to the existing area.

a.1.1. Expansion area

Here are the main items of the operation plan in the expansion area.

- At least two working faces are constructed
- Working faces are used in turn or by rotation to implement working area separation
- Disposed waste is dumped in a hole in the southeastern part of the area and working faces are shifted according to the progress of the landfill plan.

a.1.2. Existing area

The main items of the operation plan in the existing area are shown below.

- At least two working faces are constructed
- Working faces are used in turn or by rotation to implement working area separation
- To continue to construct the block with disposed waste by extending the model block (which was constructed by the team under the pilot project) to the south. It is necessary to change the location of the secondary road and working faces according to the progress of the landfill plan.

The final shape of the SMCDS after the completion of the landfill operation is shown below.

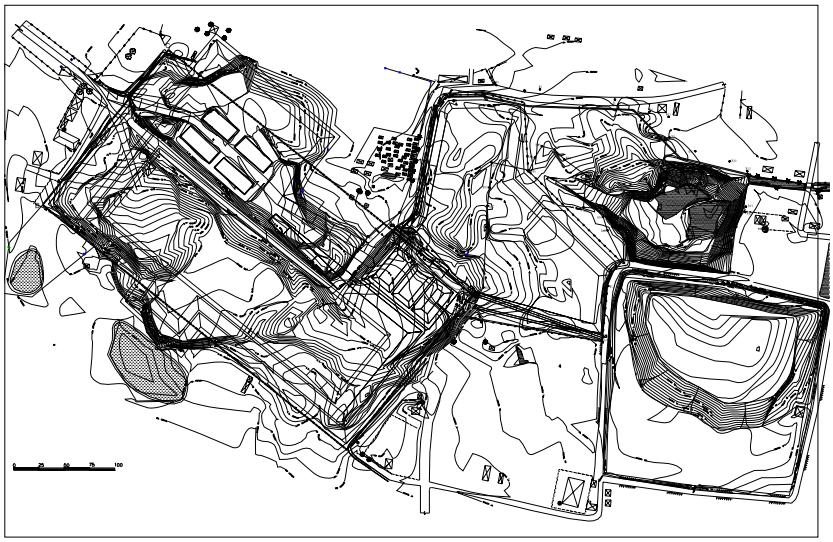


Figure 12-2: Final Shape of the SMCDS

a.2 Technical Specification

a.2.1. Expansion area

The team set the height of the road that is adjacent to the leachate treatment facilities as the base (12.5 m above sea level). According to the operation plan, the height of the landfill block is 4 m above road. The slope from the road to the basing point is gentle, so the final landfill block also has a gentle slope.

The height of the top of the final landfill block above sea level is shown in the figure below.

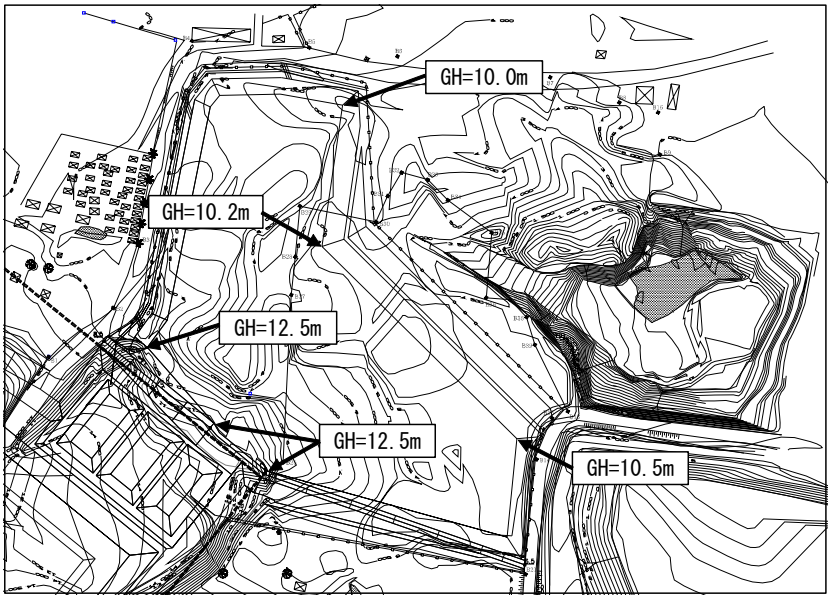


Figure 12-3: Height of the Top of the Final Landfill Block

The slope of the final landfill block is planned at 1:2.0, as shown in the following figure.

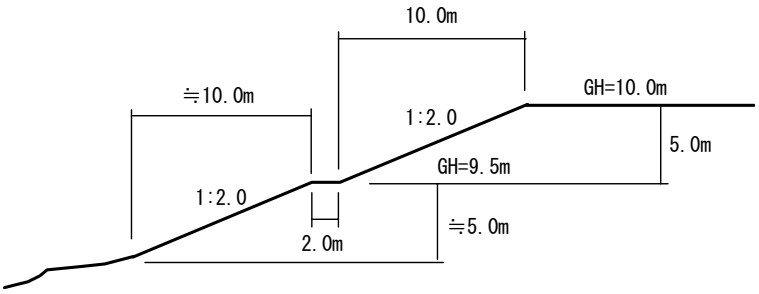


Figure 12-4: Slope Structure of Expansion Area

a.2.2. Existing area

As mentioned in a.1.2, the landfill block in the existing area is constructed with disposed waste by extending the model block to the south. The ground of the existing area inclines gently to the south, so the landfill block also inclines gently to the south.

The height of the top of the final landfill block above sea level is shown in the figure below.

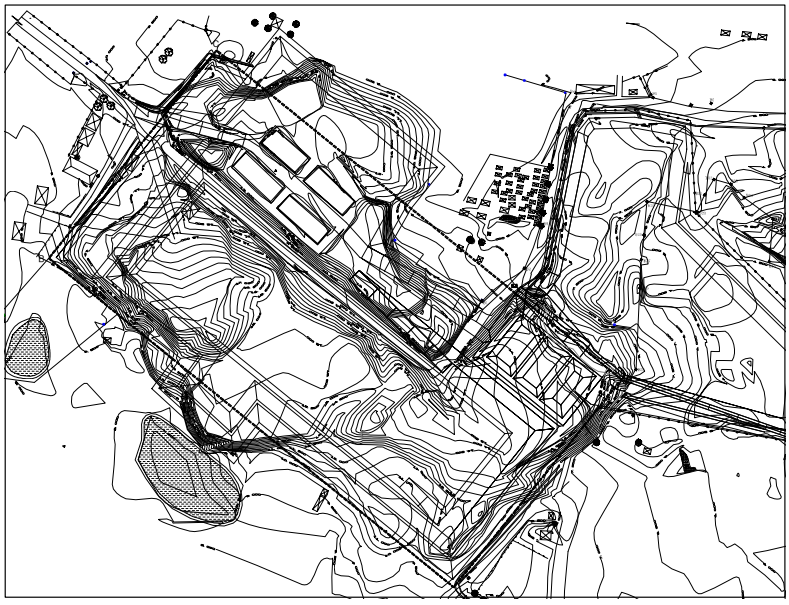


Figure 12-5: Height of the Top of the Final Landfill Block in the Existing Area

The landfill block is terraced, with steps 5m in height (except the top step of 2m) and a slope of 1:2.0.

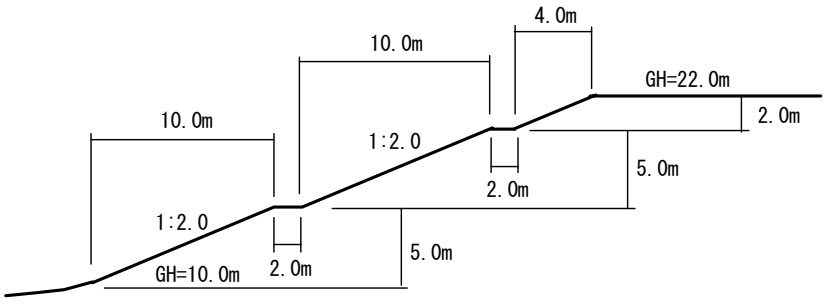


Figure 12-6: Slope Structure of the Existing Area

b. Final Soil Covering Plan

b.1 Basic Idea

Due to the lack of heavy vehicles, the existence of waste pickers, and the high price of soil, it is almost impossible for PPWM to conduct intermediate soil covering. Therefore, the closure plan includes only final soil covering.

Soil at the DKDS will be used as final cover soil. The team already investigated the quality of the soil of the DKDS, such as permeability, and the result showed that the soil at DKDS can be used as soil for final covering.

b.2 Method of Covering

It is possible for PPWM to acquire the necessary soil for covering by excavated soil in its own land at the DKDS. PPWM should cover the area where the landfill block is completed with the soil from DKDS as soon as possible.

The thickness of soil should satisfy the following value.

- flat part: 50cm
- sloping part (slope and terrace): 50cm

At the time of closure, the entire area of the SMCDS will be covered with soil. In the north part (A area) and west part (B area) where waste is disposed across the border, the layers of waste will be covered with soil in the same way mentioned above and the disposed waste will not be removed. Therefore, PPWM should fully explain the landfill plan to the landowners and make an agreement with them.

The amount of soil necessary for final soil covering is calculated as shown in the table below.

Table 12-5: Necessary Amount of Soil for Final Covering at SMCDS

Area	Flat Part	Slope Part
1．Expansion area	17,500	3,900
2．Existing area	9,900	1,400
3．Outside（North）	1,800	400
4．Outside（South）	100	300
Sub-total	29,300	6,000
Total		35,300

The target area of final covering is shown in the following figure.

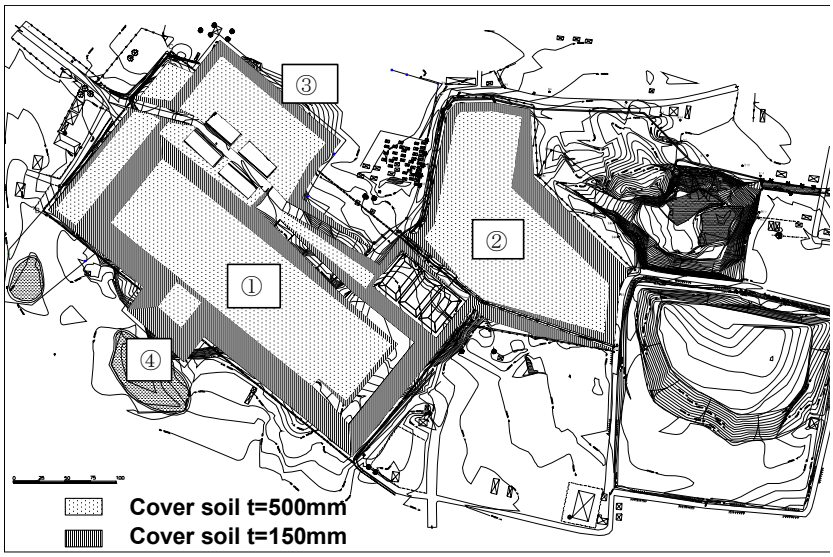


Figure 12-7: Target Area of Final Covering at SMCDS

c. Water Pollution Control (Leachate and waste water treatment)

c.1 Basic Idea

The basic idea of the plan is to separate leachate from rainwater. Leachate and rainwater are controlled in the following ways.

- Leachate is collected by drain and treated at treatment facilities which the study team installed.
- Rainwater is collected by another drain and discharged to the same point as now

c.2 Leachate Treatment Plan

Leachate is collected through branch drains that were installed on each terrace and the top step of the landfill block and the main drain that was installed around the block. Collected leachate is pumped up to the treatment facilities that were constructed under the pilot project.

The layout of the branch drains and main drain in the landfill block is shown below.

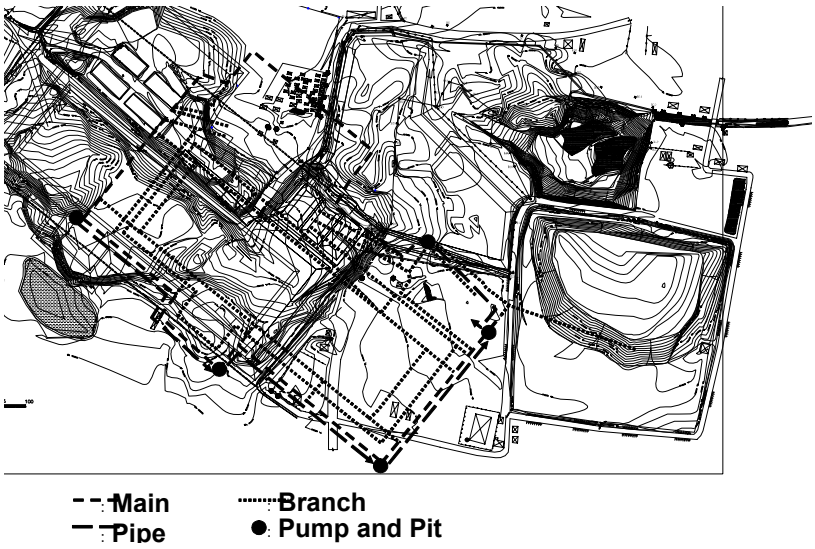
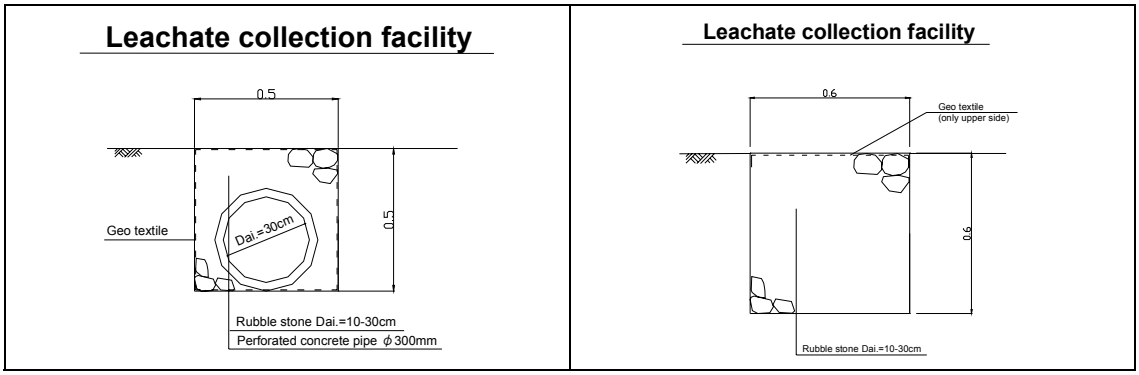


Figure 12-8: Layout of Leachate Collection Systems of SMCDS

The structure of the branch drains and the main drain is also shown below.



Main drain Branch drain

Figure 12-9: Structure of Leachate Collection Systems of SMCDS

c.3 Rainwater Drainage Plan

A drain was constructed in the expansion area of the SMCDS under the pilot project, but it covers only a limited area. It is necessary to install drains in other areas.

The team designed an open canal surrounding the disposal site as drains for rainwater mixed with domestic waste water. Rainwater and domestic waste water flow by gravity.

The outline of the drainage system is summarized below.

- Drains north and east of the disposal site are connected to the canal that was constructed under the pilot project.
- Drains west of the disposal site are connected to two ponds, which are current discharge points.
- A canal located south of the disposal site is improved and connected to Tompun Lake.

PPWM should discuss with landowners the location of drains before it finalizes the drainage plan.

The outline of the rainwater and domestic waste water drainage plan is shown in the following figure.

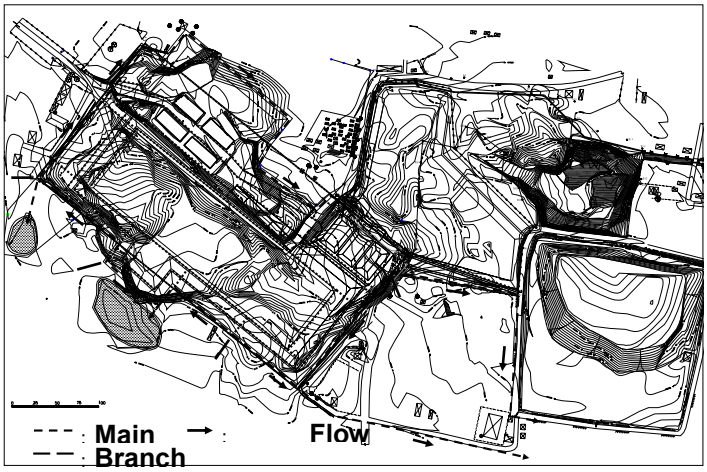
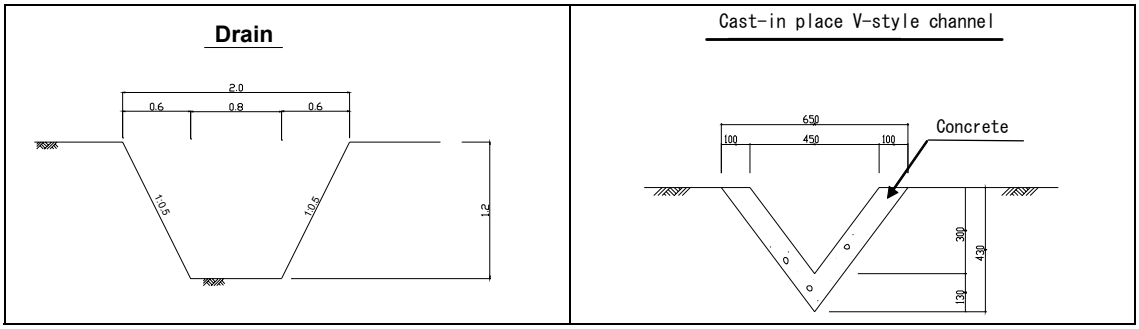


Figure 12-10: Drainage Plan of Rainwater and Domestic Waste Water at SMCDS

The structure of the branch drains and main drain are also shown below.



Main Discharge Branch Discharge

Figure 12-11: Structure of Rainwater Collection Systems of SMCDS

d. Management Plan of Generated Gas

d.1 Basic Idea

Generated gas is controlled by installing parallel and vertical gas removal pipes.

It is preferable to install vertical gas removal pipes according to the progress of the landfill operation. It is necessary for PPWM to set up a vertical pipe at a planned spot before the landfill operation starts.

Parallel pipes are installed before the final soil covering. In the model block that was constructed in the existing area, vertical pipes were already installed, so vertical pipes which are installed from this time on are to be connected to the existing pipes.

It is preferable to install gas removal pipes in the expansion area, since removing gas could hasten the process to stabilize the landfill area. However, it depends on the future use of land, and the landowners will decide whether pipes are installed in the area or not. It is necessary for PPWM to discuss this with landowners before finalizing the plan.

d.2 Technical Specifications

The installation plan of vertical and parallel gas removal pipes is shown below.

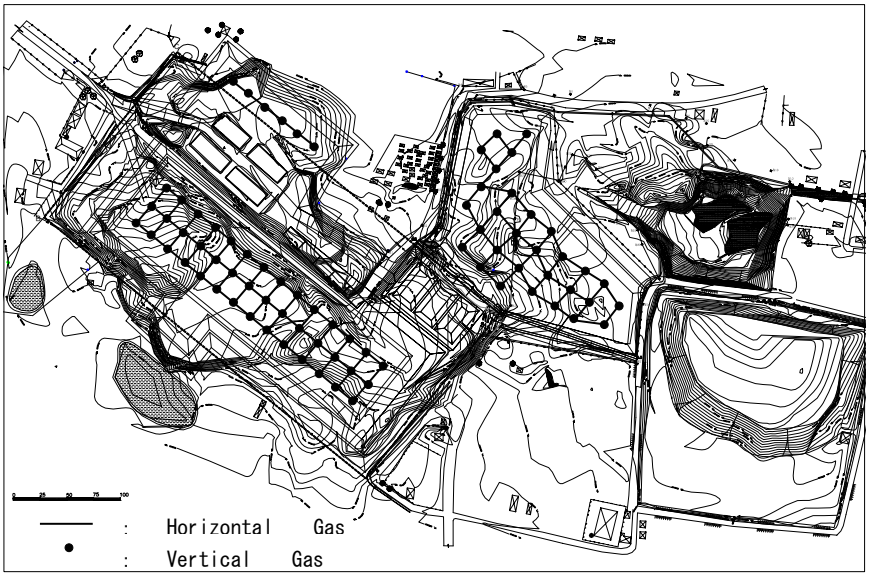


Figure 12-12: Installation Plan of Gas Removal Pipes in SMCDS

The structures of vertical and parallel pipes are shown in Figure 12-13 and Figure 12-4, respectively. Vertical pipes can be divided into two parts: an upper part and a lower part. Therefore, before the landfill operation starts, the lower part of the pipe is installed and the upper part is installed later according to the progress of the landfill operation. In addition, it is possible to change the length of the upper part of the pipe according to the height of the landfill block. After the final soil covering is completed, a combustion tube is installed at the top of the step.

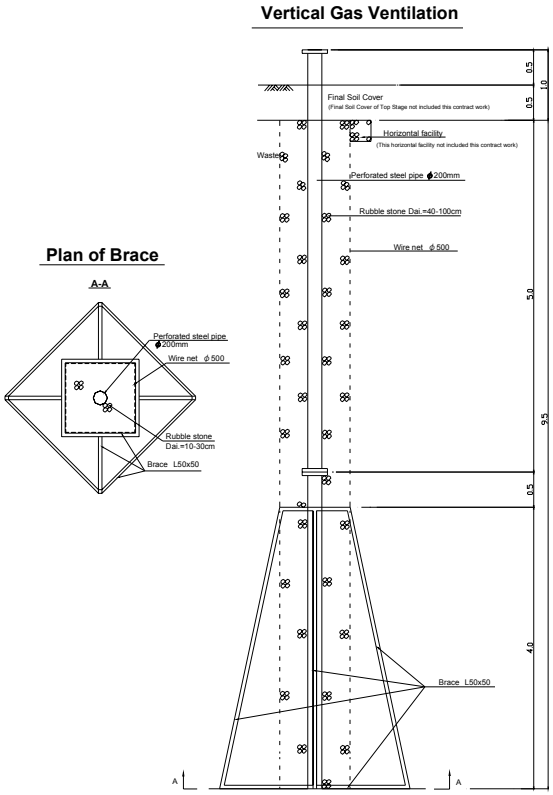


Figure 12-13: Structure of Vertical Gas Removal Pipe

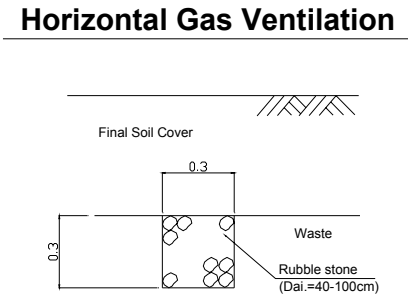


Figure 12-14: Structure of Parallel Gas Removal Pipe

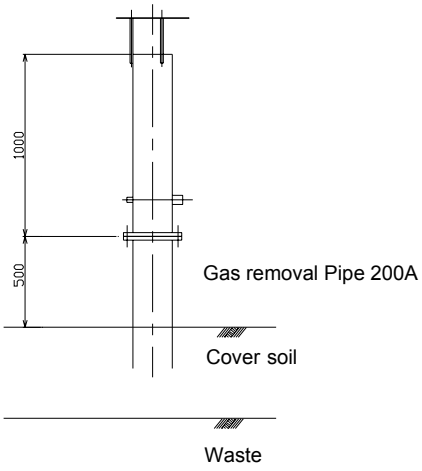


Figure 12-15: Structure of Combustion tube

12.2.4 Future Land Use Plan

The necessary items for the formulation of the future land use plan are summarized below.

Table 12-6: Future land use plan in SMCDS

No.	Land use	Description
1. PPWM's own land	(1) Construction of public park with a good view	to take advantage of the height of the final shape
	(2) Installation of facilities aiming at making an effective use of landfill gas	to install charcoal production facilities using landfill gas
2.Private land (on lease)	(1) Return to the owner after the completion of final soil covering	Due to the lease contract, private land will be basically returned to owners. When landowners develop these lands, they need approval from MPP. They have to take the necessary measures to deal with problems caused by landfill gas and subsidence and to ensure safety.
	(2) Construction of facilities without buildings	The team will show the examples of the best use of the former landfill area; facilities without heavy buildings such as a public park, a golf training field, jogging facilities. The team encourages landowners to utilize their land for these purposes after planting grass. It might be necessary to extend the lease contract.

12.3 Monitoring Plan

12.3.1 Establishment of Monitoring Systems

The monitoring system that was established under the pilot project will continue to be used until the landfill area becomes stable (for around 15 years after its closure).

It is necessary to make sure that PPWM will be able to conduct the monitoring operation in the long term. Therefore, the monitoring work of SMCDS should be a part of the management system of the DKDS. This makes it possible for PPWM to utilize necessary personnel and equipment of the DKDS for the SMCDS monitoring.

Management of the SMCDS after its closure includes a wide range of tasks from observation of the external appearance of the disposal site to the operation and management of leachate treatment systems.

A staff member of the DKDS will conduct regular patrols for the above-mentioned routine works. If necessary, engineers or workers will be dispatched for such works as measuring and repair work.

12.3.2 Installation of Monitoring Well

In the first and second phase, the study team checked the water quality of three wells located near the disposal site and the results were reported. PPWM will continue to monitor the underground water quality of these three wells.

The locations of wells are shown in the map below.

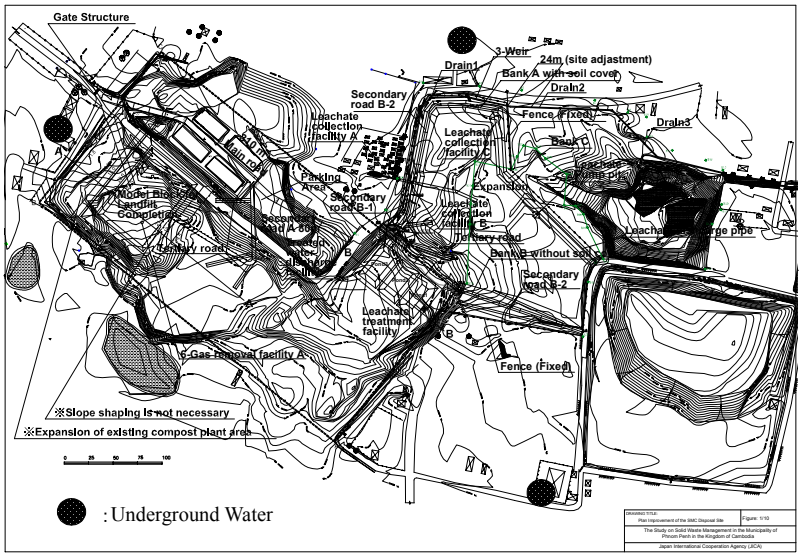


Figure 12-16: Location of Wells for Underground Waste Monitoring

12.3.3 Monitoring Items

a. External Appearance of the Disposal Site

The targets of the routine monitoring by observation are shown below.

- Condition of soil and turf (final covering)
- Condition of landfill block (subsidence, change of shape, and so on)
- Maintenance of drainage systems and leachate treatment systems

b. Condition of Soil and Turf (Final Covering)

PPWM should monitor the condition of the soil and turf that cover the disposal site. If necessary, PPWM has to repair the soil cover and turf. As for the maintenance of turf, it is necessary for PPWM to take measures to sprinkle water in order to keep the grass in good condition.

c. Condition of Completed Landfill Block

PPWM should monitor the condition of the landfill block and enclosing bank and check for problems such as subsidence and change of shape. If necessary, PPWM should take measures to reinforce by filling additional soil and so on. The slope of the landfill block is the priority target, since it is likely that the slope will collapse due to rainwater.

d. Maintenance of Drainage Systems and Leachate Treatment Systems

PPWM should take necessary measures to keep the drains for leachate and rainwater mixed with domestic waste water in good condition. In particular, during the rainy season, PPWM should keep a close watch on the drainage systems.

- **Leachate pump and pit:** check whether the pump is working properly and clean the inside of the pit. Since the on-off timer of the pump is set, the working hours of the pump have to be changed by season. If a pump is broken, a spare pump is installed promptly and the broken pump is sent for repair.
- **Leachate transportation line:** pipes which convey leachate from pumps to ponds are installed underground and this could delay the revelation of damage. It is

necessary for PPWM to carefully check the leakage along the line. Since electric wires are buried near the line, it is necessary for PPWM to pay attention to these wires when it conducts repair work of the transportation line.

- **Leachate treatment ponds:** the ponds are constructed with clay and it is likely that they will crack. It is necessary for PPWM to keep a close watch on the condition of the ponds and repair cracks promptly, if any occur. In addition, the regular cleaning of sludge accumulated on the bottom of the ponds is necessary during the dry season (twice a year).
- **Drains of treated water:** regular cleansing is necessary to prevent drains from clogging.

12.3.4 Monitoring Items

The items that PPWM should monitor at the SMCDS are shown in Table 12-7. The monitoring locations the study team recommends are also shown on the map below.

Table 12-7: Monitoring plan of the SMCDS

Items	Facility	Number of Samples	Fr.*1 time/month	Measuring Items
1.Appearances of landfill site	Landfill area	-	1	Followings are monitored regularly (1) Covering soil (2) Landfilled waste (subsidence, change of shape etc.) (3) maintenance of drain (4) Others
2. Underground Water	Monitoring well	3	1	Electric conductivity, Cl^-, pH
3. Water quality of leachate	Water sampling	3	1	Electric conductivity, Cl^-, pH
4. Landfill gas	Gas removal pipe	3	1	CH_4, CO_2, H_2O, Temperature
5. Settlement	Settlement board	4	1	Settlement level

*1: Frequency

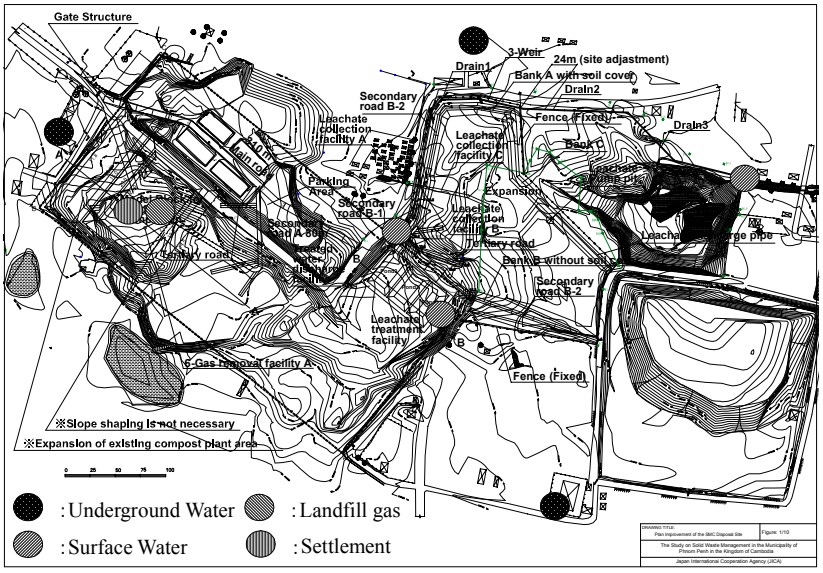


Figure 12-17: Location of Monitoring

a. Ground Water

The purpose of ground water monitoring is to check the water quality and its change. The change in quality shows to what extend the landfill block is stabilized. Three wells around the disposal site are used for the underground water monitoring.

b. Water Quality of Leachate

The leachate monitoring aims at checking the leachate quality and the change in leachate quality. The change in leachate quality shows to what extend the landfill block is stabilized. In addition, the change in quality before and after treatment reveals the efficiency of treatment ponds.

Here are the measurement points of water quality.

- inflow of leachate treatment facility
- effluent at the leachate treatment facility
- effluent at the final discharge point (Tompun Lake)

c. Landfill Gas

The monitoring of landfill gas aims at investigating the composition of generated gas. The change in composition shows to what extend the landfill block is stabilized.

Sampling is conducted at vertical gas removal pipes. The quantity and composition of gases change as time goes on after the landfill operation. Therefore, pipes for monitoring have to be fixed.

d. Settlement

The landfill area subsides because of the decomposition of disposed waste, water evaporation, and the compression of waste by its weight. The degree of subsidence depends on the compaction work, but the team expected the degree of subsidence to be 50-80% of the original height of the landfill block. In the first five years, the ground will probably sink 90% of the final subsidence.

The settlement monitoring gives an important indicator as to what extend the landfill block is stabilized and it is indispensable for PPWM in considering the land use. PPWM should not construct any heavy structures until the subsidence of the landfill area stops.

The measurement of settlement is conducted by settlement boards that are installed at appropriate places.

12.4 Cost Estimation

The investment cost necessary for the closure of the SMCDS and its schedule are shown in the table below. The cost here does not include to purchase or lease of heavy vehicles.

Table 12-8: Investment Cost of SMCDS Closure Plan and Its Schedule

Unit: 1,000 US$

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Initial Investment	75	745								
O&M Cost		24	14	14	24	14	14	24	14	14
Total	75	769	14	14	24	14	14	24	14	14

12.5 Matters to be considered for the Closure of the SMCDS

Matters to be considered by PPWM to close the SMCDS are summarized below.

1) Establishment of the management system for SMCDS (at present) and DKDS (in future)

- The management system for SMCDS should be enhanced first, and the management system for DKDS will be established based on the system for SMCDS.
- A plan for transition to DKDS will be formulated

2) Formulation of equipment plan for landfill management

- To prepare for the heavy vehicles and equipment necessary for proper landfill operation and management according to the priority list
- To consider financial assistance from international organizations and donor countries in order to reduce its financial burden
- To formulate the closure plan on the premise of the transition to DKDS

3) Implementation of waste picking rules and examination of supporting programs to find alternative jobs for waste pickers

- To realize working area separation in order to improve the landfill operation, while guaranteeing the safety of waste pickers
- To control the entrance of waste pickers, in particular those who do not follow the rules
- To make waste pickers know that they will not be allowed to enter DKDS
- To establish a recycling system in order to compensate the amount recycled at SMCDS and to maintain the current recycling rate

4) Deciding on the way to excavate and transport soil for the final covering

- To formulate the equipment plan to purchase or lease heavy vehicles such as an excavator and dump-truck necessary to excavate and transport soil
- To formulate the schedule of the soil covering work

5) Formulation of various plans in the following adjacent lands in cooperation with landowners

- The area where waste was dumped beyond the border of the disposal site
- The area where drains are to be constructed
- The expansion area (whether to install gas removal pipes or not)

It is necessary for PPWM to fully explain the plan to the landowners and try to make them understand the advantages before finalizing the plan.

6) Relocation of septage sludge treatment ponds (if the urbanization continues in Stung Mean Chey, it will be difficult to keep the treatment ponds at the SMCDS because of the odor problems)

- To formulate the septage sludge treatment plan considering its generation amount
- To decide where treatment ponds are to be constructed (If the DKDS is selected as the site of the treatment ponds, it will be able to start receiving sludge in 2009)

12.6 Consideration of Waste Pickers

The team conducted the Social Environmental Survey (SES) during the first phase. However, the situation surrounding waste pickers has changed in the past year, so it is necessary to summarize the changes which occurred in the past year.

12.6.1 Current situation of waste pickers

The result of the SES revealed that there were a lot of incomings and outgoings, while some waste pickers frequently changed their place of work between the disposal site and the city. After the trial of the working area separation finished in the beginning of 2004, many waste pickers chose to work on the streets in the downtown area of Phnom Penh because of the deteriorated conditions of the landfill area caused by improper operation and management of PPWM. In addition, a recycling center operated by a private company in cooperation with CINTRI hired around 100 waste pickers last August. As a result, the number of waste pickers considerably decreased in the past several months as shown in the table below.

Table 12-9: Number of Waste Pickers at SMCDS (the observation survey)

Date	Number of children	Number of adults	total
2003			
May 30 (Morning)	112	290	402
June 2 (Afternoon)	161	360	521
June 5 (Morning)	144	369	513
2004			
October 18	45	149	204
November 22	18	179	197
December 1	78	196	274

Since the operation and management of the disposal site was improved, it is expected that more waste pickers will return to the disposal site from now on.

The previous survey also showed that there were a lot of incomings and outgoings. Since September, 2004, PPWM resumed the registration work for the newcomers. According to the recent registration data, there are 20-30 newcomers every month.

There are still no reliable leaders or self organizations among waste pickers, even though NGOs continue their efforts. It is expected that MPP/PPWM will face enormous difficulties in negotiating with waste pickers in order to consider necessary measures.

12.6.2 Basic Approach

Since the budget and personnel MPP can manage is limited, it is important for MPP/PPWM to make its roles and responsibilities clear and formulate the plan in cooperation with related

organizations. The basic approaches the team proposed MPP should take are summarized in this section.

a. Identify the target people

According to the result of the Social Environmental Survey, waste pickers at the SMC disposal site varied in terms of age, income, living status and working status. There are many waste pickers who work at the disposal site tentatively, only during the agricultural off season, while some waste pickers who live near the disposal site work only on weekends for additional income.

When PPWM started to register waste pickers at the end of 2003, a lot of people who did not actually work at the disposal site applied for an ID card. After checking waste pickers at the disposal site for a short period, PPWM issued ID cards only to those who had been checked by PPWM staff more than three times. As of October 2004, the total number of ID card holders was 1,558 (out of applicants of 2,967). However, there are still a large number of ID card holders who have already stopped working at the disposal site. It is very important for MPP/PPWM to carefully select real targets for its supporting program.

The team proposed the following criteria to select the targets.

- Must have been working at the disposal site for a long time (Priority is given to those who got the first series of ID cards in the beginning of 2004.)
  New comers are not the targets of the supporting program. This may decrease the incentive for people in rural areas to come to the SMC disposal site.
- Must work full-time at the disposal site (Part-time waste pickers are not to be targets.)
- Must work permanently at the disposal site (Tentative waste pickers coming from rural areas are not to be targets.)
- Select targets based on the household (In order to widen the targets, it is better to select only one person from each household if the number of created jobs is limited.)

Since the actual number of waste pickers who are working at the disposal site now is much smaller than that of the ID card holders, it is necessary for MPP/PPWM to identify who is actually working at the disposal site regularly. The team proposed PPWM to check the ID numbers of waste pickers at the disposal site once a month.

b. Establish close cooperation with other stakeholders

In SMC, NGOs has been actively involved in supporting waste pickers in the past decade. They have their own programs to support waste pickers to change their jobs. When MPP/PPWM consider its supporting program, it is very important to avoid conflict with the NGOs' activities.

It is necessary for MPP/PPWM to make a mechanism in which MPP can discuss about necessary measures with other stakeholders regularly. For this purpose, the team and PPWM organized a meeting at the end of September, 2004, inviting NGOs and Christian organizations which are supporting waste pickers. At the meeting, the team and PPWM explained the closure plan and its tentative schedule and NGOs introduced their current activities and future plans. The team requested MPP/PPWM to continue to organize this kind of meeting regularly in order to exchange opinions and information. It is preferable to invite local authorities to the next meetings.

c. Ask NGOs for their support to communicate with waste pickers

As a part of the Social and Environmental Survey, the team conducted an interview survey with waste pickers and organized a focus group meeting. At the time of the survey, the development plan of the new disposal site was still uncertain and many of interviewees could not be serious about the closure of the SMC disposal site. Therefore, it is urgent for MPP/PPWM to discuss about the closure plan with waste pickers.

It was, however, impossible for MPP/PPWM to invite waste pickers to the public hearings due to the lack of leaders or self-organized groups amount waste pickers. Since many of waste pickers get some kinds of support from NGOs, it is better to ask NGOs for their support to communicate with waste pickers.

As soon as MPP makes a decision to implement the development plan of DKDS, MPP/PPWM should start discussions with waste pickers about alternative jobs and inform its criteria for selecting the target person.

d. Disseminate information on the closure plan widely (throughout Cambodia)

It is critical for MPP/PPWM to control the number of newcomers. In order to decrease the number of incomings, it is necessary to make the disclosure plan of the SMC disposal site known widely and show the criteria for selecting the targets of the supporting program clearly through such media as TV, radio and newspaper.

12.6.3 Possible supporting programs by MPP

a. Under MPP related projects

MPP/PPWM could create the following jobs under the future projects related to solid waste management. The targeted waste pickers would be given priority to get these newly created jobs along with the landowners who sold or will sell their land for the construction of DKDS. However, the number of new jobs shown below is on the planning base and limited, so MPP/PPWM have to consider other measures in cooperation with other organizations.

(1) Workers at the DK disposal site (priority will be given to former landowners)

Year	Job	Number
2007	Workers at the landfill operation area	12
	Workers at the compost plant	25

(2) Workers for waste collection and street cleansing activities by PPWM

Year	Job	Number
2007	Collection workers	48
2007	Street sweeper	25

Since there is a plan to construct a depo of collection vehicles at the SMC disposal site after its closure, waste pickers who will got the job as collection workers will not have to change their residence.

b. Supporting NGOs

Providing support to NGOs to implement their activities smoothly is also an important task of MPP/PPWM.

At present, each NGO engages in its own projects, and there are some overlaps of activities. MPP/PPWM could also arrange a place where NGOs can exchange information and coordinate their activities. The above mentioned meeting could have this function.

12.7 Project Evaluation

a. Technical Evaluation

The closure plan try to separate leachate from rainwater mixed with domestic wastewater in order to minimize the volume of leachate. In addition, the whole area e will be covered by soil and a part of the area is covered by turf. Countermeasures that are shown in the closure plan could minimize the negative impact of the disposal site on the surrounding areas, even though urbanization progresses further in the future.

Disposed waste continue to be decomposed generating various gases and the ground subsides. It is important to establish the monitoring system of settlement. Since landfill gas continues to be generated for a long time, it is worth of examining a way to make a good use of landfill gas for the establishment of proper management system after the closure.

b. Social Evaluation

Possible social impacts of the closure of the disposal site are summarized below.

1) Negative impact
- Loss of income source for waste pickers
- Damage to recycling industries in SMC

2) Positive Impact
- Improvement of environmental and hygienic conditions around the SMCDS.
- Creation of new business to make a good use of landfill gas

b.1 Basic approaches to minimize negative impacts

The basic approaches the team proposed PPWM should take to minimize negative impacts on waste pickers and recycling industries are summarized below.

b.1.1. Approach to deal with loss of income source for waste pickers

Waste pickers belong to one of the groups most affected by the closure plan. Considering their size in number, it is very important for MPP/PPWM to take necessary measures to minimize the negative impact on them. It is preferable to consider necessary measures as soon as possible in cooperation with other stakeholders.

b.1.2. Approach to deal with damage to recycling industries in SMC

Recycling related businesses such as waste buyers and brokers accumulate in SMC, in particular around the disposal site. Many of them buy waste from waste pickers at the disposal site. These businesses are very active and they contribute to the high recycling rate of MPP.

Since the new disposal site will exclude waste pickers from the disposal site, it is expected that the recycling rate would decrease for a while after the closure of the SMCDS. Waste buyers and brokers play an important role in making a recycling system work effectively.

It is important for PPWM to prevent them from losing or discontinuing their business in order to keep or increase the current recycling rate in the future. It is necessary for MPP to confer with recycling business in order to examine possible measures.

c. Environment Evaluation

c.1 General

The SMCDS has had no pollution control measures since it started its operation in the1960s. Final soil covering cannot prevent all possible environment degradation. Therefore, it is very important for PPWM to keep a close watch on ground water monitoring to prevent further environmental problems. In addition, it is necessary for MPP to impose a ban on the use of groundwater as drinking water.

Regarding land use, landfill gas could impose some risk. It is necessary for MPP to give proper instruction on the future use of the disposal site in order to secure safety.

The team assumes the necessary monitoring period is at least 15 years. It is necessary for PPWM to establish a monitoring system to conduct the operation for 15 years.

c.2 Monitoring systems

The monitoring systems that were established under the pilot project will continue to be used until the landfill area becomes stable (for around 15 years after its closure). It is necessary to make sure that PPWM will be able to conduct the monitoring operation in the long term. Therefore, the monitoring work of SMCDS should be a part of the management system of the DKDS. This makes it possible for PPWM to utilize necessary personnel and equipment of the DKDS for the SMCDS monitoring. The management of the SMCDS after its closure includes a wide range of tasks from observation of the external appearance of the disposal site to the operation and management of leachate treatment systems. A staff member of the DKDS will conduct a regular patrol for the above-mentioned routine works. If necessary, engineers or workers will be dispatched for such works as measuring and repairs.

The targets of the routine monitoring by observation are shown below.

- Condition of soil and turf (final covering)
- Condition of landfill block (subsidence, change of shape, and so on)
- Maintenance of drainage systems and leachate treatment systems

c.3 Water pollution

Leachate will continue to be produced after the site is closed although production rates and strengths will diminish with time. Therefore, it should be considered as follows.

The basic idea of the plan is to separate leachate from rainwater. Leachate and rainwater are controlled in the following ways:

- Leachate is collected through branch drains that were installed on each terrace and the top step of the landfill block and the main drain installed around the block. Collected leachate is pumped up to the treatment facilities that were constructed under the pilot project.
- The team designed an open canal surrounding the disposal site as drains for rainwater mixed with domestic waste water. Rainwater and domestic waste water flow by gravity. The drain was constructed in the expansion area of the SMCDS

under the pilot project, but its covers only a limited area. It is necessary to install drains in other areas.

c.4 Landfill gas

Landfill gases will continue to be produced after the site is closed although production rates and strengths will diminish with time. Therefore, it should be considered as follows.

Generated gas is controlled by installing parallel and vertical gas removal pipes.

- It is preferable to install vertical gas removal pipes in order according to the progress of the landfill operation. It is necessary for PPWM to set up a vertical pipe at a planned spot before the landfill operation starts.
- Parallel pipes are installed before the final soil covering. In the model block that was constructed in the existing area, vertical pipes were already installed, so vertical pipes which are installed from this time on are connected to the existing pipes.
- It is preferable to install gas removal pipes in the expansion area, since removing gas could hasten the process to stabilize the landfill area. However, it depends on the future use of land, and landowners will decide whether pipes are installed in the area or not. It is necessary for PPWM to discuss this with landowners before finalizing the plan.

d. Financial and Economic Evaluation

There are two options for raising the funds for environmentally sound and safe closure of the existing Stung Mean Chay Disposal Site (SMCDS). One is the allocation of budget from MPP, and the other is the allocation of income obtained from the operation of the new final disposal site in Dang Kor. The Study here estimates the cost of environmentally sound and safe closure of SMCDS and its impact upon the tipping fee at the disposal site in Dang Kor if its income is allocated for the closure of SMCDS.

d.1 Cost of environmentally sound and safe closure of SMCDS

The cost of initial investment for closure of SMCDS is estimated to be about 580 thousand US dollars including final soil cover, establishment of leachate treatment facilities, landfill gas pipes, leachate monitoring wells, and so forth. Monitoring of the closed landfill, on the other hand, is estimated to require 14 thousand US dollars annually while 12 thousand US dollars are also required to replace the leachate pumps every three years during the monitoring period. The table below shows the trend of the cost for closure of SMCDS.

d.2 The use of income from operation of the New Disposal Site in Dang Kor and its impact upon the tipping fee

The Study analyzes the impact upon the tipping fee to be set for the operation of the new disposal site in Dang Kor if its income is allocated for closure of SMCDS. As mentioned in 1.1.2 above, it requires a tipping fee of 5 US dollars per ton of waste received to reach the financially viable operation of the Dang Kor disposal site with the IRR of more than 10%. If the income from the Dang Kor disposal site is allocated for closure of SMCDS , the required tipping fee is estimated to increase to 5.07 US dollars per ton of waste received. The increase in tipping fee by 0.07 US dollars per ton of waste is only a small change that can be easily addressed by Dang Kor disposal site operation as far as it is operated in a financially viable manner.

Part V

Conclusion

and

Recommendations

Chapter 13

Conclusion and Recommendations

13 Conclusion and Recommendations

13.1 Conclusion

13.1.1 Problems concerning the Current Municipal Solid Waste Management

a. a. Unserviced and insufficiently serviced areas

CINTRI, who is a private waste collection company, has the right to collect waste and fees in the whole city of Phnom Penh except for a part, according to the contract agreed on on March 21, 2002. This contract stipulates that CINTRI has no obligation to provide collection services to economically unfeasible areas and that MPP shall not permit any third party, nor be permitted itself, to provide any of the services in the city.

According to the results of the study, it was found that the waste collection coverage rate in the four urban Khans is 95% and 40% in the three peri-urban Khans but that there are many unserviced and insufficiently serviced areas in the city. The waste in these areas is thrown away in open spaces and/or waterways. This waste deteriorates the urban environment severely and the waste thrown into waterways blocks the drainage facilities and causes flooding.

b. Open dumping

The Stung Mean Chey（SMC）disposal site, which has been used from the 1960s, is the only disposal site in the municipality of Phnom Penh. Urbanization has reached the site and many houses are in the surrounding area. Due to inappropriate operation, SMC disposal site has become an open dump and is having a negative impact on the environment such as the daily occurrence of fires, widely diffused smoke and offensive odor, and the breeding of flies and vermin. In spite of the many improvements made in the pilot project conducted in this study, there are still many problems because soil covering cannot be carried out due to the insufficient budget (less than 0.5US$/ton). In addition to the environmental problems mentioned above, the remaining capacity of the SMC disposal site was estimated at about two years as of the end of 2004. Therefore, urgent development of the new disposal site is indispensable.

c. Garbage heap and waste littering in the city

In Phnom Penh, even in the central part where the collection service is adequately provided, garbage heaps and waste littering are ubiquitous due to the lack of discharge rules. This not only causes a decline in the urban sanitary conditions but also has a negative impact on the tourist industry due to the spoiled scenery. Although the beauty along the main road is maintained by the street sweeping services, which are carried out somewhat to excess, garbage heaps and waste littering should also be urgently improved through the establishment of discharge rules with public cooperation.

d. Weakness of the public executing system

Because the cleansing activities have been carried out by the private sector for so long, the public cleansing capability has become as weak as it is today. As a result, the MPP cannot respond to the request to receive equal public services made by the citizens living in areas where the private company does not provide services.

13.1.2 Master Plan

The master plan (M/P) was formulated based on the current conditions of SWM mentioned above, aiming to "establish a sustainable SWM system in Phnom Penh by the target year 2015".

If the M/P is realized, the waste flow in the year 2015 will be as follows:

Year	Generation amount	Amount improperly disposed of at generation source	Collection amount	Amount treated at compost plants	Final disposal amount	Recycling amount
2004	978 (100)	68 (6.9)	717 (73.3)	5.3 (0.5)	693 (70.8)	93 (9.5)
2015	1,739 (100)	0 (0)	1,598 (91.8)	33.3 (1.9)	1,461 (84)	242 (13.9)

Unit : tons/day (the value in parentheses is the ratio of waste generated)

In the M/P, improvement measures to cope with the various problems mentioned above from both technical and institutional aspects were planned.

a. Technical aspects

a.1 Waste collection expansion to eliminate unserviced area

- The private company (CINTRI) provides the waste collection service to the entire area of the four urban Khans and the area in the three peri-urban Khans where it is economically feasible. MPP/PPWM provides the collection service to the remaining area in the three peri-urban Khans where is not economically feasible for the private company by receiving foreign grant assistance.
- MPP/DOE should monitor and control the waste collection service provided by PPWM and the private company so that the citizens can receive fair and proper services.
- MPP and the private company should review the territories based on the results of monitoring prepared by the DOE periodically. The contract agreement should also be amended if necessary to reflect the results of the monitoring.

a.2 Improvement of final disposal

- MPP should develop the new disposal site as soon as possible by obtaining foreign grant assistance.
- PPWM should continue the pilot project for improvement of the SMC disposal site commenced in this study and build up landfill techniques and operational know-how until the new disposal site is opened.
- PPWM should raise the level of sanitary landfill operation in the SMC disposal site step by step and reduce the environmental impact on the surrounding area gradually.
- PPWM should make repeated efforts to ensure that the users, such as the collection service providers, understand the necessity of raising the disposal fee and accept to pay it by explaining the benefits that the users will receive, such as the shortening of time required for unloading, a reduction in cost of repairing vehicles that break down at the disposal site and increased work efficiency. Through those repeated efforts, PPWM should gradually raise the disposal fee up to 4.4 US$/ton by the commencement of operation of the new disposal site.

- PPWM should establish a system so that the citizens understand SWM properly and accept to bear the waste fee for proper treatment and disposal by showing the sanitary landfill operation.

a.3 Prevention of garbage heaps and littering

- In order to eliminate garbage heaps and littered waste, the collection service providers (PPWM and CINTRI) should establish waste discharge rules specifying the containers to be used and the discharge times, days, and place.
- The service providers should publicize the waste discharge rules to obtain residents' cooperation.
- The service providers should provide a reliable service according to the discharge rules.
- The administrative side (MPP/DOE) should raise public awareness by educating the residents (the beneficiaries of the service) about the need for public sanitation and environmental conservation so that they strictly adhere to the rules. The public education should include the required programs to eliminate the scattering of waste and littering.

a.4 Promotion of the 3Rs

In this study, it was found that the amount of waste generated per person is small (487g/person/day), and the traditional private material recovery system is very active and well established (recycling rate is 9.3 %). However, the majority of the valuables recovered are recycled in Thailand and Vietnam. Based on that, in order to promote the 3Rs (Reduce, Reuse, Recycle), the following measures are recommended.

- In order to maintain and preserve the existing recycling system, the MPP should establish a support mechanism (the provision of education and information to dischargers and collectors of valuable materials, small loan system, etc.) for Et Chhay (recycler) and WPs.
- In order to increase the recycling rate, degradable organic waste (kitchen wastes, grass and wood), which currently accounts for 70% of the waste composition by weight, has to be adequately recycled. Therefore, the composting of waste should be promoted. In doing so, judging from the profitability of compost activities and product marketability, it is important to ① target waste that can be produced into good-quality compost at a low cost, such as market waste, yard waste, etc; ② target customers who will buy high cost products, such as fruit and vegetable farmers; and ③ promote community level composting activities in order to progressively increase production according to the increase in demand.

b. b. Institutional aspects

b.1 Administration and organization

The roles and responsibility of the organizations concerned with SWM in Phnom Penh should be clarified.

Cabinet: To establish and enforce comprehensive SWM policy

DPWT: To supervise the disposal site construction works conducted by PPWM

DOE: To monitor and control the waste disposal services provided by PPWM and the private contractor for educating and informing the public

PPWM: To operate and manage the waste disposal works under its jurisdiction (collection, intermediate treatment, final disposal, etc.)

b.2 Public-private partnership

- MMP should establish a collaborative relationship among the stakeholders such as Khans, Sangkats, etc. to eliminate unserviced areas and insufficiently serviced areas together with the private sector.
- MPP should publicize, educate and enforce the citizens as an administration regardless of whether it is public or private territory.
- The private sector should recognize MPP's obligation to ensure that all citizens enjoy this public service and should take the appropriate measures in response to any requests by MPP regarding this point. At the same time, the private sector should request to receive the support from MPP to obtain public cooperation (payment of fees, proper discharge, etc.) for implementing their activities.

b.3 Establishment of financial base

- MPP guides PPWM and CINTRI to manage their services by their own income obtained from the user fees.
- MPP should decide on an appropriate waste fee based on the unit costs of works such as collection and transport, street sweeping, park cleansing, final disposal and management. MPP should request the customers to pay the waste fee by explaining that the service provider uses the fees efficiently.
- MPP should lighten the burden on PPWM by obtaining foreign grant assistance because PPWM has to provide the collection service to the areas that are not economically unfeasible for the private sector.

13.1.3 Priority Projects

a. Priority projects

The following priority projects were selected to solve the problems urgently.

Table 13-1: Priority Projects and Investments

(unit: US$ 1,000)

Project Name	Contents	investment (2005 - 2006)	Investment (2007)
Dang Kor Disposal Site Development Project	Construction of new disposal site	8,890	0
	Construction of compost plant	1,194	0
	Construction of maintenance workshop	1,574	0
	Sub total	**11,658**	**0**
Waste Collection Service Expansion Project		1,804	195
SMC Disposal Site Closure Project		75	745
Total		**13,537**	**940**

b. Project appraisal

The priority projects were evaluated from technical, social, environmental and economic aspects, and the appropriateness of the projects was verified.

Dang Kor Disposal Site Development Project

The cost required to sustain the sanitary landfill operation in the case that foreign grant assistance is obtained is 4.4US$/ton. Therefore, for PPWM to secure the required funds, it needs to make repeated efforts to obtain the understanding of the users during operation of the existing disposal site and gradually raise the disposal fee.

Waste Collection Service Expansion Project

On May 12, 2004, CINTRI agreed to the master plan where PPWM provides the collection service to the unserviced area, which is a precondition for implementation of this project. In addition, this project requires a fee collection rate of 80% or more, and a fee collection rate of 80% has already been achieved in the pilot project. As the plan for the expansion of collection services by PPWM targets areas that are not economically feasible for the private company, foreign grant assistance must be obtained for its implementation.

SMC Disposal Site Closure Project

As a result of the financial analysis, it was found that assuming the funds for this project are raised through the disposal fee of the new disposal site in Dang Kor, a mere 0.28 dollars/ton will be required. Therefore, implementation of this project is feasible, provided that the new Dang Kor disposal site is carried out as an economically viable project.

c. Matters to be considered for the project implementation

The following matters should be considered to implement the priority projects.

Technical aspect

- In the Dang Kor Disposal Site Development Project, a geological survey should be conducted in the detailed design stage, and measures against groundwater contamination by leachate should be taken.
- Leachate runoff should be estimated, and the necessary measures should be taken.
- The improvement pilot project carried out by the study team at the SMC disposal site was an emergency measure. As a long term measure, the closure plan must be strictly adhered to. Also, in closing the site, a monitoring system should be established and continued. The conditions for suspending monitoring should be established by the time of closure.

Social aspect

- As a result of the construction of the new disposal site and closure of the existing one, waste pickers will lose their livelihood and recycling businesses in the surrounding area will be hard hit. For the waste pickers, it is necessary to establish a basis of livelihood for them over time, with the cooperation of NGOs. As for the recycling businesses, PPWM should exchange views with them and examine countermeasures to cope with the situation.
- A foundation to ensure the stakeholders fulfil their responsibilities will be established based on a common understanding by the stakeholders,

administration, citizens, private companies, and NGOs on solid waste management. Therefore, rules for waste management must be established.

Environmental aspects

- In the results of the environmental survey, EIA survey and water quality survey, some data was questionable and some minimum quantitative limits were higher than the standard of Cambodia. These include SS, lead, cadmium, total mercury, organic mercury, BOD, COD, nitrogen as ammonium and TSP. However, this data should be reviewed because of the analytical level of the MOE laboratory and lack of advanced equipment for analysis. In order to monitor the environment of the project site effectively, a re-survey of the data mentioned above is indispensable as baseline data.
- It is important to establish measurement systems to meet the Cambodian standard before the start of operation; that is, measurement systems that can detect levels lower than the standard. Therefore, raising of the analytical level of analysts, strengthening of data management and installation of advanced equipment are urgently needed
- At the planned site of the new disposal site, an observation well should be constructed in the shallow part of the permeable layer to monitor water quality and check for groundwater contamination by harmful substances.
- In the dry season, the concentrations of mercury in samples from the Prek Thot River and the irrigation canal at Choeung Eak commune located in and around DKDS exceeded the standard for public water areas in Cambodia. The team tried to find out the pollution source but it could not be determined. The team suggests the possibility of contamination by pesticide. If so, the possibility of organic mercury is very high. Therefore, not only total mercury but also organic mercury must be re-surveyed for confirmation before the operation of DKDS.

d. fProgress of the Dang Kor disposal site development project

d.1 Environmental Impact Assessment (EIA)

Based on the IEE implemented in advance, the EIA for the Disposal Site Development Project, which includes the construction of a final disposal site, compost plant, and maintenance workshops, was carried out to determine the impacts of the project on the following:

economic activity, traffic and public facilities, ruins and cultural property, public health, the socially vulnerable, hydrological conditions, fauna and flora, landscape/aesthetics, air pollution, water pollution, soil contamination, noise and vibration, and offensive odour.

It has been concluded that the allowable limit can be maintained by preparing suitable countermeasures based on the results of the EIA.

The EIA was approved by the Ministry of Environment of Cambodia on July 15, 2004.

d.2 Land acquisition and public hearing

MPP has already acquired 31.4 ha and 5,500m^2 of land for the new disposal site and access road for implementing the Dang Kor disposal site development project.

MPP also held three public hearings targeting the residents living in the project site and surrounding area (96 persons on Oct. 10, 2003; 279 persons on Dec. 25, 2003; and 352 persons on July 15, 2004) and obtained public consensus.

13.1.4 Other SWM Problems and Recommended Countermeasures

a. Medical Waste Management

The generation amount of infectious and hazardous medical wastes, estimated on the basis of the medical waste survey results, is 0.96 tons/day, or 350 tons/year. A technical system (separation of infectious and hazardous medical wastes at the source for separate collection, transport and treatment/disposal) for such wastes needs to be established as quickly as possible. Because the amount of hazardous medical waste generated is very limited compared to municipal solid waste, the disposal of such waste will not be such a big burden, on the condition that it is strictly separated from non-hazardous medical waste (general medical waste : 9.7 tons/day, 3,540 tons/year). Therefore, the Ministry of Health (MOH), which is responsible for supervising waste disposal at medical institutions, must ensure the strict separation of hazardous medical waste at the source, at every stage including collection, intermediate treatment, storage, and discharge.

As for non-hazardous medical waste, after strict separation from hazardous waste, it can be collected and disposed of as general waste, as is done at present.

Regarding non-hazardous medical waste, there are problems with disposal at individual medical institutions by small-scale incinerators in respect to air pollution and operation and maintenance. On the other hand, with the construction of large-scale incinerators, it is necessary to overcome problems in terms of size and investment cost recovery.

Hence, as a provisional method, the study team recommends disposal at individual medical institutions by small scale incinerators along with disposal by sanitary landfilling at disposal sites approved by the Ministry of Environment as being suitable for hazardous industrial waste. In the future, hazardous medical waste should be treated en masse at appropriate incineration plants along with other hazardous wastes. When the hazardous waste incineration plants are in operation, strict air pollution controls should be applied to existing small scale incinerators.

This kind of improvement work is accompanied by a rise in expenses. By law, medical institutions must bear all costs for handling hazardous medical waste, from collection to final disposal. Therefore, the Ministry of Environment, with the cooperation of the MOH, should examine ways in which medical institutions should cover the rise in costs.

b. Industrial waste management

According to the factory survey, the generation amount of hazardous industrial waste (1.9 tons/day, 694 tons/year) is very limited compared to that of non-hazardous industrial waste (56.3 tons/day, 20,550 tons/year). Furthermore, an industrial waste disposal site that has been approved of by the Ministry of Environment as being suitable for hazardous industrial waste is located in the neighboring of Kandal province. Therefore, the DOE and PPWM should establish a strict monitoring system for incoming vehicles to prevent hazardous industrial waste from being disposed of with general waste at the municipal disposal site. Industries categorized as highly potential hazardous industrial waste generators will not be permitted to dispose waste at the municipal disposal site until they have proven their waste is not hazardous.

Meanwhile, standards and guidelines for implementing control and regulations at the national level should be immediately established, driving home the guiding principle that the polluter is responsible for the waste he generates.

As for non-hazardous industrial waste, after strict separation from hazardous industrial waste, it should be collected and disposed of as general waste, as is done at present.

c. Septic tank sludge management

According to the septic tank sludge survey, the amount of sludge disposed of in the treatment ponds installed at SMC disposal site is a mere 5.8m3 a day on average (based on 2003 data). Supposing that 30% of Phnom Penh' population of 1,200,000 are using sludge treatment tanks, the generation amount, estimated based on Japanese data, would be 306m3 per day, which is 53 times more sludge than is generated at present.

Judging from this result, ① septic tanks are not working because the majority of them are full with sludge, or ② if the sludge is being collected, it is being improperly disposed of somewhere other than the treatment ponds at SMC disposal site.

In order to improve this situation, MPP should take the following measures:

- Investigate the condition of the installation of tanks and the collection of sludge, and based on the findings, formulate a management for plan septic tanks and septage sludge.
- Examine standards for septic tank management, establish laws for septic tanks, and clamp down on the improper disposal of septage sludge.
- Based on the management plan for septic tanks and septage sludge, establish a collection system and install new sludge treatment facilities.
- While the new sludge treatment facilities are being installed, maintain and use the existing treatment ponds at the SMC disposal site.

13.2 Recommendation

13.2.1 Recommendation for improvement of the Master Plan

a. Unserviced and insufficiently serviced areas

- MPP and the private company (CINTRI) should identify the unserviced and insufficiently serviced areas remaining in the city and amend the agreement to allow PPWM to provide the collection service to those areas.
- MPP/DOE should establish a system to monitor and control the service provided by PPWM and the private company.

b. Establishment of a proper final disposal

- PPWM should continue the pilot project for improvement of the SMC disposal site and develop its capability of landfill management.
- PPWM should raise the level of sanitary landfill operation in the SMC disposal site step by step.

- PPWM should explain the increased benefit resulting from improvement of the landfill operation to the users and ask them to understand the necessity of raising the disposal fee and agree to pay it.
- PPWM should negotiate with the user for raising the disposal fee step by step to cover the cost of landfill operation.
- PPWM should explain the activities conducted for improvement of the SMC disposal site and persuade not only the residents living in the surrounding area but all citizens to share the cost for proper landfill operation.

c. Implementation of the priority projects

- Considering the internal difficulty in raising funds, the team recommends that MPP make every effort to secure the funds with foreign assistance to implement the Dang Kor Disposal Site Development Project and Waste Collection Service Expansion Project.
- To make the project financially sustainable by only the income from the waste fee, MPP should secure a stable fee income system based on the establishment of a reasonable and transparent fee rate system that can be well accepted by all MSW users.
- MPP should repeatedly explain the Dang Kor Disposal Site Development Project to the citizens living in the project site and the surrounding area until the implementation stage of the project to ensure their adequate understanding and to build public consensus.
- PPWM should have a meeting with the waste pickers earning their daily bread in the SMC disposal site to discuss the future plan and treatment.
- In order to supervise the operation of the new disposal site in Dang Kor, the DOE should set up a monitoring committee with the cooperation of the MOE, Khan and Sangkat offices, local residents, NGOs, etc.

d. Acquisition of land for the facilities needed to implement the M/P

- MPP should acquire the land for waste treatment and disposal facilities according to the strategies set in Section 3 of this report. However, site acquisition becomes increasingly difficult as more and more residents have the NIMBY syndrome. The MPP should secure the sites in advance.