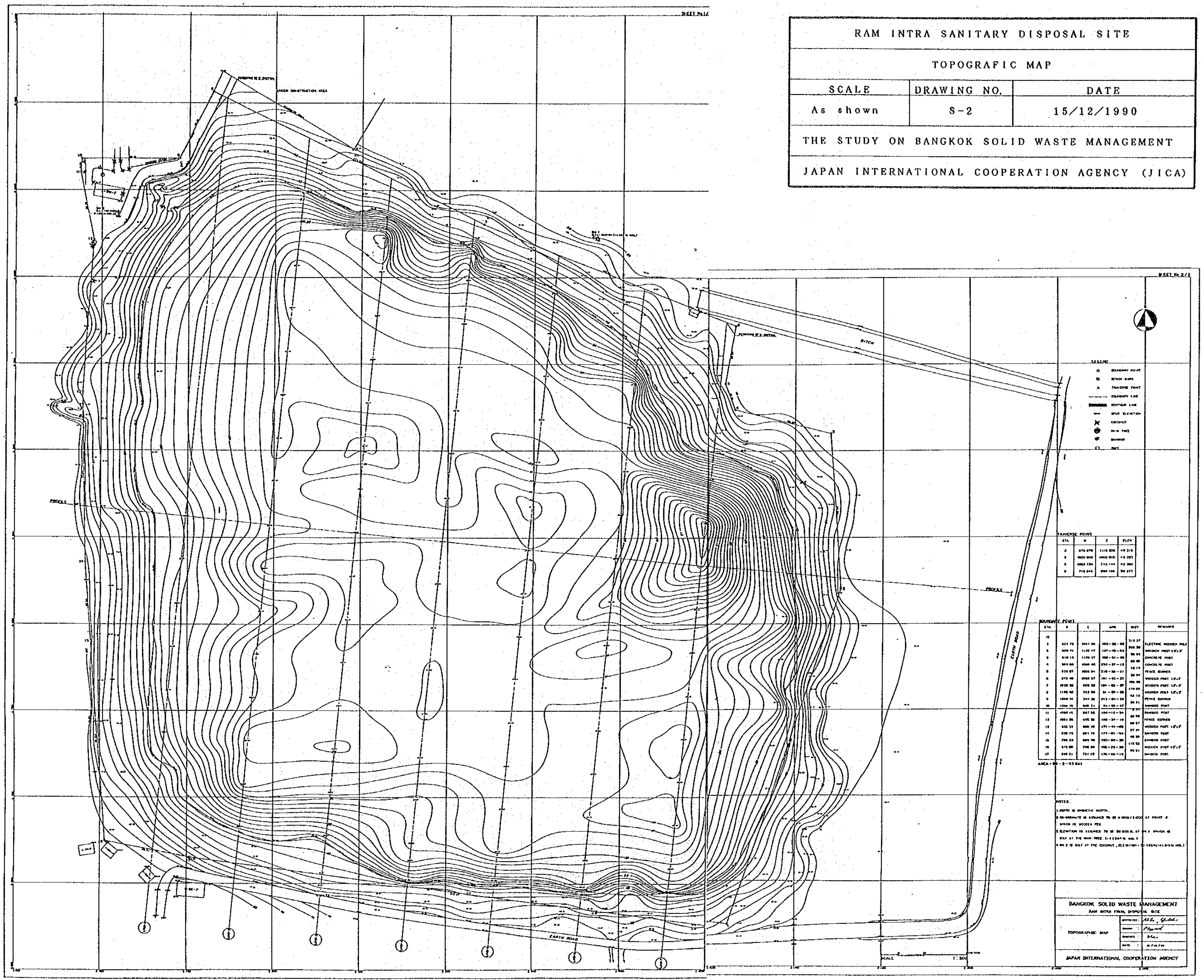
RAM INTRA SANITARY DISPOSAL SITE

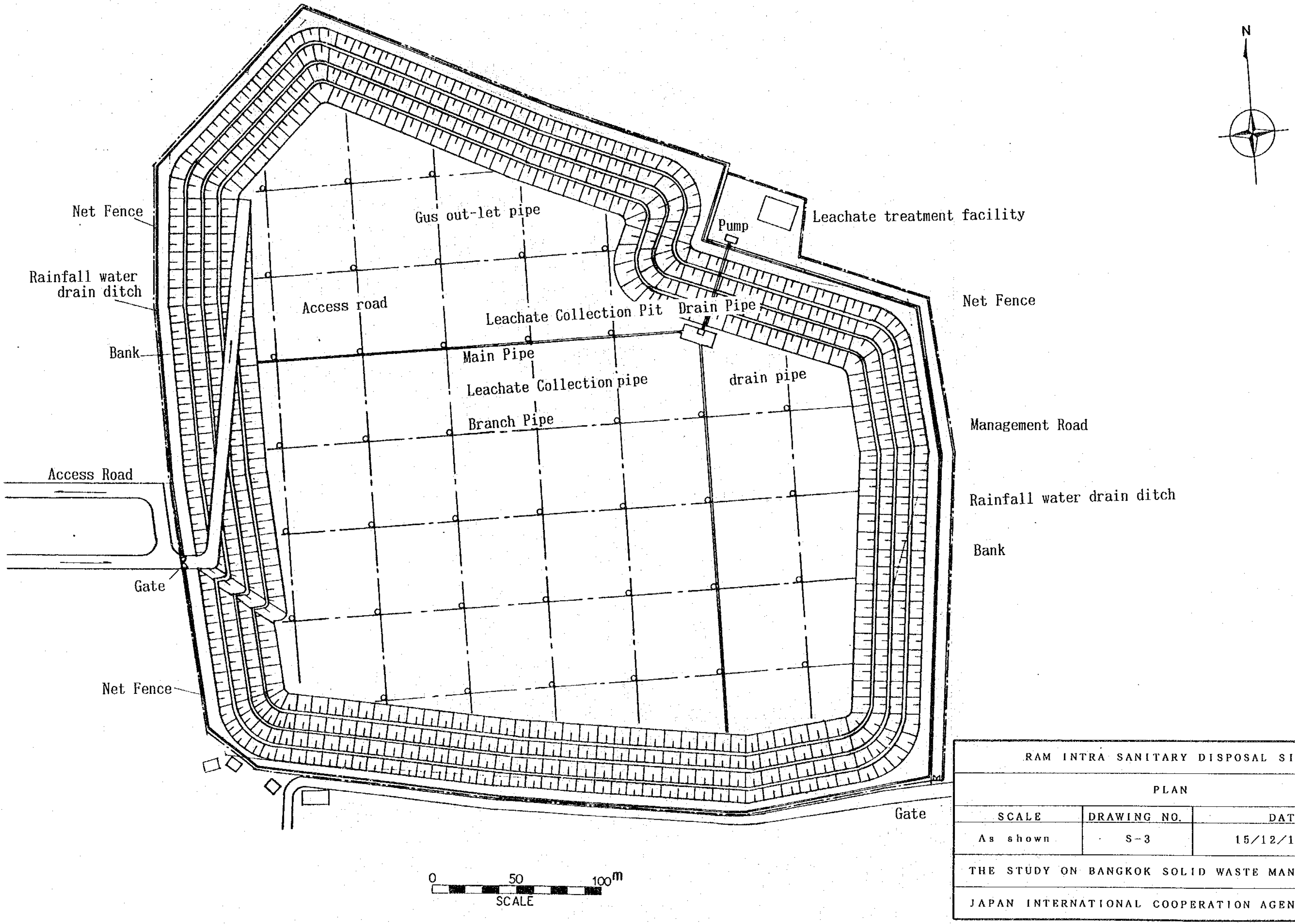
TOPOGRAFIC MAP

SCALE	DRAWING NO.	DATE
As shown	S-2	15/12/1990

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)





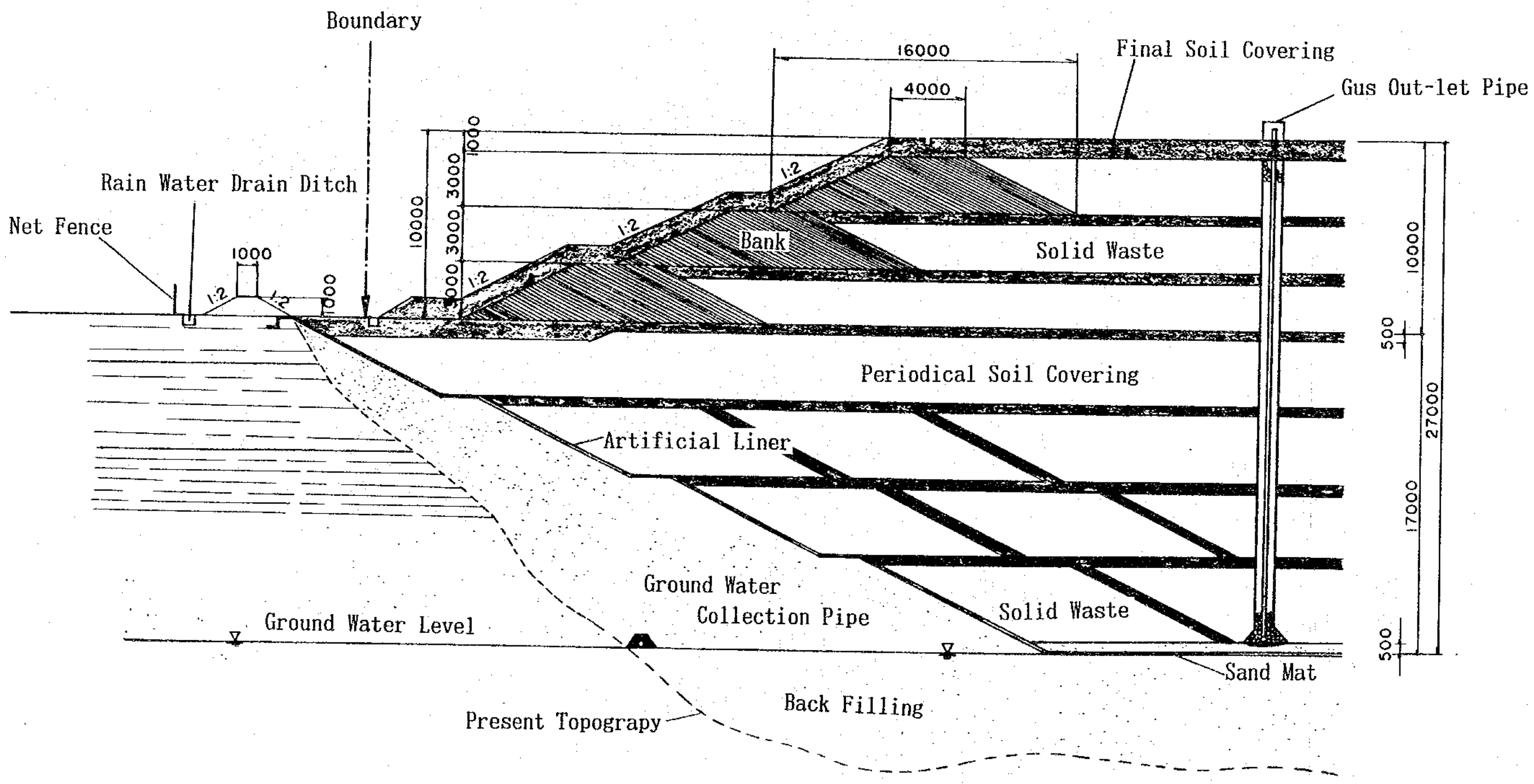
RAM INTRA SANITARY DISPOSAL SITE

PLAN

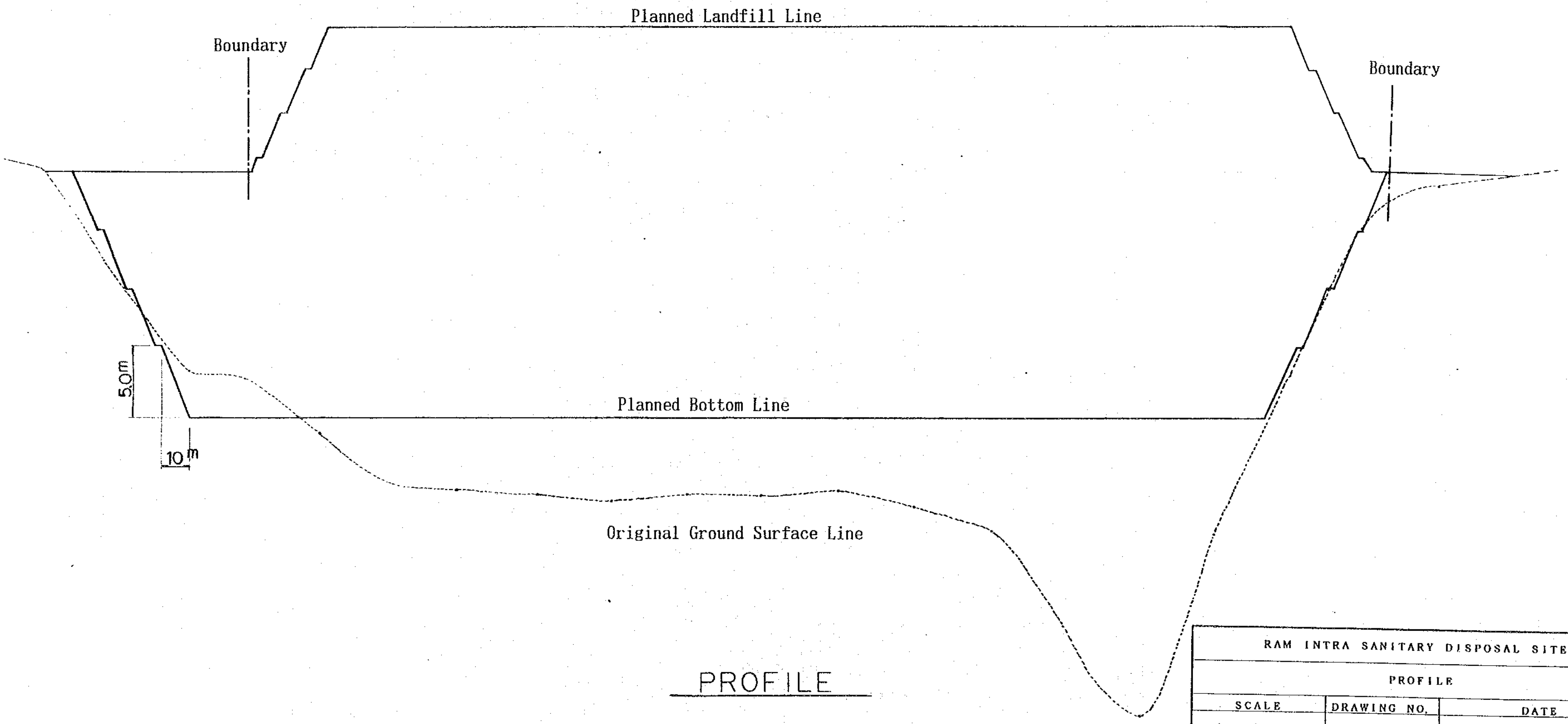
SCALE	DRAWING NO.	DATE
As shown	S-3	15/12/1990

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



RAM INTRA SANITARY DISPOSAL SITE		
TYPICAL CROSS SECTION		
SCALE	DRAWING NO.	DATE
As shown	S-4	15/12/1990
THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT		
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)		



PROFILE

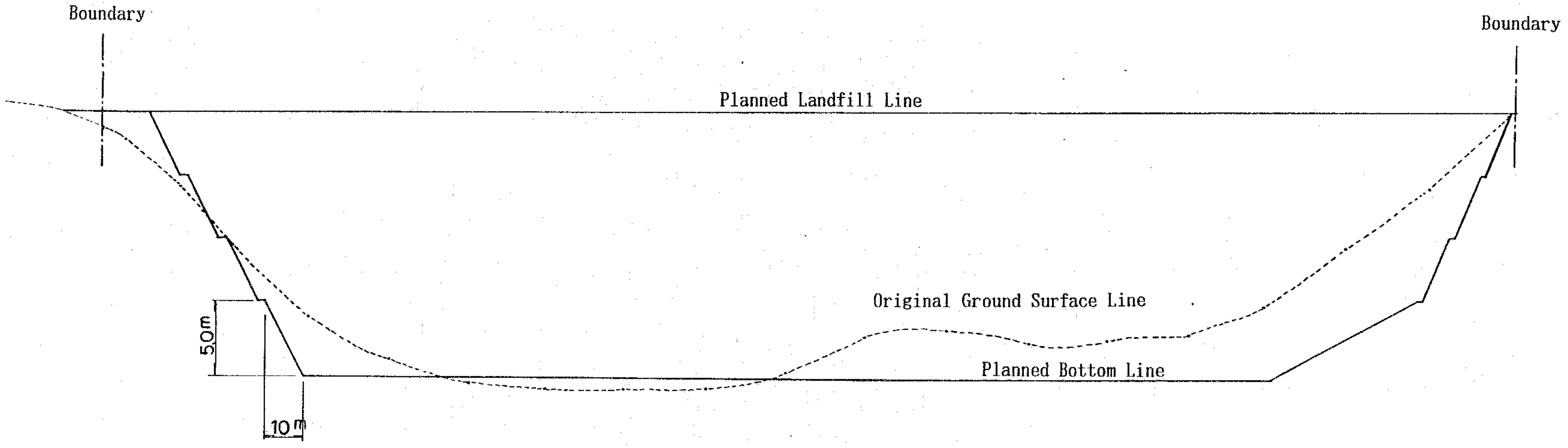
RAM INTRA SANITARY DISPOSAL SITE

PROFILE

SCALE	DRAWING NO.	DATE
As shown	S-5	15/12/1990

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



LINE-I

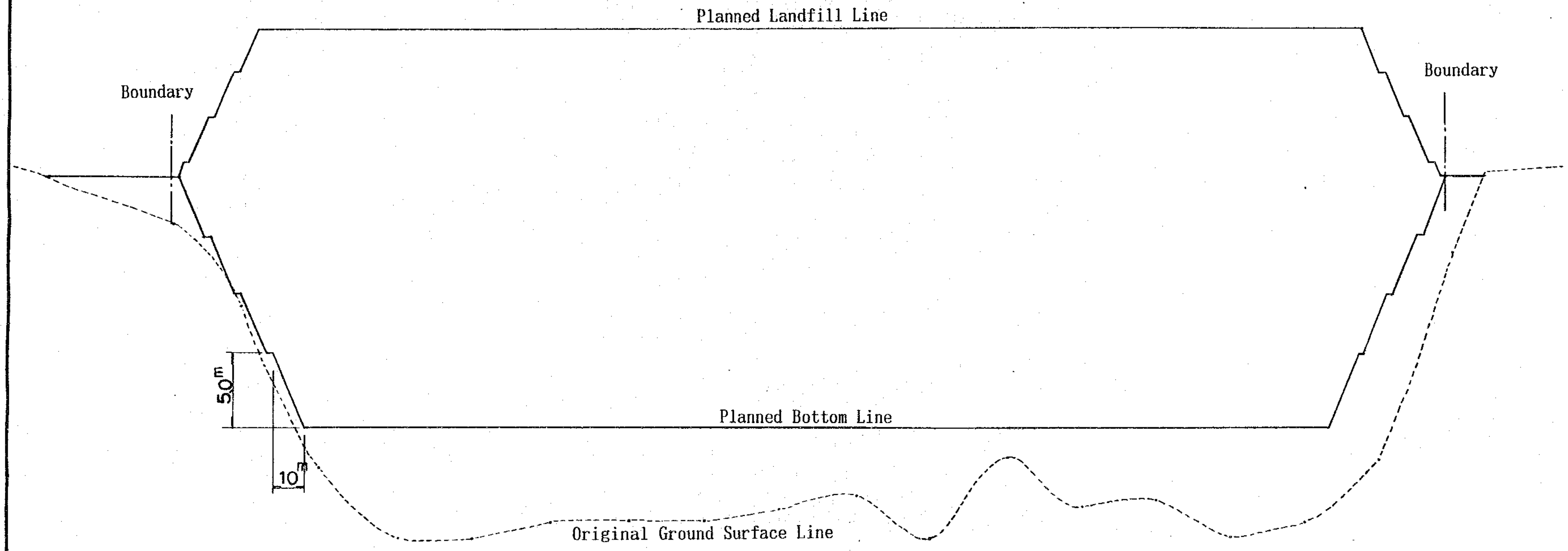
RAM INTRA SANITARY DISPOSAL SITE

CROSS SECTION (1)

SCALE	DRAWING NO.	DATE
As shown	S-6	15/12/1990

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



LINE-2

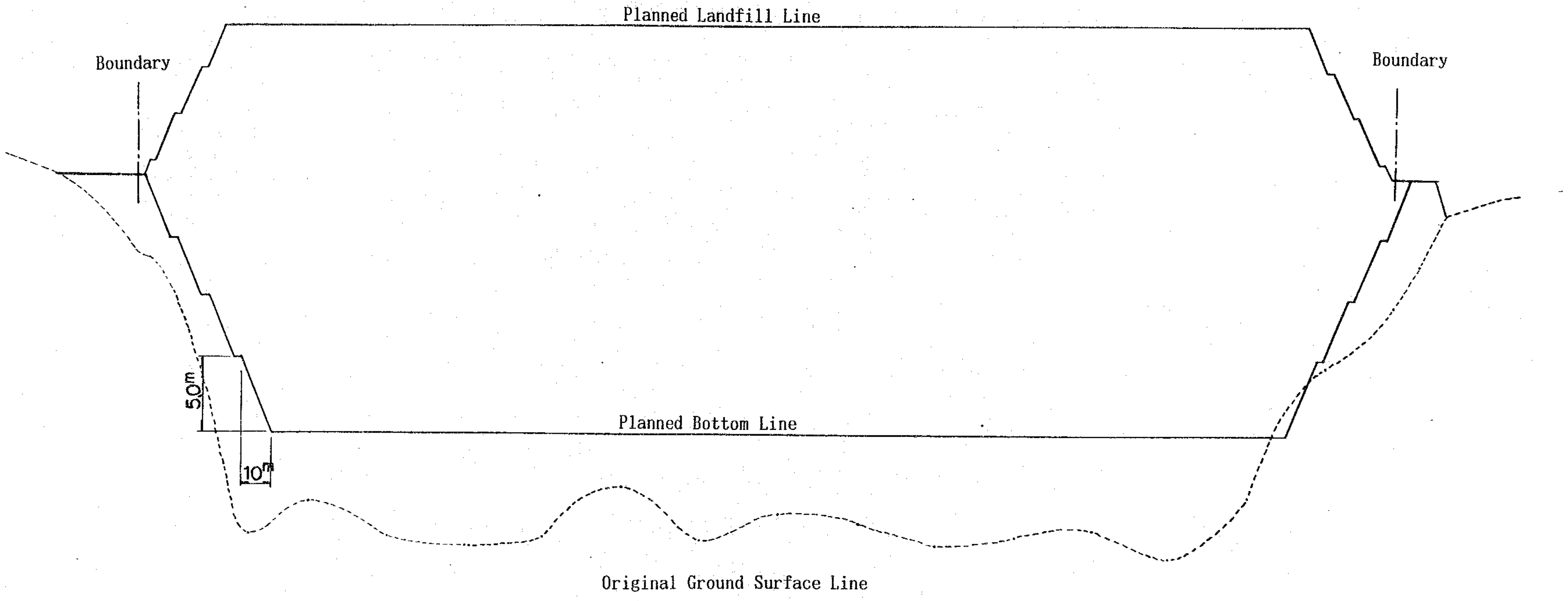
RAM INTRA SANITARY DISPOSAL SITE

CROSS SECTION (2)

SCALE	DRAWING NO.	DATE
As shown	S-7	15/12/1990

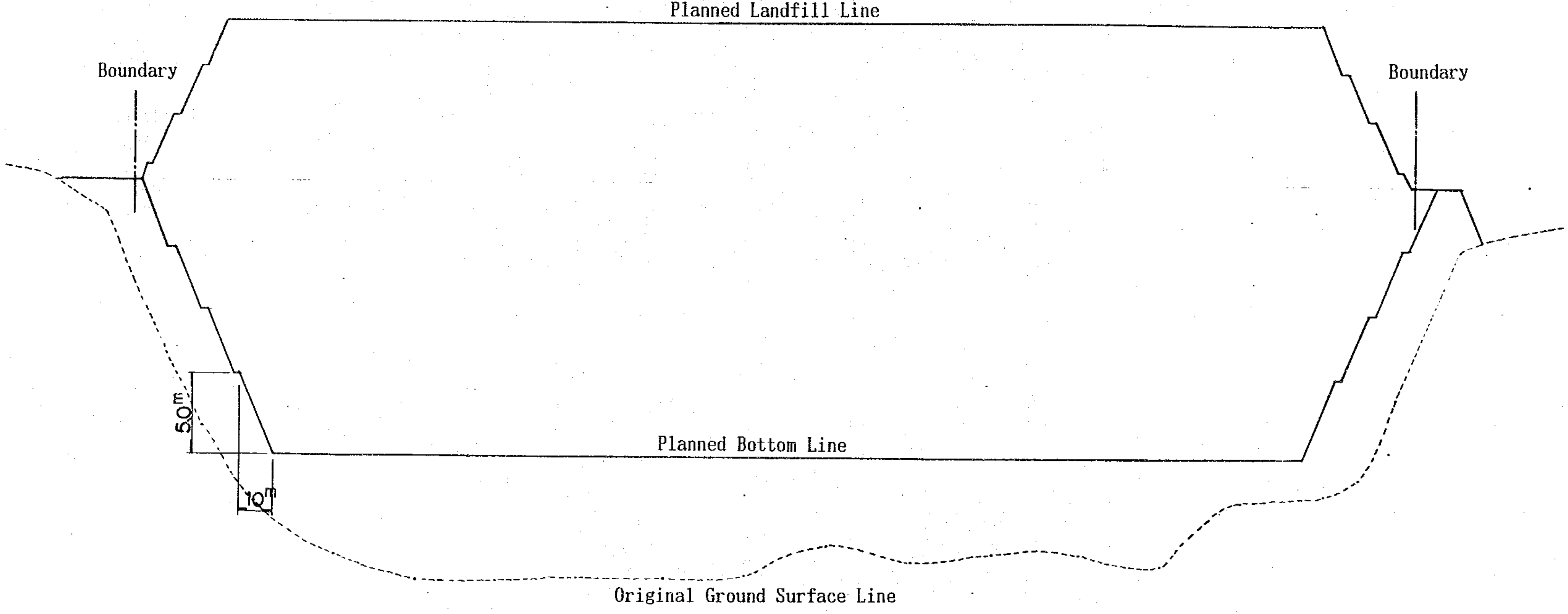
THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



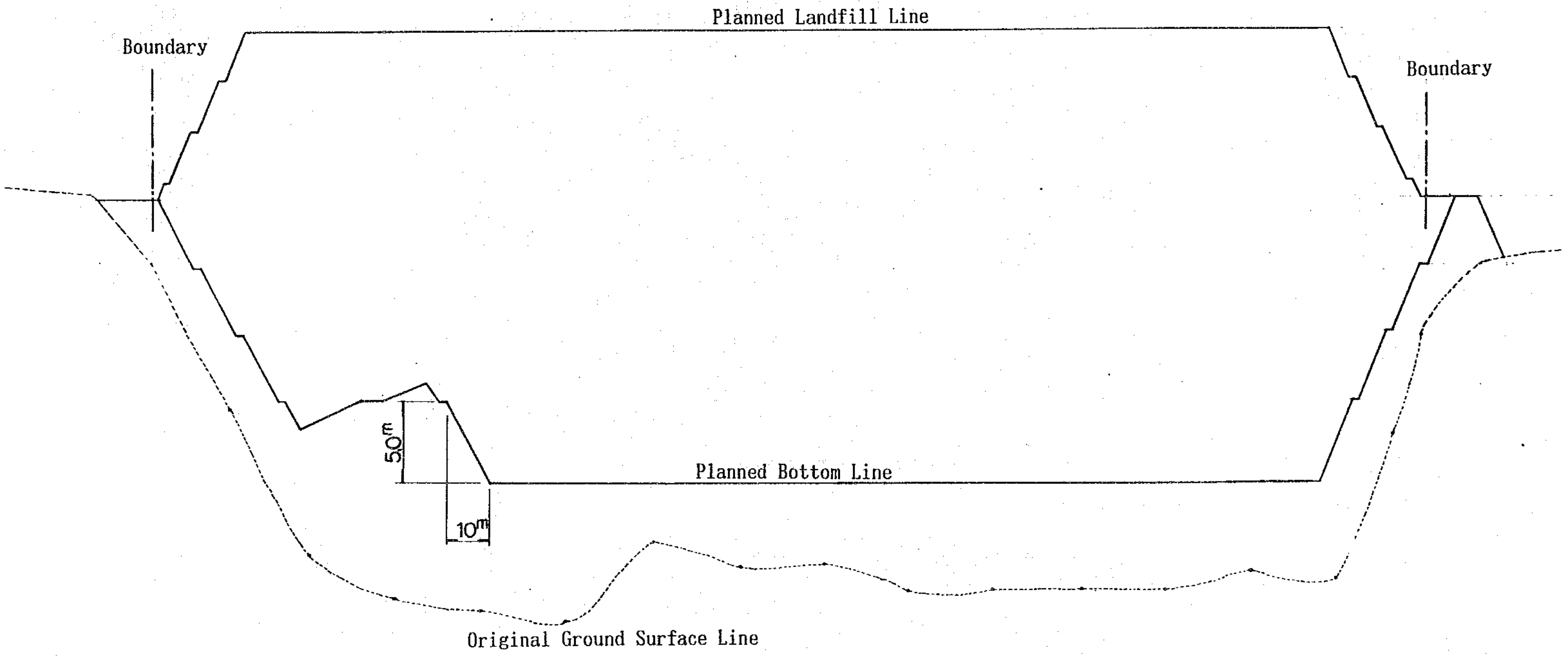
LINE-3

RAM INTRA SANITARY DISPOSAL SITE		
CROSS SECTION (3)		
SCALE	DRAWING NO.	DATE
As shown	S-8	15/12/1990
THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT		
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)		



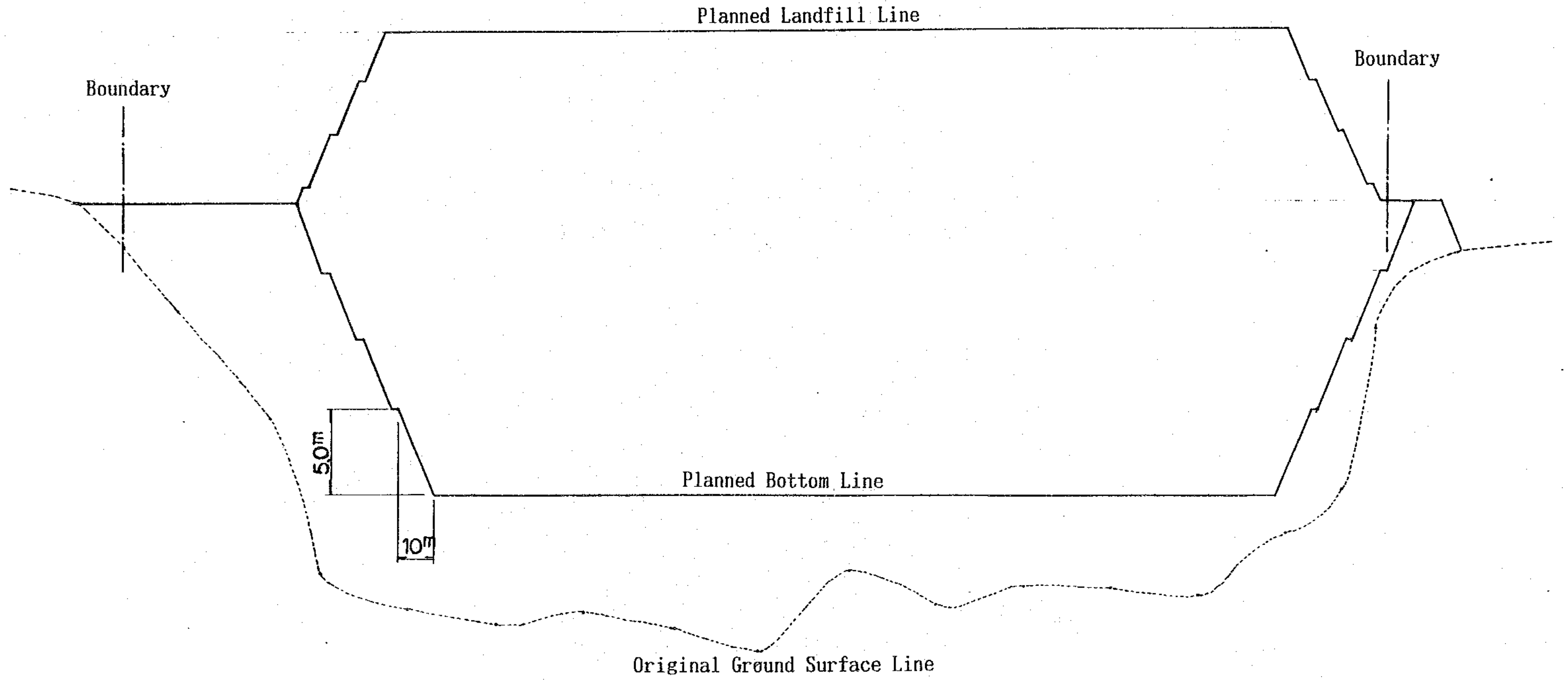
LINE-4

RAM INTRA SANITARY DISPOSAL SITE		
CROSS SECTION (4)		
SCALE	DRAWING NO.	DATE
As shown	S-9	15/12/1990
THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT		
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)		



LINE-5

RAM INTRA SANITARY DISPOSAL SITE		
CROSS SECTION (5)		
SCALE	DRAWING NO.	DATE
As shown	S-10	15/12/1990
THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT		
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)		



LINE-6

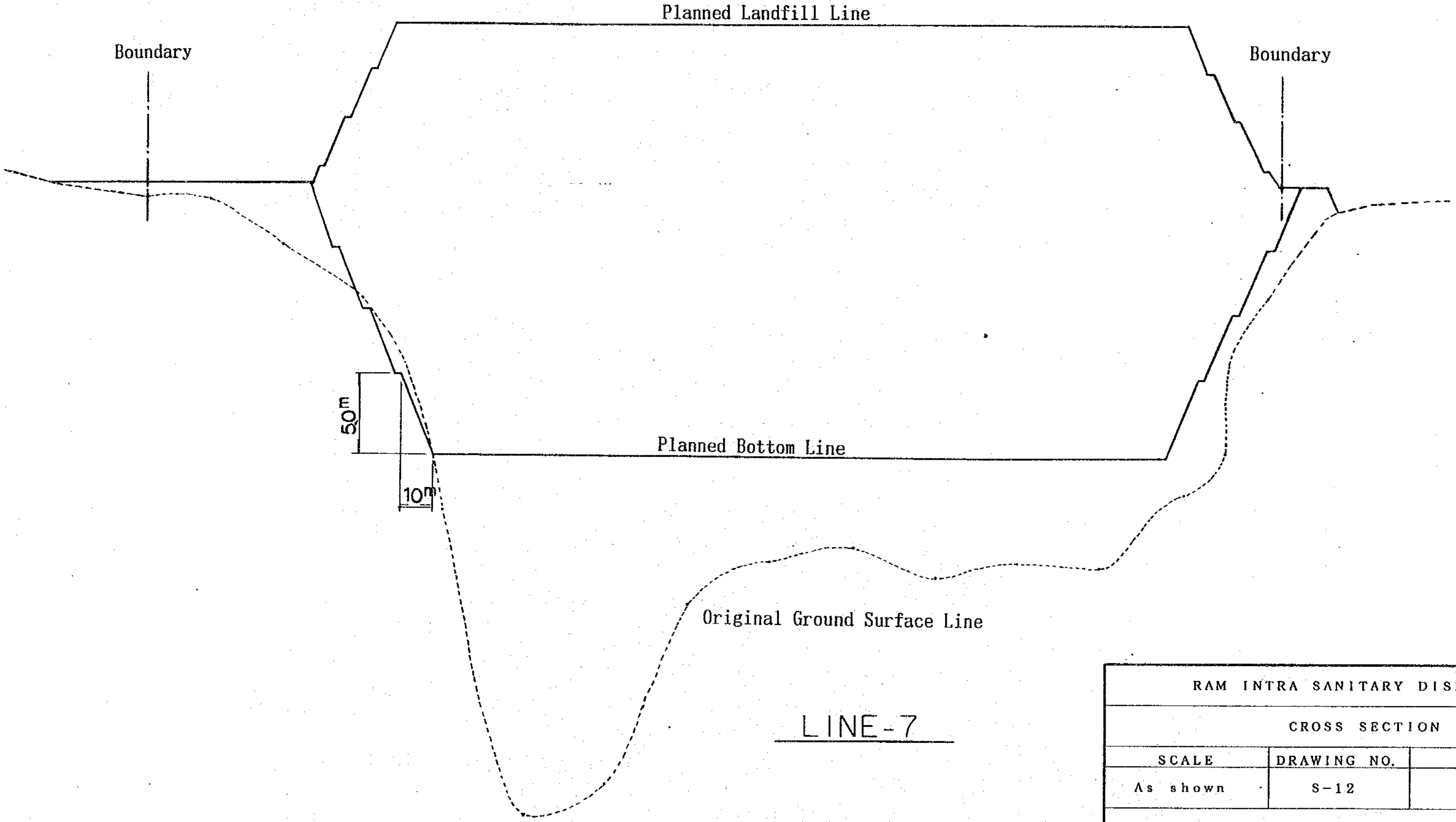
RAM INTRA SANITARY DISPOSAL SITE

CROSS SECTION (6)

SCALE	DRAWING NO.	DATE
As shown	S-11	15/12/1990

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



LINE-7

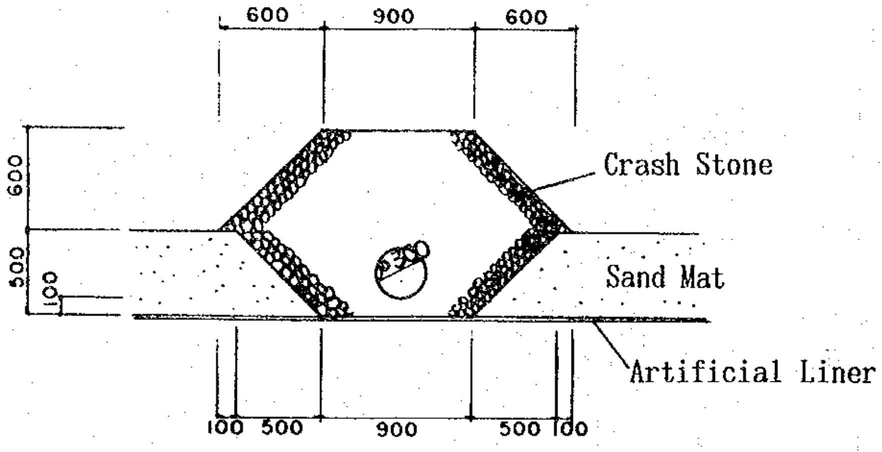
RAM INTRA SANITARY DISPOSAL SITE

CROSS SECTION (7)

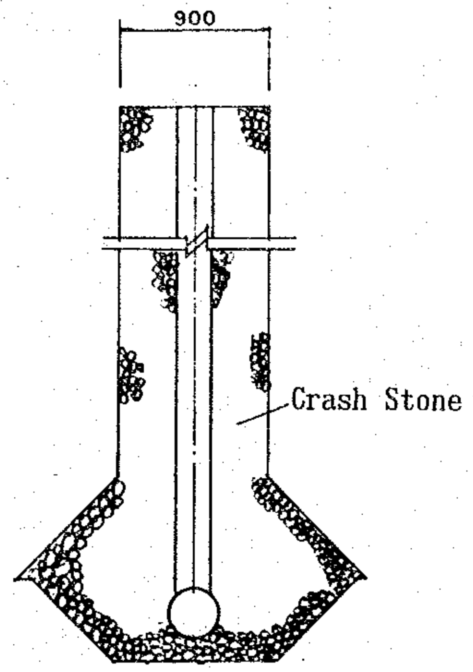
SCALE	DRAWING NO.	DATE
As shown	S-12	15/12/1990

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

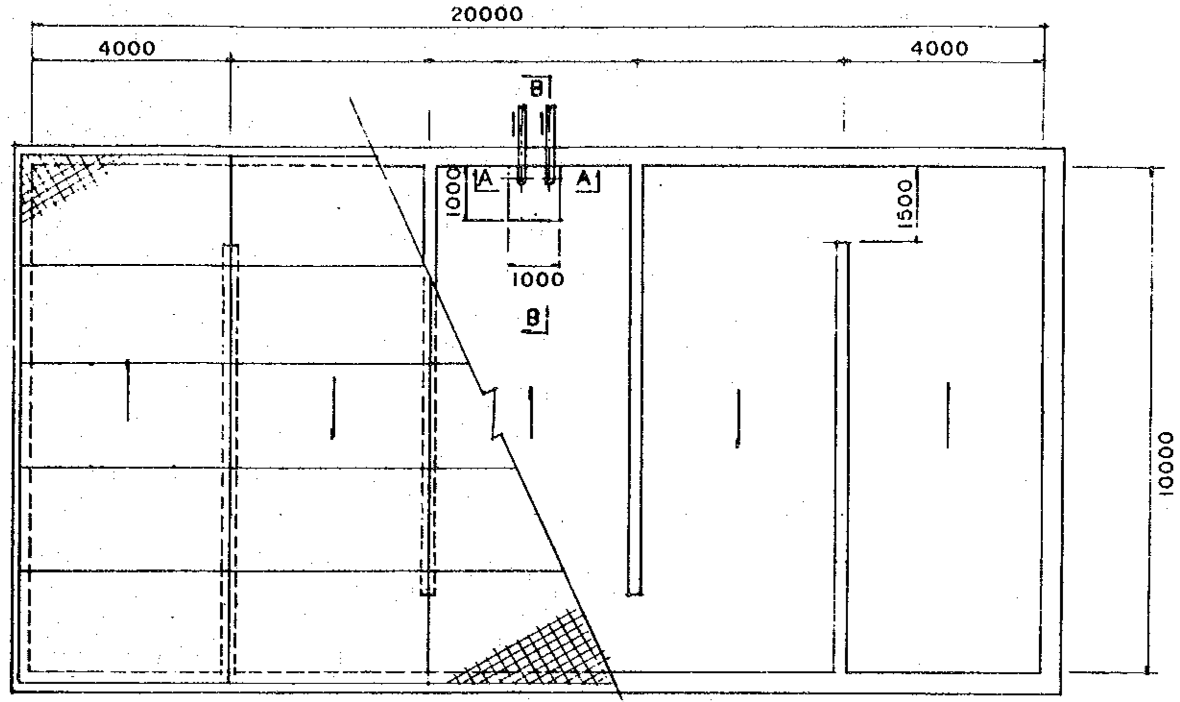
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



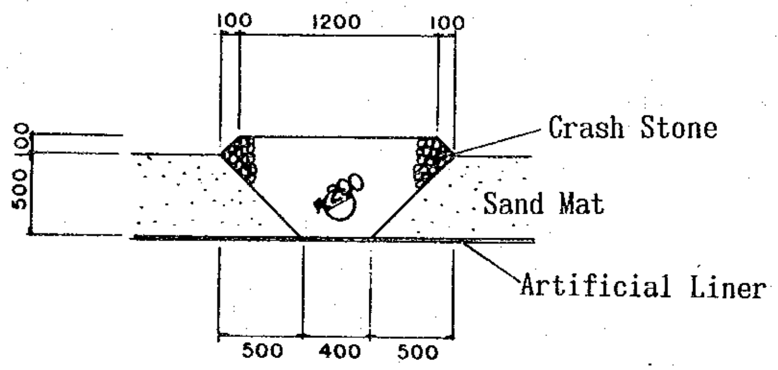
Typical Cross Section
of a leachate Collection Facility(Main Pipe)



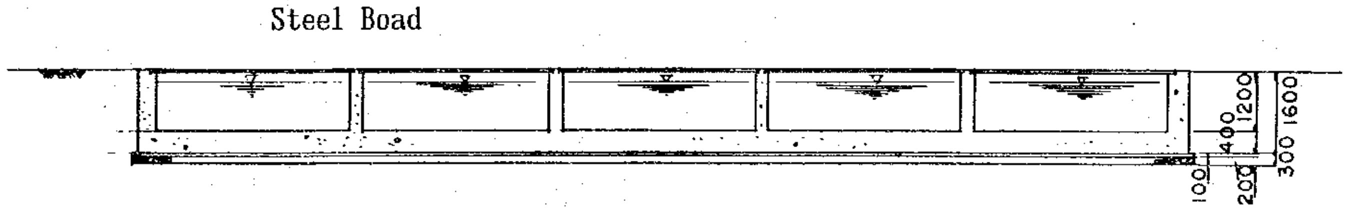
Typical Cross Section
of a Gus Out-let Pipe



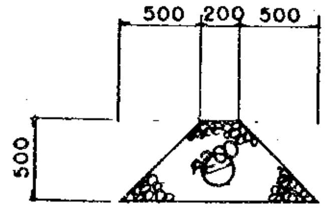
Plan of a Leachate Store Pond



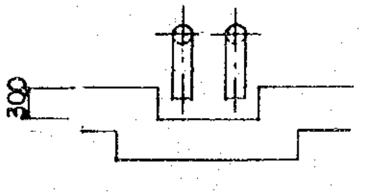
Typical Cross Section
of a Lechate Collection Facility(Branch Pipe)



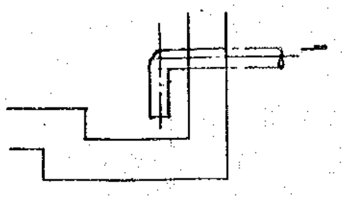
Cross Section of a Lechate Store Pond



Typical Cross Section of a Groundwater Drain Facility

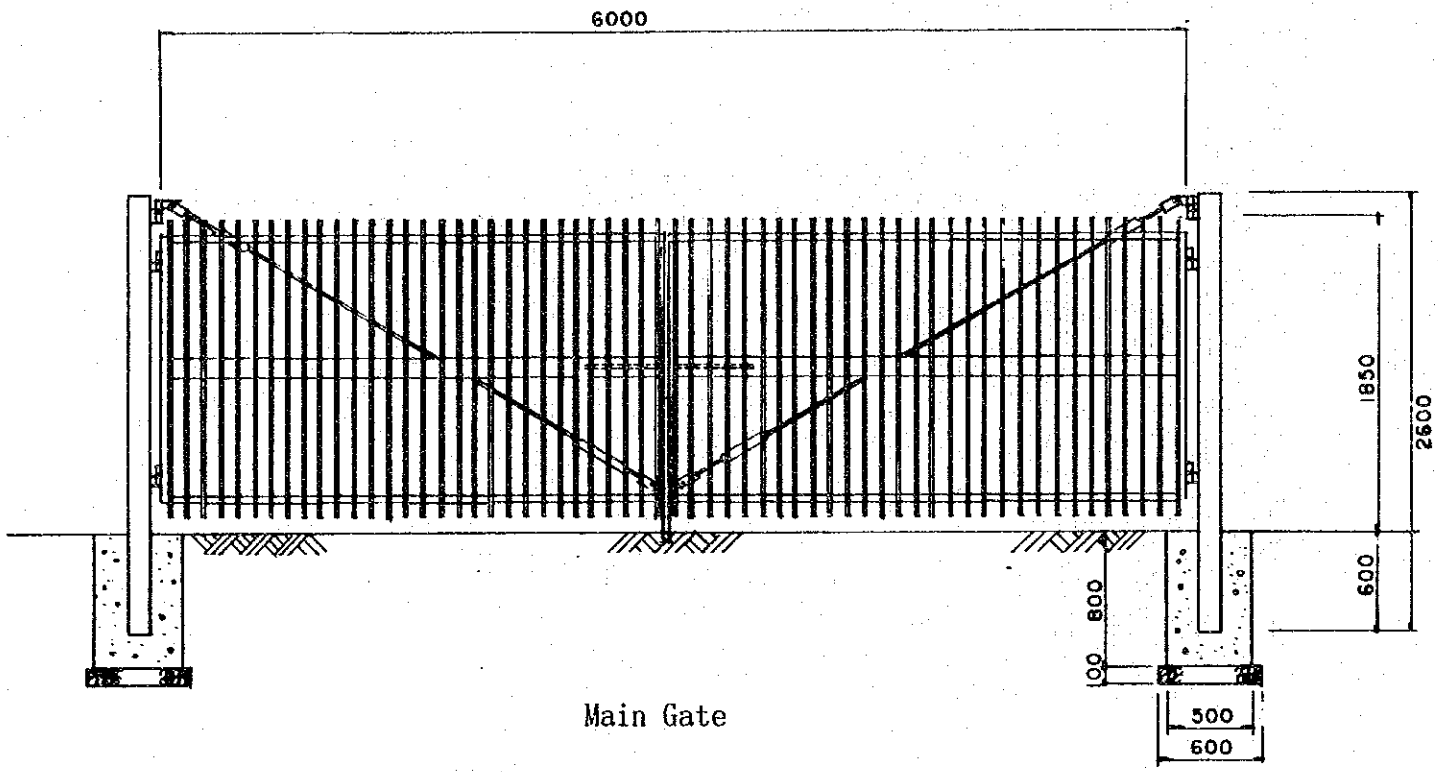


SECTION A-A

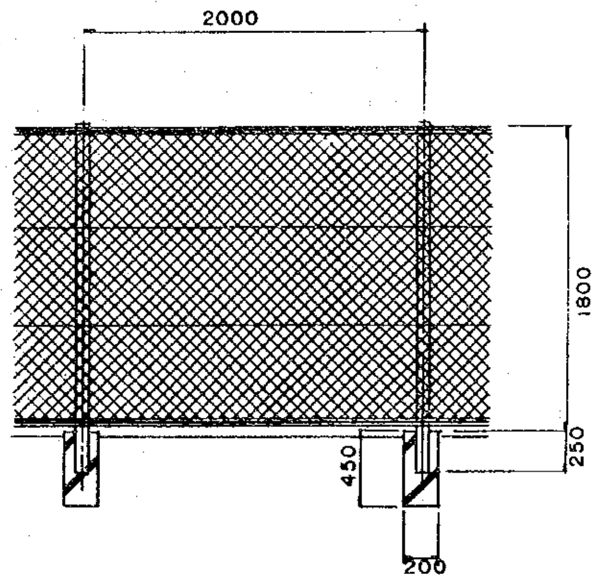


SECTION B-B

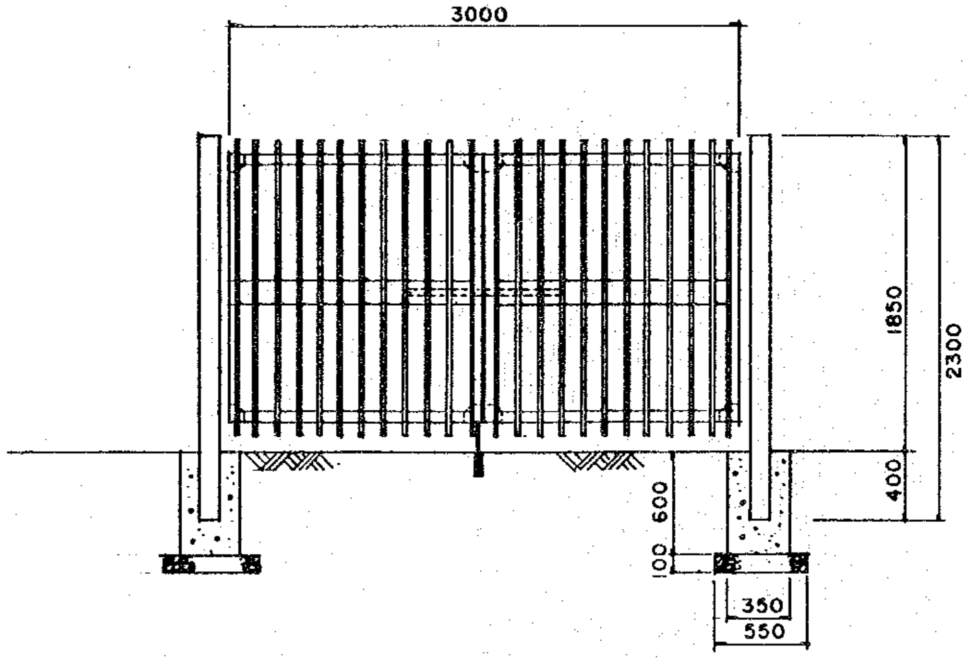
RAM INTRA SANITARY DISPOSAL SITE		
FACILITY STRUCTURE (1)		
SCALE	DRAWING NO.	DATE
As shown	S-13	15/12/1990
THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT		
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)		



Main Gate



Net fence



Small Gate of a Leachate Treatment Facility

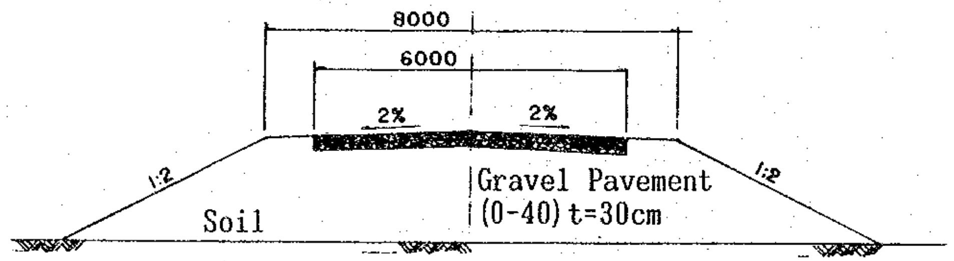
RAM INTRA SANITARY DISPOSAL SITE

FACILITY STRUCTURE (2)

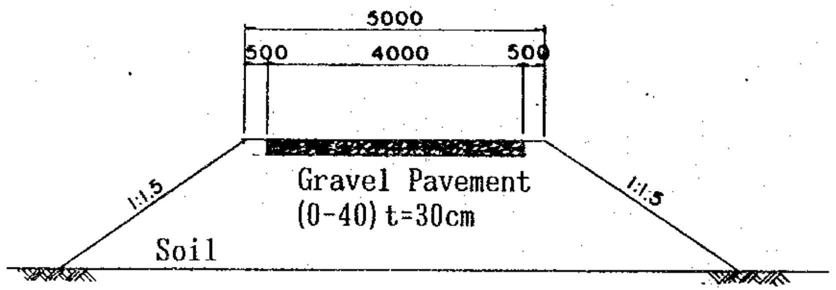
SCALE	DRAWING NO.	DATE
As shown	S-14	15/12/1990

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

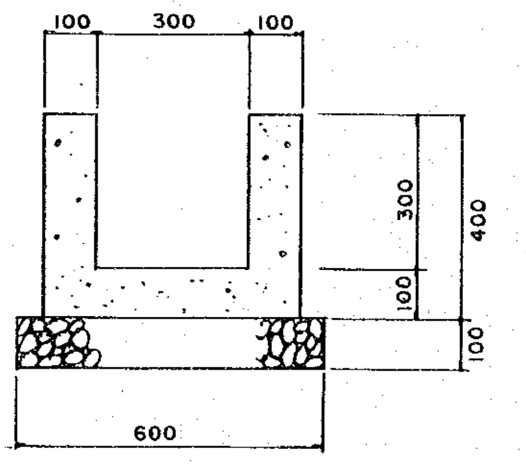
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



Typical Cross Section of an Access Road

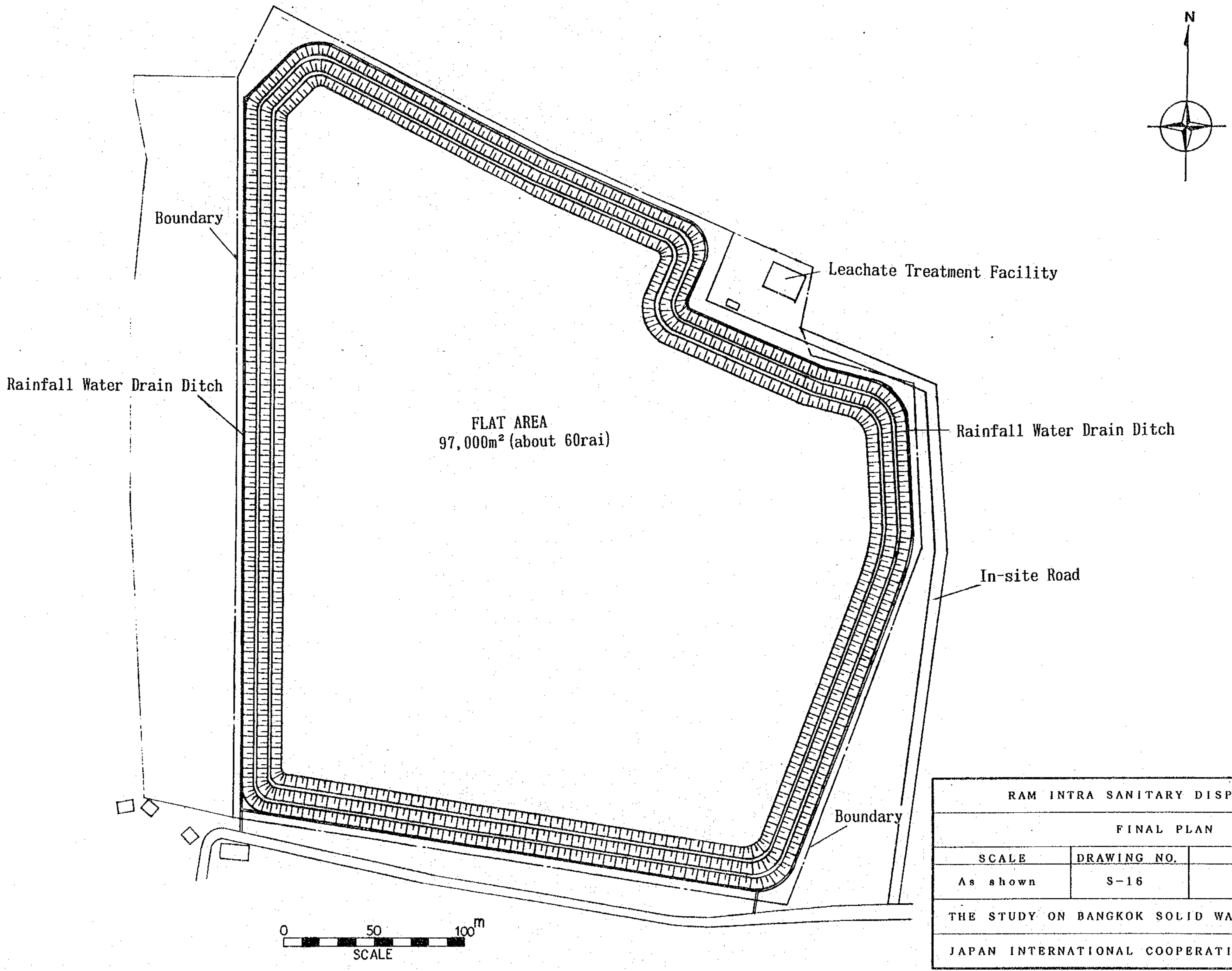


Typical Cross Section of a Management Road



Typical Cross Section of a
Rainfall Water Drain Ditch

RAM INTRA SANITARY DISPOSAL SITE		
FACILITY STRUCTURE (3)		
SCALE	DRAWING NO.	DATE
As shown	S-15	15/12/1990
THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT		
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)		



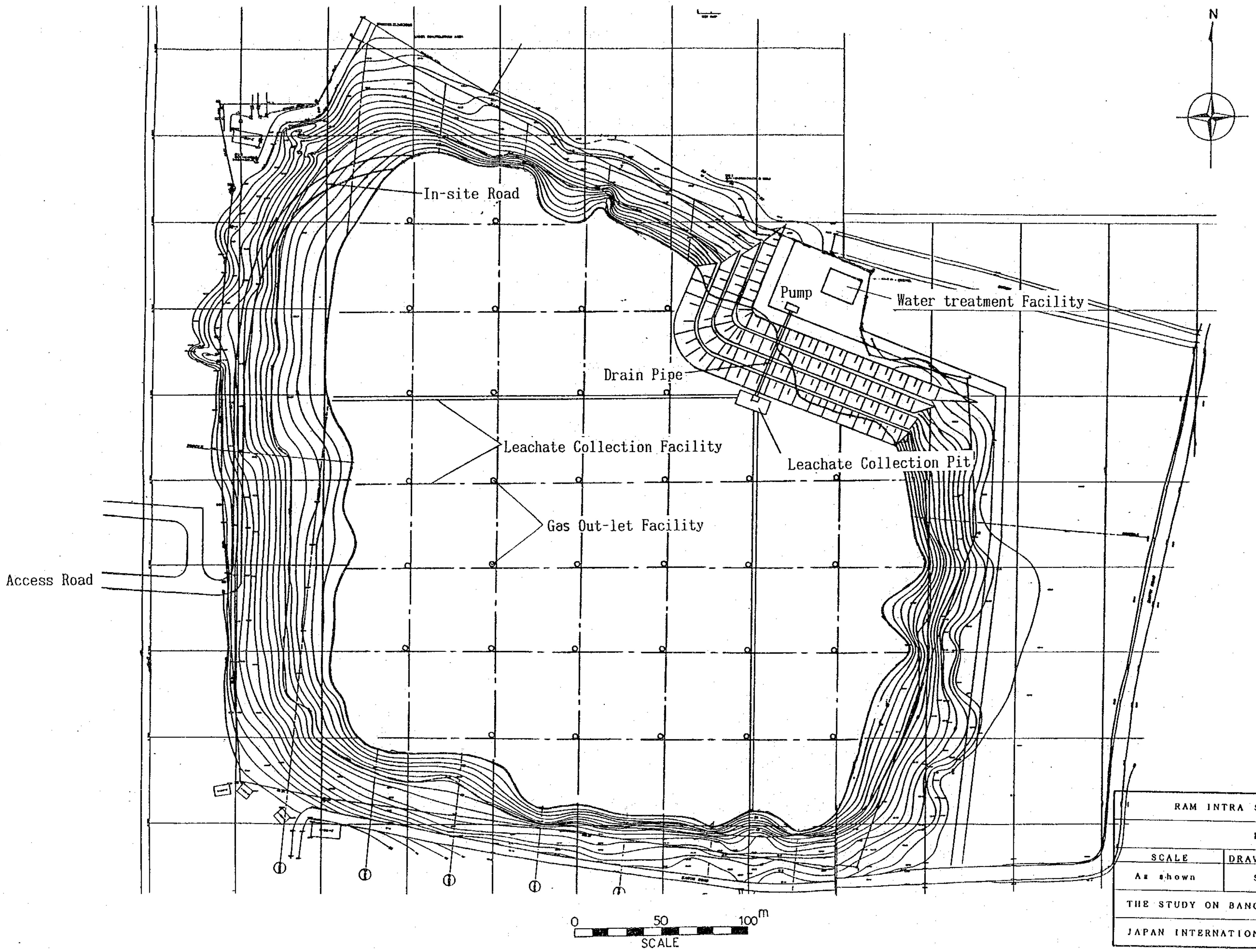
RAM INTRA SANITARY DISPOSAL SITE

FINAL PLAN

SCALE	DRAWING NO.	DATE
As shown	S-16	15/12/1990

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



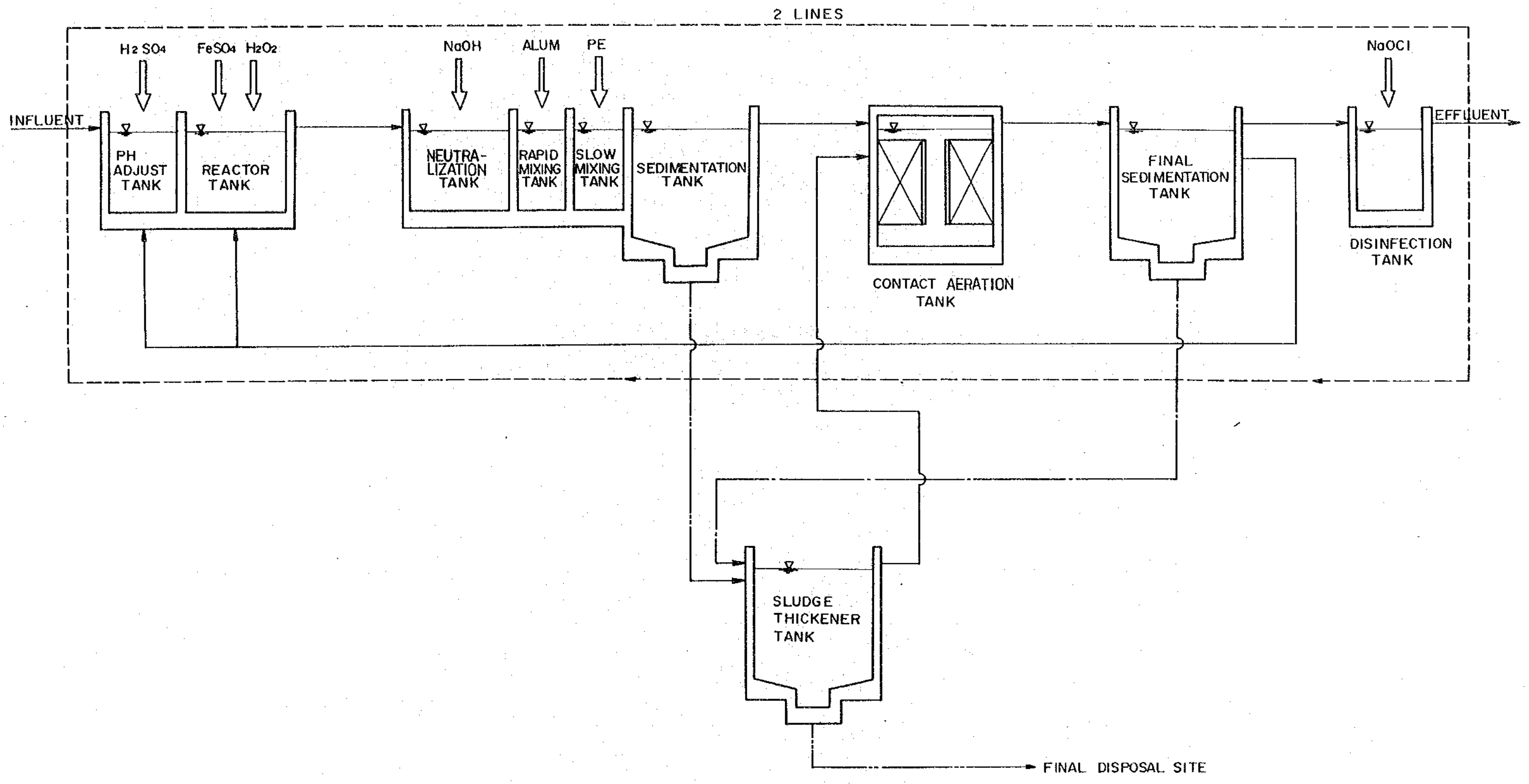
RAM INTRA SANITARY DISPOSAL SITE

PLAN (CASE2)

SCALE	DRAWING NO.	DATE
As shown	S-17	15/12/1990

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



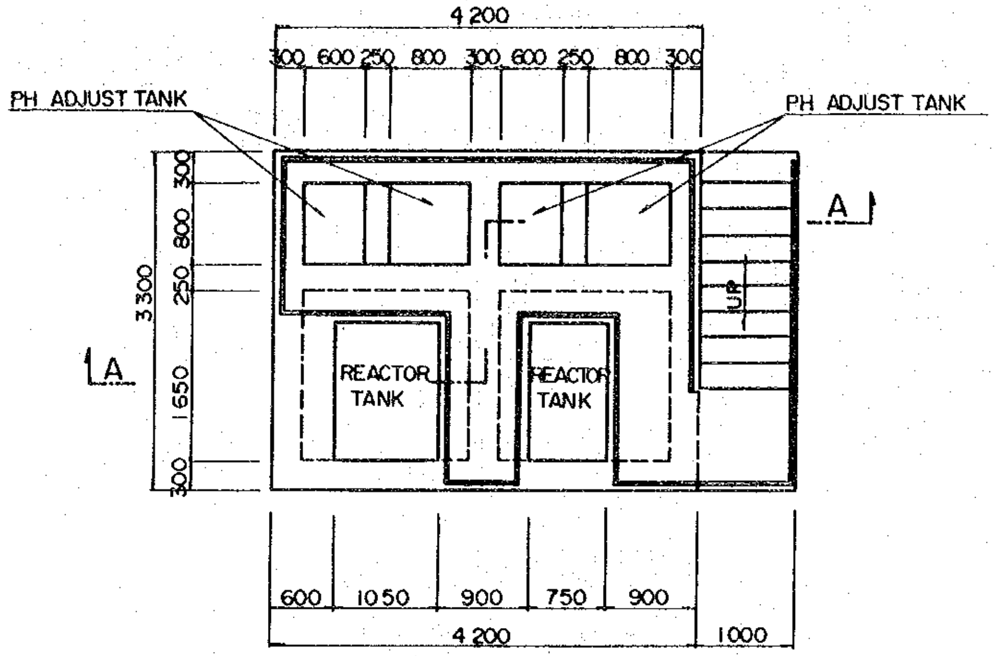
RAM INTRA SANITARY DISPOSAL SITE

LEACHATE TREATMENT FACILITY FLOW CHART

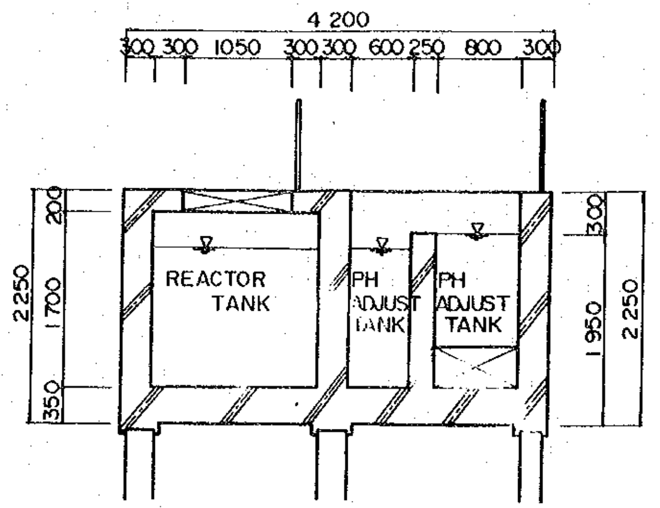
SCALE	DRAWING NO.	DATE
As shown	S-18	15/12/1990

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

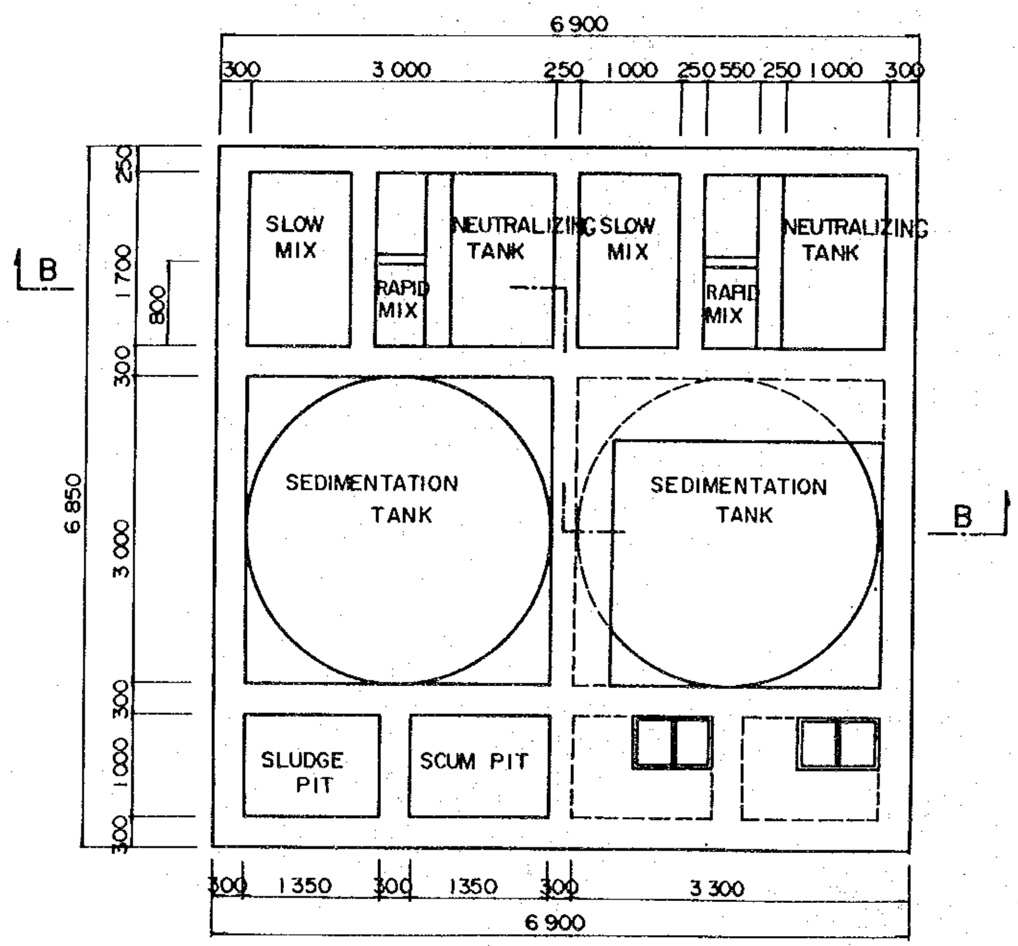
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



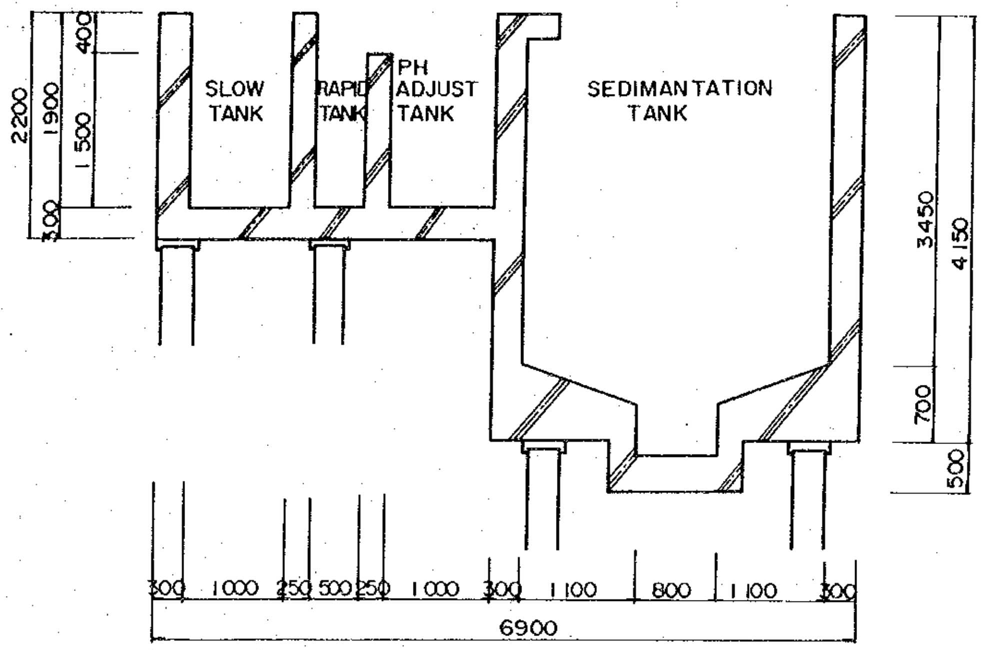
PH ADJUST TANK AND REACTOR TANK
GROUND PLAN



PH ADJUST TANK AND REACTOR TANK
A-A SECTION PLAN



COAGULATION
GROUND PLAN



COAGULATION
B-B SECTION PLAN

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<tr><td colspan="3">LEACHATE TREATMENT FACILITY STRUCTURE (3)</td></tr>
<tr><td>SCALE</td><td>DRAWING NO.</td><td>DATE</td></tr>
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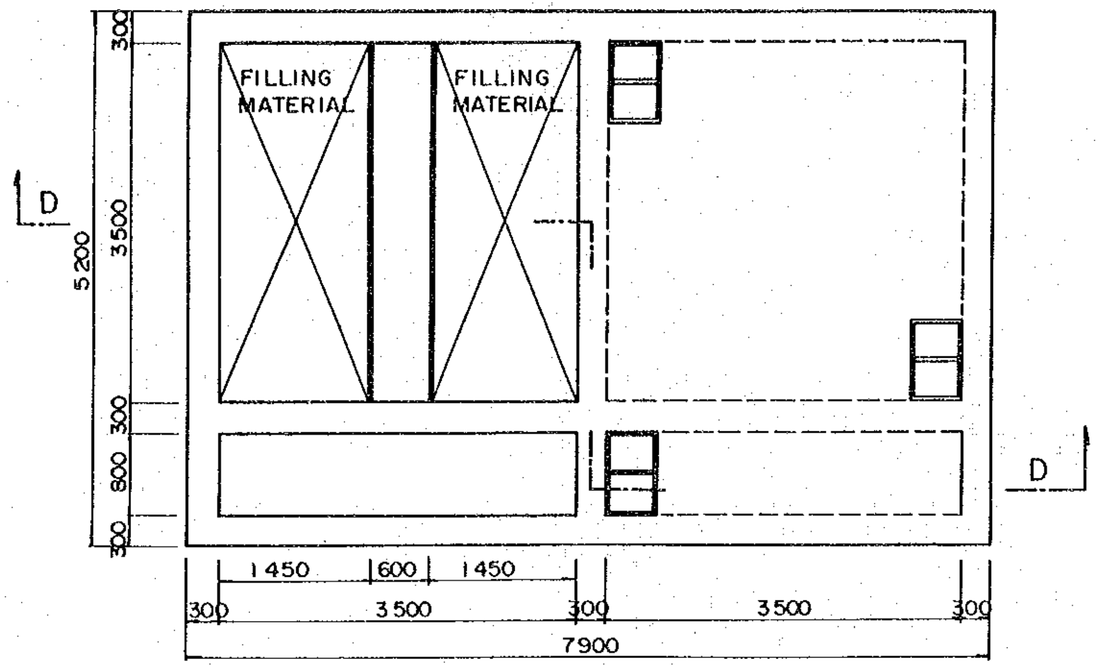
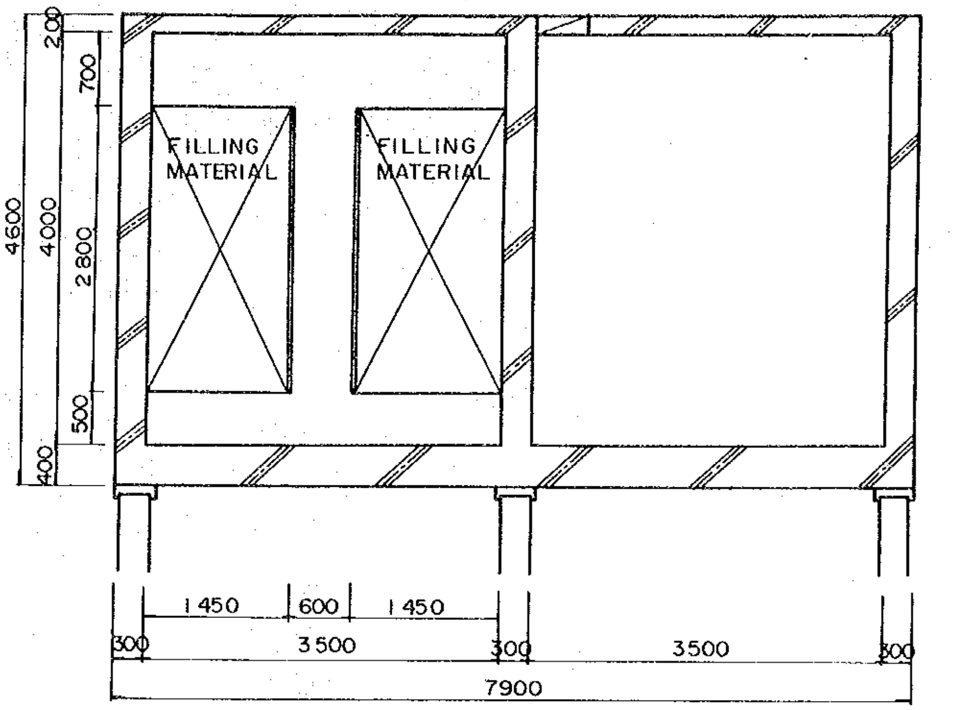
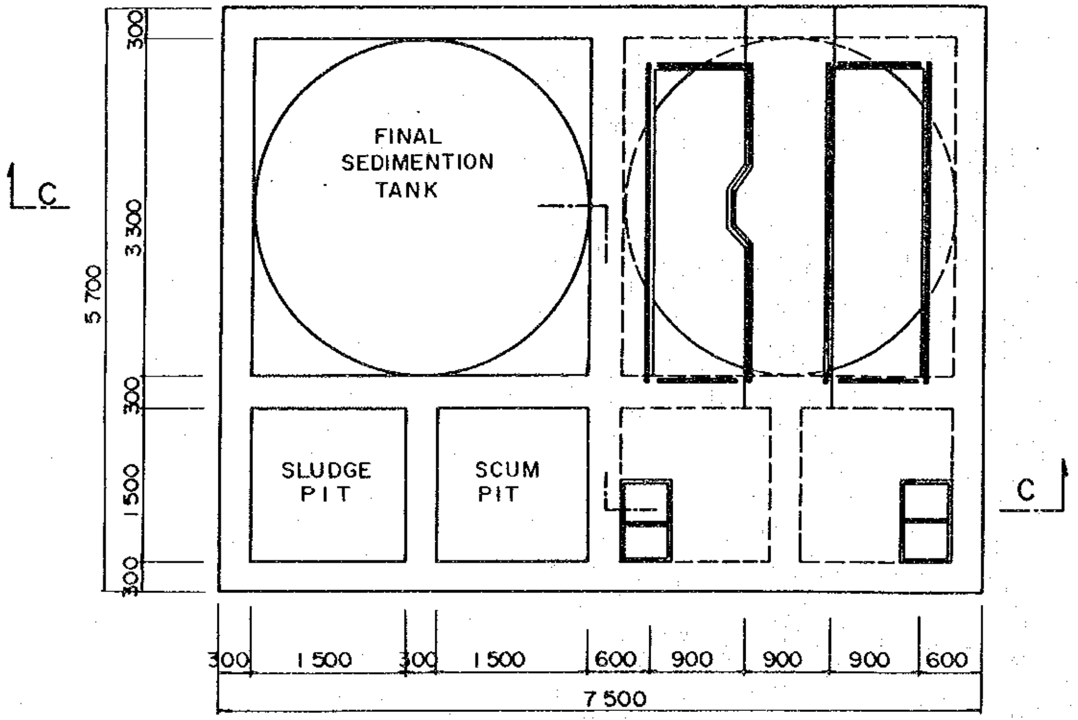


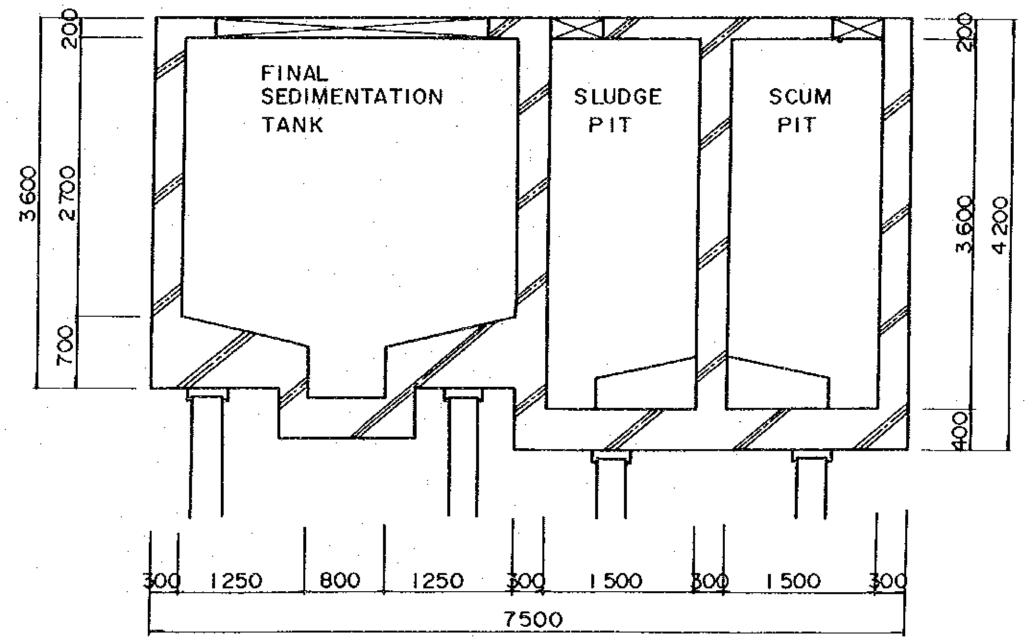
CONTACT AERATION TANK
GROUND PLAN



CONTACT AIRATION TANK
D-D SECTION PLAN



FINAL SEDIMENTATION
GROUND PLAN



FINAL SEDIMENTATION
C-C SECTION PLAN

<table>
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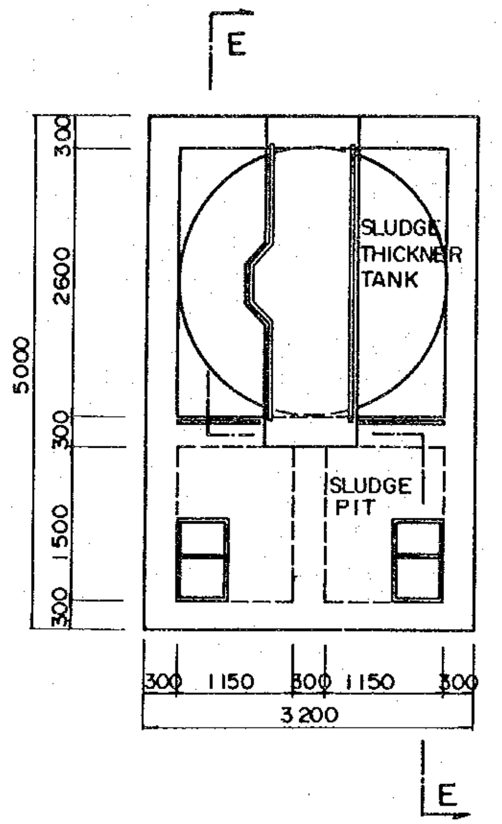
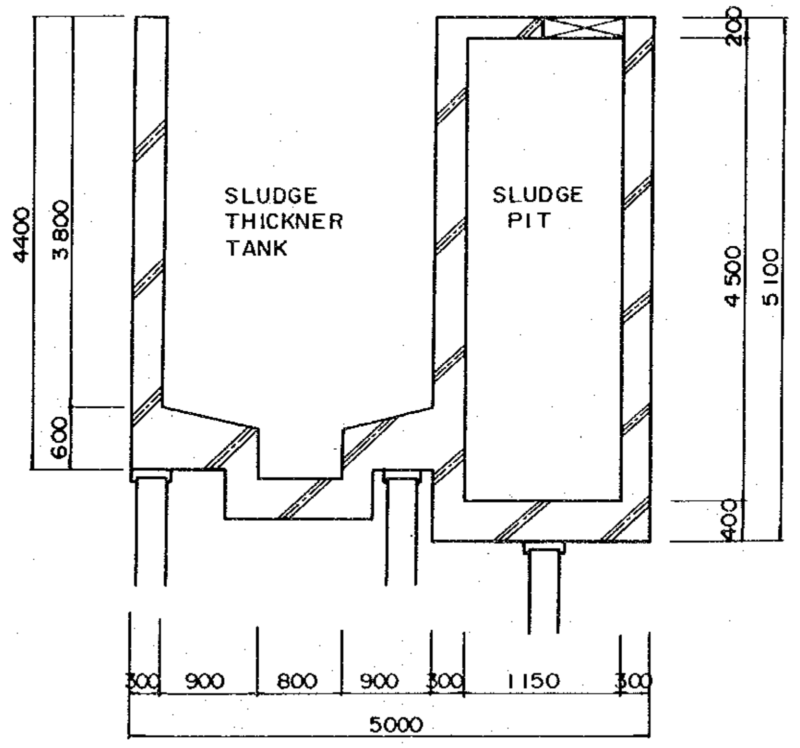


SLUDGE THICKENER
GROUND PLAN



SLUDGE THICKENER
E - E SECTION PLAN

RAM INTRA SANITARY DISPOSAL SITE

LEACHATE TREATMENT FACILITY STRUCTURE (3)

SCALE	DRAWING NO.	DATE
As shown	S-21	15/12/1990

THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

11.4 Cost Estimation

11.4.1 Cost Estimation Back-fill Type (Ram Intra) Case 1

1) Civil Work

Site Area		
Disposal Area		
Capacity	3,000,000 m^3	
Waste quantity volume	2,300,000 m^3	1,825,000 t
Covering material volume	700,000 m^3	910,000 t
Civil Work Cost	304,500,000 B	

(purchase of backfill material 110,138,000B)

2) Water Treatment Facility

Capacity	200 m^3/d
Initial Cost	52,000,000 B

3) Total Initial Cost 356,500,000 B

(195 B/t)

(purchase of backfill material 60B/t)

Table 11.4-1 O/M Cost

	1994	1995	1996	1997	1998	1999
Management	13	9	7	6	6	15
Operation	(96)	(92)	(89)	(88)	(88)	(100)
Land fill	22	22	22	22	22	22
Covering material	39	39	39	39	39	39
Labour fee	15	11	8	7	7	19
Water treatment	20	20	20	20	20	20
Maintenance	3	3	3	3	3	3
Total	112	104	99	97	97	118

Land Acquisition Cost

Offer Price	95,200,000 B	(1,120,000B/rai)

Table 11.4-2 Management

Item / Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Site 5person (B/month)	75,000	77,250	79,568	81,954	84,413	86,945	89,554	92,240	95,008	97,858	100,794
Water treatment 3person (B/month)	45,000	46,350	47,741	49,173	50,648	52,167	53,732	55,344	57,005	58,715	60,476
Management car (B/month)	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
Total (B/month)	180,000	183,600	187,309	191,127	195,061	199,112	203,286	207,584	212,013	216,573	221,270
Disposal Volume (t/d)	—	—	—	—	500	700	1,030	1,100	1,200	470	—
Unit cost (t/d)	—	—	—	—	13	9	7	6	6	15	—

Table 11.4-3 Operation

Item / Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Labor 40persons 40×5,000 (B/month)	200,000	206,000	212,180	218,545	225,102	231,855	238,810	245,975	253,354	260,954	268,783
Dispsal volume(t/d)	—	—	—	—	500	700	1,030	1,100	1,200	470	—
Unit cost	—	—	—	—	15	11	8	7	7	19	—

Water Treatment

$$\frac{82\,(\mathrm{B}/\mathrm{m}^3) \times 200\,(\mathrm{m}^3/\mathrm{d}) \times 365\,(\mathrm{day}) \times 6\,(\mathrm{years})}{1,825,000} = 20\mathrm{B}/\mathrm{t}$$

Table 11.4-4 Civil Work (Case 1)

NO. 1

WORK ITEM		NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
Earth work	Cut and Excavation work		59,300	m^3	56	B	3,320.8	
	Embankment work		846,000	m^3	60	B	50,760.0	
	Adjustment work		171,000	m^2	18	B	3,078.0	
Earth work material	Embankment material		786,700	m^3	140	B	110,138.0	
Unpervious work	P.V.C sheet		171,000	m^2	420	B	71,820.0	
	Sand mat work		50,000	m^3	60	B	3,000.0	
	Sand mat material		50,000	m^3	180	B	9,000.0	
Leachate collection facility	Main pipe	¢300	480	m	1,840	B	883.2	
	Branch pipe	¢200	3,500	m	870	B	3,045.0	
	Crushed stone	1.1 ×1.5 ×480 0.9 ×0.6 ×3,500	2,682	m^3	220	B	590.04	
	Leachate collection pit		200	m^3	6,600	B	1,320.0	
	Pump facility		2	place	32,000	B	64.0	
	Drain pipe		240	m	870	B	208.8	

Civil Work (Case 1)

NO. 2

WORK ITEM		NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
Gus out-let facility	Porous pipe	φ200	680	m	870	B	591.6	
	Crushed stone	680 ×0.81	551	m^3	220	B	121.22	
	Construction		17	places	240	B	4.08	
Underground water collection facility	Porous pipe	φ200	1,300	m	870	B	1,131.0	
	Crushed stone	0.35×1,300	455	m^3	220	B	100.1	
	Drain pipe		240	m	870	B	208.8	
	Pump facility		2	places	32,000	B	64.0	
Rainfall water drain ditch	Surround drain ditch		1,550	m	2,500	B	3,875.0	
	End of embankment		1,450	m	2,500	B	3,625.0	
Access road	Pavement of access road		1,350	m^3	220	B	297.0	
	Pavement of management road		925	m^3	220	B	203.5	

Civil Work (Case 1)

NO. 3

WORK ITEM		NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
Outside	Main gate		1	place	33,000	B	33.0	
	Small gate		2	place	10,000	B	20.0	
	Chain link fence		1,610	m^3	550	B	885.5	
Sub total							268,387.64	
Out lay		Include tax 3.5% Sub total ×13.5%					36,112.36	
Total							304,500.0	

11.4.2 Cost Estimation Back-fill Type (Ram Intra) Case 2

1) Civil Work

Site Area		
Disposal Area		
Capacity	3,250,000 m^3	
Waste quantity volume	2,500,000 m^3	2,000,000 t
Covering material volume	750,000 m^3	975,000 t
Civil Work Cost	167,500,000 B	

(purchase of backfill material 85,540,000B)

2) Water Treatment Facility

Capacity	300 m^3/d
Initial Cost	60,000,000 B

3) Total Initial Cost

3) Total Initial Cost	227,500,000 B
	(114 B/t)

(purchase of backfill material 43B/t)

Table 11.4-5 O/M Cost

	1994	1995	1996	1997	1998	1999
Management	13	9	7	6	6	15
Operation	(81)	(79)	(76)	(73)	(73)	(85)
Land fill	22	22	22	22	22	22
Covering material	39	39	39	39	39	39
Labour Fee	15	11	8	7	7	19
Water treatment	5	5	5	5	5	5
Maintenance	2	2	2	2	2	2
Total	96	90	85	81	81	102

Land Acquisition Cost

Offer Price 95,200,000 B (1,120,000B/rai)

Water Treatment

$$\frac{20(B/m^3) \times 200(m^3/d) \times 365(day) \times 6(years)}{1,825,000} = 4.8 \fallingdotseq 5(B/t)$$

Table 11.4-6 Civil Work (Case 2)

NO. 1

WORK ITEM		NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
Earth work	Cut and Excavation work		0	m^3	56	B	0	
	Embankment work		611,000	m^3	60	B	36,660.0	
	Adjustment work		8,300	m^2	18	B	149.4	
Earth work material	Embankment material		611,000	m^3	140	B	85,540.0	
Leachate collection facility	Main pipe	1.1 ×1.5 ×480	792	m^3	220	B	174.24	
	Branch pipe	0.9 ×0.6 ×3,500	1,890	m^3	220	B	415.8	
	P.V.C sheet	0.2mm	96,900	m^2	40	B	3,876.0	
	Sand mat		48,700	m^3	180	B	8,766.0	
	Leachate collection pit		200	m^3	6,600	B	1,320.0	
	Pump facility		2	place	32,000	B	64.0	
	Prain pipe		240	m	870	B	208.8	

Civil Work (Case 2)

NO. 2

WORK ITEM		NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
Gus out-let facility	Crushed stone		551	m^3	220	B	121.22	
Underground collection facility	Porous pipe	φ200	1,300	m	870	B	1,131.0	
	Crushed stone	0.35×1,300	455	m^3	220	B	100.1	
	Drain pipe		240	m	870	B	208.8	
	Pump facility		2	places	32,000	B	64.0	
Rainfall water drain ditch	Surround drain ditch		1,550	m	2,500	B	3,875.0	
	End of embankment		1,450	m	2,500	B	3,625.0	
Access road	Pavement of access road		1,350	m^3	220	B	297.0	
	Pavement of management road		925	m^3	220	B	203.5	

Civil Work (Case 2)

NO. 3

WORK ITEM		NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
Outside	Main gate		1	place	33,000	B	33.0	
	Small gate		2	place	10,000	B	20.0	
	Chain link fence		1,610	m^3	550	B	885.5	
Sub total						B	147,738.36	
Out lay		Include tax 3.5% Subtotal×13.5%				B	19,761.64	
Total						B	167,500.0	

Table 11.4-7 COST ESTIMATE OF L/C TREATMENT PLANT

NO. 1

WORK ITEM	NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
1.Direct cost					B	41,433	
1) CIVIL WORK		1	LS		B	6,870	
2) EQUIPMENT		1	〃		B	24,533	
3) ELECTRIC WORK		1	〃		B	7,500	
4) CONDUIT		1	〃		B	2,530	
2.Job site expense		10	%		B	4,143	
Sub Total	(1+2)	1	LS		B	45,576	
3.Over head	(1+2) ×10%	10	%		B	4,557	
Total	(1+2+3)				B	50,133	
4.Tax	(1+2+3) ×3.5%	3.5	%		B	1,754	
Ground Total	(1+2+3+4)				B	51,887	

COST ESTIMATE OF L/C TREATMENT PLANT

NO. 2

WORK ITEM	NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
1) CIVIL WORK							
pH Adjustment & Reactor		1	LS		B	450	
Coagulation & Sedimentaion Tank		1	〃		B	1,300	
Contact Aeration Tank		1	〃		B	1,160	
Final Sedimentation Tank		1	〃		B	1,130	
Disinfection Tank		1	〃		B	150	
Sludge Thicknnere		1	〃		B	900	
In Plant Road	(Included garden)	1	〃		B	800	
Dranage System		1	〃		B	760	
Intake Pump Pit		1	〃		B	220	
(total)					B	6,870	

COST ESTIMATE OF L/C TREATMENT PLANT

NO. 3

WORK ITEM	NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	PRICE (×1,000)
						(Equipment)	(Installation)
2) EQUIPMENT							
Intake pump		2	set	14 108	B	216	28
Rapid Mixer	(R/2)	2	set	10 234	B	468	20
〃	(R/L)	2	〃	10 291	B	582	20
〃	(R/L)	2	〃	12 336	B	672	24
〃	(R/L)	2	〃	10 291	B	582	20
〃		2	〃	10 234	B	468	20
Slow Mixer		2	〃	27 501	B	1,002	54
Scraper	○3m	2	〃	50 500	B	1,000	100
Sludge Pump		4	〃	8 69	B	276	32
Contacter		80	m³	5 55	B	4,400	400
Blower		2	set	20 213	B	416	40
Scraper	○3.3m	2	〃	55 552	B	1,104	110
Sludge Pump		4	〃	8 69	B	276	32
Scum Skimming Pump		4	〃	8 69	B	276	32
Scraper	○2.6m	1	〃	0 440	B	440	0
Sludge Drain Off Pump		2	〃	8 69	B	138	16

COST ESTIMATE OF L/C TREATMENT PLANT

NO. 4

WORK ITEM	NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	PRICE (×1,000)
Separated Water Supply Pump		2	set	8 69	B	138	16
City Water Supply Unit		1	〃	70 800	B	800	70
City Water Offer Fee		1	〃	0 400	B	400	0
Chemical Pump		21	〃	4 126	B	2,646	84
Chemical Tank	10m³	3	〃	50 495	B	1,485	150
	5m³	8	〃	20 325	B	2,600	160
	2m³	2	〃	15 200	B	400	30
	1m³	1	〃	10 150	B	150	10
Chemical Mixer	FeSo₄	3	〃	30 312	B	936	90
	Alum	2	〃	24 240	B	480	48
Chemical Mixer	Polymer	2	〃	24 240	B	480	48
					B	(22,835)	(1 ,698)
(total)					B	24,533	

COST ESTIMATE OF L/C TREATMENT PLANT

NO. 5

WORK ITEM	NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
3) ELECTRIC WORK							
Offer Fee for Power Receiving		1	LS		B	600	
Panel, Wiring		1	〃		B	2,400	
Lighting		1	〃		B	400	
Flow Meter		2	set	463	B	926	
pH Meter		6	〃	280	B	1,680	
D.O.Meter		2	〃	280	B	560	
Superintendence Panel		1	〃	934	B	934	
(total)					B	7,500	

COST ESTIMATE OF L/C TREATMENT PLANT

NO. 6

WORK ITEM	NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
4) CONDUIT							
Material		1	LS		B	2,000	
Labour Fee		1	〃		B	530	
(total)					B	2,530	

COST ESTIMATE OF AIRLATION LAGOON

NO. 1

WORK ITEM	NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
1.Direct cost					B		
1) CIVIL WORK		1	LS		B	36,170	
2) EQUIPMENT		1	〃		B	1,700	
3) ELECTRIC WORK		1	〃		B	7,500	
4) CONDUIT		1	〃		B	2,530	
2.Job site expense		10	%		B	4,800	
Sub Total	(1+2)				B	52,700	
3.Over head	(1+2) ×10%	10	%		B	5,300	
Total	(1+2+3)				B	58,000	
4.Tax	(1+2+3) ×3.5%	3.5	%		B	2,000	
Ground Total	(1+2+3+4)				B	60,000	

COST ESTIMATE OF AIRLATION LAGOON

NO. 2

WORK ITEM	NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
1) CIVIL WORK							
Reguration Tank	^{L}5m ×^{B}5m ×^{H}5m ×3unit	1	LS		B	2,475	
Airlation Lagoon Tank	^{L}33m×^{B}15m×^{H}5m ×3unit	1	〃		B	33,190	
Sedimation Tank	^{L}6m ×^{B}3m ×^{H}3.5m ×1unit	1	〃		B	505	
(total)					B	36,170	

COST ESTIMATE OF AIRLATION LAGOON

NO. 3

WORK ITEM	NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
2) EQUIPMENT							
Floating Airlatior	Cable 50m	6	machine	200,000	B	1,200	
Pipe		18	m	5,000	B	90	
Operating Panel		1	LS		B	410	
(total)					B	1,700	

COST ESTIMATE OF AIRLATION LAGOON

NO. 4

WORK ITEM	NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
3) ELECTRIC WORK							
Offer Fee for Power Receiving		1	LS		B	600	
Panel, Wiring		1	〃		B	2,400	
Lighting		1	〃		B	400	
Flow Meter		2	set	463	B	926	
pH Meter		6	〃	280	B	1,680	
D.O.Meter		2	〃	280	B	560	
Superintendence Panel		1	〃	934	B	934	
(total)					B	7,500	

COST ESTIMATE OF AIRLATION LAGOON

NO. 5

WORK ITEM	NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
4) CONDUIT							
Material		1	LS		B	2,000	
Labour fee		1	〃		B	530	
(total)					B	2,530	

11.5 Cost Estimation Fill-up Type

10.5.1 Cost Estimation Fill-up Type (East Part of Bangkok) Case 1

1) Civil Work

Site Area	2,720,000 m^2	(1,700rai)
Disposal Area	2,400,000 m^2	
	(800,000x3Steps)	
Capacity	18,300,000 m^3	
	(6,100,000x3Steps)	
Note;1Step		
Waste quantity	4,700,000 m^3	3,650,000 t
Covering material	1,400,000 m^3	1,800,000 t
Civil Work Cost	1,050,000,000 B	
Note;1Step	350,000,000 B	

2) Water Treatment Facility

Capacity	1,000 m^3/d
Initial Cost	120,000,000 B

3) Optional Facilities

Control Office	6,000,000 B
Weigh Bridge	2,000,000 B
	8,000,000 B

Table 11.5-1 Total Initial cost

(×1,000)

	1st Step	2nd Step	3rd Step
Civil work	350,000	350,000	350,000
Water Treatment Facility	120,000	0	0
Optional Facility	8,000	0	0
Total	550,000	350,000	350,000

Table 11.5-2 O/M Cost (1st Step)

		1997	1998	1999	2000
Management		4	4	4	4
Operation		(70)	(70)	(70)	(71)
	Land fill	22	22	22	23
	Labour Fee	7	7	7	7
	Water treatment	41	41	41	41
Maintenance		2	2	2	2
Total		76	76	76	77

4) Land Acquisition Cost

Offer Price
(560,000B/rai)

1st Step	392,000
2nd Step	280,000
3rd Step	280,000

5) Landfilling Cost

·15t Bull dozer	
Rental charge	33,000 (¥/day)
Fuel Cost	18 (ℓ/hr)×50 (¥/ℓ) ×7.0hour = 6,300(¥/day)
	39,300(¥/day)
	39,300(¥/day) ÷6(¥/B)≒ 6,550(B/day)
·Labour	400(B/day) ···· 12,000(B/m)
Subtotal	6,950(B/day)

·Capability of landfilling 45(t/h)×7hour=315(t/d)

·Landfill cost 6,950 ÷315=22.06 ≒22(B/t)

Table 11.5-3 Landfill Cost

Year	Heavy Equipment (B/t)	Labor fee (B/t)	Total (B/t)	
1990	20.8	1.3	22.1	22
1991	〃	1.31	22.11	22
1992	〃	1.35	22.15	22
1993	〃	1.39	22.19	22
1994	〃	1.43	22.23	22
1995	〃	1.47	22.27	22
1996	〃	1.52	22.32	22
1997	〃	1.56	22.36	22
1998	〃	1.61	22.41	22
1999	〃	1.66	22.46	22
2000	〃	1.71	22.51	23

6) Leachate Water Treatment Cost

	Japanese Yen	Thai Baht
(1) Management Cost	415 (¥/m³)	70 (B/m³)
(a) Electric Cost	137 (¥/m³)	23 (B/m³)
(b) Chemical injection materials cost		
(i) biological treatment	60 (¥/m³)	10 (B/m³)
(ii) coagulant	48 (¥/m³)	8 (B/m³)
(iii) filtration	153 (¥/m³)	26 (B/m³)
(iv) disinjection	9 (¥/m³)	2 (B/m³)
(v) sludge treatment	8 (¥/m³)	1 (B/m³)
(2) Maintenance Cost	70 (¥/m³)	12 (B/m³)
(a) Expendables	70 (¥/m³)	12 (B/m³)
TOTAL	485 (¥/m³)	82 (B/m³)

$$\frac{82\,(\mathrm{B/m^3}) \times 1,000\,(\mathrm{m^3/d}) \times 365\,(\mathrm{day}) \times 5\,(\mathrm{years})}{3,650,000\,(\mathrm{t})} = 41\mathrm{B/t}$$

Table 11.5-4 Management

Year Item	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Site (5person)	75,000	77,250	79,568	81,954	84,413	86,945	89,554	92,240	95,008	97,858	100,794
Water treatment (3person)	45,000	46,350	47,741	49,173	50,648	52,167	53,732	55,344	57,005	58,715	60,476
Management car	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
Total	180,000	183,600	187,309	191,127	195,061	199,122	203,286	207,584	212,013	216,573	221,270
Disposal Volume (t/d)	—	—	—	—	—	—	—	1,700	1,700	2,000	2,000
Unit cost	—	—	—	—	—	—	—	4	4	4	4

Table 11.5-5 **Labour fee**

Year Item	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Labour(60persons)	300,000	309,000	318,270	327,818	337,652	347,782	358,216	368,962	380,031	391,432	403,175
Dispsal volume (t/d)	—	—	—	—	—	—	—	1,700	1,700	2,000	2,000
Unit cost	—	—	—	—	—	—	—	7	7	7	7

Table 11.5-6 East Part of Bangkok (Case 1)

NO. 1

WORK ITEM		NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
Earth work	excavation	500,000 ×3 = 1,500,000 ×3	4,500,000	m^3	56	B/m^3	252,000	8-1)
	embankment	6,560 ×42=280,000×3	840,000	m^3	60	B/m^3	50,400	8-2)
	pavement	8,800 ×8 ×0.5 = 35,000	35,000	m^3	220	B/m^3	7,700	2-2)
	Adjustment of excavated slope	(470+1,050) ×2 ×4.5=14,000×3	42,000	m^2	18	B/m^2	756	
	Adjustment of embanked slope	6,560 ×20≒131,000 ×3	390,000	m^2	18	B/m^2	7,020	
							317,876	
Leachate collection facility and Gas out-let facility	main pipe	⌀300 17,500×3	52,000	m	1,840	B/m	96,600	9-1)
	branch pipe	⌀200 63,300×3	189,000	m	870	B/m	164,430	9-2)
	Crushed stone	1.1 ×1.5 ×17,500×3 0.9 ×0.6 ×63,300×3	768,000	m^3	220	B/m^3	168,960	
							429,990	
Rain water drain ditch		U300 Surround (1,200 +600)×2	3,600	m	2,500	B/m	9,000	10-1)
		Inside (1,700×2)×3	10,200	m	2,500	B/m	25,500	
		Top of bank (1,500×2)×3	9,000	m	2,500	B/m	22,500	
							57,000	

East part of bangkok (Case 1)

NO. 2

WORK ITEM		NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
Fence		H=1.8m 32,300×2	64,600	m	550	B/m	35,530	11-1)
Gate		H=1.2m W=6.0m	1	place	33,000	B	33	
Sub total							840,429	
Out lay		25%					209,571	
Total							1,050,000	

7) Leachate Water Treatment Cost

	Japanese Yen	Thai Baht
(1) Management Cost	415 (¥/m³)	70 (B/m³)
(a) Electric Cost	137 (¥/m³)	23 (B/m³)
(b) Chemical injection materials cost		
(i) biological treatment	60 (¥/m³)	10 (B/m³)
(ii) coagulant	48 (¥/m³)	8 (B/m³)
(iii) filtration	153 (¥/m³)	26 (B/m³)
(iv) disinjection	9 (¥/m³)	2 (B/m³)
(v) sludge treatment	8 (¥/m³)	1 (B/m³)
(2) Maintenance Cost	70 (¥/m³)	12 (B/m³)
(a) Expendables	70 (¥/m³)	12 (B/m³)
TOTAL	485 (¥/m³)	82 (B/m³)

11.5.2 Cost Estimation Fill-up Type (East Part of Bangkok) Case 2

1) Civil Work

Site Area	2,720,000 m^2	(1,700rai)
Disposal Area	2,400,000 m^2 (800,000x3Steps)	
Capacity	18,300,000 m^3 (6,100,000x3Steps)	

Note;1Step

Waste quantity	4,700,000 m^3	3,650,000 t
Covering material	1,400,000 m^3	1,800,000 t

Civil Work Cost	724,000,000 B
Note;1Step	242,000,000B

2) Water Treatment Facility

Capacity	1,500 m^3/d
Initial Cost	260,000,000 B

3) Optional Facilities

Control Office	6,000,000 B
Weigh Bridge	2,000,000 B
	8,000,000 B

Table 11.5-7 Total Initial Cost

(×1,000)

	1st Step	2nd Step	3rd Step
Civil work	242,000	242,000	242,000
Water Treatment Facility	260,000	0	0
Optional Facility	8,000	0	0
Total	510,000	242,000	242,000

Table 11.5-8 O/M Cost (1st Step)

		1997	1998	1999	2000
Management		4	4	4	4
Operation		(39)	(39)	(39)	(40)
	Land fill	22	22	22	23
	Labour Fee	7	7	7	7
	Water treatment	10	10	10	10
Maintenance		2	2	2	2
Total		46	46	46	47

4) Land Acquisition Cost

Offer Price
(560,000B/rai)

(×1,000)

1st Step	392,000
2nd Step	280,000
3rd Step	280,000

Water Treatment Cost

Electric Cost 20B/m³

$$\frac{20(B/m^3) \times 1,000(t/d) \times 365(day) \times 5(years)}{3,650,000(t)} = 10B/t$$

Table 11.5-9 East Part of Bangkok (Case 2)

NO. 1

WORK ITEM		NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
Earth work	excavation	500,000 ×3 = 1,500,000 ×3	4,500,000	m^3	56	B/m^3	252,000	8-1)
	embankment	6,560 ×42=280,000×3	840,000	m^3	60	B/m^3	50,400	8-2)
	pavement	8,800 ×8 ×0.5 = 35,000	35,000	m^3	220	B/m^3	7,700	2-2)
	Adjustment of excavated slope	(470+1,050) ×2 ×4.5=14,000×3	42,000	m^2	18	B/m^2	756	
	Adjustment of embanked slope	6,560 ×20≒131,000 ×3	390,000	m^2	18	B/m^2	7,020	
							317,876	
Leachate collection facility and Gas out-let facility	crushed stone	1.1 ×1.5 ×17,500×3 0.9 ×0.6 ×63,300×3	768,000	m^3	220	B/m^3	168,960	
							168,960	
Rain water drain ditch		U300 Surround (1,200 +600)×2	3,600	m	2,500	B/m	9,000	10-1)
		Inside (1,700×2)×3	10,200	m	2,500	B/m	25,500	
		Top of bank (1,500×2)×3	9,000	m	2,500	B/m	22,500	
							57,000	

East part of bangkok (Case 2)

NO. 2

WORK ITEM		NOTE	AMOUNT		UNIT PRICE		PRICE (×1,000)	REMARK
Fence		H=1.8m 32,300×2	64,600	m	550	B/m	35,530	11-1)
Gate		H=1.2m W=6.0m	1	place	33,000	B	33	
Sub total							579,399	
Out lay		25%					144,601	
Total							724,000	

11.6 Subsurface Investigation

SUBSURFACE INVESTIGATION
THE STUDY ON BANGKOK SOLID
WASTE MANAGEMENT
AT
RAM INTRA AND ON NUT
BANGKOK

CONTENTS

STS Job No. 2870

October 22, 1990

1. INTRODUCTION

The subsurface investigation for THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT located at Lam Intra Final Disposal Site and On Nut Incinerator Facility Area has been completed. Total of six borings were performed at above sites. Four borings, namely BH-1L, 2L, 3L, and 4L, were conducted at Lam Intra Site whereas the remained boreholes, BH-1N and BH-2N for On Nut Site. The depth of boring is 20 m except BH-4L, BH-1N & 2N, down to 40 m. The location of boreholes is shown in Figure 1& 2.

At Lam Intra Site, the borings were carried out on the corner of the pit which was excavated about 25 m deep but for On Nut site, they were drilled on the garbage.

The purpose of this report is to summarize the field and laboratory testing data.

2. SUBSURFACE INVESTIGATION PROCEDURE

The boreholes were executed by skid mounted drilling rig. The drilling was commenced by means of augering within 2 m and afterwards continued by means of wash boring method till the end of boring. The upper part of borehole was stabilized by steel casing, while the lower part was stabilized by bentonite slurry.

The disturbed samples were collected at 1.5 m intervals by using standard split spoon sampler during the performance of the standard penetration tests carried out according to ASTM D-1586-84.

The six undisturbed samples were also taken in soft to medium clay layer by using pushed thin wall tube having diameter of 3 in. with 1 m length at the depth of 1 m and 4 m for BH-1L and BH-3L but at 4 m and 9 m for BH-2L.

In a standard penetration test, a 2 in. O.D. split barrel sampler was driven into the soil stratum with a 140 lbs safety type hammer falling through a distance of 30 inches successively until a total of 18 in. has been achieved. The number of blows in the last 12 in. penetration will be taken as the standard penetration resistance SPT N VALUE.

Field permeability tests were done at the depth of 20 m in sand layer in borehole no. BH-1L & 3L. The type of test is variable head method.

In addition, pocket penetrometer was also used to find undrained shear strength on all cohesive soil samples.

The elevation of boreholes referred to B.M. Ele + 50.00 m for Lam Intra Site and + 10.00 m for On Nut Site is shown as follow.

BOREHOLE NO.	Elevation, m
BH-1L	+ 45.2
BH-2L	+ 45.8
BH-3L	+ 44.1
BH-4L	+ 43.9
BH-1N	+ 10.2
BH-2N	+ 10.5

3. LABORATORY TESTING PROGRAMME

The laboratory programme for undisturbed samples includes the following.

1) Soil Description (Visual description and Unifined Soil Classification)

2) Specific Gravity

3) Grain Size analysis including sieve and hydrometer test.

4) Natural moisture content

5) Unit Weight

6) Atterberg limit

7) Unconfined compression test

8) Unconsolidated undrained triaxial compression test

9) One-dimensional consolidation test

The testing procedures were done in accordance with ASTM specification. The test results were presented in the Appendix of this report.

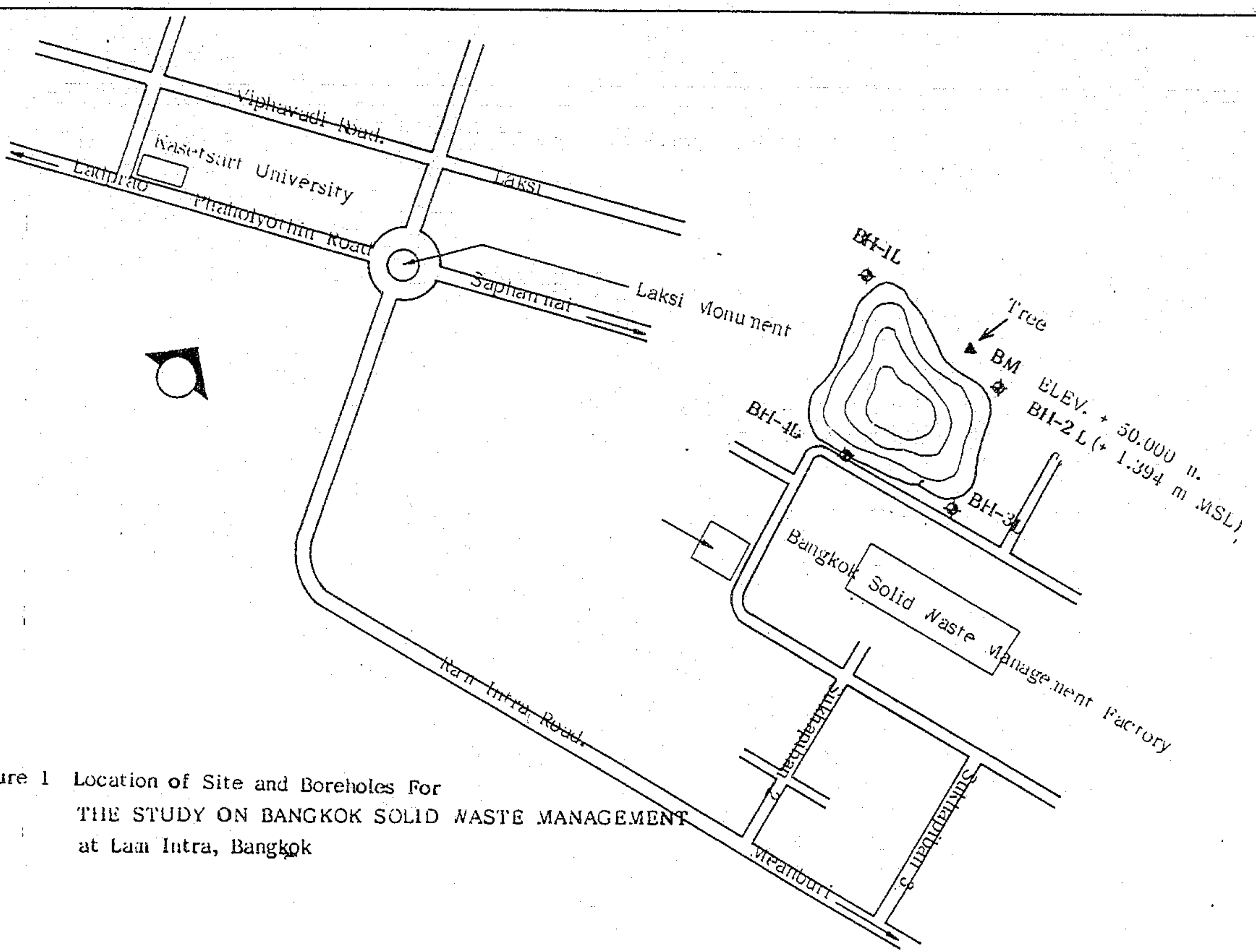


Figure 1 Location of Site and Boreholes For
THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT
at Lam Intra, Bangkok

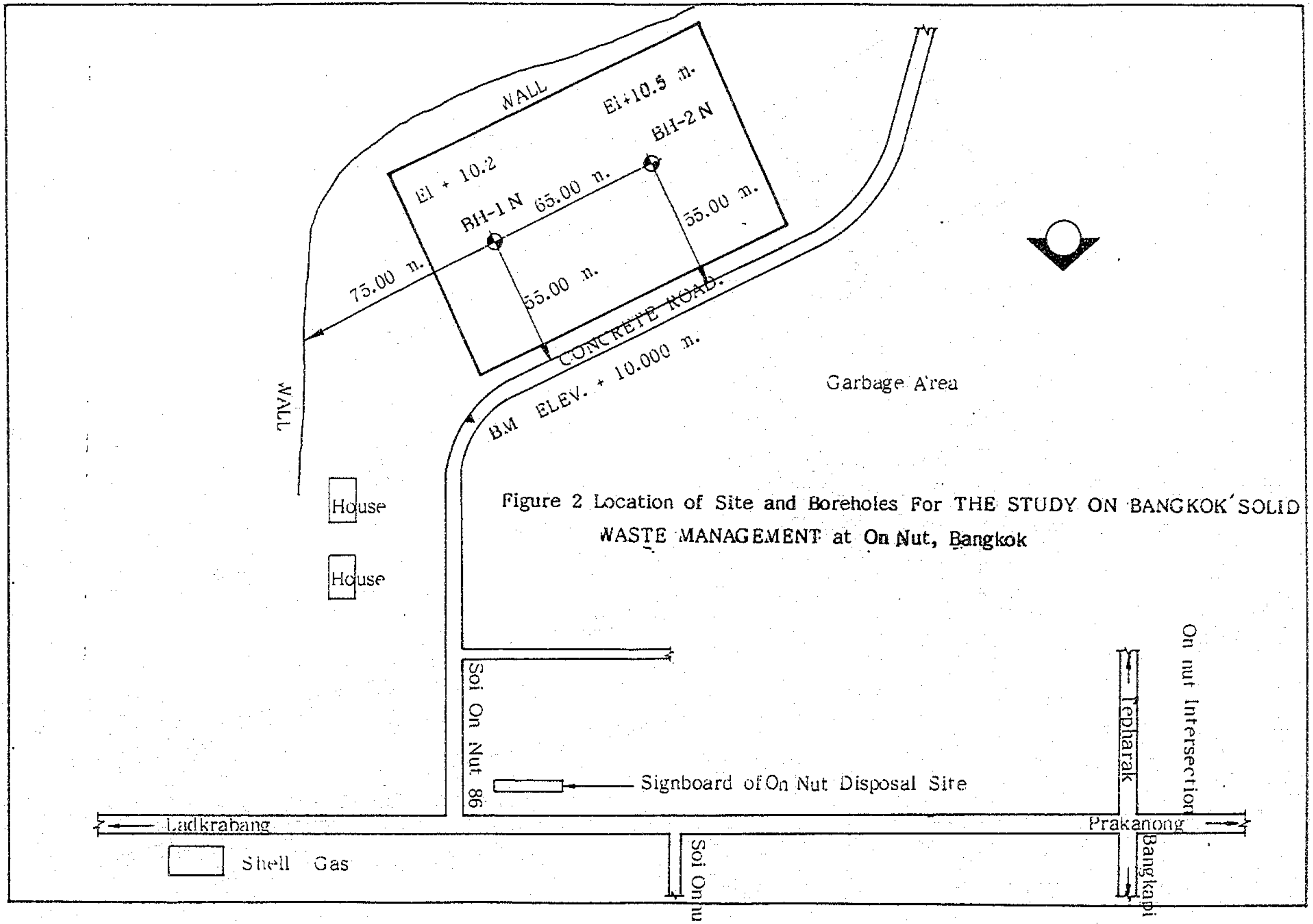


Figure 2 Location of Site and Boreholes For THE STUDY ON BANGKOK'SOLID WASTE MANAGEMENT at On Nut, Bangkok

APPENDIX

1. List of Terms Used
2. Unified Soil Classification
3. Characteristics Pertinent to Embankments & Foundations
4. ASTM Specification

   D 1587 - 83

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5. Summary of Test Results
6. Log of Boring
7. Gradation Curve
8. Field Permeability Test Results
9. Unconsolidated Undrained Triaxial Test Results
10. Consolidation Tests Results

LIST OF TERMS USED

DRILLING & SAMPLING SYMBOLS

SS : Split-Spoon – 1 3/8" I. D., 2" O. D., except where noted
ST : Shelby Tube – 2" O. D., except where noted
PA : Power Auger Sample
DB : Diamond Bit – NX: BX: AX:
CB : Carbology Bit – NX: BX: AX:
OS : Osterberg Sampler – 3" Shelby Tube
HS : Housel Sampler
WS : Wash Sample
FT : Fish Tail
RB : Rock Bit
WO : Wash Out

Standard "N" Penetration: Blows per foot of a 140 pound hammer falling 30 inches on a 2 inch OD split spoon, except where noted.

WATER LEVEL MEASUREMENT SYMBOLS

WL : Water Level
WCI : Wet Cave In
DCI : Dry Cave In
WS : While Sampling

WD : While Drilling
BCR : Before Casing Removal
ACR : After Casing Removal
AB : After Boring

Water levels indicated on the boring logs are the levels measured in the boring at the times indicated. In pervious soils, the indicated elevations are considered reliable ground water levels. In impervious soils, the accurate determination of ground water elevations is not possible in even several days observation, and additional evidence on ground water elevations must be sought

CLASSIFICATION

COHESIONLESS SOILS

"Trace"	1 % to 10 %
"Trace to some"	10 % to 20 %
"Some"	20 % to 35 %
" And "	35 % to 50 %
Very Loose	N = 0 – 4 blows
Loose	N = 4 – 10 blows
Medium	N = 10 – 30 blows
Dense	N = 30 – 50 blows
Very Dense	N = over 50 blows

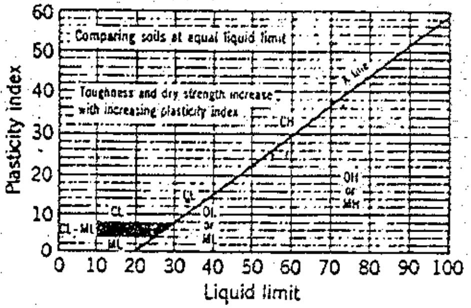
COHESIVE SOILS

If clay content is sufficient so that clay dominates soil properties, then clay becomes the principle noun with the other major soil constituent as modifier; i.e., silty clay. Other minor soil constituents may be added according to classification breakdown for cohesionless soils; i.e., silty clay, trace to some sand, trace gravel.

Very Soft	0.00 – 0.25 Tsf.	or 0 – 2 blows
Soft	0.25 – 0.50 Tsf.	or 2 – 4 blows
Medium	0.50 – 1.00 Tsf.	or 4 – 8 blows
Stiff	1.00 – 2.00 Tsf.	or 8 – 16 blows
Very Stiff	2.00 – 4.00 Tsf.	or 16 – 32 blows
Hard	over 4.00 Tsf.	or over 32 blows

LIST OF TERMS USED

Unified Soil Classification

<table>
<tr><th colspan="6">Field Identification Procedures
(Excluding particles larger than 3 in. and basing fractions on estimated weights)</th><th>Group Symbols[a]</th><th>Typical Names</th><th>Information Required for Describing Soils</th><th colspan="4">Laboratory Classification Criteria</th></tr>
<tr><td rowspan="8">Coarse-grained soils
More than half of material is *larger* than No. 200 sieve size[b]
(The No. 200 sieve size is about the smallest particle visible to naked eye)</td><td rowspan="4">Gravels
More than half of coarse fraction is larger than No. 4 sieve size</td><td rowspan="2">Clean gravels (little or no fines)</td><td colspan="3">Wide range in grain size and substantial amounts of all intermediate particle sizes</td><td>*GW*</td><td>Well graded gravels, gravel-sand mixtures, little or no fines</td><td rowspan="8">Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbols in parentheses
For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics
Example:
Silty sand, gravelly; about 20% hard, angular gravel particles ½-in. maximum size; rounded and subangular sand grains coarse to fine; about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)</td><td rowspan="18">Use grain size curve in identifying the fractions as given under field identification</td><td rowspan="8">Determine percentages of gravel and sand from grain size curve
Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse grained soils are classified as follows:
Less than 5%: *GW, GP, SW, SP*
More than 12%: *GM, GC, SM, SC*
5% to 12%: *Borderline* cases requiring use of dual symbols</td><td colspan="2">$C_U = \frac{D_{60}}{D_{10}}$ Greater than 4
$C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3</td></tr>
<tr><td colspan="3">Predominantly one size or a range of sizes with some intermediate sizes missing</td><td>*GP*</td><td>Poorly graded gravels, gravel-sand mixtures, little or no fines</td><td colspan="2">Not meeting all gradation requirements for *GW*</td></tr>
<tr><td rowspan="2">Gravels with fines (appreciable amount of fines)</td><td colspan="3">Nonplastic fines (for identification procedures see *ML* below)</td><td>*GM*</td><td>Silty gravels, poorly graded gravel-sand-silt mixtures</td><td>Atterberg limits below "A" line, or *PI* less than 4</td><td rowspan="2">Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols</td></tr>
<tr><td colspan="3">Plastic fines (for identification procedures, see *CL* below)</td><td>*GC*</td><td>Clayey gravels, poorly graded gravel-sand-clay mixtures</td><td>Atterberg limits above "A" line, with *PI* greater than 7</td></tr>
<tr><td rowspan="4">Sands
More than half of coarse fraction is smaller than No. 4 sieve size
(For visual classification, the ¼ in. size may be used as equivalent to the No. 4 sieve size)</td><td rowspan="2">Clean sands (little or no fines)</td><td colspan="3">Wide range in grain sizes and substantial amounts of all intermediate particle sizes</td><td>*SW*</td><td>Well graded sands, gravelly sands, little or no fines</td><td colspan="2">$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6
$C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3</td></tr>
<tr><td colspan="3">Predominantly one size or a range of sizes with some intermediate sizes missing</td><td>*SP*</td><td>Poorly graded sands, gravelly sands, little or no fines</td><td colspan="2">Not meeting all gradation requirements for *SW*</td></tr>
<tr><td rowspan="2">Sands with fines (appreciable amount of fines)</td><td colspan="3">Nonplastic fines (for identification procedures, see *ML* below)</td><td>*SM*</td><td>Silty sands, poorly graded sand-silt mixtures</td><td>Atterberg limits below "A" line or *PI* less than 5</td><td rowspan="2">Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols</td></tr>
<tr><td colspan="3">Plastic fines (for identification procedures, see *CL* below)</td><td>*SC*</td><td>Clayey sands, poorly graded sand-clay mixtures</td><td>Atterberg limits below "A" line with *PI* greater than 7</td></tr>
<tr><td rowspan="8">Fine-grained soils
More than half of material is *smaller* than No. 200 sieve size</td><td colspan="5">Identification Procedures on Fraction Smaller than No. 40 Sieve Size</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td colspan="3" rowspan="10">
Plasticity chart
for laboratory classification of fine grained soils</td></tr>
<tr><td colspan="2"></td><td>Dry Strength (crushing characteristics)</td><td>Dilatancy (reaction to shaking)</td><td>Toughness (consistency near plastic limit)</td></tr>
<tr><td colspan="2" rowspan="3">Silts and clays liquid limit less than 50</td><td>None to slight</td><td>Quick to slow</td><td>None</td><td>*ML*</td><td>Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity</td><td rowspan="7">Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses
For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions
Example:
Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*)</td></tr>
<tr><td>Medium to high</td><td>None to very slow</td><td>Medium</td><td>*CL*</td><td>Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays</td></tr>
<tr><td>Slight to medium</td><td>Slow</td><td>Slight</td><td>*OL*</td><td>Organic silts and organic silt-clays of low plasticity</td></tr>
<tr><td colspan="2" rowspan="3">Silts and clays liquid limit greater than 50</td><td>Slight to medium</td><td>Slow to none</td><td>Slight to medium</td><td>*MH*</td><td>Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts</td></tr>
<tr><td>High to very high</td><td>None</td><td>High</td><td>*CH*</td><td>Inorganic clays of high plasticity, fat clays</td></tr>
<tr><td>Medium to high</td><td>None to very slow</td><td>Slight to medium</td><td>*OH*</td><td>Organic clays of medium to high plasticity</td></tr>
<tr><td colspan="3">Highly Organic Soils</td><td colspan="3">Readily identified by colour, odour, spongy feel and frequently by fibrous texture</td><td>*Pt*</td><td>Peat and other highly organic soils</td></tr>
</table>

From Wagner, 1957.

[a] *Boundary classifications.* Soils possessing characteristics of two groups are designated by combinations of group symbols. For example *GW–GC,* well graded gravel-sand mixture with clay binder.

[b] All sieve sizes on this chart are U.S. standard.

Field Identification Procedure for Fine Grained Soils or Fractions

These procedures are to be performed on the minus No. 40 sieve size particles, approximately $\frac{1}{64}$ in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

Dilatancy (Reaction to shaking):

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (Crushing characteristics):

After removing particles larger than No. 40 sieve size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (Consistency near plastic limit):

After removing particles larger than the No. 40 sieve size, a specimen of soil about one-half inch cube in size, is moulded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eight inch in diameter. The thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic [illegible]

CHARACTERISTICS PERTINENT TO EMBANKMENTS AND FOUNDATIONS

Major Divisions (1)	(2)	Letter (3)	Symbol Hatching (4)	Color (5)	Name (6)	Value for Embankments (7)	Permeability Cm Per Sec (8)	Compaction Characteristics (9)	Std AASHO Max Unit Dry Weight Lb Per Cu Ft (10)	Value for Foundations (11)	Requirements for Seepage Control (12)
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	░	Red	Well-graded gravels or gravel-sand mixtures, little or no fines	Very stable, pervious shells of dikes and dams	$k > 10^{-2}$	Good, tractor, rubber-tired, steel-wheeled roller	125-135	Good bearing value	Positive cutoff
		GP	░		Poorly-graded gravels or gravel-sand mixtures, little or no fines	Reasonably stable, pervious shells of dikes and dams	$k > 10^{-2}$	Good, tractor, rubber-tired, steel-wheeled roller	115-125	Good bearing value	Positive cutoff
		GM	▥	Yellow	Silty gravels, gravel-sand-silt mixtures	Reasonably stable, not particularly suited to shells, but may be used for impervious cores or blankets	$k = 10^{-3}$ to 10^{-6}	Good, with close control, rubber-tired, sheepsfoot roller	120-135	Good bearing value	Toe trench to none
		GC	▨		Clayey gravels, gravel-sand-clay mixtures	Fairly stable, may be used for impervious core	$k = 10^{-6}$ to 10^{-8}	Fair, rubber-tired, sheepsfoot roller	115-130	Good bearing value	None
	SAND AND SANDY SOILS	SW	░	Red	Well-graded sands or gravelly sands, little or no fines	Very stable, pervious sections, slope protection required	$k > 10^{-3}$	Good, tractor	110-130	Good bearing value	Upstream blanket and toe drainage or wells
		SP	░		Poorly-graded sands or gravelly sands, little or no fines	Reasonably stable, may be used in dike section with flat slopes	$k > 10^{-3}$	Good, tractor	100-120	Good to poor bearing value depending on density	Upstream blanket and toe drainage or wells
		SM	▥	Yellow	Silty sands, sand-silt mixtures	Fairly stable, not particularly suited to shells, but may be used for impervious cores or dikes	$k = 10^{-3}$ to 10^{-6}	Good, with close control, rubber-tired, sheepsfoot roller	110-125	Good to poor bearing value depending on density	Upstream blanket and toe drainage or wells
		SC	▩		Clayey sands, sand-silt mixtures	Fairly stable, use for impervious core for flood control structures	$k = 10^{-6}$ to 10^{-8}	Fair, sheepsfoot roller, rubber tired	105-125	Good to poor bearing value	None
FINE GRAINED SOILS	SILTS AND CLAYS LL < 50	ML	▥	Green	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Poor stability, may be used for embankments with proper control	$k = 10^{-3}$ to 10^{-6}	Good to poor, close control essential, rubber-tired roller, sheepsfoot roller	95-120	Very poor, susceptible to liquefaction	Toe trench to none
		CL	▨		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Stable, impervious cores and blankets	$k = 10^{-6}$ to 10^{-8}	Fair to good, sheepsfoot roller, rubber tired	95-120	Good to poor bearing	None
		OL	▦		Organic silts and organic silt-clays of low plasticity	Not suitable for embankments	$k = 10^{-4}$ to 10^{-6}	Fair to poor, sheepsfoot roller	80-100	Fair to poor bearing, may have excessive settlements	None
	SILTS AND CLAYS LL > 50	MH	▥	Blue	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor stability, core of hydraulic fill dam, not desirable in rolled fill construction	$k = 10^{-4}$ to 10^{-6}	Poor to very poor, sheepsfoot roller	70-95	Poor bearing	None
		CH	▨		Inorganic clays of high plasticity, fat clays	Fair stability with flat slopes, thin cores, blankets and dike sections	$k = 10^{-6}$ to 10^{-8}	Fair to poor, sheepsfoot roller	75-105	Fair to poor bearing	None
		OH	▩		Organic clays of medium to high plasticity, organic silts	Not suitable for embankments	$k = 10^{-6}$ to 10^{-8}	Poor to very poor, sheepsfoot roller	65-100	Very poor bearing	None
HIGHLY ORGANIC SOILS		Pt	▤	Orange	Peat and other highly organic soils	Not used for construction		Compaction not practical		Remove from foundations	

Notes:
1. Values in columns 7 and 11 are for guidance only. Design should be based on test results.
2. In column 9, the equipment listed will usually produce the desired densities with a reasonable number of passes when moisture conditions and thickness of lift are properly controlled.
3. Column 10, unit dry weights are for compacted soil at optimum moisture content for Standard AASHO (Standard Proctor) compactive effort.

Designation: D 1587 - 83

Standard Practice for
THIN-WALLED TUBE SAMPLING OF SOILS[1]

This standard is issued under the fixed designation D 1587; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This practice has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.

1. Scope

1.1 This practice covers a procedure for using a thin-walled metal tube to recover relatively undisturbed soil samples suitable for laboratory tests of structural properties. Thin-walled tubes used in piston, plug, or rotary-type samplers, such as the Denison or Pitcher, must comply with the portions of this practice which describe the thin-walled tubes (5.3).

NOTE 1—This practice does not apply to liners used within the above samplers.

2. Applicable Documents

2.1 *ASTM Standards:*

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]

D 3550 Practice for Ring-Lined Barrel Sampling of Soils[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

3. Summary of Practice

3.1 A relatively undisturbed sample is obtained by pressing a thin-walled metal tube into the in-situ soil, removing the soil-filled tube, and sealing the ends to prevent the soil from being disturbed or losing moisture.

4. Significance and Use

4.1 This practice, or Practice D 3550, is used when it is necessary to obtain a relatively undisturbed specimen suitable for laboratory tests of structural properties or other tests that might be influenced by soil disturbance.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment may be used that provides a reasonably clean hole; that does not disturb the soil to be sampled; and that does not hinder the penetration of the thin-walled sampler. Open borehole diameter and the inside diameter of driven casing or hollow stem auger shall not exceed 3.5 times the outside diameter of the thin-walled tube.

5.2 *Sampler Insertion Equipment*, shall be adequate to provide a relatively rapid continuous penetration force. For hard formations it may be necessary, although not recommended, to drive the thin-walled tube sampler.

5.3 *Thin-Walled Tubes*, should be manufactured as shown in Fig. 1. They should have an outside diameter of 2 to 5 in. and be made of metal having adequate strength for use in the soil and formation intended. Tubes shall be clean and free of all surface irregularities including projecting weld seams.

5.3.1 *Length of Tubes*—See Table 1 and 6.4.

5.3.2 *Tolerances*, shall be within the limits shown in Table 2.

5.3.3 *Inside Clearance Ratio*, should be 1 % or as specified by the engineer or geologist for the soil and formation to be sampled. Generally, the inside clearance ratio used should increase with the increase in plasticity of the soil being sampled. See Fig. 1 for definition of inside clearance ratio.

5.3.4 *Corrosion Protection*—Corrosion, whether from galvanic or chemical reaction, can damage or destroy both the thin-walled tube and the sample. Severity of damage is a function of

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[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved Aug. 17, 1983. Published October 1983. Originally published as D 1587 - 58 T. Last previous edition D 1587 - 74.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

time as well as interaction between the sample and the tube. Thin-walled tubes should have some form of protective coating. Tubes which will contain samples for more than 72 h shall be coated. The type of coating to be used may vary depending upon the material to be sampled. Coatings may include a light coat of lubricating oil, lacquer, epoxy, Teflon, and others. Type of coating must be specified by the engineer or geologist if storage will exceed 72 h. Plating of the tubes or alternate base metals may be specified by the engineer or geologist.

5.4 *Sampler Head*, serves to couple the thin-walled tube to the insertion equipment and, together with the thin-walled tube, comprises the thin-walled tube sampler. The sampler head shall contain a suitable check valve and a venting area to the outside equal to or greater than the area through the check valve. Attachment of the head to the tube shall be concentric and coaxial to assure uniform application of force to the tube by the sampler insertion equipment.

6. Procedure

6.1 Clean out the borehole to sampling elevation using whatever method is preferred that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above ground water level during the sampling operation.

6.2 Bottom discharge bits are not permitted. Side discharge bits may be used with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted. Remove loose material from the center of a casing or hollow stem auger as carefully as possible to avoid disturbance of the material to be sampled.

NOTE 2—Roller bits are available in downward-jetting and diffused-jet configurations. Downward-jetting configuration rock bits are not acceptable. Diffuse-jet configurations are generally acceptable.

6.3 Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler without rotation by a continuous relatively rapid motion.

6.4 Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays.

NOTE 3—Weight of sample, laboratory handling capabilities, transportation problems, and commercial availability of tubes will generally limit maximum practical lengths to those shown in Table 1.

6.5 When the formation is too hard for push-type insertion, the tube may be driven or Practice D 3550 may be used. Other methods, as directed by the engineer or geologist, may be used. If driving methods are used, the data regarding weight and fall of the hammer and penetration achieved must be shown in the report. Additionally, that tube must be prominently labeled a "driven sample."

6.6 In no case shall a length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 in. for sludge-end cuttings.

NOTE 4—The tube may be rotated to shear bottom of the sample after pressing is complete.

6.7 Withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample.

7. Preparation for Shipment

7.1 Upon removal of the tube, measure the length of sample in the tube. Remove the disturbed material in the upper end of the tube and measure the length again. Seal the upper end of the tube. Remove at least 1 in. of material from the lower end of the tube. Use this material for soil description in accordance with Practice D 2488. Measure the overall sample length. Seal the lower end of the tube. Alternatively, after measurement, the tube may be sealed without removal of soil from the ends of the tube if so directed by the engineer or geologist.

NOTE 5—Field extrusion and packaging of extruded samples under the specific direction of a geotechnical engineer or geologist is permitted.

NOTE 6—Tubes sealed over the ends as opposed to those sealed with expanding packers should contain end padding in end voids in order to prevent drainage or movement of the sample within the tube.

7.2 Prepare and immediately affix labels or apply markings as necessary to identify the sample. Assure that the markings or labels are adequate to survive transportation and storage.

8. Report

8.1 The appropriate information is required as follows:

8.1.1 Name and location of the project.

8.1.2 Boring number and precise location on project.

8.1.3 Surface elevation or reference to a datum.

8.1.4 Date and time of boring—start and finish.

8.1.5 Depth to top of sample and number of sample.

8.1.6 Description of sampler: size, type of metal, type of coating.

8.1.7 Method of sampler insertion: push or drive.

8.1.8 Method of drilling, size of hole, casing, and drilling fluid used.

8.1.9 Depth to groundwater level: date and time measured.

8.1.10 Any possible current or tidal effect on water level.

8.1.11 Soil description in accordance with Practice D 2488.

8.1.12 Length of sampler advance, and

8.1.13 Recovery: length of sample obtained.

9. Precision and Bias

9.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

TABLE 1 Suitable Thin-Walled Steel Sample Tubes[A]

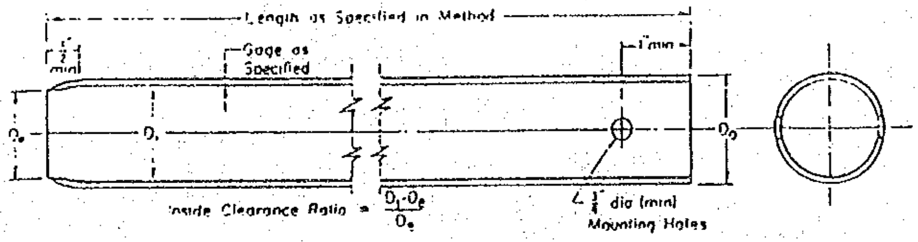
Outside diameter:			
in.	2	3	5
mm	50.8	76.2	127
Wall thickness:			
Bwg	18	16	11
in.	0.049	0.065	0.120
mm	1.24	1.65	3.05
Tube length:			
in.	36	36	54
m	0.91	0.91	1.45
Clearance ratio, %	1	1	1

[A] The three diameters recommended in Table 1 are indicated for purposes of standardization, and are not intended to indicate that sampling tubes of intermediate or larger diameters are not acceptable. Lengths of tubes shown are illustrative. Proper lengths to be determined as suited to field conditions.

TABLE 2 Dimensional Tolerances for Thin-Walled Tubes

Nominal Tube Diameters from Table 1[A] Tolerances, in.			
Size Outside Diameter	2	3	5
Outside diameter	+0.007 −0.000	+0.010 −0.000	+0.015 −0.000
Inside diameter	+0.000 −0.007	+0.000 −0.010	+0.000 −0.015
Wall thickness	±0.007	±0.010	±0.015
Ovality	0.015	0.020	0.030
Straightness	0.030/ft	0.030/ft	0.030/ft

[A] Intermediate or larger diameters should be proportional. Tolerances shown are essentially standard commercial manufacturing tolerances for seamless steel mechanical tubing. Specify only two of the first three tolerances; that is, O.D. and I.D., or O.D. and Wall, or I.D. and Wall.



NOTE 1—Minimum of two mounting holes on opposite sides for 2 to 3½ in. sampler.

NOTE 2—Minimum of four mounting holes spaced at 90° for samplers 4 in. and larger.

NOTE 3—Tube held with hardened screws.

NOTE 4—Two-inch outside-diameter tubes are specified with an 18-gage wall thickness to comply with area ratio criteria accepted for "undisturbed samples." Users are advised that such tubing is difficult to locate and can be extremely expensive in small quantities. Sixteen-gage tubes are generally readily available.

Metric Equivalents

in.	mm
¼	6.77
½	12.7
1	25.4
2	50.8
3½	88.9
4	101.6

FIG. 1 Thin-Walled Tube for Sampling

Designation: D 1586 – 84

Standard Method for

PENETRATION TEST AND SPLIT-BARREL SAMPLING OF SOILS[1]

This standard is issued under the fixed designation D 1586; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This method has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.

1. Scope

1.1 This method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample and a measure of the resistance of the soil to penetration of the sampler.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific precautionary statement, see 5.4.1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standards:*

D 2487 Test Method for Classification of Soils for Engineering Purposes[2]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

3. Descriptions of Terms Specific to This Standard

3.1 *anvil*—that portion of the drive-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.4 *drive-weight assembly*—a device consisting of the hammer, hammer fall guide, the anvil, and any hammer drop system.

3.5 *hammer*—that portion of the drive-weight assembly consisting of the 140 ± 2 lb (63.5 ± 1 kg) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.6 *hammer drop system*—that portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.8 *N-value*—the blowcount representation of the penetration resistance of the soil. The *N*-value, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.9 *ΔN*—the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.10 *number of rope turns*—the total contact angle between the rope and the cathead at the

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[1] This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved Sept. 11, 1984. Published November 1984. Originally published as D 1586 – 58 T. Last previous edition D 1586 – 67 (1974).

[2] *Annual Book of ASTM Standards*, Vol 04.08.

beginning of the operator's rope slackening to drop the hammer, divided by 360° (see Fig. 1).

3.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.12 *SPT*—abbreviation for Standard Penetration Test, a term by which engineers commonly refer to this method.

4. Significance and Use

4.1 This method provides a soil sample for identification purposes and for laboratory tests appropriate for soil obtained from a sampler that may produce large shear strain disturbance in the sample.

4.2 This method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and widely published correlations which relate SPT blowcount, or *N*-value, and the engineering behavior of earthworks and foundations are available.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment that provides at the time of sampling a suitably clean open hole before insertion of the sampler and ensures that the penetration test is performed on undisturbed soil shall be acceptable. The following pieces of equipment have proven to be suitable for advancing a borehole in some subsurface conditions.

5.1.1 *Drag, Chopping, and Fishtail Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjuction with open-hole rotary drilling or casing-advancement drilling methods. To avoid disturbance of the underlying soil, bottom discharge bits are not permitted; only side discharge bits are permitted.

5.1.2 *Roller-Cone Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods if the drilling fluid discharge is deflected.

5.1.3 *Hollow-Stem Continuous Flight Augers*, with or without a center bit assembly, may be used to drill the boring. The inside diameter of the hollow-stem augers shall be less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm).

5.1.4 *Solid, Continuous Flight, Bucket and Hand Augers*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used if the soil on the side of the boring does not cave onto the sampler or sampling rods during sampling.

5.2 *Sampling Rods*—Flush-joint steel drill rods shall be used to connect the split-barrel sampler to the drive-weight assembly. The sampling rod shall have a stiffness (moment of inertia) equal to or greater than that of parallel wall "A" rod (a steel rod which has an outside diameter of 1⅝ in. (41.2 mm) and an inside diameter of 1⅛ in. (28.5 mm).

NOTE 1—Recent research and comparative testing indicates the type rod used, with stiffness ranging from "A" size rod to "N" size rod, will usually have a negligible effect on the *N*-values to depths of at least 100 ft (30 m).

5.3 *Split-Barrel Sampler*—The sampler shall be constructed with the dimensions indicated in Fig. 2. The driving shoe shall be of hardened steel and shall be replaced or repaired when it becomes dented or distorted. The use of liners to produce a constant inside diameter of 1⅜ in. (35 mm) is permitted, but shall be noted on the penetration record if used. The use of a sample retainer basket is permitted, and should also be noted on the penetration record if used.

NOTE 2—Both theory and available test data suggest that *N*-values may increase between 10 to 30 % when liners are used.

5.4 *Drive-Weight Assembly:*

5.4.1 *Hammer and Anvil*—The hammer shall weigh 140 ± 2 lb (63.5 ± 1 kg) and shall be a solid rigid metallic mass. The hammer shall strike the anvil and make steel on steel contact when it is dropped. A hammer fall guide permitting a free fall shall be used. Hammers used with the cathead and rope method shall have an unimpeded overlift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged.

NOTE 3—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic, or automatic hammer drop systems may be used, providing the lifting apparatus will not cause penetration of the sampler while re-engaging and lifting the hammer.

5.5 *Accessory Equipment*—Accessories such as labels, sample containers, data sheets, and groundwater level measuring devices shall be provided in accordance with the requirements of the project and other ASTM standards.

6. Drilling Procedure

6.1 The boring shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 mm) or less in homogeneous strata with test and sampling locations at every change of strata.

6.2 Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

6.2.1 Open-hole rotary drilling method.

6.2.2 Continuous flight hollow-stem auger method.

6.2.3 Wash boring method.

6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable borings. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the boring below a water table or below the upper confining bed of a confined non-cohesive stratum that is under artesian pressure. Casing may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

6.4 The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

7. Sampling and Testing Procedure

7.1 After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

7.1.1 Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling rods and sampler are lowered into the borehole.

7.1.3 Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the boring, remove the sampler and sampling rods from the boring and remove the cuttings.

7.1.4 Mark the drill rods in three successive 6-in. (0.15-m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-in. (0.15-m) increment.

7.2 Drive the sampler with blows from the 140-lb (63.5-kg) hammer and count the number of blows applied in each 6-in. (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 6-in. (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

7.2.4 The sampler is advanced the complete 18 in. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.3 Record the number of blows required to effect each 6 in. (0.15 m) of penetration or fraction thereof. The first 6 in. is considered to be a seating drive. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance", or the "*N*-value". If the sampler is driven less than 18 in. (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 6-in. (0.15-m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 1 in. (25 mm), in addition to the number of blows. If the sampler advances below the bottom of the boring under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lb

(63.5-kg) hammer shall be accomplished using either of the following two methods:

7.4.1 By using a trip, automatic, or semi-automatic hammer drop system which lifts the 140-lb (63.5-kg) hammer and allows it to drop 30 ± 1.0 in. (0.76 m ± 25 mm) unimpeded.

7.4.2 By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM, or the approximate speed of rotation shall be reported on the boring log.

7.4.2.3 No more than 2¼ rope turns on the cathead may be used during the performance of the penetration test, as shown in Fig. 1.

NOTE 4—The operator should generally use either 1¾ or 2¼ rope turns, depending upon whether or not the rope comes off the top (1¾ turns) or the bottom (2¼ turns) of the cathead. It is generally known and accepted that 2¾ or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be maintained in a relatively dry, clean, and unfrayed condition.

7.4.2.4 For each hammer blow, a 30-in. (0.76-m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

7.5 Bring the sampler to the surface and open. Record the percent recovery or the length of sample recovered. Describe the soil samples recovered as to composition, color, stratification, and condition, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing job designation, boring number, sample depth, and the blow count per 6-in. (0.15-m) increment. Protect the samples against extreme temperature changes. If there is a soil change within the sampler, make a jar for each stratum and note its location in the sampler barrel.

8. Report

8.1 Drilling information shall be recorded in the field and shall include the following:

8.1.1 Name and location of job,

8.1.2 Names of crew,

8.1.3 Type and make of drilling machine,

8.1.4 Weather conditions,

8.1.5 Date and time of start and finish of boring,

8.1.6 Boring number and location (station and coordinates, if available and applicable),

8.1.7 Surface elevation, if available,

8.1.8 Method of advancing and cleaning the boring,

8.1.9 Method of keeping boring open,

8.1.10 Depth of water surface and drilling depth at the time of a noted loss of drilling fluid, and time and date when reading or notation was made,

8.1.11 Location of strata changes,

8.1.12 Size of casing, depth of cased portion of boring,

8.1.13 Equipment and method of driving sampler,

8.1.14 Type sampler and length and inside diameter of barrel (note use of liners),

8.1.15 Size, type, and section length of the sampling rods, and

8.1.16 Remarks.

8.2 Data obtained for each sample shall be recorded in the field and shall include the following:

8.2.1 Sample depth and, if utilized, the sample number,

8.2.2 Description of soil,

8.2.3 Strata changes within sample,

8.2.4 Sampler penetration and recovery lengths, and

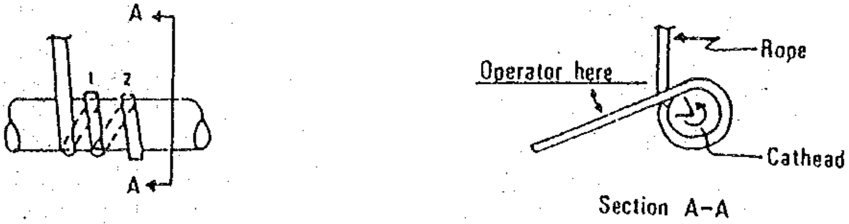
8.2.5 Number of blows per 6-in. (0.15-m) or partial increment.

9. Precision and Bias

9.1 Variations in *N*-values of 100 % or more have been observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, *N*-values in the same soil can be reproduced with a coefficient of variation of about 10 %.

9.2 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in *N*-values obtained between operator-drill rig systems.

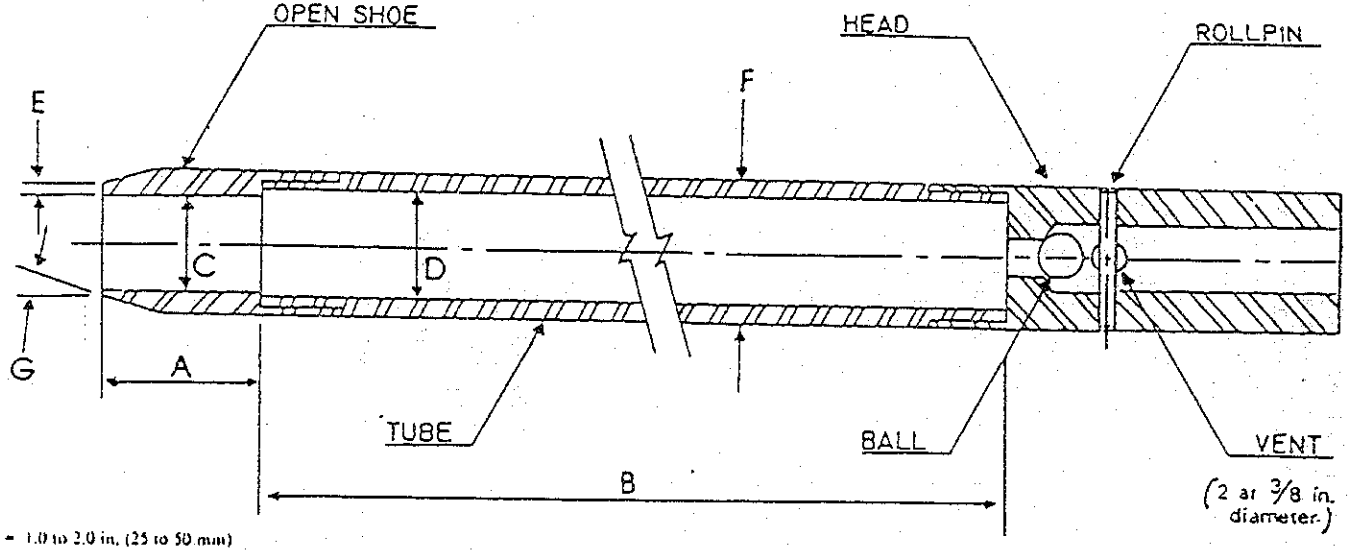
9.3 The variability in *N*-values produced by different drill rigs and operators may be reduced by measuring that part of the hammer energy delivered into the drill rods from the sampler and adjusting *N* on the basis of comparative energies. A method for energy measurement and *N*-value adjustment is currently under development.



(*a*) counterclockwise rotation approximately 1¾ turns

(*b*) clockwise rotation approximately 2¼ turns

FIG. 1 Definitions of the Number of Rope Turns and the Angle for (*a*) Counterclockwise Rotation and (*b*) Clockwise Rotation of the Cathead



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 − 0.00 in. (38.1 ± 1.3 − 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 − 0.00 in. (50.8 ± 1.3 − 0.0 mm)
G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

FIG. 2 Split-Barrel Sampler

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103.

SUMMARY OF TEST RESULTS

PROJECT THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

LOCATION LAM INTRA FINAL DISPOSAL SITE

DATE : 22/10/90

BORING No. BH-1L

JOB No. 2870

BY CK

OBSERVED W.L. -0.6 m.

SAMPLE No.	DEPTH M		WATER CONTENT %	ATTERBERG LIMIT %			WET UNIT WEIGHT t/m^3	SIEVE ANALYSIS % FINER					CLASSIFICATION	UNDRAINED SHEAR STRENGTH t/m.^{2}					STANDARD PENETRATION (N)	SPECIFIC GRAVITY	
														UNCONFINED SHEAR		FIELD VANE SHEAR		POCKET PENETRATION			
	FROM	TO		LL	PL	PI		No 3/8"	No 4	No 10	No 40	No 200		Qu/2	Qu'/2	Qv	Qv'	$\frac{1}{2}$Qp			
ST-1	0.50	1.50	30.5	71.0	22.6	48.4	1.96				100	98	CH	3.7				2.5		2.63	
SS-2	1.50	1.95		(No Recovery)									CH						1		
SS-3	3.00	3.45											CH					1.3	2		
ST-4	4.00	5.00	84.1	99.5	31.6	67.9	1.53			100	99	99	CH	1.5				2.5		2.61	
SS-5	5.00	5.45											CH					1.3	1		
SS-6	6.00	6.45											CH					1.3	2		
SS-7	7.50	7.95											CH						2		
SS-8	9.00	9.45											CH					1.3	2		
SS-9	10.50	10.95											CH					1.3	2		
SS-10	12.00	12.45											CH					11.2	4		
SS-11	13.50	13.95											CH					16.3	17		
SS-12	15.00	15.45											CH					18.2	20		
SS-13	16.50	16.95											CH					18.8	25		
SS-14	18.00	18.45											CH					14.4	19		
SS-15	19.50	19.95											CH/SM					11.9	45		

SUMMARY OF TEST RESULTS

PROJECT THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT LOCATION LAM INTRA FINAL DISPOSAL SITE

DATE 22/10/90 BORING No. BH-2L JOB No. 2870 BY CK OBSERVED W.L. -0.6 m.

SAMPLE No.	DEPTH M		WATER CONTENT %	ATTERBERG LIMIT %			WET UNIT WEIGHT t/m³	SIEVE ANALYSIS % FINER					CLASSIFICATION	UNDRAINED SHEAR STRENGTH t/m.²					STANDARD PENETRATION (N)	SPECIFIC GRAVITY
														UNCONFINED SHEAR		FIELD VANE SHEAR		POCKET PENETRATION		
	FROM	TO		LL.	PL.	PI.		No 3/8"	No. 4	No. 10	No 40	No. 200		Qu/2	Qu'/2	Qv	Qv'	½Qp		
SS-1	1.50	1.95											CH					2.5	2	
SS-2	3.00	3.45											CH					1.4	2	
ST-3	4.00	5.00	84.0	88.5	28.7	59.8	1.51					100	CH	1.4				3.2		2.65
SS-4	5.00	5.45											CH					1.9	2	
SS-5	6.00	6.45											CH					1.8	2	
SS-6	7.50	7.95											CH					1.7	2	
ST-7	8.50	9.50	61.1	79.8	33.2	46.6	1.60				100	99	CH	3.2				3.2		2.67
SS-8	9.50	9.95											CH					1.3	2	
SS-9	10.50	10.95											CH					3.7	4	
SS-10	12.00	12.45											CH					8.8	10	
SS-11	13.50	13.95											CH					13.8	14	
SS-12	15.00	15.45											CH					20.0	22	
SS-13	16.50	16.95											CH					12.5	18	
SS-14	18.00	18.45											CH					22.5+	26	
SS-15	19.50	19.95											CH/SC					22.5+	42	

SUMMARY OF TEST RESULTS

PROJECT THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT			LOCATION LAM INTRA FINAL DISPOSAL SITE	
DATE 22/10/90	BORING No. BH-3L	JOB No. 2870	BY CK	OBSERVED W.L. -1.0 m.

SAMPLE No.	DEPTH M		WATER CONTENT %	ATTERBERG LIMIT %			WET UNIT WEIGHT t/m^3	SIEVE ANALYSIS % FINER					CLASSIFICATION	UNDRAINED SHEAR STRENGTH t/m.^{2}					STANDARD PENETRATION (N)	SPECIFIC GRAVITY	
														UNCONFINED SHEAR		FIELD VANE SHEAR		POCKET PENETRATION			
	FROM	TO		LL	PL	PI		No 3/8"	No. 4	No 10	No 40	No. 200		Qu/2	Qu'/2	Qv	Qv'	$\frac{1}{2}Q_p$			
ST-1	0.50	1.50	64.2	74.4	33.4	41.0	1.57				100	93	CH	1.8				2.5		2.61	
SS-2	1.50	1.95											CH					1.3	2		
SS-3	3.00	3.45											CH					2.5	2		
ST-4	4.00	5.00	78.1	80.6	29.6	51.0	1.48			100	99	95	CH	1.0				2.5		2.65	
SS-5	5.00	5.45											CH					2.5	2		
SS-6	6.00	6.45											CH					2.5	2		
SS-7	7.50	7.95											CH					2.5	2		
SS-8	9.00	9.45											CH					3.8	2		
SS-9	10.50	10.95											CH					7.5	6		
SS-10	12.00	12.45											CH					8.8	10		
SS-11	13.50	13.95											CH					18.8	18		
SS-12	15.00	15.45											CH						27		
SS-13	16.50	16.95											SM						49		
SS-14	18.00	18.45											SM						23		
SS-15	19.50	19.95											SM						30		

SUMMARY OF TEST RESULTS

PROJECT THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT
LOCATION LAM INTRA FINAL DISPOSAL SITE
DATE 22/10/90
BORING No. BH-4L
JOB No. 2870
BY CK
OBSERVED W.L. -1.0 m.

SAMPLE No.	DEPTH M		WATER CONTENT %	ATTERBERG LIMIT %			WET UNIT WEIGHT t/m³	SIEVE ANALYSIS % FINER					CLASSIFICATION	UNDRAINED SHEAR STRENGTH t/m.²					STANDARD PENETRATION (N)		
														UNCONFINED SHEAR		FIELD VANE SHEAR		POCKET PENETRATION			
	FROM	TO		LL.	PL.	PI.		No. 3/8"	No. 4	No. 10	No. 40	No. 200		Qu/2	Qu'/2	Qv	Qv'	$\frac{1}{2}$Qp			
SS-1	1.50	1.95											CH					2.5	2		
SS-2	3.00	3.45											CH					2.5	2		
SS-3	4.50	4.95											CH					2.5	2		
SS-4	6.00	6.45											CH					2.5	1		
SS-5	7.50	7.95											CH					2.5	2		
SS-6	9.00	9.45											CH					10.0	13		
SS-7	10.50	10.95											CH					12.5	15		
SS-8	12.00	12.45											CH						27		
SS-9	13.50	13.95											SM						40		
SS-10	15.00	15.45											SM						38		
SS-11	16.50	16.95											CH					20.0	27		
SS 12	18.00	18.45											SM-SP						57		
SS-13	19.50	19.95											SM-SP						46		
SS-14	21.00	21.45											SM-SP						53		
SS-15	22.50	22.95											SM-SP						28		
SS-16	24.00	24.45											CH					15.0	21		
SS-17	25.50	25.95											CH					20.0^{+}	31		
SS-18	27.00	27.45											CH					20.0^{+}	35		
SS-19	28.50	28.95											CH					20.0	38		
SS-20	30.00	30.45											CH					20.0^{+}	37		
SS-21	31.50	31.95											CH					20.0^{+}	44		

SUMMARY OF TEST RESULTS

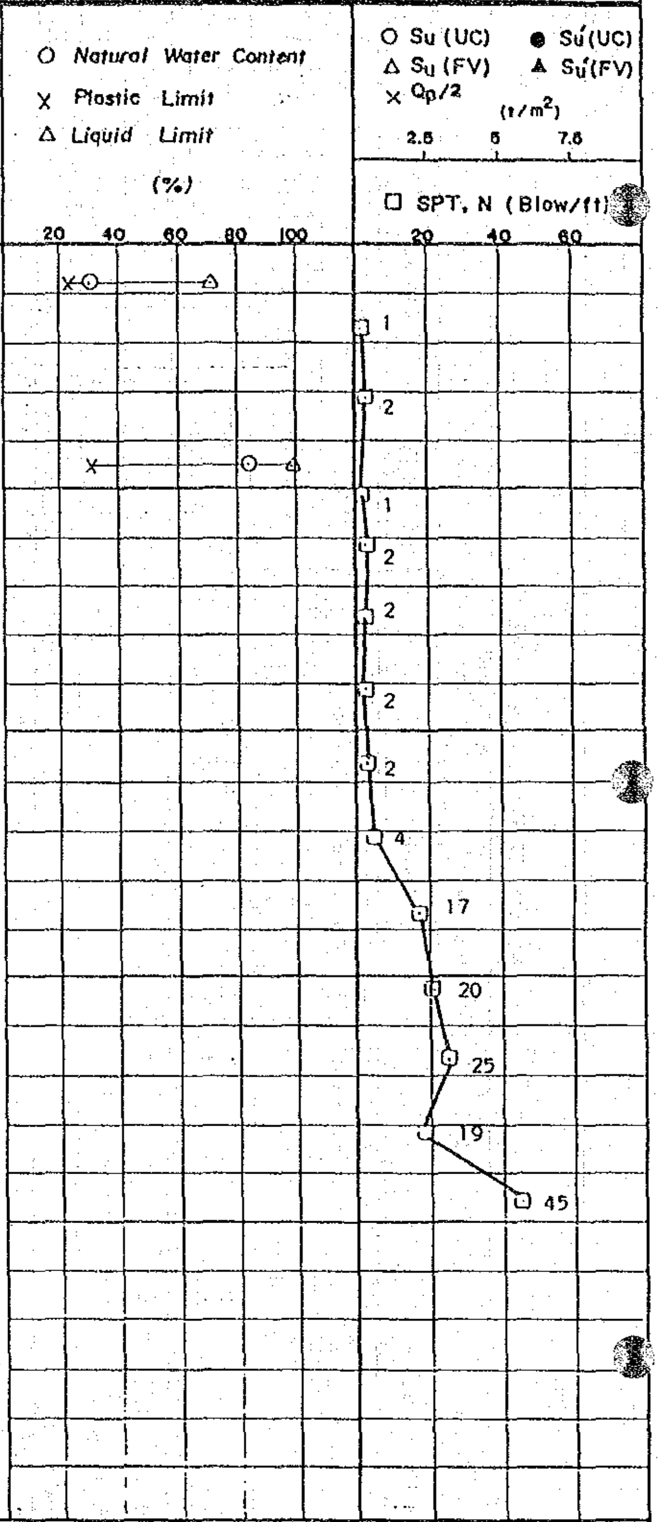
PROJECT THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT
LOCATION LAM INTRA FINAL DISPOSAL SITE
DATE 22/10/90
BORING No. BH-4 L
JOB No. 2870
BY CK
OBSERVED W.L. -1.0 m.

SAMPLE No.	DEPTH M		WATER CONTENT %	ATTERBERG LIMIT %			WET UNIT WEIGHT t/m³	SIEVE ANALYSIS % FINER					CLASSIFICATION	UNDRAINED SHEAR STRENGTH t/m.²					STANDARD PENETRATION (N)		
														UNCONFINED SHEAR		FIELD VANE SHEAR		POCKET PENETRATION			
	FROM	TO		LL.	PL.	PI.		No. 3/8"	No. 4	No. 10	No. 40	No. 200		Qu/2	Qu'/2	Qv	Qv'	$\frac{1}{2}Q_p$			
SS-22	33.00	33.45											CH					20.0	41		
SS-23	34.50	34.95											CH					20.0^+	40		
SS-24	36.00	36.45											CH					20.0^+	40		
SS-25	37.50	37.95											CH					20.0	34		
SS-26	39.00	39.45											CH					20.0	57		
SS-27	40.50	40.95											CH					20.0	64		

LOG OF BORING No. BH-1L

PROJECT NAME. THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT	LOCATION. LAM INTRA FINAL DISPOSAL SITE
OWNER	

DEPTH, m. 0	SAMPLE No.	TYPE OF SAMPLE	SAMPLE DIST / RECOVERY	DESCRIPTION OF MATERIAL	GRAPHIC LOG
	1	ST	▤	Silty CLAY trace fine sand, greyish brown, medium stiff. (CH) 1.5 m	
	2	SS	▨		
	3	SS	▨		
	4	ST	▤		
5	5	SS	▨	CLAY trace fine sand, dark grey, soft to medium stiff. (CH)	
	6	SS	▨		
	7	SS	▨		
10	8	SS	▨		
	9	SS	▨		
	10	SS	▨	13.2 m	
	11	SS	▨		
15	12	SS	▨	Silty CLAY trace fine sand, brown, very stiff. (CH)	
	13	SS	▨		
	14	SS	▨	19.8 m	
20	15	SS	▨	Silty fine SAND, brown, dense, 19.95 m (SM)	
				END OF BORING	
25					



BORING STARTED. 30/9/90	RIG. PORTABLE	WL. -0.60 M. 24 HRS. AFTER BORING.
BORING FINSHED. 30/9/90	FOREMAN. SR	JOB No. 2870

ak

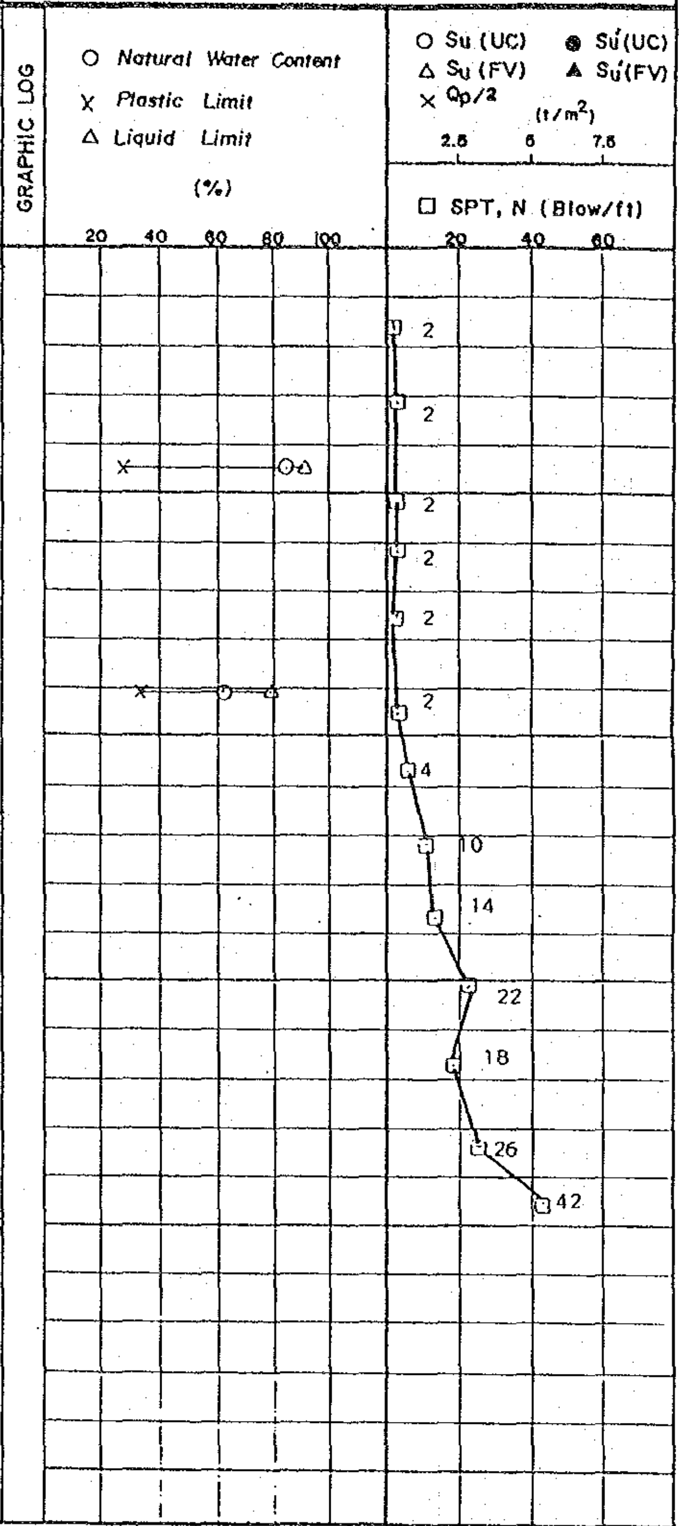
LOG OF BORING No. BH-2L

PROJECT NAME. THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

LOCATION. LAM INTRA FINAL DISPOSAL SITE

OWNER

DEPTH, m.	SAMPLE No.	TYPE OF SAMPLE	DESCRIPTION OF MATERIAL
0			Silty CLAY trace fine sand with plastic bag, brown. (CH) 1.5 m
	1	SS	CLAY, dark grey, soft to medium stiff. (CH) 11.6 m
	2	SS	
	3	ST	
5	4	SS	
	5	SS	
	6	SS	
	7	ST	
10	8	SS	
	9	SS	
	10	SS	Silty CLAY trace fine sand and lime concretion, greyish brown, stiff to very stiff. (CH) 19.8 m
	11	SS	
15			
	12	SS	
	13	SS	
	14	SS	
20	15	SS	Clayey fine SAND, greyish li-brown, dense. (SC) 19.95 m END OF BORING
25			



BORING STARTED. 25/9/90	RIG. PORTABLE	WL. -0.60 M. 24 HRS. AFTER BORING.
BORING FINSHED. 25/9/90	FOREMAN. SR	JOB No.. 2870

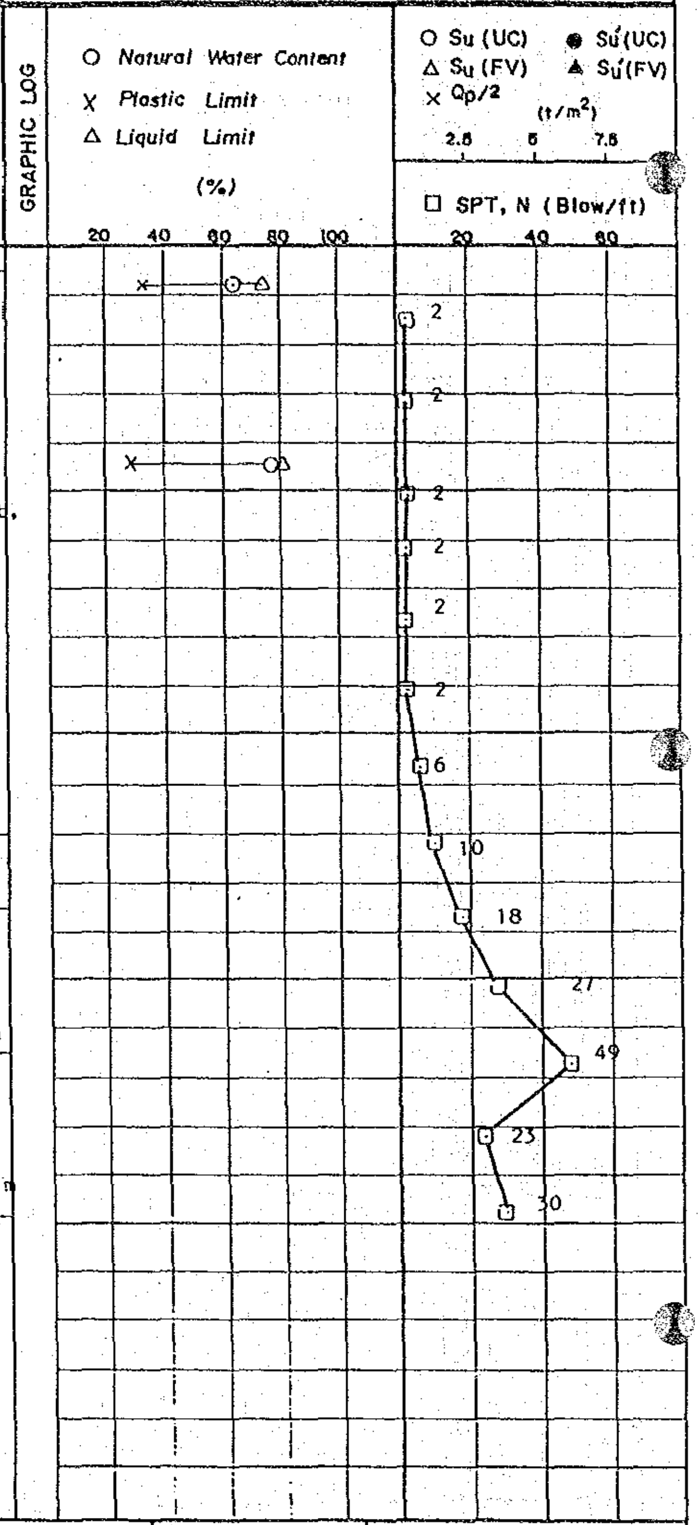
LOG OF BORING No. BH-3L

PROJECT NAME. THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

LOCATION. LAM INTRA FINAL DISPOSAL SITE

OWNER

DEPTH, m.	SAMPLE No.	TYPE OF SAMPLE	SAMPLE DIST	RECOVERY	DESCRIPTION OF MATERIAL
0					~~Silty CLAY trace fine sand and root, brown. (CH) 0.5 m~~
	1	ST			
	2	SS			
	3	SS			
	4	ST			
5	5	SS			CLAY trace fine sand and shell fragment, dark grey, soft to medium stiff. (CH)
	6	SS			
	7	SS			
10	8	SS			
	9	SS			12.0 m
	10	SS			CLAY, dark grey, stiff. (CH) 13.5 m
	11	SS			
15	12	SS			Silty CLAY trace fine sand pocket, grey some brown, very stiff. (CH) 16.5 m
	13	SS			Silty fine SAND, brown, medium to dense. (SM)
	14	SS			
20	15	SS			19.95 m
					END OF BORING
25					



BORING STARTED. 23/9/90	RIG. PORTABLE	WL. -1.00 M. 24 HRS. AFTER BORING.
BORING FINSHED. 23/9/90	FOREMAN. PC	JOB No, 2870

ak

LOG OF BORING No. BH-4L

PROJECT NAME. THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT

LOCATION. LAM INTRA FINAL DISPOSAL SITE

OWNER

○ Natural Water Content
X Plastic Limit
△ Liquid Limit
(%)
20 40 60 80 100

○ Su (UC) ● Su′(UC)
△ Su (FV) ▲ Su′(FV)
× Qp/2 (t/m²)
2.5 5 7.5

☐ SPT, N (Blow/ft)
20 40 60

DEPTH, m.	SAMPLE No.	TYPE OF SAMPLE	DESCRIPTION OF MATERIAL	GRAPHIC LOG	SPT, N (Blow/ft)
0			Silty CLAY trace fine sand and plastic bag, brown. (CH) 1.5 m		
	1	SS	CLAY trace organic matter, dark grey, soft. (CH)		2
	2	SS			2
5	3	SS			2
	4	SS			1
	5	SS	9.0 m		2
	6	SS	Silty CLAY trace fine sand, greyish brown, stiff to very stiff. (CH)		13
10	7	SS			15
	8	SS	13.5 m		27
	9	SS	Silty fine SAND, brown, dense. (SM)		40
15	10	SS	16.5 m		38
	11	SS	Silty CLAY some fine sand, grey, some yellowish brown, very stiff. (CH) 18.0 m		27
	12	SS	Fine to coarse SAND but fine grain @ SS-12, brown, medium to very dense. (SM-SP)		57
20	13	SS			46
	14	SS			53
	15	SS	24.0 m		28
	16	SS	(CH)		21
25					

BORING STARTED. 23/9/90	RIG. PORTABLE	WL -1.00 M. 24 HRS. AFTER BORING.
BORING FINSHED. 25/9/90	FOREMAN. PC	JOB No. 2870

ak