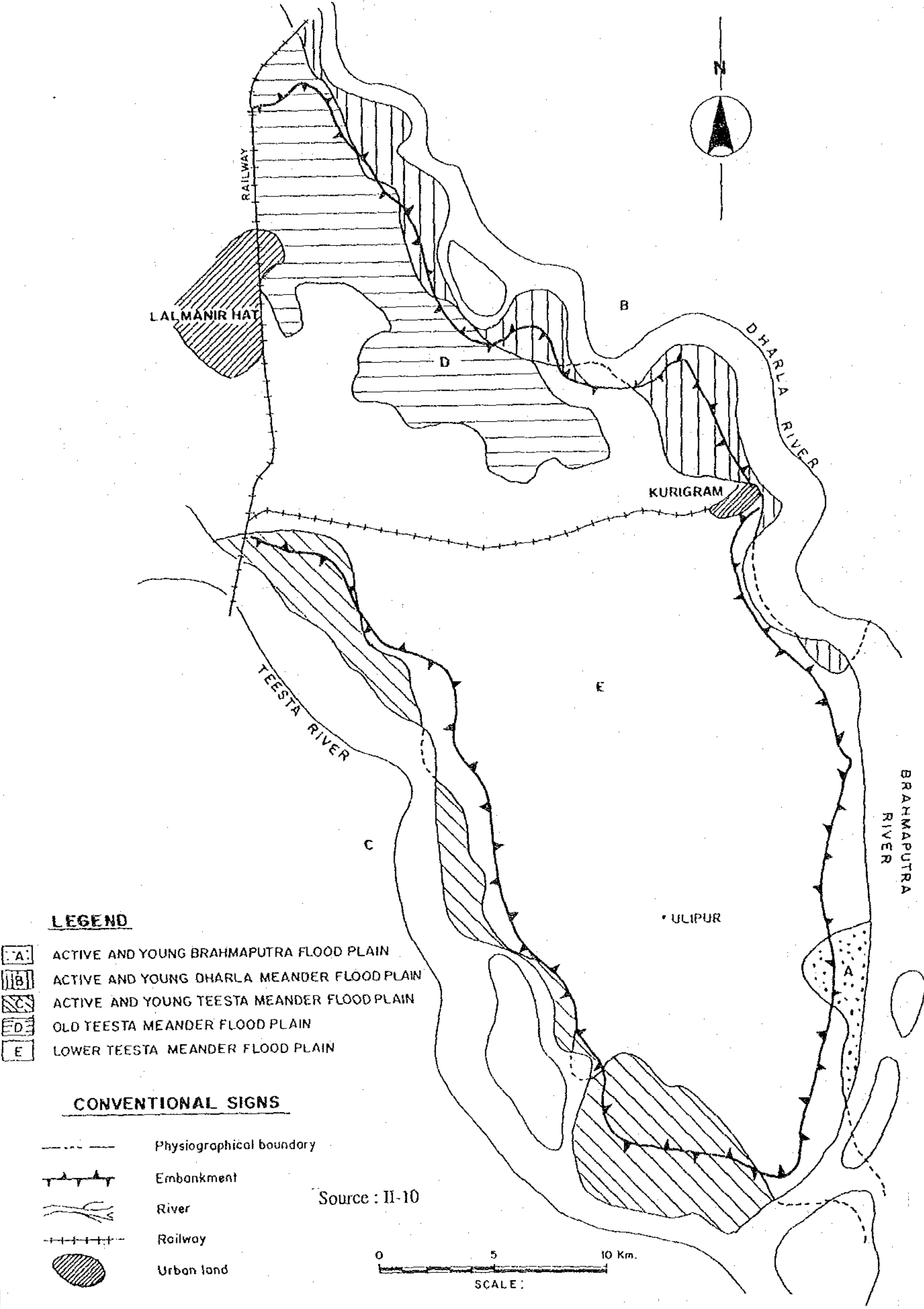
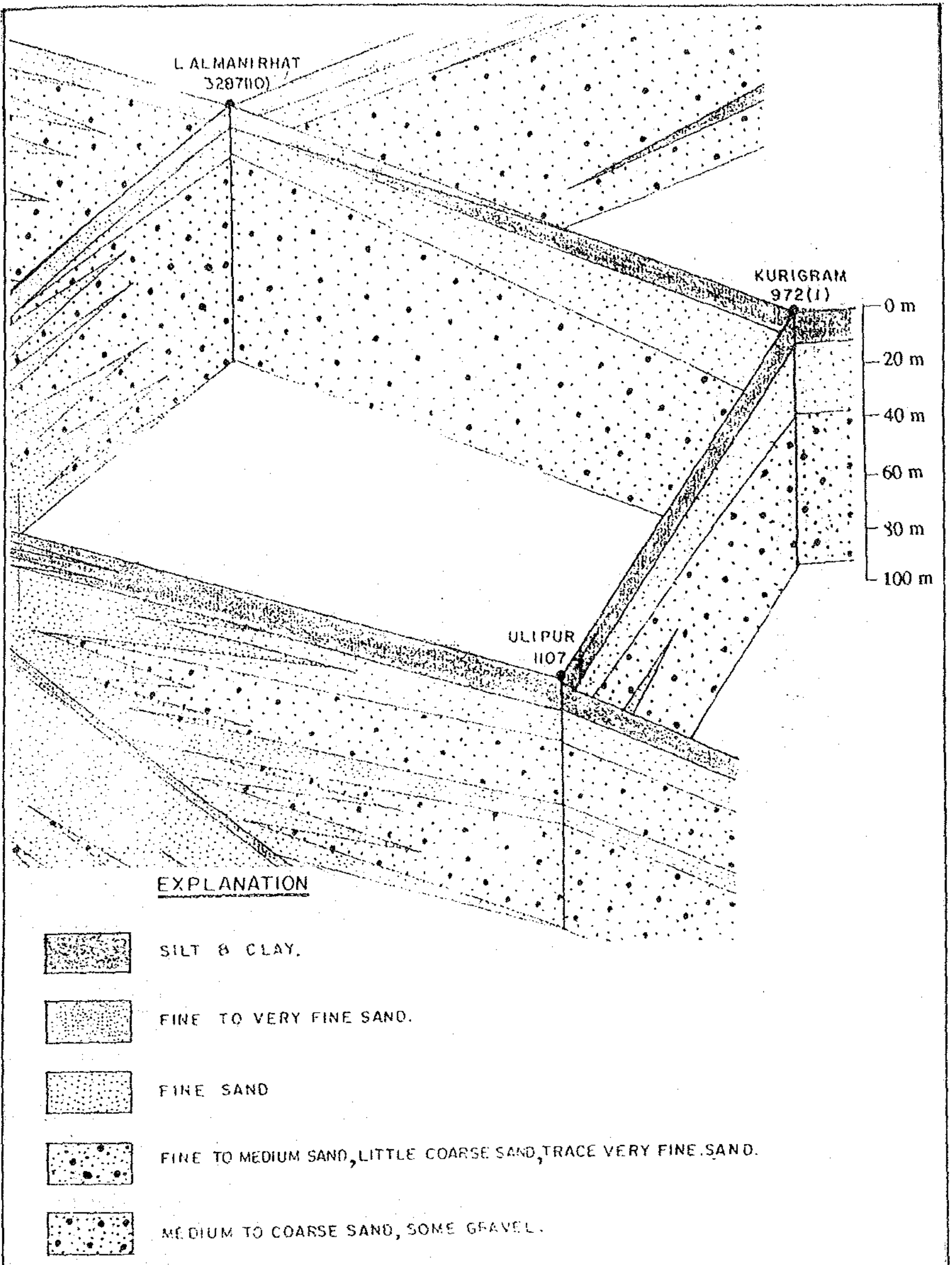


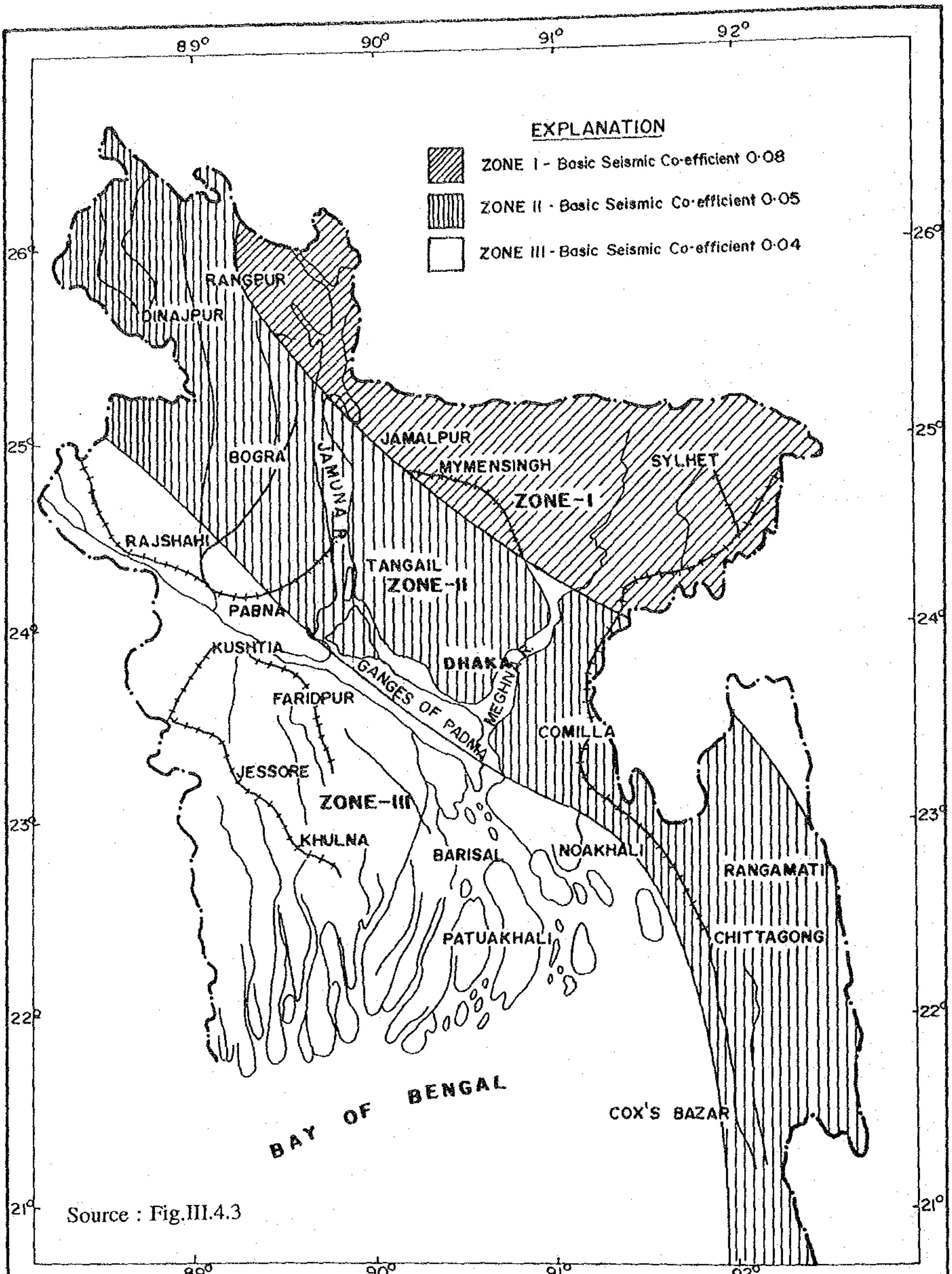
Source : II-10

Fig.III.3.3 PHYSIOGRAPHIC UNITS OF THE STUDY AREA



Source : Fig.III.6.2

Fig. III.3.4 GEOLOGICAL PANEL DIAGRAM OF THE STUDY AREA



Source : Fig.III.4.3

Fig.III.4.1 SEISMIC ZONING MAP OF BANGLADESH

Miles 25 0 25 50 75 100 Miles

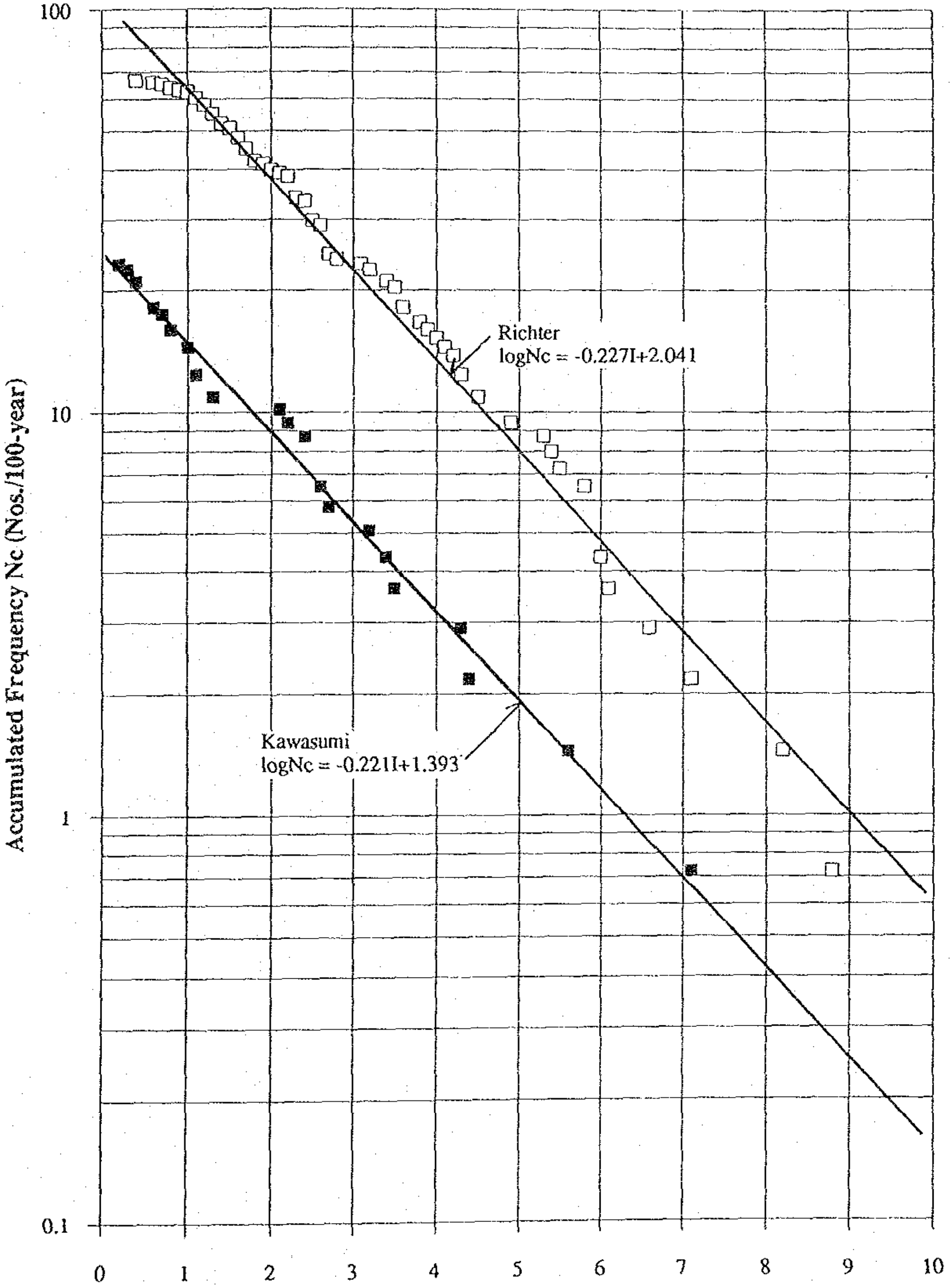


Fig.III.4.2 EARTHQUAKE INTENSITY AND FREQUENCY

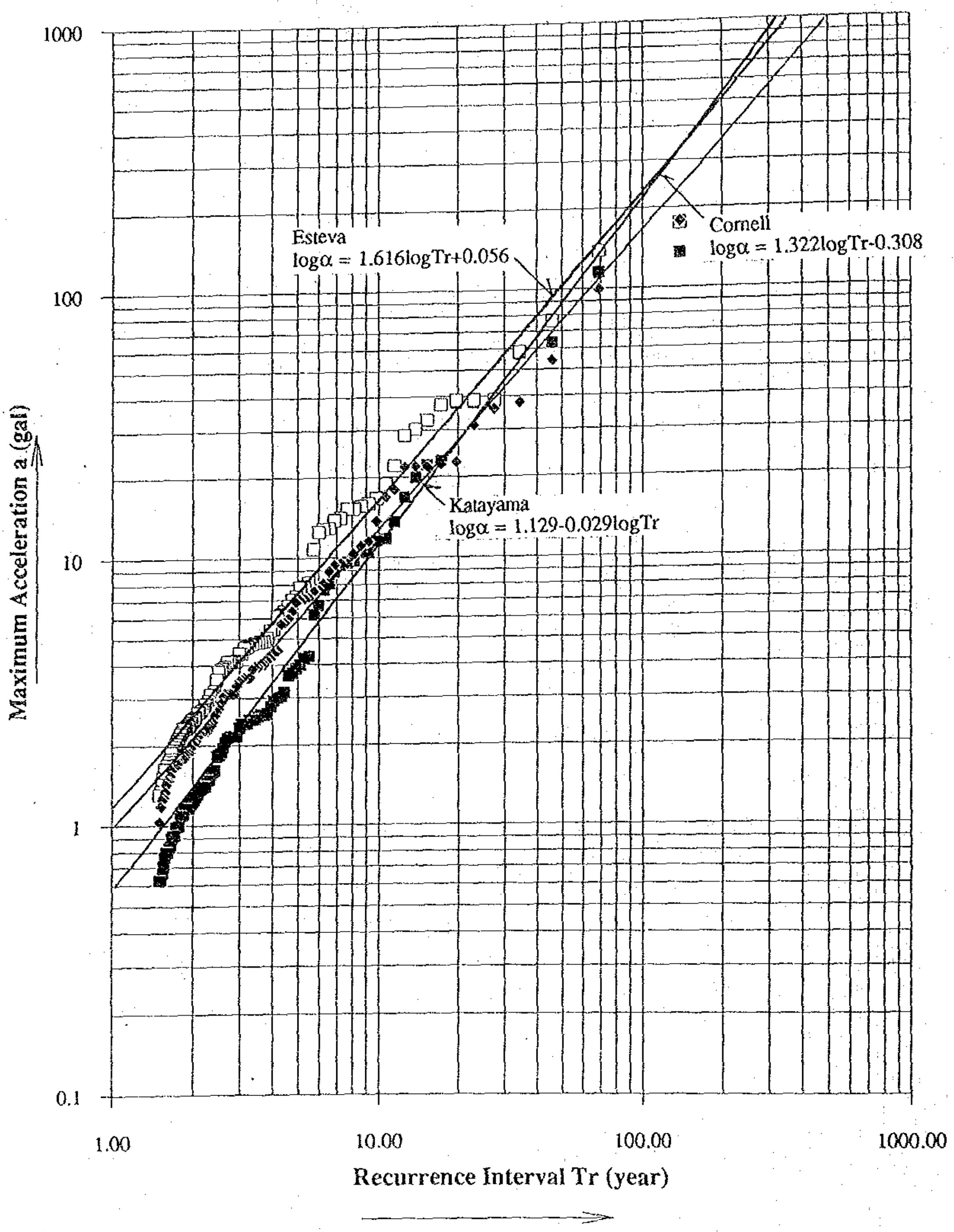
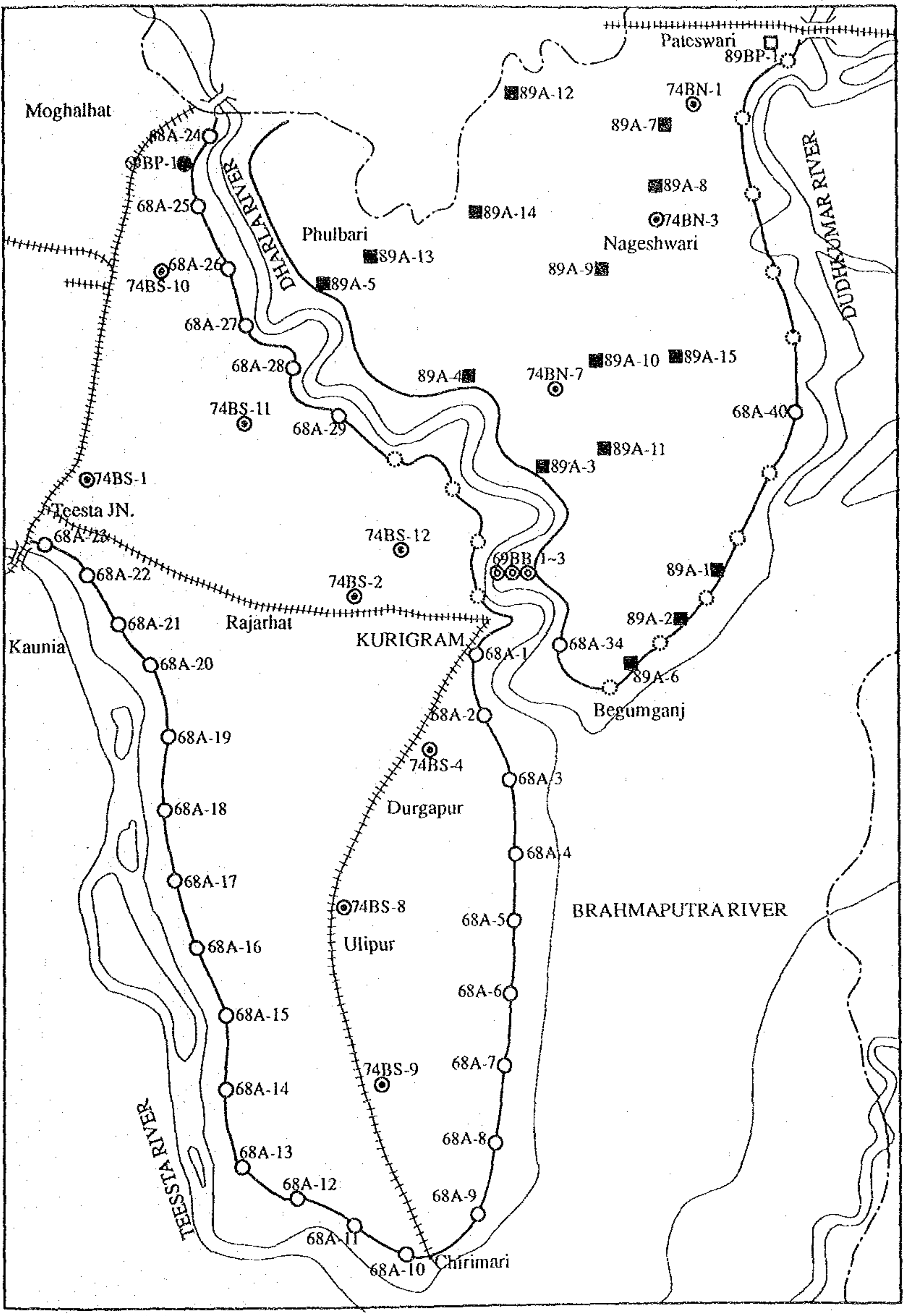


Fig.III.4.3 SEISMIC RECURRENCE CURVE



Note : Refer to Table II - 4

Fig.III.5.1 LOCATION OF SAMPLING FOR PREVIOUS LABORATORY TESTS

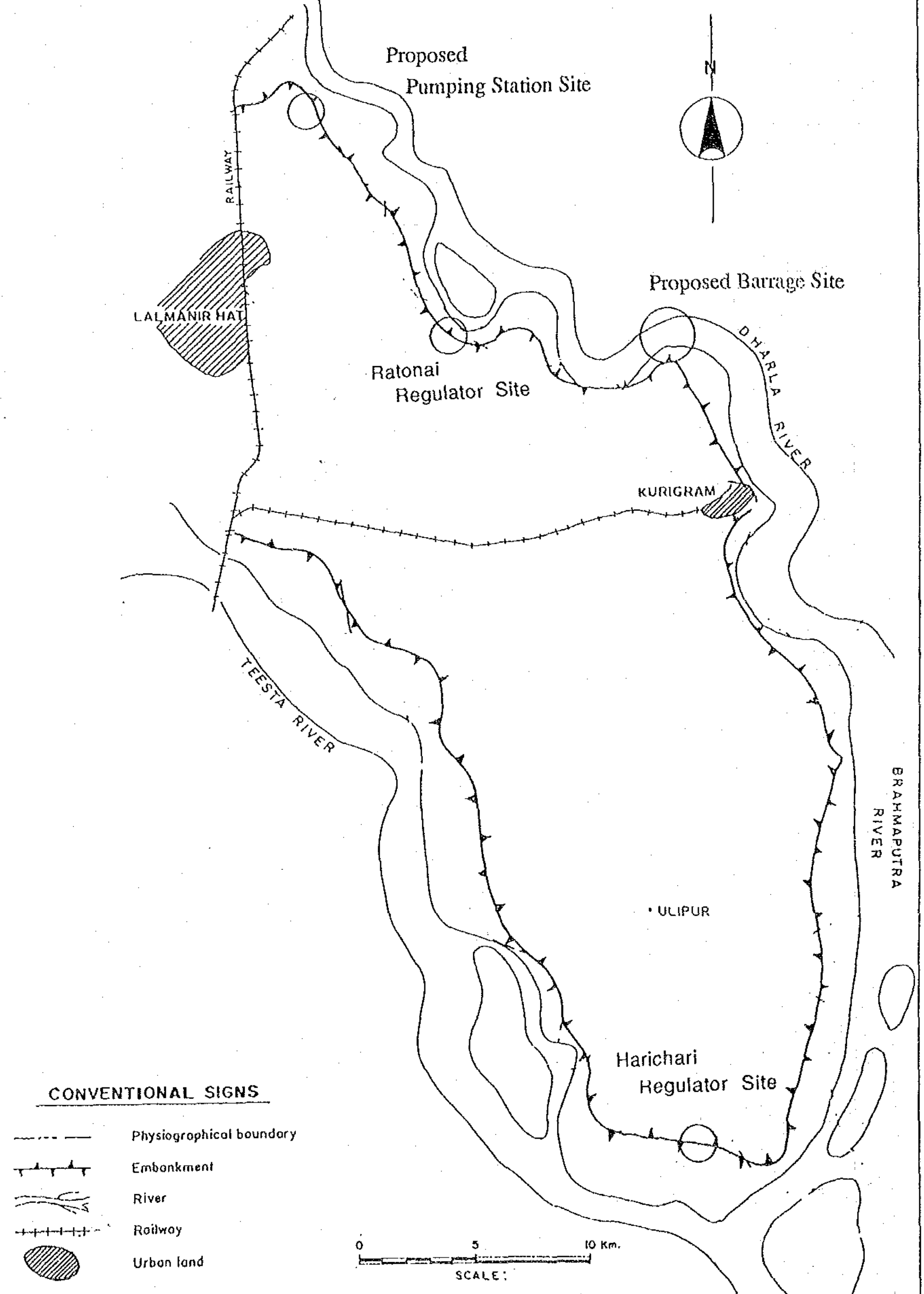
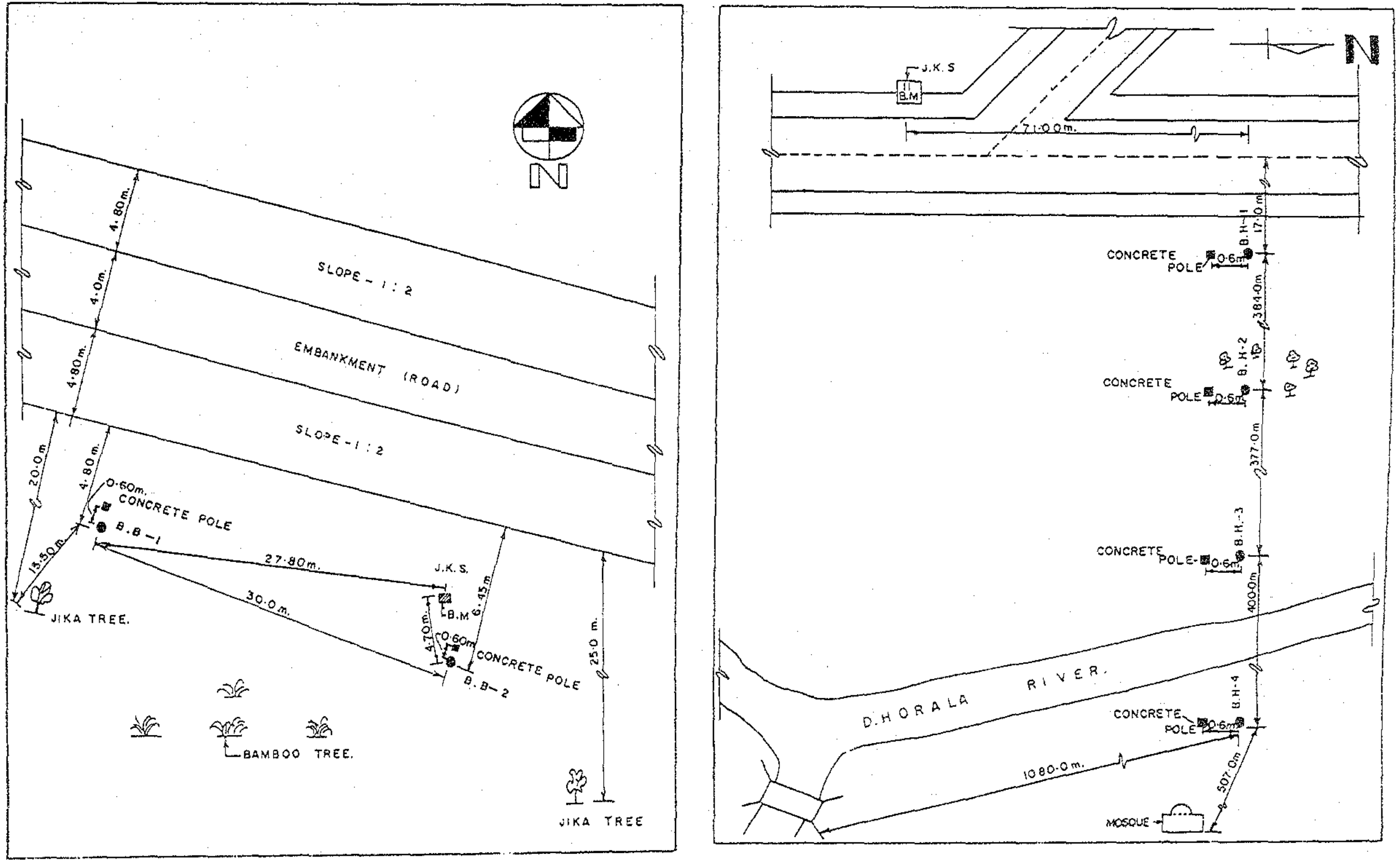


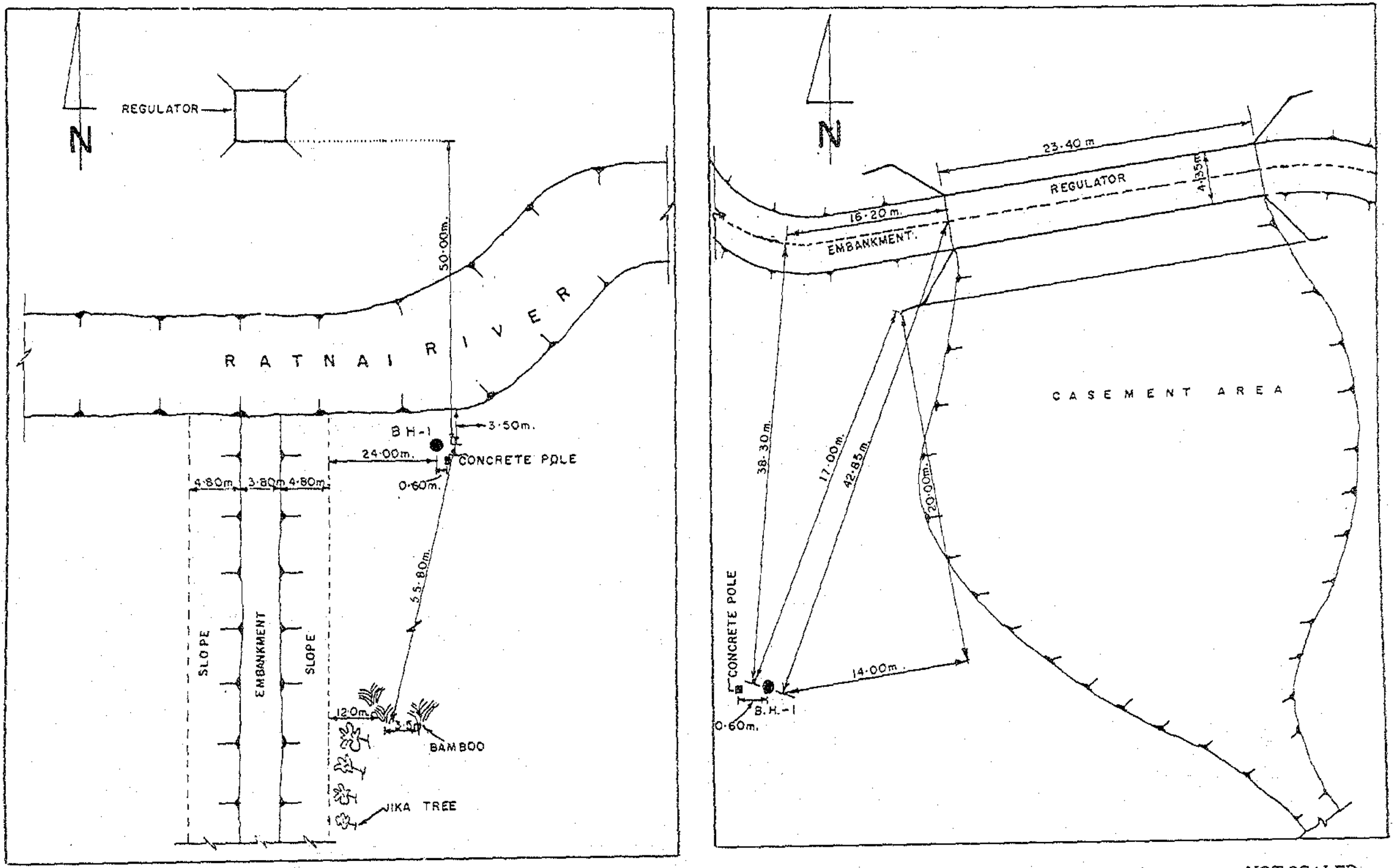
Fig.III.6.1 LOCATION OF TEST BORING SITES


Proposed Pumping Station Site

Proposed Barrage Site

NOT SCALED

Fig.III.6.2 LOCATION OF EACH BORING SITES (1/2)



Ratonai Regulator Site

Harichari Regulator Site

NOT SCALED

Fig.III.6.2 LOCATION OF EACH BORING SITES (2/2)

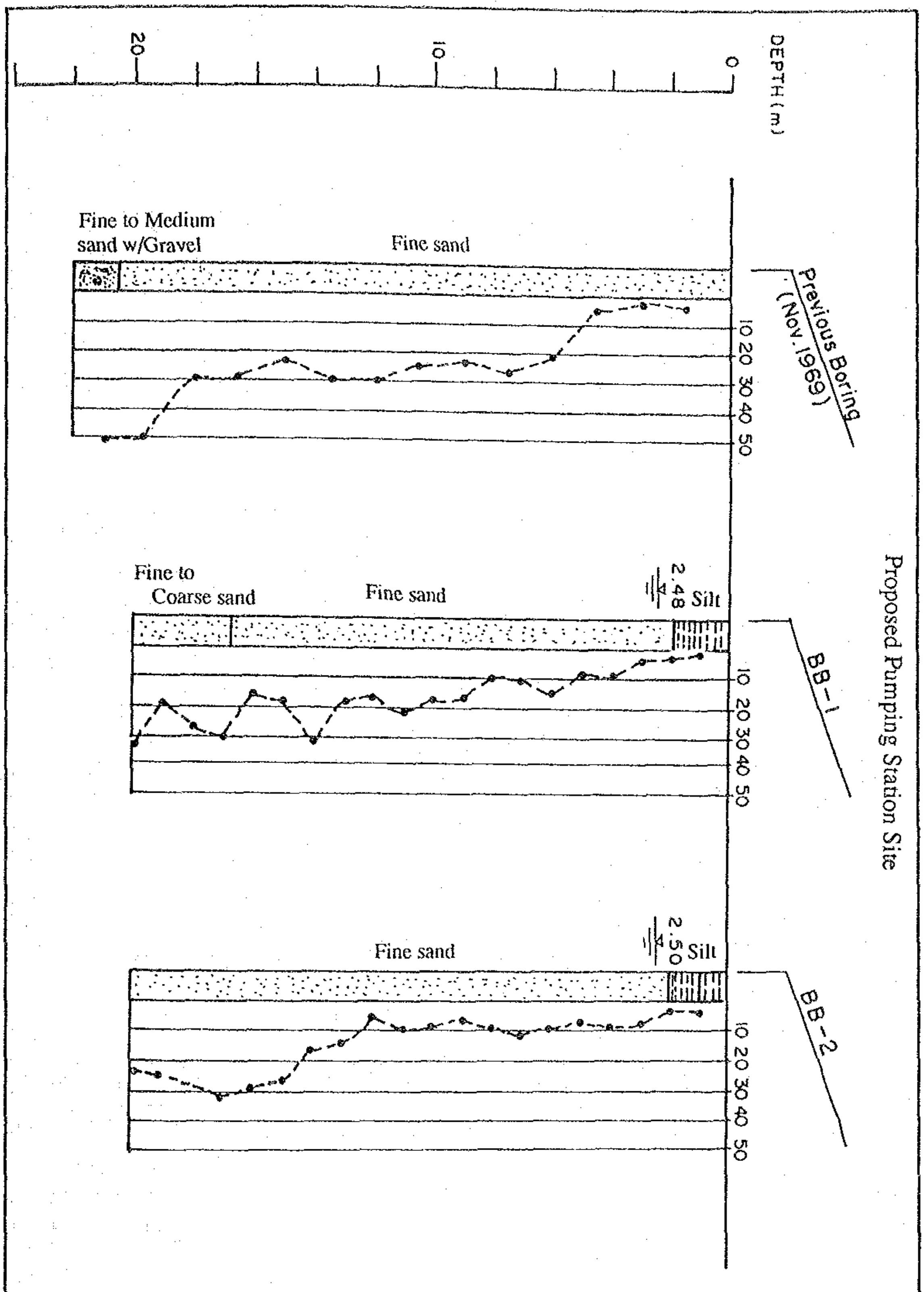


Fig.III 6.3 SUMMARY OF BORING LOGS (1/3)

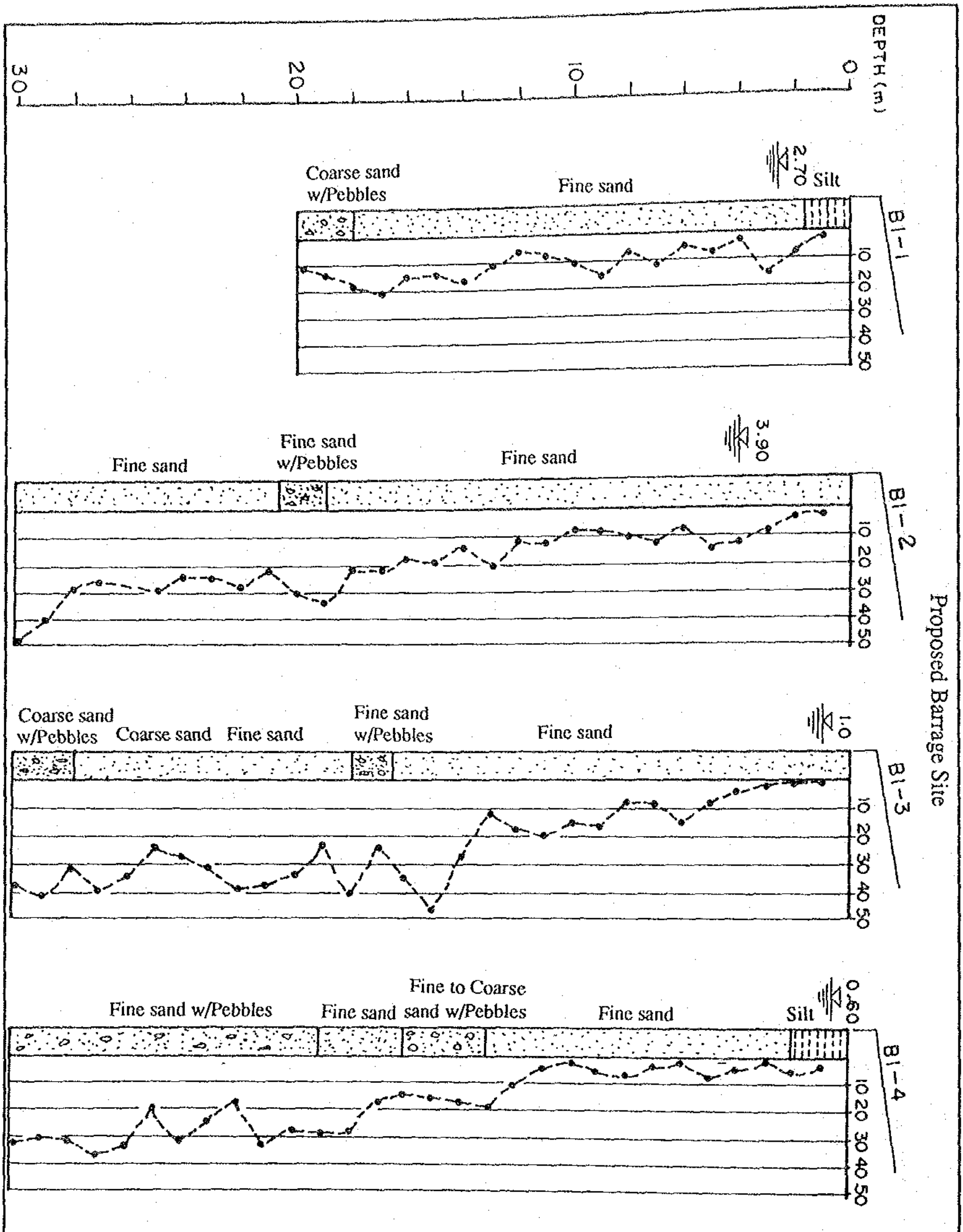


Fig.III 6.3 SUMMARY OF BORING LOGS (2/3)

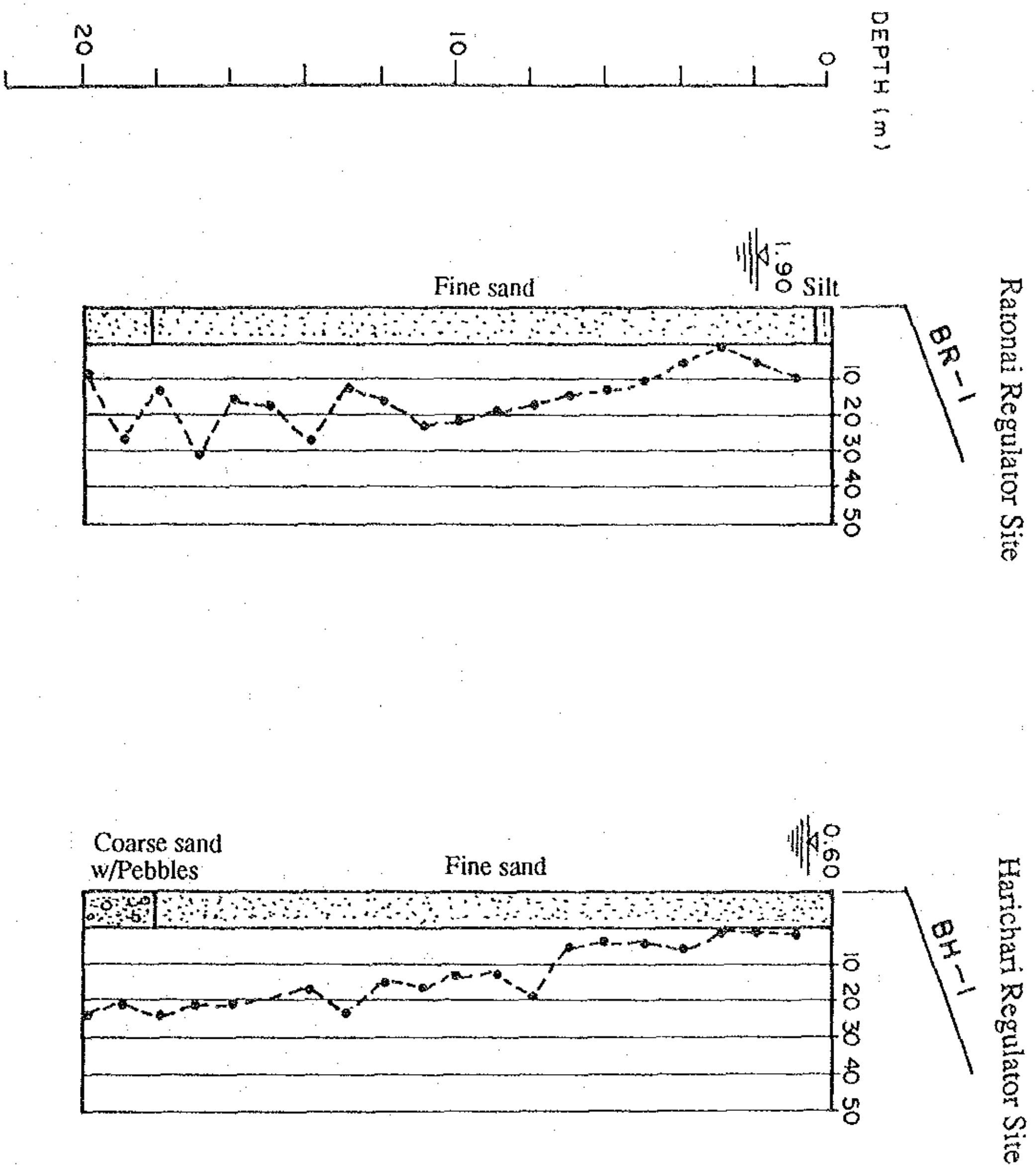
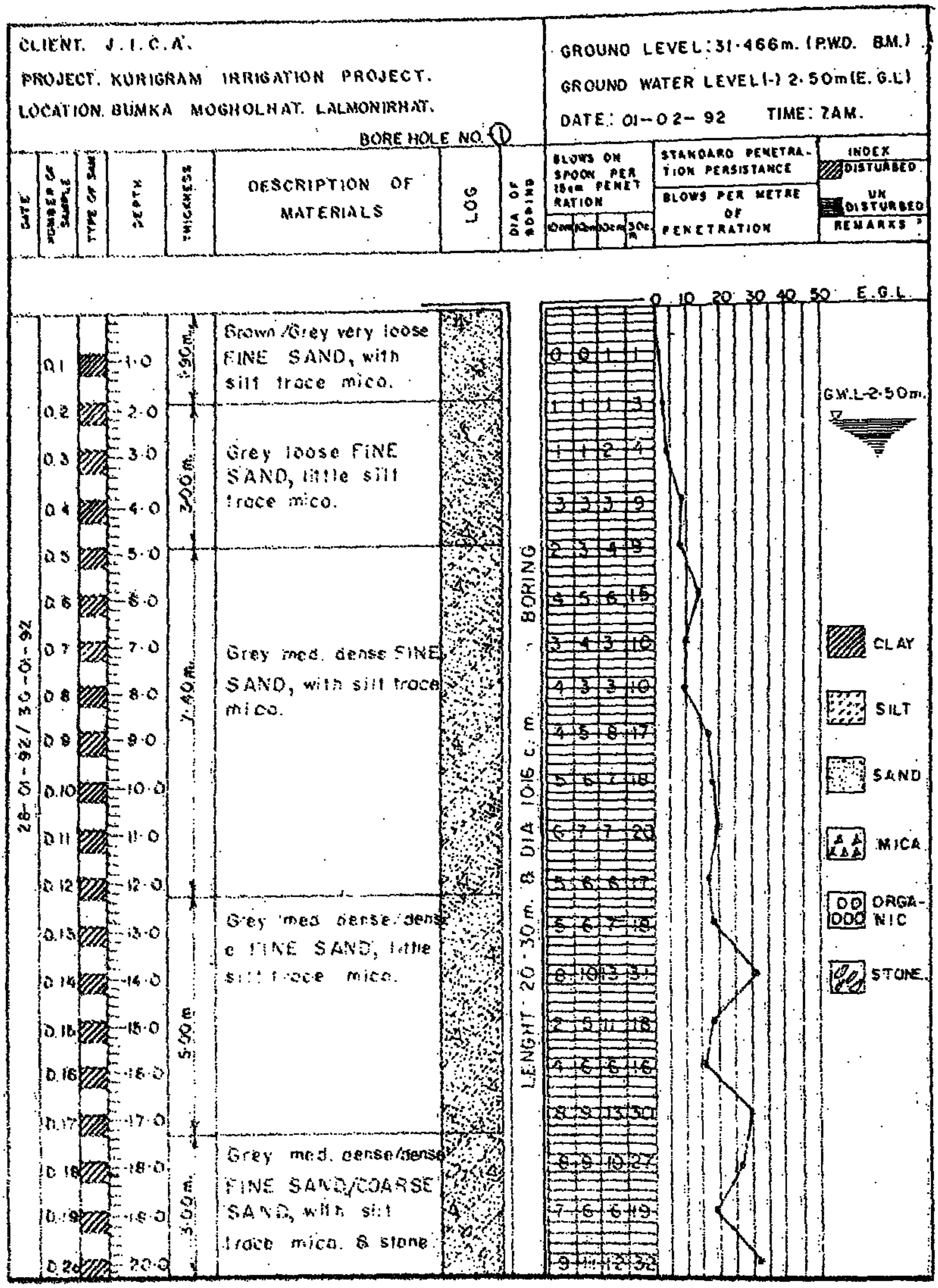


Fig.III 6.3 SUMMARY OF BORING LOGS (3/3)

Proposed Pumping Station Site



CLIENT. J.I.C.A.
PROJECT. KURIGRAM IRRIGATION PROJECT.
LOCATION. BUMKA MOGHOLHAT. LALMONIRHAT.
BORE HOLE NO. ①

GROUND LEVEL: 31·466m. (P.W.D. BM.)
GROUND WATER LEVEL (-) 2·50m (E.G.L)
DATE: 01-02-92 TIME: 7AM.

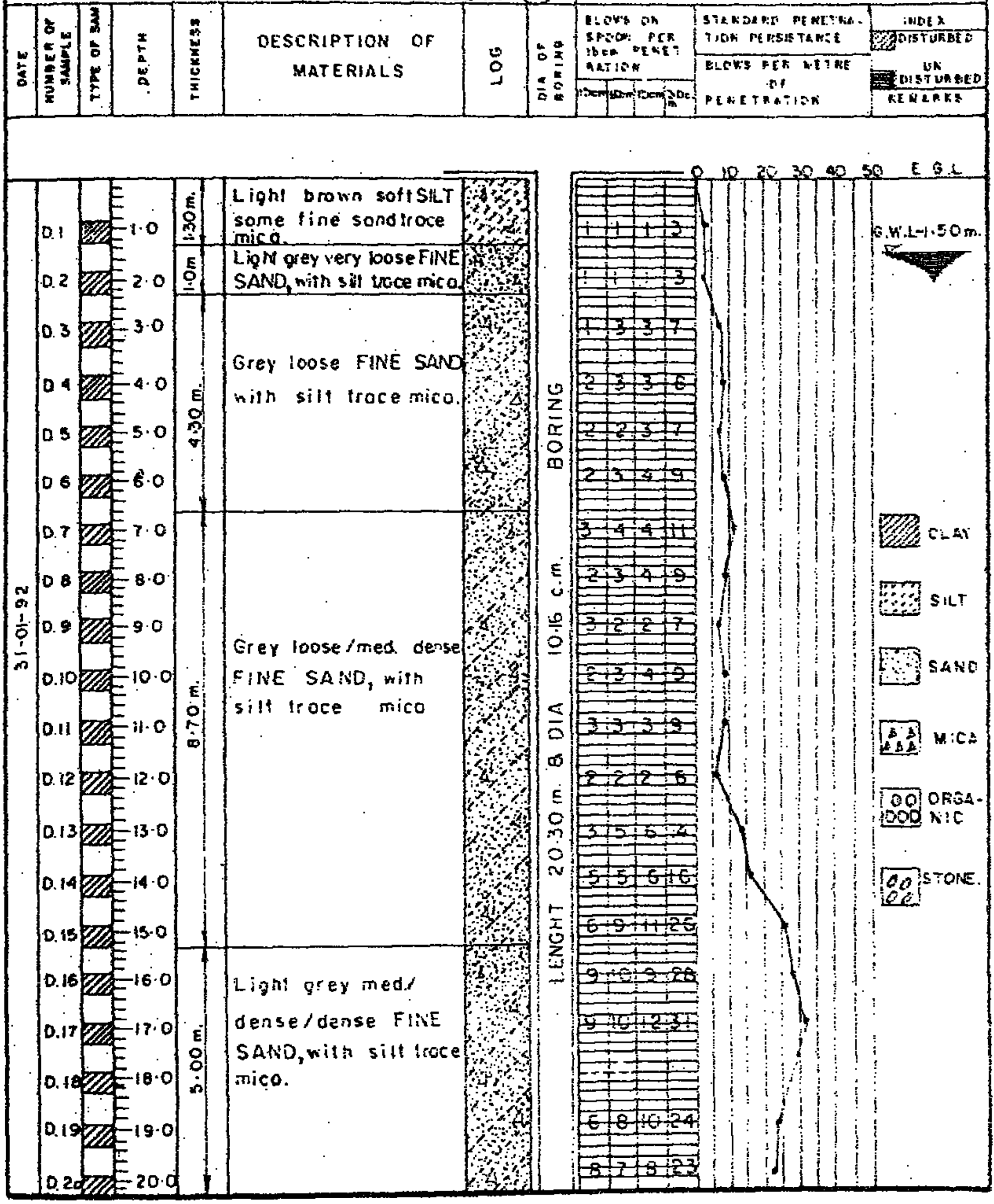
DATE	NUMBER OF SAMPLE	DEPTH	THICKNESS	DESCRIPTION OF MATERIALS	DIA OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	30cm	REMARKS
28-01-92 / 30-01-92	0.1	1·0	1.90m.	Brown /Grey very loose FINE SAND, with silt trace mica.	LENGHT 20·30m. & DIA 10.16 c.m. BORING	0	0	1	1	
	0.2	2·0	3.00m.	Grey loose FINE SAND, little silt trace mica.		1	1	1	3	G.W.L-2·50m.
	0.3	3·0				1	1	2	4	
	0.4	4·0				3	3	3	9	
	0.5	5·0	7.40m.	Grey med. dense FINE SAND, with silt trace mica.		2	3	4	9	
	0.6	6·0				4	5	6	15	
	0.7	7·0				3	4	3	10	
	0.8	8·0				4	3	3	10	
	0.9	9·0				4	5	8	17	
	0.10	10·0				5	6	7	18	
	0.11	11·0				6	7	7	20	
	0.12	12·0				5	6	6	17	
	0.15	13·0	5.00m.	Grey med dense/dense FINE SAND, little silt trace mica.		5	6	7	18	
	0.14	14·0				8	10	13	31	
	0.16	15·0				2	5	11	18	
	0.16	16·0				4	6	6	16	
	0.17	17·0				8	9	13	30	
	0.18	18·0	3.00m.	Grey med. dense/dense FINE SAND/COARSE SAND, with silt trace mica. & stone		8	9	10	27	
	0.19	19·0				7	6	6	19	
	0.20	20·0				9	11	12	32	

Fig.III.6.4 PROPOSED PUMPING STATION SITE (1/8)

Proposed Pumping Station Site

CLIENT. J.I.C.A.
PROJECT. KURIGRAM IRRIGATION PROJECT.
LOCATION. BUMKA, U.P. MOGHOLHAT LALMONIRHAT.
BORE HOLE NO ②

GROUND LEVEL 31·61m.(B.M. PWD)
GROUND WATER LEVEL(-) 1·50m.(E.G.L)
DATE 0-02-92 TIME 7AM.



DATE: 31-01-92

DIA OF BORING: LENGHT 20.30 m. & DIA 10.16 c.m. BORING

THICKNESS	DESCRIPTION OF MATERIALS
1.30m.	Light brown soft SILT some fine sand trace mica.
1.0m	Light grey very loose FINE SAND, with silt trace mica.
4.30 m.	Grey loose FINE SAND with silt trace mica.
8.70 m.	Grey loose/med. dense FINE SAND, with silt trace mica
5.00 m.	Light grey med./dense/dense FINE SAND, with silt trace mica.

NUMBER OF SAMPLE	DEPTH	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	STANDARD PENETRATION RESISTANCE BLOWS PER METRE OF PENETRATION 30cm
D.1	1·0	1	1	1	3
D.2	2·0	1	1	1	3
D.3	3·0	1	3	3	7
D.4	4·0	2	3	3	6
D.5	5·0	2	2	3	7
D.6	6·0	2	3	4	9
D.7	7·0	3	4	4	11
D.8	8·0	2	3	4	9
D.9	9·0	3	2	2	7
D.10	10·0	2	3	4	9
D.11	11·0	3	3	3	9
D.12	12·0	2	2	2	6
D.13	13·0	3	5	6	4
D.14	14·0	5	5	6	16
D.15	15·0	6	9	11	26
D.16	16·0	9	10	9	28
D.17	17·0	9	10	12	31
D.18	18·0				
D.19	19·0	6	8	10	24
D.20	20·0	8	7	8	23

Fig.III.6.4 PROPOSED PUMPING STATION SITE (2.8)

CLIENT J.I.C.A.

PROJECT: KURIGRAM IRRIGATION PROJECT.

LOCATION: HOLLOWKHANA. KURIGRAM. BORE HOLE NO. ①

GROUND LEVEL 26.12m (B.M. PW 0)

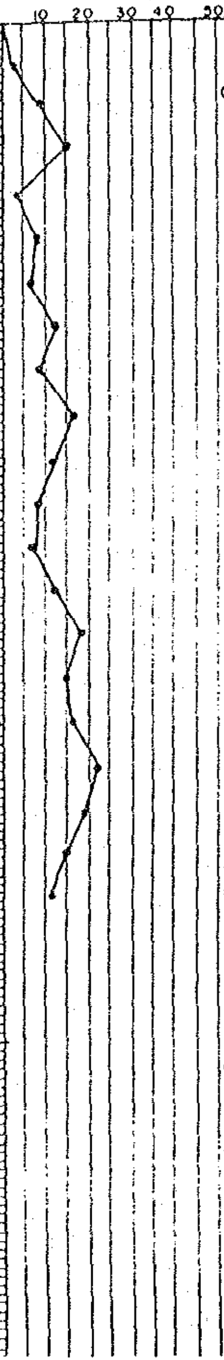
GROUND WATAR LEVEL:(-) 2.65 m (E.G.L)

DATE: 7-02-92 TIME: 7.A.M.

DATE	NUMBER OF SAMPLE	TYPE OF SAMPLE	DEPTH(m)	THIKNESS	DESCRIPTION OF MATERIALS	DEPTH(m)	BLOWS ON SPOON PER 15cm PENETRATION 10cm	10cm	10cm	30cm
6-02-92	D-1	▨	1	1.60m.	Grey soft SILT, little clay & fine sand.	LENGHT 20.30 m. & DIA 10.16 c.m. BORING	1	1	1	3
	D-2	▨	2	9.70 m.	Grey loose / med. dense FINE SAND with silt trace mica.		2	3	3	8
	D-3	▨	3				4	5	6	15
	D-4	▨	4				1	1	2	4
	D-5	▨	5				2	3	3	8
	D-6	▨	6				2	2	2	6
	D-7	▨	7				4	4	4	12
	D-8	▨	8				2	3	3	8
	D-9	▨	9				4	6	6	16
	D-10	▨	10				3	4	4	11
	D-11	▨	11				3	3	3	9
	D-12	▨	12	1.30m	Grey loose COARSE SAND with silt trace mica.		2	2	3	7
	D-13	▨	13	5.30 m.	Grey med. dense FINE SAND, with silt trace mica.		4	4	4	12
	D-14	▨	14				5	6	7	18
	D-15	▨	15				4	5	6	15
	D-16	▨	16				4	6	6	16
	D-17	▨	17				5	7	10	22
	D-18	▨	18	2.40m.	Grey med. dense FINE SAND/COARSE SAND, with silt trace mica & stone		6	6	7	19
	D-19	▨	19				4	5	6	15
	D-20	▨	20				4	3	4	11
	D-21	▨	21							
	D-22	▨	22							
	D-23	▨	23							
	D-24	▨	24							
	D-25	▨	25							
	D-26	▨	26							
	D-27	▨	27							
	D-28	▨	28							
	D-29	▨	29							
	D-30	▨	30							

STANDANO PENETRATION PERSISTANCE

BLOWS PER METRE OF PENETRATION



INDEX

▨ DISTURBED

▤ UNDISTURBED

REMARKS

E.G.L.

G.W.L-2.65m.

CLAY ▨

SILT ▨

SAND ▩

MICA ΔΔ

ORGANIC ○○

▨ STONE

Fig.III.6.4 PROPOSED PUMPING STATION SITE (3/8)

CLIENT: J. I. C. A.

PROJECT: KURIGRAM IRRIGATION PROJECT.

LOCATION: HOLLOWKHANA, KURIGRAM. BORE HOLE NO.
BORE HOLE NO②

GROUND LEVEL 27·19m. (B.M. PWD)

GROUND WATAR LEVEL:(-) 3·80m.(E.G.L.)

DATE: 10-02-9 TIME: 7 A.M.

THIKNESS	DESCRIPTION OF MATERIALS
2·60 m	Ligh brown soft SILT, little clay & fine sand trace mica.
12·70 m.	Grey loose/med. dense FINE SAND with silt, trace mica.
3·60 m.	Grey med dense FINE SAND with silt, trace mica.
1·70 m	Grey dense FINE SAND with silt, trace mica.
8·00 m	Grey med. dense FINE SAND with silt, trace mica.
1·70 m	Grey dense FINE SAND with silt, trace mica & stone

DATE: 08-02-92 to 09-02-92

BORING LENGHT 30·20m. & DIA 10·16 c.m.

NUMBER OF SAMPLE	DEPTH (m)	10 cm	10 cm	10 cm	30 cm
D-1	1	1	1	1	3
D-2	2	1	1	2	4
D-3	3	3	3	3	9
D-4	4	4	4	5	13
D-5	5	5	5	5	15
D-6	6	3	3	3	9
D-7	7	5	4	4	13
D-8	8	4	3	4	11
D-9	9	3	3	3	9
D-10	10	3	3	3	9
D-11	11	4	5	5	14
D-12	12	4	3	6	13
D-13	13	6	7	8	21
D-14	14	4	5	6	15
D-15	15	5	7	8	20
D-16	16	5	6	8	19
D-17	17	6	7	10	23
D-18	18	7	8	8	23
D-19	19	9	12	14	35
D-20	20	7	11	13	31
D-21	21	7	9	7	23
D-22	22	9	10	10	29
D-23	23	7	9	10	26
D-24	24	7	7	11	25
D-25	25	9	10	11	30
D-26	26				
D-27	27	7	9	11	27
D-28	28	8	10	11	29
D-29	29	11	14	16	41
D-30	30	12	17	20	49

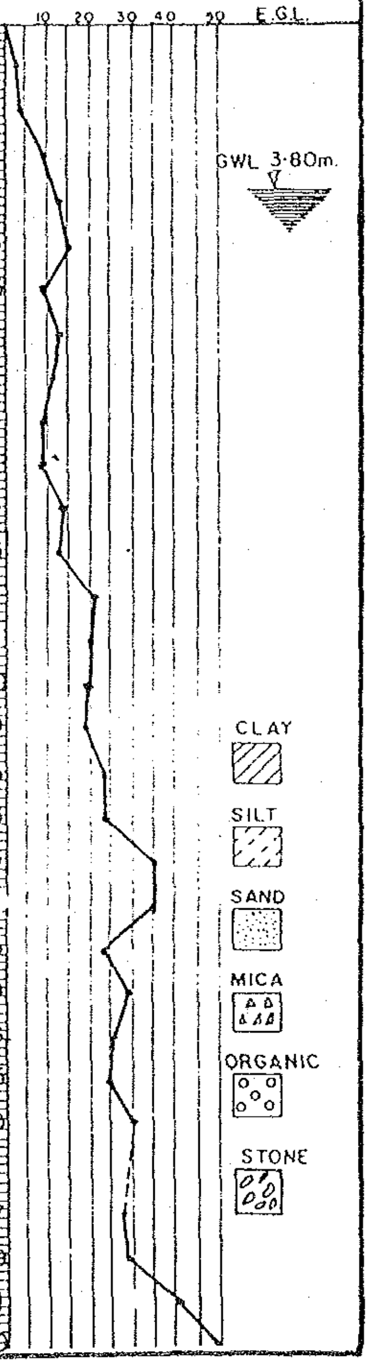
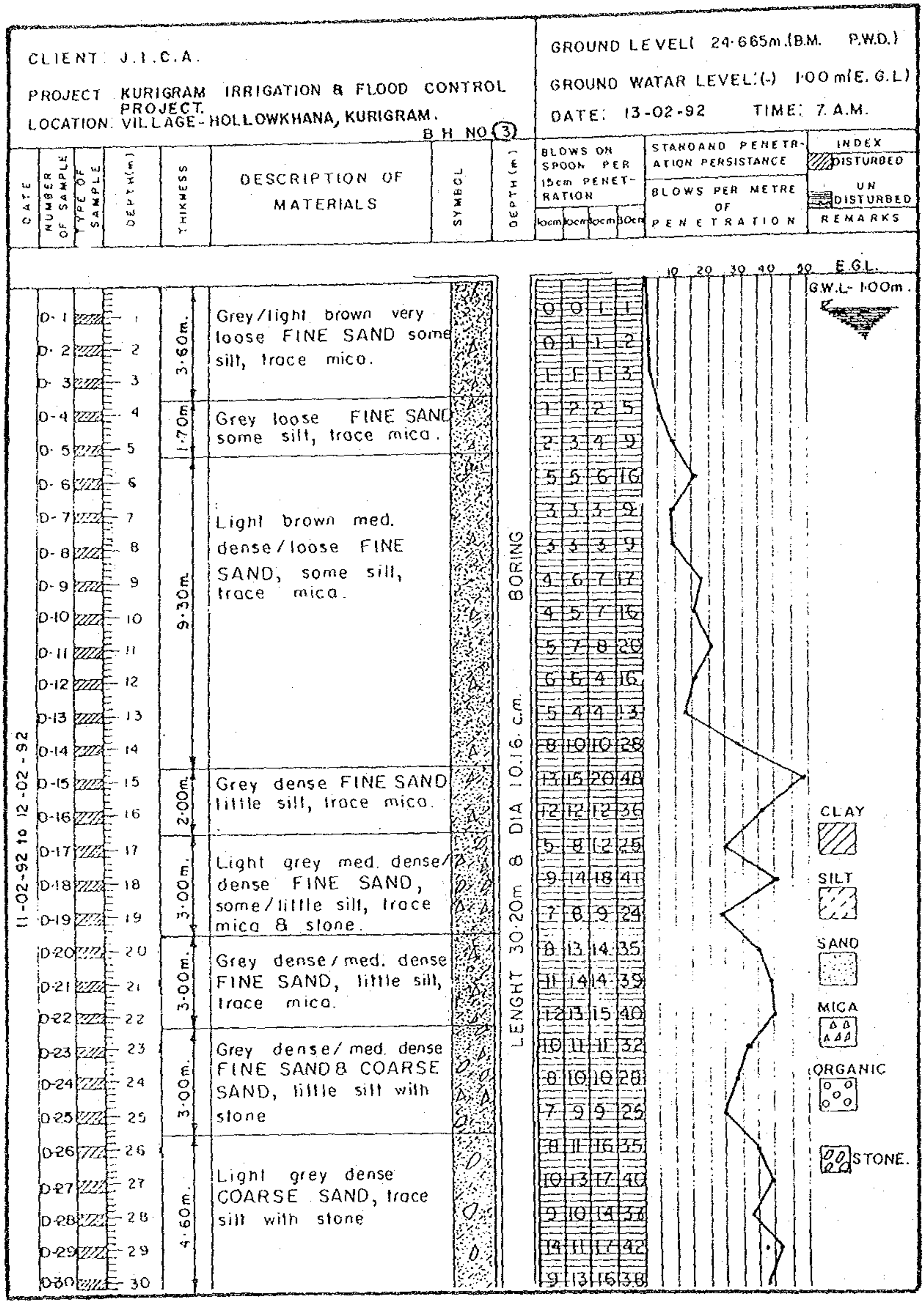


Fig.III.6.4 PROPOSED PUMPING STATION SITE (4/8)

Proposed Barrage Site



CLIENT: J.I.C.A.

PROJECT: KURIGRAM IRRIGATION & FLOOD CONTROL PROJECT.

LOCATION: VILLAGE - HOLLOWKHANA, KURIGRAM.

B H NO ③

GROUND LEVEL(24·665m.(B.M. P.W.D.)

GROUND WATAR LEVEL:(-) 1·00 m(E. G.L)

DATE: 13-02-92 TIME: 7. A.M.

THIKNESS	DESCRIPTION OF MATERIALS
3·60m.	Grey/light brown very loose FINE SAND some silt, trace mica.
1·70m.	Grey loose FINE SAND some silt, trace mica.
9·30m.	Light brown med. dense/loose FINE SAND, some silt, trace mica.
2·00m.	Grey dense FINE SAND little silt, trace mica.
3·00m.	Light grey med. dense/dense FINE SAND, some/little silt, trace mica & stone.
3·00m.	Grey dense/med. dense FINE SAND, little silt, trace mica.
3·00m.	Grey dense/med. dense FINE SAND & COARSE SAND, little silt with stone
4·60m.	Light grey dense COARSE SAND, trace silt with stone

DATE: 11-02-92 to 12-02-92

BORING LENGHT 30·20m & DIA 10.16. c.m.

NUMBER OF SAMPLE	DEPTH (m)	15cm	15cm	15cm	30cm
D-1	1	0	0	1	1
D-2	2	0	1	1	2
D-3	3	1	1	1	3
D-4	4	1	2	2	5
D-5	5	2	3	4	9
D-6	6	5	5	6	16
D-7	7	3	3	3	9
D-8	8	3	3	3	9
D-9	9	4	6	7	17
D-10	10	4	5	7	16
D-11	11	5	7	8	20
D-12	12	6	6	4	16
D-13	13	5	4	4	13
D-14	14	8	10	10	28
D-15	15	13	15	20	48
D-16	16	12	12	12	36
D-17	17	5	8	12	25
D-18	18	9	14	18	41
D-19	19	7	8	9	24
D-20	20	8	13	14	35
D-21	21	11	14	14	39
D-22	22	12	13	15	40
D-23	23	10	11	11	32
D-24	24	8	10	10	28
D-25	25	7	9	9	25
D-26	26	8	11	16	35
D-27	27	10	13	17	40
D-28	28	9	10	14	33
D-29	29	14	11	17	42
D-30	30	9	13	16	38

Fig.III.6.4 PROPOSED PUMPING STATION SITE (5/8)

CLIENT J.I.C.A.

PROJECT: KURIGRAM IRRIGATION & FLOOD CONTROL PROJECT.

LOCATION: VILLAGE HOLLOWKHANA, KURIGRAM. B. H-④

GROUND LEVEL 24·937m.(B.M. PWD)

GROUND WATAR LEVEL:(-) 1·70m.(E.G.L)

DATE: 16-02-92 TIME: 7 A.M.

DATE	NUMBER OF SAMPLE	TYPE OF SAMPLE	DEPTH (m)	THIKNESS	DESCRIPTION OF MATERIALS	SYMBOL	DEPTH (m)	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	30cm	STANDAND PENETRATION PERSISTANCE BLOWS PER METRE OF PENETRATION	INDEX / REMARKS
14-02-92/15-02-92	D-1	▨	1	2.30m.	Light grey loose FINE SAND, with silt trace mica.		BORING LENGHT 30.30 m. & DIA 10.16c.m.	1	2	2	5		G.W.L-1·70m.
	D-2	▨	2					2	3	2	7		
	D-3	▨	3	1.30m	Grey very loose FINE SAND some silt trace mica.			1	1	1	3		
	D-4	▨	4	9.30m.	Grey loose FINE SAND, some silt trace mica.			1	2	3	6		
	D-5	▨	5					3	2	3	8		
	D-6	▨	6					1	1	2	4		
	D-7	▨	7					1	2	2	5		
	D-8	▨	8					2	3	4	9		
	D-9	▨	9					2	2	3	7		
	D-10	▨	10					1	1	2	4		
	D-11	▨	11					1	2	2	5		
	D-12	▨	12					5	3	3	11		
	D-13	▨	13	1.70m.	Grey med. dense FINE SAND /COARSE SAND, little silt trace mica & stone			7	6	6	19		
	D-14	▨	14					5	6	7	18		
	D-15	▨	15	4.30m.	Grey med. dense FINE SAND, some silt trace mica.			4	5	7	16		
	D-16	▨	16					4	5	6	15		
	D-17	▨	17					4	6	8	18		
	D-18	▨	18					9	9	10	28		
	D-19	▨	19	1.70m.	Grey med. dense FINE / COARSE SAND, little silt trace mica with stone.			8	10	11	29		
	D-20	▨	20					10	10	9	29		
	D-21	▨	21	3.00 m	Grey dense/med. dense FINE SAND, some/little silt trace mica.			7	12	15	34		
	D-22	▨	22					5	6	7	18		
	D-23	▨	23					7	8	10	25		
	D-24	▨	24	6.70m.	Grey med. dense/dense FINE SAND, little silt with stone.			10	10	12	32		
	D-25	▨	25					7	6	7	20		
	D-26	▨	26					10	11	13	34		
	D-27	▨	27					15	11	11	37		
	D-28	▨	28					9	11	12	32		
	D-29	▨	29					10	10	11	31		
	D-30	▨	30					8	10	14	32		

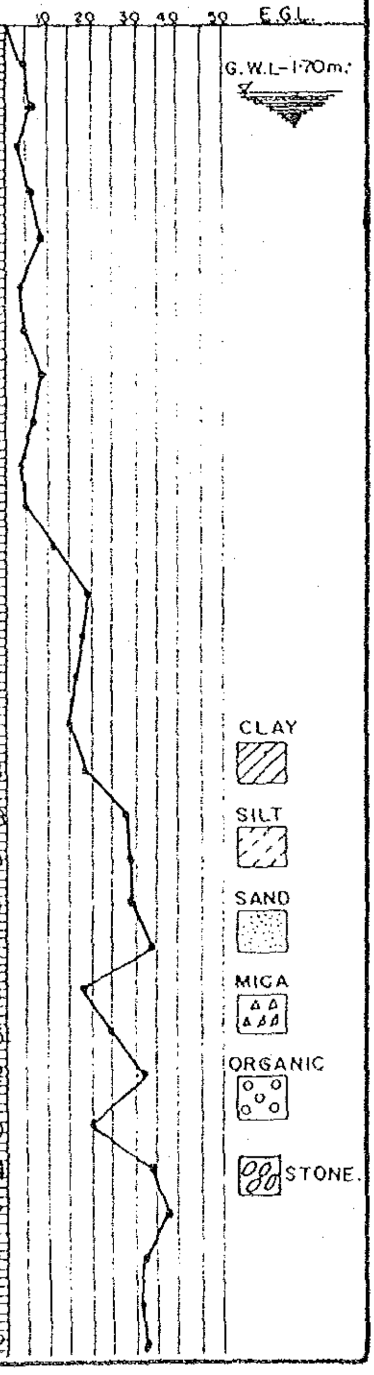
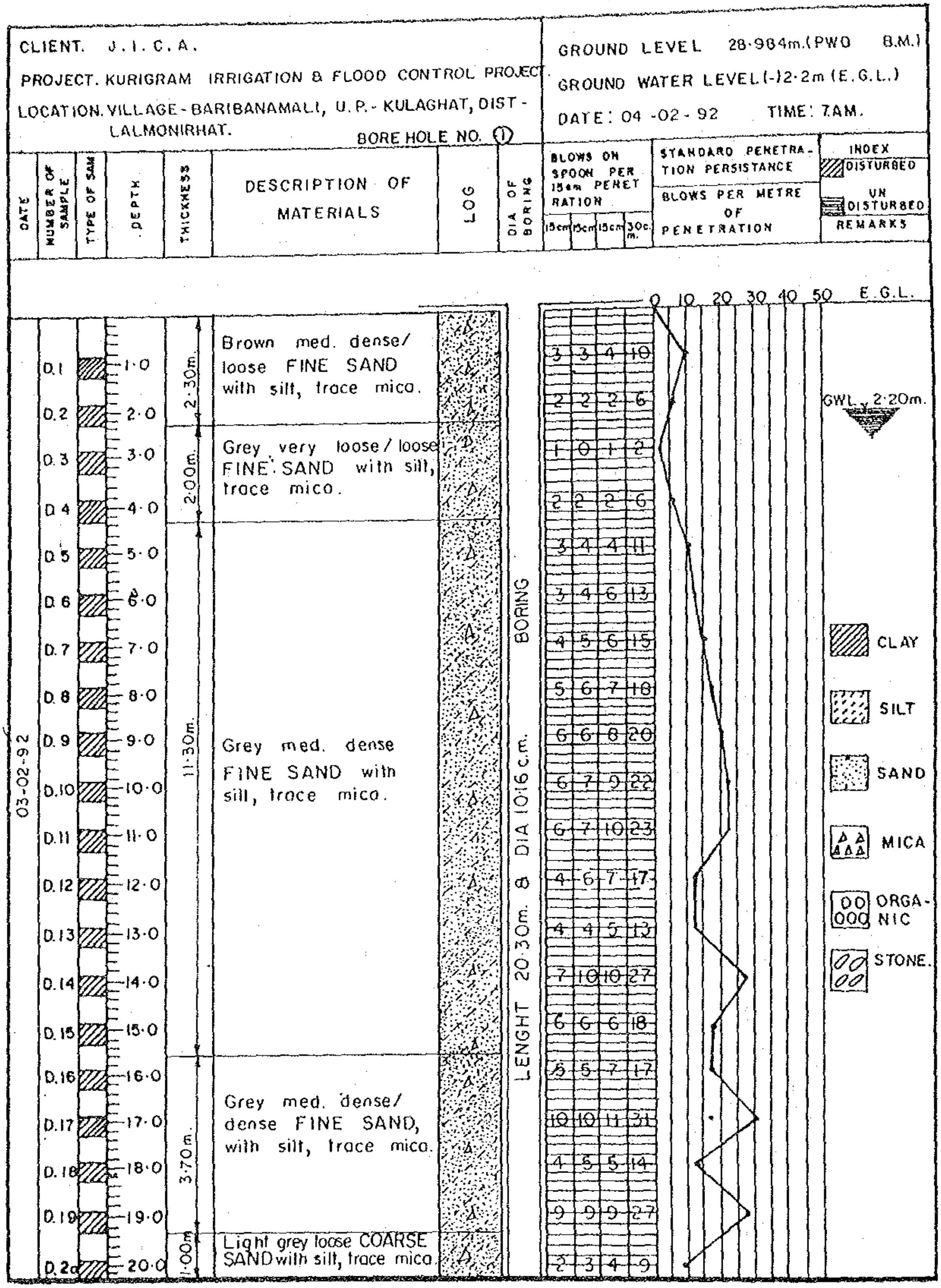


Fig.III.6.4 PROPOSED PUMPING STATION SITE (6/8)

Ratonai Regulator Site



CLIENT. J. I. C. A.
PROJECT. KURIGRAM IRRIGATION & FLOOD CONTROL PROJECT.
LOCATION. VILLAGE - BARIBANAMALI, U.P. - KULAGHAT, DIST - LALMONIRHAT.
BORE HOLE NO. ①

GROUND LEVEL 28·984m.(PWD B.M.)
GROUND WATER LEVEL (-)2·2m (E.G.L.)
DATE: 04 -02 - 92 TIME: 7AM.

THICKNESS	DESCRIPTION OF MATERIALS
2·30m.	Brown med. dense/ loose FINE SAND with silt, trace mica.
2·00m.	Grey very loose / loose FINE SAND with silt, trace mica.
11·30m.	Grey med. dense FINE SAND with silt, trace mica.
3·70m.	Grey med. dense/ dense FINE SAND, with silt, trace mica.
1·00m.	Light grey loose COARSE SAND with silt, trace mica.

DATE	NUMBER OF SAMPLE	TYPE OF SAM	DEPTH	15cm	15cm	15cm	30cm.
03-02-92	D.1	▨	1·0	3	3	4	10
	D.2	▨	2·0	2	2	2	6
	D.3	▨	3·0	1	0	1	2
	D.4	▨	4·0	2	2	2	6
	D.5	▨	5·0	3	4	4	11
	D.6	▨	6·0	3	4	6	13
	D.7	▨	7·0	4	5	6	15
	D.8	▨	8·0	5	6	7	18
	D.9	▨	9·0	6	6	8	20
	D.10	▨	10·0	6	7	9	22
	D.11	▨	11·0	6	7	10	23
	D.12	▨	12·0	4	6	7	17
	D.13	▨	13·0	4	4	5	13
	D.14	▨	14·0	7	10	10	27
	D.15	▨	15·0	6	6	6	18
	D.16	▨	16·0	5	5	7	17
	D.17	▨	17·0	10	10	11	31
	D.18	▨	18·0	4	5	5	14
	D.19	▨	19·0	9	9	9	27
	D.20	▨	20·0	2	3	4	9

Fig.III.6.4 PROPOSED PUMPING STATION SITE (7/8)

CLIENT. J.I.C.A.

PROJECT. K. I. & F. C. PROJECT.

LOCATION. HORICHORI REGULATOR, VILLAGE - PATRAKHATA, MOZA - ROMNA, KURIGRAM.

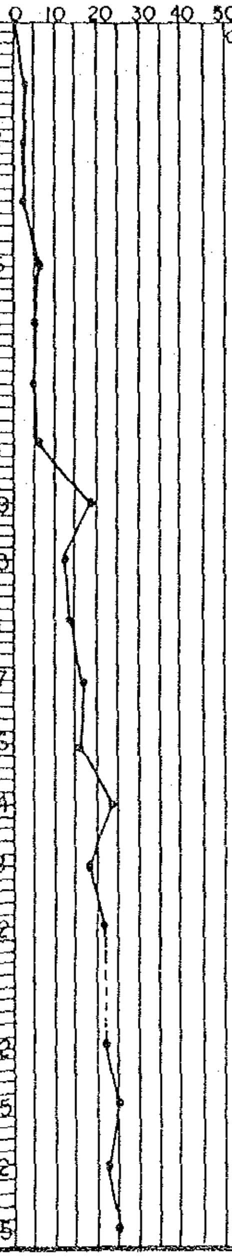
BORE HOLE NO. -①

GROUND LEVEL 19·55m. (B.M. P.W.D.)

GROUND WATER LEVEL(-) 0·60 m.(E.G.L.)

DATE: 19-02-92 TIME: 7AM.

DATE	NUMBER OF SAMPLE	TYPE OF SAM	DEPTH	THICKNESS	DESCRIPTION OF MATERIALS	LOG	DIA OF BORING	BLOWS ON SPOON PER 15cm PENETRATION				STANDARD PENETRATION PERSISTANCE BLOWS PER METRE OF PENETRATION	INDEX ▨ DISTURBED ▤ UNDISTURBED REMARKS
								15cm	15cm	15cm	30cm	0 10 20 30 40 50	E.G.L.
18-02-92	D.1	▨	1·0	3·60 m.	Grey very loose FINE SAND, with silt trace mica.		LENGHT 2030m & DIA 10.16 C.m. BORING	1	1	1	3		G.WL-0·60m
	D.2	▨	2·0					0	1	1	2		
	D.3	▨	3·0					0	1	1	2		
	D.4	▨	4·0	4·65 m.	Grey loose FINE SAND, with silt trace mica.			2	2	2	6		
	D.5	▨	5·0					1	2	2	5		
	D.6	▨	6·0					1	2	2	5		
	D.7	▨	7·0					1	2	3	6		
	D.8	▨	8·0	8·65 m.	Grey med. dense FINE SAND, some silt trace mica.			5	6	8	19		
	D.9	▨	9·0					5	4	4	13		
	D.10	▨	10·0					4	5	5	14		
	D.11	▨	11·0					5	6	6	17		
	D.12	▨	12·0					4	5	7	16		
	D.13	▨	13·0					6	9	9	24		
	D.14	▨	14·0					5	6	7	18		
	D.15	▨	15·0					5	7	10	22		
	D.16	▨	16·0										
	D.17	▨	17·0	4·00 m.	Grey med. dense COARSE SAND, little silt trace mica & stone.			6	7	9	22		
	D.18	▨	18·0					8	8	9	25		
	D.19	▨	19·0					5	8	9	22		
	D.20	▨	20·0					7	8	10	25		



▨ CLAY

▦ SILT

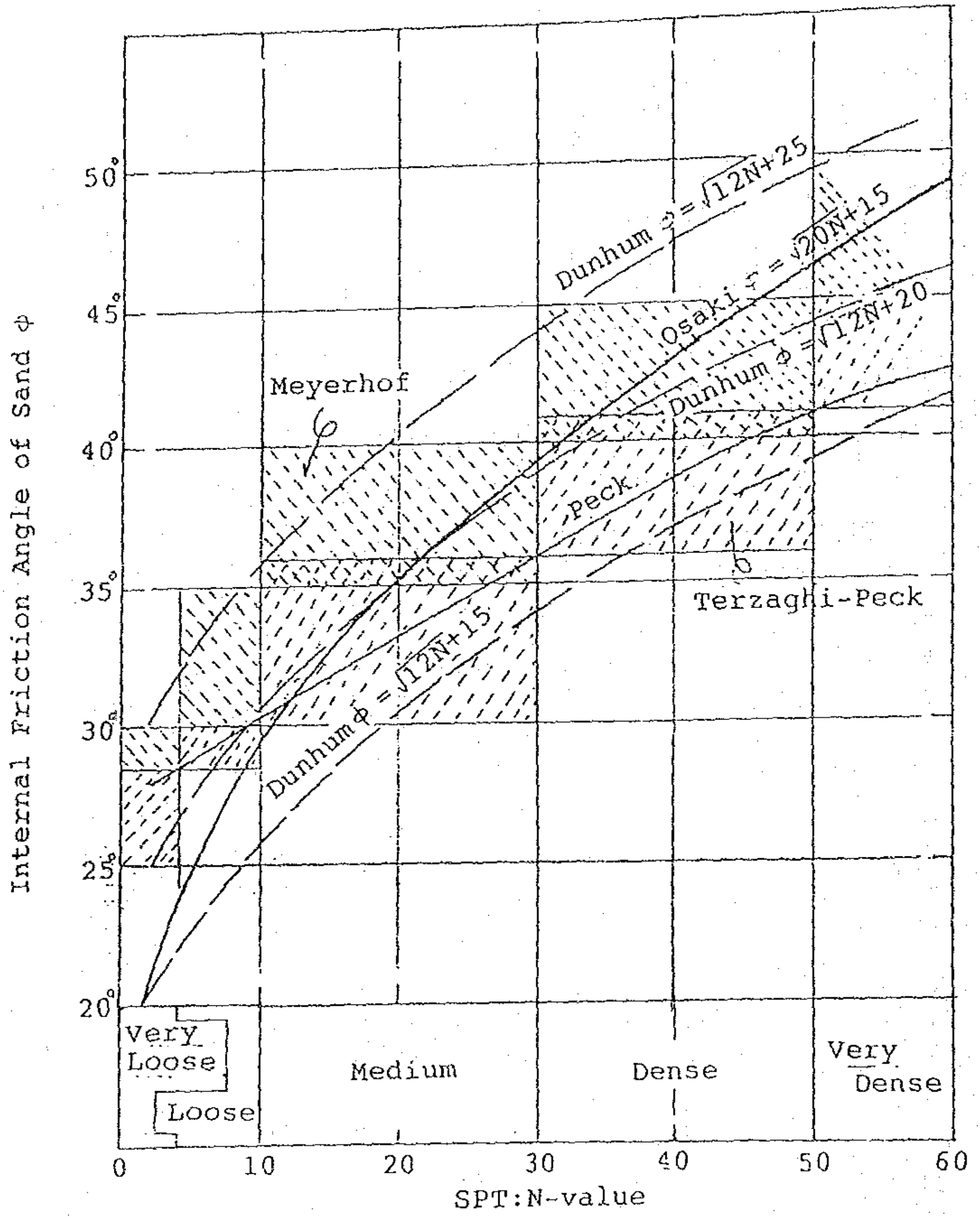
▤ SAND

△ MICA

○ ORGANIC

◇ STONE.

Fig.III.6.4 PROPOSED PUMPING STATION SITE (8/8)



Note; $\phi = \sqrt{12N+15}$: Grain with uniform size and round-shape
$\phi = \sqrt{12N+25}$: Grain with angilar-shape
and well distribution
$\phi = \sqrt{12N+20}$: Grain with round-shape
and well distribution, or
Grain with uniform size and angular-shape

Fig.III.7.1 RELATIONSHIP BETWEEN INTERNAL FRICTION ANGLE AND N-VALUES

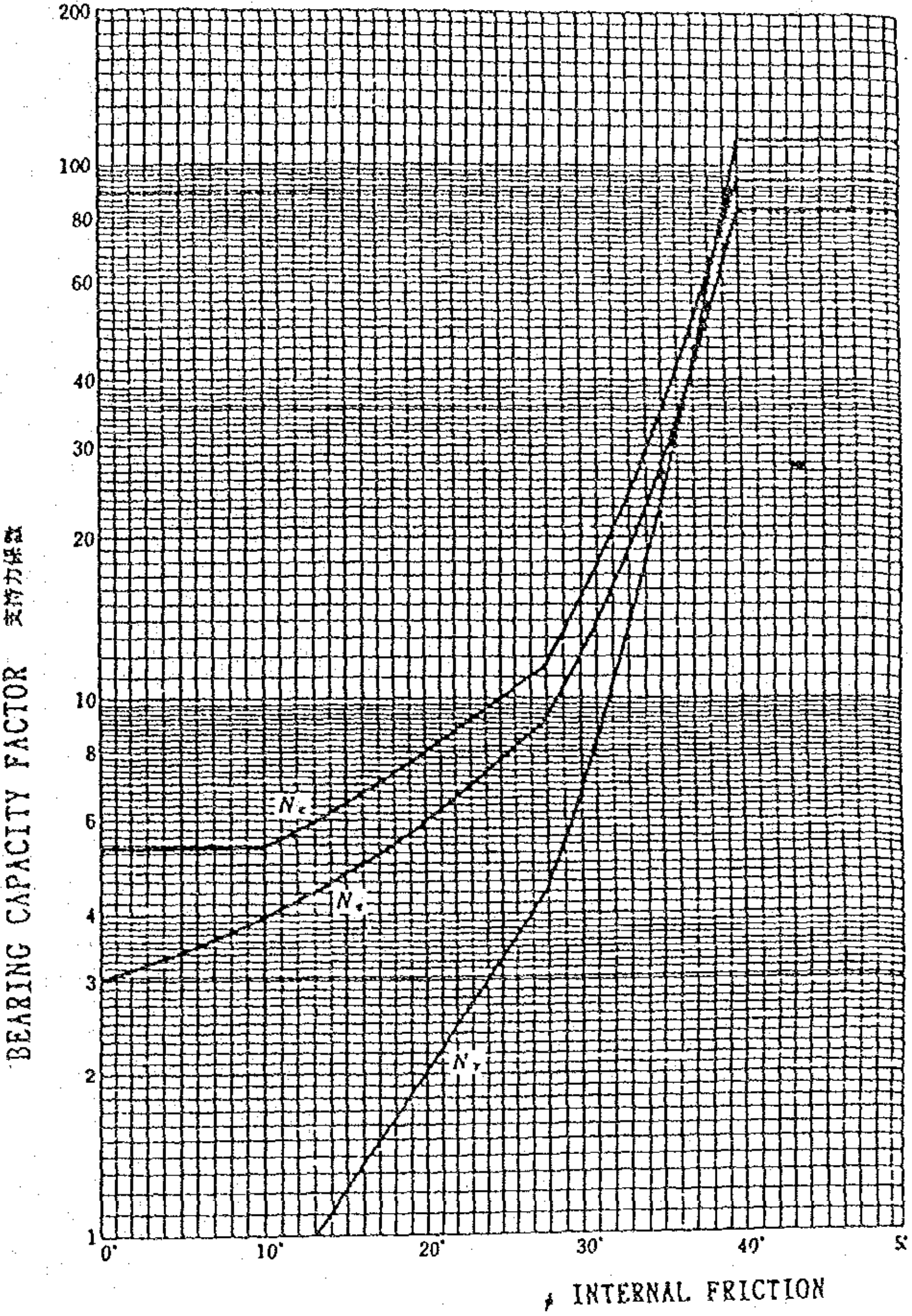


Fig.III.7.2 BEARING CAPACITY FACTOR

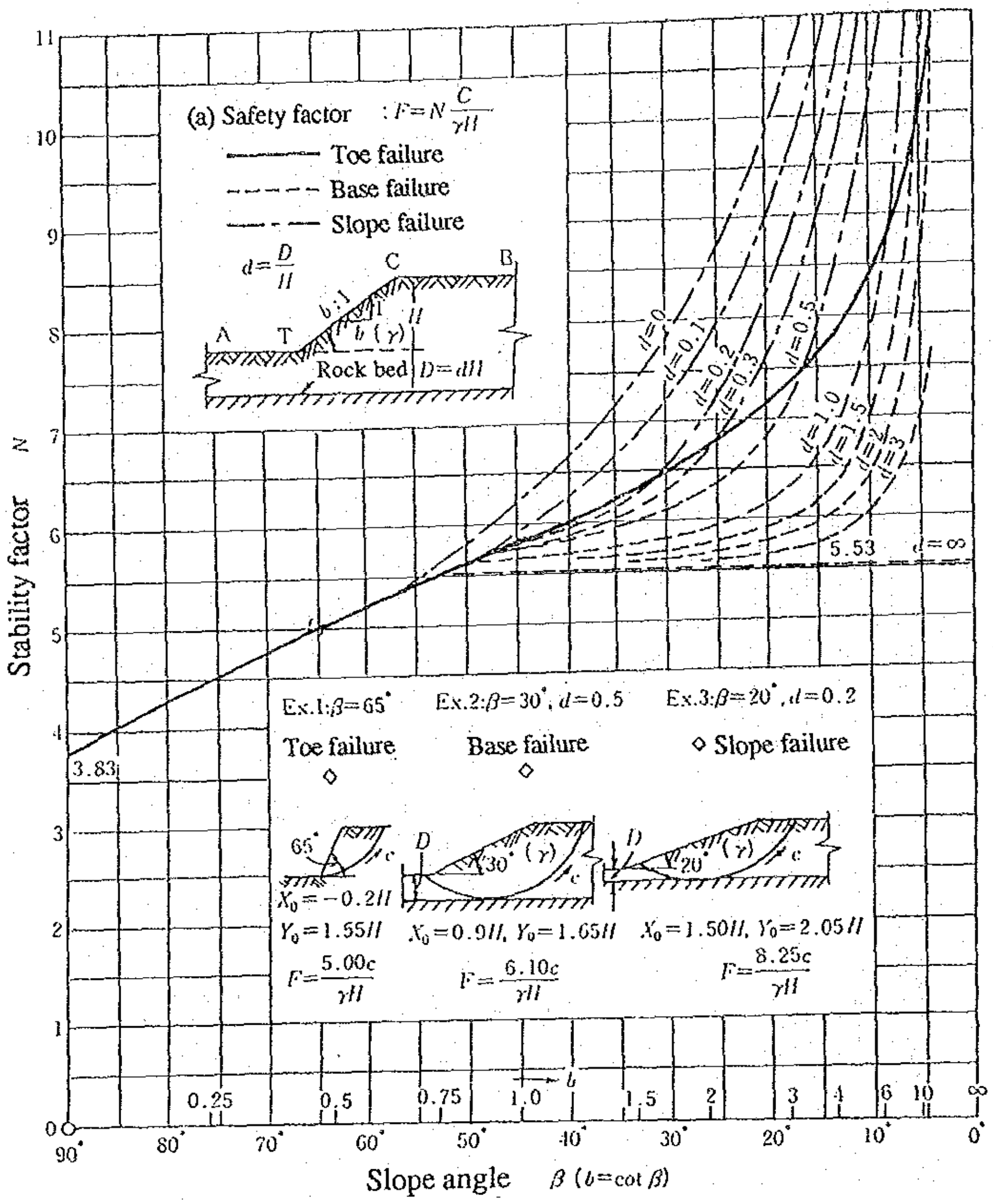
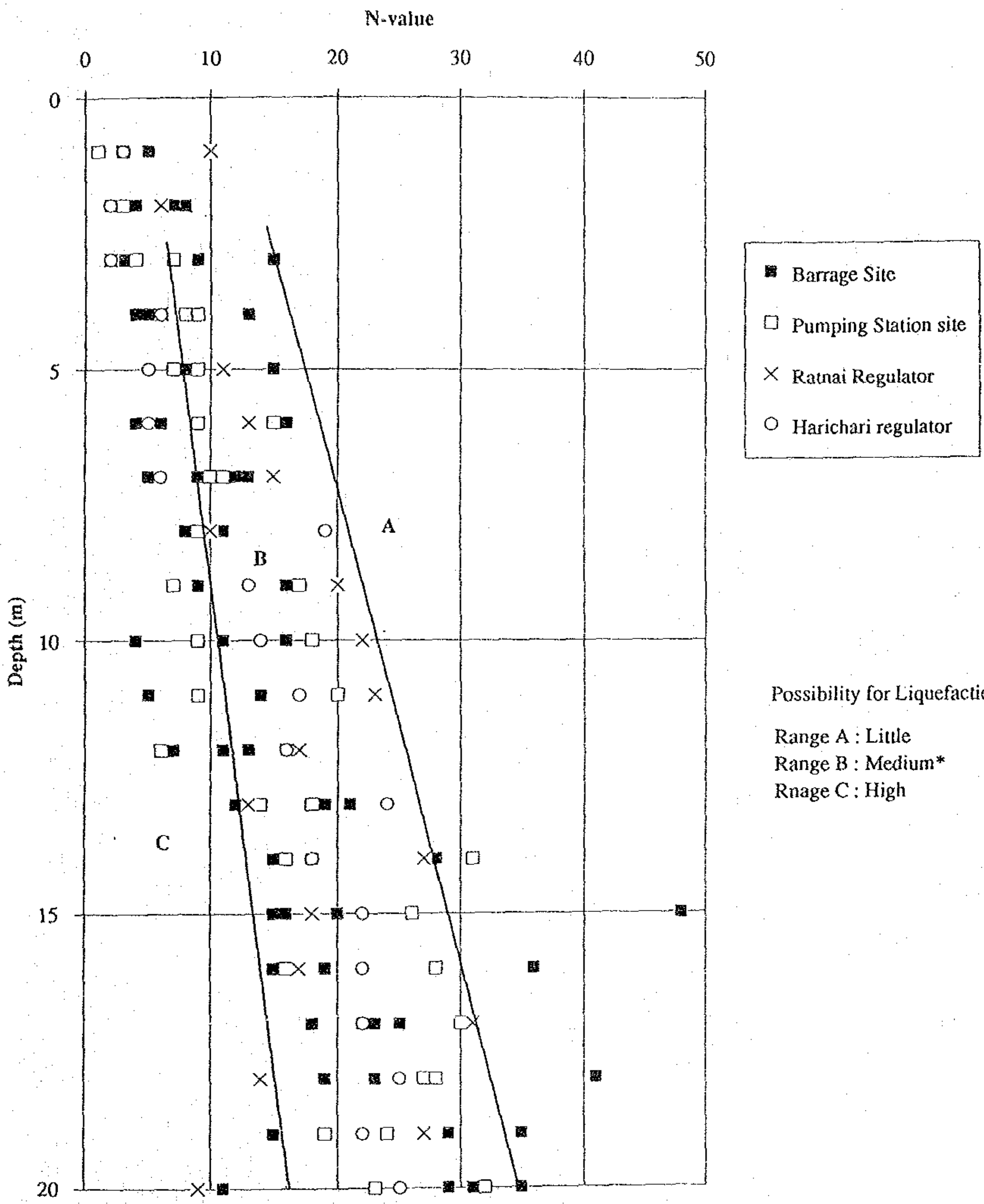


Fig.III.9.1 JANBU'S STABILITY CHART



Possibility for Liquefaction

Range A : Little
Range B : Medium*
Rnage C : High

Source: Standard for Structual Calculation of Reinforceced Concrete Foundation
Issued by the Architectural Institute of Japan

Note, Medium* : It is difficult to judge as the liquefaction is governed by
the characteristic of the ground and seismic mortion

Fig.III.11.1 POSSIBILITY OF LIQUEFACTION

APPENDIX - IV

EXISTING STW/DTW SCHEMES AND GROUND WATER POTENTIAL

FEASIBILITY STUDY ON

KURIGRAM IRRIGATION AND FLOOD CONTROL PROJECT (SOUTH UNIT)

APPENDIX - IV EXISTING STW/DTW SCHEM AND GROUNDWATER POTENTIAL

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APPENDIX-IV EXISTING STW/DTW SCHEMES AND GROUNDWATER POTENTIAL

1. General

The Phase-I Study recommended that the irrigation development should be made through conjunctive use of both groundwater and surface water resources. According to this basic concept, the groundwater potential survey was newly added under the Phase-II Study. The groundwater investigation consists of (a) data collection from the offices and agencies concerned, (b) questionnaire/interview survey focused on the present groundwater development condition by tubewells, (c) field for existing DTWs and (d)analys is ofcollected data and information in order to estimate groundwater potential in the Study area.

The required data were mainly obtained from the Thana Agricultural Office, the BADC Thana Office, the Groundwater Circle-II of the BWDB and the MPO. The collected data include actual operation data of the DTWs, groundwater level of 10 observation holes, geological and pumping test data of 54 DTWs and groundwater simulation data.

2. Existing STW/DTW Schemes

Present condition of minor irrigation development by STW/DTW is grasped through the questionnaire/interview and field surveys. The STWs have been constructedby local method,mainly oflocally manufactured components.The STW is usually 4 to 6 m from the ground surface and uses a centrifugal pump to lift groundwater by suction.The pump of the STW is located at the top of well at the ground surface and is driven by a 5 HP diesel engine with a normal discharge capacity of 14 l/sec. The DTWs have been drilled with imported machinery, lined with imported casing and screen. The depth of DTWs and its screen length range from 50 to 70 m and 24 to 30 m respectively. The DTW uses a turbine pump and most of wells are driven by 18 to 35 HP diesel engine with a normal discharge capacity of 57 l/sec.

The DTWs have been planned with 20 to 51 ha of scheme area and 14 to 50 ha of command area. The tubewells have been installed according to the following standard spacing rule.

Present spacing rule in Bangladesh

DTW to DTW	762 m	2,500 ft.
DTW to STW	549 m	1,800 ft.
STW to STW	244 m	800 ft.

There are some differences in number of tubewells between Phase-I survey and Phase-II survey. The revised number of tubewells and average areas irrigated by them are summarized as follows :

Thana	STW Installed (nos.)	STW Irri.Area (ha/well)	DTW Installed (nos.)	DTW Operated (1992) (nos.)	DTW Irri.Area (ha/well)
Lalmonirhat	523	3.6	45	25	18.9
Rajarhat	850	4.0	64	55	21.6
Kurigram	339	4.2	30	16	16.6
Ulipur	969	4.1	128	120	19.4
Chilmari	139	4.2	40	20	15.7
Total/(Weighted Average)	2,820	(4.0)	292	236	(19.4)

All of the tubewells in the Study area are not in operation, due to mechanical trouble, no commission or no consensus by well using farmer's group. Actual operation hours during 1992's irrigation season, from January to May, are generally 8 to 10 hours a day. In the case of the DTWs, annual operation hours are 521 hours on an average and 18 hours a day in maximum. The area irrigated by STWs ranges from 3.6 to 4.2 ha with an average of 4.0 ha. The irrigated area by DTWs varies from 15.7 to 21.6 ha with an average of 19.4 ha against the command area of 14 to 50 ha.

Among the existing irrigated area of 9,800 ha, about 4,600 ha (47 %) are covered by DTWs in this season and the rest of 5,200 ha (53 %) are irrigated by STWs. The number of operational STWs is estimated at about 1,300 which are about 46 % of existing installed number of STWs. The decrease in operational number of STWs is supposedly due to use for other purposes (cultivation, transportation, milling, etc.), depreciation over durable years, low capacity and less profitability, weak farmer's group, etc.

3. Hydrogeological Condition

3.1 Aquifer Condition

The Study area is underlain by upper silty to clayey layer, fine sand,medium sand and coarse sand as shown Figs.IV-1 to IV-5, Thana wise hydrogeological panel diagram. From thiscondition, aquifer formation in the Study area is divided into 3 units of top aquitard layer, composite aquifer and main aquifer. Occurrence probability of aquitard and aquifer materials were also analyzed based on the total 54 BADC DTW logs: 6 in Lalmonirhat, 22 in Rajarhat, 3 in Kurigram, 12inUlipur and 11inChilmari. The occurrence probability of materials for each Thana and the Study area is shown in Fig.IV-6.

The top aquitard layer consists of silty and clayey materials. The probability of occurrence of aquitard materials is 75 to 100 % at the depth up to 3 m, 17 to 66 % at the depth of 3 to 6 m, 0 to 34 % at the depth of 6 to 9m and less than 10 % at the depth below 9 m. The thickness of the top aquitard layer is 0 to 6m from the ground surface.

The composite aquifer consists of very fine to fine sand, sometimes medium sand with occasional silty layer. The probability of occurrence of very to fine sand is 17 to 82 % at the depth of 3 to 21 m, and decreases to 0 to50 % at the depth below 21 m. The composite aquifer appears at the depth from 3 to 18 5 and its thickness varies from about 9 to 15 m. In addition to the above, interbeded aquitard andfiner grained materials appear in Thana Lalmonirhat at the depth below 64 m, and the probability of very fine to fine sand is 33 to 60 %. Development potential of the transitional layer is poor because its grain size is too fine for high discharge well screen.

The main aquifer is one of a series of medium to coarse sands containing gravel layer. The main aquifer materials appears at the depth of 12 to 18 m with 50 to 100 % probability. The thickness ofthe main aquifer is more than 40 m in every Thana. Fromthe materials characteristics,the main aquifer is suitable for groundwater development by using high discharge screened wells. The aquifer condition for eachThana is summarized as follows :

Aquifer System	Lalmonirhat	Rajarhat	Kurigram	Ulipur	Chilmari	Study Area
1) <u>Aquitard Layer: Silty to clayey layer</u>						
Depth (m)	0 - 6	0 - 6	0 - 3	0 - 3	0 - 3	0 - 3
Thickness (m)	6	6	3	3	3	3
Probability (%)	67 - 100	55 - 100	100	75	73	91
2) <u>Composite Aquifer: Very fine to fine sand</u>						
Depth (m)	6 - 15	6 - 15	3 - 15	3 - 18	3 - 12	3 - 15
Thickness (m)	9	9	12	15	9	12
Probability (%)	50 -67	59 - 68	33 - 6	58 - 92	63 -82	55 - 72
3) <u>Main Aquifer: Medium to coarse sand with gravel</u>						
Depth (m)	15 - 64	15 - 61>	15 - 55>	18 - 61>	12 -61>	15 - 61
Thickness (m)	49	46>	40>	43>	49>	46>
Probability (%)	50 -100	50 - 100	100	58 - 100	55 - 100	56 -100

3.2 Hydraulic Properties

1) Specific Yield

The typical specific yield for each materials has been estimated by the MPO as follows:

Sandy to silty clay:	2 %	Fine sand:	10 %
Silt to very Fine sand:	5 %	Medium sand:	15 %
Very fine sand:	8 %	Coarse sand:	25 %

Based on the above typical values and occurrence probability of materials, the specific yield for each aquifer formation was computed. The specific yield ranges from 3 to 6 % in the aquitard layer, 8 to 20 % in the composite aquifer and 18 to 25 % in the main aquifer. Vertical distribution of the specific yield for each Thana and the Study area are also shown in Fig. IV-6.

2) Specific Drawdown, Specific Capacity and Transmissivity

Total 54 DTWs pump test records conducted by the BADC during Dec.'88 to Jan.'90 were collected. According to the 4 hr multiple step test, the total drawdown under the 3 cusec discharge and the specific drawdown of the mainaquifer vary from 3.57 to 13.56 m with an average of 5.22 m and 1.19 to 2.85 m/csc with an average of 1.74 m/csc.

The specific capacity of the aquifer was calculated from the relationship between discharge and net drawdown. Thenet drawdown was obtained from the following Jacob's formula.

$Sw = BQ + CQ^2$

where, Sw : Total drawdown
BQ : Net drawdown designated as formation loss
CQ^2 : Part of drawdown designated as well loss
B,C : Formation loss and well loss coefficient
Q : Discharge

The specific capacities in the Study area range from 10 to 26 l/sec/m with a mean value of 20 l/sec/m. According to the MPO, good theoretical relationship between transmissivity(T) and specificcapacity(SC) has been established for Bangladesh. The theoretical curve obtained shows $T = 95.1\ SC^{1.07}$. From this relation, the transmissivity in the Study area is estimated to be about 1,100 to 3,000 m^2/day. The specific drawdown, specific capacity and transmissivity of the aquifer at each DTW are shown in Table IV-1, and its Thana-wise mean values are summarized below:

Thana	Specific Drawdown (m/cusec)	Specific Capacity (l/sec/m)	Transmissivity (m2/day)
Lalmonirhat	2.63	14.4	1,658
Rajarhat	1.83	19.07	2,230
Kurigram	1.56	22.43	2,652
Ulipur	1.45	21.52	2,540
Chilmari	3.81	22.45	2,656
Study area	1.74	19.85	2,341

The obtained values are quite high, therefore it indicates that the interference between the allowable spaced wells is less.

3.3 Groundwater Level

Groundwater level in and around the Study area has been measured weekly by the Groundwater Circle II of the BWDB from a observation hole network, 3 holes in Lalmonirhat, 3 holes in Kurigram, 2 holes each in Ulipur and Chilmari as shown in Fig.IV-7. The observation data including survey period, highest and lowest groundwater level were summarized as shown below;

Hole No.	Thana	Mauza	Measuring Period (Since)	Elevation of Hole (m)	Heighest Water Level		Lowest Water Level		Fluctuation (m)
					Level (G.L-m)	Date	Level (G.L-m)	Date	
RA-32	Lalmonirhat	Lalmonirhat	May '67	33.21	0.05	Jul.'82	3.97	May '68	3.92
RA-70		Gokunda	May '79	29.75	0.20	Jul.'85	3.58	Nov.'83	3.38
RA-75		Khodrasaptana	Apr.'78	33.40	0.61	Oct.'86	2.67	May '86	2.06
RA-37	Kurigram	Kurigram	Jan.'67	27.37	1.35	Jul.'72	6.05	Apr.'79	4.70
RA-65		Sara	Apr.'81	27.75	0.00	Jul.'84	5.13	Nay '89	5.13
RA-76		Hingonroyi	Mar.'78	26.99	0.70	Aug.'88	6.44	May '89	5.74
RA-38	Ulipur	Ulipur	Jan.'61	25.78	0.00	Aug.'83	4.54	May '69	4.54
RA-64		Durgapur	Jan.'78	26.39	0.03	Aug.'88	4.80	May '89	4.77
RA-63	Chilmari	Thanahat	Jan.'78	23.32	0.02	Aug.'87	4.35	May '89	4.33
RA-81		Ramna	Jan.'80	23.78	0.41	Aug.'87	4.78	May '83	4.37

Groundwater level in the Study area is generally shallow. The high water level ranges from 0 to 4 m from ground surface and the high water level is2.7to 6.5 m. The lowest groundwater level appears in April. It rises by recharge during May and reaches its highest level in late July. After keeping the highest level during August to September, the groundwater level gradually draw down to its lowest level. Seasonal fluctuation of the groundwater level ranges from 3.4 to 5.1 m. The groundwater fluctuation from1986 to1989 in the Study area is shown in Figs.IV-8 to IV-11.

4. Groundwater Recharge

The comprehensive assessment of groundwater resources in Bangladesh has been made by the MPO through the Phase-I and Phase-II studies of the NWP. The national/regional basis groundwater recharge has been calculated in the Phase-I study by simulating the recharge process on the basis of rainfallandevaporation records for the periodfrom 1964to 1982 using a 10 day time step, and re-evaluated during the Phase-II study using hydrological data from 1972/73 to 1988/89 and additional data.

In addition to the national/regional wise recharge, Thana level groundwater recharge has also been calculated during the Phase-II of the NWP. The simulation model for recharge calculation includes various parameters such as land type, soil characteristics, percolation rate, rainfall, evapotranspiration,surfacewater storage capacity, surface run-off and cropping pattern.

Three recharge types have been defined by the MPO, viz. potential recharge, usable recharge and available recharge. The potential recharge defined as the maximum annual volume of surface water entering the aquifer. The usable recharge has been taken as 75% of the potential recharge considering the calibration error and future land use changes. The available recharge is an aerial modification of the usable recharge considering the development constrains such as salinity,terrain,etc. It has been estimated at 76.38 to 97.22 % of the usable recharge for each Thana in the Study area.

The recharge rate (depth) and available recharge for each Thana in the Study area are summarized below:

Thana	Area (km2)	Potential Recharge (mm)	Usable Recharge (mm)	Available Recharge (mm)	(MCM)
Lalmonirhat	120.7	550	413	390	47.07
Rajarhat	147.5	600	450	437	64.46
Kurigram	71.1	338	283		20.12
Ulipur	217.3	500	375	311	67.58
Chilmari	37.4	500	375	286	10.70
Study Area	594.0			(353)	209.93

Total available recharge in the Study area of 594 km2 (inside of the main embankment) is 210 MCM or 353 mm.

5. Groundwater Development Potential

The Optimum groundwater development potential on Thana basis has been derived by the MPO by simulating the recharge, available storage in the aquifer system, well technology and hydraulic constrains.

In the assessment of development potential,pumping discharge was used 0.5 cusec in STW and 2.0 cusec in DTWs. The pumping limits in the technology were used 7 m in STW and 20 m in DTW from the ground surface which were evaluated considering the safe-yield basis. Based on the depth of MPO estimate, the usable recharge and unconstrained development potential by the said technology in the Study area were obtained and summarized as follows:

		Usable Recharge		Unconstrained Development Potential			
				STW (0.5 csc)		DTW (2 csc)	
Thana	Area (km2)	Volume (MCM)	Depth (mm)	Volume (MCM)	Depth (mm)	Volume (MCM)	Depth (mm)
Lalmonirhat	120.7	49.85	413	47.44	393	49.85	413
Rajarhat	147.5	66.38	450	49.86	338	66.38	450
Kurigram	71.1	24.03	338	13.69	191	24.03	338
Ulipur	217.3	81.49	375	79.75	367	81.49	375
Chilmari	37.4	14.03	375	9.39	251	14.03	375
Study Area	594.0	235.78	397	200.13	337	235.78	397

The total unconstrained groundwater development potential in the Study area was estimated at 200 MCM or 337 mm for STWs and 236 MCM or 397 mm for DTWs.

Table IV-1 Specific Drawdown,Specific Capacity and Transmissivity in the Study Are

DTW No. (JL-Plot)	Depth of DTW (m)	Screen Length (m)	Date of Testing	Static Level (m:-GL)	Discharge		Total Draw-down (m)	Specific Draw-down (m/csc)	Well Loss Constant		Well Loss CQ2 (m)	Net Draw-down (m)	Specific Capacity (l/sec/m)	Trans-missivity (m2/m)
					(csc)	(l/sec)			B	C				
Thana:Lalmonirhat														
2-9730	61	30	Dec.'89	2.62	3	84.95	7.28	2.43	0.35	0.69	1.89	5.38	15.78	1820
23- 295	60	30	Apr.'89	2.62	3	84.95	7.28	2.43	0.35	0.69	1.89	5.38	15.78	1820
78- 334	60	30	May '89	4.32	3	84.95	7.37	2.44	1.06	0.46	1.26	6.10	13.92	1591
85- 431	62	30	Apr.'89	2.62	3	84.95	7.04	2.43	0.33	0.70	1.92	5.12	16.59	1920
116- 194	66	30	Dec.'89	3.25	3	84.95	7.90	2.63						
124-1836	51	24	Jan.'90	2.90	3	84.95	8.56	2.85	2.61	0.08	0.22	8.34	10.19	1140
Thana Mean								2.53	0.94	0.52			14.45	1658
Thana:Rajarhat														
8- 149	57	30	Feb.'89	3.18	3	84.95	3.90	1.30	3.78	0.04	0.11	3.79	22.42	2651
12- 624	63	30	May '89	3.35	3	84.95	5.77	1.92	4.66	0.37	1.01	4.75	17.88	2081
12-2304	63	30	Apr.'89	3.40	3	84.95	5.51	1.84	4.13	0.46	1.26	4.25	19.99	2344
18-1455	57	30	Jun.'89	3.07	3	84.95	5.74	1.91	4.39	0.45	1.23	4.51	18.85	2202
19- 442	63	30	Apr.'89	4.11	3	84.95	5.77	1.92	4.54	0.41	1.12	4.64	18.30	2133
20- 478	57	30	Apr.'89	5.23	3	84.95	5.74	1.91	4.36	0.46	1.26	4.48	18.97	2217
23- 305	63	30	Dec.'88	1.98	3	84.95	4.58	1.53	4.10	0.16	0.44	4.15	20.49	2407
23-2113	71	30	Jun.'89	2.97	3	84.95	5.77	1.92	4.45	0.44	1.21	4.56	18.63	2175
27- 415	63	30	Jan.'89	1.52	3	84.95	5.05	1.68	3.46	0.53	1.45	3.60	23.59	2799
29- 518	69	30	Jan.'89	2.03	3	84.95	6.63	2.21	5.40	0.41	1.12	5.50	15.43	1777
31- 41	63	30	Jan.'89	2.21	3	84.95	5.50	1.83	4.57	0.31	0.85	4.65	18.27	2130
37- 612	60	30	Jun.'89	1.75	3	84.95	5.66	1.89	4.37	0.43	1.18	4.48	18.94	2213
43- 342	63	30	Jun.'89	1.83	3	84.95	5.77	1.92	4.54	0.41	1.12	4.64	18.30	2133
43-1303	60	30	Apr.'89	3.35	3	84.95	5.30	1.76	3.77	0.51	1.40	3.90	21.80	2572
49- 972	63	30	Jan.'89	2.90	3	84.95	5.77	1.92	4.45	0.44	1.21	4.56	18.63	2175
49-1568	66	30	May '89	4.42	3	84.95	5.79	1.93	4.50	0.43	1.18	4.61	18.42	2148
49-1752	60	30	Jan.'89	2.08	3	84.95	4.37	1.45	3.50	0.29	0.80	3.57	23.77	2822
70- 138	57	30	Apr.'89	3.84	3	84.95	5.99	2.00	4.70	0.43	1.18	4.81	17.64	2051
82- 250	63	30	Jan.'89	2.13	3	84.95	5.32	1.77	4.54	0.26	0.71	4.61	18.44	2150
91-7774	65	30	May '89	2.97	3	84.95	5.77	1.92	4.45	0.44	1.21	4.56	18.63	2175
171- 476	60	30	Dec.'88	1.83	3	84.95	5.63	1.87	4.91	0.24	0.66	4.97	17.10	1984
173- 209	63	30	Dec.'88	1.83	3	84.95	5.79	1.93	5.67	0.04	0.11	5.68	14.95	1718
Thana Mean								1.83	4.42	0.36			19.07	2230
Thana:Kurigram														
12- 792	50	24	Apr.'89	4.88	3	84.95	5.31	1.77						
33- 873	48	24	Apr.'89	4.06	3	84.95	4.09	1.35	3.76	0.11	0.30	3.79	22.43	2652
62-7553	51	24	Nov.'89	3.23	3	84.95	4.65	1.55						
Thana Mean								1.56						
Thana:Ulipur														
58- 722	57	30	May '89	4.00	3	84.95	4.51	1.50	3.91	0.20	0.55	3.96	21.45	2528
60- 597	53	27	Dec.'88	2.24	3	84.95	4.56	1.52	4.53	0.01	0.03	4.53	18.75	2189
69-9171	54	30	Mar.'90	3.51	3	84.95	5.80	1.93	5.44	0.12	0.33	5.47	15.52	1788
84-1798	57	24	Jun.'89	0.46	3	84.95	5.46	1.82	5.13	0.11	0.30	5.16	16.47	1905
98-1793	54	27	Jan.'89	2.34	3	84.95	3.71	1.23	3.38	0.11	0.30	3.41	24.94	2970
99- 545	54	27	Jan.'89	2.82	3	84.95	3.56	1.19	3.29	0.09	0.25	3.31	25.67	3064
100-2567	54	27	Jan.'89	2.49	3	84.95	4.25	1.42	4.16	0.03	0.08	4.17	20.36	2391
134- 86	57	30	May '89	3.40	3	84.95	4.28	1.43	4.13	0.05	0.14	4.14	20.51	2409
145-2203	54	27	Jan.'89	2.69	3	84.95	4.05	1.35	3.39	0.22	0.60	3.45	24.64	2932
155-1252	51	24	Jan.'89	2.03	3	84.95	3.78	1.26	3.21	0.19	0.52	3.26	26.03	3110
167- 494	54	27	Jan.'89	3.51	3	84.95	3.57	1.19	3.39	0.06	0.16	3.40	24.96	2973
173- 120	51	24	Mar.'90	4.57	3	84.95	4.67	1.56	4.46	0.07	0.19	4.48	18.96	2215
Thana Mean								1.45	4.04	0.11			21.52	2540
Thana:Chilmari														
1-852	57	30		4.72	3	84.95	3.38	1.17	3.02	0.12	0.33	3.05	27.86	3345
3- 12	54	27		3.05	3	84.95	5.13	1.72						
5-4604	49	24	Feb.'89	3.45	3	84.95	4.27	1.42	4.21	0.02	0.05	4.21	20.17	2367
7-3717	51	24	Jan.'89	3.43	3	84.95	4.17	1.39	3.75	0.14	0.38	3.78	22.46	2656
7-5566	54	27	Jan.'89	4.06	3	84.95	5.00	1.67	4.46	0.18	0.49	4.51	18.84	2200
9-1712	57	24	Feb.'89	3.76	3	84.95	4.58	1.53	4.52	0.02	0.05	4.53	18.75	2190
9-2471	51	24	Feb.'89	3.68	3	84.95	4.50	1.51	3.93	0.19	0.52	3.97	21.37	2519
13- 790	57	27	Jan.'89	4.34	3	84.95	3.68	1.23	3.23	0.15	0.41	3.27	25.97	3102
13-1502	60	27	Jan.'89	4.85	3	84.95	4.83	1.61	4.05	0.26	0.71	4.11	20.66	2428
14- 34	57	27	Jan.'89	2.51	3	84.95	3.89	1.30	3.47	0.14	0.38	3.50	24.26	2884
14-1072	54	27	Jan.'89	2.69	3	84.95	3.82	1.27	3.49	0.11	0.30	3.52	24.13	2867
Thana Mean								1.44	3.81	0.13			22.45	2656
Study Area Mean								1.74	3.80	0.27			19.85	2329

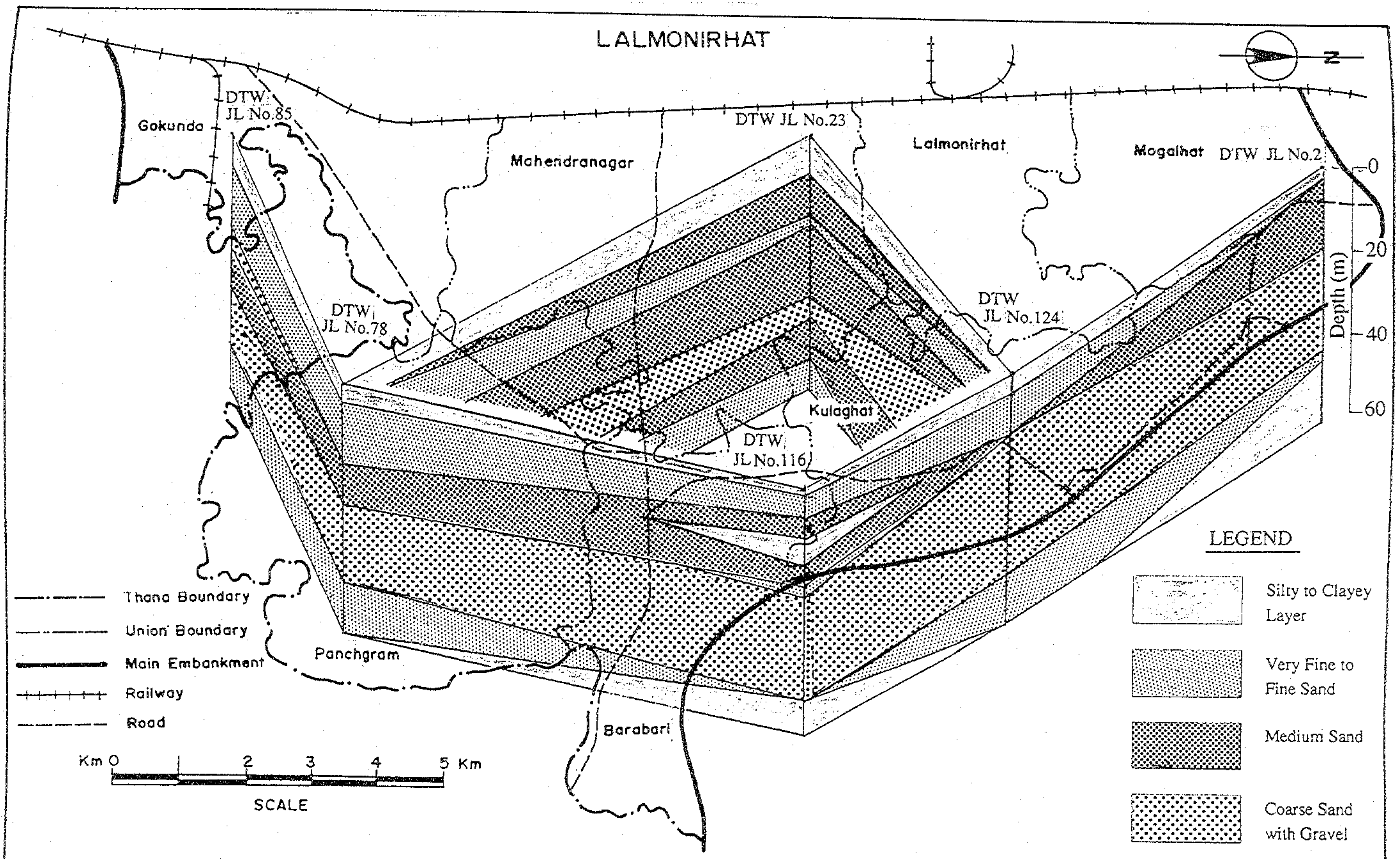

Fig.IV-1 HYDROGEOLOGICAL PANEL DIAGRAM IN LALMONIRHAT

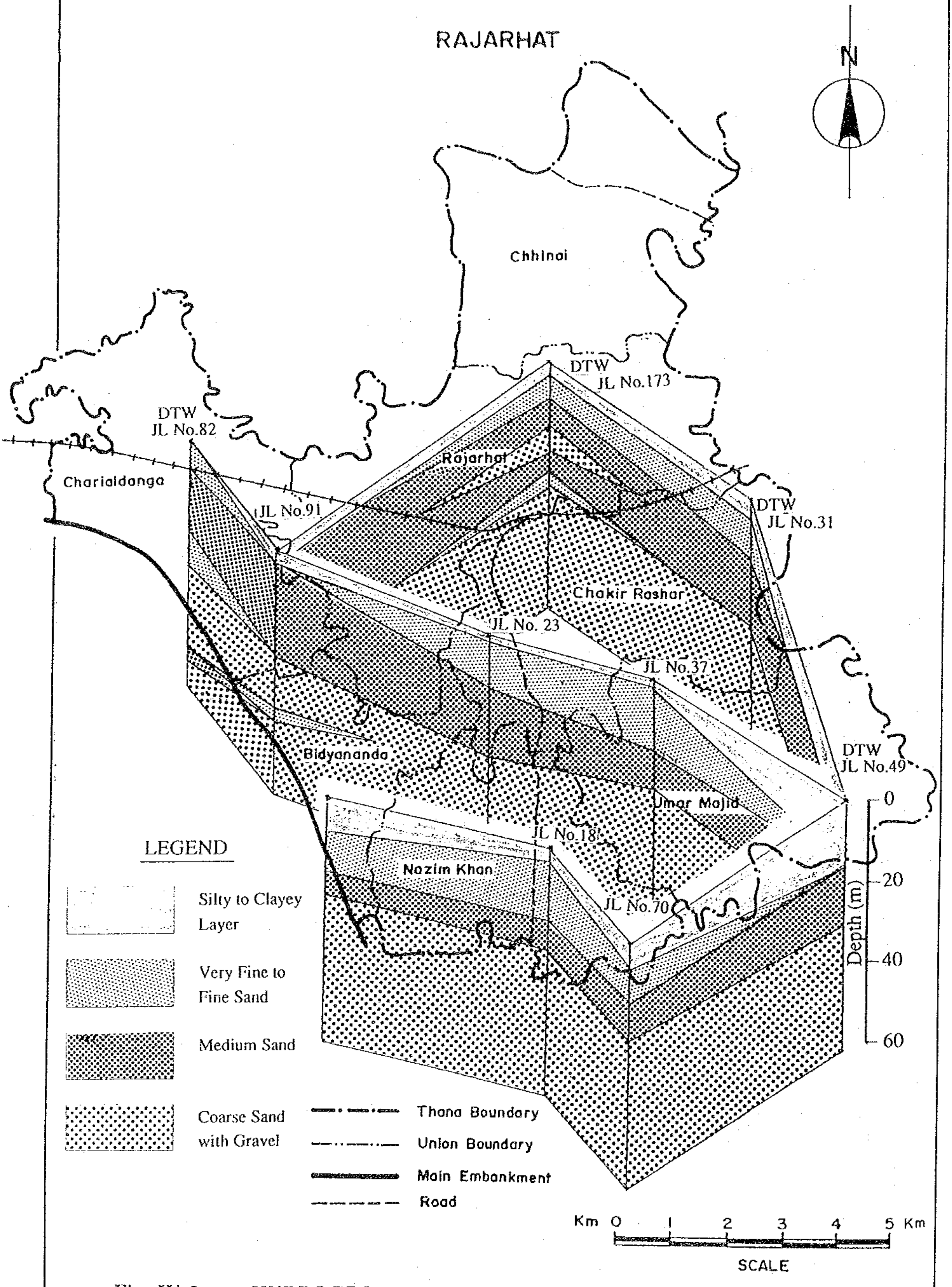

Fig. IV-2 HYDROGEOLOGICAL PANEL DIAGRAM IN RAJARHAT

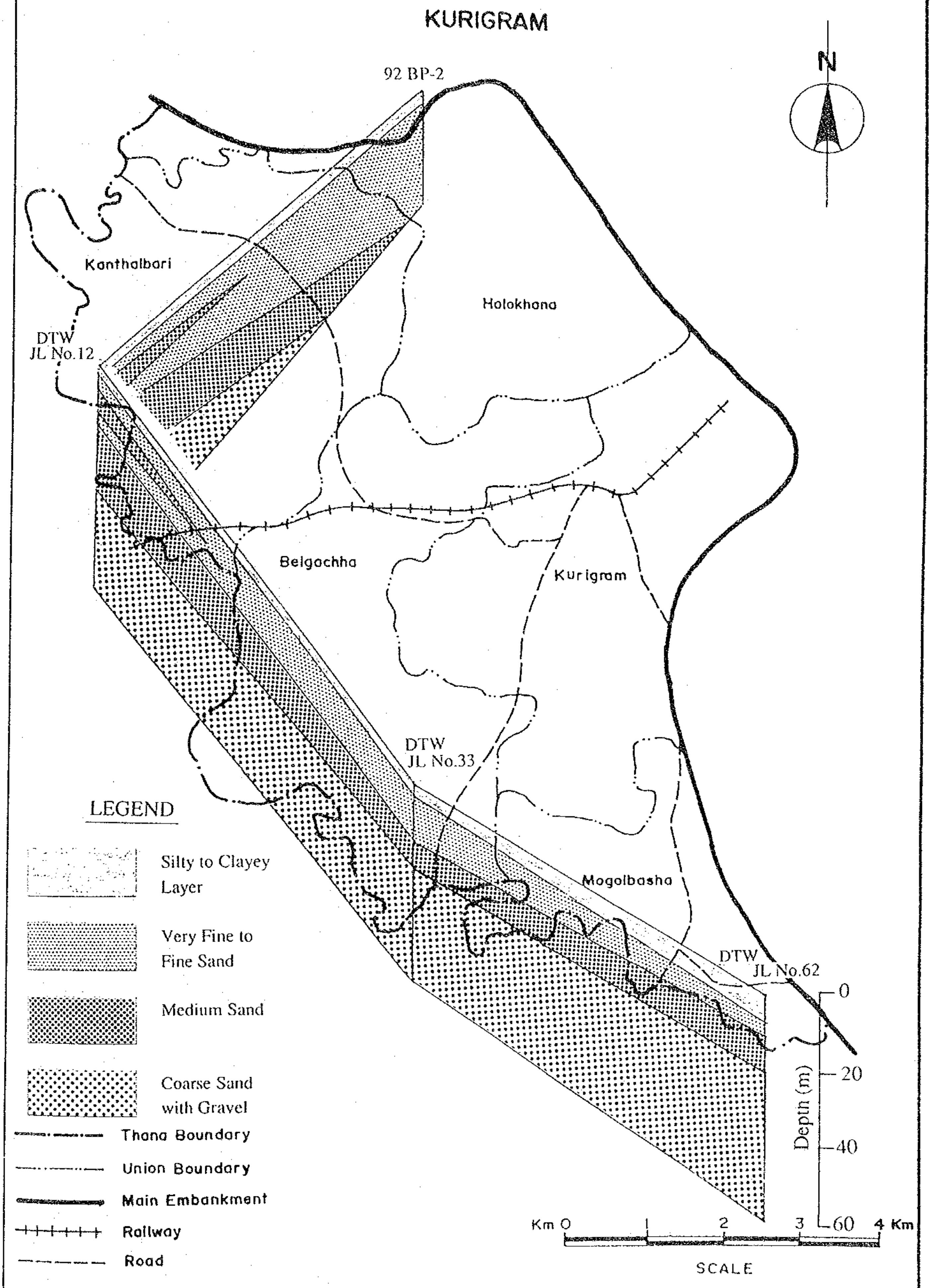

Fig. IV-3 HYDROGEOLOGICAL PANEL DIAGRAM IN KURIGRAM

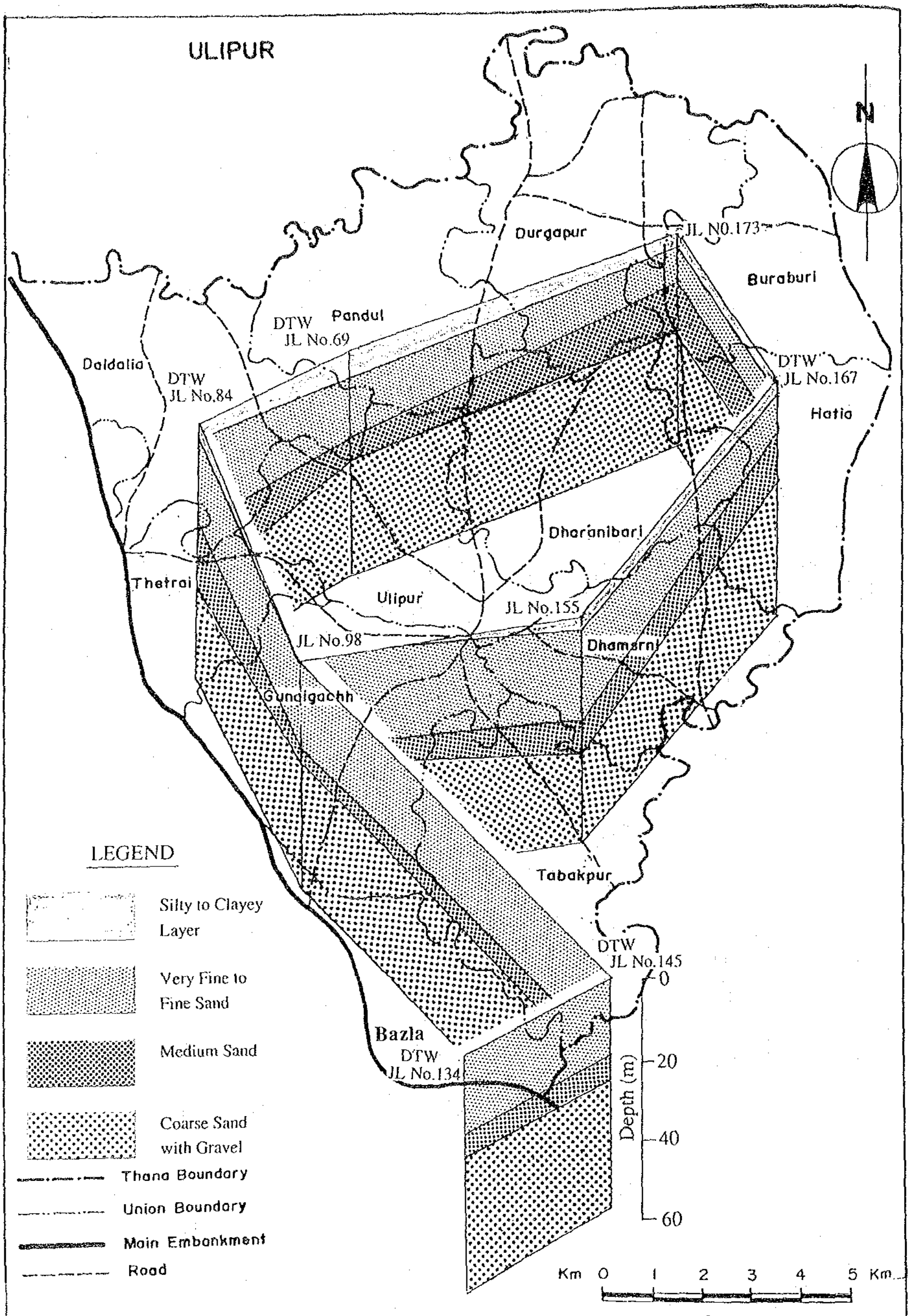

Fig. IV-4 HYDROGEOLOGICAL PANEL DIAGRAM IN UILIPUR

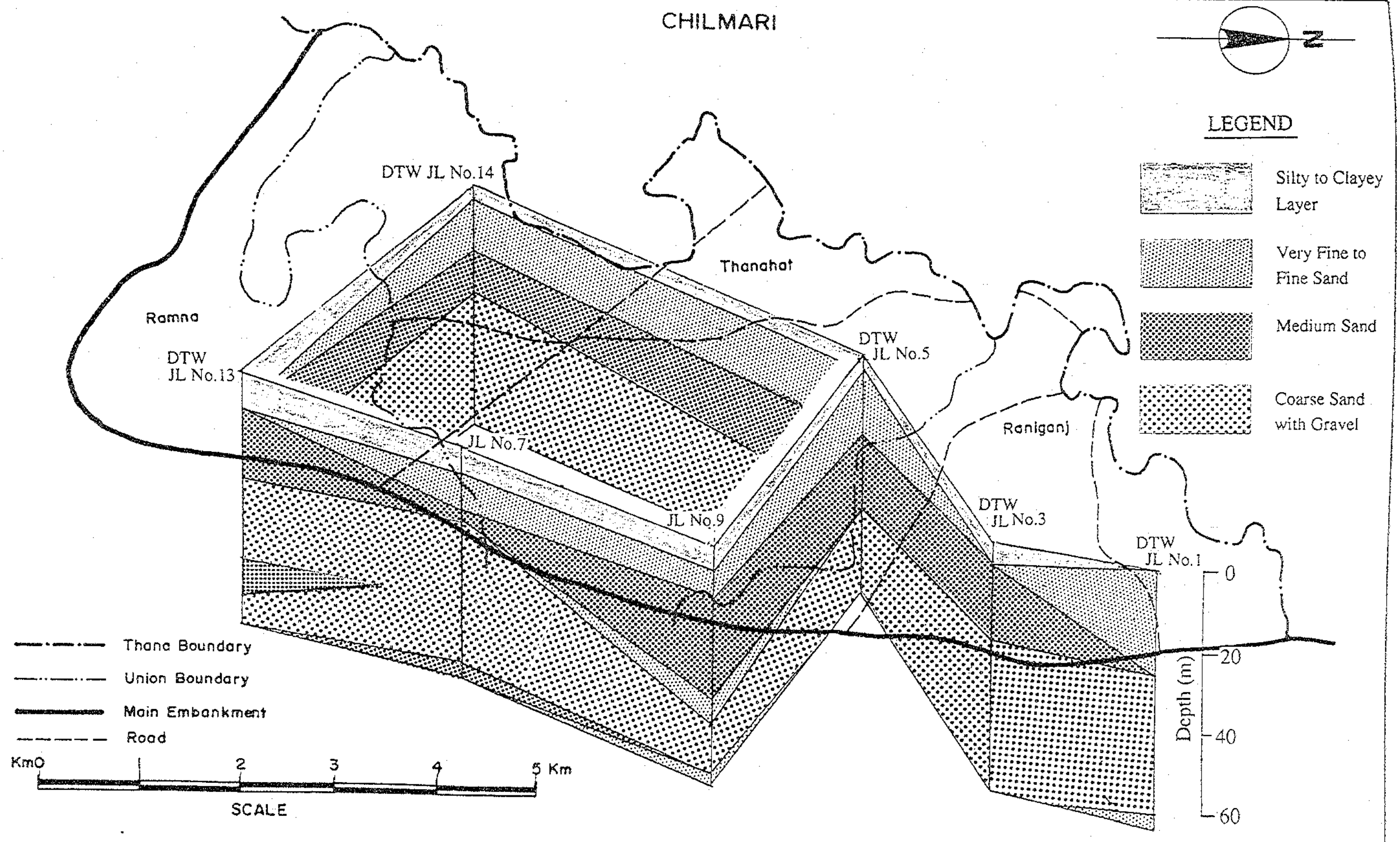

Fig. IV-5 HYDROGEOLOGICAL PANEL DIAGRAM IN CHILMARI

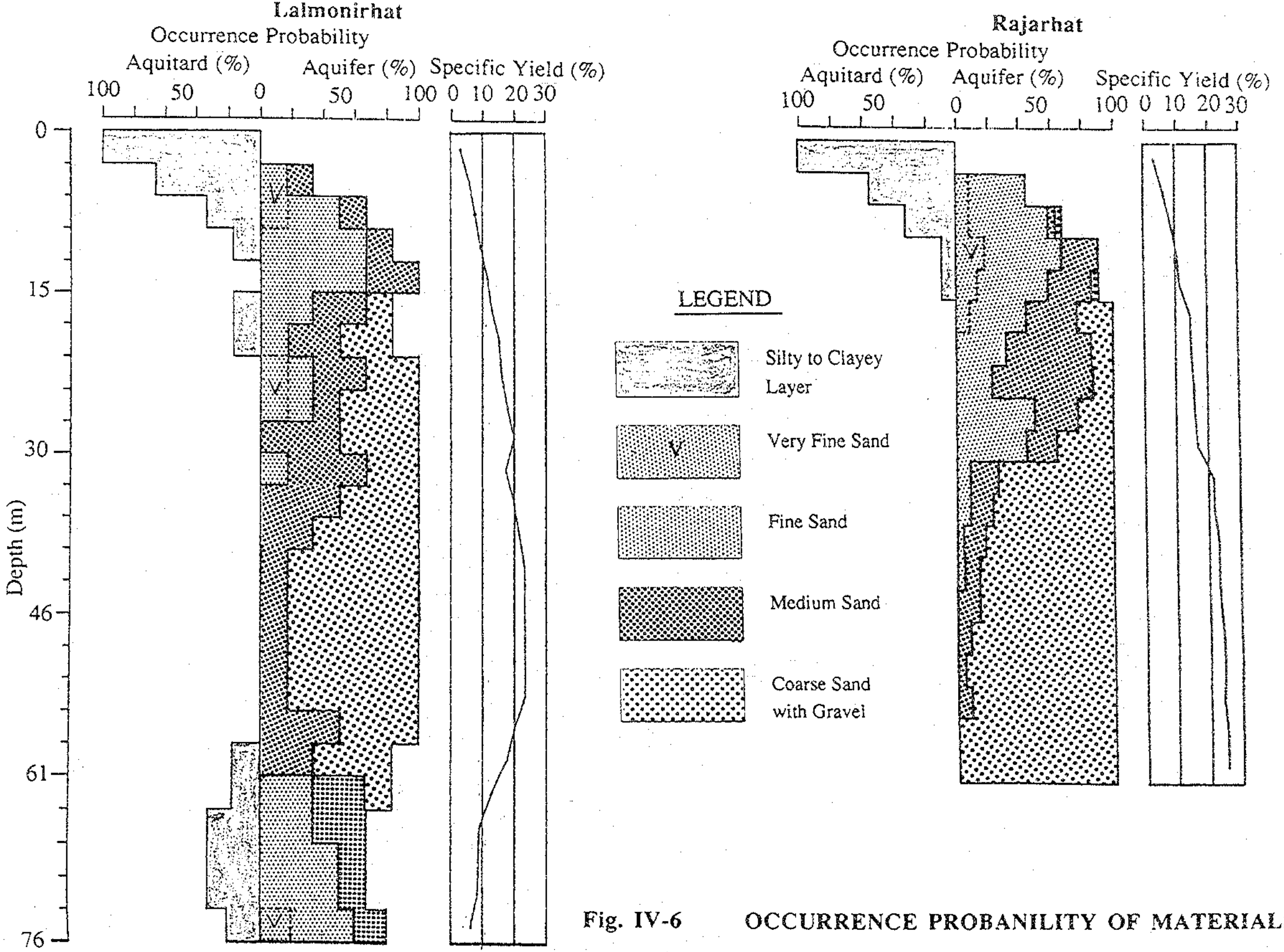

Fig. IV-6 OCCURRENCE PROBANILITY OF MATERIALS (1/3)

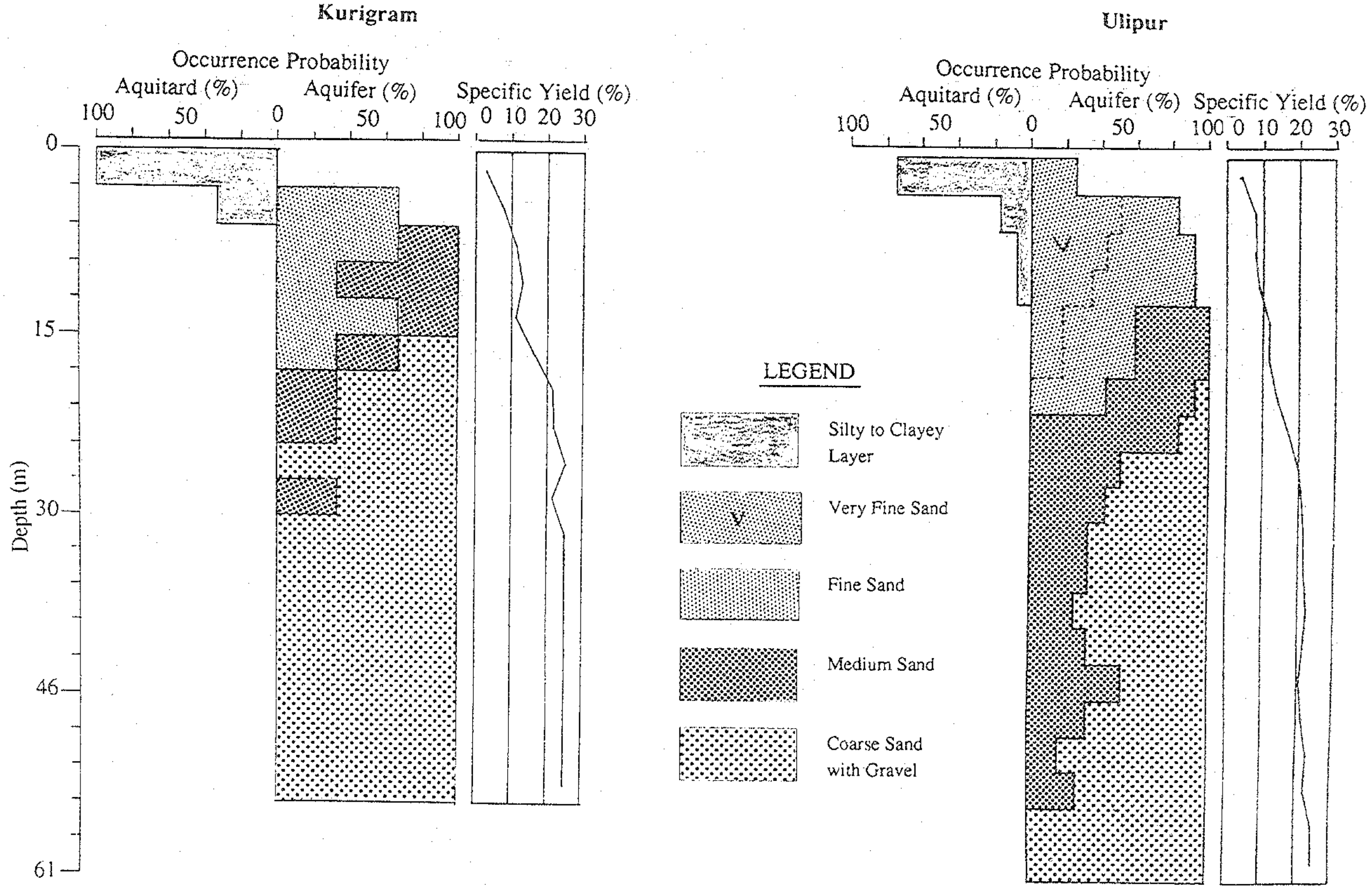

Fig. IV-6 OCCURRENCE PROBANILITY OF MATERIALS (2/3)

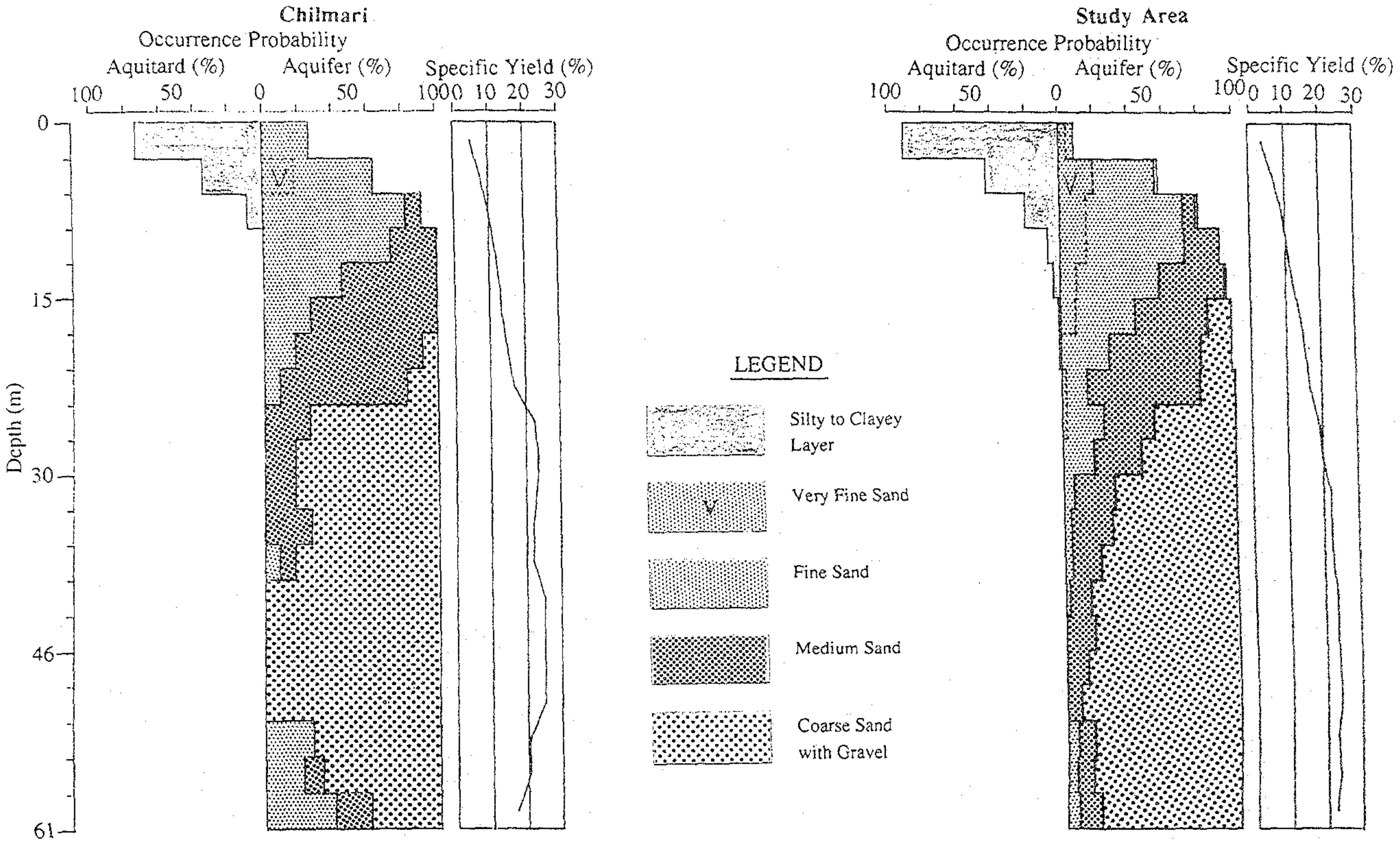

Fig. IV-6 OCCURRENCE PROBANILITY OF MATERIALS (3/3)

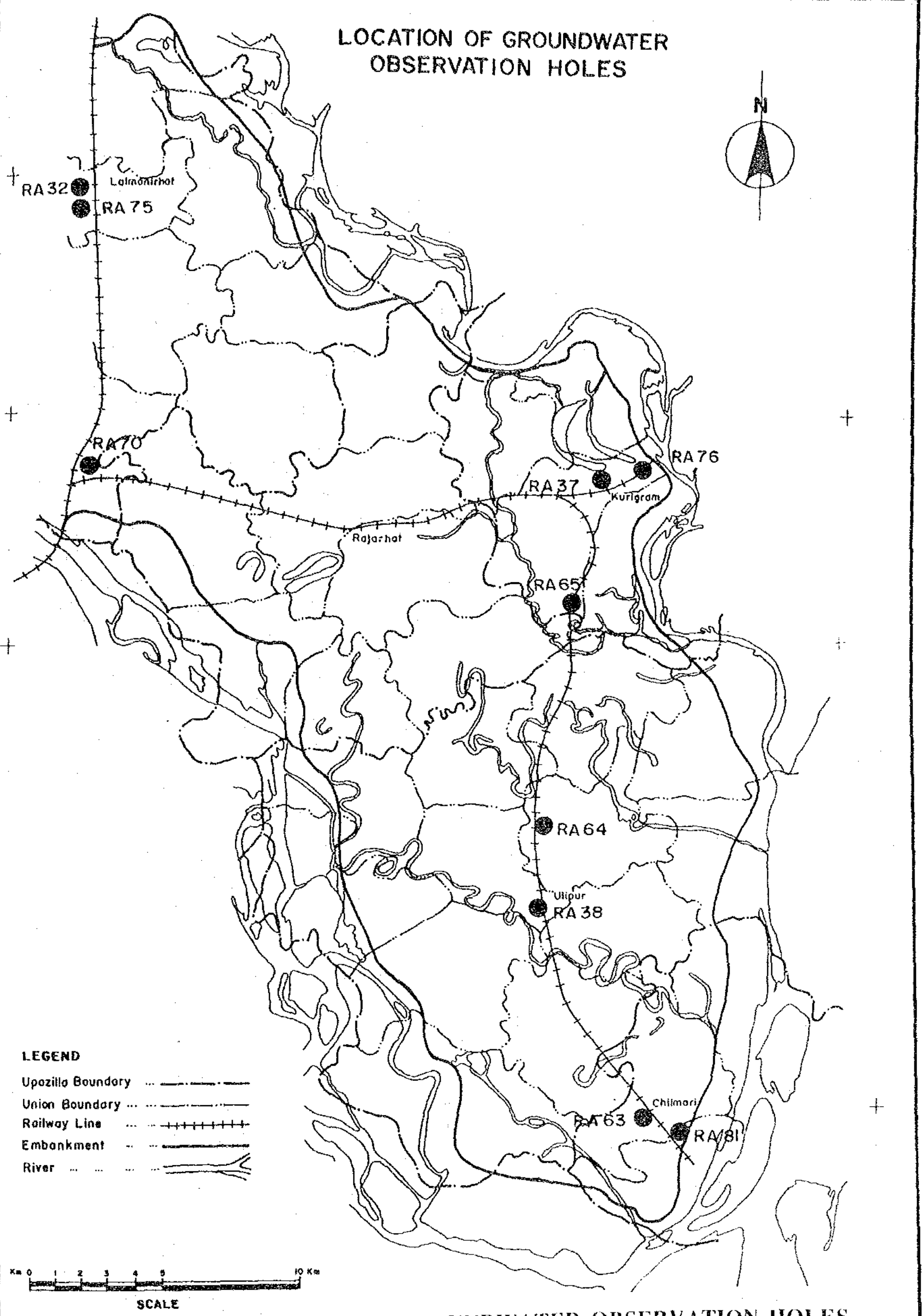

Fig. IV-7 LOCATION OF GROUNDWATER OBSERVATION HOLES

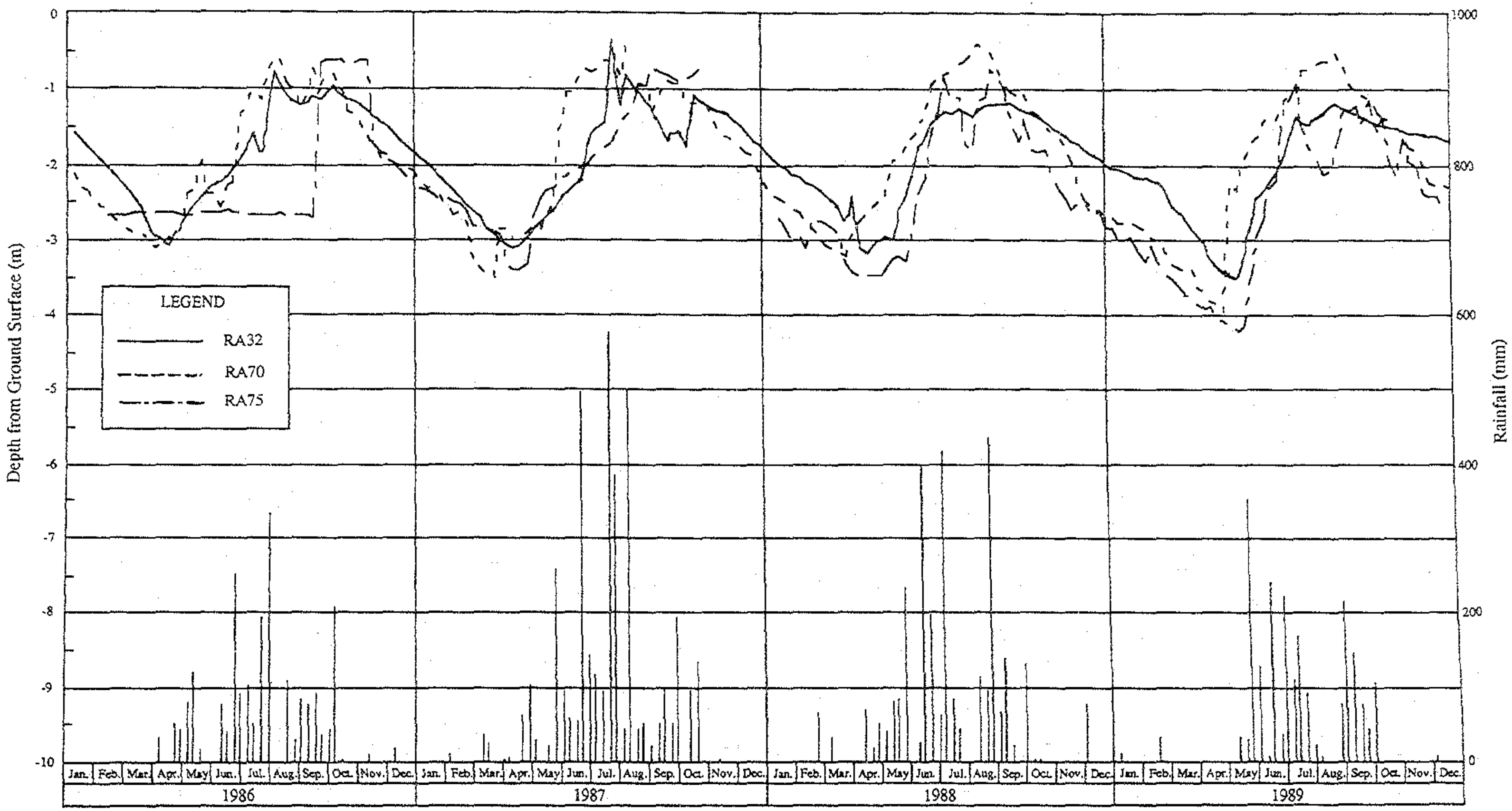

Fig. IV-8 FLUCTIATION OF GROUNDWATER LEVEL IN LALMONIRHAT

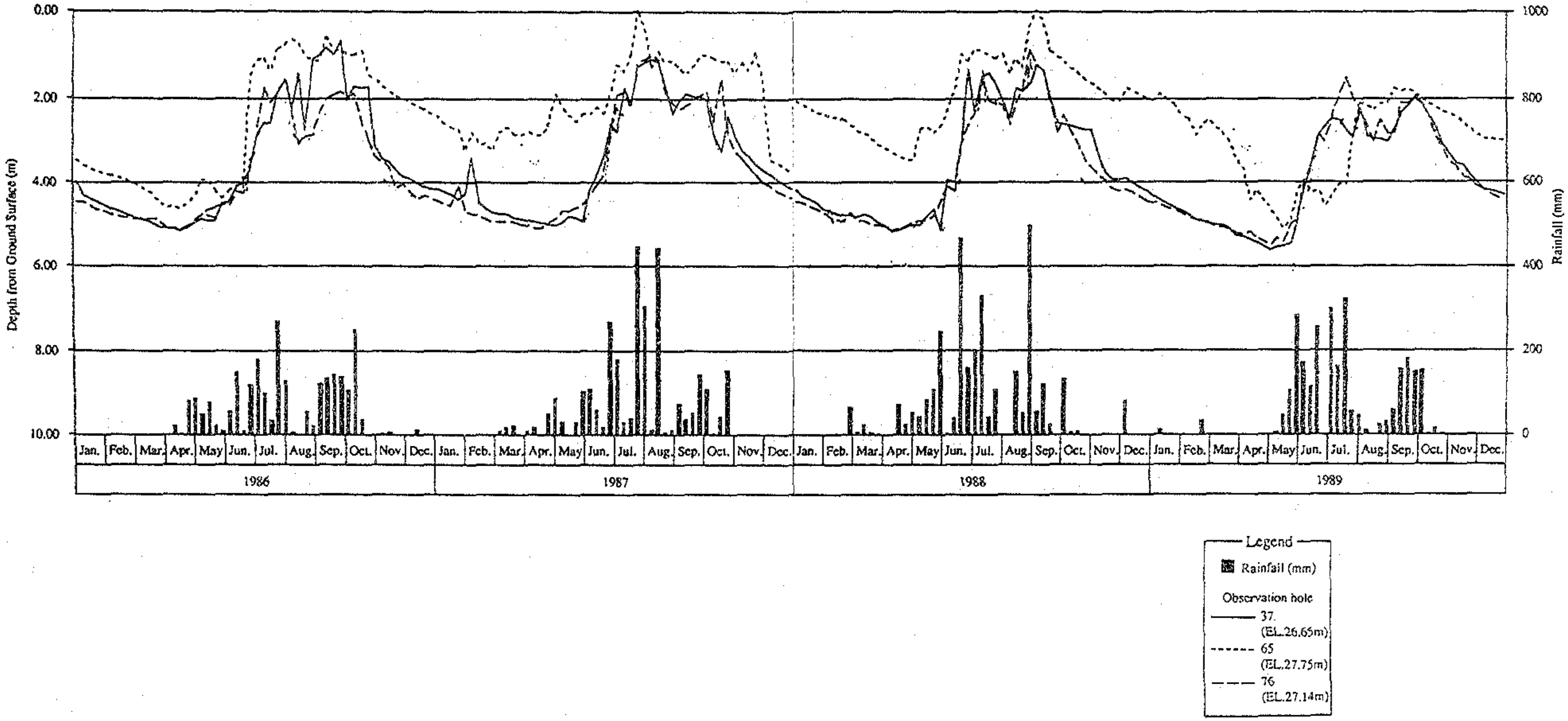

Fig. IV-9 FLUCTUATION OF GROUNDWATER LEVEL IN KURIGRAM

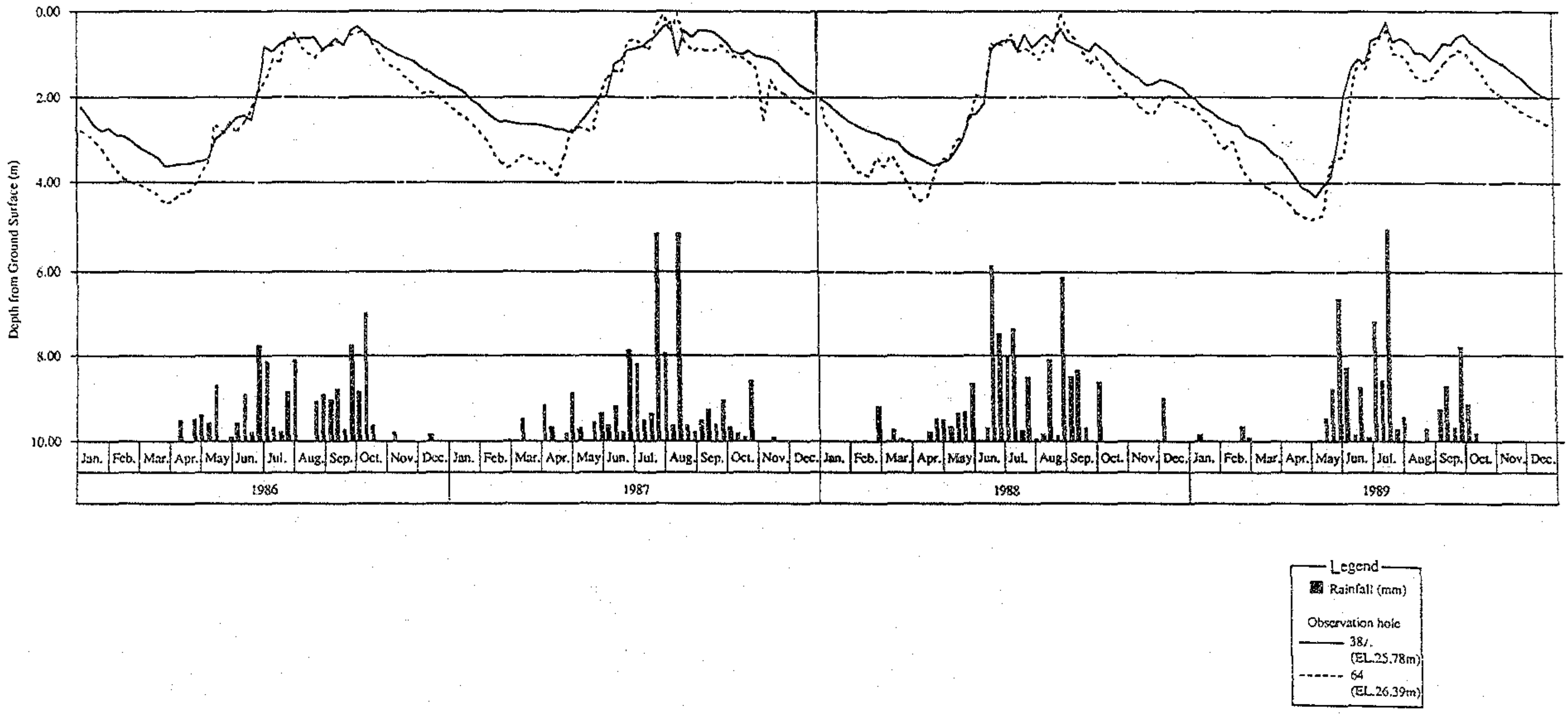

Fig. IV-10 FLUCTUATION OF GROUNDWATER LEVEL IN ULIPUR

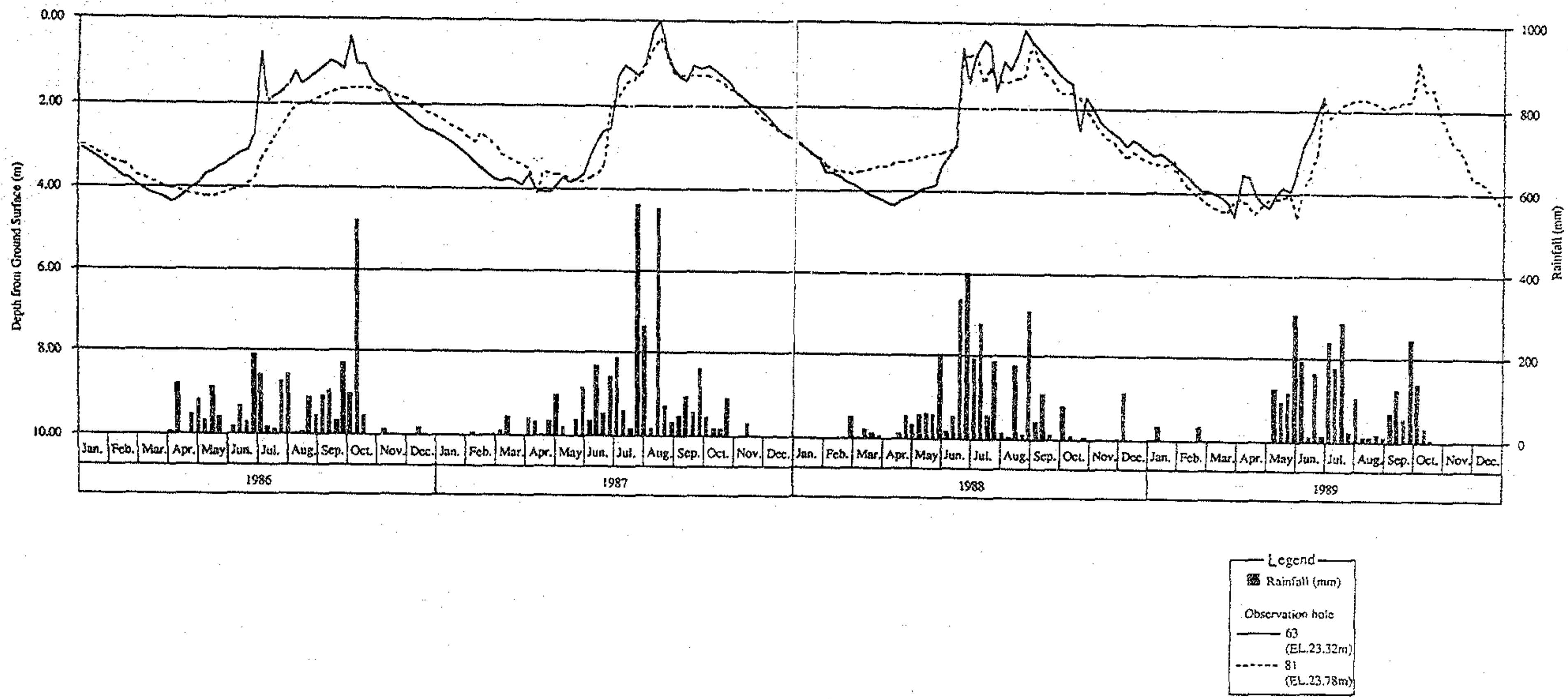

Fig. IV-11 FLUCTUATION OF GROUNDWATER LEVEL IN CHILMARI

APPENDIX - V

SOIL AND LAND CLASSIFICATION

FEASIBILITY STUDY ON
KURIGRAM IRRIGATION AND FLOOD CONTROL PROJECT (SOUTH UNIT)

APPENDIX - V SOIL AND LAND CLASSIFICATION

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1. INTRODUCTION

1.1 Previous Studies

The Reconnaissance Soil Survey was carried out in Kurigram and Gaibandha Sub-divisions in 1968/69 by the Directorate of Soil Survey, East Pakistan (now Soil Resources Development Institute, SRDI) under the assistance of UNDP/FAO, as a series of Reconnaissance Soil Surveys covering the whole country of Bangladesh. This Reconnaissance Soil Survey covered the Study area of the Kurigram Irrigation and Flood Control Project, South Unit.

The report provides basic information on land resources, soils, their description, identification and classification on the basis of USDA Soil Survey Manual or FAO Guidelines etc. Soil units recognised in the this survey were soil series, however, mapping units were described as soil association. It includes 4 physiographic units, 10 soil associations and 20 soil series, as shown Tables V.1.1 to V.1.3 and Figs. V.1.1 and V.1.2. The maps published in the Reconnaissance Soil Survey report are as follows;

	Scale
- Reconnaissance soil map (2 sheets)	1:125,000
- Land Capability map (2 sheets)	1:125,000
- Land use map	1:25,000
- Generalized physiographic map	1:500,000

1.2 Objectives of Soil Survey

The purpose of the present soil survey is to collect existing available data, to review and to correlate them to update and to provide additional information on soils and land resources of the Study area. The outline of the objective is;

- To verify chemical and physical characteristics of the major soils,
- To classify soils according to the soil classification standard of Bangladesh,
- To identify distribution pattern and extent of major soil,
- To assess the soil-crop suitability of major soils for irrigated agriculture purpose, and
- To setup proper soil management practices to be introduced.

1.3 Method of the Present Soil Survey

The following aerial photographs, maps and satellite imageries are utilized for the soil survey:

	Scale	
- Aerial photographs	1 : 50,000	(1983/84)
- Aerial photographs	1 : 50,000	(1990)
- Topographic map	1 : 50,000	(1970)
- Topographic map	1 : 15,840	(1963)
- Spot satellite imagery	1 : 50,000	(1990)

Land types and soil associations identified in the Reconnaissance Soil Survey are shifted on the base maps (scale 1:50,000), and the provisional maps on land types and soil series were prepared through interpretation of the Spot Imagery, extensive field checking, correlation of soils with physiographical positions. Intensive field survey was carried out on the provisional maps across all the land forms using aerial photographs and soil auger, so as to check the soil and land type units. 12 soil pits from selected typical pedon were dug upto the depth of 1 metre and described the profiles according to the USDA Soil Survey Manual and Taxonomy. Soil samples were taken from different depth of the typical pedon, and 30 samples in total were collected from 10 typical pedon for laboratory analysis. The locations of augerholes, pits and observation points were marked on the maps, using the Global Positioning System.

Both physical and chemical analysis were made according to the standard test methods. The samples were analysed partly in the Soil Research Laboratory, BWDB and mostly in the Department of Soil Science, University of Dhaka. The analysis items are;

(1) Soil texture
(2) pH
(3) EC value
(4) Organic matter
(5) Total nitrogen
(6) CEC
(7) Exchangeable cations (Na, K, Ca, Mg)
(8) Available cations
(9) Phosphorus
(10) Zinc
(11) Potassium
(12) Bulk density
(13) Moisture content and
(14) Water holding capacity

2. SOIL CLASSIFICATION

2.1 Physiographic Units

All the soils of the Study area are developed in alluvium floodplain sediments. Four physiographic units are included in the the Study area, namely, 1) Active and young Teesta and Dharla Meander floodplain, 2) Older Teesta Meander floodplain, and 3) Lower Teesta meander floodplain, and 4) Active and Young Brahmaputra Floodplain. The area of 4) Active and Young Brahmaputra Floodplain is negligible small less than 1% of the Study area, and mainly three physiographic units can be included in the Study area. Outline of the physiographic units are as shown below;

1) Active and Young Teesta and Dharla Meander Floodplain:

They have shallow soils over a stratified substratum and include infiled abandoned channels and inter-ridge depressions. The soils are poorly drained and subject to shallow to moderately deeply flooding. Active and young floodplain of both Teesta and Dharla are closely resembles each other. They are grey to greyish brown and stratified. The texture is mainly silt-loam to sandy loam. This physiographic units may be classified into the Active and Young Teesta Meander Floodplain and the Active and Young Dharla Meander Floodplain.

2) Older Teesta Meander Floodplain:

They comprise a distinctive landscape of relatively high, broad, north-south ridges variably dissected by inter-ridge depressions. The deposits are mainly silty, but generally over lie a deep sandy substratum within one metre. The soil are dark brown to olive brown in colour.

3) Lower Teesta Meander Floodplain:

They comprise extensive area in the southern part of the Kurigram. The landscapes are very gently undulating ridges and shallow basins. The basins are moderately deeply to locally deeply flooded. The ridge soils are moderately well to imperfectly drained and dark brown to olive brown in colour. Rest of the soils, are poorly drained, having grey to dark greyish brown base colour and are variably mottled. The ridge soils are mostly silt loams and basins are usually silt loam it silty clay loam. Silty clay soils occupy deep basins and are grey to dark grey in colour.

2.2 Soils and Classification

There are 12 soil series identified in the Study area, i.e. 1) Amgaon series, 2) Bonarpara series, 3) Chilmari, series, 4) Farabari series, 5) Gangachara series, 6) Kaunia series, 7) Laskara series, 8) Palashbari series, 9) Pirgacha series, 10) Uttargaon series, 11) Ulipur series, and 12) Sand and Silty Alluvium Complex, as shown Table V.2.1. Distribution by textural classes are shown in Table V.2.2.

Effect of flood during the monsoon season are important factor of the farm land in Bangladesh. Hydrological land type is employed to express range of inundation depth during the kharif (rainy) season. The followings are summary of land types and their distribution in the Study area. The soil series by land type in the Study area are shown in Table V.2.3;

Sl. No.	Land form	Land types	Flood depth (cm)	Nature of flooding	Suitability of crops grown in wet season	Area (ha)	(%)
1	Highland	F0	< 30	Intermittent	HYV rice	23,600	38.9
2	Medium highland	F1	30 - 90	Seasonal	L. Aus & HYV Aman	28,600	48.1
3	Medium lowland	F2	90 - 180	Seasonal	B. Aman	5,700	9.6
4	Lowland	F3	180 - 360	Seasonal	B. Aman can be grown	-	-
5	Very lowland	F4	> 360	perennial	B. Aman can not be grown	1,500	2.5
	Total					59,400	100.1

Source : MPO/BARC (1986)

The soils series have been correlated with the Soil Taxonomy and FAO/UNESCO Classification System. The soil development in the normal floodplain alluvium is generally rather rapid. Only soils in the active and young floodplain are classified as Entisoils. Soils in all other floodplain are less developed and classified as Inceptisols. In the classification of the soils of the Study area, special attention are given to the characteristics of epipedons and sub-soils horizon. Many soils show strong prismatic and blocky structure with prominent cutans along the ped faces in the sub-soils. These cutans apparently results from down washing of the surface materials (clay and silt) when the soils are flooded. They cannot be regarded as diagnostic for an argillic horizon. The clay percentage of the horizon in which this cutans occurs may be higher or lower than the underlying horizons. They are considered as cambic rather than argillic according to the nomenclature of the USDA Soil Taxonomy (1987). Detailed classification and correlation of soils of the Study area with the USDA Taxonomy are given based on H. Brahmar (1986) in the Table V.2.4.

The soils correlated with FAO/UNESCO Soil Map Legend and General Soil Type of Bangladesh are shown in Tables V.2.5 and V.2.6, respectively. General Soil Type is local system and a group of soils which are broadly similar in appearance and characteristics reflecting similar development factor such as climate, physiography and drainage. The land type and soil maps are compiled in the Drawings of the separate volume.

2.3 Description of Soil Series

A technical description of the soil series and miscellaneous land type contain an introductory statement of the major differentiating features of the soil, distribution and extent of the soil, detailed description of a typical pedon. The nomenclature of FAO (Guideline of Soil

Profile Description) and USDA Soil Survey Manual has been followed. The colour notation is according of the Munsell Colour Chart. In describing the drainage, the terms "seasonally flooded" or "intermittently flooded" have been used. Soil reactions were determined on the dried laboratory samples, except where noted in brackets, in which case they were determined on the field samples (usually moist or wet) using a Hellige-Truong Test kit. The descriptions are given in Table V.2.7 in alphabetical order of the soil series. Schematic column of typical soil series are shown in Fig. V.2.1.

3. DESCRIPTION OF SOIL MAPPING UNITS

The mapping units are arranged according to the alphabetic order of soil series. Description of each soil mapping unit comprises - map code, location of occurrence, area, land type, salient soil features, present land use, limitations of cultivation and development possibilities.

3.1 Mapping Unit Code - 1b, c

They cover about 3,700 ha and 6.2%of the Study area.

Soils:
Soils are olive grey and olive brown in colour, profusely mottled, Silty clay loam in the sub-soil with very coarse prismatic and coarse angular blocky structure, Continuous grey cutan along ped faces. Top-soil colour ranges from grey to pale olive having silt loam to silty clay loam texture. Substratum texture ranges from Silt loam to silty clay loam.

Physiography:
Teesta alluvium.

Topography:
Nearly level to gently undulating ridges, inter-ridges depressions and remnant of channels.

Drainage:
Poor, seasonally flooded upto 30 - 180 cm, and includes medium highland;4.9% and medium lowland;1.0%.

Land use:
Mainly double cropped with some triple cropped area, Aus/Jute - T.Aman - Rabi on the lower part of ridge, Aus - Rabi crops on the upper part of ridges, and Boro/Rabi on low land.

Limitations on development possibilities:
Shallow to mod. deep flooding in the wet season and droughtness in the dry season are main limitations. With small scale irrigation H.Boro and H.T.Aman can be grown extensively. Improved varieties of seeds and proper inputs could produce high yield crops.

3.2 Mapping Unit Code - 2 a, b

They occupy about 5,300 ha and 8.9% of the Study area.

Soils :
are usually dark greyish brown, mottled with olive brown to yellowish brown, silt loam in sub-soil. Structure from weak to strong, very coarse to coarse prismatic,

consistence from friable to firm, cutans are grey, Top soil colour ranges from grey to olive grey and texture loam to Silt loam. Substratum texture ranges from loamy sand to silty clay loam.

Physiography:
Teesta alluvium.

Topography:
Developed in former levee deposits presently ridge and lower part.

Drainage:
Imperfect, mainly intermittently flooded but sometimes shallowly flooded upto 30-90 cm, highland:6.6% and medium highland:2.3%.

Land use:
Mainly double cropped and party triple cropped ; Aus - T.Aman, Aus - T.Aman - Rabi.

Limitations and development possibilities:
Possibilities. Intermittent wetness or shallow flooding in rainy season and droughtness in the dry season restrict cultivation of kharif and Boro. Irrigation would improve cultivation practices for two transplanted rice crops. Application of organic and chemical fertilizers, along with proper inputs could increase crop yields potentialities.

3.3 Mapping unit code - 3a, b

They occupy about 1,200 ha and 2.0% of the Study area.

Soils :
are olive colour, mottled, Silt loam, friable with moderately prismatic structure in the B-horizon. Top soil texture Silt loam to loam with grey to olive grey colour. Texture of the Substratum ranges from loamy sand to silty clay loam and buried dark greyish brown layer occurs at variable depth. Locally stratified.

Physiography:
The soils developed in Teesta and Dharla alluvium.

Topography:
Very gently undulating ridges and depressions.

Drainage:
Poor, intermittently or shallowly flooded upto 30 - 90 cm in the wet season, highland : 0.9% and medium highland : 1.3%.

Land use:
Mainly double cropped ; Aus/Jute-T.Aman with some tripped cropping Aus/Jute-T.Aman - Boro/Rabi.

Limitations on development possibilities:
shallow flooding or wetness in the rainy season, droughtness in the dry season, locally irregular relief, sudden rise of water level are the main limitations. With irrigation two transplanted rice crops could be grown. Use of proper doge of fertilizer, insecticides and improved inputs could increase the yield potentialities.

3.4 Mapping Unit Code - 4b, c

It coves about 6,400 ha and 10.% of the total Study area.

Soils :
are dark greyish brown, silty clay loam mottled, moderate to strong angular blocky structure, firm moist & have grey cutans. Texture of top - soils are silt loam to silty clay loam having olive to grey in colours. Substratum texture ranges from loamy sand to silty clay loam.

Physiography:
Soils developed in older Teesta floodplain.

Topography:
Occupy intermittent depression sites and Very gently undulating basins.

Drainage:
Poor, seasonally shallowly flooded ranges from 30 to 180 cm, medium highland and medium lowland occupy 9.6% and 1.2% respectively.

Land use:
Mainly used for double cropped, Aus/Jute-T.Aman/Rabi and partly for Boro/Rabi.

Limitations on development possibilities:
shallow flooding in the rainy season and droughtness in the dry season limits the crop cultivation. With small scale irrigation and application of organic and chemical fertilizers along with HYV seeds and improved cultural practices, this soil could produce HYV Boro and wet land crops.

3.5 Mapping unit code - 5a, b

They occupy about 11,800 ha and 19.9% of the total Study area.

Soils :
They are olive grey or grey with mottles mainly yellowish brown, silt loam in sub-soil, moderate structure, friable moist, olive grey cutans on ped faces. Top soil texture Silt loam to loam with grey to olive grey in colours. Substratum texture ranges from loamy sand to silt loam.

Physiography :
Soil developed on older Teesta alluvium.

Topography :
Usually gently undulating ridges and slopes.

Drainage:
Poor, intermittently or shallowly flooded in the rainy season., medium highland and medium low land occupy 17.5% and 2.4% respectively.

Land use:
Highlands are mainly double cropped (Aus/Jute - T.Aman), locally tripled cropped (Aus/Jute - T. Aman - Rabi/Boro). Medium highland are mainly used for Aus - T. Aman.

Limitations on development possibilities:
shallow flooding or wetness in the rainy season and droughtness in the dry season and locally irregular relief are the main limitations for agriculture possibilities. Provision of short/long term irrigation would facilitate two transplanted rice crops along with Rabi.

3.6 Mapping unit code - 6b,c

The soils occupy about 13,000 ha and 21.9% of the Study area.

Soils:
They are grey or olive grey mottles yellowish brown, silty clay loam with moderate to strong angular blocky structure and grey cutans in the sub-soil.Texture of the top soil ranges from loam to silty clay loam with grey to olive grey in colours. Substratum textures ranges from sandy loam to Silty clay. A dark greyish buried horizon occurs within 1 meter.

Physiography:
Soils developed in lower Teesta alluvium.

Topography:
They occupy very gently undulating basin edge and basins.

Drainage:
Imperfect to poorly drained, seasonally shallowly to intermittently flooded, highland and medium highland occupying about 21.2% and 0.7% respectively.

Land use:
They are mainly used for double cropped (Aus/Jute-T. Aman) or (T.Aman - Rabi), locally (Aus/Jut - Rabi), and partly used for triple cropped (Aus/Jute - T.Aman - Boro/Rabi) and locally single cropped (Boro).

Limitations on development possibilities:
Seasonal shallow or moderately deep flooding in the rainy season, locally wetness in the early and droughtness in late dry season are main limitations. With flood protection and irrigation two transplanted rice crops could be grown satisfactorily.

3.7 Mapping unit code - 7b, c

The soils occupy about 1,700 ha and 2.9% of the total area.

Soils:
The area dark grey mottled yellowish brown, silty clay with strong prismatic and angular blocky structure and dark grey cutans in the sub-soils, very firm moist. Top soil texture ranges from silt loam to silty clay and very dark grey to grey colours. Substratum texture ranges from silt loam to clay. A buried dark greyish brown layer usually occurs at variable depth with in one meter.

Physiography:
The Soils developed in older Teesta alluvium.

Topography :
They occur in lower slope of very gently undulating basins and basins centres.

Drainage:
Poor, seasonally shallowly to moderately deeply flooded, medium highland and medium lowland occupy 2.6% and 0.3% respectively.

Land use :
Mainly used for double cropped, mainly double cropping (Aus/Jute - T. Aman), (Aus - T. Aman), a part is used for (T. Aman - Boro), some are used for single crop (Boro).

Limitations on development possibilities :
Seasonal moderately to deeply flooding, wetness in early and droughtness in late dry season are the main limitation for agricultural development. With dry season irrigation and proper fertilizer, insecticide, modern inputs, HYV Boro could follow the Kharif rice.

3.8 Mapping unit code - 8a, b

The soils occupy about 5,900 ha and 9.9% of the total area.

Soils:
The soils are olive brown, mottled yellowish brown silt loam with moderate structure, friable moist in the sub-soil. Top soil textures ranges from loam to silt loam with dark brown to olive grey in colour. Substratum ranges from loamy sand to silty clay loam.

Physiography:
The Soils developed in old levee deposits now the older Teesta mender floodplain.

Topography :
Occupying summits and slope of the gently undulating ridges.

Drainage :
Moderately well drained to imperfect, highland and medium highland occupy about 8.0% and 1.9% respectively.

Land use :
Mainly used for double crops (Aus/Jute - T.Aman/Rabi), some are used for triple crop (Aus/Jute - T. Aman - Rabi), locally sugarcane is grown extensively.

Limitations on development possibilities:
Wetness in the rainy season and droughtness in the dry season makes limitations for agricultural development. Introduction of drainage, irrigation and application of modern inputs would improve cropping intensity.

3.9 Mapping unit code - 9a

The soils occupy about 4,000 ha and 6.7% of the Study area.

Soils:
The soils are dark brown, silt loam with weak structure development, friable moist in the sub-soil. Texture of the Top-soil ranges from silt loam to sandy loam with olive yellowish brown in colour. Substratum texture ranges from locally sand to silt loam.

Physiography:
Soils occupy higher ridges on the older Teesta mender floodplain.

Topography:
Occupying summits and slope of very gently undulating ridges. They are usually above normal flood level.

Drainage:
Moderately well drained, and located on highland only.

Land use:
The soils are mainly used for double crops (Aus/Jute - Rabi) and partly (Aus/Jute - T.Aman - Rabi), locally sugarcane is grown extensively.

Limitations on development possibilities:
Droughtness in dry season & low fertility are the main limitation with small scale irrigation, improved perennial/annual dry land crops could be introduced.

3.10 Mapping unit code - 10c

The occupy about 2,500 ha and 4.2% of the Study area.

Soils:
They are very dark greyish brown diffusely mottled with dark brown or dark yellowish brown. Silty clay or clay with strong prismatic and angular blocky structure and thick dark grey cutans on ped faces in the sub-soil, very firm moist. Top-soil texture ranges from silty clay loam to clay having olive grey to dark greenish grey. Substratum texture ranges from sandy loam to silty clay. A buried dark greyish brown layer occurs with in one meter locally.

Physiography:
The soils developed in the older Teesta floodplain deposits.

Topography:
They occupy gently undulating basin and basin centres.

Drainage:
Poor. Seasonally moderately deeply flooded.

Land use:
Mainly used for double crops (T. Aman - Boro), single crop (Boro) or (deep water T. Aman) also grown locally.

Limitations on development possibilities:
Moderately deeply flooding, sudden rise of flood water due to heavy rains, wetness in the early and droughtness in dry season make moderate to severe limitations for agriculture practices. With the provision of drainage and irrigation two transplanted rice crops could be introduced successfully.

3.11 Mapping unit code - 11b, c

They occupy about 1,100 ha and 1.9% of the Study area.

Soils :
They are grey, mottled yellowish brown silty clay or clay with strong prismatic and angular blocky structure, thick grey cutans, firm moist, in the sub-soil. Top soil textures ranges from Loam to silty clay with olive grey or light grey in colour. Substratum texture ranges from silt loam to clay.

Physiography :
They developed in Lower Teesta alluvium.

Topography :
Very gently sloping basin and basin centre.

Drainage
Poor. Seasonally shallowly and moderately deeply flooded, medium highland and medium lowland occupy 1.0% and 0.9% respectively.

Land use -
Medium highland are mainly used for double cropping (Aus - T. Aman), medium lowland are used (Aus - deep water T. Aman) or (L. T. Aman - Boro/Rabi).

Limitations on development possibilities
Shallow to moderately deep seasonal flooding, wetness in early and droughtness in dry season provide moderate to severe limitation for agriculture development. With irrigation and drainage system two HYV transplanted rice crop could be grown stisfactorily.

3.12 Mapping unit code - 12b, c

They cover about 1,500 ha and 2.5 percent of the total Study area.

Soils -
The soils are sandy and silty alluvium complex. They are grey, stratified, mottled, medium to moderately fine textured in the sub-soil. Top-soil texture ranges from sand to silty clay loam with colour grey to high grey. Substratum texture ranges from loamy sand to silt loam.

Physiography
Teesta alluvium complex.

Topography
Gently to very gently undulating charland and inter ridges.

Drainage
Poor. Seasonally flooded upto 90-180 cm and sometimes more for 4-5 months. The unit includes medium highland (1.2%) and medium lowland (1.3%)

Land use -
Mainly single cropped with some double cropped, usually (Boro/Rabi - L. T. Aman/deep water L. Aman/fallow).

Limitations on development possibilities
Draughtness in the dry season and flooding in the wet season, sometimes flash flood are the main limitations. Boro/Rabi and usually T. Aman (L) deep water could be grown satisfactorily with traditional irrigation method locally. But unsuitable for major agricultural development.

4. SOIL ANALYSIS

4.1 Methods of Soil Analysis

The Soil Samples were analysed partly by the Soil Research Laboratory, BWDB and mostly by the Department of Soil Science, University of Dhaka. Soil samples from 3 different depth (top-soil, sub-soil and substratum) from 10 (ten) typical pedons were collected for detailed laboratory analysis. The results are furnished separately for both chemical and physical characteristics along with salient features and range in characteristics. The standard methods adopted for determination of various chemical and physical characteristics are shown in Table V.4.1. Results of chemical and physical analysis are shown in Tables V.4.2 and V.4.3, respectively.

4.2 Chemical Properties of Soil

Organic Matter Content (OM%)
is generally low to medium. It ranges from 1.16 - 2.19% for top soil and 0.58 - 1.30% for sub-soil and on an average 1.62% and 1.03% respectively. The content of an usually falls with depth.

Total Nitrogen Content (TN)
is usually low to very low and ranges 0.07 - 0.16% in top soil and 0.03 - 0.12% for sub-soil and on an average 0.10% and 0.07% respectively. The content falls with depth.

Soil Reaction (pH) Value
varies from 5.2 - 6.4 in top-soil and 5.9 - 6.9 in sub-soil and on an average 5.9 and 6.4 respectively. pH value increases with depth. In substratum pH values are 6.0 - 7.0. It appeass that most of the soils of the Study area belong to moderately acid to neutral groups.

Electrical Conductivity (EC)
of the soils are below 0.1 ms/cm through out the profile. It is non-saline in nature.

Cation exchange Capacity (CEC) of the Top-Soil
varies from 10.21 - 13.36 me/100g and sub-soils 8.59-14.79 me/100g. On an average it ranges from 11.64 and 12.79 me/100g for top-soil and sub-soil respectively. The CEC is usually medium is rating.

Exchangeable Cations (K, Cl, Ca, Mg)
is slight to medium in nature for both top-soil and sub-soil and ranges from 0.17 to 0.64; 0.66 to 4.85 and 0.23 to 1.78 me/100g for top-soil and 0.09 to 1.88; 0.58 to 5.32 and 0.18 to 1.88 me/100g, for sub-soil respectively. Na-content varies from low to high for top-soil and low to medium for sub-soil. It ranges from 0.18 to 1.21 and 0.17 to 0.68 me/100g for top-soil and sub-soil respectively.

Available Phosphorous (P)
varies from 5.1 to 12.0 ppm and average about 7.1 ppm for top-soil. It ranges from 4.8 to 7.6 ppm and average 5.6 ppm for sub-soil. It appeass very low to low in rating.

Available Zinc (Zn)
ranges from 3.0 to 9.1 ppm and average 6.6 ppm for top-soil. It ranges from 2.2 to 22.2 ppm and average 6.7 ppm for sub-soil. Less than 2 ppm Zinc content is regarded as critical level.

Available potassium (K)
ranges from 45 to 164 ppm and average 74 ppm for top-soil but it varies from 22 to 90 ppm and average 57 ppm for sub-soil. Average K in the substratum is lower than upper layer & ranges from 18 to 100 ppm with an average 47 ppm.

4.3 Physical Properties for Soils.

Soil Texture (ST)
refers to the relative proportion of particle size distribution of sand, soil and clay & expressed in percentage. The soils are mainly silt loom to silty clay loom in the USDA texture triangle and the rest are silty clay to clay, mainly in basin and basin centre. The clay content ranges from 9 to 38% and average 26% for top-soil and 13 to 48% for sub-soil and average 28%. Silt content ranges 41 to 78% and average 55% for top-soil but varies from 45 to 72% with an average 56% for sub-soil. The content of sand ranges from 13 to 15% for top-soil and 13 to 58% for sub-soil. The variation of sand,

silt and clay content of the column both in horizontal & vertical directions are mainly due to sediment variation rather than the result of a soil forming processes.

Bulk Density (BD)
ranges from 1.18 to 1.40 g/cc with an average of 1.30 g/cc for top-soil and 1.24 to 1.55 g/cc with an average of 1.38 g/cc for sub-soil. Bulk density of basin-soils are higher than that of ridge & inter ridges.

Maximum Water Holding Capacity (WHC) of Top-Soil
ranges from 45.46 to 57.02% with an average of 52.15% and the sub-soil ranges from 46.32 to 55.68% with an average 50.39%. Water holding capacity is higher in the substratum.

Moisture Content
ranges from 19.1 to 41.9 vol% with an average 29.5 vol% for top-soil and 11.8 to 32.9 vol% with an average 25.7 vol% for sub-soil. Variation is little for substratum.

5. LAND SUITABILITY CLASSIFICATION

5.1 General

One of the main objective of the soil survey is to evaluate the land in terms of their potentialities (land characteristics and land qualities) in order to determine the crop suitability rating for individual crop under different management practices.

Land suitability classification for the Study area is evaluated through the approach developed by Zijvelt (1980) and revised by Brammer (1985), "Soil - Crop suitability classification of Bangladesh". The following land factors are taken into account. Each of them are classified, the terms & symbols are used for describing land factors;

(A) Agro edaphic suitability

- effective soil depth (d)
- available soil moisture holding capacity (m)
- permeability (p)
- drainage (w)
- top soil consistency & bearing capacity (t)
- soil reaction (a)
- nutrient availability (n)
- soil salinity (s)

(B) Agro inundation suitability

- depth of inundation (i) or land type
- flood hazard. (f)

(C) Agro-land form suitability

- slope (e)

A brief description of factors are given below;

Land type (5 classes):
refers to the position of the land in relation to the depth of monsoon season flooding. The classes are ;

		inundation
F_0	Highland (H)	up to 30 cm
F_1	Medium highland (MH)	30 - 90 cm
F_2	Medium lowland (ML)	90 - 180 cm
F_3	Low land (L)	180 -360 cm
F_4	Very low (VL)	> 360 cm

Slope (6 classes):

refers to the difference in elevation in meter for each 30 meter horizontal distance and expressed in terms of percentage. The following class have been considered ;

(e_1)	Flat/level/nearly level	less than 3% slope
(e_2)	Gently sloping/undulating/Irregular	3-8% slope
(e_3)	Sloping and rolling	8-16% slope
(e_4)	Moderately steep and hilly	16-30% slope
(e_5)	Steep	30-45% slope
(e_6)	Very steep	>45% slope

Soil Texture (5 classes):

refers to the relative percentage of sand, silt and clay in a given soil. Top-soil and sub-soil texture has been considered for the present purpose. Instead of 14 individual classes, 5 textural groups have been considered and they are as follows ;

(T_5)	Sands (coarse)	Sands, Loamy sand
(T_4)	Sandy loams (Mod.Coarse)	Sandy Loam, Fine sandy loam
(T_1)	Clay loams (mod.fine).........	Loams, VF sandy loams silt loam, silt
(T_2)	Clay loams (Mod.fine)	Sandy clay loam silty-loam, clay loam
(T_3)	Clays (Fine)	Sandy clay, silty clay, clay

Top-Soil Consistency & Bearing Capacity (4 classes):

refers to the attribute of the soil materials that determine their workability. Soil consistence indicates the degree, kind of cohesion & adhesion or resistance to deformation based on different moisture level (dry, moist & wet). They are classified as follows ;

(t_1)	Soil without tillage problem	Not more than slightly (firm/sticky /plastic) and hard,
(t_2)	Soil with mod.tillage problem	Mineral surface firm, very fine sticky, plastic hard to very hard.
(t_3)	Soil with serious tillage problem....	Soil Extremely firm, very sticky, very plastic, extremely hard.
(t_4)	Organic soil...........................	Organic within 25 cm of the surface.

Effective soil depth (4 classes):

refers to the depth of soil profiles where most of the active crop roots occur to obtain their necessary water, air, nutrients, below which root activities are restricted. The following classes have been considered ;

(d_1)	Deep	> 90 cm
(d_2)	Mod. deep/Mod. shallow	50 - 90 cm
(d_3)	Shallow	25-50 cm
(d_4)	Very shallow	< 25 cm

Soil drainage (6 classes):
refers to the rapidity and extent of the removal of water from the soil surface, in addition by flowing through soil mass to underground space ;

(W_o)	Well	a) Water on surface not more than a few hours b) Soil not saturated for more than 2-3 days after heavy rainfall
(W_1)	Moderate	a) Water as surface more than few days and b) Soil remain saturated for less than 2 weeks at a time
(W_2)	Imperfect	a) Water on surface for more than 2 weeks b) Soil remain wet for not-more than several weeks
(W_3)	Poor	a) Soil remain wet for longtime but surface drained before middle of November b) Ground water table is at near the surface for considerable time for the year
(W_4)	Slow	a) Soil remain wet for longtime but surface drained after Mid November
(W_5)	Very poor	a) Soil remain wet almost through the year b) Ground water is near the surface

Available Moisture Holding Capacity (5 classes):
refers to the residual soil moisture status during the rabi season when the plant available moisture is at its important state in relation to rainfed agriculture ;

(M_o)	Very high	> 40 cm
(M_1)	High	30-40 cm
(M_2)	Moderate	20-30 cm
(M_3)	Low	10-20 cm
(M_4)	Very low	< 10 cm

Soil Reaction (6 classes):
refers to the measure of the intensity of the H-ion concentration, soil acidity or alkalinity. The classes are ;

(a_5)	Extremely acid	pH < 4.5
(a_4)	Highly acid	pH 4.6 - 5.5
(a_2)	Moderately acid	pH 5.6 - 6.5
(a_1)	Neutral	pH 6.6 - 7.3
(a_3)	Moderately alkaline	pH 7.4 - 8.3
(a_6)	Highly alkaline	pH > 8.4