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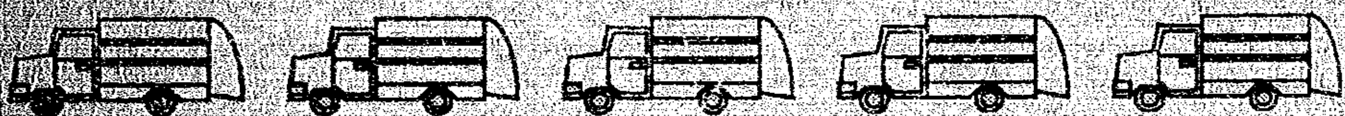
No. 52

THE ROYAL THAI GOVERNMENT
THE BANGKOK METROPOLITAN ADMINISTRATION

THE STUDY ON BANGKOK

SOLID WASTE MANAGEMENT

FINAL REPORT



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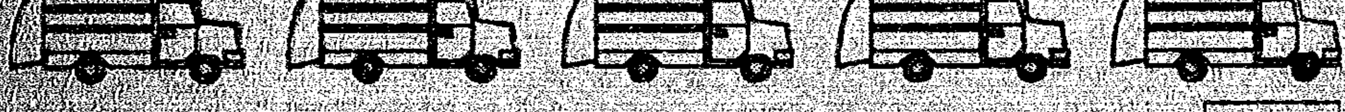

JAPAN INTERNATIONAL COOPERATION AGENCY

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91-014

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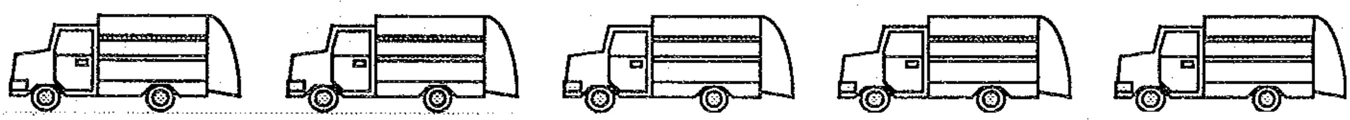

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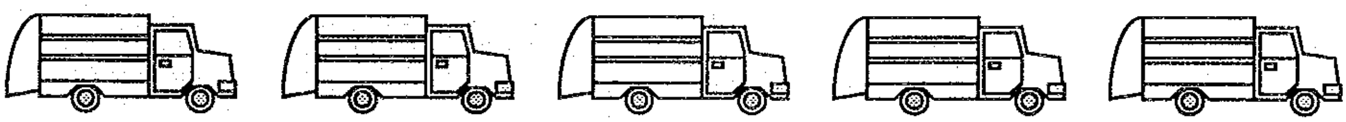

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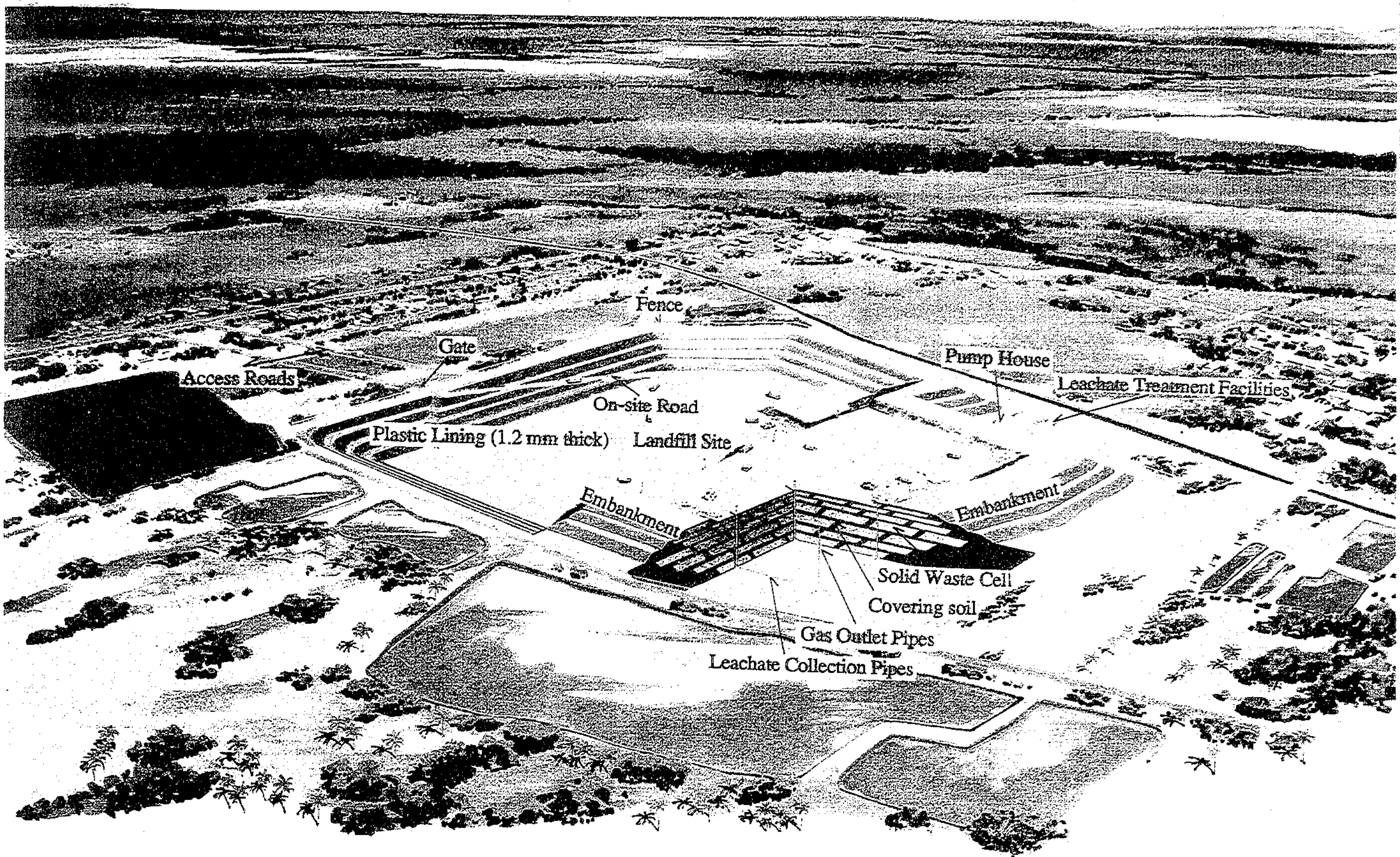
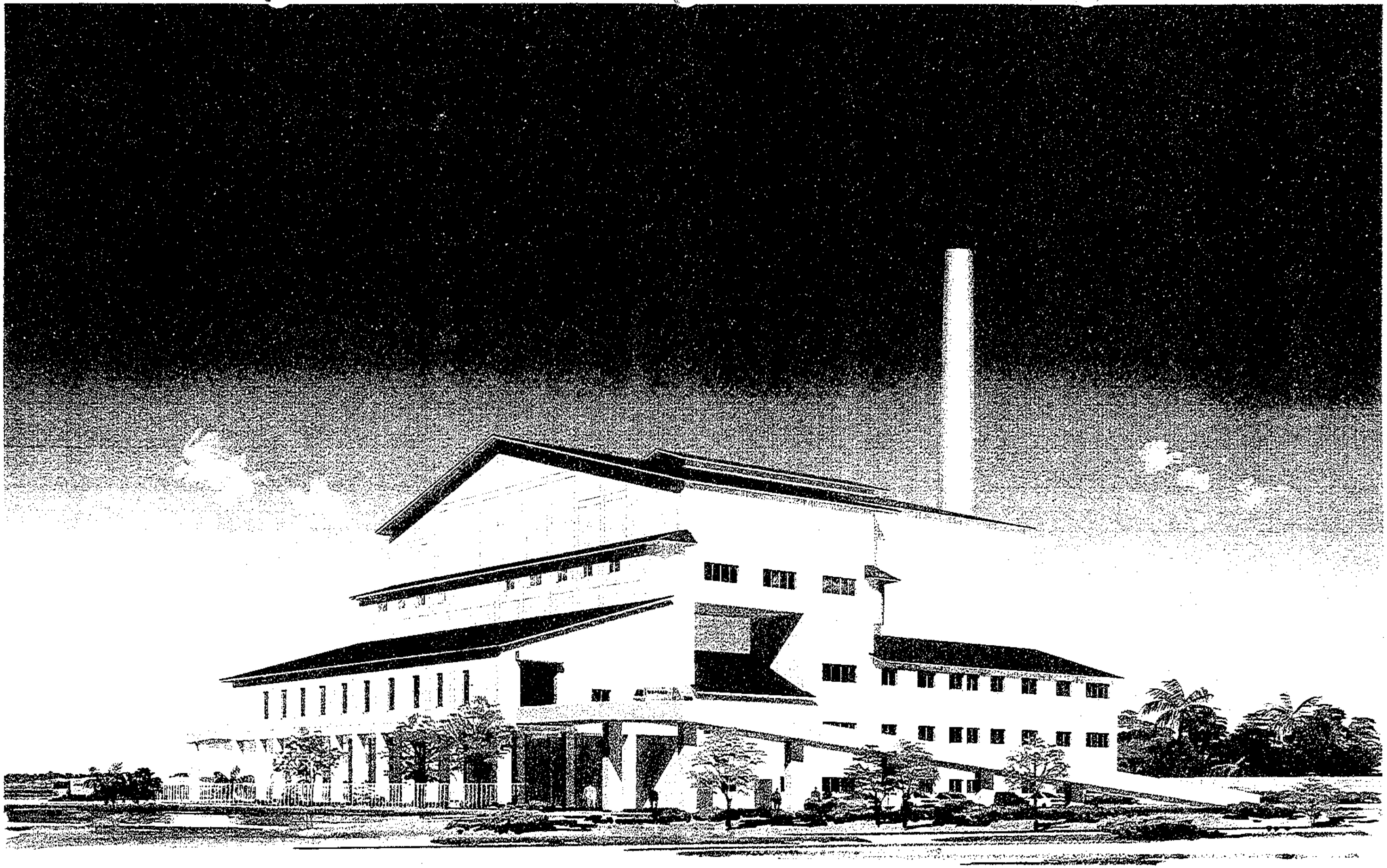


Planned Sanitary Landfill Site (Complete Type) in Ram Intra



Planned Incineration Plant in On Nut

PREFACE

In response to a request from the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a study on the Bangkok Solid Waste Management and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Thailand a study team headed by Mr. Kyoichi Miyazaki, and composed of members from the EX Corporation and Pacific Consultants International, three times between January 1990 and January 1991.

The team held discussions with the officials concerned of the Government of Thailand, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

March 1991

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

Abbreviations (Listed in alphabetical order)

B	Baht
BMA	Bangkok Metropolitan Administration
BOD	Biochemical Oxygen Demand
BPP	Beneficiary Pay Principle
$Ca(OH)_2$	Calcium Hydroxide
COD	Chemical Oxygen Demand
DDS	Department of Dranage and Sewage
DPC	Department of Public Cleansing
DTEC	Department of Technical and Economic Cooperation
F/S	Feasibility Study
GDP	Gross Domestic Product
GPP	Gross Provincial Product
HCl	Hydrogen Chloride
JICA	Japan International Cooperation Agency
LHV	Low Heat Value
MB	Million Baht
MMD	Mechanical and Maintenance Division (Central Workshop) of Finance Department, BMA
m^3N/h	Cubic meter Normal / hour
M/P	Master Plan
N.D.	Not Detective
NESDB	National Economic Social Development Board
ONEB	Office of National Environmental Board
PPP	Polluter Pay Principle
Pt-Co unit	unit of Platinum-Cobalt method
PVC	Poly Vinyl Chloride
SWM	Solid Waste Management
SS	Suspended Solid
t/d	tons/day
T-KN (T-N)	Total Nitrogen (Kjeldahl method)

Rai (Thai Unit) = 1,600 m^2
Soi (Thai Words) : Narrow Street
Khlong (Thai Words) : Canal

Exchange Rate (as of January 1991)

1 \$ = 25 Baht = 130 Yen (Approximately)

Study on Bangkok Solid Waste Management

VOLUME 3 FEASIBILITY STUDY

CONTENTS

Part II Feasibility Study on the Incinerator at On Nut

Part I

Feasibility Study on the Sanitary Landfill at Ram Intra

Chapter 1. Objectives and Outline of the Project

1.1 Objectives

The objective of the project is to realize a sanitary landfill as the BMA's the first sanitary and environmentally sound disposal site.

This project is both important and socially desirable since:

1. This project is the first of its kind for the BMA. The successful implementation of the project will imply remarkable "Take-off" from the low level disposal system (open dumping) to a higher level system (sanitary landfill).

2. This project is an important pilot project since it uses a borrow pit for the sanitary landfill. The successful implementation will imply that the BMA can possibly use many other borrow pits (similar to that at Ram Intra) in the future.

3. This project will contribute to an increase in the land value by converting a hole (borrow pit) to a flat land that could be used as a public park or other purpose, which can be beneficial to the Bangkok citizens.

1.2 Outline

The feasibility study considers the following two cases:

Case 1: A complete sanitary landfill with:
- Artificial lining (thickness = 1.2 mm) on the entire pit (both the bottom and sides) for the prevention of seepage of leachate
- Both biological and chemical treatment

Case 2: A lower level sanitary landfill with
- Artificial lining (t = 0.2 mm) only on the bottom of the pit (no lining on the sides of the pit) for making the bottom part less permeable. A permeable layer made of crushed stone will be provided below the lining.
- Biological treatment (without chemical treatment)

Case 1 and Case 2 are both technically feasible. Case 1 is much more effective in the prevention of water pollution. However it requires a 43 % higher unit cost (per ton) than Case 2. A detailed evaluation of the two cases are shown in Chapter 8. It is expected that the planned site (in both cases) will be used for about 5 years (1994 - 1998) based on of 1,000 tons of waste per day. A summary of the two cases is shown in Table 1.2-1.

Table 1.2-1 Summary of Case 1 and Case 2 for Sanitary Landfill at Ram Intra

	CASE 1	CASE 2
ITEMS	COMPLETE SANITARY LANDFILL	A LOWER LEVEL SANITARY LANDFILL
Site area	176,000m^2 (110rai)	176,000m^2 (110rai)
Disposal area	157,000m^2 (98rai)	157,000m^2 (98rai)
Capacity	3,000,000m^3	3,250,000m^3
Waste volume	2,300,000m^3 (1,825,000t)	2,500,000m^3 (2,000,000t)
Cover material volume	700,000m^3 (910,000t)	750,000m^3 (975,000t)
Construction cost	356,500,000B (195B/t)	227,500,000B (114/t)
Civil work	304,500,000B (167B/t)	167,500,000B (84/t)
Leachate treatment facility	52,000,000 (28B/t)	60,000,000 (30B/t)
O/M cost (Average)	115 B/t	91 B/t
Land acquisition cost	95,200,000B (52B/t) (85 rai)	95,200,000B (48 B/t) (85 rai)
Total Disposal cost	362 B/t	253 B/t
Soil cover	Daily covering	Daily covering
Leachate treatment	Chemical and Biological treatment	Biological treatment
Lining	Artificial lining (t = 1.2 mm) for the prevention of seepage of leachate	Artificial lining (t = 0.2 mm) only on the bottom of the pit (no lining on the sides of the pit) for making the bottom part less permeable. A permeable layer made of crushed stone will be provided below the lining.

Chapter 2. Site Conditions

2.1 Location and Boundary

The planned site for sanitary landfill is a borrow pit located adjacent to the BMA's closed compost plant at Ram Intra. The site is about 20 km to the north of the central part of Bangkok. A site map and topographical map of the site are shown in Fig. 2.1-1 and Fig. 2.1-2 respectively.

It should be noted that the legal boundary of the premise (85 rai) exists within the upper edge of the borrow pit. (It is planned that the entire pit will be filled with waste, and the filled area outside the boundary will be returned to the land owner after the completion of the landfill.)

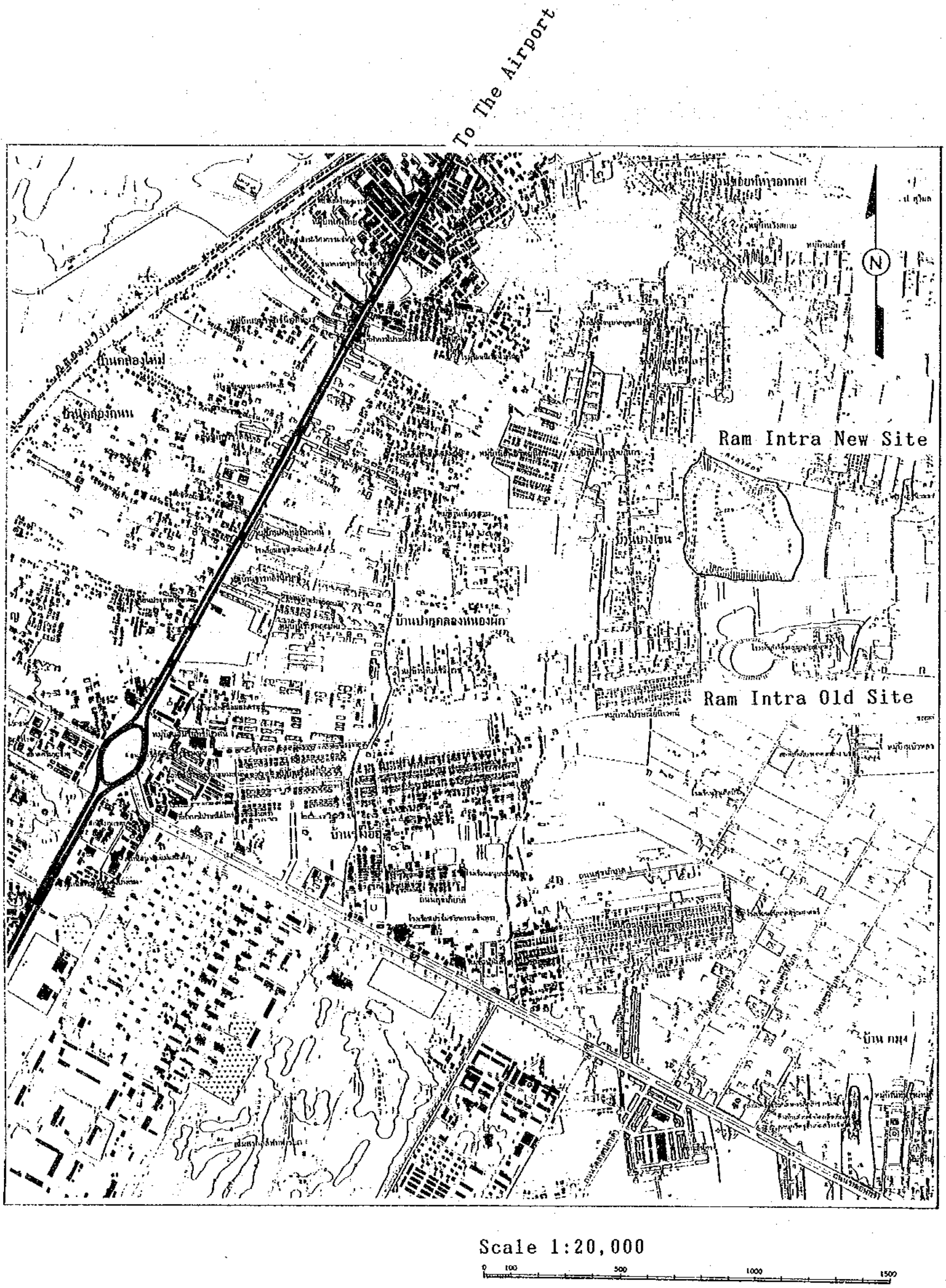


Fig. 2.1-1 Location Map

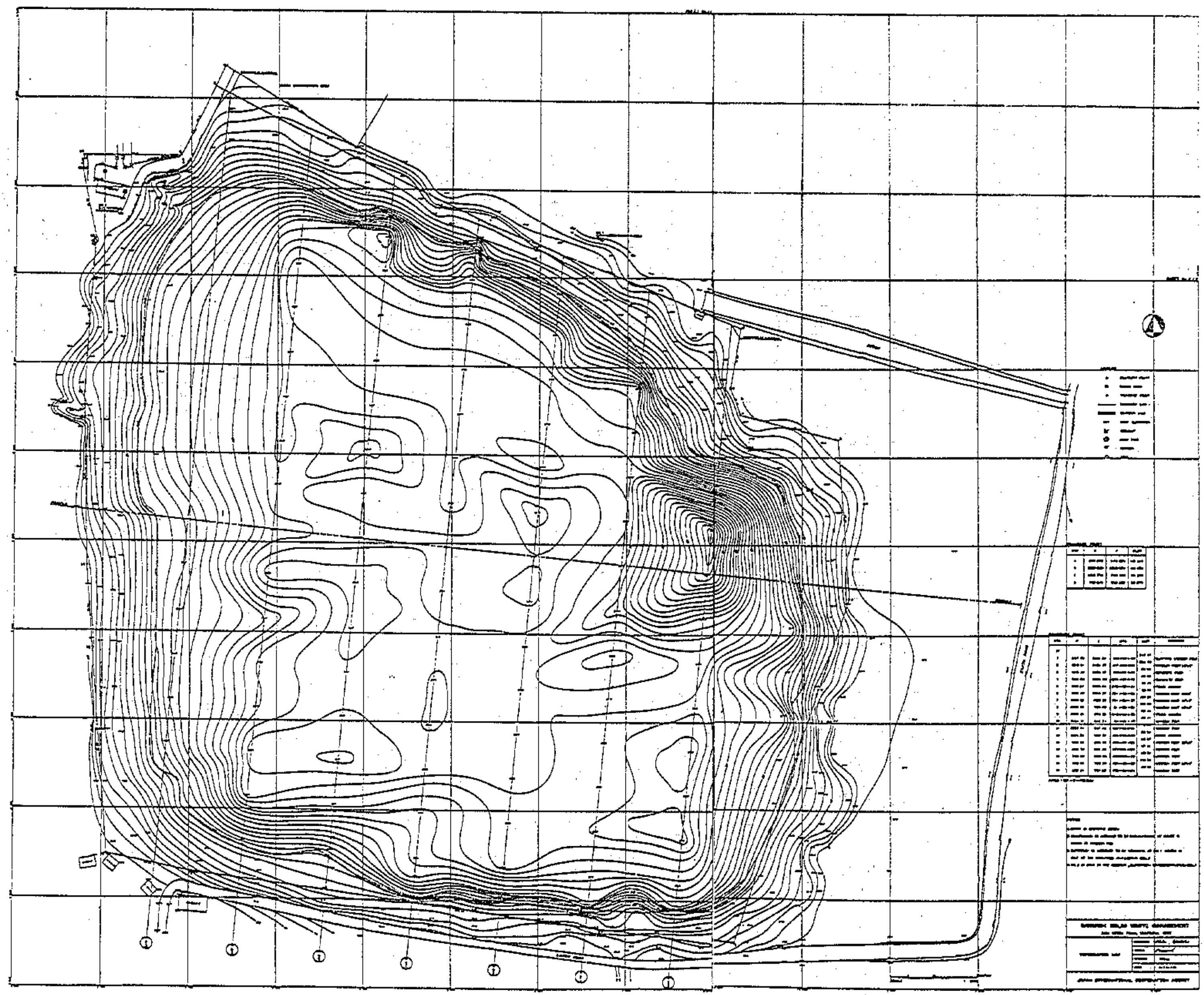


Fig. 2.1-2 Topographical Map and Boundary of the Site

2.2 Environmental Conditions

2.2.1 Physical Resources

1) Climate

Thailand has a tropical climate with wet and dry seasons. The dry season can be divided into cool and hot seasons. Such seasonal changes occur as a result of changes in monsoon wind directions.

Temperatures, humidity, and rainfall recorded between 1956 and 1985 in Bangkok by Meteorological Department are shown in Fig. 2.2-1. Annual mean temperature is about 28°C. The highest monthly mean temperature is 30°C in April, and the lowest monthly mean temperature is 26°C in December. Monthly mean humidity ranges from approximately 70% to 80%.

In Bangkok, average annual rainfall is about 1500 mm. Mean maximum monthly rainfall is over 200 mm in September and October, and mean minimum monthly rainfall is less than 10 mm in December and January. The heaviest daily rainfall was 167.3 mm (June 1979).

In Bangkok wind is not strong, mean wind speed is 1.7 m/s. Most frequent wind direction is south to southwest in February through August and north to northeast in October through December according to data recorded between 1951 - 1980.

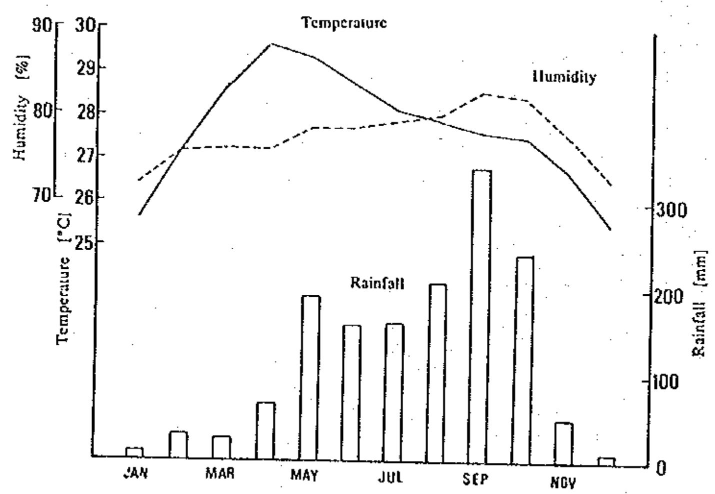


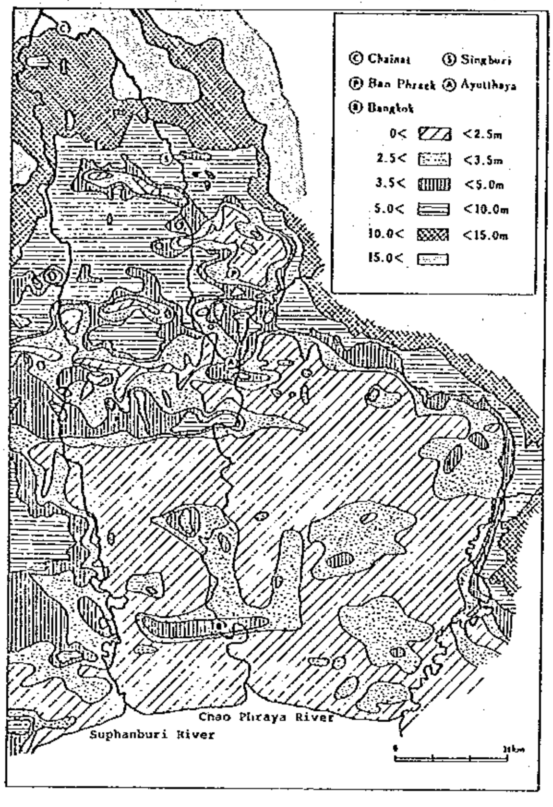
Fig. 2.2-1 Average Monthly Climate in Bangkok (1956 - 1985)

Source : Ministry of Communication

2) Topography

Bangkok is situated in Bangkok Plain which is a southern part of Central Plain. The Bangkok Plain is part of the alluvial delta of the Chao Phraya river basin. The quaternary alluvial deposit in this plain reaches to a 300 m depth in the Bangkok area. The surface layers of the Bangkok Plain are composed of recent and semi-recent alluvial deposits.

The elevation of Bangkok is less than 5 m, and there is little slope. The contour map of the Chao Phraya delta is shown in Fig. 2.2-2. The inner districts of Bangkok has been subsiding at a rate of 5 to 10 cm a year.



Source : Y. Tanaka (Agricultural Development of Tropical Delta)

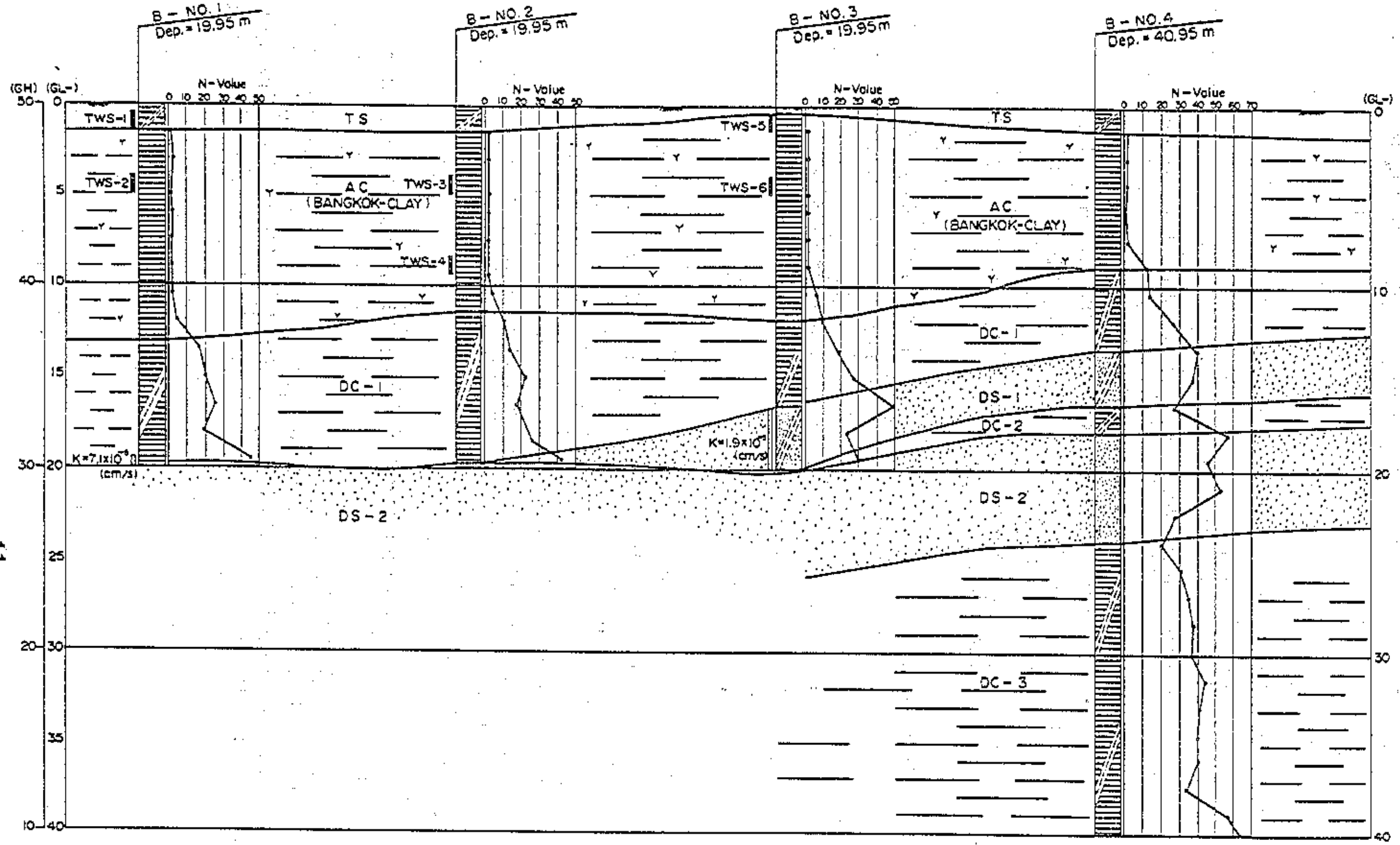
Fig. 2.2-2 Contour Map of the Chao Phraya Delta

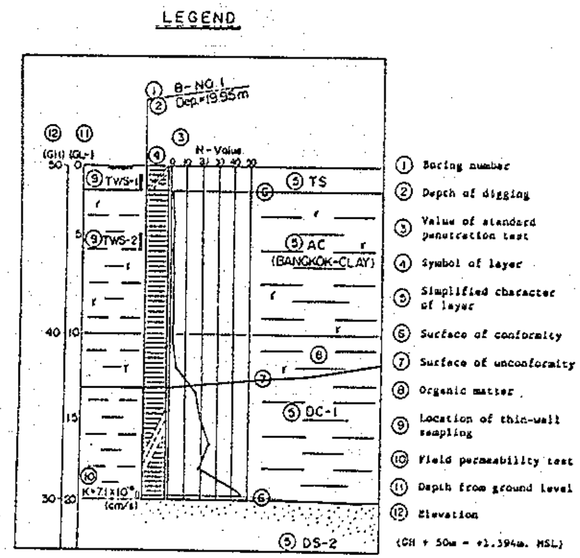
The planned site is a borrow pit located at Ram Intra. This pit has an area of about 100 rai. Its depth is 25 m on average, and 40 m in the deepest part (east part of the hole). Topographical map is shown in Fig. 2.1-2.

3) Geology

Fig. 2.2-3 shows geological logs and cross section of the site, which were prepared based upon the field investigation. The result of logs and detailed information of investigation are shown in Chapter 6 of Volume 4 Supporting Report. The report shows that alluvium and diluvium deposits are distributed over the site area. The alluvium deposit is a very soft clay layer with about 10 m thickness that is called Bangkok clay. The diluvium deposit consists of silty-clay layer and a layer containing both fine and coarse sand. The diluvium sand layer exists in the bottom of the pit. The alluvium clay has a very low permeability, however, the diluvium sand layer has 1×10^{-5} to 1×10^{-4} cm/sec permeability coefficient. Since these values indicate the layer may not be used as a impervious liner, a counter-measure against leachate seepage to ground water is needed.

A supporting layer of the pile foundation exists at about 20 m depth from ground level. However, in the case that light structures such as small office buildings are built by using friction pile foundations, the length of pile can be shorter than 20 m.





Time classification	Simplified character	Symbol	Characteristic
Alluvium	TS		Silty clay trace fine sand, brown. (CH)
	AC		Clay trace organic matter, dark gray, soft. (CH), Bankok clay.
Diluvium	DC-1		Silty clay trace fine sand, grayish brown, stiff to very stiff. (CH)
	DS-1		Silty fine sand, brown, dense, (SM)
	DC-2		Silty clay some fine sand, gray, some yellowish brown, very stiff. (CH)
	DS-2		Fine to coarse sand, brown, medium to very stiff. (SM-SP)
	DC-3		Silty clay trace fine sand, brown some li-gray, hard. (CH)

Fig. 2.2-3 Geological Logs and Cross Section of the Planned Ram Intra Site

4) Surface Water

There are some klongs around the planned Ram Intra site. The Khlong to which effluent will be drained from the site has been eutrophicated due to the slow current. Results of the observation of water quality of the Khlong are shown in Table 2.2-2. Observation points are shown in Fig. 2.2-4. BOD of the water ranges 22 - 23 at points (R-1 & R-2) near to the planned site.

The ONEB of Ministry of Science, Technology and Energy has the classification of water by quality as shown in Table 2.2-1. The water of the Khlong near the planned site may fall into Class 4 or 5 judging from results of the analysis of organic matter contained in the water.

Table 2.2-1 Classification of Water by Quality

CLASSIFICATIONS	OBJECTIVES/CONDITION & BENEFICIAL USAGES
Class 1	Extra clean fresh surface water resources used for: (1) conservation. Not necessary to pass through water treatment processes, require only ordinary process for pathogenic destruction (2) ecosystem conservation which basic living organisms can spread breeding naturally
Class 2	Very clean fresh surface water resources used for: (1) consumption which requires the ordinary water treatment process (2) aquatic organism conservation for living and assisting for fishery (3) fishery (4) recreation
Class 3	Medium clean fresh surface water resources used for: (1) consumption after an ordinary treatment process (2) agriculture
Class 4	Fairly clean fresh surface water resources used for: (1) consumption after special water treatment process (2) industry (3) other activities
Class 5	The resources which are not classified in class 1-4 and used for: (1) navigation

Source : Notification of the Ministry of Science,Technology and Energy, 1985
Laws and Standards on Pollution Control in Thailand – Second Edition, ONEB 1989

Table 2.2-2 Quality of Surface Water near the Planned Ram Intra

ITEM\SAMPLING POINTS		R-1	R-2	R-3	R-4
pH	(-)	8.0	8.0	7.7	7.2
DO	(mg/l)	22.6	19.4	14.6	7.3
BOD	(mg/l)	22	23	15	5
COD	(mg/l)	77	53	51	37
SS	(mg/l)	71	35	18	14
T-N	(mg/l)	5.4	3.8	2.7	2.2
T-P	(mg/l)	1.15	0.37	0.30	0.12
HEM	(mg/l)	4.7	3.6	3.1	1.1
Number of Coliform Group	(MPN/1 ml)	<2.3 x 10^4	<2.3 x 10^4	<2.3 x 10^4	1.7 x 10^3
Number of Fecal Coliform Group	(MPN/1 ml)	<2.3 x 10^4	<2.3 x 10^4	<2.3 x 10^4	2 X 10^2
Cd	(μg/l)	4.4	3.9	2.9	1.9
CN	(mg/l)	<0.02	<0.02	-	<0.02
Pb	(μg/l)	25	20	16	15
Cr	(μg/l)	5.5	6.7	6.8	9.3
As	(μg/l)	<0.1	<0.1	-	<0.1
Cu	(μg/l)	20	15	12	32
Zn	(μg/l)	90	140	170	120
Mn	(mg/l)	2.4	2.0	1.6	0.7
T-Hg	(μg/l)	<0.1	<0.1	-	0.16
R-Hg	(μg/l)	<0.5	<0.5	-	<0.5
Org-P	(μg/l)	<1.0	<1.0	-	<1.0
PCB	(μg/l)	<0.05	<0.05	-	<0.05

Sampling Date: September 21, 1990

HEM: Hexane Extraction Method

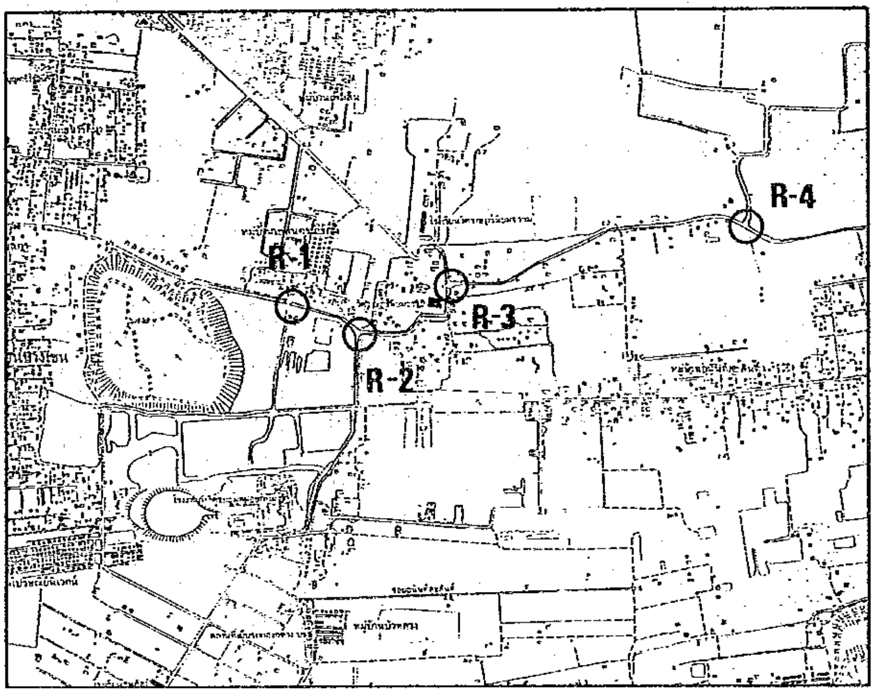


Fig. 2.2-4 Location of Sampling Points

5) Ground Water

Ground water exists in the whole Bangkok area. Usually, there are large and high-yielding aquifers in alluvium and terrace deposits. Ground water exists within crack formation in limestone, sandstone and some types of shale.

There are 8 aquifers in Bangkok as follows.

- Bangkok Aquifer	(50 m zone)
- Phra Pradaeng Aquifer	(100 m zone)
- Nakhon Luang Aquifer	(150 m zone)
- Nontha Buri Aquifer	(200 m zone)
- Sam Khok Aquifer	(300 m zone)
- Phaya Thai Aquifer	(350 m zone)
- Thon Buri Aquifer	(450 m zone)
- Pak Nam Aquifer	(550 m zone)

The ground water is pumped out mainly from the Phara Pradaeng, Nakhon Luang and Nontha Buri Aquifers. The consumption of ground water in Bangkok is shown in Table 2.2-3.

Table 2.2-3 Ground Water Use in the BMA in August, 1990

	DOMESTIC CONSUMPTION	BUSINESS	AGRICULTURE	TOTAL
Number of Well	2,831	1,489	222	4,542
Consumption Volume (m^3)	263,367	230,700	13,347	507,414

Sources : Ministry of Mineral Resources

Quality of the ground water at the Ram Intra candidate site examined by JICA team and that recorded in the testing well near the candidate site of Ministry of Minerals Resources are shown in Tables 2.2-4, and 2.2-5 respectively.

Table 2.2-4 Quality of Ground Water at Ram Intra by JICA Team

ITEM	pH	COD mg/l	BOD mg/l	SS mg/l	T-N mg/l	T-P mg/l	HEM mg/l	Cd μg/l	CN mg/l
Concentration	6.8	32	3.5	36	2.1	0.03	0.25	0.2	< 0.01

ITEM	Pb μg/l	Cr μg/l	As μg/l	Cu μg/l	Zn μg/l	Mn mg/l	T-Hg μg/l	R-Hg μg/l
Concentration	2	24	1.2	20	100	1.2	< 0.1	< 0.5

Sampling Date: October 2, 1990

HEM: Hexane Extraction Method

Table 2.2-5 Quality of Ground Water at Ram Intra Testing Well (Depth 145m)

Unit: mg/l

ITEM	Fe	Mn	Cu	Zn	SO_4	Cl	F	NO_3
Concentration	0.20	0.01	0	0	0	4.4	0	0

ITEM	Total hardness as $CaCO_3$	Noncarbonate hardness	Total Solid
Concentration	132	0	426

Sampling Date : December 11, 1980

Source : Ministry of Minerals resources

6) Air Quality

The Office of National Environment Board (ONEB) has monitored ambient air quality with 8 permanent monitoring stations in Bangkok. Location of monitoring stations and monitored parameters are shown in Volume 4 Supporting Report.

Suspended Particulate Matter (SPM) level is always highest in the early morning due to heavy traffic and calm wind condition.

Level of nitrogen dioxide in Bangkok is estimated at 0.02 mg/m^3 (hour), which is much less than the ambient air quality standards of 0.32 mg/m^3.

Level of sulfur dioxide (24-hour average) in Bangkok at 4 stations are 0.03 mg/m^3, which are much less than the ambient air quality standard of 0.3 mg/m^3.

Level of photochemical oxidant (1 hour) at the ONEB station is lower than the ambient air quality standards of 0.2 mg/m^3. The highest level of photochemical oxidant is observed around noon time in March and May, when solar radiation is strong. However, in rainy season the level declines to 0.05 mg/m^3.

2.2.2 Land Use and Transportation

1) Land Use

Land use of Bang Khen district where the planned site is located, and of the whole Bangkok are shown in Table 2.2-6. A land use map of Bang Khen district is shown in Fig. 2.2-5 Bang Khen district has an area of approximately 170km2. The total of empty space and agriculture areas account for about 67% of total area of Bang Khen district. Residential area accounts for approximately 10%.

Table 2.2-6 Land Use in Bang Khen District

Area		Residen-tial	Commer-cial	Industry	Ware House	Govern-ment Institute	Education Institute	Religion	Recrea-tion
Bang Khen District	area (km^2)	16.40	1.35	0.83	0.37	24.75	1.20	0.29	0.48
	%	9.69	0.80	0.49	0.22	14.62	0.71	0.17	0.28
Bangkok	area (km^2)	180.99	17.84	22.25	6.86	41.73	13.10	7.08	4.00
	%	11.54	1.14	1.42	0.44	2.66	0.83	0.45	0.25

Area		Public Utility	Road, Soil	Space	Agricul-ture	River Canal	Other	Total
Bang Khen District	area (km^2)	1.14	5.51	66.32	46.48	2.17	2.02	169.31
	%	0.67	3.25	39.17	27.45	1.28	1.20	100.00
Bangkok	area (km^2)	4.29	38.45	623.87	543.13	54.36	10.80	1,568.75
	%	0.29	2.45	39.77	34.62	3.47	0.69	100.00

Source: BMA

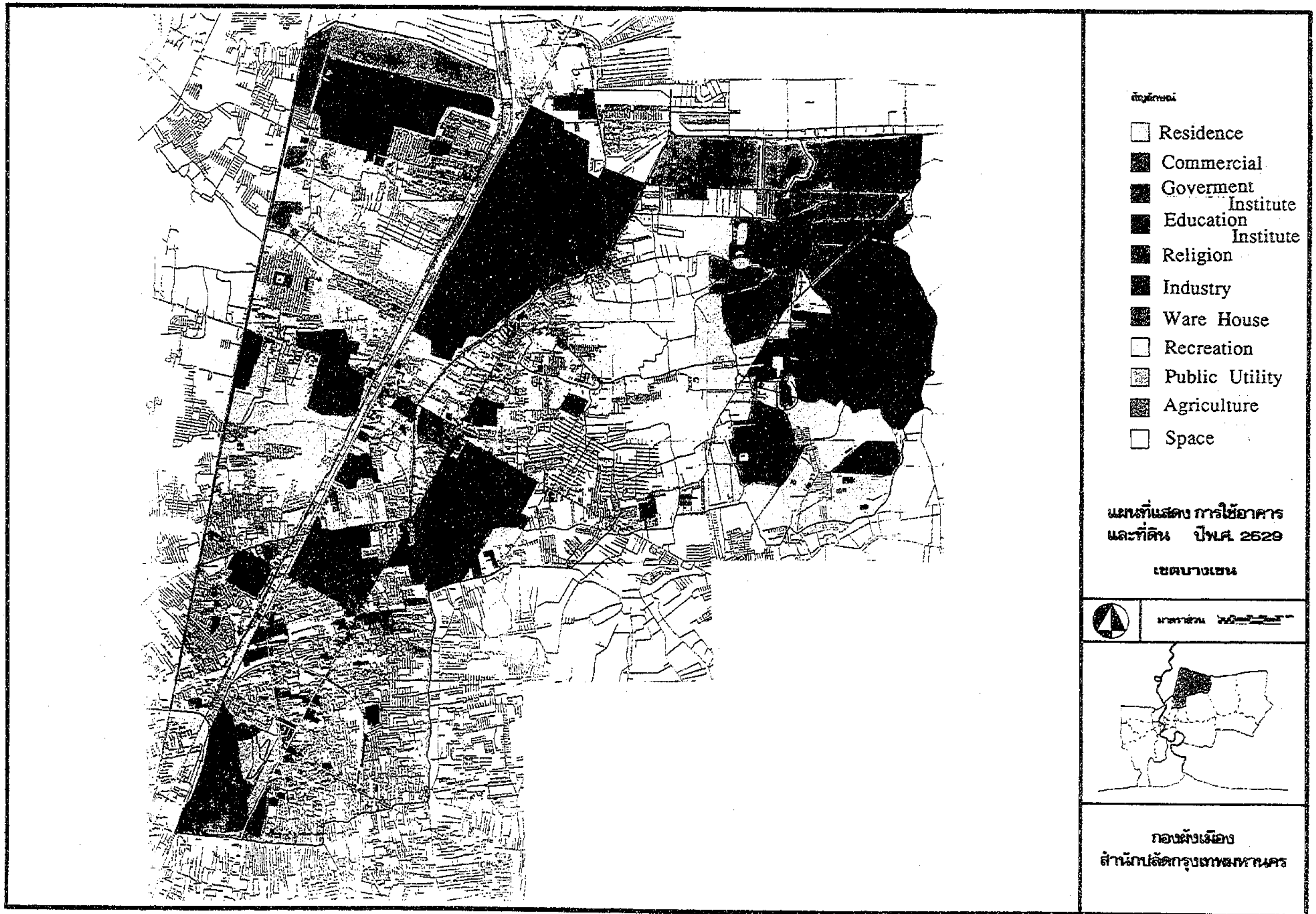


Fig 2.2-5. Landuse Map of Bang Khen District

2) Transportation

(1) Road

The road network around the planned Ram Intra site is shown in Fig. 2.2-6 Main roads include Phahonyothin Road which is located 1 to 1.5km east of the site, and Ram Intra Road which is located 1.5 to 2km south of the site. The Ram Intra Road connects to the Phahonyothin Road. There is no access road to the planned site with two or more lanes for each direction.

(2) Traffic Noise

Traffic noise observed at the access road to the planned site and background noise around the site surveyed in the current study are shown in Tables 2.2-7 and 2.2-8 respectively.

Table 2.2-7 Traffic Noise Observed at Ram Intra

Unite: dB (A)

STATION	RT-1	
TIME	11:58	12:09
L_{eq}	68.1	86.0
L_{50}	55	56
L_{max}	89	128.3

Sampling Data: 27 September 1990

Number of traffic volume was surveyed for 10 minutes.

Table 2.2-8 Background Noise Level Observed at Ram Intra

Unite: dB (A)

STATION	R-1	R-2	R-3
TIME	11:32	12:32	12:58
L_{eq}	47.9	64.8	57.3
L_{50}	46	51	46

Sampling Data: 27 September 1990

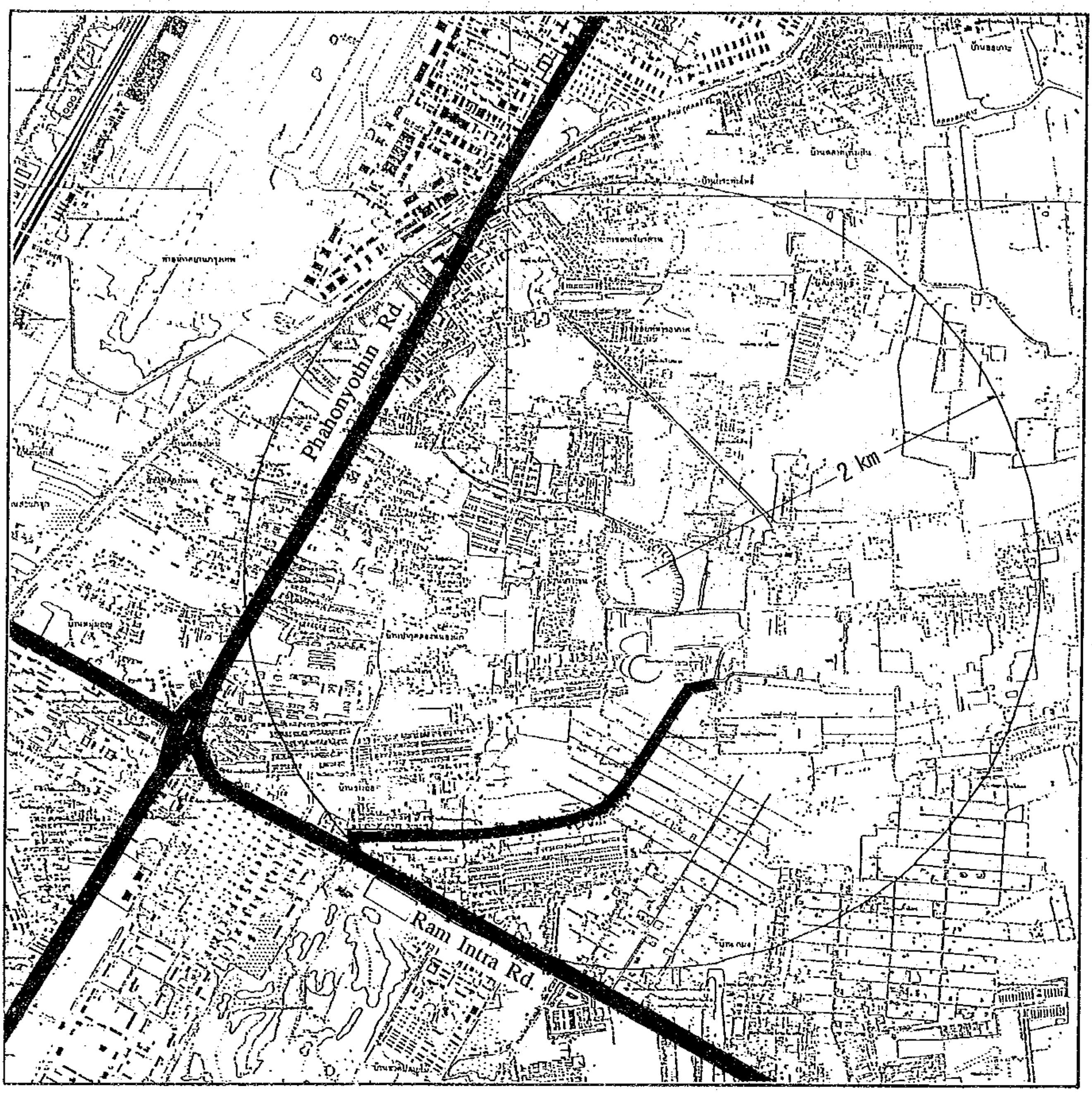


Fig. 2.2-6 Road Network in Ram Intra

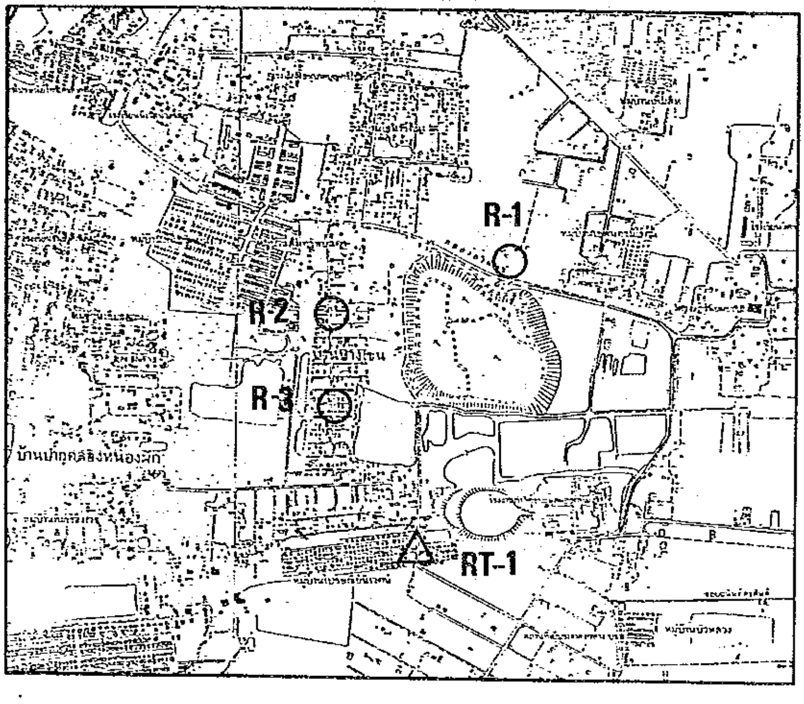


Fig. 2.2-7 Location of Noise Level Observation Points

3) Recreation

In Bang Khen district, recreation area accounts for 0.17% or 0.29km^2 of the total area of this district. However, there is no large scale recreation facility such as park within a 2 km radius of the planned site.

2.2.3 Social Culture Values

1) Cultural assets

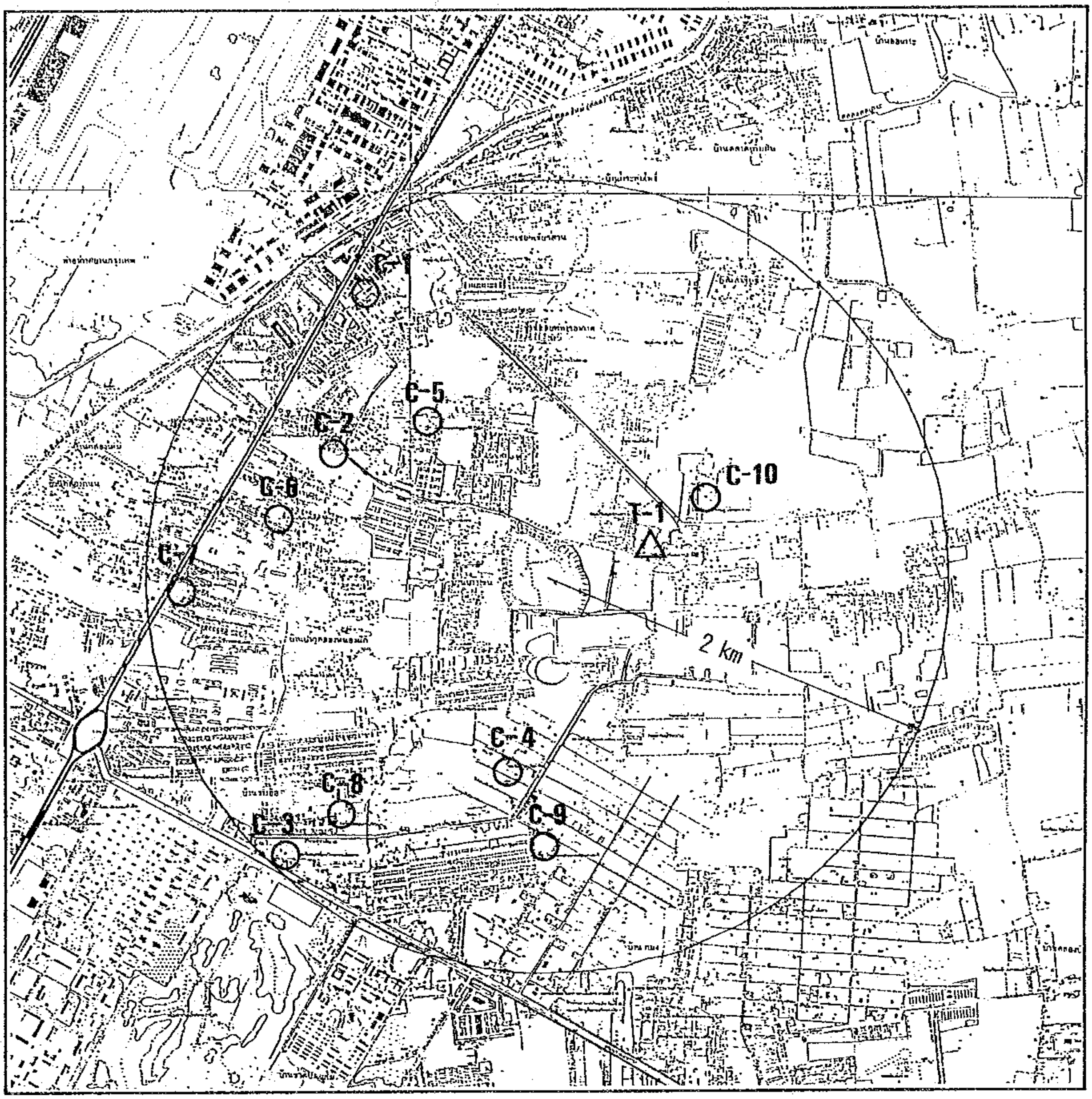
Location of Cultural assets around the planned site is shown in Table 2.2-9 and Fig. 2.2-7. There are five elementary schools and five junior high schools in the area within 2 km radius of the site.

Table 2.2-9 Educational Institutes

ITEM	INSTITUTES WITHIN 2 KM RADIUS OF THE PLANNED SITE
Public Elementary School	1
Private Elementary School	4
High School	5
Total	10

2) Archaeology

There is no historical site within 2 km radius area of the candidate site.



Private Elementary School	C-1,2,3,4
Junior Hight	C-5,6,7,8,9
Public Elementary School	C-10
Buddist Temple	T-1

Fig. 2.2-8 Location of Cultural Assets

Chapter 3. Planning Policy

The Ram Intra sanitary landfill has been planned based upon the following policies:

Policy 1. Minimization of Negative Environmental Impacts

The planned sanitary landfill site should have facilities necessary for minimizing negative impacts on the environment. The landfilling should be operated in such a manner as to also minimize such impacts.

The planned sanitary landfill site should be constructed and operated in such a manner as to satisfy the "Proposed Industrial Emission Standards by Industrial Environment Division, Ministry of Industry", although disposal sites are not legally subject to the Standard.

Policy 2. Cost-Effectiveness

The planned sanitary landfill shall be cost-effective. The planned sanitary landfill shall be of the least cost, given the environmental conditions to be met.

Policy 3. Utilization of Land after the Completion of Landfill

The sanitary landfill will be operated in such a manner that the site can be used as a public park after the completion of the landfill operation. In other words, this sanitary landfill project will bring about not only disposal benefits but also the future value increases of the land.

Policy 4. Maximization of Disposal Capacity

Although the legal boundary of the premise (85 rai) exists within the upper edge of the site, it is planned that the entire hole will be filled with waste so that the waste receiving amount will be maximized. The waste-filled area outside the premise boundary will be returned to the owner of the land after the completion of the sanitary landfill operation.

Chapter 4. Design Policy and Conditions

The planned sanitary landfill has been designed based upon the following design policy:

Policy 1. Prevention of Environment Pollution

1) Prevention of Water Pollution

a. Effluent Standards to be Met

The planned sanitary landfill shall be constructed and operated in such a manner as to comply with the following standards:

	MAX.
BOD (mg/l)	60*
SS (mg/l)	40*
Color (Pt-Co unit)	250
pH	5 - 9*

Note: Values marked with asterisks "*" are the same as those indicated in the Industrial Effluent Standards of Ministry of Industry. A standard for color is not included in the said Standard.

b. Facilities Required to Meet the Standards

The following facilities shall be provided to meet the above-shown standards:

- Lining
- Leachate treatment facilities
- Monitoring well

2) Prevention of Odor Diffusion and Breeding of Insects and Rodents

Soil cover will be applied everyday to prevent the diffusion of odor.

Policy 2. Safety

Explosive gas such as methane are normally generated in disposal sites. Gas collection and exhaust facilities will be provided to avoid explosion. Fire fighting equipment will also be provided.

Policy 3. Anti-Flood Measures

Embankments will be provided around the site to prevent flood water from flowing into the site.

Policy 4. Acquisition of Ownership of the Site

It is planned that the BMA shall purchase the planned area (85 rai) so that the BMA will continue to maintain the safety of the site, and convert it into a public park after the completion of the landfill.

Policy 5. Appropriate Duration of Landfill

The daily incoming waste amount will be controlled at about 1,000 tons/day so that the site can be used for more than 5 years. (The longer the site is used, the larger the amount of waste that can be disposed as a result of waste decomposition.)

Policy 6. Access Road

It is planned that the BMA will use the access roads leading to the south-west corner of the pit. The location of the access roads is shown in Fig. 3.1-1. As can be seen from the figure, one road will be used as an incoming traffic road, and the other will be used as an outgoing road. It is proposed that the BMA will widen the pavement up to the boundaries of the private land along the both sides of the road.

Policy 7. Use of the Closed Ram Intra Compost Plant Site as a Stock Yard for Construction Materials

It is planned that the DPC's closed compost plant site at Ram Intra will be used as a stock yard for construction materials during the site construction.

Chapter 5. Facilities and Construction Plan

5.1 Major Facilities Plan

Table 5.1-1 shows major facilities required for sanitary landfill, their function, and specifications for both Cases 1 and 2.

Table 5.1-1 Outline of Major Facilities for Both Cases 1 and 2 for Sanitary Landfill at Ram Intra

MAJOR FACILITY	FUNCTION	SPECIFICATIONS	
		CASE 1	CASE 2
Embankment	To prevent garbage from flowing out of the site and rainfall water from flowing in	Soil band of one meter height around the site	Same as Case 1
Lining	To avoid seepage of leachate and contamination of ground water	Artificial liner Thickness = 1.2mm	Construction of permeability layer (with crushed stone) higher than the existing bottom level & Artificial liner thickness = 0.2mm
Leachate Collection Facility	To collect leachate quickly	Ø 200 to Ø 300mm PVC porous pipe covered with crushed stone	Crushed stone only
Rainfall Water Drain Facility	To prevent water from flowing into the site	Concrete drain ditch (width = Depth = 300 mm) are constructed around the site	Same as Case 1
Leachate Treatment Facility	To treat leachate and improve quality of water to be discharged outside the site	Chemical and biological treatment	Biological treatment
Gas Exhaust Facility	To collect and release the gas generated from decomposed waste	Ø 200 to Ø 300mm PVC porous pipe covered with crushed stone	Crushed stone with PVC pipe (only at the top part)

Case 1: Complete sanitary final disposal system

Case 2: Simplified sanitary final disposal system

5.2 Leachate Treatment Facility Plan

Case 1 has both chemical and biological treatment, while Case 2 has only biological treatment. The former is more costly, and satisfy the Industrial Emission Standards proposed by Ministry of Industry. The latter is less costly, but does not meet the Standards. Both types of treatment facilities are outlined in Table 5.2-1. The flow of the treatment and major specifications are shown in Fig. 5.2-1 and 5.2-2 and Tables 5.2-2 and 5.2-3. Refer to Volume 4 Supporting Report for further details.

Table 5.2-1 Outlines of Leachate Treatment Facility for Cases 1 and 2

	CASE 1	CASE 2
Treatment Method	Chemical + Biological treatment	Biological treatment
Quality of Leachate to be Treated	High COD under anaerobic condition	Low COD under aerobic condition
Treated volume	Daily leachate treatment volume will be constant regardless of daily rainfall amount and daily generation amount of leachate. Excess leachate will remain inside the site.	All the leachate daily generated will be treated on the same day. Naturally, treatment volume will be much larger in rainy season than in dry season. Consequently, leachate amount will be kept at a low level inside the site throughout the year.
Treatment Capacity	200 tons/day	300 tons/day
Quality of Effluent	Meets the Industrial Emission Standards proposed by Ministry of Industry	Does not meet the Standards
O/M cost	Higher cost	Lower cost

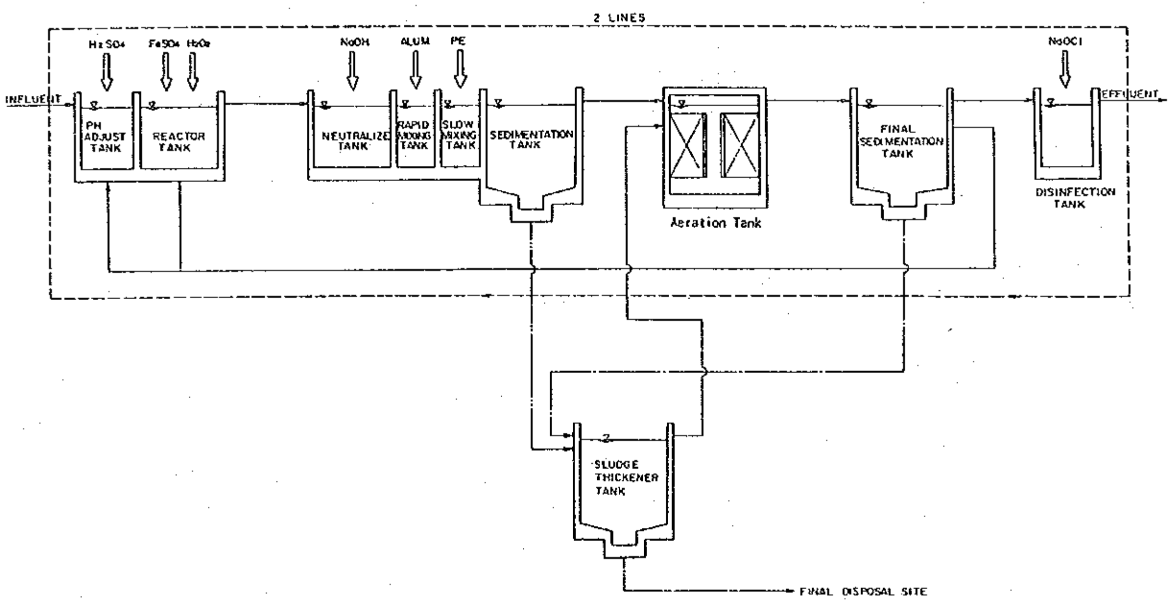


Fig 5.2-1 Flow of Case A

Table 5.2-2 Main Items of Case A

Method	Chemical treatment (Fenton Method) + Biological treatment
Capacity	100 t/d x 2 Lines = 200 t/d
Daily average treatment amount	200 t/d
Construction Cost	52,000,000 B
O/M Cost	82 B/t
Effluent water quality to be guaranteed	BOD 60 mg/l (Max.) SS 30 mg/l (Max.) pH 5-9 Color 250(Max.) Heavy metal ND

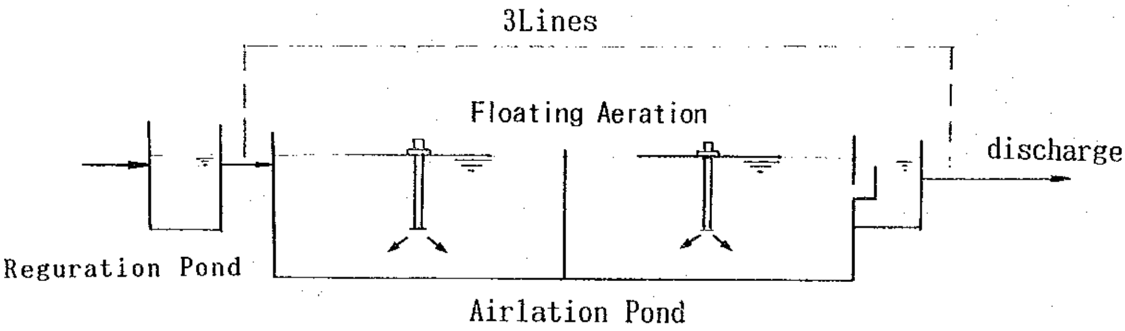


Fig. 5.2-2 Flow of Case B Airlation lagoon

Table 5.2-3 Main Items of Case B

Method	Biological treatment + (Airlation lagoon method)	
Capacity	100 t/d x 3 Lines = 300 t/d	
Annual average treatment amount	200 t/d	
Construction Cost	60,000,000 B	
O/M Cost	20 B/t	
Effluent water quality to be guaranteed	BOD	180 mg/l (Max.)
	SS	300 mg/l (Max.)
	pH	5-9
	Color	500 (Max.)
	Heavy metal	ND

5.3 Plan for Operation Control Facility and Monitoring

Major operation control facilities consist of the following facilities; Those facilities are common for both Cases 1 and 2.

1. Site Office
2. Weigh-bridge
3. Surface settlement measurement facility
4. Ground water quality monitoring facility (Well)

The planned landfill operation period is only 5 to 6 years. Therefore it would not be necessary for the BMA to construct a new site office and a weigh-bridge on the planned site. The BMA can utilize the existing site office and weigh-bridge located in the closed compost plant site at Ram Intra.

Typical facilities for the measurement of surface settlement and for monitoring ground water quality are shown in Figs. 5.3-1 and 5.3-2 respectively.

The exact specifications of those facilities have to be decided based upon the actual conditions of the site, waste, leachate, ground water, gas, etc.

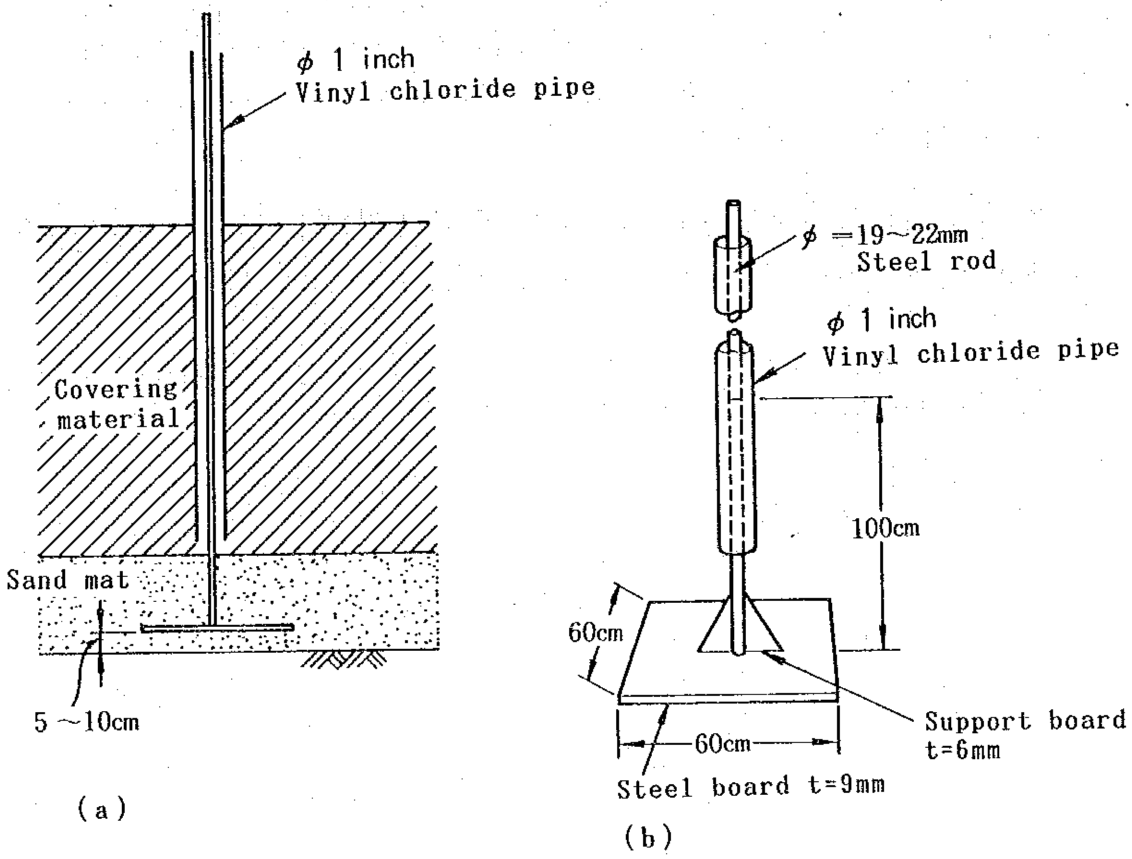


Fig. 5.3-1 Typical Surface Settlement Measurement Facility

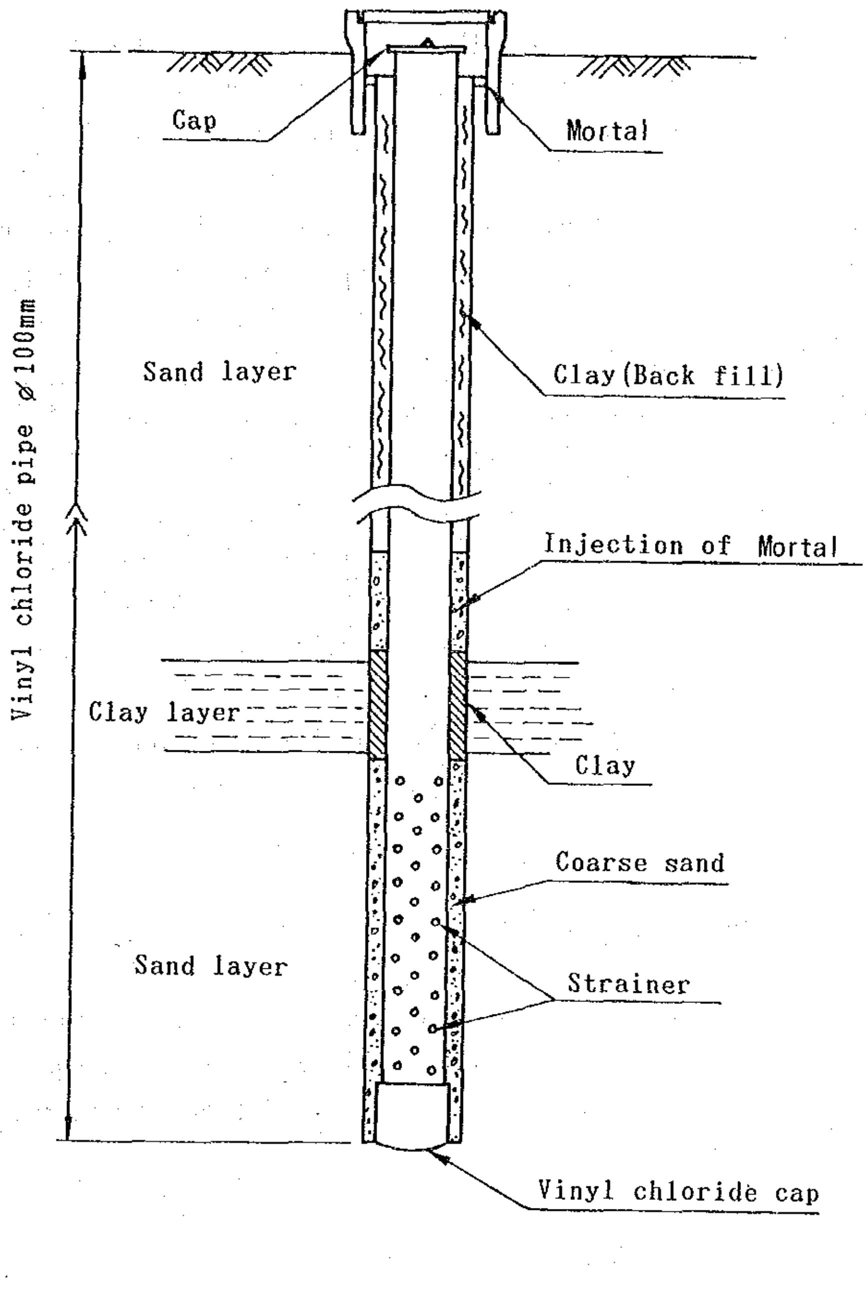


Fig. 5.3-2 Structure of Monitoring Well

5.4 Plan for Other Facilities

Other facilities required on the site are outlined in Table 5.4-1. Those facilities are common for both Cases 1 and 2.

Table 5.4-1 Other Facility

FACILITY	FUNCTION	OUTLINE
Access road	Access to the site from the public road	8 m wide, two way road. Paved part is 6 m wide, and covered with 0.5 m crushed stone
On-site road	Access to the leachate treatment facility	6 m wide, two way road. Pavement is 6 m, covered with 0.5 m crushed stone.
Fence	To prevent waste from flowing out	Net fence height = 1.8 m
Bulletin board	To inform neighborhood residents of the outline of the site	Board size W2.0m x H1.5m
Gate	To maintain security	Main gate is 6m wide. Small gate for leachate treatment facility is 3m wide.
Fence	To maintain security and avoid waste flowing out	Net fence
Fire fighting facility	To extinguish fire on the site	Handy fire extinguishers and cover soil to be placed on the site.

5.5 Heavy Equipment Plan

Some heavy equipment is required for bedding and compaction of waste and cover material. It is estimated that 10 bulldozers with wide caterpillars will be required for the planned sanitary landfill judging from the amount of waste and cover material to be handled.

Table 5.6-1 Required Heavy Equipment (Bulldozer)

Number:	10 units (1 unit is a standby.) with wide caterpillars
Class:	15 t/unit
Capability:	45 m3/h/unit

Note: The following assumptions are used for calculating required number of units:

- Waste to be handled:	2,500 m3/day
- Cover soil to be applied:	280 m3/day
- Operation hours:	7 hours/day/unit

5.6 Construction Schedule

It is planned that the construction period will be about two years starting in May 1991 so that the landfill operation may start by the end of 1993. For the successful construction of the facilities, the following should be noted:

1. The construction schedule should be so arranged that the lining work will be done during the dry season.

2. Water collected in the bottom of the pit should be discharged outside the pit before starting the lining work. The water should be continuously discharged after laying the lining.

3 All construction work should be completed before the beginning of the rainy season of 1993.

4. The landfill operation should commence after the end of the rainy season in 1993. (If it commences during the rainy season, the lining may be damaged by pressure from ground water.)

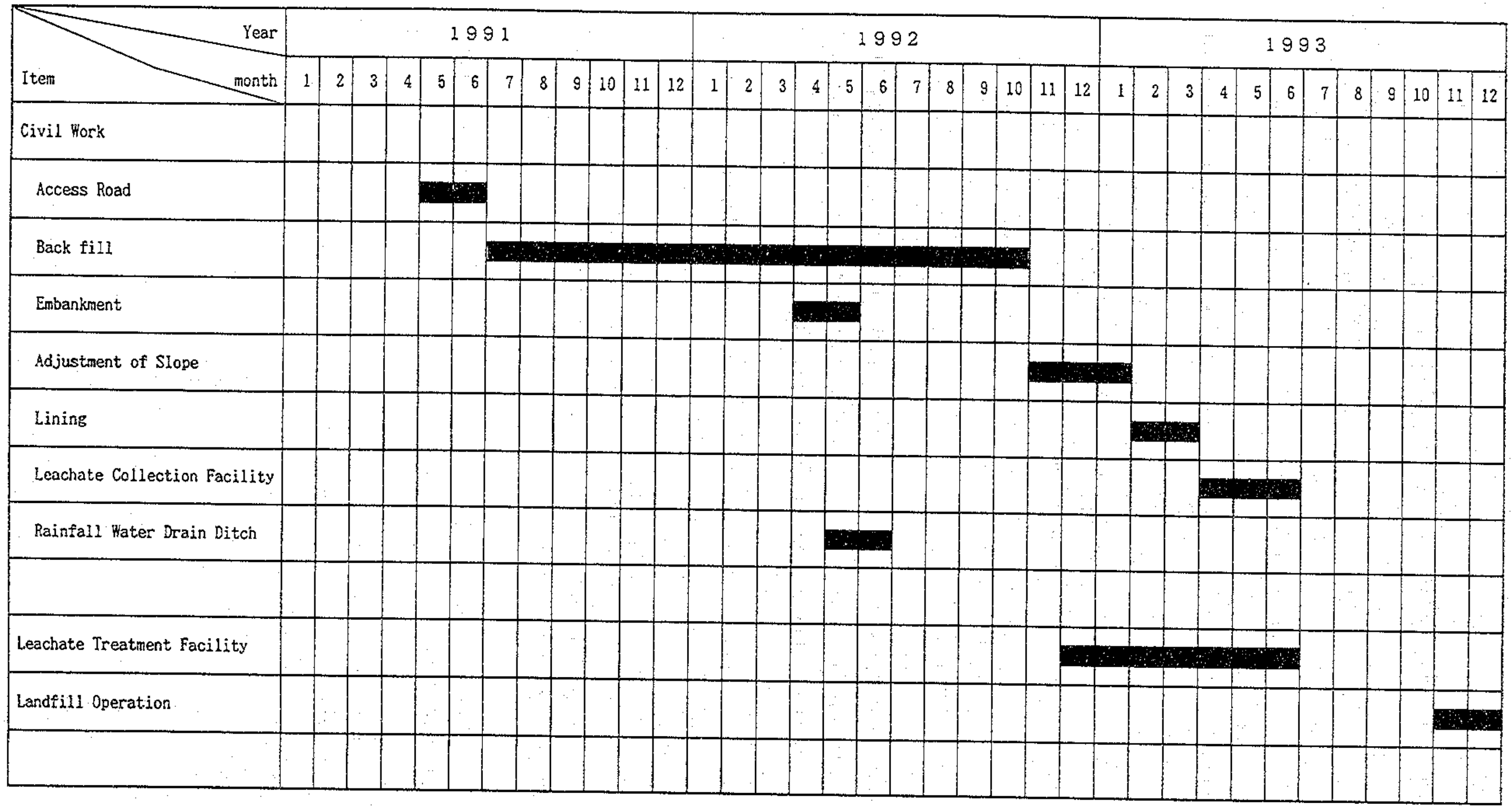


Fig. 5.6-1 Construction Schedule for the Planned Sanitary Landfill in Ram Intra

Chapter 6. Operation and Maintenance Plan

6.1 Landfill Operation Plan

6.1.1 Application of Cover Soil

Dumped waste should be covered with soil every day. Daily application of cover soil is required due to the following:

1. It will reduce odor.
2. It will reduce the number of insects and rodents.
3. It will accelerate waste decomposition.

6.1.2 Bedding and Compaction

Bedding and compaction are two important activities required for sanitary landfill operation. There are two methods for the bedding and compaction: down-fill method and up-fill method. The former is not recommended as it is difficult to keep the waste layer at the same thickness. (The down hill side easily becomes too thick with this method.) The up-fill method is preferred and is illustrated in Figs. 6.1-1, 6.1-2 and 6.1-3.

6.1.3 Landfill Method

The cell method is recommended for the sanitary landfill at Ram Intra in view of the large area of the landfill. Waste layers will be made as shown in Fig. 6.1-4. Thickness and area of the layer are shown below:

	THICKNESS	AREA REQUIRED
1. Each waste layer:	2.7 m	926 m^2/day
2. Cover material layer:	0.3 m	926 m^2/day
3. Total	3.0 m	926 m^2/day

Note: The required area is calculated as follows:

Incoming waste volume 2,500 m3 ÷ Layer Thickness 2.7 m = 962 m^2

For further details, refer to Volume 2 Appendix 4 Technical Guidelines for Construction and Operation of Sanitary Landfill.

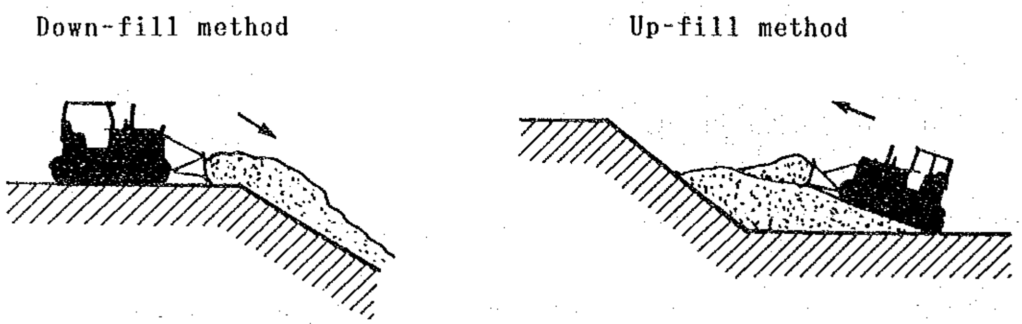


Fig 6.1-1 Method of Bedding and Compaction

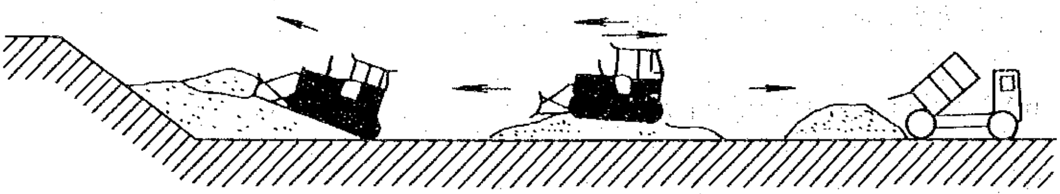


Fig 6.1-2 Preparation of A Unit of Cell with the Up-fill Method

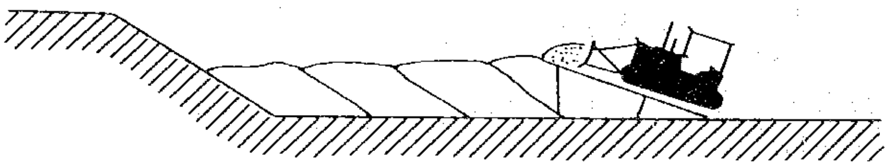


Fig 6.1-3 Preparation of Cells with the Up-fill Method

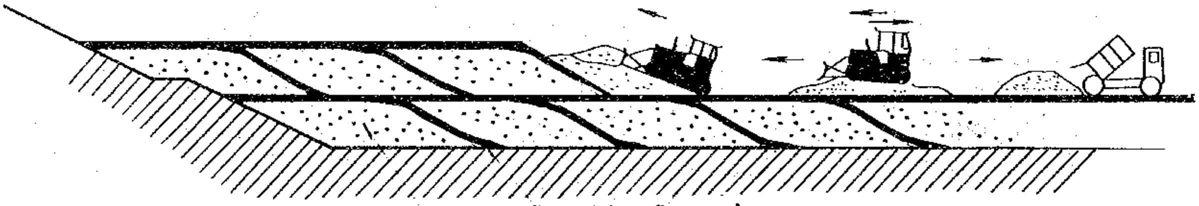


Fig. 6.1-4 Typical Landfill by Cell Method

6.2 Operation Plan for Leachate Treatment Facilities

6.2.1 Monitoring of Leachate Amount and Quality

Regular monitoring of leachate amount and quality is very important for effective operation and maintenance because leachate amount and quality vary much according seasons and other factors. It is required to adjust the operation as often as necessary to meet the amount and quality of the leachate.

6.2.2 Important Points on the Plant Operation

1) First Landfill Phase (About 1.5 Years)

Since biological treatment is main treatment in this phase, BOD of leachate should be frequently checked because it contains much organic matter in the first phase. For the successful treatment, an appropriate amount of oxygen should be supplied according to the amount and quality of leachate.

2) Subsequent Landfill Phase

Management of sludge is important during this phase.

3) Dry Season

The leachate treatment machine should be carefully operated to meet the leachate amount. Biological treatment system should be checked occasionally.

4) Rainy season

The facilities should be carefully maintained because the facilities are operated at their maximum capacity during rainy seasons.

The following data should be recorded:

1. Amount and quality of leachate and effluent
2. Weather conditions: rainfall, temperature, winds speed, etc.
3. Operation records

These data can be useful for improving effectiveness of treatment system and for economizing the operation.

6.3 Periodical Monitoring Plan

Table 6.3-1 summarizes items and frequency of monitoring and inspection.

Table 6.3-1 Periodical Monitoring Item

MONITORING ITEMS	MONITORING FACILITY	INSPECTION ITEMS	FREQUENCY
Ground water	Ground water monitoring well	pH, CN, Pb, T-Hg, Cd, BOD COD, SS, MPN, Color	1/month
Gas	Gas out-let pipe	Temperature and humidity of original ari, Temperature and volume of gas, component analysis (CH_4, CO_2)	4/year
Settlement	Ground surface settlement measurement board	Settlement of ground level	1/month
Odor	-	Items should be selected by surround conditions	2/year
Leachate	Leachate reservoir pond	pH, CN, Pb, T-Hg, Cd, BOD COD, SS, MPN, Color	1/month
Effluent water from leachate treatment facility	-	pH, CN, Pb, T-Hg, Cd, BOD COD, SS, MPN, Color	1/month
		pH, CN, Pb, Cr (VI), As, T-Hg, Cd, PCB, TCE PCE MC, R-Hg, BOD COD, SS, MPN, Cl^-, n-C_6H_{14} (plant oil, Ph, Cu, Zn, S-Fe, S-Mn, T-Cr, F, $CaCo_3$, NO_3-N, NO_2-N, $KMnO_4$-C, Color, Muddiness	1/year

6.4 Organization and Manpower Plan

The operation and maintenance of the Ram Intra final disposal site requires 58 persons. All of them can be deployed from the existing DPC's manpower. Fig. 6.4-1 shows the organization and manpower plan for the Ram Intra disposal site.

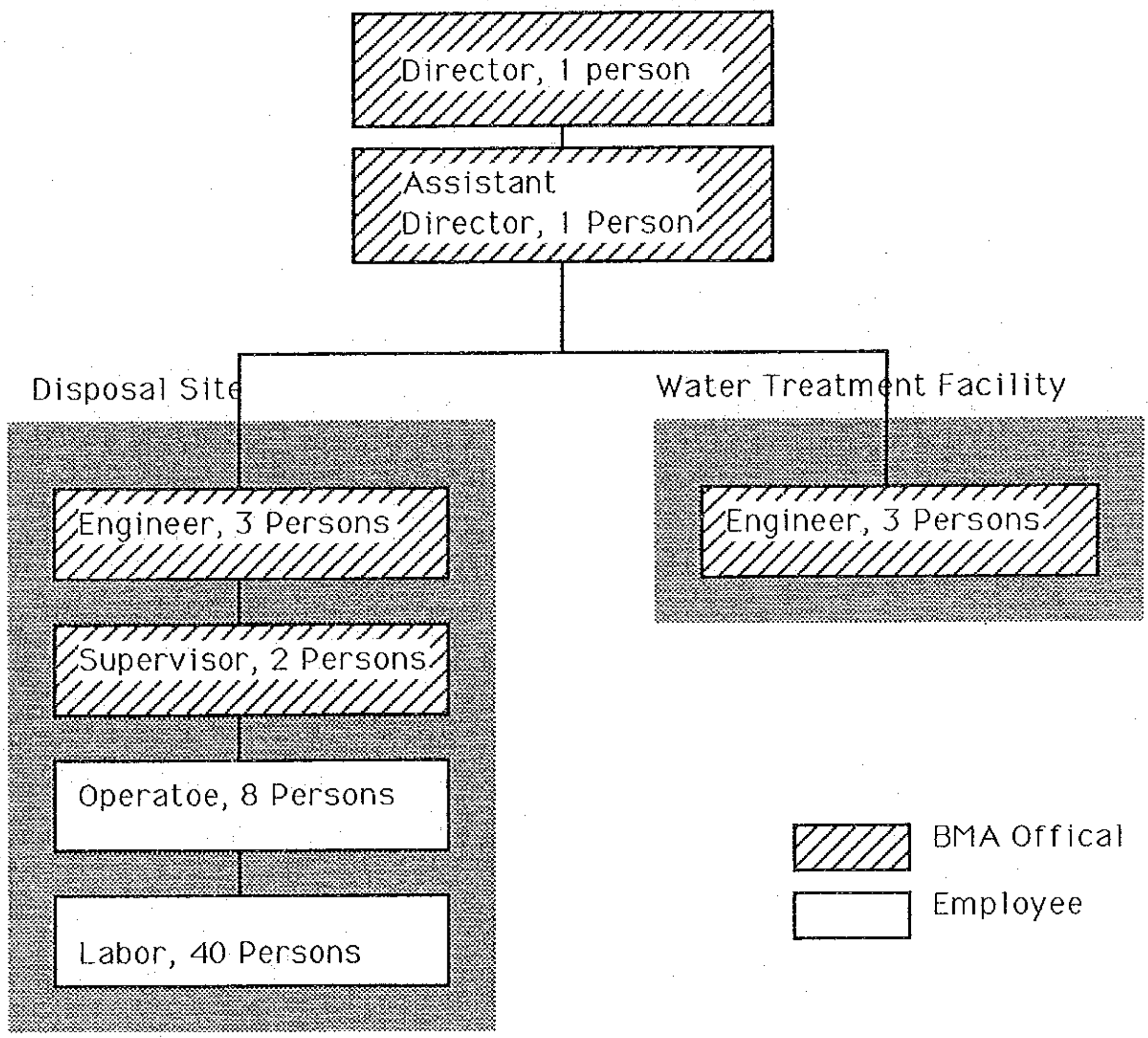


Fig. 6.4-1 Organization and Manpower Plan

Chapter 7. Project Costs

The total project costs of land purchase, site construction and operation are estimated at 662 million Baht for Case 1 and 505 million Baht for Case 2 as shown in Table 7-1.

Table 7-1 Estimated Project Costs

Unit: Million Baht in 1990 Price expect otherwise indicated

	CASE 1	CASE 2
1. Land Purchase (85 rai)	95.2 (52 B)	95.2 (52 B)
2. Site Construction	356.5 (195 B)	227.5 (125 B)
3. Total (1 + 2)	451.7 (247 B)	322.7 (177 B)
4. Operation/Maintenance	210.4 (115 B)	182.4 (91 B)
5. Grand Total (3 + 4)	662.1 (362 B)	505.1 (268 B)
6. Total Waste Disposal Amount	1,825,000 tons	2,000,000 tons

Note: Figures in parentheses indicate cost per ton (Baht).

Overall average cost per ton is 362 Baht for Case 1, and 268 Baht for Case 2.

Annual costs required for land purchase, site construction and operation/maintenance are shown in Table 7-2. Details of the costs of site construction and land purchase are shown in Table 7-3. Further details of the costs are shown in Volume 4 Supporting Report.

Table 7-2 Annual Costs

Unit: Million Baht in 1990 Price

YEAR	COST ITEM	CASE 1	CASE 2
1991	Land Purchase	95.20	95.20
1992	Construction	178.25	113.75
1993	Construction	178.25	113.75
1994	O/M	20.44	17.52
1995	O/M	26.57	23.00
1996	O/M	37.22	31.96
1997	O/M	38.95	32.52
1998	O/M	42.49	35.48
1999	O/M	44.7	41.96
Total		662.07	505.14

Table 7-3 Costs of Land Purchase and Site Construction

Unit: Thousand Baht in 1990 Price

	CASE 1	CASE 2
1. Land Purchase	95,200	95,200
2. Site Construction (2.1+2.2)	356,500	275,500
2.1 Leachate Treatment Facilities	52,000	60,000
2.2 All Other Works	304,500	167,500
1) Earth work	57,158.8	36,809.4
2) Purchase of backfill and embankment material	110,138.0	85,540.0
3) Impervious work (lining)	83,820.0	14,824.8
4) Leachate collection facility	6,111.0	
5) Gas outlet facility	716.9	121.2
6) Underground water collection facility	1,503.9	1,503.9
7) Rainfall water drain facility	7,500.0	7,500.0
8) Access road	500.5	500.5
9) Net fence and gates	938.5	938.5
10) Outlay	36,112.4	19,761.6
3. Total (1+2)	451,700	322,700

Note: Land purchase cost is estimated as follows:

1,120,000 Baht/rai (An official price offered by the land owner) x 85 rai = 95,200,000 Baht

Chapter 8. Project Evaluation

8.1 Technical Evaluation

The construction and operation of the planned sanitary landfill will be made possible with the application of common technology related to civil, building, mechanical and electrical engineering. It does not require an advanced technology. It is considered, from technological point of view that the planned sanitary landfill can be operated by the BMA's existing personnel.

Among the facilities required for the sanitary landfill, leachate treatment facility consists of slightly complicated components. However, the BMA/DPC already has this kind of facilities in the existing disposal sites, and the DPC operates it.

As a conclusion, it is judged that the planned sanitary landfill is technically feasible for the BMA/DPC.

8.2 Environmental Evaluation

8.2.1 Source of Potential Impacts

The purpose of the introduction of the sanitary landfill to Bangkok is to minimize environmental pollution that would be caused by the open dumping, which is currently applied in Bangkok as a major disposal method.

As a matter of fact, the sanitary landfill is much superior than the open dumping in terms of reducing water pollution, offensive odor, and insect breeding.

However, even with the sanitary landfill, it is not possible to perfectly eliminate negative impacts to the environment.

This section will examine and evaluate possible negative impacts on the environment that might by caused with the introduction of the planned sanitary landfill at Ram Intra.

Table 8.2-1 Possible Pollution Factors related to Sanitary Landfill

Environmental Factor / Environmental Impact Element	Air Pollution	Water Pollution	Odor	Noise	Vibration	Trans-portation	Fauna Flora
Vehicle	Δ			o		o	
Landfill Site		o	o	Δ	Δ		o

o: Important Factor

Δ: Minor Factor

As can be seen from the table 8.2-1, possible pollution factors include the following

1. Water pollution
2. Odor
3. Noise
4. Transportation
5. Fauna and Flora

The environmental evaluation was made for both Case 1 (a complete sanitary landfill method) and Case 2 (a simplified sanitary landfill method).

8.2.2 Forecast and Evaluation of Environmental Impact with Case 1

1) Water Pollution

(1) Surface Water

It is predicted that the quality of the effluent to be discharged after treating leachate with Case 1 will satisfy the Industrial Effluent Standards of Ministry of Industry with respect to all the relevant items such as BOD, SS, and pH. See Table 8.2-3.

Table 8.2-2 Quality and Amount of Predicted Leachate and Effluence with Case 1 and the Industrial Effluent Standards of Ministry of Industry

	BOD mg/*l*	SS mg/*l*	pH	Color Pt-Co unit	AMOUNT (tons/day)
Leachate	350	550	8.5	30,000	160
Industrial Effluent Standards	60	30	5 to 9	Not specified	Not specified
Maximum Effluent	60	30	5 to 9	250	160

However, the expected maximum BOD 60 mg/l of the effluent (after treatment of leachate) is higher than the BOD 20 mg/l observed at the Khlong Lam Pak Chee to which the effluent would be discharged from the planned site after treatment of leachate. (This observation was made by the JICA Study Team in the rainy season in 1990.) It is reasonably predicted that the water of Khlong Lam Pack will exhibit much higher BOD values in the dry season than those observed in the rainy season.

The planned sanitary landfill may cause the water quality of the Khlong Lam Pak Chee to deteriorate though it will satisfy the Industrial Effluent Standards of the Ministry of Industry.

(2) Ground Water

Since the Ram Intra disposal site will use artificial lining for preventing from pollution of groundwater, the effect of leachate to the groundwater is not significant.

2) Odor

Generation of odor is unavoidable in any kind of disposal sites. The planned sanitary landfill is superior to the open dumping in reducing the diffusion of offensive odor because waste will be covered with cover soil. The application of daily cover soil will be necessary for effective reduction of odor.

The amount of gas to be generated in the planned site is estimated at 0.61 $m^3/t/d$ on average in the first year of the operation. Refer to the Technical Note for the calculation of the gas generation amount.

Technical Note

a. Calculation Model

The gas volume produced as a result of anaerobic decomposition of the solid waste can be roughly estimated by applying the following chemical formula:

$$CH_aO_bN_c + 1/4(4-a-2b+3c)H_2O$$
$$\longrightarrow 1/8(4-a+2b+3c)CO_2 + 1/8(4+a-2b-3c)CH_4 + cNH_3$$

C, H, O, N: Carbon, Hydrogen, Oxygen and Nitrogen
a, b, c: Chemical composition ratio by weight of hydrogen, oxygen and nitrogen

b. Conditions for Forecast

With the chemical composition of the waste of Bangkok (C: 23.02%, H: 3.10%, O: 16.67%, N: 0.82%) the above formula can be written as follows:

$$C_{1.918}H_{3.100}O_{1.042}N_{0.059} + 0.667\ H_2O$$
$$\longrightarrow 0.854CO_2 + 1.064CH_4 + 0.059NH_3$$

Thus, 44.3 liters of gas per 100 g of waste or 443 m^3/t will be produced.

c. Result of Forecast

Assuming all the planned waste will be carried into the site during the first year, and one half of the expected total gas will be produced in the first year, gas volume to be produced during the first year is estimated as follows:

$$443 \times 1/2 \times 1/365 = 0.61\ \ (m^3/t \cdot d)$$

3) Noise

It is estimated that an average of about 300 round-trips/day will be made by waste collection vehicles between the collection areas and the planned site. A study has been made to predict and evaluate the impacts of noise to be generated by collection vehicles assuming the above-shown number of trips will be made during 11 hours every day.

The result of the study shows:

1) Average background noise level without noise of collection vehicles (at a place near the planned access road):	48 dB(A)
2) Predicted average noise level caused only by collection vehicles:	43.2 dB(A)
3) Predicted average noise level with collection vehicles:	49.2 dB(A)

The above results indicate that waste collection vehicles will cause the noise level to increase only by 1.2 dB(A). It is therefore judged that the effect (noise) of collection vehicles is not significant. Refer to the Technical Note for the calculation of the noise level.

Technical Note

a. Calculation Model

The current study used L-50 (simple time average of the sample) as a prediction method, and the following formula, which is established by the Japan Society of Acousticians in 1975 and has been used by the Ministry of Construction of Japan.

$$L50 = Lw - 8 - 20 \log_{10} l + 10 \log_{10} l \ (\pi l/d \tan h \ 2 \pi l/d) + ad + ai$$

L50	:	Average Noise level	(dB(A))
Lw	:	Average power level of a vehicle	(dB(A))
l	:	Distance between source and receiver	(m)
d	:	Average headway d = 1000 v/N	(m)
v	:	Average running speed	(km/h)
N	:	Traffic volume	(vehicle/h)
ad	:	Attenuation due to acoustic shielding	(dB(A)
ai	:	Adjustment to account for the road type and the height of receiver	(dB(A))

b. Conditions for Forecast

Conditions for calculation of the average noise level of collection vehicles are set as follows:

Table 8.2- 3 Conditions for Forecast of Traffic Noise Level

Item	Conditions
Power level of a collection vehicle	Lw = 100 dB(A)
Ordinary traffic volume	N = 55 vehicle/h (= 300 vehicle/day)
Average running speed	v = 30 km/h
Adjustment values	ad = -3 dB(A)
	ai = -4 dB(A)

N : 300 vehicle/day / 11h x 2 times

The background noise level around the landfill site is set 48 at dB(A) as shown in Table 2.2-8.

c. Result of Forecast

The noise level caused by collection vehicles is forecasted at access road as shown in table 8.2-4. The noise level at 2m from the road is added to background noise level.

$$L = 10 \log_{10} (10^{\frac{Lt}{10}} + 10^{\frac{lb}{10}})$$

L	:	Added noise level	(dB(A))
Lt	:	Traffic noise level	43.2 (dB(A))
Lb	:	Background noise level	48 (dB(A))

L = 49.2 dB

Table 8.2-4 Predicted Noise Level caused by the Collection Vehicles

Distance	(m)	2	10	20	50
Noise Level	dB(A)	43.2	43.2	43.1	42.8

4) Transportation

As shown in Fig. 8.2-1, the planned access roads (both incoming and outgoing roads) to the site has a width of 4 m, and have been paved only in the center part (about 2 m wide). With this condition, frequent trips of waste collection vehicles will damage the roads, and disturb the traffic of other vehicles. Therefore, it is advised that entire road area should be paved.

5) Fauna and Flora

There are no endangered species of animals or plants existing in the planned site and its vicinity. Therefore, no special measures are required.

8.2.3 Evaluation of Environment Impacts with Case 2

Case 2 (without adequate lining and leachate treatment) will not satisfy the the Industrial Effluent Standards of Ministry of Industry as shown in Table 8.2-6.

Table 8.2-5 Quality and Amount of Predicted Leachate and Effluence with Case 2 and the Industrial Effluent Standards of Ministry of Industry

	BOD mg/l	SS mg/l	pH	Color Pt-Co unit	AMOUNT (tons/day)
- Leachate	350	550	8.5	30,000	300
- Industrial Effluent Standards	60	30	5 to 9	Not specified	Not specified
- Maximum Effluent	180	300	5 to 9	500	300

Note: The above indicated amount of effluent (300 t/d) will be discharged outside the site only during June through November.

Case 2 will affect the ground water as leachate will seep into the ground water.

As a conclusion, Case 2 is not advisable for the BMA from environmental view points because it would significantly and adversely impact the ground and surface water.

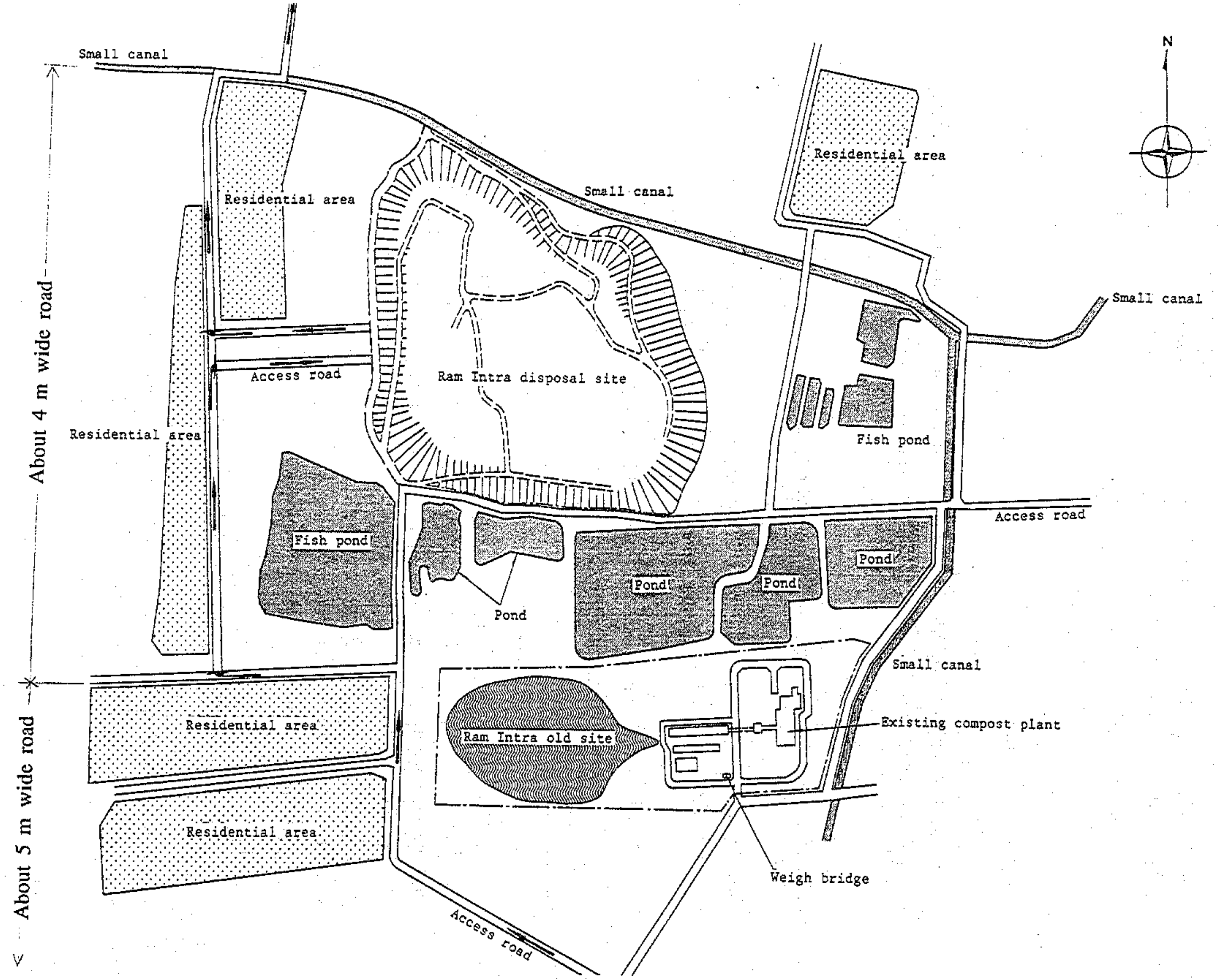


Fig. 8.2-1 Access Road to the Planned Ram Intra Site

8.3 Economic and Financial Evaluation

8.3.1 Financial Evaluation

The construction of the planned sanitary landfill will require land purchase at a cost of 95.2 million Baht in addition to the construction cost of 356.5 million Baht with Case 1 and 227.5 million Baht with Case 2. These amounts are well within the affordable range of investment for the BMA judging from the facts that 1) the BMA/DPC already has a budget of 200 million Baht available for land purchase, and 2) the BMA signed, in August 1990, a 369 million Baht contract for the construction of a compost plant.

Annual average operation/maintenance costs to be incurred during the operation period of 6 years are about 35 million Baht/year with Case 1 and 30 million Baht/year with Case 2. Those amounts are much smaller than the annual operation/maintenance costs of the existing compost plants ranging 100 - 120 million Baht.

Therefore, it is judged that the planned sanitary landfill will be feasible from the BMA's conditions and the size of the current SWM budget.

8.3.2 Economic Evaluation

1) Recognition of the Future Increases in Land Value

From the economic viewpoint of the citizens of Bangkok, it is necessary to consider increases of land value that can be caused by the landfilling and resulting conversion of the borrow pit to a flat land that can be used as a public park or some other purposes. The benefit arising from the land value increase is estimated at 306 million Baht due to the following calculations:

A x B = 3.6 million Baht/rai x 85 rai = 306 million Baht

where,

A = Land value per rai expected some time after the completion of landfill, which is estimated at 60 % of the current market price (6 million Baht/rai) of a flat land neighboring the pit, i.e. 6 million Baht/rai x 60 % = 3.6 million Baht/rai

B= Area of the land to be purchased

With the recognition of this benefit, net cost of implementing the planned sanitary landfill at Ram Intra can be estimated at 356.1 million Baht or 195 Baht/ton instead of the total costs of 662.1 million Baht or 362 Baht/ton, as shown Table 8.3-1.

Table 8.3-1 Total and Net Costs for the Implementation of the Planned Sanitary Landfill at Ram Intra

Unit: Million Baht in 1990

	Million Baht	Unit Cost
1. Total implementation cost	662.1	362 Baht/ton
2. Land value expected after completion of sanitary landfill	306	167 Baht/ton
3. Net implementation cost (1-2)	356.1	195 Baht/ton

Note: The total implementation cost include costs of land purchase (95.2 million Baht) construction (356.5 million Baht) and a total operation/maintenance (210.4 million Baht) to be incurred during 6 years of operation.

It is also possible to apply the concept of net cost to the land price taking into account the future land value expected after the completion of the sanitary landfill.

Table 8.3-2 Total and Net Costs for the Land Purchase

	Million Baht	Unit Cost
1. Total land purchase cost	95.2	52 Baht/ton
2. Land value expected after completion of sanitary landfill	306	167 Baht/ton
3. Net land purchase cost	- 210.8	- 115 Baht/ton

The net land purchase cost is a negative amount 210.8 million Baht or minus 115 Baht/ton. This negative cost or the positive benefit is the land value increase to be caused by implementing the planned sanitary landfill.

2) Recognition of Locational Advantage

There is a trade-off relationship between the land price of a site and distance and costs of haulage to a site. The longer the haulage distance, the smaller the land price of a site, but the higher the haulage cost.

The planned site is not far from the core districts (about 20 km). In view of the situation where it would be increasingly difficult to purchase land in places near to the inner part of Bangkok, it would be useful to consider how much haulage cost may be saved by having a sanitary landfill in the planned site instead of having sanitary landfill in a more distant place. A case study is shown in Table 8.3-3.

Table 8.3-3 Net Saving Expected by Having Sanitary Landfill Site at Ram Intra instead of in Nong Chock

Unit: Million Baht in 1990 Price

	PLANNED BORROW PIT AT RAM INTRA (A)	A PLACE IN NONG CHOCK (B)	DIFFERENCE (SAVING) (C)=(B)-(A)
1. Total Land Purchase Cost	95.2	47.2	- 47.6
2. Total Collection & Haulage	483.6	666.1	182.5
3. Total (1+2)	578.8	713.3	134.9

Note: It is assumed that:

1) Land purchase cost in Nong Chock is 0.56 million Baht/rai, a half of the corresponding cost at Ram Intra.
2) Collection & haulage costs are 265 Baht/ton to the Ram Intra site, and 365 Baht/ton to a Nong Chock site.
3) Total waste amount to be collected and hauled is 1,825,000 ton.

The above table shows that choice of the Ram Intra site will require 47.6 million Baht higher land cost than choosing a place in Nong Chock, but enable the BMA to save as much as 182.5 million Baht worth of haulage cost, resulting in a net saving of 134.9 million Baht.

Conclusion

With the recognition of the benefits arising from both the land value increase and haulage cost saving, the planned sanitary landfill project at Ram Intra is judged economically feasible.

8.4 Overall Evaluation

The result of the technical, environmental and financial/economic evaluation of the planned sanitary landfill can be summarized as shown in Table 8.4-1.

Table 8.4-1 Results of Evaluation of the Sanitary Landfill at Ram Intra with Case 1 and Case 2 Methods

EVALUATION	COMPLETE SANITARY LANDFILL AT RAM INTRA (CASE 1)	SIMPLIFIED SANITARY LANDFILL AT RAM INTRA (CASE 2)
- Technical Evaluation	Feasible	Feasible
- Environmental Evaluation	Feasible (No significant negative impacts anticipated)	There will be significant negative impacts on both ground and surface water.
- Financial/Economic Evaluation	Feasible	Feasible
Total Cost	662.1 million Baht	505.1 million Baht

The table shows that Case 1 is feasible in all the evaluation aspects, while Case 2 is not recommendable from environmental viewpoint.

Another important aspect is the acceptance of the plan by neighborhood residents. It should be noted that the former compost plant and disposal site at Ram Intra were closed partly due to the residents' complaints about the environmental deterioration caused by the operation of those facilities. There is a strong possibility that residents may not accept the planned sanitary landfill if the BMA plans to apply Case 2 which will cause significant impacts on the surrounding surface and ground water.

As a conclusion, it is judged that:

1. The sanitary landfill with Case 1 method at Ram Intra is feasible from technical, environmental, and financial/economic viewpoints, and therefore strongly recommended for the BMA.

2. The sanitary landfill with Case 2 method at Ram Intra causes significant environmental problems. Its negative impacts on the residents and public water system is too great to accept even though Case 2 is a lower cost alternative to Case 1.

Part II

Feasibility Study on the Incinerator at On Nut

Chapter 1. Summary of the Study

1.1 Background

The current feasibility study for an incineration plant was carried out based upon the discussions made in the Steering Committee Meeting held on 14th August, 1990. In that meeting, the BMA/DPC has requested the Japanese side to execute a feasibility study on an incineration plant, sanitary landfill, and waste collection improvement projects.

It is understood by both the BMA/DPC and the Japanese side that:

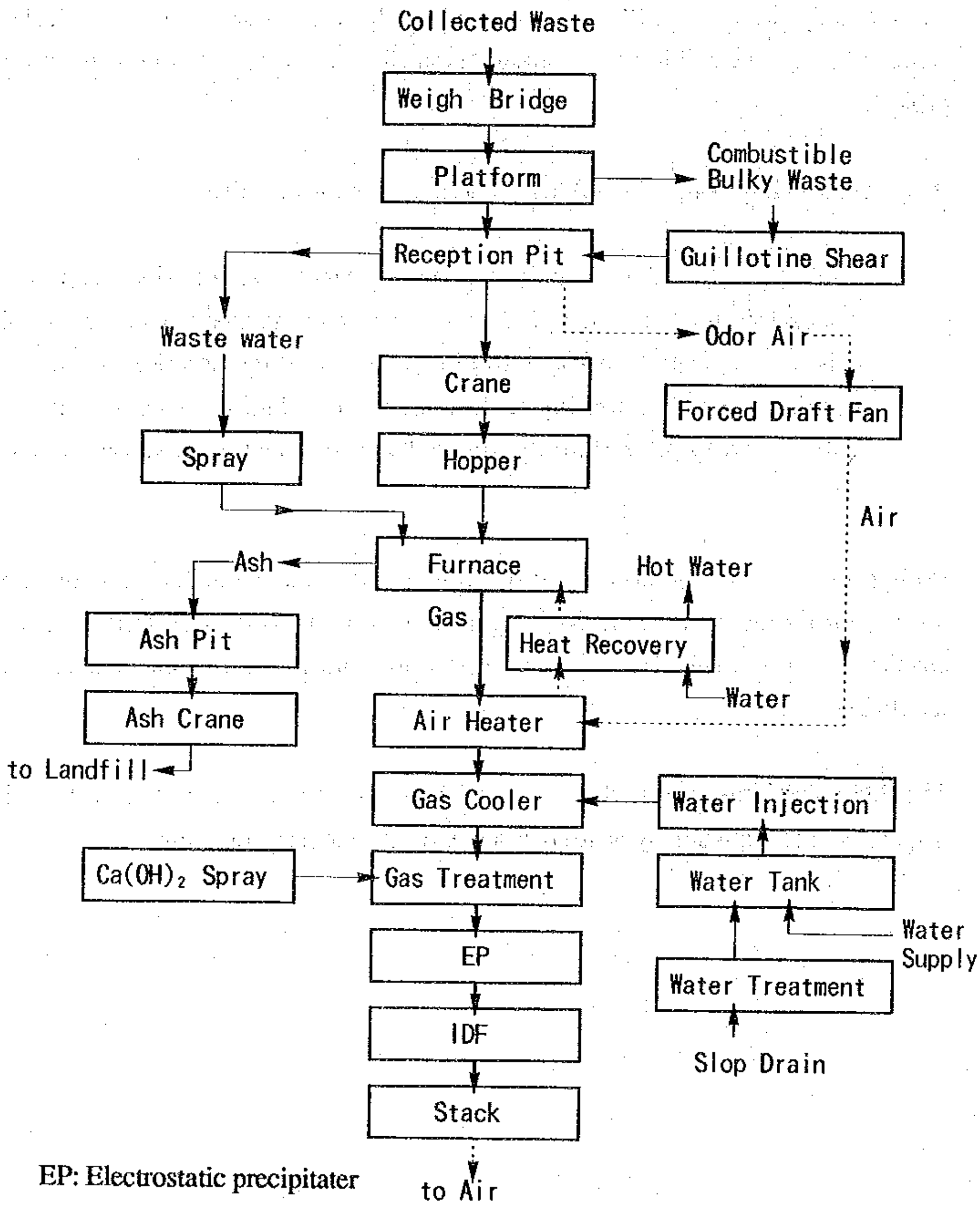
> The BMA/DPC should apply the sanitary landfill as a major mean of waste disposal during the master plan period. However, if financial conditions allow, it is advisable for the BMA to construct a new incineration in view of its significance as a pioneering project and its contribution to the management of risks that may arise from the difficulty in the land acquisition for sanitary landfill.

With this understanding, the current study aims at defining an incineration plant or the most appropriate size (capacity), operation systems, specifications considering characteristics of waste of Bangkok, as well as the budget size and technical capacity of the BMA.

The BMA/DPC has indicated that a part (about 10.6 rai or 17,000 m^2) of the existing disposal site at On Nut may be used as a site for the incineration plant.

1.2 The Proposed Incinerator

The capacity of proposed incinerator is 600 t/d (200 t/d x 3 units - 24 hours/day continuous operation). Its flow of operation is as shown in Fig. 1.2-1. Table 1.2-1 shows major specifications of the incinerator. The plan and the section of the planned incineration plant are shown in Figs. 1.2-2 and 1.2-3 respectively.



EP: Electrostatic precipitater
IDF: Induced Draft Fan

Fig. 1.2-1 Flowchart of the Incinerator

Table 1.2-1 Major Specifications of Incinerator

Item of Incinerator	Specifications
Furnace capacity	600 t/d (8.33 t/h x 3 units - 24 hours)
Number of furnace	3 units (200 t/d/unit x 3 units)
Land required	17,000 m^2 (approx. 10.6 rai) at On Nut
Design Lower heat calorific values of waste	750 - 1,500 kcal/kg, standard 1,150 kcal/kg
Gas Cooling System	Water Injection System
Weigh Bridge	30 ton/unit x 2 units
Reception Pit	5,200 m^3 (3-days-capacity) Design bulk density of waste: 0.35
Number of pit gate	9, (platform is 42 m wide)
Crane	2 units with backet
Type of furnace	Step grate stoker
Burner	Diesel oil burner
Gas treatment for Anti-Pollution	HCl remover (dry $Ca(OH)_2$ spray) Electric precipitator
Heat utility	Hot water recovery
Draft	Induced draft fan (approx. 69,000 m^3 N/h x 3 units) Forced draft fan (approx. 34,000 m^3 N/h x 3 units)
Stack	60 m high 1 stack with 3 inner stacks inside
Ash pit	840 m^3 (ratio of ash 17% weight of waste)
Ash crane	1 unit
Water treatment	Closed system, spray for gas cooling, organic drain treatment system
Guillotine shear	150 t x 1 unit
Utilities required - Electricity - Fuel - Water - Ca $(OH)_2$	 900 kWh 4.5 t/d 1,100 m^3/d 4.8 kg/t (garbage)

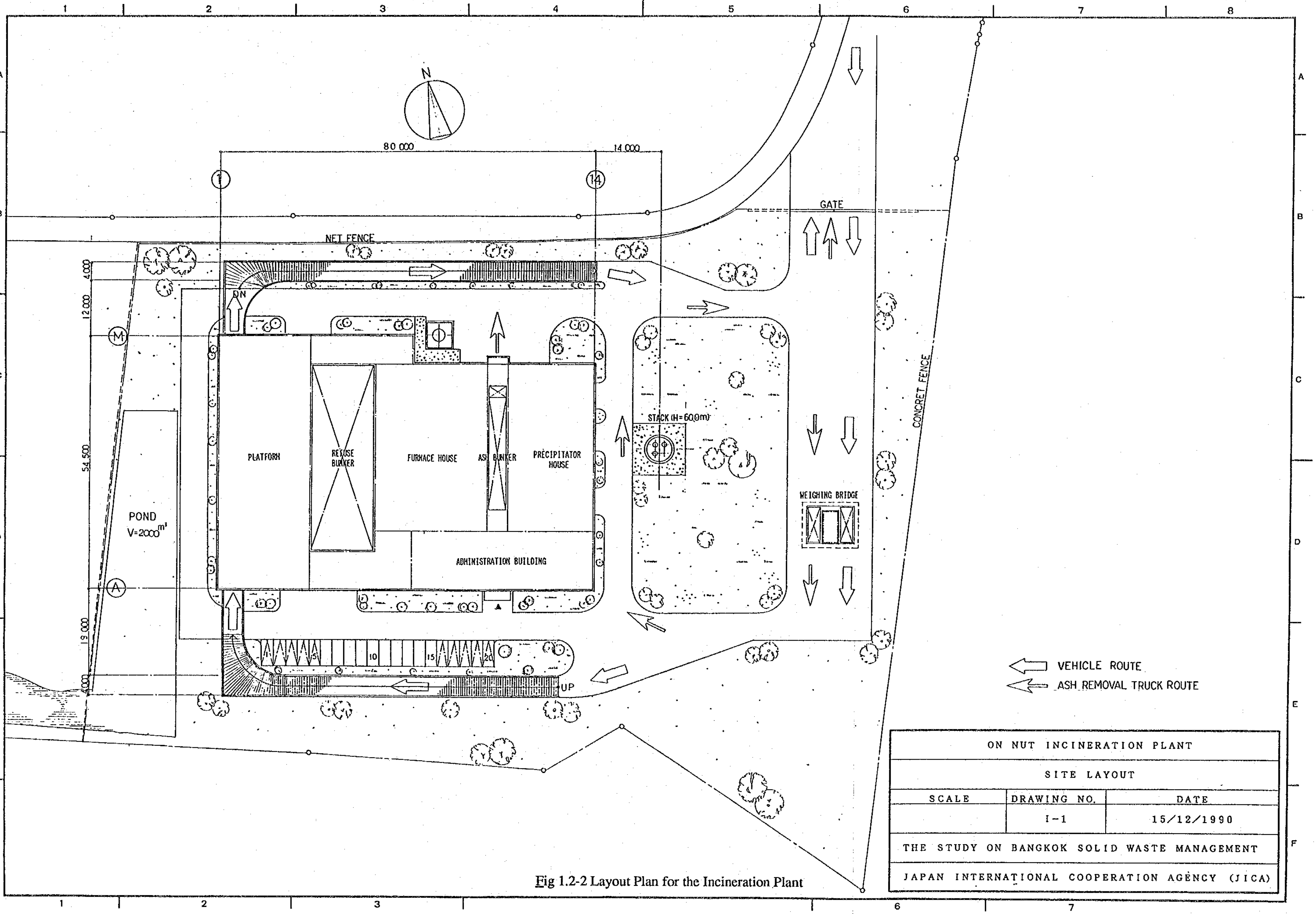


Fig 1.2-2 Layout Plan for the Incineration Plant