total iron and hardness (see Table B-10, The Results of Chemical Analysis of Selected Ponds on Pilot Area in APPENDIX B).

3) Alluvial Formation

The aquifer in the Alluvial Formation is distributed in the flood plain of recent river courses and is composed of laterite gravel in the bottom, silt and clayey fine sand in the middle, and loamy fine sand in the uppermost. The formation is about 2 m in maximum thickness and it is supportedly subject to contaminate by the groundwater of high EC from the siltstone aquifer when piezometric head of the siltstone aquifer ascends to overlying alluvial beds. This idea supports by the following fact that great number of ponds in the alluvial plain show high EC ranging from 1,300 to 20,000 μS/cm in comparison with the ponds in the higher places.

As compare with the Terrace Deposit, the groundwater potential of the alluvial Formation is almost equivalent but the quality is lesser than that.

B-3-4. Groundwater Quality

The groundwater samples from two exploratory wells were analyzed by the laboratory. The results are shown in Table B-8. The water samples from ten observation wells were also tested in the field. Tested data is shown in Table B-9.

As compare with the drinking standard of WHO, water quality of W-1 indicates within the standard except total iron, however, many chemical items of the sample in W-2 chows out of the standard.

The tested data of W-1 and W-2 are plotted in the trilinear diagram. The diagram indicates that groundwater from gravel aquifer, W-1, shows a quality of typical unconfined groundwater of the carbonate hardness type and groundwater from the siltstone aquifer, W-2, shows mineralized or saline contaminated water of the noncarbonated hardness type (see Figure B-42).

The water quality test in the existing wells indicates that a zone of heavy concentration of TDS locates in the west of Ban Phra Yun trending north-south direction. The location of this zone is quite identical with the zone of low resistivity analyzed by the geo-resistivity (see Figure B-38, Groundwater Conductivity Map in Siltstone Aquifer).

B-4. Mechanism of Salt Emergence

B-4-1 Saline Groundwater Flow in the Siltstone

Although many hypotheses have been put forward to explain the mechanism of salt emergence, a satisfactory interpretation may be worked out when the detailed study for groundwater movement in both the consolidated siltstone and unconsolidated Quaternary aquifers is carraied out.

The origin of the salt water is of dissolved groundwater from the rock salt which is interbedded member of the Siltstone. The rock salt drilling of K-53 conducted by DMR, on Ban Lao Na Ki along Huai Yai in the northern end of the study area, reveals that a layer of the rock salt underlies at depth of 180 mugs with 80 m thick. Depth of the rock salt near Ban Phra Yun is not identified due to lack of drilling data but it estimates almost same as K-53.

The siltstone bed which overlies the rock salt, is interbedded with mudston and fine sandstone and estimated thickness in the study area is about 170 m. The bed is overlain by thin unconsolidated Quaternary beds. The siltstone aquifer is widely exploited for the groundwater sources but quality of it indicates local variation. A variation of EC in the siltstone aquifer is shown in Figure B-38, Groundwater Conductivity Map in Siltstone Aquifer in APPENDIX B. The figure shows that a zone of high EC ranging from 10,000 to 20,000 μS/cm is located in the west of Ban Phra Yun with trending in a north-southerly direction EC decreases toward east and west of the zone.

The results of the geo-resistivity sounding is quite in agreement with EC distribution that a zone of low resistivity is distributed the west of Ban Phra Yun trending toward north-southerly direction (see Figure B-4 Resistivity Contour Map at depth of 140 M in APPENDIX B). This figure shows that the prospected bed indicates extremely low resistivity from maximum sounding depth of 190 m to the surface. The feature described above suggests that the salt water is discharging through cracky aquifer system in the siltstone from more than 190m depth to the surface.

Furthermore, a zonal distribution of resistivity and EC indicates that the salt water is concentrically discharging through the particular tectonic zone, e.g. fault, unconformity etc. An upward potential of discharge can be gained at the recharge area in the west of the study area where the Khorat Group is distributed with an altitude of more than 200 mamsl. The rain water at the recharge area infiltrates to the deeper part of the rock of Khorat Group through the cracks and beddings which mostly trend to eastward. The infiltrated recharged groundwater can be retained the upward potential by the overlying confined layers in the Khorat Group until it encountered said tectonic zone in the Siltstone where the recharged groundwater ascend through cracks and fissures dissolving the rock salt.

The contour map of the groundwater table in the siltstone aquifer is shown in Figure B-40 in APPENDIX B.

B-4-2 Saline Groundwater Flow in the Quaternary

When the saline groundwater is discharged to the surface of the siltstone, it takes two flow ways, lateral flow in the unconsolidated layers and vertical movement by capillary rise. The velocity and quantity of flows can be regulated by the permeability of overlying sediments.

The gravel bed, for instance the Pa Mo Gravel Bed, takes a part in a lateral flow because of its comparatively high permeability. When a lateral flow arrive a terminal of the gravel bed it decreased velocity and retard in the terminal and finally, it emerge to the surface. The recrystallization of salt on the ground may be observed during dry season.

The drilling records of exploratory wells reveal that outcrops of the Pa Mo Gravel Bed extend to the east end of rolling hill and then it submerge under the Terrace Deposit.

The location of severely salt-affected land delineated by the soil survey is quite identical with the terminal of the gravel bed.

Although the Terrace Deposit is interbedded with laterite gravel, however it seems a bed of low permeability. According to the field permeability test in the Terrace Deposit and Alluvial Formation which conducted by the study, an average permeability of 9 soil samples indicates 2.8×10^{-5} cm/sec (see Table B-6, Summarized results of Permeability Test in APPENDIX B). Also the results of laboratory test of a soil sample at site J-6 indicates 5.0×10^{-4} cm/sec.
Based on above data, the Trace Deposit can be categorized into the semipermeable layer or aquitard (see APPENDIX C).

When the salt water emerge to the semi-permeable layers a vertical groundwater movement may be activated by a capillary rise instead of a horizontal movement. However, the groundwater by a vertical rise could not attains to the upper part of the Terrace Deposit if a thickness of the Depose it is greater than a limit of the capillary rise.

Following field data support above idea that EC in the ponds on the terrace terrain shows about less than 600 μS/cm in contrast with EC in the ponds on the alluvial plain shows ranging from 1,300 to 19,000 μS/cm.

Based on the drilling record of DMR, a distribution of the rock salt in the Korat Plateau, a depth of rock salt on the Plateau is drawn in Figure B-43 in APPENDIX B.

Summarized above idea is schematically drawn in figure B-44 Schematic idea of Salt Water Emergence in APPENDIX B.

TABLE B-1 TABLE OF FORMATIONS

Geologic Age	Formation	Lithology
Quaternary	Riverbed Deposits	Clay,sand and gravel
	Terrace Deposits(1)	Sand and gravel with clay
	Terrace Deposits(2)	Clay,sand and lateritic gravel
	Pa Mo Gravel Deposits	Sand and gravel with clay
Tertiary	Siltstone Formation	Siltstone,claystone and sandstone
Cretaceous	Khok Kruat Formation	Sandstone,siltstone and shale
	Phu Phan Formation	Quartoze sandstone and siltstone

Table B-2 Electrical Conductance of Ponds and Streams

ELECTRICAL CONDUCTANCE OF PONDS AND STREAMS

Site No	EC (μS/cm/25)			PH			Source
	Jul.1990	Aug.1990	Jan.1991	Jul.1990	Aug.1990	Jan.1991	
Q- 1	723	598	683	7.2	6.9	7.5	Stream
Q- 2	427	899	512	7.1	7.1	7.2	Stream
Q- 3	684	585	830	7.3	7.5	7.3	Stream
Q- 4	597	692	494	7.1	7.7	6.8	Stream
Q- 5	589	737	1,861	7.5	7.2	7.3	Stream
Q- 6	709	599	2,209	7.6	7.5	7.3	Stream
Q- 7	684	556	2,002	7.8	7.7	7.4	Stream
Q- 8	728	426		7.5	7.3		Stream
Q- 9	554	660		8.9	7.1		Stream
Q- 10	462	380		7.2	7.2		Stream
Q- 11	695	444	6,006	7.4	7.6	7.2	Stream
Q- 12	364	214	290	6.9	7.3	7.2	Stream
Q- 13	252	206	212	7.2	7.4	7.5	Stream
Q- 14	233	241	543	7.5	7.4	7.6	Stream
Q- 15	209	248	453	7.5	7.2	8.1	Stream
Q- 16	393	196	559	7.1	7.5	7.3	Stream
Q- 17	265	260	977	8.2	7.8	7.2	Stream
Q- 18	235	108	311	7.4	7.9	7.5	Stream
Q- 19	238	183	353	7.3	7.7	7.7	Stream
Q- 20	245	173	504	7.4	7.6	7.7	Stream
Q- 21	1,046	1,003	1,107	7.4	8.0	6.9	Reservoir
Q- 22	537	450	632	7.9	7.3	7.3	Stream
Q- 23	224	254	386	7.2	7.1	7.7	Stream
Q- 24	167	153	266	6.6	6.9	7.8	Stream
Q- 25	526	185	315	7.0	6.8	7.5	Stream
Q- 26	4,574	3,880	2,166	7.8	7.8	7.3	Reservoir
Q- 27	1,546	1,636	468	7.0	6.8	7.5	Stream
Q- 28	444	472	793	6.7	7.7	6.8	Reservoir
Q- 29	49	60	217	7.9	8.7	7.3	Reservoir
Q- 30	203	136	250	7.9	7.0	7.4	Reservoir
Q- 31	646	659	621	7.7	7.2	7.2	Reservoir
Q- 32	2,348	2,305	786	7.1	6.5	7.4	Reservoir
Q- 33	611	430	770	7.3	7.3	7.3	Reservoir
Q- 34	1,454	1,269		7.3	8.2		Stream
Q- 35	1,350	1,240		7.0	7.8		Stream
Q- 36	717	958		7.0	6.8		Stream
Q- 37	37	37	631	8.5	7.4	7.1	Reservoir
Q- 38	1,473	1,418	1,142	7.3	7.3	7.6	Stream
Q- 39	1,535	1,623	853	7.5	6.6	7.1	Reservoir
Q- 40	212	224	239	7.6	7.2	7.5	Reservoir
Q- 41	1,381	991	1,671	8.6	7.3	7.4	Stream
Q- 42	1,471	1,311	878	7.8	8.3	8.2	Reservoir

Site No	EC(μS/cm/25℃)			PH			Source
	Jul.1990	Aug.1990	Jan.1991	Jul.1990	Aug.1990	Jan.1991	
Q- 43	263	178		7.5	6.2		Stream
Q- 44	1,307	2,343	2,697	8.8	7.2	8.5	Reservoir
Q- 45	868	877	804	8.8	8.2	7.3	Reservoir
Q- 46	390	0	971	7.9	0.0	7.4	Stream
Q- 47	5,669	4,573	1,535	8.5	7.1	7.1	Reservoir
Q- 48	9,056	8,488	7,191	9.2	7.0	7.6	Reservoir
Q- 49	6,981	5,394	2,895	8.7	8.3	7.4	Reservoir
Q- 50	749	1,181	478	6.2	6.8	7.1	Reservoir
Q- 51	1,419	262	1,419	7.4	7.0	6.8	Stream
Q- 52	347	108	735	7.6	6.8	7.5	Stream
Q- 53	3,724	2,367	1,651	7.5	6.8	7.6	Reservoir
Q- 54	160	276	268	8.4	8.5	7.7	Stream
Q- 55		139			6.9		
Q- 56	249	167	1,237	7.1	6.9	7.2	Stream
Q- 57	196	244	236	7.9	7.8	7.7	Stream
Q- 58	187	304	255	8.6	8.2	7.9	Reservoir
Q- 59	37	50	94	9.0	8.9	8.1	Reservoir
Q- 60	8	12		8.5	7.7		Reservoir
Q- 61	288	318	403	7.3	7.5	7.4	Stream
Q- 62	316	430	1,763	6.8	7.2	7.5	Stream
Q- 63	1,767	491	1,693	8.5	7.3	7.0	Reservoir
Q- 64	3,528	1,426	1,777	7.7	7.5	7.8	Stream
Q- 65	364	1,208		7.2	7.5		Stream
Q- 66	304	294	334	6.9	7.3	8.0	Reservoir
Q- 67	301	570	332	7.7	7.0	7.5	Reservoir
Q- 68	3,806	30	3,427	8.2	8.6	8.1	Stream
Q- 69	2,083	2,009	5,510	7.9	7.9	8.2	Reservoir
Q- 70	683	478	632	7.0	8.9	8.0	Reservoir
Q- 71	166	149	196	7.0	7.1	7.4	Reservoir
Q- 72	55	73	89	7.1	8.4	7.4	Reservoir
Q- 73	5,187	4,704	2,571		7.9	7.0	Reservoir
Q- 74	973	1,130	779	7.6	8.8	8.0	Reservoir
Q- 75	64	118	138	6.4	6.9	7.5	Reservoir
Q- 76	854	858	669	8.0	7.8	7.6	Reservoir
Q- 77	1,043	1,198	5,435	7.5	7.4	7.3	Stream
Q- 78	305	316	959	7.8	7.4	7.2	Stream
Q- 79	748	742	544	7.0	7.3	7.0	Stream
Q- 80	314	320	917	7.7	7.6	7.4	Stream
Q- 81	237			7.9			
Q- 82			3,346			7.3	Stream
Q- 83			940			6.8	Stream

Table B-3 Water Quality of the Existing Wells

WATER QUALITY OF THE EXISTING WELLS

(1)

WELL		WELL STRUCTURE				EC(mS/cm)		PH	T(°C)
No	Type	TD(m)	H(m)	Dia(m)	WD(m)	Feb.1991	Jul.1990		
EW-01	DW	3.0	0.50	1.20	1.20	-	0.443	7.24	31.2
-02	TW	30.0	0.50	0.05	6.00	3.29	2.111	6.70	33.1
-03	TW	35.0	0.90	0.05	25.00	1.33	1.248	7.89	32.0
-03	TW	18.0	0.50	0.038	12.00	-	2.392	5.99	29.5
-03	TW	30.0	0.50	0.038	14.00	-	2.852	5.82	28.2
-04	DW	10.0	0.30	1.20	1.30	0.63	0.797	9.00	29.3
-05	TW	25	0.90	0.05	15.00	>20	9.540	6.96	33.7
-06	TW	25	0.60	0.125	9.00	0.91	0.831	7.28	29.1
-07	DW	6.5	0.60	1.20	1.20	0.11	0.215	6.52	31.8
-08	TW	20.0	0.60	0.05	15.00	0.75	0.797	7.37	36.3
-09	TW	15.0	0.60	0.05	7.00	1.42	1.408	7.02	32.9
-10	TW	14.0	0.30	0.05	10.00	2.27	2.198	7.55	28.3
-11	TW	14.0	0.60	0.05	10.00	1.69	1.231	8.57	33.0
-12	TW	15.0	0.60	0.10	8.00	5.28	5.539	7.58	30.2
-13	TW	12.0	0.60	0.05	6.00	2.66	4.117	7.38	27.9
-14	TW	24.0	0.60	0.05	4.00	1.72	1.830	7.03	30.8
-15	DW	4.5	0.50	0.75	2.50	1.16	1.565	6.53	29.0
-16	DW	5.5	0.50	0.75	5.00	0.93	1.091	7.31	28.8
-17	DW	6.0	0.50	1.20	1.00	2.15	1.752	7.15	31.3
-18	TW	18.3	0.50	0.075	3.66	9.07	9.199	6.87	35.0
-19	TW	18.0	0.50	0.038	11.00	6.54	6.045	6.74	31.4
-20	TW	36.0	0.50	0.038	12.00	0.86	0.836	7.38	32.4
-21	TW	20.0	0.50	0.05	8.00	3.70	5.060	6.64	31.6

(2)

WELL		WELL STRUCTURE				EC(mS/cm)		PH	T(°C)
No	Type	TD(m)	H(m)	Dia(m)	WD(m)	Feb.1991	Jul.1990		
EW-22	TW	30.0	0.50	0.05	15.0	2.56	2.483	6.70	30.2
-23	TW	54.0	0.50	0.10	32.0	7.80	8.245	6.60	29.2
-24	TW	30.0	0.50	0.10	72.0	10.73	13.672	6.60	29.2
-24	DW	6.0	0.50	0.95	1.50	7.53	8.892	7.10	28.1
-25	TW	18.0	0.50	0.10	10.0	4.43	3.927	7.02	28.5
-25	DW	6.0	0.80	1.20	1.30	7.90	3.459	7.68	27.8
-26	DW	6.0	0.65	1.00	2.30	8.91	13.025	8.44	28.7
-26	TW	21.0	0.50	0.10	10.0	>20	6.379	7.05	30.0
-27	TW	32.0	0.50	0.10	16.0	8.25	11.612	7.25	29.9
-28	DW	6.0	0.40	1.15	1.20	0.96	1.210	7.97	29.5
-29	DW	6.0	0.50	0.95	1.75	1.52	1.679	6.67	28.2
-30	TW	32.0	0.50	0.10	20.0	1.34	1.259	6.90	30.2
-31	DW	5.0	0.70	0.85	1.30	2.88	3.367	7.10	29.5
-32	TW	18.0	0.70	0.10	12.0	4.14	4.925	6.54	32.1
-33	DW	4.0	0.50	0.85	1.30	3.02	1.389	7.65	29.7
-34	TW	30.0	0.50	0.15	25.0	1.25	1.375	6.52	31.3
-35	TW	12.0	0.50	0.05	9.0	1.90	2.109	6.73	29.3
-36	TW	40	0.50	0.10	35	2.05	0.999	6.83	29.4
-37	DW	10.0	0.90	0.90	8.00	0.46	0.492	7.52	29.2
-38	TW	45.0	0.70	0.10	36.0	0.97	1.031	6.53	29.9
-39	TW	43	0.60	0.10	30	9.76	10.046	6.58	30.1
-40	TW	24	0.70	0.10	16.0	0.51	0.497	6.08	26.0

WELL		WELL STRUCTURE				EC(mS/cm)		PH	T(°C)
No	Type	TD(m)	H(m)	Dia(m)	WD(m)	Feb.1991	Jul.1990		
EW-41	DW	6.0	0.60	1.1.	2.50	0.05	0.172	6.72	28.9
41	DW	5.0	0.60	0.75	3.60	1.28	1.066	6.96	26.3
41	DW	5.5	-	0.75	3.10	1.27	0.623	7.78	26.7
42	TW	42.0	0.50	0.10	32	8.42	9.701	6.73	28.0
43	TW	27	0.60	0.10	23	2.84	3.506	6.65	28.0
44	TW	25	0.60	0.10	20	3.05	3.438	6.74	30.4
45	TW	40	0.60	0.10	32	3.08	3.221	6.97	27.4
46	DW	5.0	0.40	1.20	1.50	1.56	1.303	6.70	28.4
47	TW	25	0.60	0.10	15	3.32	3.177	7.05	27.5
48	DW	5.0	0.40	0.75	2.00	1.70	2.218	7.03	26.1

TABLE B-4 Summary of Aquifer Test in the Exploratory Wells

Well	Transmissivity (m^2/day)		Specific Capacity (lit/min/m)
	Jacob'Method	Recovery	
W-1	70.4	97.2	25.0
W-2	-	0.7	0.5

Table B-5 OBSERVED DATA FOR ELECTRICAL MAGNETIC SURVEY

SITE	EMV1	EMH1	EMV2	EMH2	EMV3	EMH3
M1	11.60	7.10	38.00	48.00	38.00	42.00
M2	18.50	12.00	36.00	43.00	42.00	48.00
M3	22.00	13.00	60.00	62.00	53.00	44.00
M4	0.00	0.00	64.00	42.00	69.00	70.00
M5	1.00	0.00	56.00	72.00	64.00	66.00
M6	0.00	0.00	20.00	30.00	38.00	57.00
M7	5.00	0.00	62.00	63.00	58.00	42.00
M8	0.00	0.00	10.00	11.00	12.00	18.00
M9	19.00	11.00	66.00	62.00	75.00	60.00
M10	6.00	4.00	18.00	29.50	28.00	40.00
M11	6.00	5.00	16.00	26.00	24.00	42.00
M12	51.00	35.00	96.00	110.00	92.00	86.00
M13	10.60	5.40	44.00	60.00	59.00	62.00
M14	5.00	1.40	26.00	38.00	40.00	44.00
M15	0.00	0.00	11.50	18.00	18.00	26.00
M16	5.00	5.00	16.50	25.50	24.50	27.50
M17	30.00	12.00	90.00	86.00	115.00	75.00
M18	24.80	10.60	69.00	78.00	49.00	64.00
M19	152.00	91.00	205.00	64.00	180.00	43.00
M20	24.60	26.20	74.00	80.00	90.00	80.00
M21	68.80	37.00	145.00	74.00	160.00	41.00
M22	24.40	4.20	110.00	90.00	140.00	74.00
M23	124.00	120.00	145.00	43.00	140.00	34.00
M24	44.00	18.00	100.00	92.00	140.00	54.00
M25	9.00	7.00	39.50	42.00	62.00	60.00
M26	20.60	10.60	80.00	82.00	100.00	70.00
M27	53.00	30.00	135.00	44.00	150.000	59.00

Table B-5 OBSERVED DATA FOR ELECTRICAL MAGNETIC SURVEY

SITE	EMV1	EMH1	EMV2	EMH2	EMV3	EMH3
M28	35.00	20.00	125.00	74.00	150.00	68.00
M29	12.00	5.60	52.00	70.00	88.00	76.00
M30	79.60	46.00	170.00	55.00	145.00	67.00
M31	0.00	0.00	150.00	46.00	170.00	43.00
M32	35.00	20.00	60.00	71.00	70.00	74.00
M33	10.00	5.00	66.00	76.00	85.00	67.00
M34	54.00	29.80	130.00	110.00	134.00	78.00
M35	260.00	211.00	175.00	38.00	165.00	42.00
M36	39.40	27.40	105.00	96.00	125.00	93.00
M37	78.40	59.80	125.00	70.00	130.00	59.00
M38	30.00	20.00	110.00	78.00	149.00	71.00
M39	6.20	2.00	70.00	74.00	88.00	64.00
M40	9.40	4.00	48.00	63.00	78.00	72.00
M41	19.80	10.60	60.00	72.00	85.00	64.00
M42	112.00	110.00	135.00	84.00	135.00	85.00
M43	46.40	24.80	130.00	86.00	130.00	82.00
M44	3.20	0.00	60.00	70.00	80.00	69.00
M45	81.20	43.20	155.00	48.00	155.00	43.00
M46	66.40	32.80	125.00	110.00	145.00	92.00
M47	98.40	60.00	145.00	80.00	155.00	40.00
M48	35.50	26.80	72.00	76.00	135.00	70.00
M49	3.00	0.00	34.00	50.00	68.00	65.00
M50	40.00	22.00	110.00	100.00	135.00	74.00
M51	1.00	1.00	35.00	52.00	60.00	72.00
M52	242.00	268.00	200.00	4.00	180.00	20.00
M53	165.00	141.00	170.00	100.00	165.00	64.00
M54	132.00	130.00	165.00	20.00	170.00	87.00
M55	90.00	54.00	160.00	83.00	150.00	35.00

Table B-5 OBSERVED DATA FOR ELECTRICAL MAGNETIC SURVEY

SITE	EMV1	EMH1	EMV2	EMH2	EMV3	EMH3
M56	140.00	101.00	170.00	62.00	170.00	30.00
M57	121.00	104.00	135.00	72.00	150.00	37.00
M58	127.00	87.60	200.00	55.00	195.00	17.00
M59	0.00	0.00	13.50	24.00	30.00	44.00
M60	75.00	51.80	94.00	66.00	110.00	68.00
M61	45.00	25.00	115.00	86.00	120.00	66.00
M62	43.80	25.00	100.00	91.00	130.00	79.00
M63	100.60	63.00	165.00	110.00	175.00	92.00
M64	29.20	16.20	83.00	37.00	100.00	78.00
M65	17.00	13.00	50.00	69.00	73.00	87.00
M66	116.00	60.00	190.00	34.00	195.00	100.00
M67	173.00	160.00	170.00	62.00	150.00	51.00
M68	16.80	8.90	169.00	70.00	100.00	57.00
M69	90.80	57.20	125.00	76.00	120.00	76.00
M70	110.00	100.00	170.00	70.00	160.00	52.00
M71	101.00	71.00	140.00	76.00	130.00	52.00
M72	66.40	35.20	120.00	84.00	120.00	68.00
M73	194.00	116.00	175.00	94.00	150.00	70.00
M74	53.60	30.20	110.00	96.00	125.00	91.00
M75	50.00	27.00	145.00	92.00	160.00	75.00
M76	17.00	13.60	62.00	84.00	82.00	68.00
M77	50.00	40.00	100.00	64.00	115.00	76.00
M78	90.00	75.00	200.00	80.00	195.00	44.00
M79	230.00	140.00	180.00	84.00	170.00	57.50
M80	27.00	17.00	175.00	86.00	170.00	43.00
M81	101.00	66.00	170.00	96.00	170.00	66.00
M82	34.00	20.00	110.00	82.00	120.00	86.00
M83	35.20	15.60	100.00	87.00	105.00	81.00

Table B-5 OBSERVED DATA FOR ELECTRICAL MAGNETIC SURVEY

SITE	EMV1	EMH1	EMV2	EMH2	EMV3	EMH3
M84	15.20	9.60	45.00	60.00	59.00	60.00
M85	15.60	11.80	36.00	57.00	50.00	62.00
M86	40.00	19.00	91.00	100.00	100.00	78.00
M87	48.00	29.00	125.00	125.00	140.00	100.00
M88	216.00	193.0	195.00	67.00	180.00	47.00
M89	10.20	1.60	120.00	94.00	135.00	91.00
M90	39.20	22.60	72.00	76.00	90.00	73.00
M91	61.00	39.00	86.00	98.00	105.00	96.00
M92	81.00	50.00	130.00	86.00	120.00	63.00
M93	16.00	9.20	64.00	75.00	94.00	72.00
M94	54.80	36.20	95.00	88.00	110.00	71.00
M95	24.00	21.00	90.00	99.00	100.00	76.00
M96	29.60	19.40	61.00	62.00	82.00	68.00
M97	215.00	218.00	175.00	50.00	125.00	54.00
M98	29.00	26.00	65.00	68.00	82.00	70.00
M99	50.00	35.00	95.00	110.00	110.00	93.00
M100	48.00	42.00	72.00	68.00	83.00	74.00
M101	40.00	25.00	63.00	84.00	85.00	84.00
M102	27.00	14.60	115.00	105.00	130.00	73.00
M103	16.60	8.80	110.00	88.00	130.00	68.00
M104	73.00	49.00	120.00	77.00	120.00	78.00
M105	18.60	11.80	63.00	80.00	80.00	74.00
M106	46.40	22.00	110.00	76.00	115.00	62.00
M107	14.20	14.20	65.00	77.00	84.00	77.00
M108	72.40	39.60	130.00	78.00	120.00	67.00
M109	0.00	0.00	100.00	80.00	100.00	78.00
M110	53.00	34.00	100.00	74.00	100.00	71.00
M111	12.60	8.60	68.00	86.00	84.00	68.00

Table B-5 OBSERVED DATA FOR ELECTRICAL MAGNETIC SURVEY

SITE	EMV1	EMH1	EMV2	EMH2	EMV3	EMH3
M112	69.80	41.80	120.00	84.00	100.00	58.00
M113	0.00	0.00	110.00	80.00	140.00	58.00
M114	22.10	12.60	69.00	69.00	90.00	68.00

Note : EM-38 · · · · · EMV1=Vertical Dipole
EMH1=Horizontal Dipole

EM-34-3 · · · · EMV2=Horizontal Dipole by Coil Space 10 m
EMH2=Vertical Dipole by Coil Space 10 m
EMV3=Horizontal Dipole by Coil Space 20 m
EMH3=Vertical Dipole by Coil Space 20 m

Table B-6 SUMMARIZED RESULTS OF PERMEABILITY TEST

Hole	D(m)	Tex.	Q(cm3/sec)	GWL(mbg)	h(m)	H(m)	k(cm/s)
A-01	1.86	LS	6.8 $\times 10^{-2}$	2.77	1.88	1.88	3.1x10-5
A-02	0.94	SCL	1.4626 $\times 10^{-4}$	4.87	1.96	1.96	6.2x10-5
02	2.08	LG	2.3 $\times 10^{-3}$	4.87	3.98	3.98	4.9x10-7
02	2.98	SiC	0.517	4.87	3.99	3.99	1.1x10-4
A-04	1.50	SL	0.0506	2.63	1.92	1.92	2.2x10-5
A-05	0.49	LS	0.03	4.87	1.91	1.91	1.3x10-5
A-06	3.70	L.G	0.2837	-	3.99	3.99	6.0x10-5
A-15	1.70	LS	0.02	4.04	1.90	1.90	8.9x10-6
A-22	3.10	gSL	1.6 $\times 10^{-4}$	1.59	3.74	2.23	6.1x10-8
A-31	0.97	gSC	2.53 $\times 10^{-4}$	0.99	1.93	1.93	1.1x10-7
31	1.51	sSC	1.9 $\times 10^{-4}$	0.99	1.97	1.44	1.1x10-5
A-34	1.04	vgSC	0.018	1.48	1.91	1.91	8.0x10-6
A-36	0.50	LS	3.45 $\times 10^{-3}$	0.92	0.94	0.94	2.2x10-5
A-38	0.87	sgSC	7.9 $\times 10^{-4}$	1.10	1.91	1.91	3.5x10-7
A-43	0.90	sgSC	0.25	-	1.96	1.96	1.1x10-4
A100	0.30	LS	1.39 $\times 10^{-4}$	0.67	0.92	0.92	1.3x10-7
A101	0.57	SiS	3.18 $\times 10^{-3}$	1.20	0.94	0.94	2.9x10-6
A103	0.24	SiS	0.025	1.12	0.95	0.95	2.2x10-5

Note : h= depth of GWL. H=head, from bottom to const. WL or height from GWL to const. WL, if GWL locate above bottom of hole.
D=depth of tested soil
Q=injected flow rate
K=permeability

Table B-7 DATA SUMMARY FOR AQUIFER TEST IN EXISTING DUG WELLS

Name of Well	Location	Well Struc.		S.W.L. (mbgs)	Results of Test			Specific Capacity (1/min/m)	EC (μS/cm)
		Depth (m)	Dia. (m)		Q (1/m)	T (min)	D/D (m)		
DW-1	Ban Pa Mo	8.39	1.20	4.77	26.10	33	6.91	3.80	470
DW-3	Ban Phra Yun	4.88	1.32	2.78	22.50	76	4.30	5.20	1,800
DW-5	Ban Chat	4.40	1.20	3.21	22.50	32	4.27	5.30	290

Table B-8 The Results of Water Quality Test in the Exploratory Wells

Name of Well		W-1	W-2
Sample Date		Sep. 6,1990	Sep. 3, 1990
Prepared Date		Sep. 13,1990	Sep. 13, 1990
pH		6.19	6.94
Specific Conductance	(μs/cm)	171	1760
Chioride	(ppm as Cl)	20	230
Sulphate	(ppm as SO_4)	8.42	17.31
Nitrate	(ppm as NO_3)	0.33	94.26
Total Iron	(ppm as Fe)	2.01	4.65
Sodium	(ppm as Na)	9.6	107.5
Potassium	(ppm as K)	2.3	3.7
Calcium	(ppm as Ca)	9.6	134.40
Magnesium	(ppm as Mg)	7.78	35.74
Total Hardness	(ppm as $CaCO_3$)	56	483
Noncarbonate Hardness	(ppm as $CaCO_3$)	nil	228
Carbonate	(ppm as CO_3)	nil	nil
Bicarbonate	(ppm as HCO_3)	80	255
Total Dissolved Solid	(mg/l)	146	1176

Table B-9 The results of Field Water Quality Test in The Exploratory Wells

Well	Tested Date	Water Tem. (°C)	EC (μS/cm)	TDS (mg/lit)	pH
W-1	6/9/90	31.1	184	92	5-6
W-2	3/9/90	32.5	1,625	810	6
P-1	27/8/90	32.5	17,710	8,850	7
P-2	4/9/90	33.1	3,070	1,540	6
P-3	3/9/90	31.5	17,330	8,670	6-7
P-4	4/9/90	32.2	8,930	4,470	7
P-5	5/9/90	31.1	651	310	6-7
P-6	4/9/90	31.5	20,000+	18,000	7
P-7	5/9/90	32.8	4,780	2,380	7
P-8	5/9/90	32.5	2,940	1,460	7
P-9	3/9/90	31.9	20,000+	10,430	7
P-10	18/9/90	32.7	14,780	7,340	7.8

Table B-10 RESULTS OF CHEMICAL ANALYSIS OF SELECTED PONDS ON PILOT AREA

No. of Sites	Location	Topographic Units	Total Hardness (ppm)	Fe+2 (ppm)	Total Fe (ppm)
PP-1	Nong Bua Ban Phra Yun	Lower Terrace	72	0.12	0.15
PP-4	Nong Bai Sri Ban Phra Yun	Lower Terrace	38	1.31	1.38
PP-7	Nong No Ban Bo Kae	Lower Terrace	74	0.02	0.04
DW-5	Dug Well Ban Chet	Depth 4.4m L. Tarrace	63	6.42	25.17
P -78	Nong, West of Ban Pa San	Lower Terrace	81	1.69	18.76

FIGURE B-1
GEOLOGICAL MAP OF THE STUDY AREA

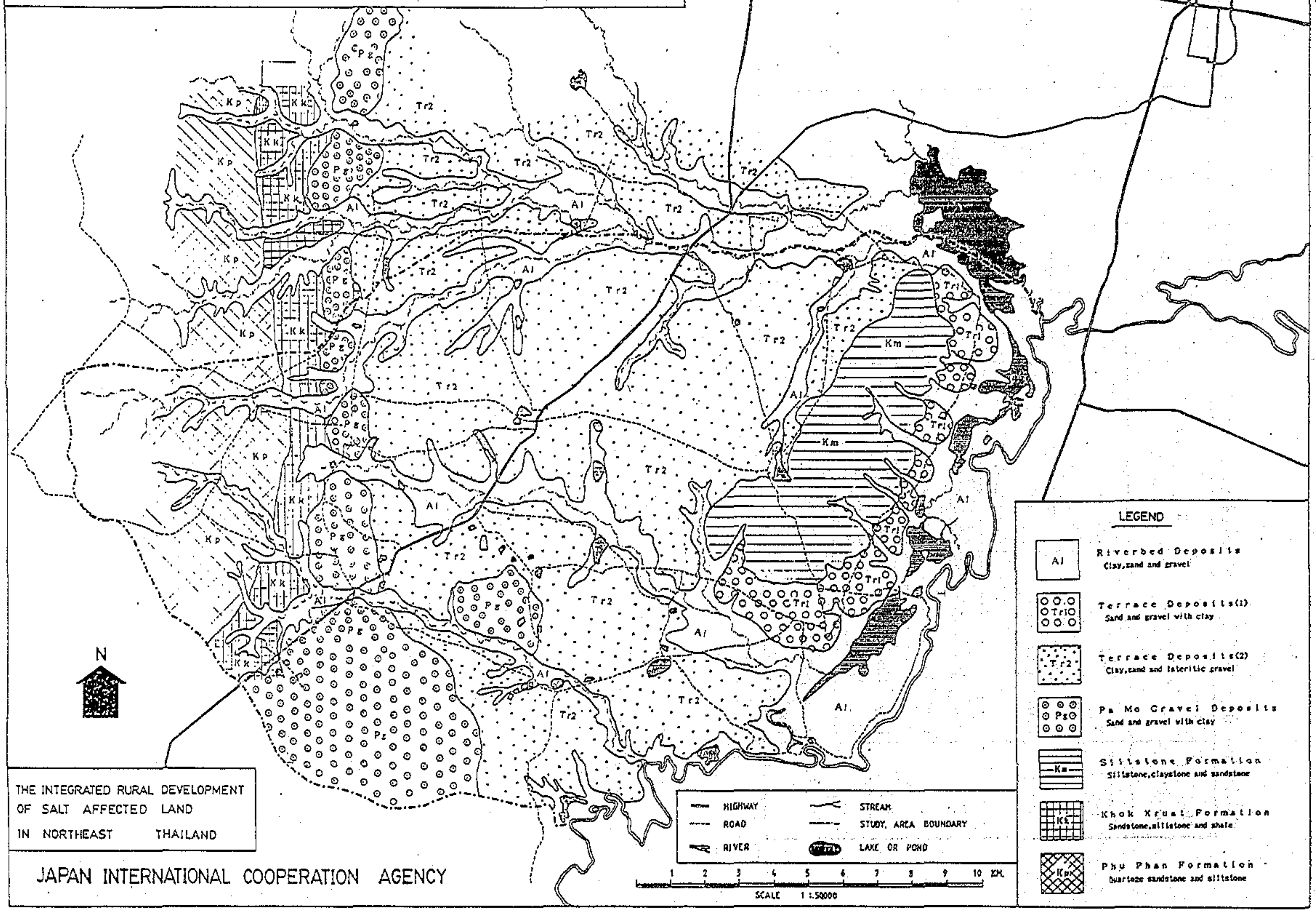
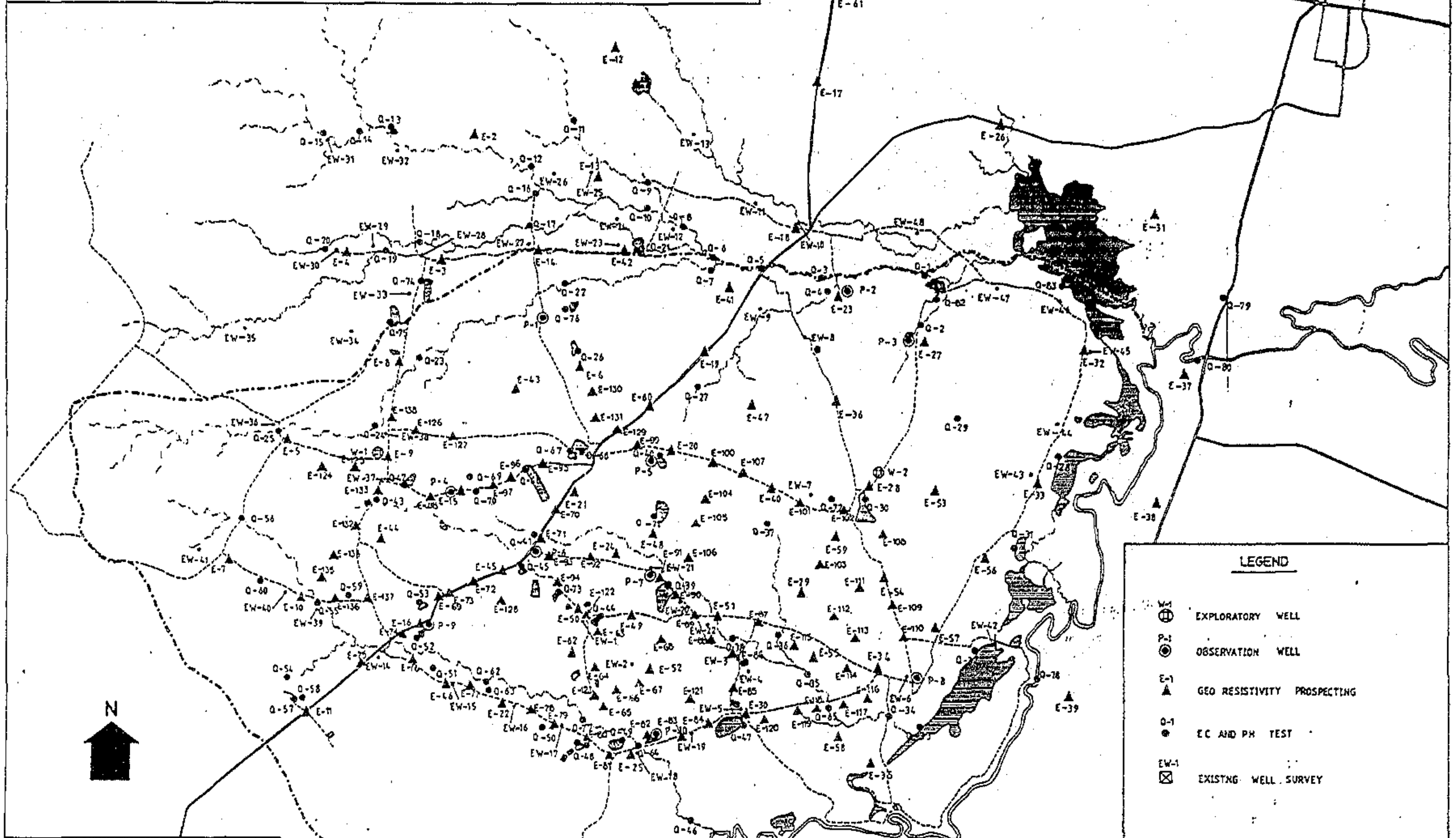


FIGURE B-2
LOCATION MAP OF HYDROGEOLOGICAL STUDY



THE INTEGRATED RURAL DEVELOPMENT
OF SALT AFFECTED LAND
IN NORTHEAST OF THAILAND

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE B-3

SURFACE TOPOGRAPHY OF THE SILTSTONE

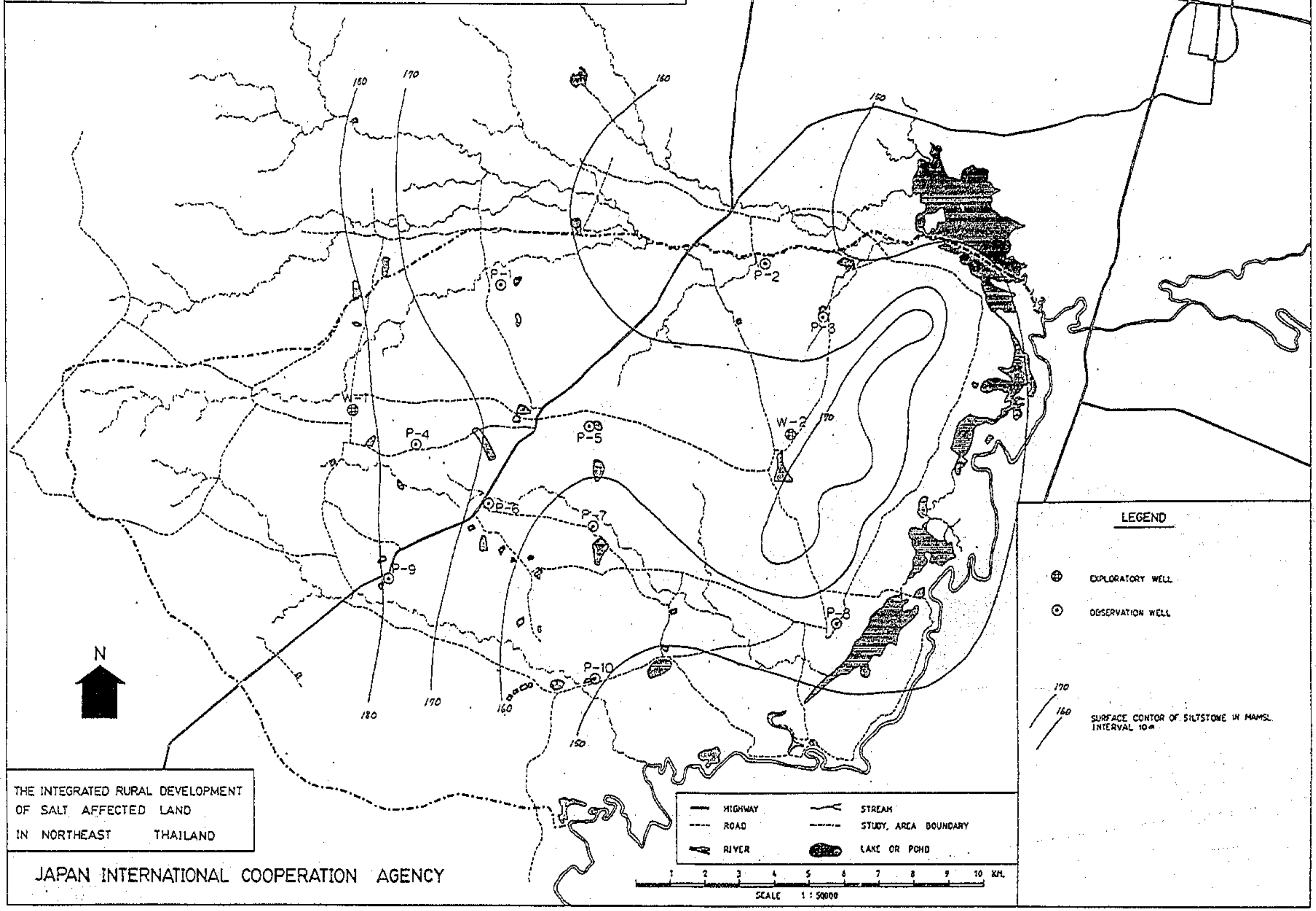
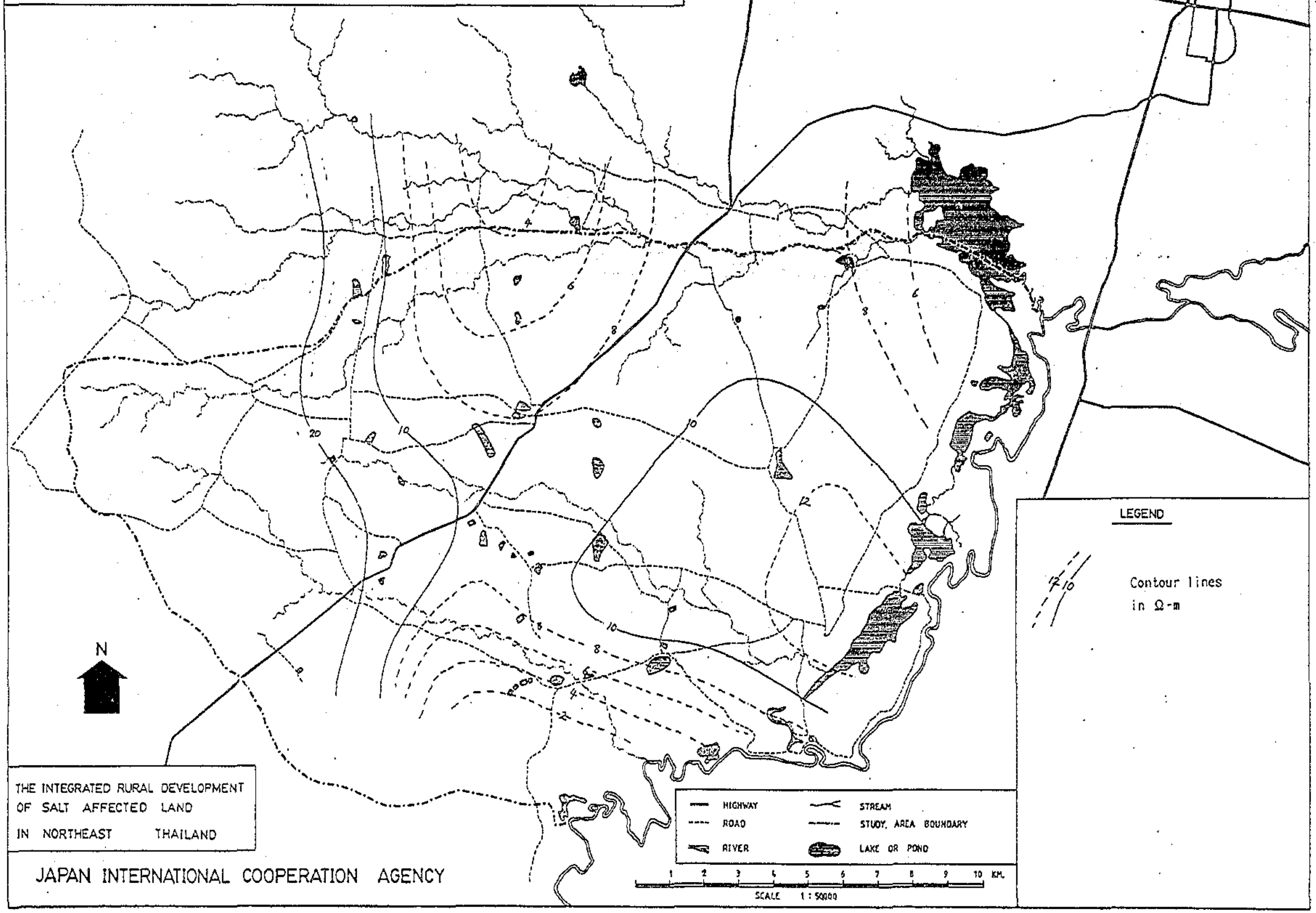


FIGURE B-4

RESISTIVITY CONTOUR MAP AT DEPTH OF 140 M

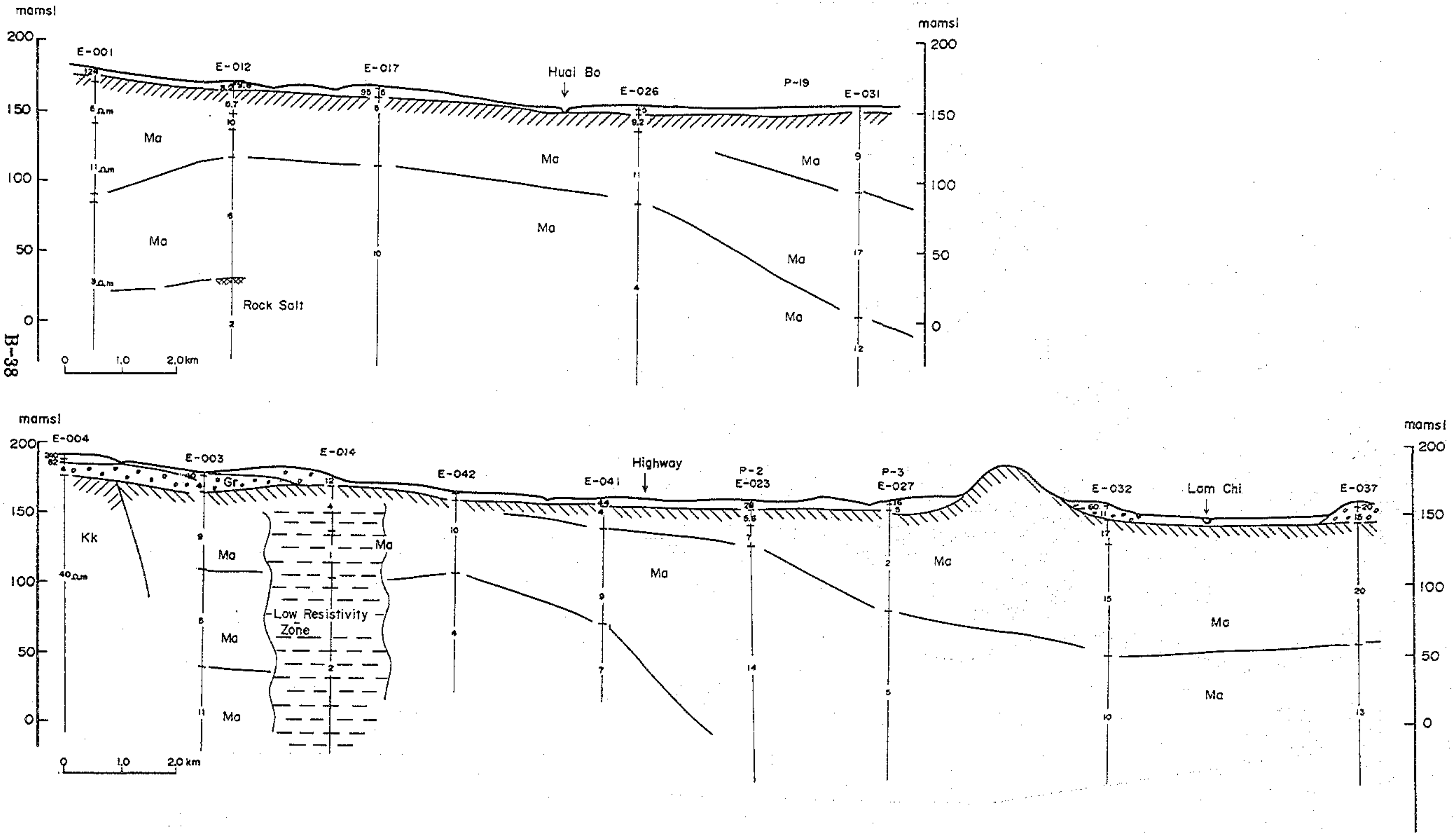


THE INTEGRATED RURAL DEVELOPMENT
OF SALT AFFECTED LAND
IN NORTHEAST THAILAND

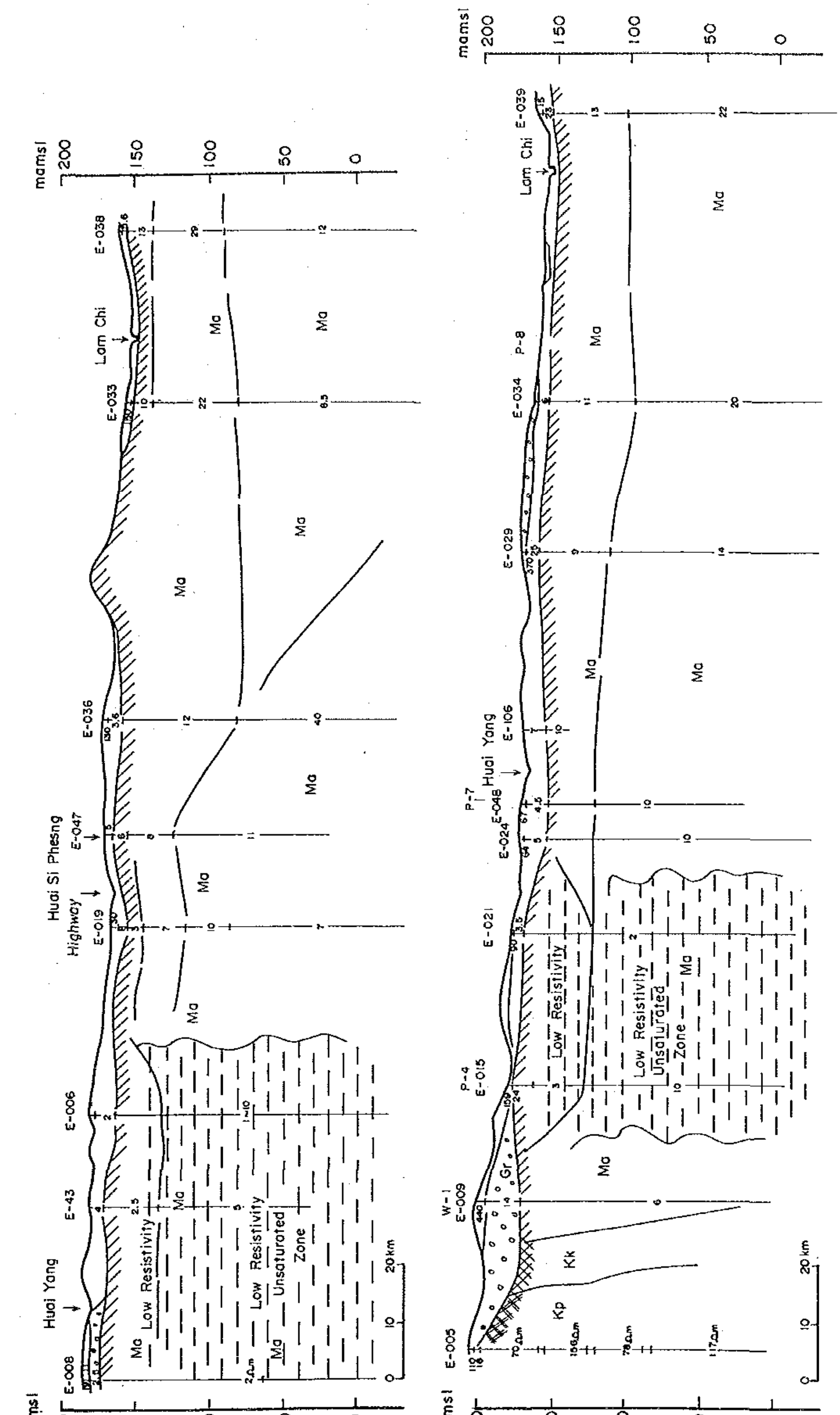
JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE B-5 RESISTIVITY PROFILES

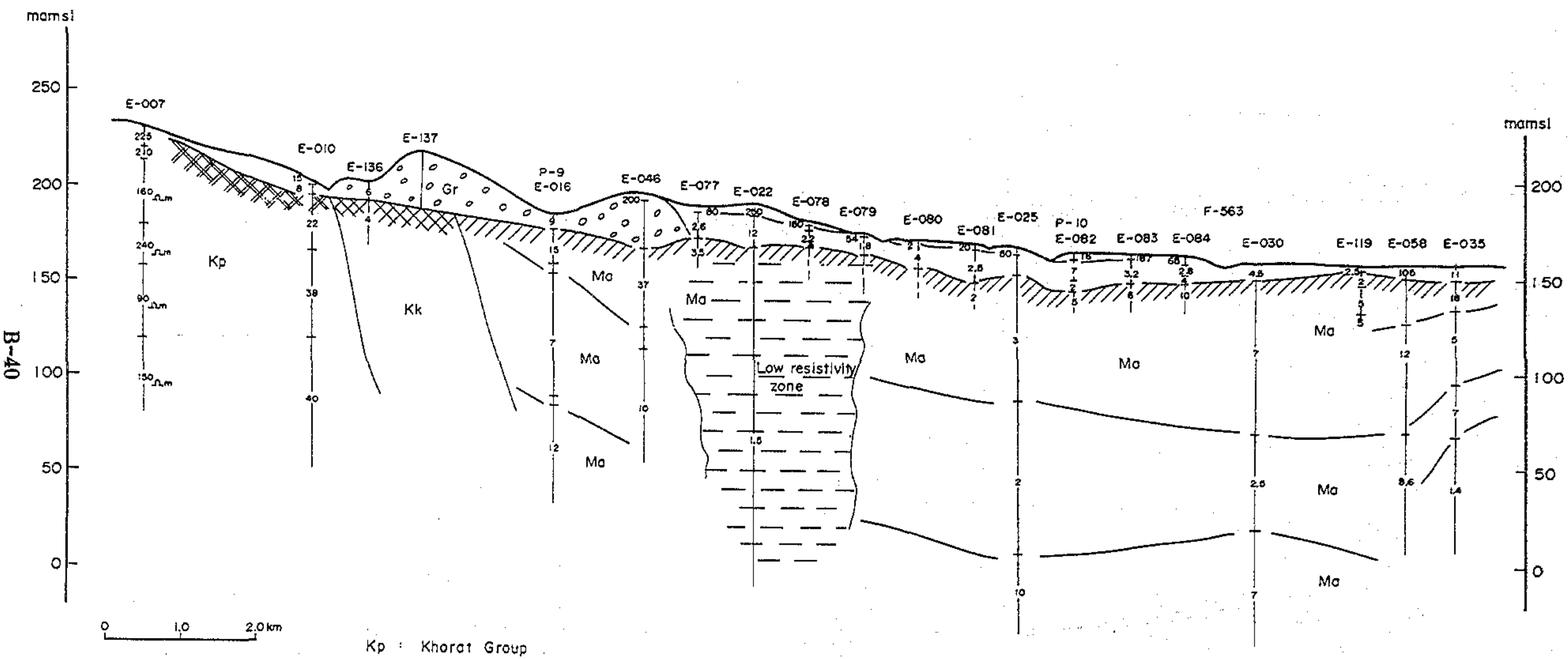
(1)



(2)


mamsl
200
150
100
50
0
E-008
Huai Yang
E-43
E-006
Highway
E-019
Huai Si Phesng
E-047
E-036
E-033
Lam Chi
E-038
Ma
Low Resistivity
Low Resistivity
Unsaturated
Zone
0
10
20 km
E-005
W-1
E-009
P-4
E-015
E-021
E-024
E-048
P-7
Huai Yang
E-106
E-029
E-034
P-8
E-039
Kp
Kk
Gr
Low Resistivity
Low Resistivity
Unsaturated
Zone
Ma
20 km

(3)



Kp : Khorat Group

Kk : Khok Kruat Formation

Ma : Siltstone Formation

FIGURE B-6

DISTRIBUTION OF EC IN STREAMS AND PONDS

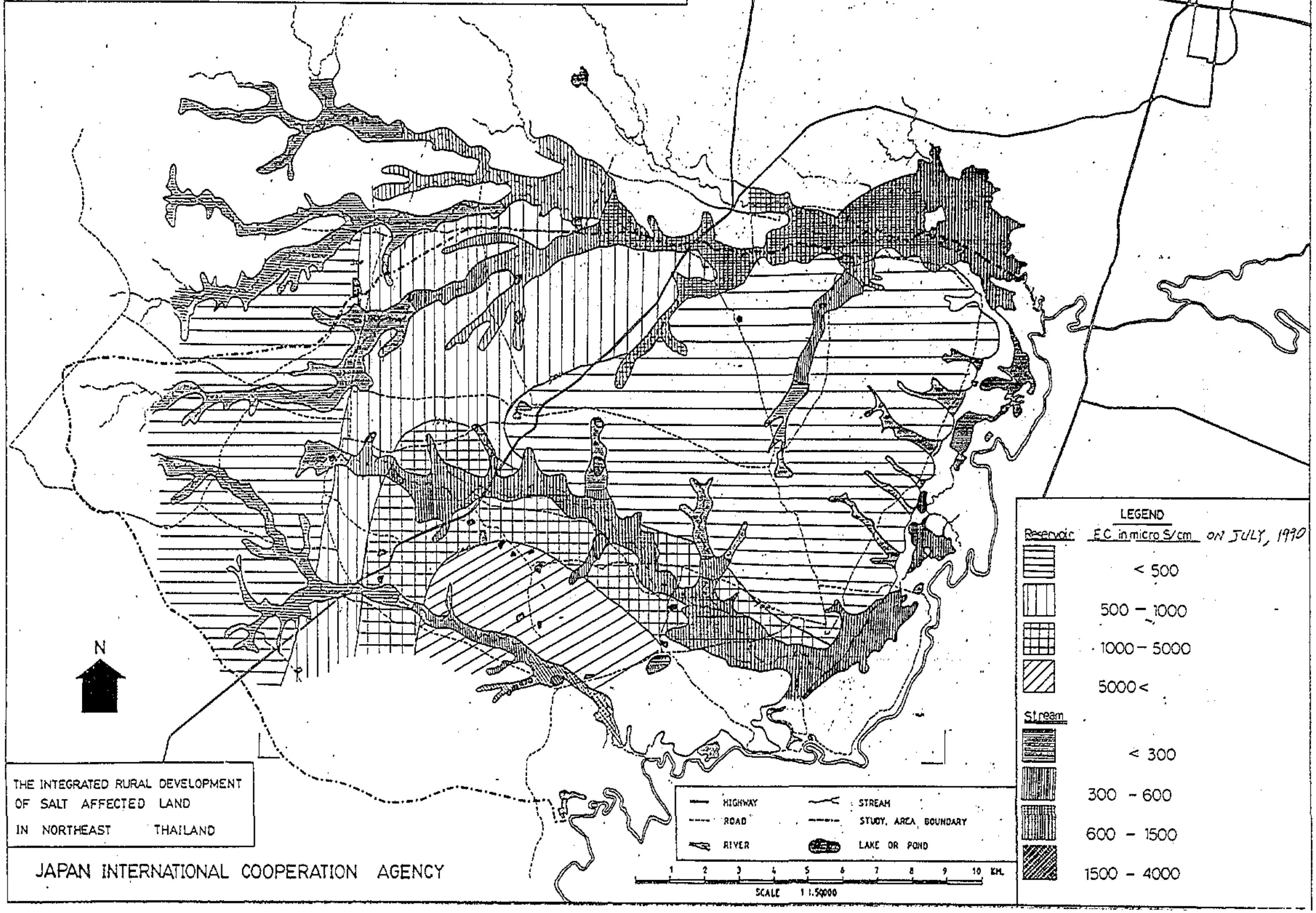


FIGURE. B-7 STANDARD DESIGN OF EXPLORATION WELL

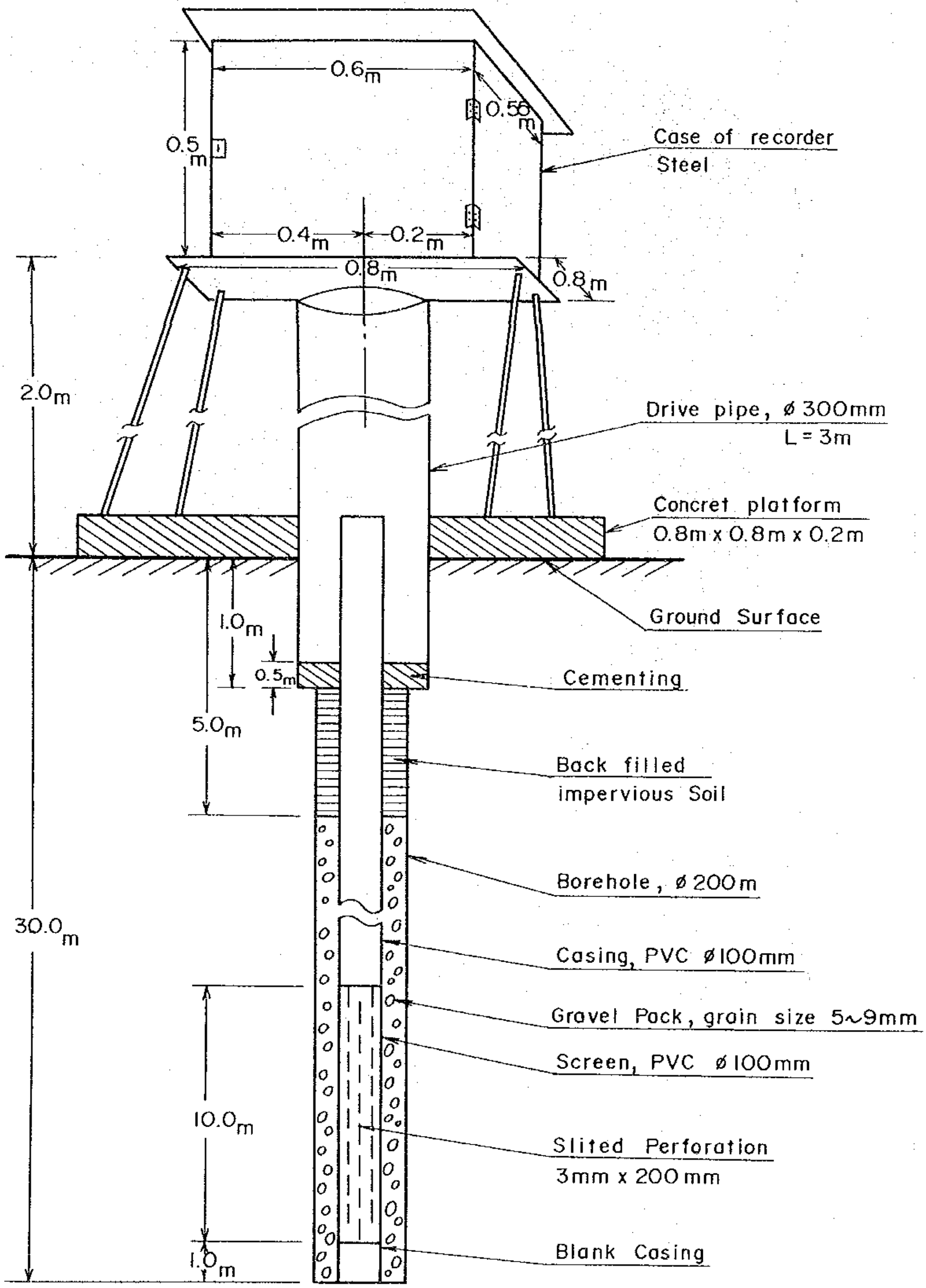


FIGURE. B-8 STANDARD DESIGN OF OBSERVATION WELL

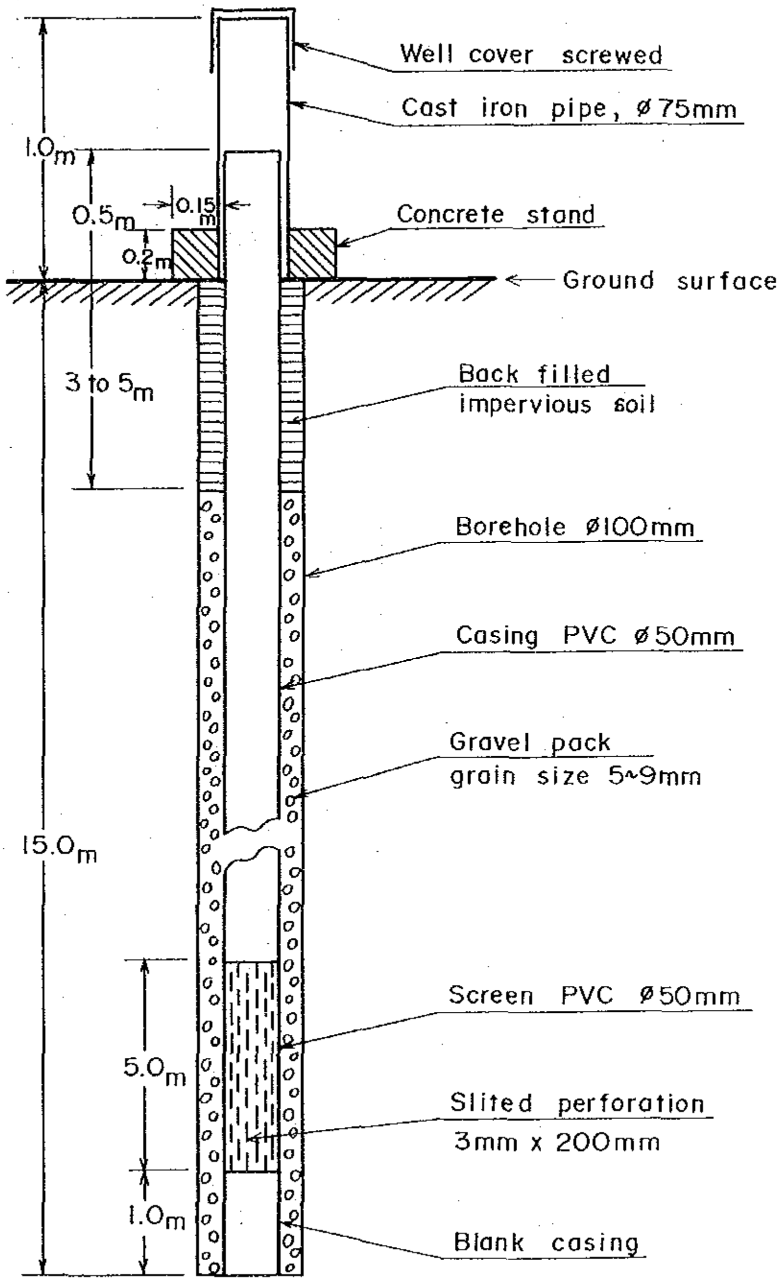


FIGURE B-9 GEOLOGIC LOG OF EXPLORATION WELL, W-1

WELL No. : W-1 SITE ALT.: 207.98 (mamsl) S.W.L.: 17.90 (mbgs)

WELL DEPTH: 30.0 (m) DRILLING DIA.: 225 (mm) WELL DIA.: 100 (mm)

DISCHARGE : 21.4 (lit/min) DRAWDOWN: 1.0 (m) DATE, COMPLETED: 11/9/90

LOCATION : School yard, Ban Pa Mo, Phra Yun, Changwat Khon Kaen

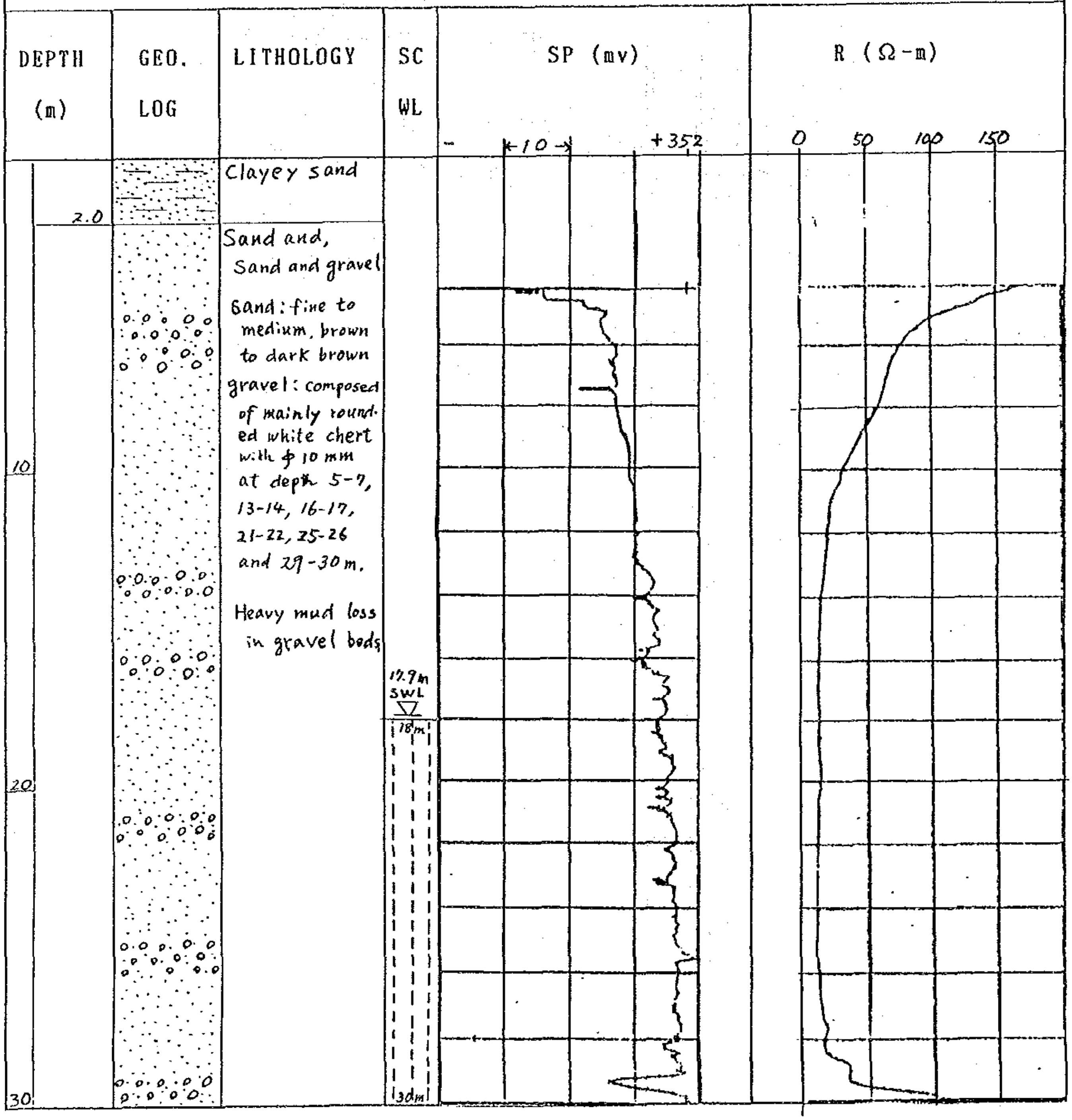


FIGURE B-10 GEOLOGIC LOG OF EXPLORATION WELL, W-2

WELL No. : W-2 SITE ALT.: 176.49 (mamsl) S.W.L.: 5.90 (mbgs)

WELL DEPTH: 30.0 (m) DRILLING DIA.: 225 (mm) WELL DIA.: 100 (mm)

DISCHARGE : 3.75 (lit/min) DRAWDOWM: 7.48 (m) DATE, COMPLETED: 20/8/90

LOCATION : Wat Si Tan Waravat, Ban Non Tun, T. Non Waeng, Phra Yun, Khon Kaen

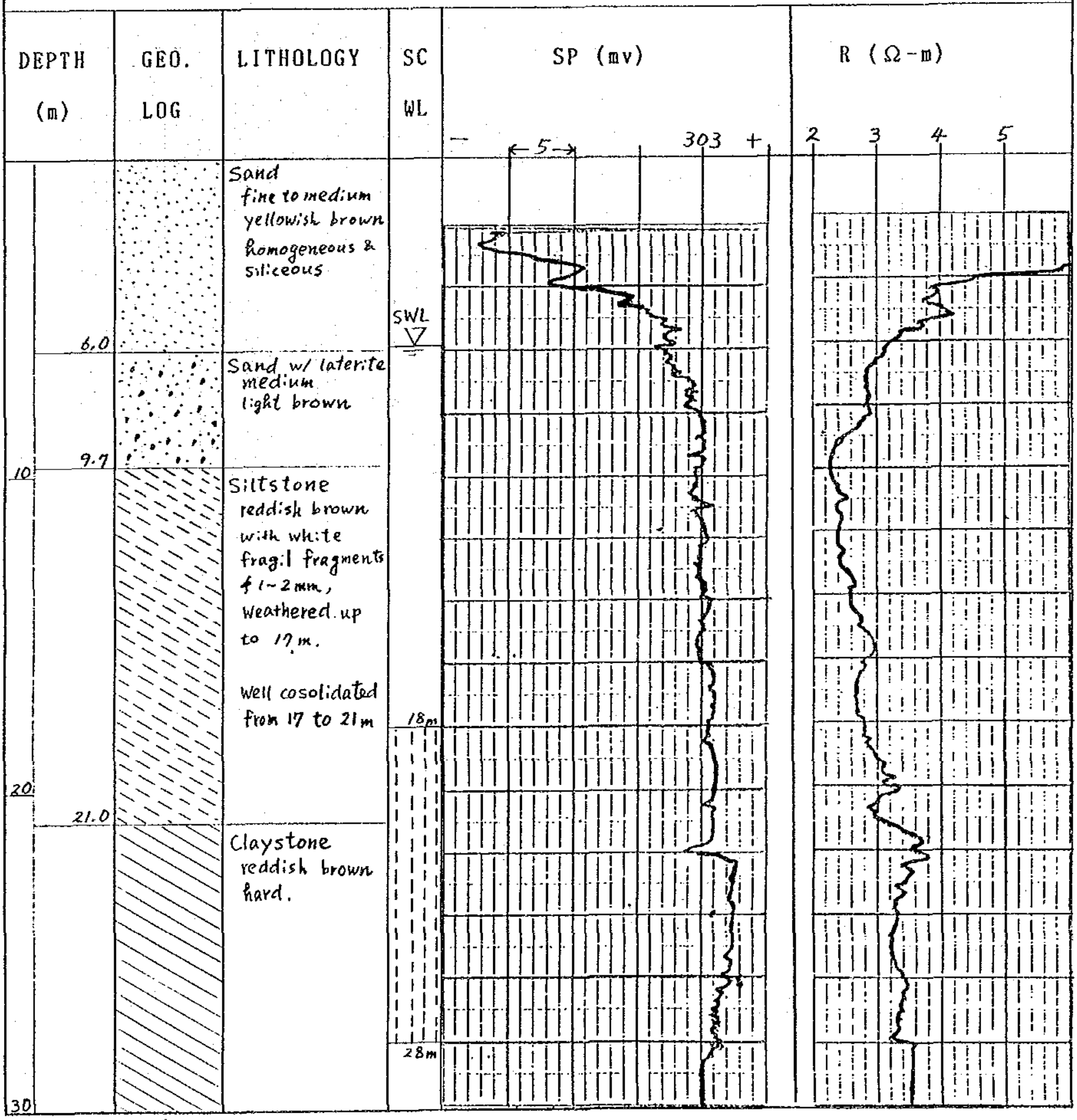


FIGURE B-11 GEOLOGIC LOG OF OBSERVATION WELL, P-1

WELL No. : P-1 SITE ALT.: 174.01 (mamsl) S.W.L.: 0.81 (mbgs)

WELL DEPTH: 15.0 (m) DRILLING DIA.: 150 (mm) WELL DIA.: 100 (mm)

LOCATION : Wat Suthi Mongkhon, Ban Non Bo, Phra Yun DATE, COMPLETED: 27/8/90

DEPTH (m)	GEO. LOG	LTHOLOGY	WL
2.6		Sand fine, reddish brown siliceou	SWL
4.0		Clayey silt w/ laterite brown	
6.3		Clayey silt w/gravel gravel: chert	
15		Siltstone reddish brown	9 – 14

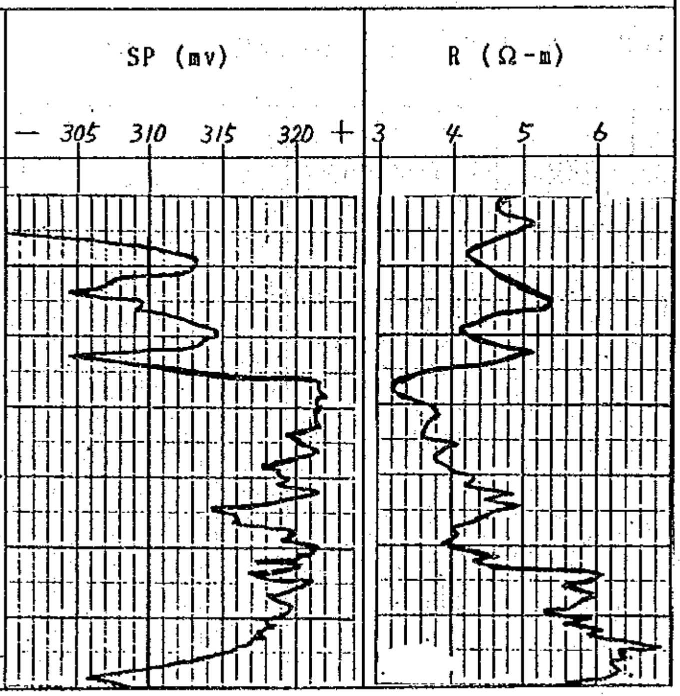


FIGURE B-12 GEOLOGIC LOG OF OBSERVATION WELL, P-2

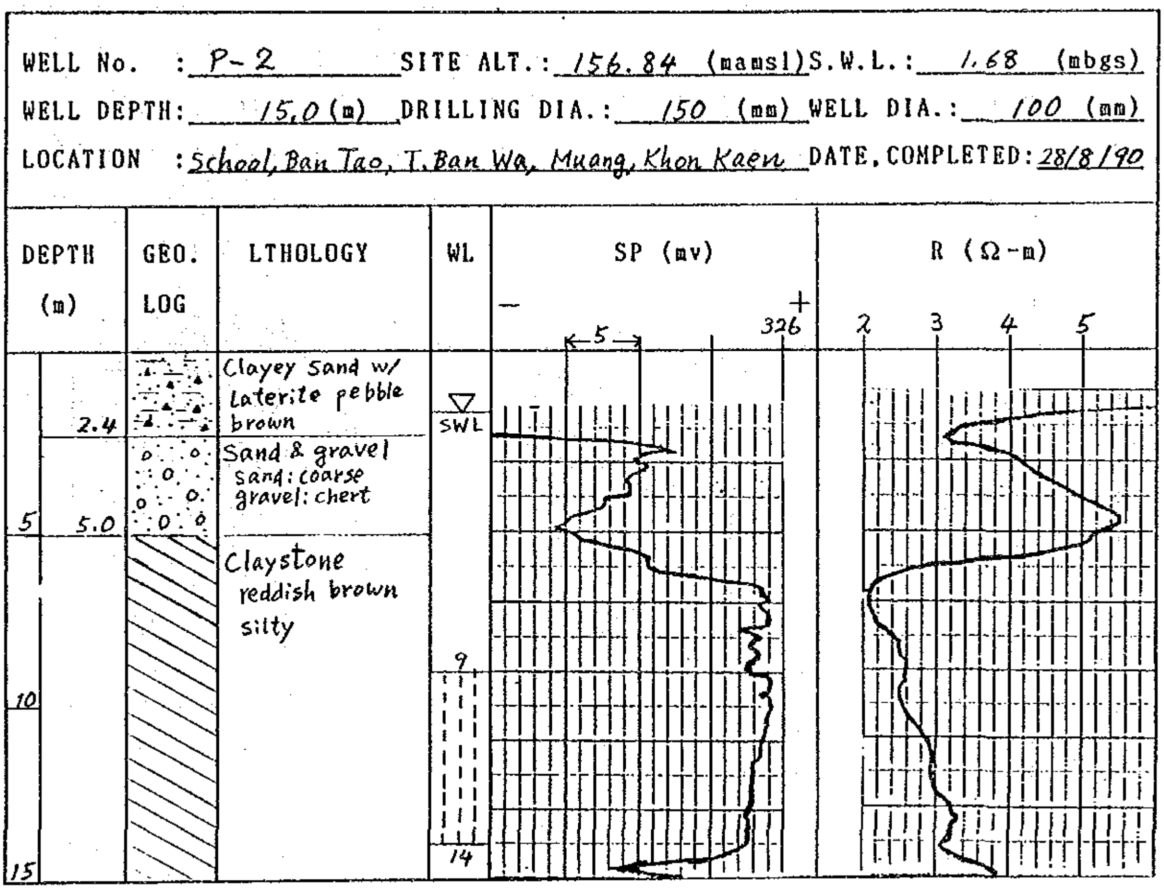


FIGURE B-13 GEOLOGIC LOG OF OBSERVATION WELL, P-3

WELL No. : P-3 SITE ALT.: 158.20 (mamsl) S.W.L.: 1.60 (mbgs)

WELL DEPTH: 15.0 (m) DRILLING DIA.: 150 (mm) WELL DIA.: 50 (mm)

LOCATION : Wat Nam Khang, Ban Ya Nang, T. Don Chang A. Muang, Khon Kaen DATE, COMPLETED: 30/8/90

DEPTH (m)	LTHOLOGY	WL
1.0	Sand fine, reddish brown	SWL (1.60)
3.5	Sand medium, clayey reddish brown	
7.0	Sand & gravel ϕ 1mm quartz grain black shale frag.	4 – 9 (screen)
8.0	Sand, fine brown	
10.0	Gravel contain. clay	
11.5	Clay sticky, yellow brown	
12.4	Sand, fine, yel. brown	
15	Clay containing sand and carbonize woods.	

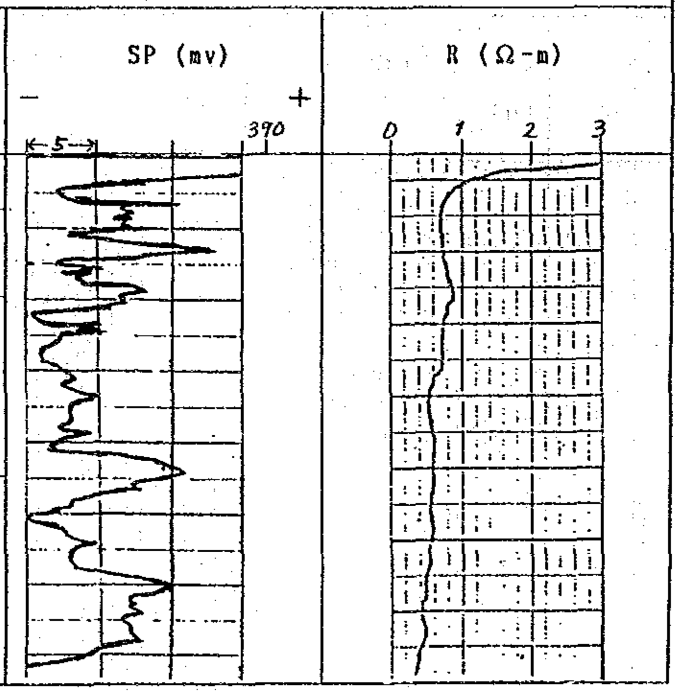


FIGURE B-14 GEOLOGIC LOG OF OBSERVATION WELL, P-4

WELL No. : P-4 SITE ALT.: 185.64 (mamsl) S.W.L.: 3.49 (mbgs)

WELL DEPTH: 15.0 (m) DRILLING DIA.: 150 (mm) WELL DIA.: 50 (mm)

LOCATION : 2 km east of Ban Pa Mo, A. Phra Yun, Khon Kaen DATE, COMPLETED: 25/8/90

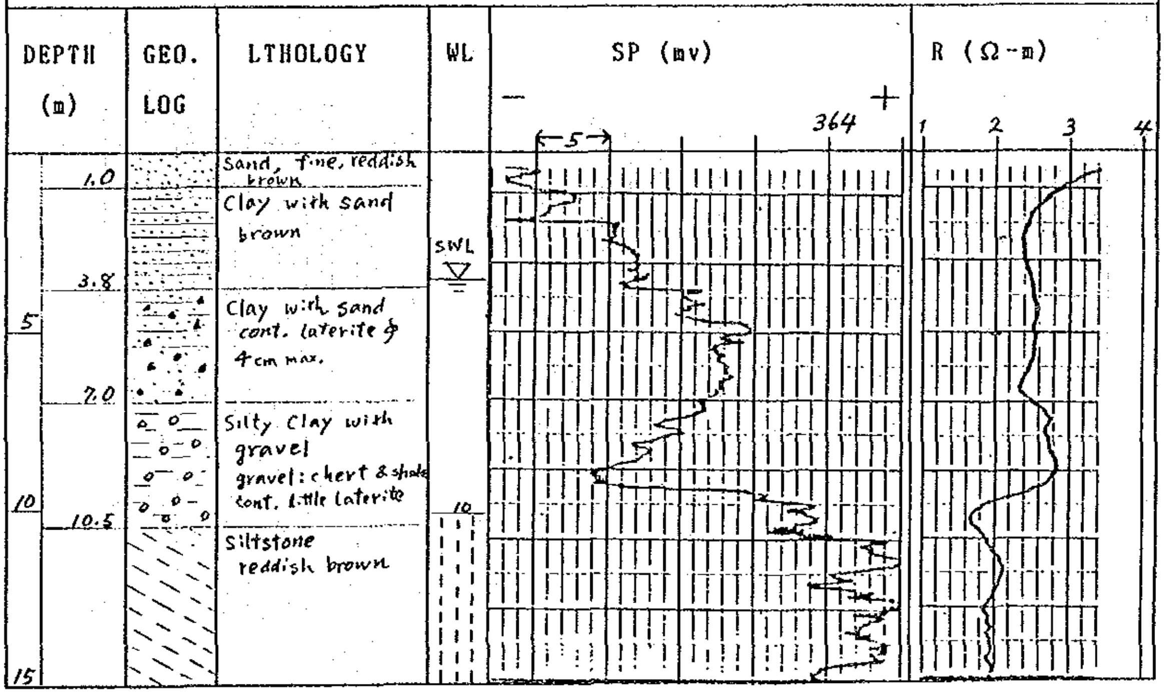


FIGURE B-15 GEOLOGIC LOG OF OBSERVATION WELL, P-5

WELL No. : P-5 SITE ALT.: 165.60 (mamsl) S.W.L.: ⊕ 0.09 (mags)
WELL DEPTH: 15.0 (m) DRILLING DIA.: 150 (mm) WELL DIA.: 50 (mm)
LOCATION : West of Nong Bua, Ban Phra Yun, Khon Kaen DATE.COMPLETED: 31/8/90

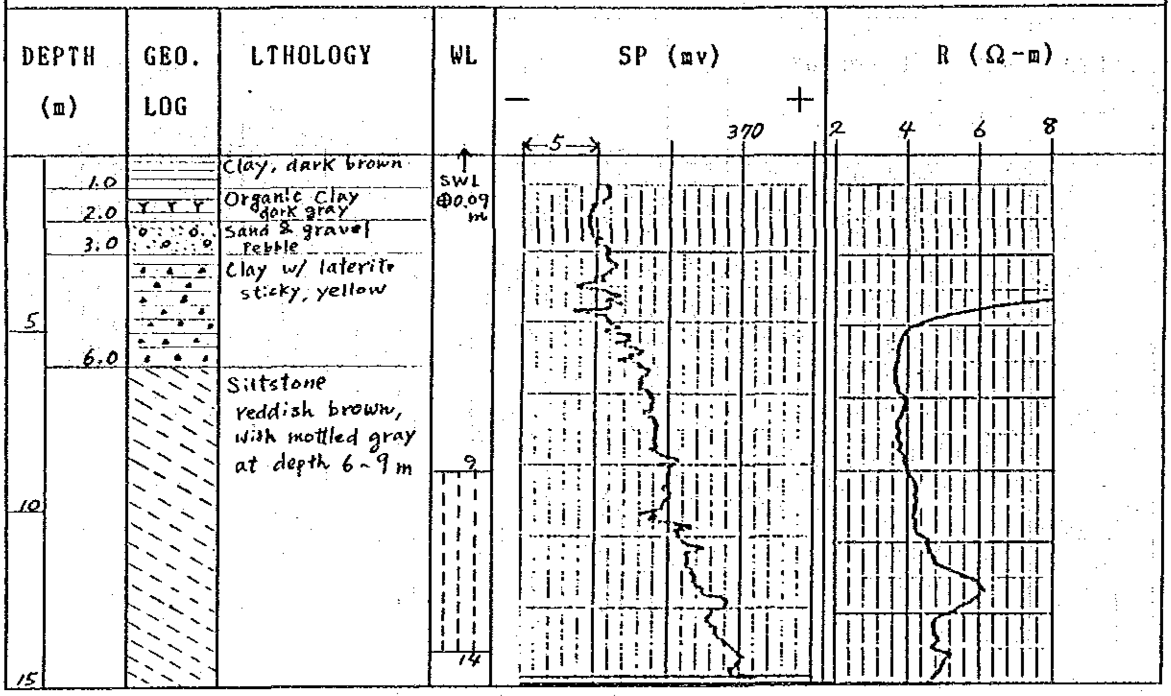


FIGURE B-16 GEOLOGIC LOG OF OBSERVATION WELL, P-6

WELL No. : P-6 SITE ALT.: 180.35 (mamsl) S.W.L.: 1.30 (mbgs)

WELL DEPTH: 15.0 (m) DRILLING DIA.: 150 (mm) WELL DIA.: 50 (mm)

LOCATION : School, Ban Bo Kae, T. Kham Pom, A. Phra Yun, Khon Kaen DATE, COMPLETED: 23/8/90

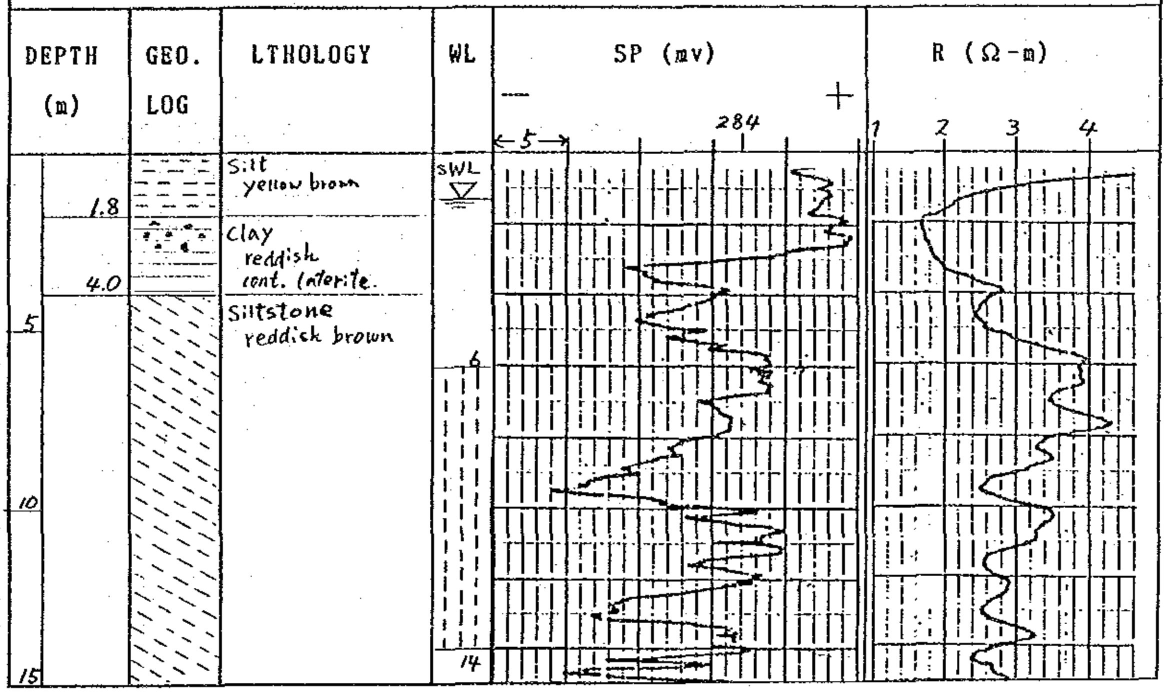


FIGURE B-17 GEOLOGIC LOG OF OBSERVATION WELL, P-7

WELL No. : P-7 SITE ALT.: 167.95 (mamsl) S.W.L.: 0.08 (mbgs)

WELL DEPTH: 15.0 (m) DRILLING DIA.: 150 (mm) WELL DIA.: 50 (mm)

LOCATION : Wat Chedi, Ban Chat, Phra Yun, Khon Kaen DATE COMPLETED: 22/8/90

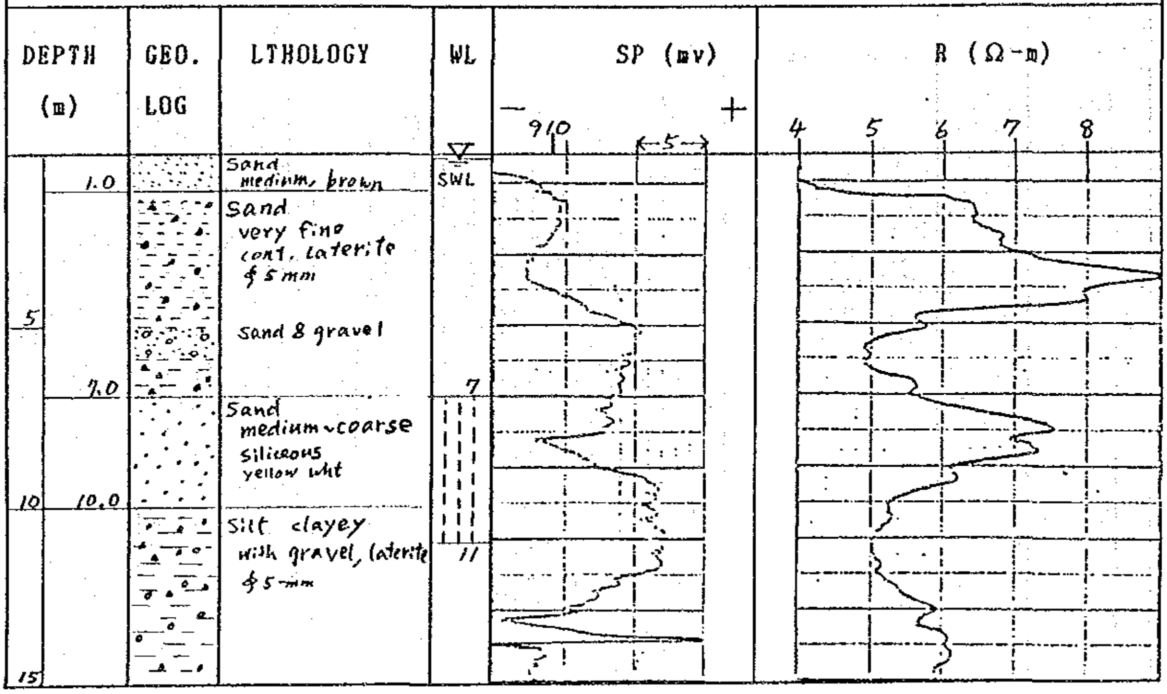


FIGURE B-18 GEOLOGIC LOG OF OBSERVATION WELL, P-8

WELL No. : P-8 SITE ALT.: 160.40 (mamsl) S.W.L.: 5.24 (mbgs)

WELL DEPTH: 15.0 (m) DRILLING DIA.: 150 (mm) WELL DIA.: 50 (mm)

LOCATION : Wat Si Phimon, Ban Tou, Phra Yun, Khon Kaen DATE, COMPLETED: 20/8/90

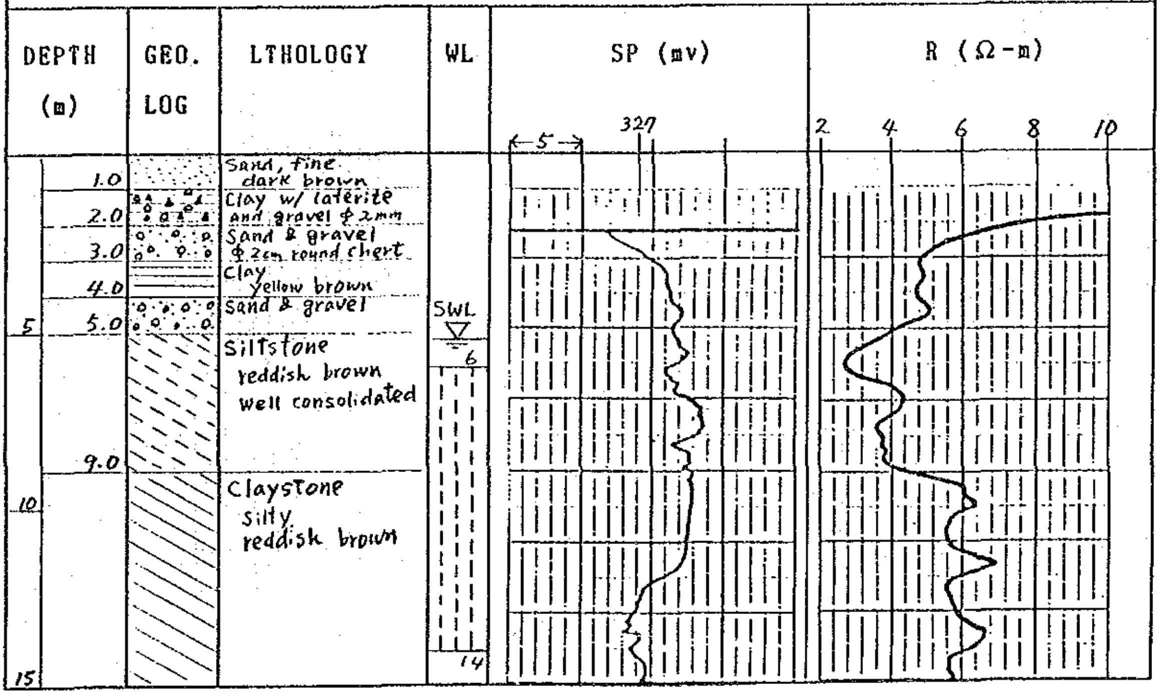


FIGURE B-19 GEOLOGIC LOG OF OBSERVATION WELL,P-9

WELL No. : P-9 SITE ALT.: 185.40 (mamsl) S.W.L.: 1.83 (mbgs)

WELL DEPTH: 15.0 (m) DRILLING DIA.: 150 (mm) WELL DIA.: 50 (mm)

LOCATION : Rd Junction, Ban Pa San, Phra Yun, Khon Kaen DATE.COMPLETED: 8/8/90

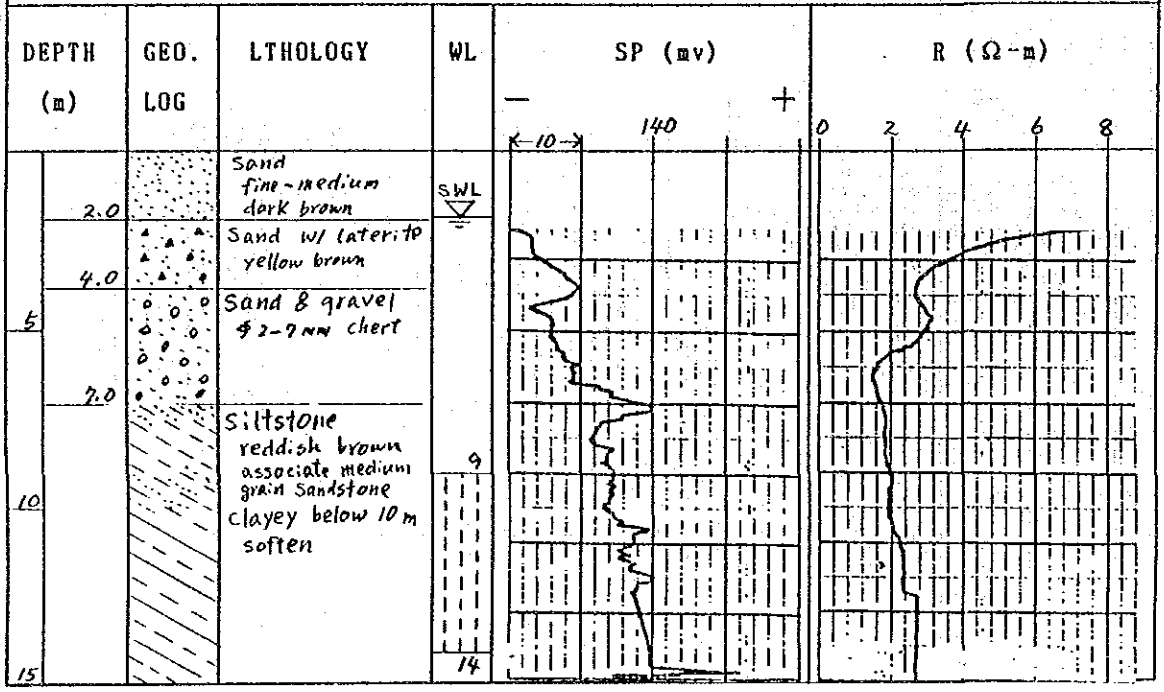


FIGURE B-20 GEOLOGIC LOG OF OBSERVATION WELL, P-10

WELL No. : P-10 SITE ALT.: 163.52 (mamsl) S.W.L.: 0.38 (mbgs)

WELL DEPTH: 15.0 (m) DRILLING DIA.: 150 (mm) WELL DIA.: 50 (mm)

LOCATION : 0.7 Km east of Ban Dong Kheng, T. Tha Sala, Manchakiri Khon Kaen DATE, COMPLETED: 10/8/90

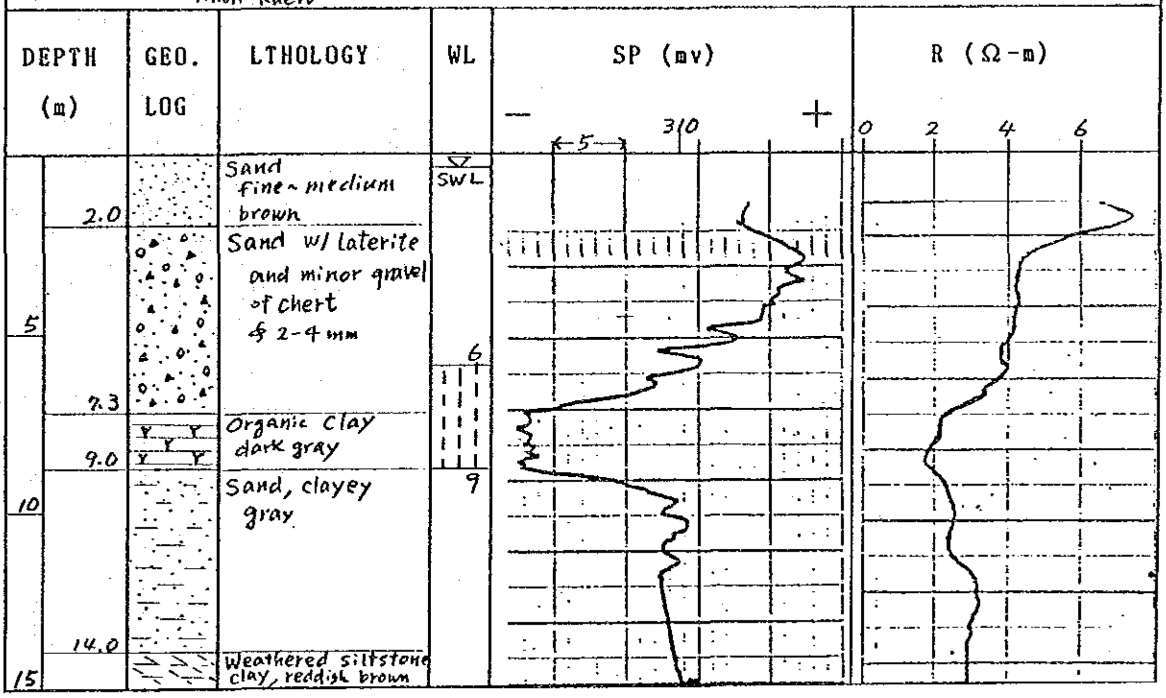


FIGURE B-21 TIME-DRAWDOWN RELATION IN W-1 WELL

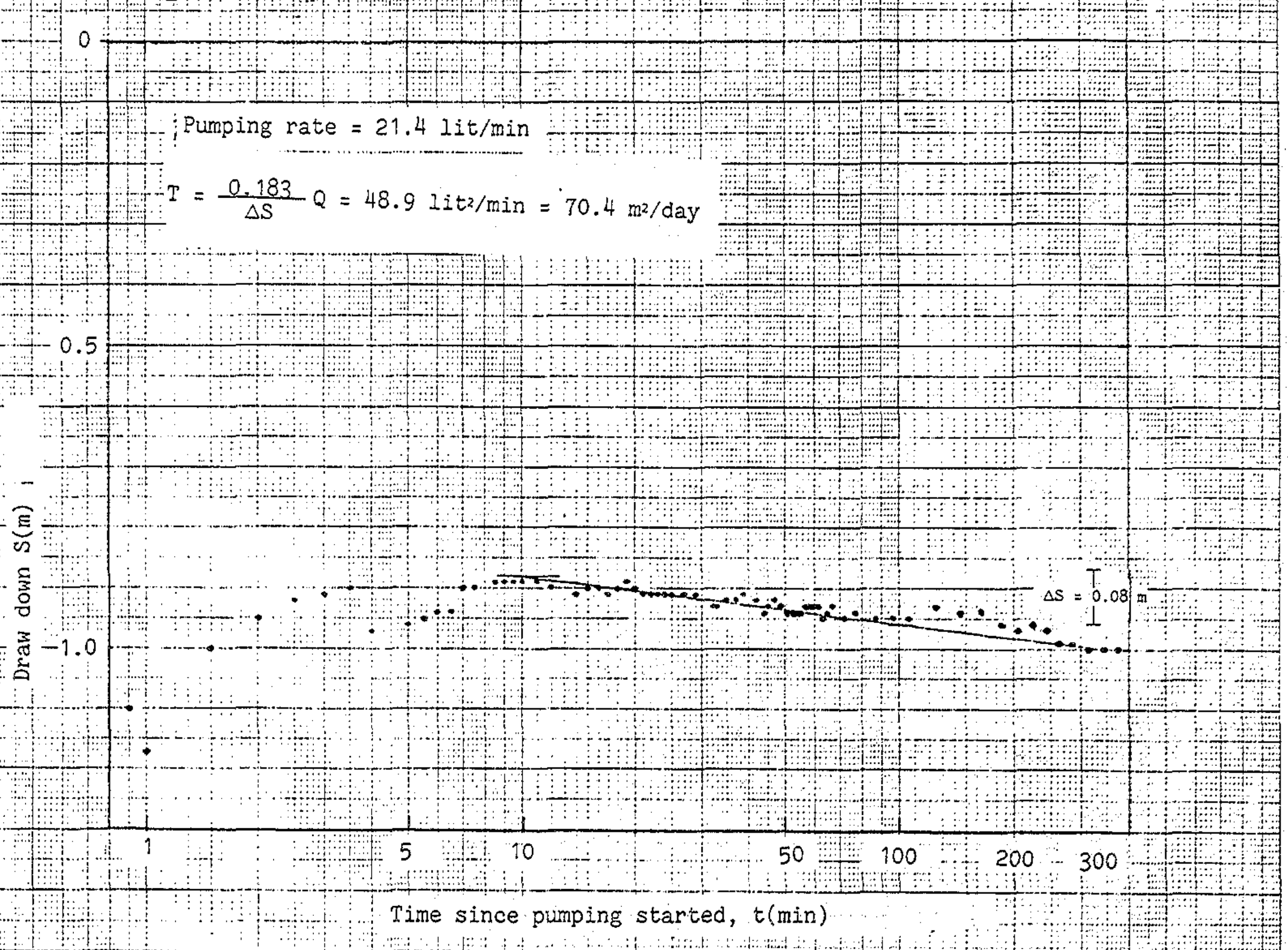
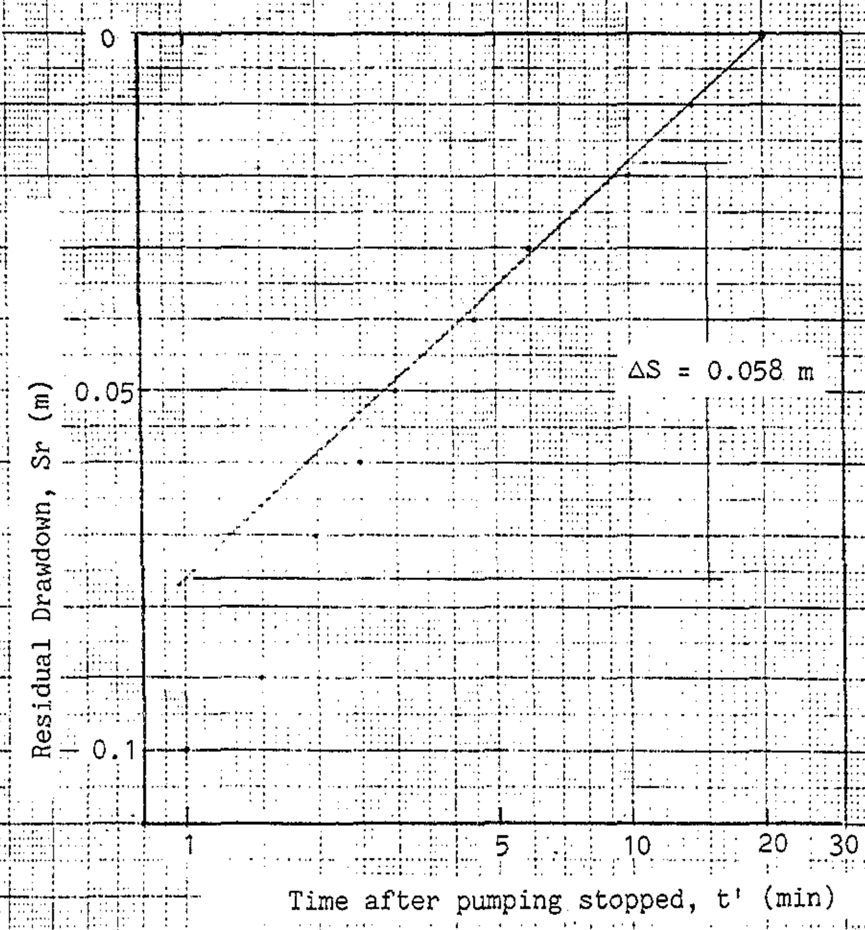


FIGURE B-22 TIME-RECOVERY RELATION IN W-1 WELL



Pumping rate Q = 21.4 lit/min

$$T = \frac{0.183}{\Delta S} Q = 67.5 \text{ lit}^2\text{/min} = 97.2 \text{ m}^2\text{/day}$$

FIGURE B-23 TIME-RECOVERY RELATION IN W-2 WELL

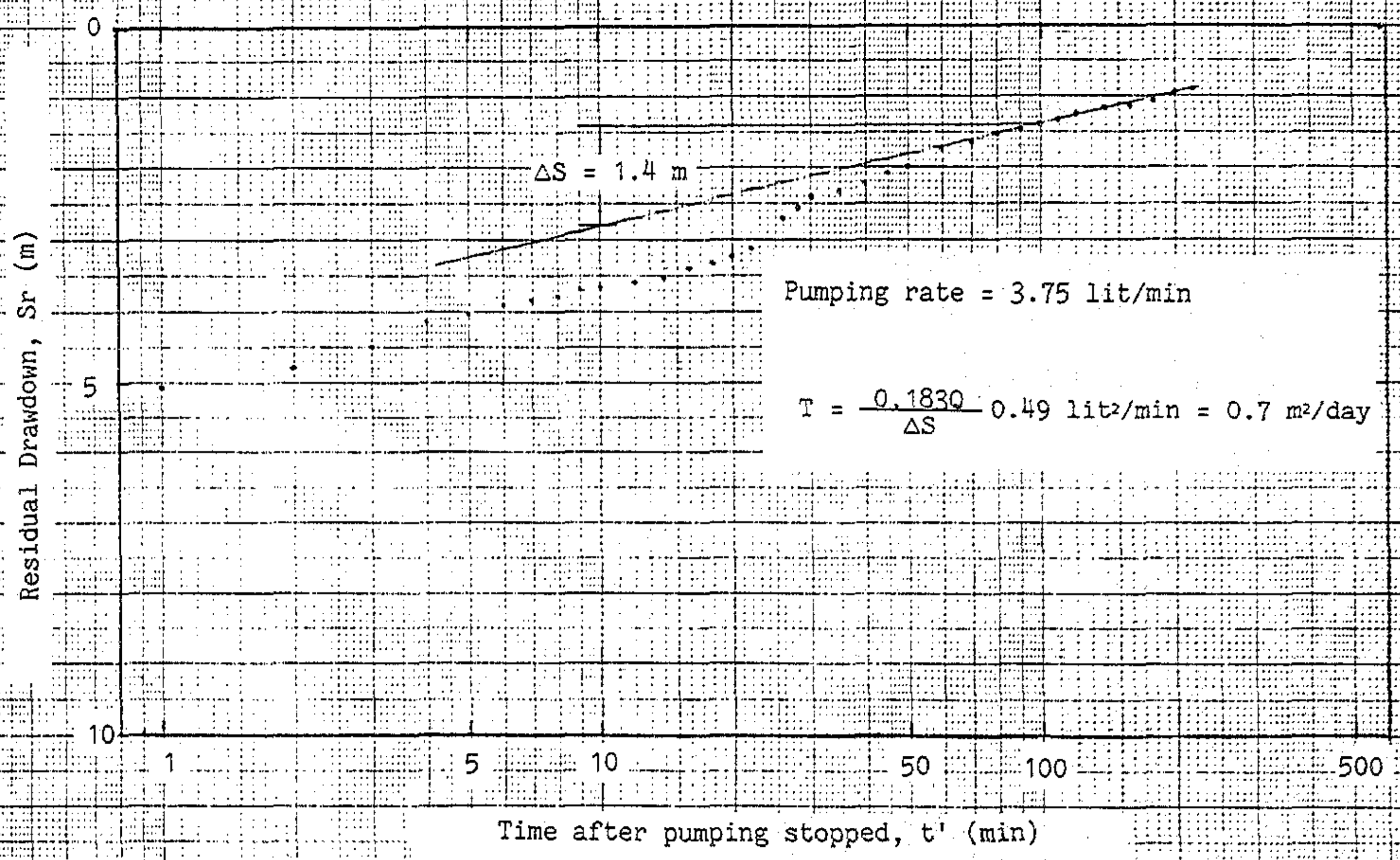


FIGURE B-24

LOCATION MAP OF HYDROGEOLOGICAL SURVEY IN PILOT AREA

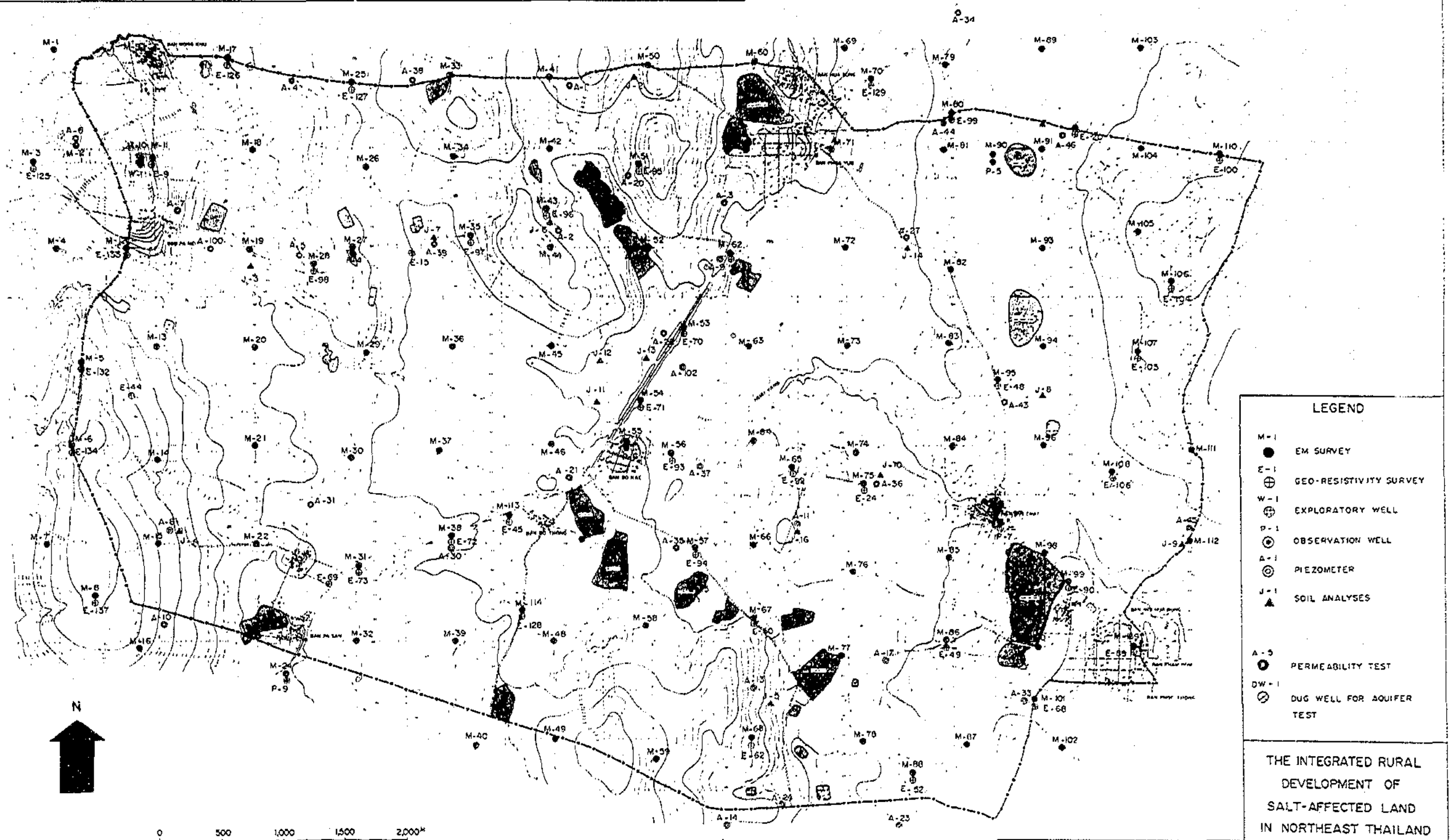


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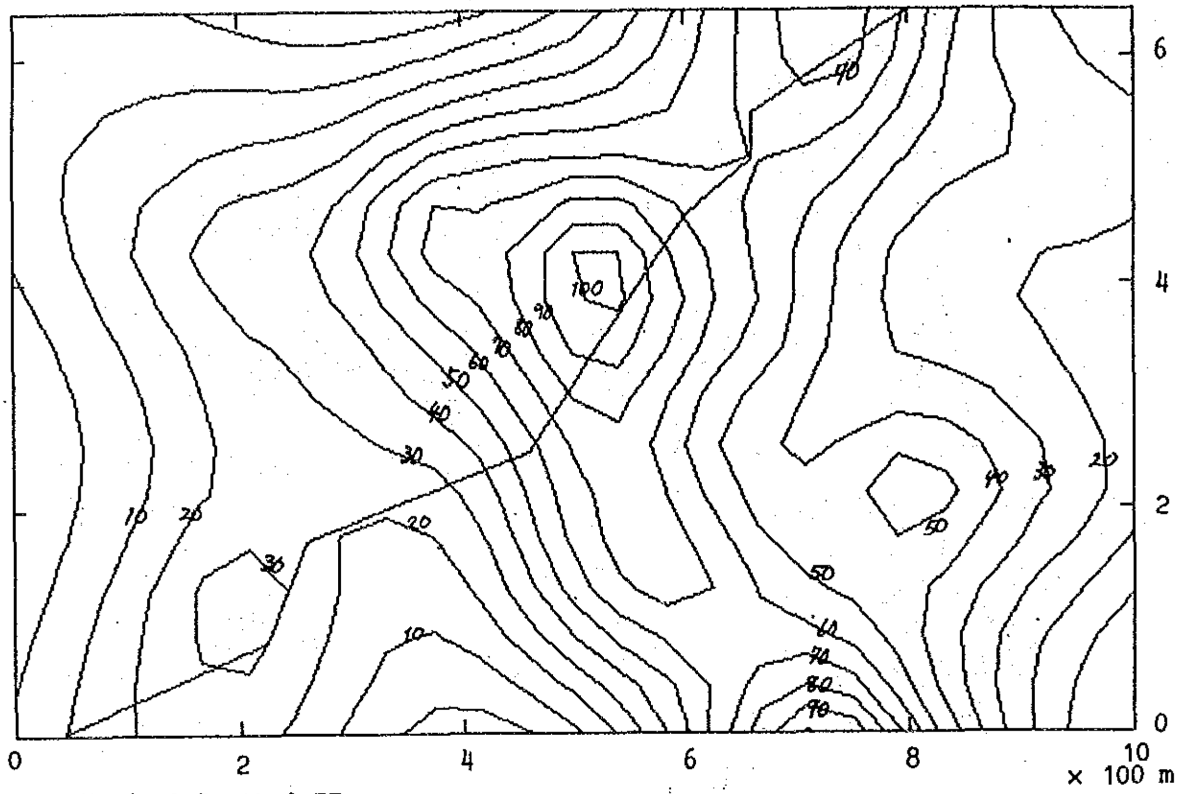
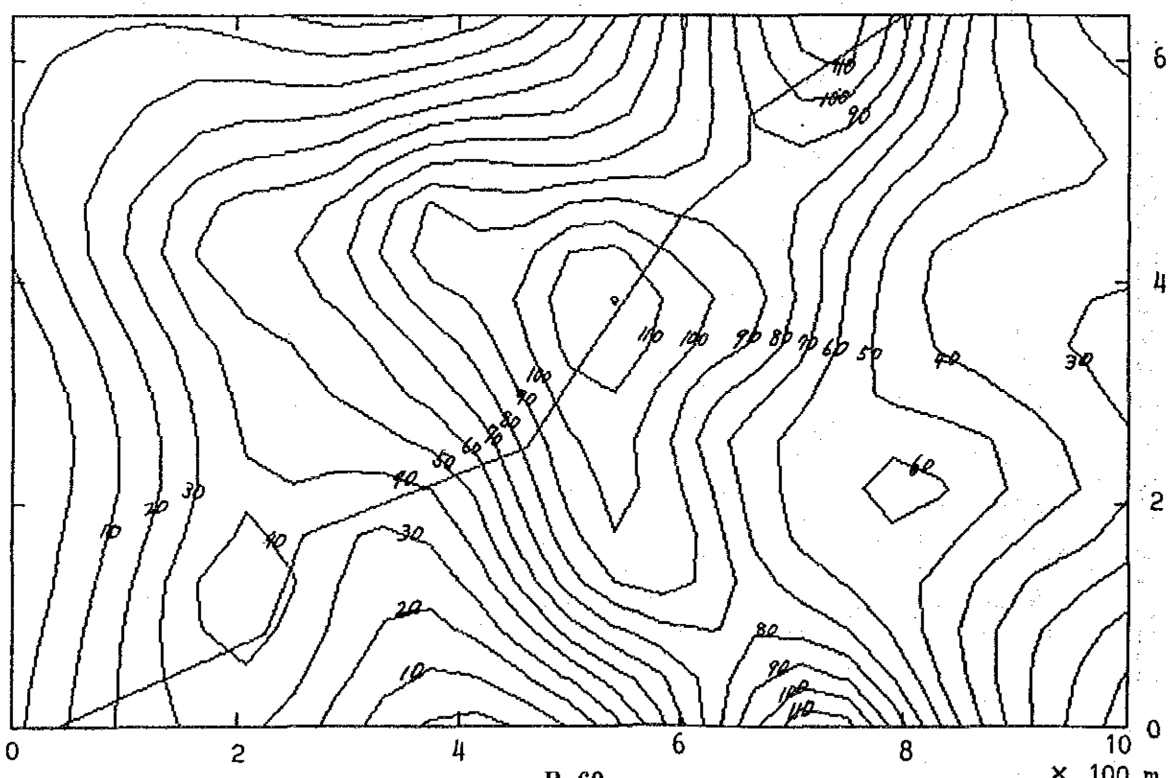
FIGURE B-25 APPARENT CONDUCTIVITY MAP BY COIL SPACE 1 M in PILOT AREA IN mS/m

grid data = B:PL-EMH1.FIL obs.data = B:PL-EMH1.XY2 Horizontal Dipole



Nominal Depth 0.75 m

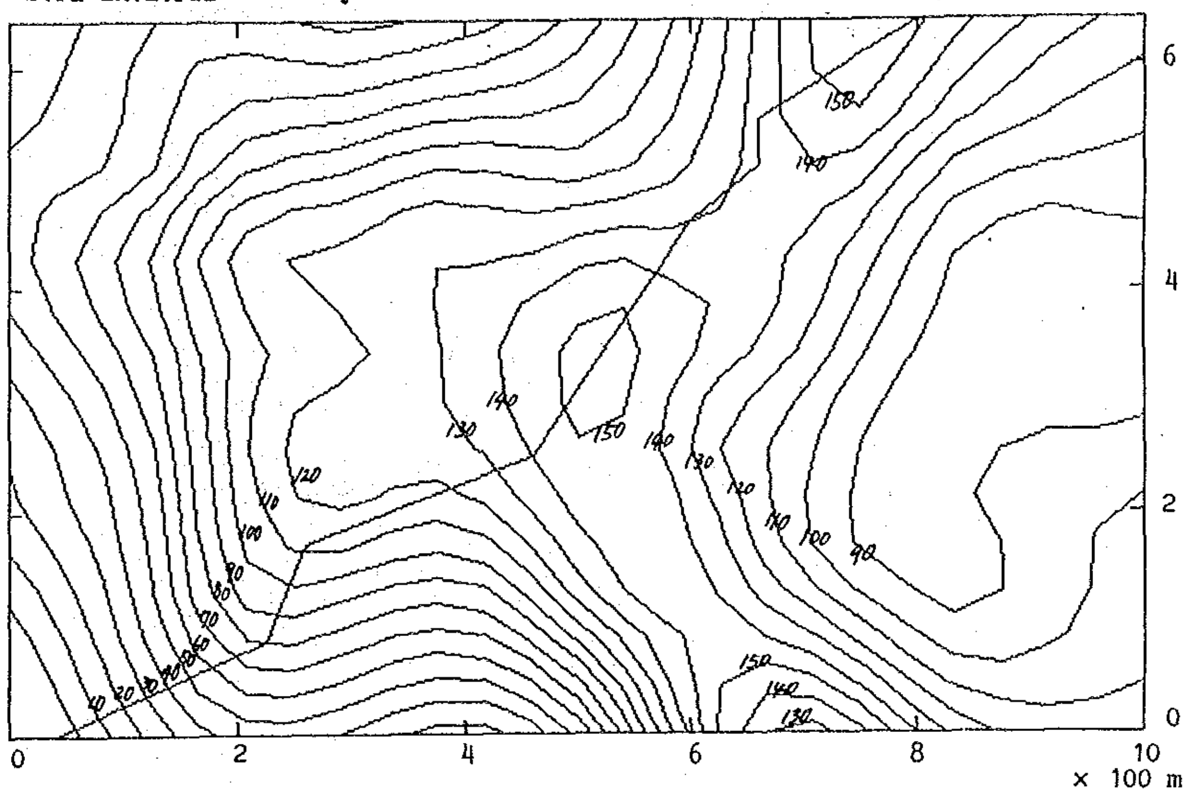
grid data = B:PL-EMV1.FIL obs.data = B:PL-EMV1.XY2 Vertical Dipole



Nominal Depth 1.5 m

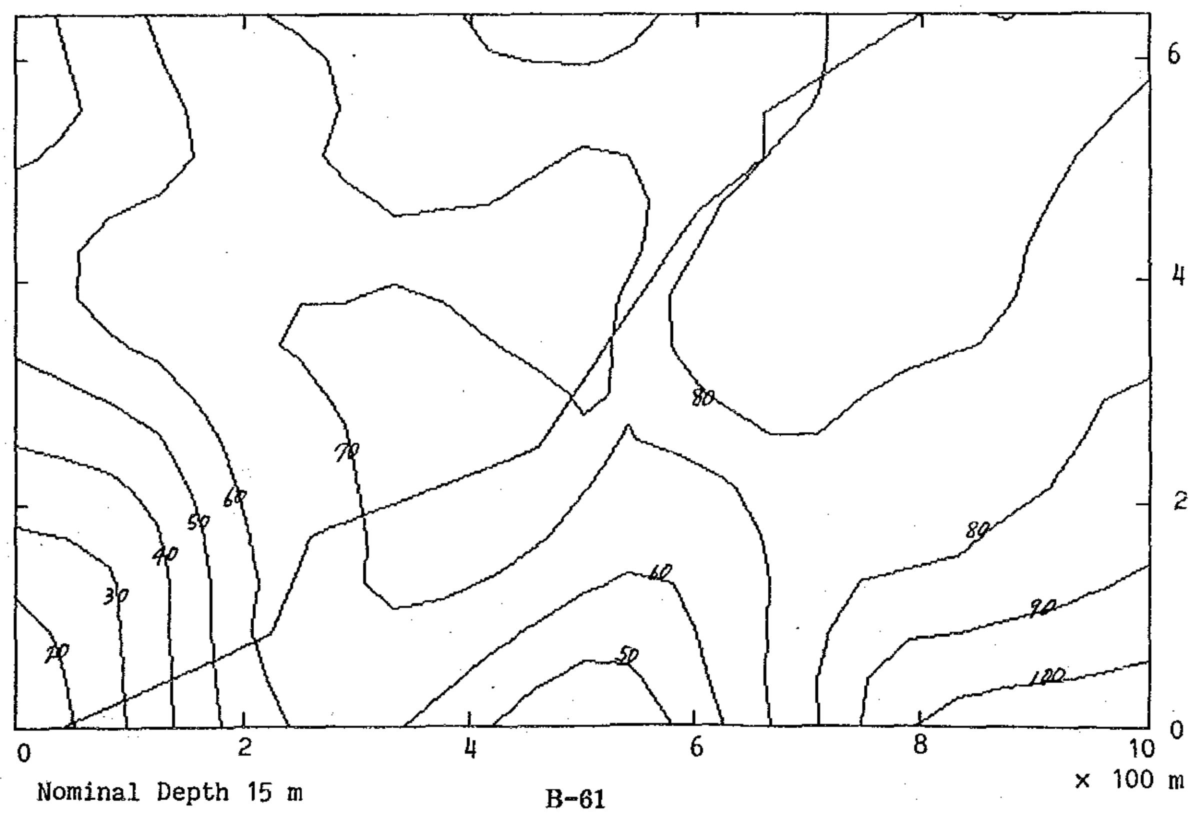
FIGURE B-26 APPARENT CONDUCTIVITY MAP BY COIL SPACE 10 M IN PILOT AREA IN mS/m

B:PL-EMV2.FIL   EM by COIL SPACE 10 m   Horizontal Dipole



Nominal Depth 7.5 m

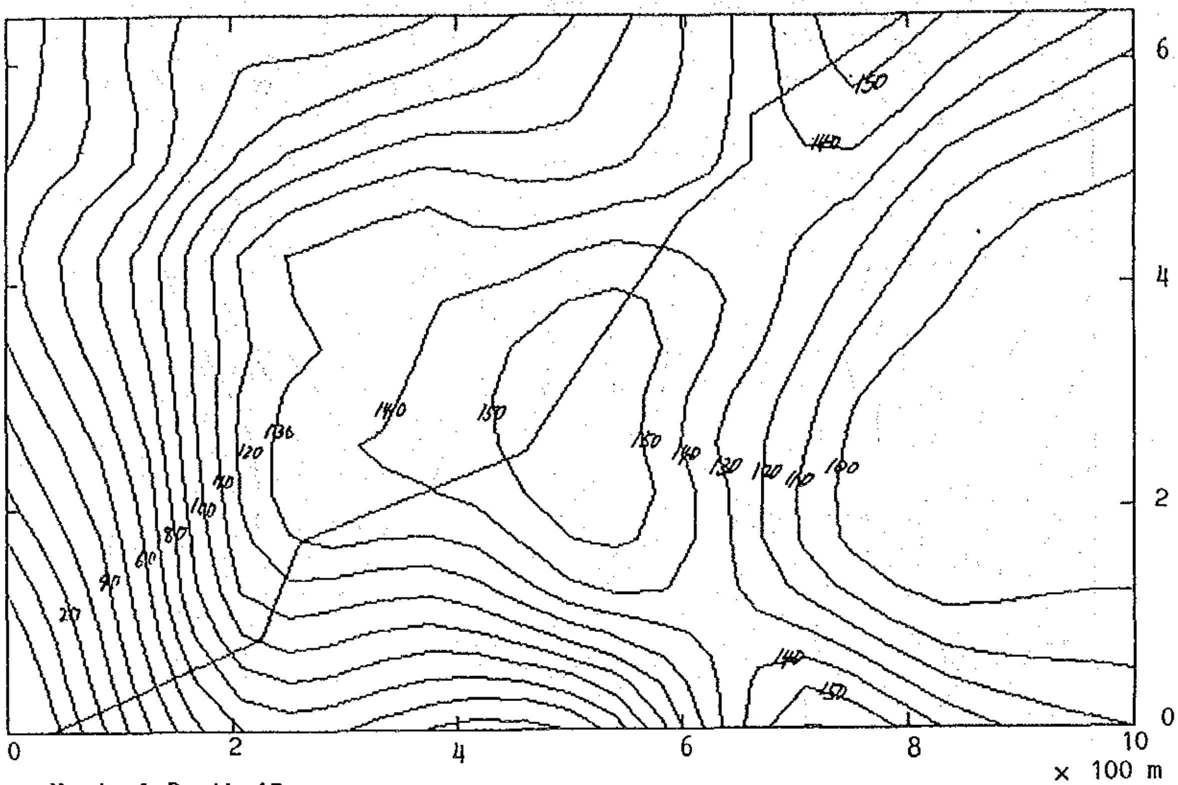
B:PL-EMH2.FIL   EM by COIL SPACE 10m   Vertical Dipole



Nominal Depth 15 m

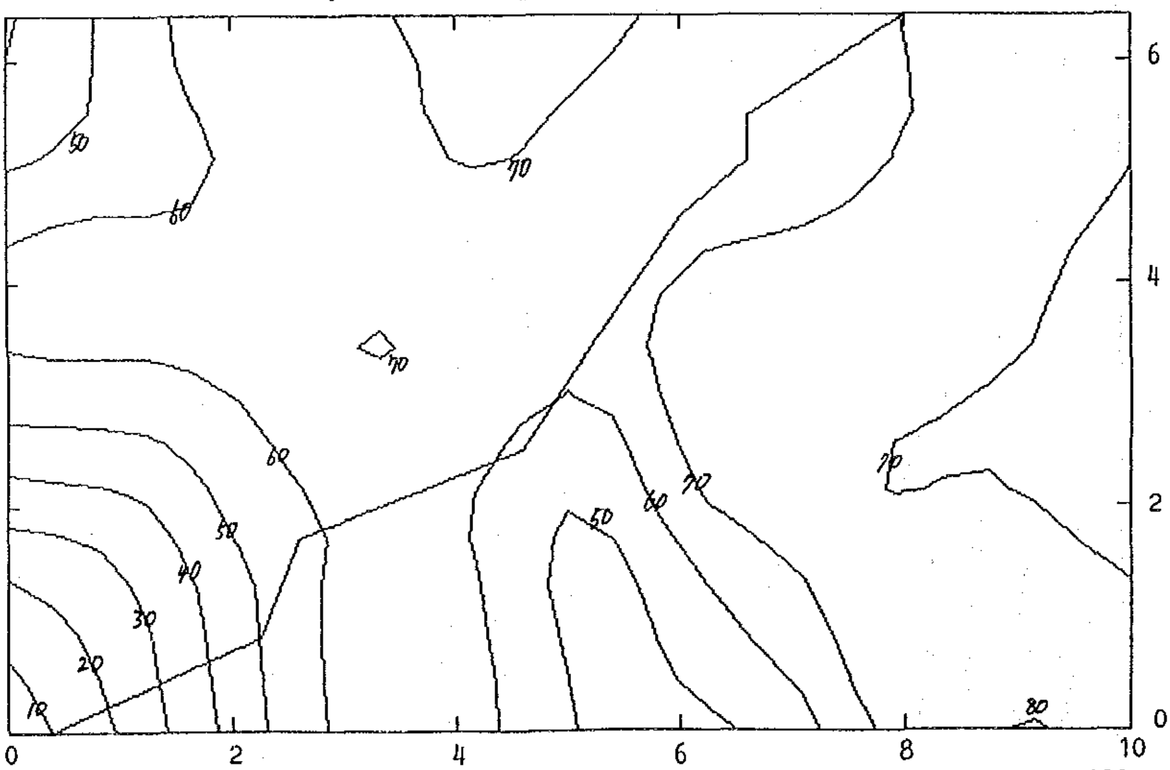
FIGURE B-27 APPARENT CONDUCTIVITY MAP BY COIL SPACE 20 M IN PILOT AREA IN mS/m

B:PL-EMV3.FIL EM by COIL SPACE 20 m Horizontal Dipole



Nominal Depth 15 m

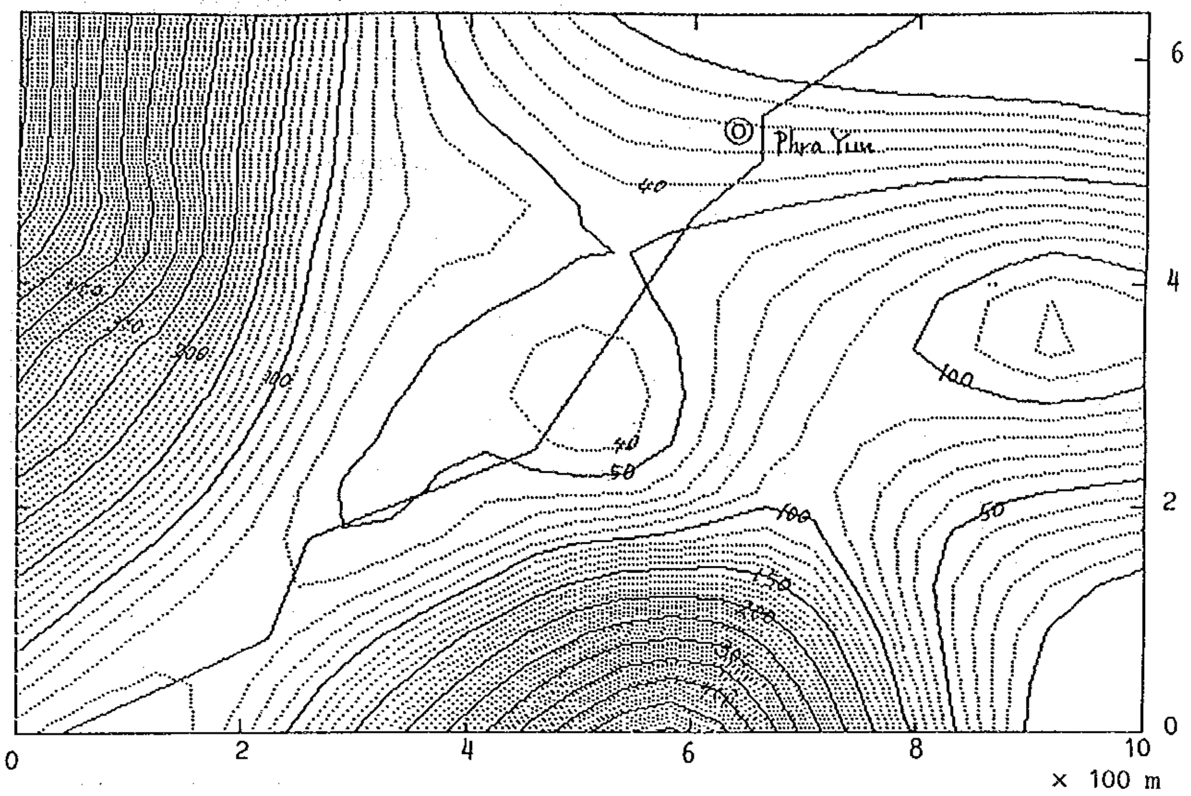
B:PL-EMH3.FIL EM by COIL SPACE 20m Vertical Dipole



Nominal Depth 30 m

FIGURE B-28 APPARENT RESISTIVITY CONTOUR MAP AT a = 1 m ON PILOT AREA

B:PL-G1.FIL RESISTIVITY AT a = 1 m in mΩ



B:PL-G10.FIL RESISTIVITY AT a = 10 m in mΩ

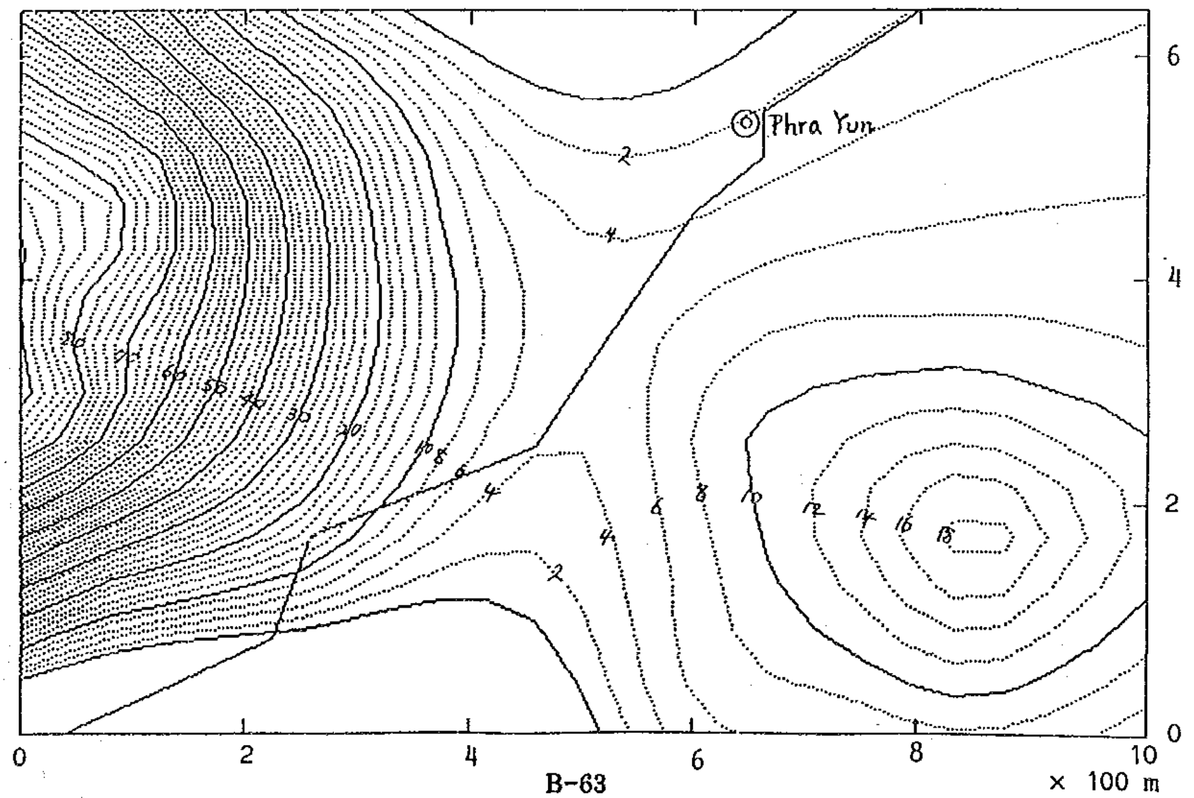
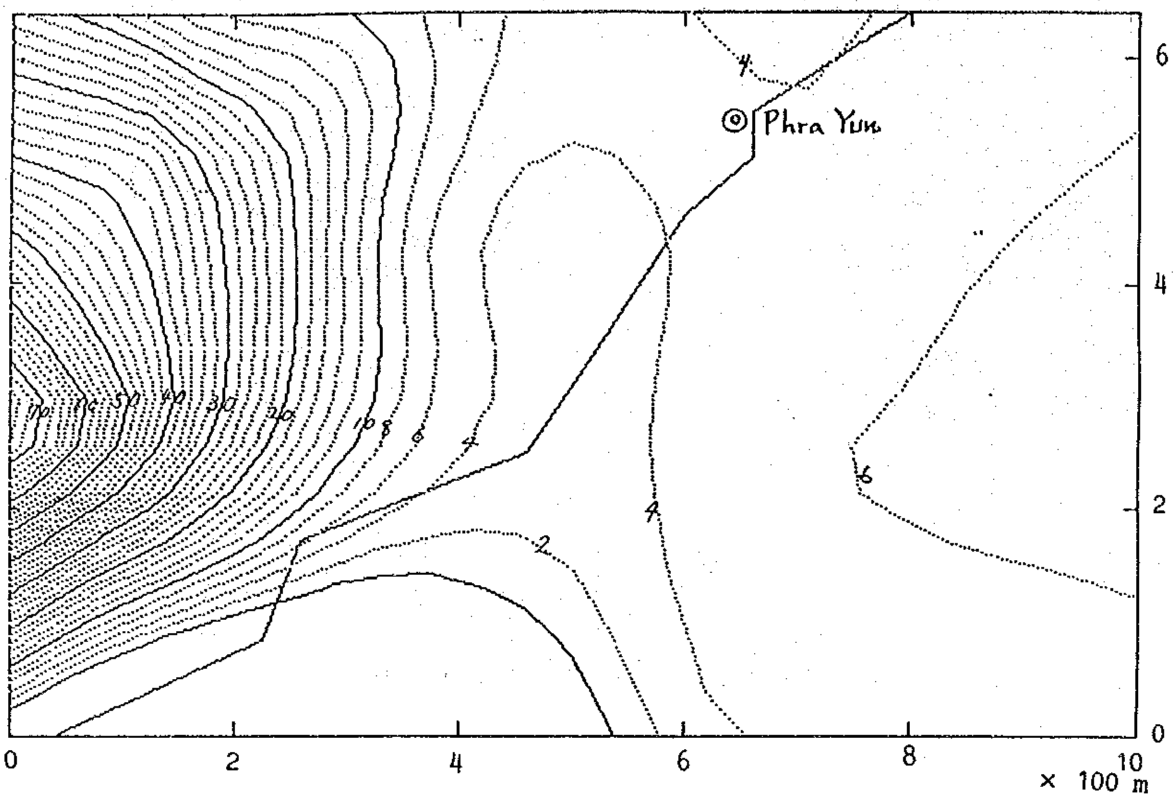


FIGURE B-29 APPARENT RESISTIVITY CONTOUR MAP AT a=16 m AND a=30 m ON PILOT AREA

B:PL-G16.FIL RESISTIVITY AT a = 16 m in mΩ



B:PL-G30.FIL RESISTIVITY AT a = 30 m in mΩ

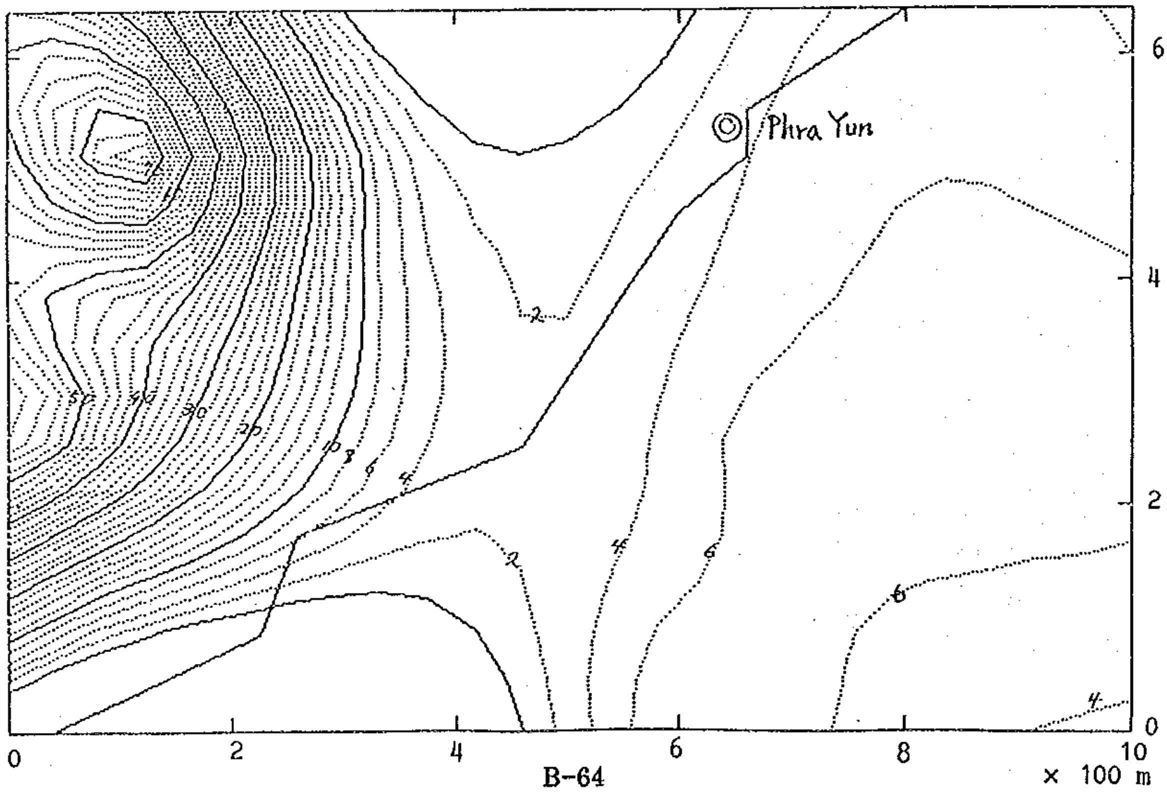
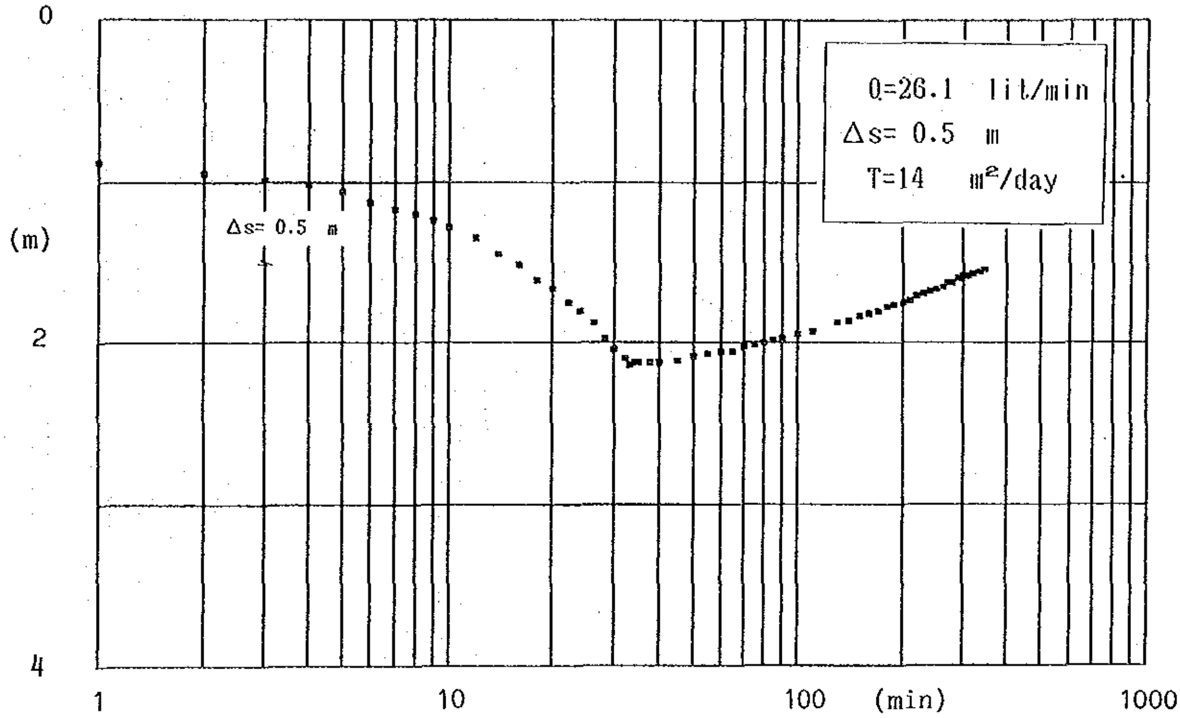


FIGURE B-30 RESULTS OF AQUIFER TEST IN DW-1

Well Name:DW-1 TIME-DRAWDOWN CURVE



Well Name:DW-1 TIME-RECOVERY CURVE

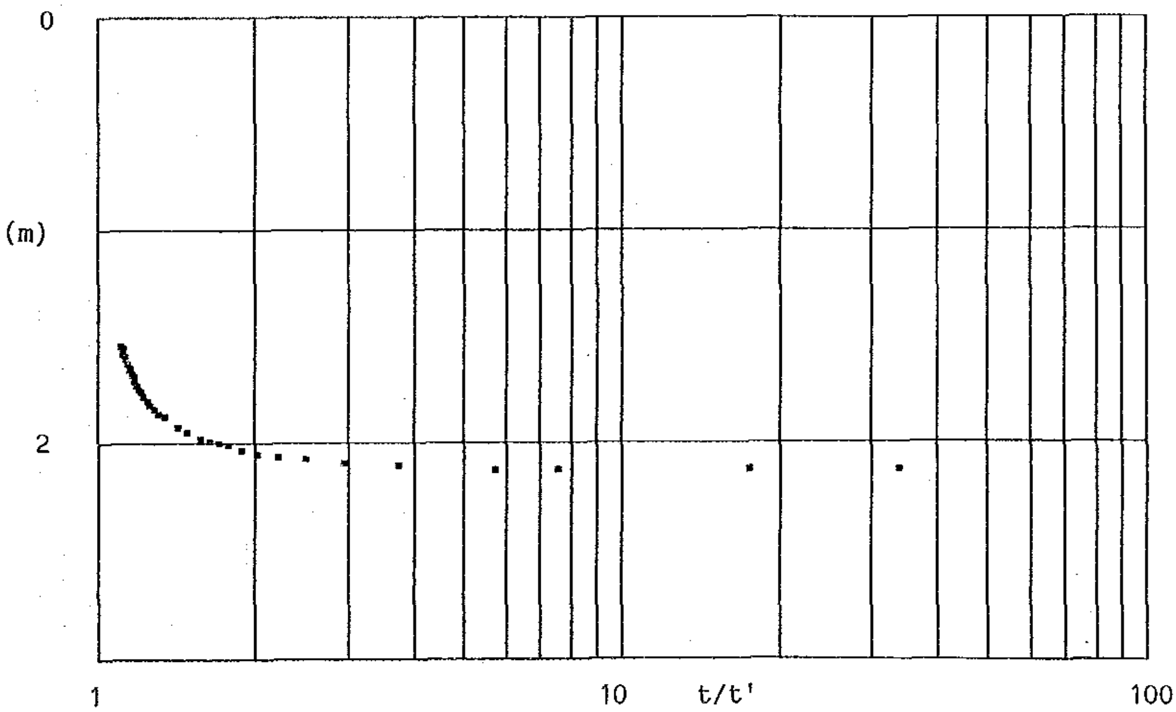
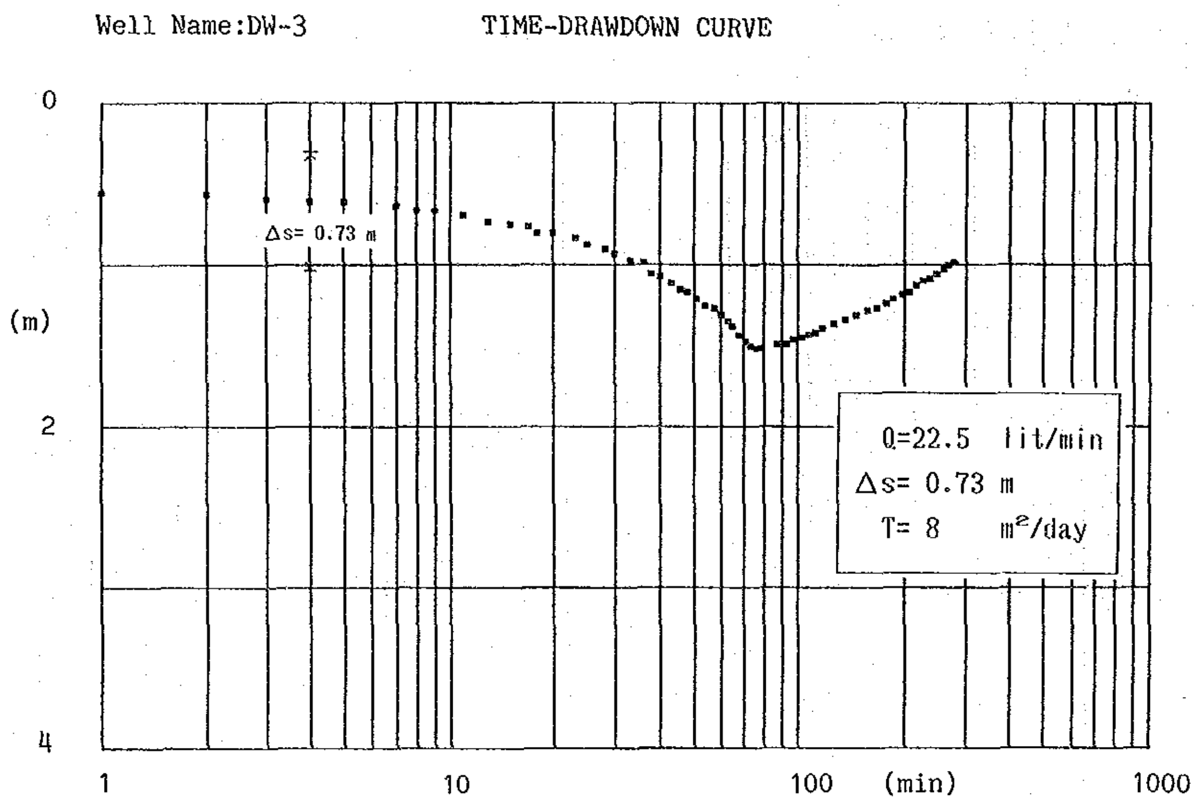


FIGURE B-31 RESULTS OF AQUIFER TEST DW-3



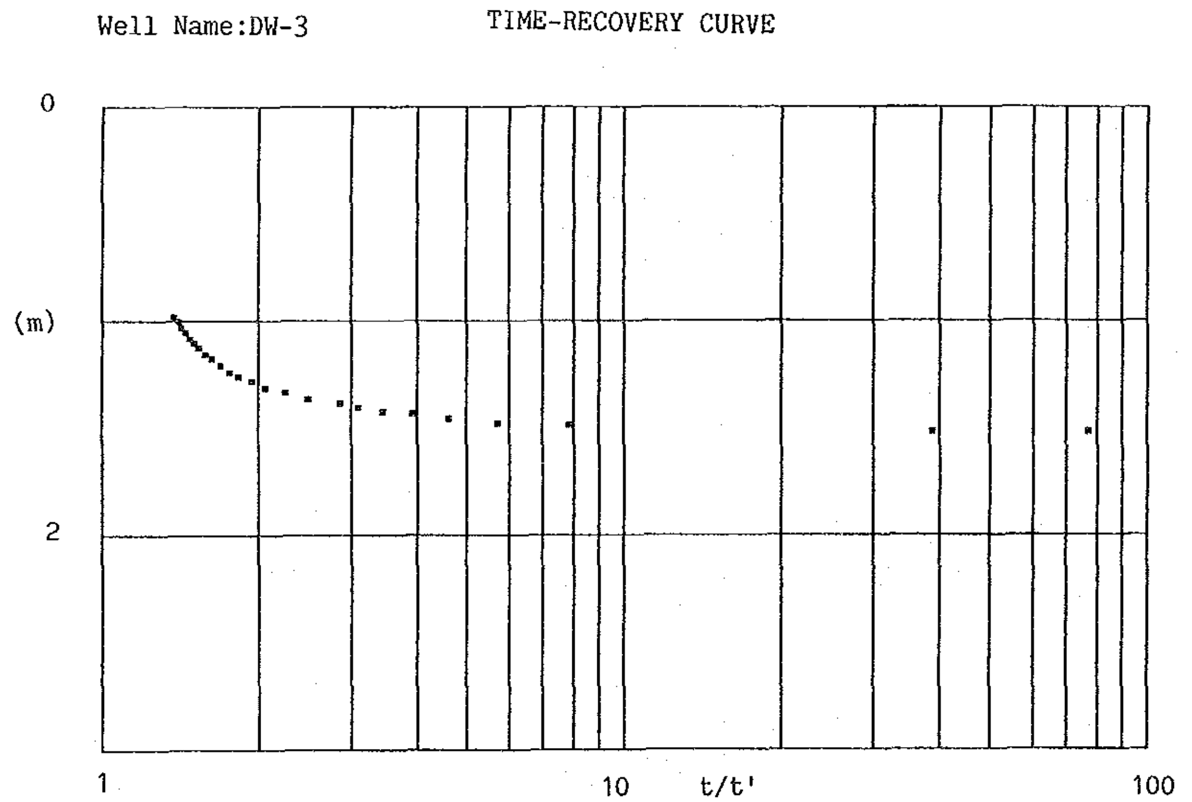
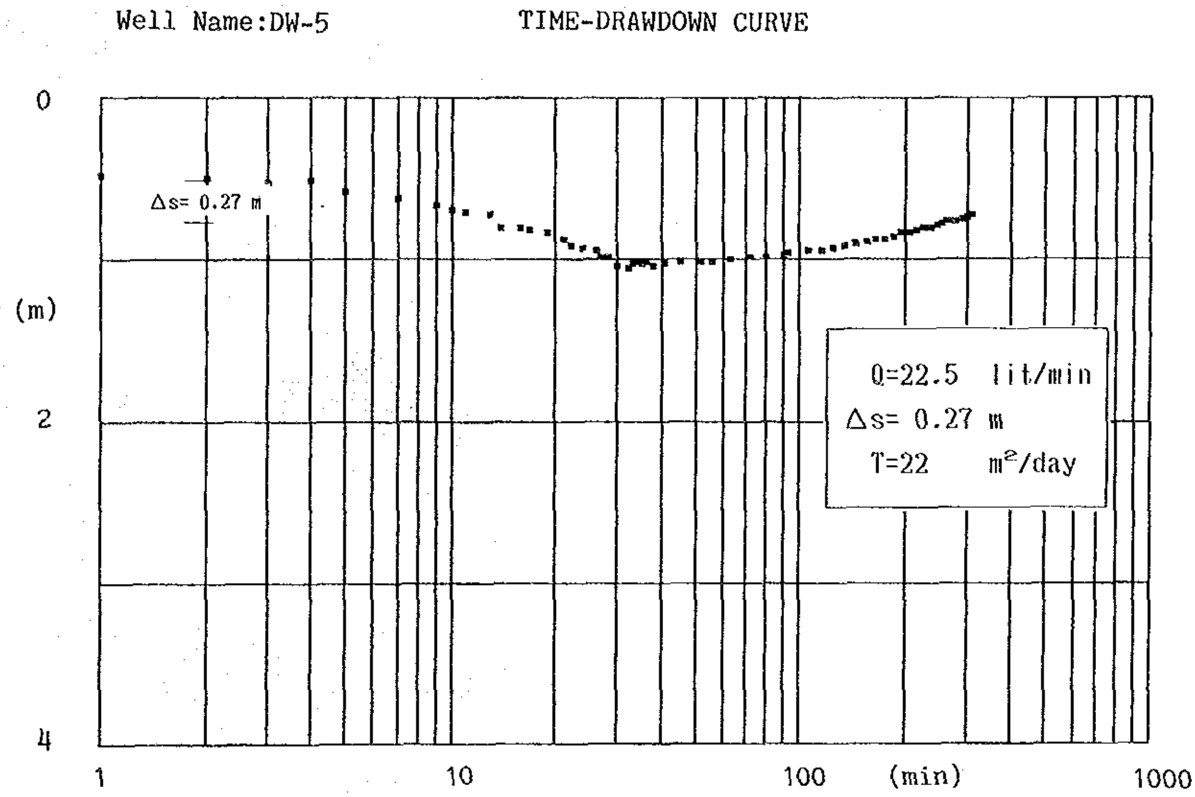


FIGURE B-32 RESULTS OF AQUIFER TEST IN DW-5



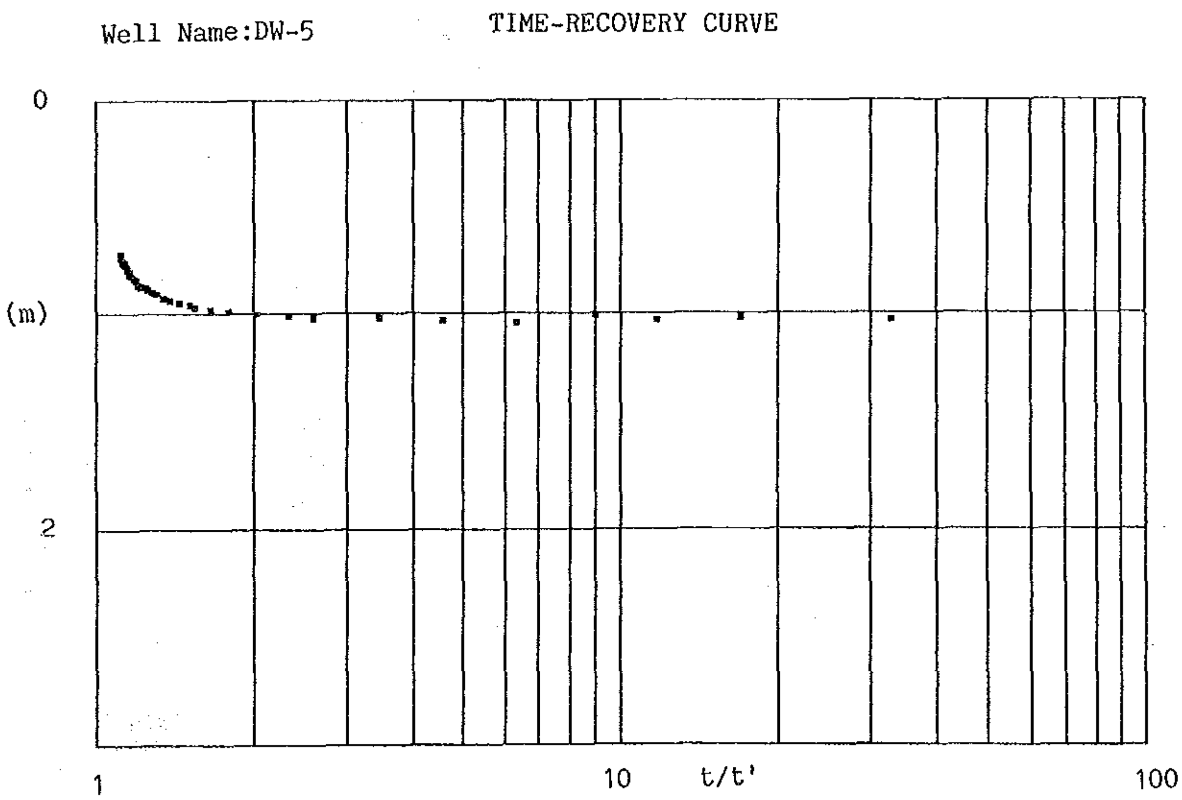
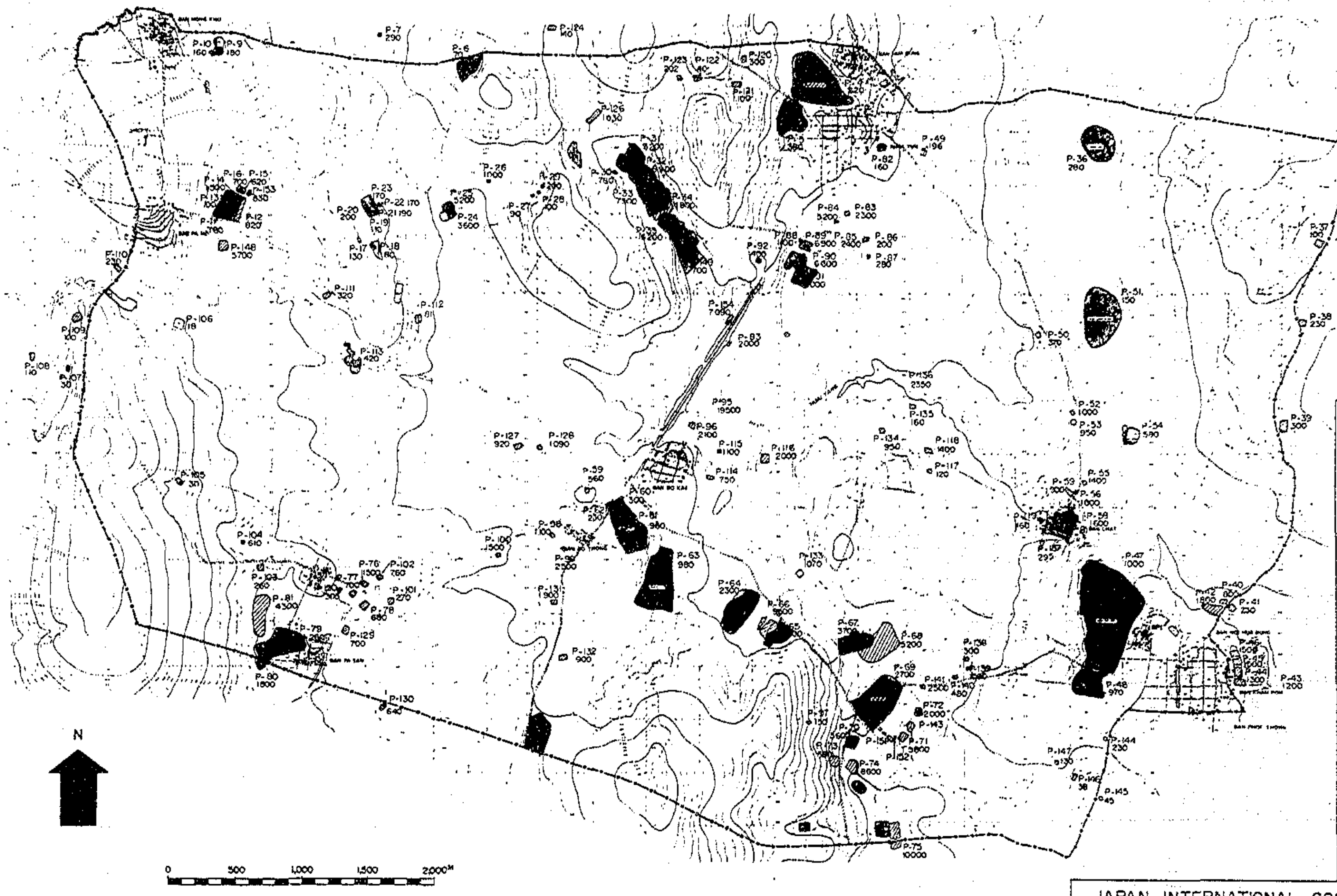


FIGURE B-33 **EC IN EXISTING PONDS ON THE PILOT AREA**



LEGEND

P-6
70

P-6 , No. of pond

70 , Conductivity in μmho/cm

measured in Jan. 1990

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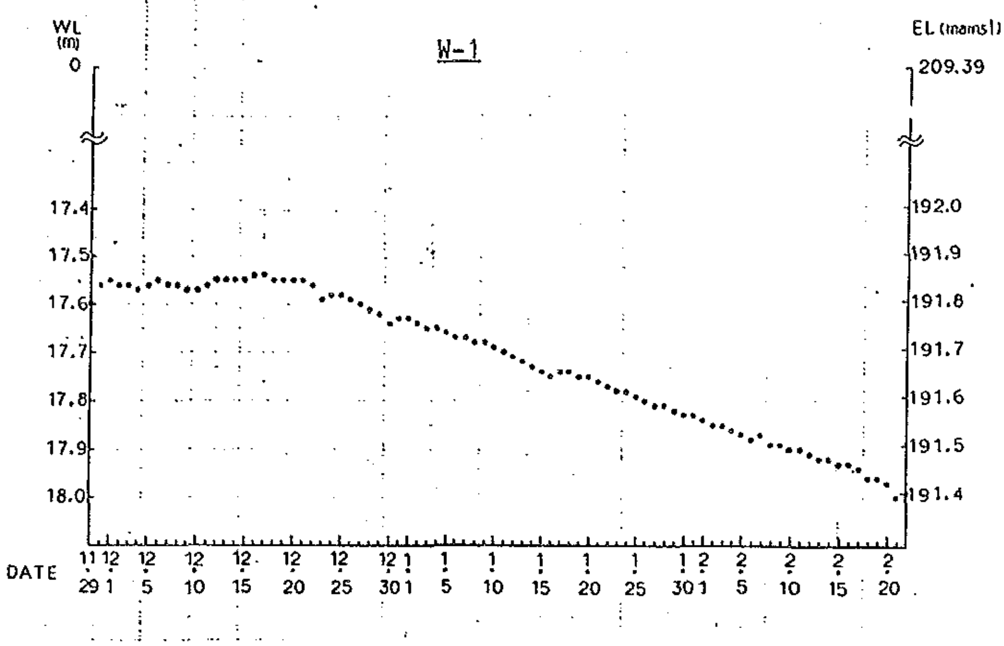
JAPAN INTERNATIONAL COOPERATION AGENCY
(J I C A)

FIGURE B-34 WELL-HYDROGRAPH OF EXPLORATORY WELLS, W-1 AND W-2



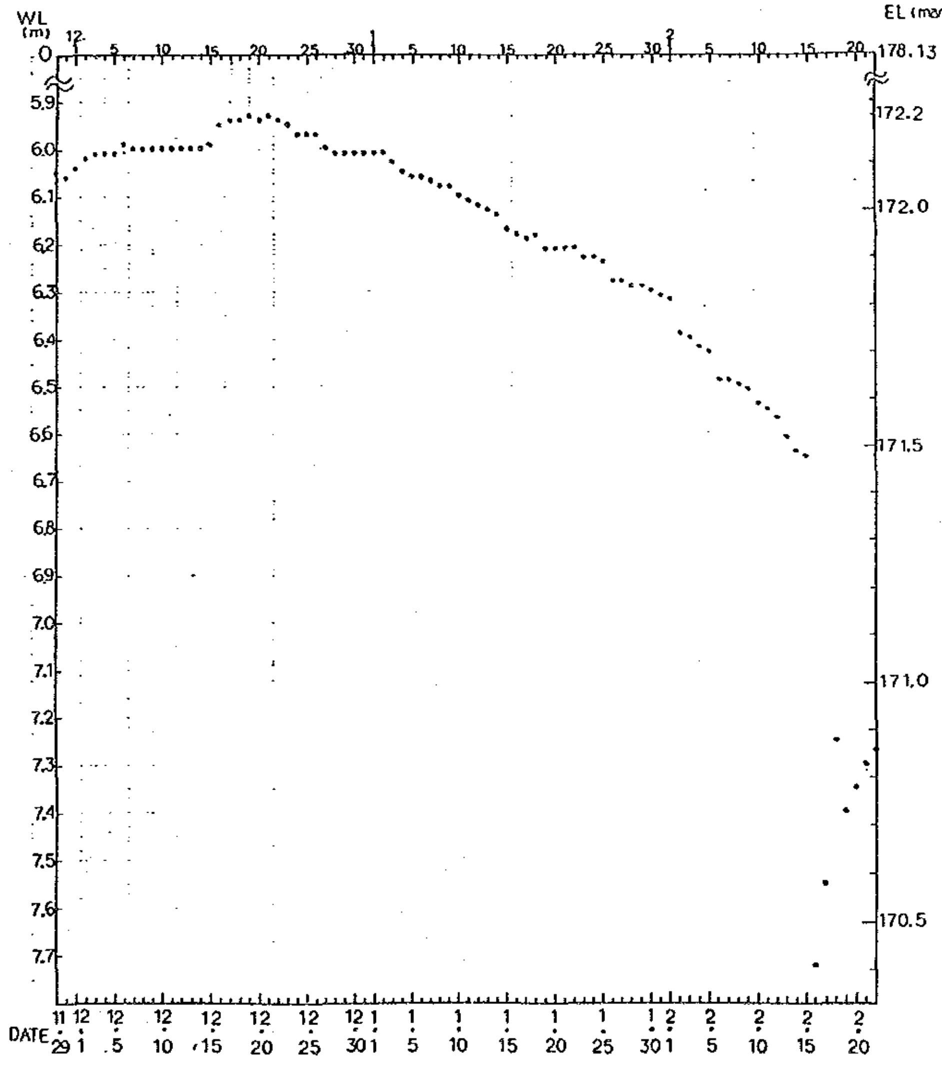


FIGURE B-35 WELL-HYDROGRAPH IN OBSERVATION WELLS, P-1, P-2, P-3 AND P-4

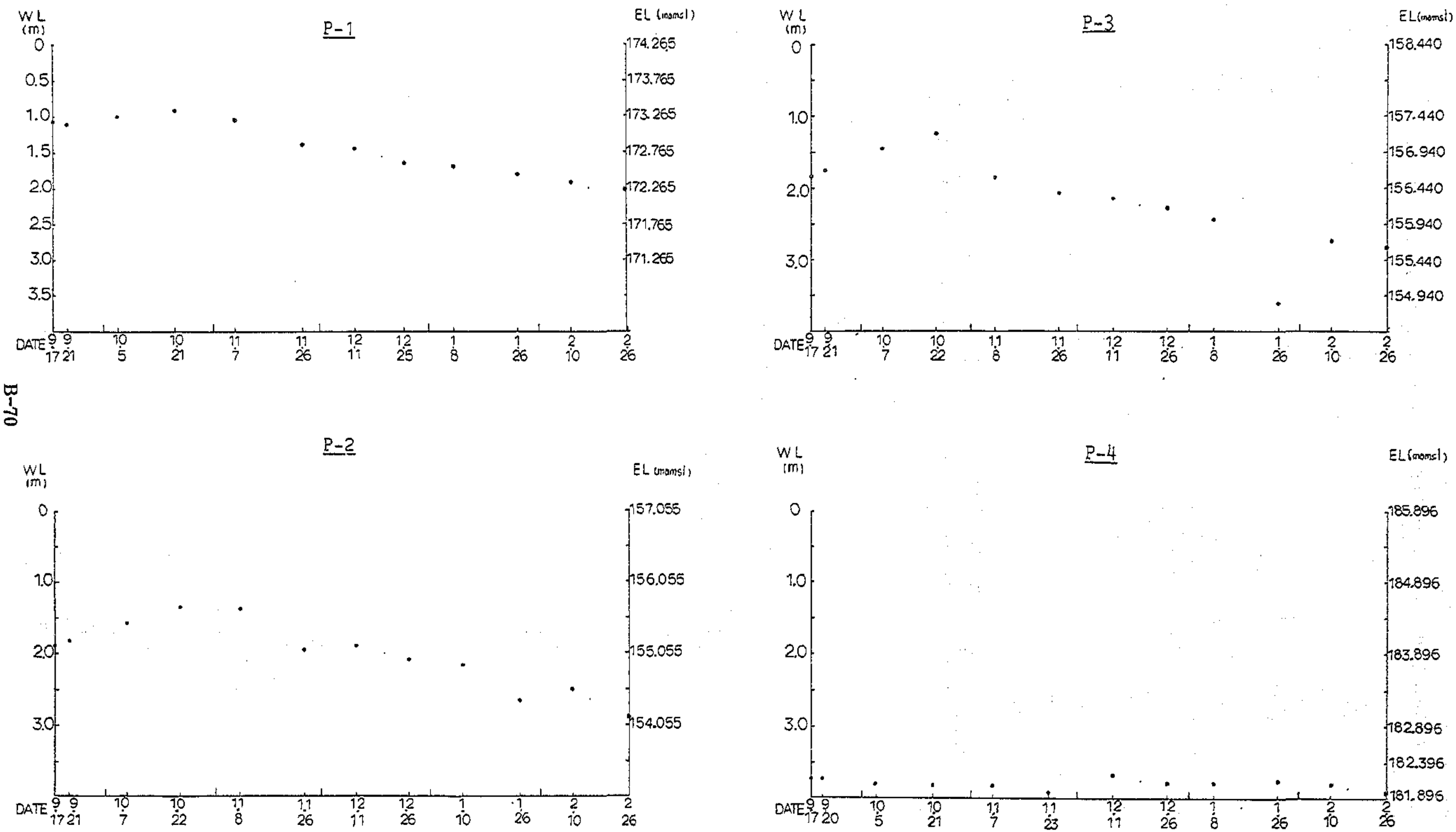
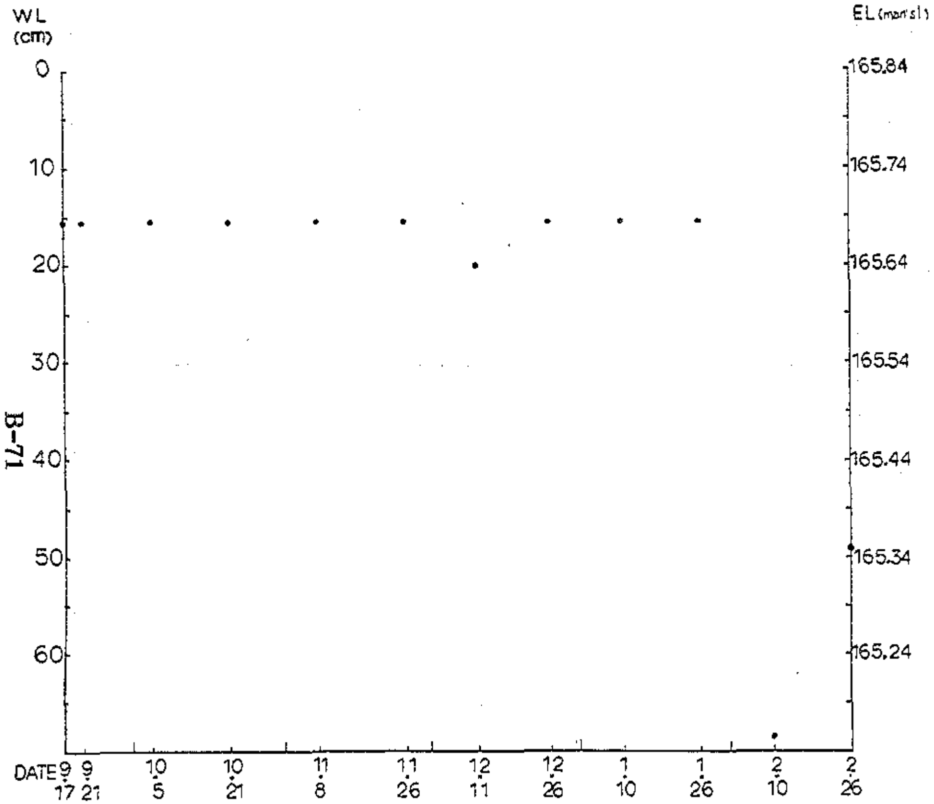
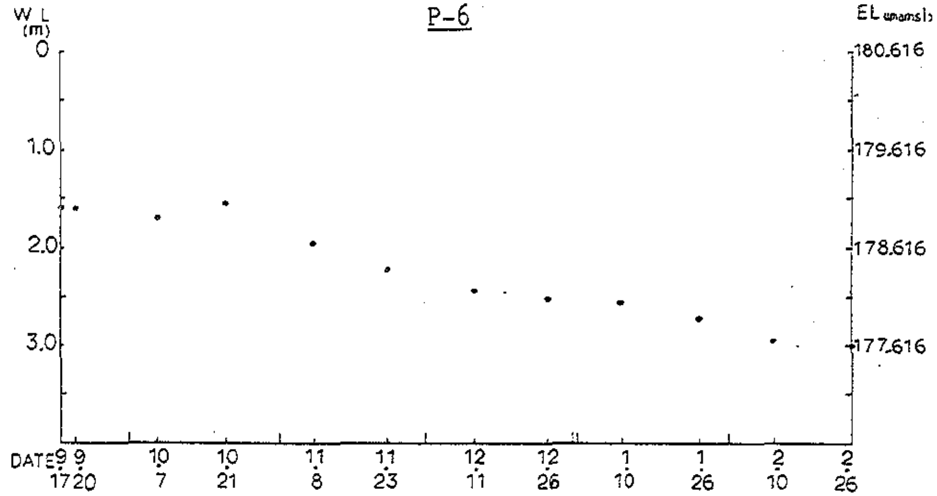


FIGURE B-36 WELL-HYDROGRAPH IN OBSERVATION WELLS, P-5, P-6, AND P-7

P-5



P-6



P-7

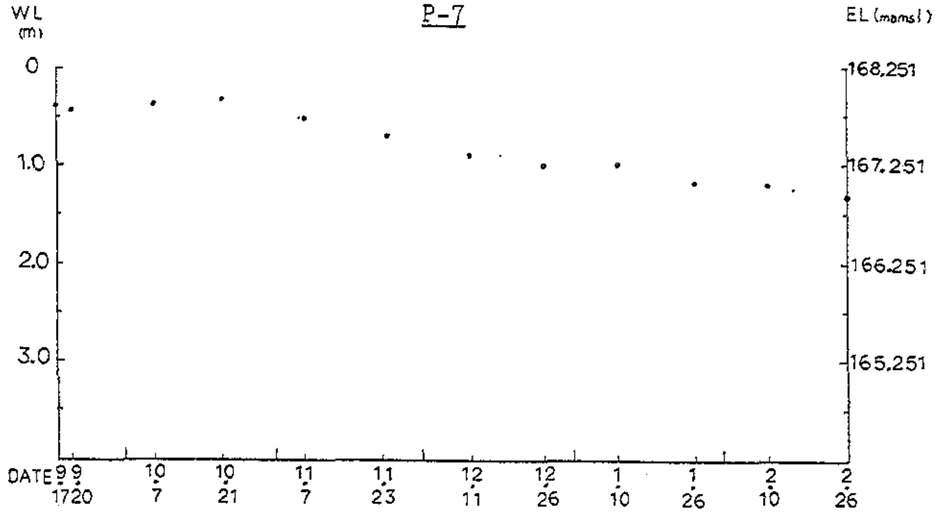


FIGURE B-37 WELL-HYDROGRAPH IN OBSERVATION WELLS, P-8, P-9, AND P-10

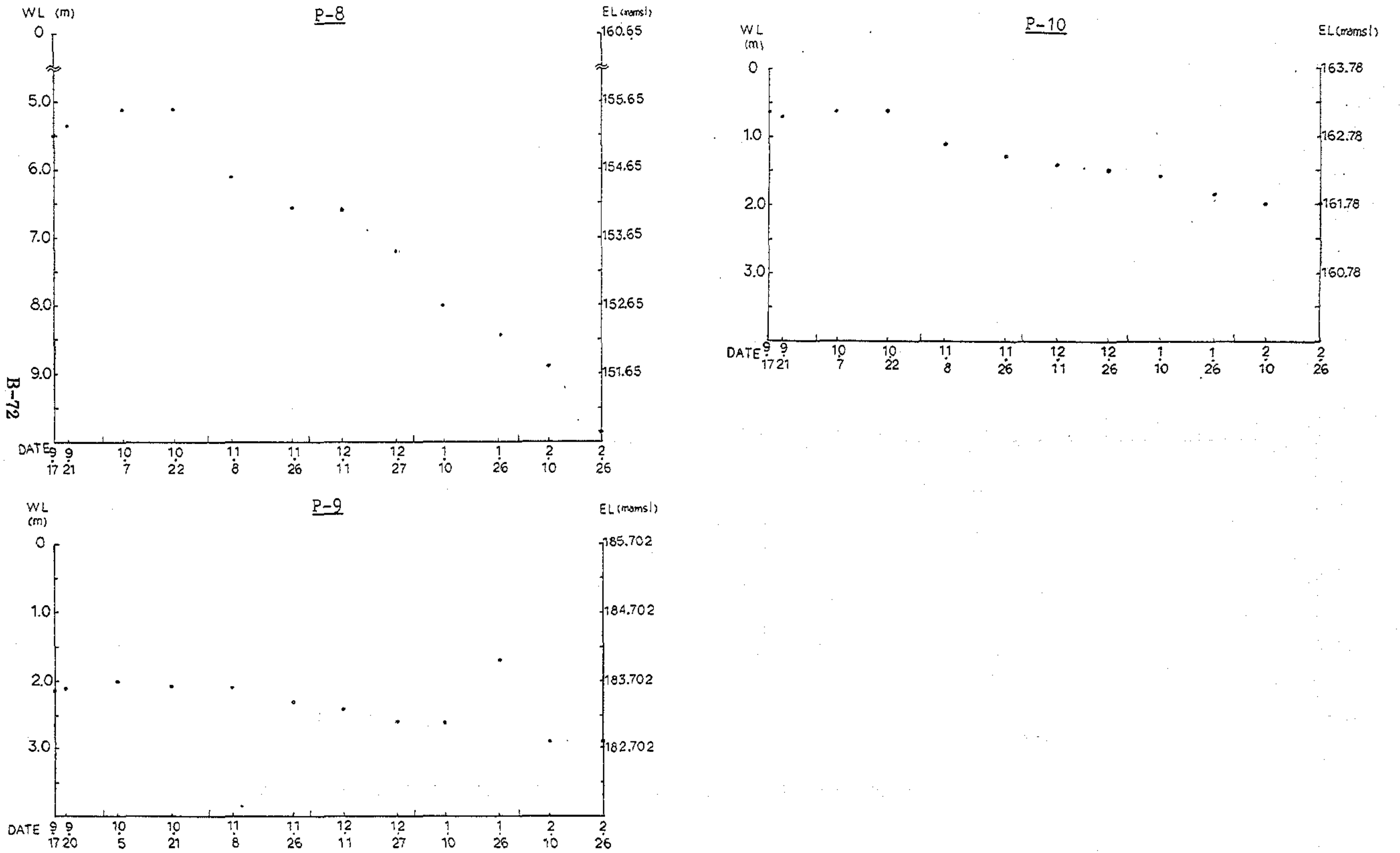


FIGURE B-38

GROUNDWATER CONDUCTIVITY MAP IN SILTSTONE AQUIFER

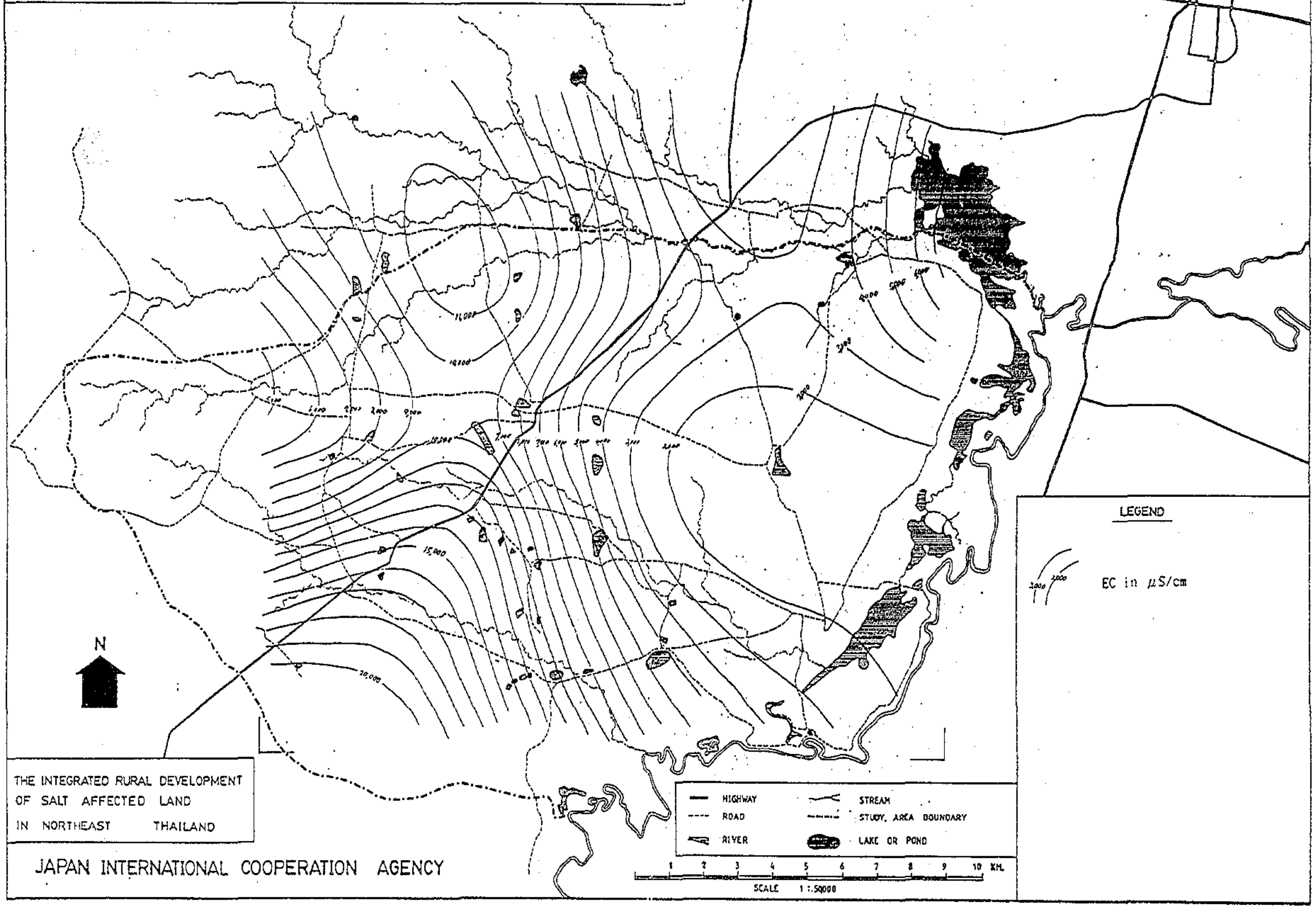


FIGURE B-40 PIEZOMETRIC SURFACE OF THE SILTSTONE AQUIFER

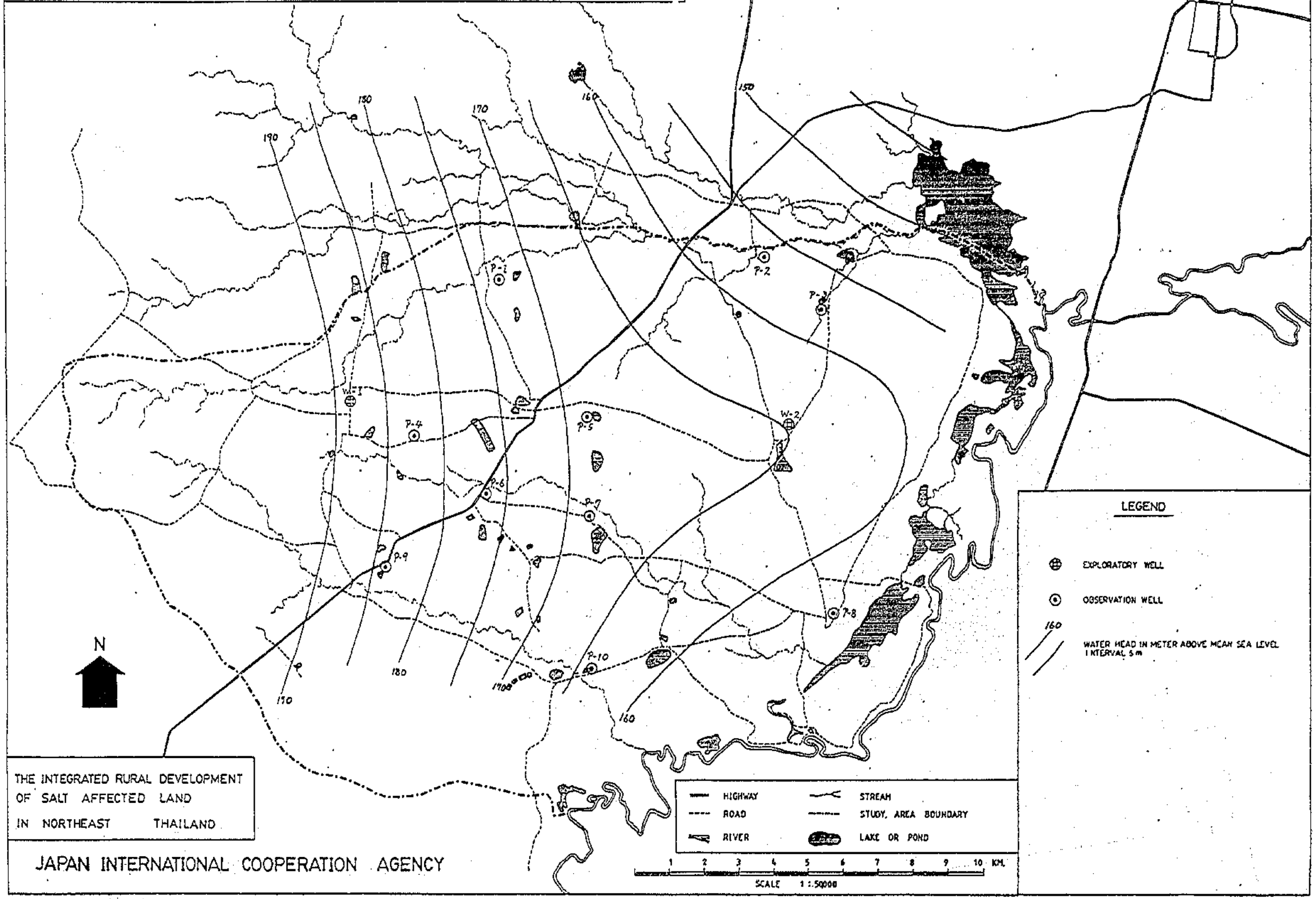
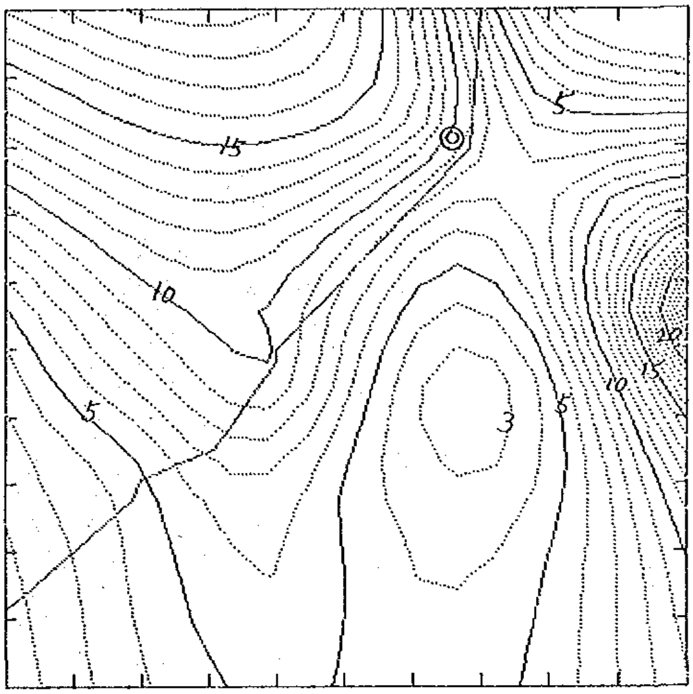


FIGURE B-41 SPECIFIC CAPACITY OF EXISTING WELL IN SILTSTONE AQUIFER



◎ Phra Yun

Specific Capacity in lit/min/m

FIGURE B-42 TRILINEAR DIAGRAM OF THE EXPLORATION WELLS

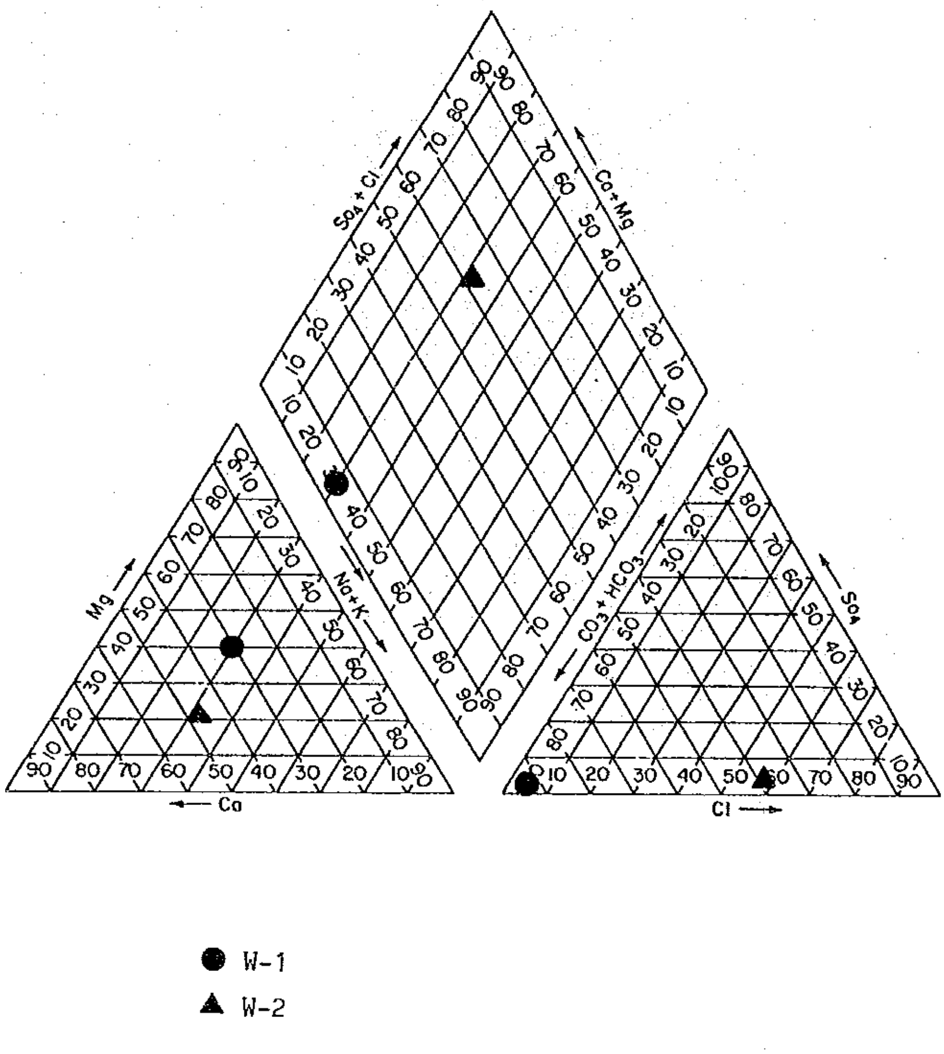
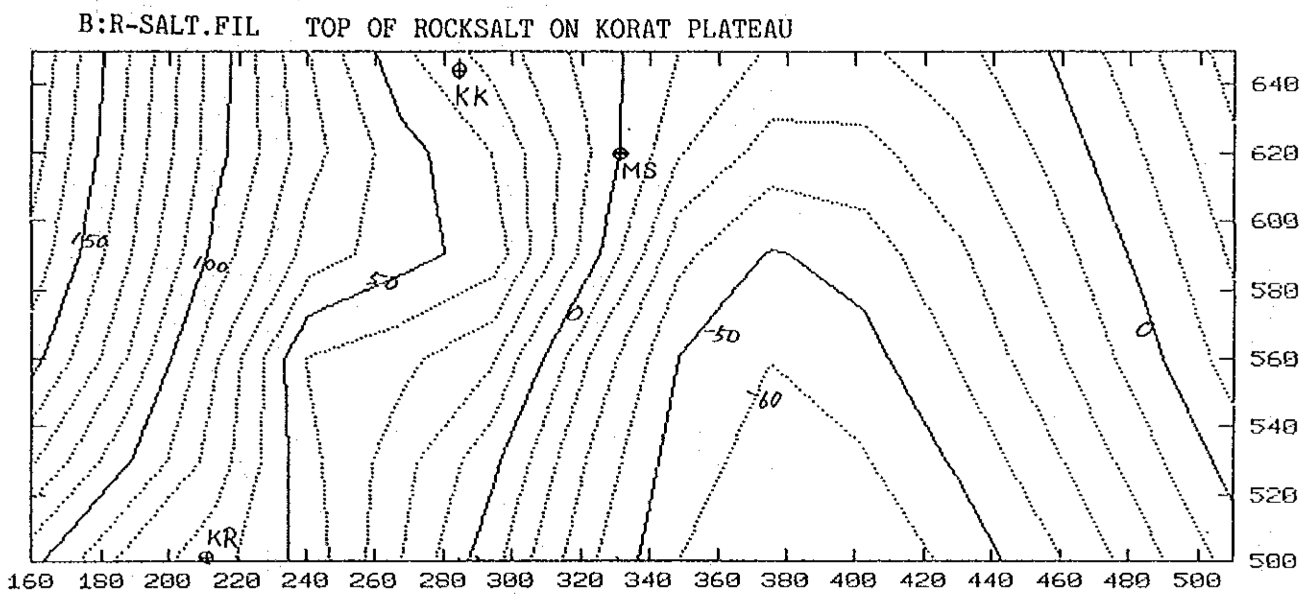


FIGURE B-43 TOP OF ROCK SALT ON KORAT PLATEAU IN mams 1



KK:Khon Kaen KR:Korat MS:Maha Sarakham

FIGURE. B-44 SCHEMATIC IDEA OF SALT EMERGENCE

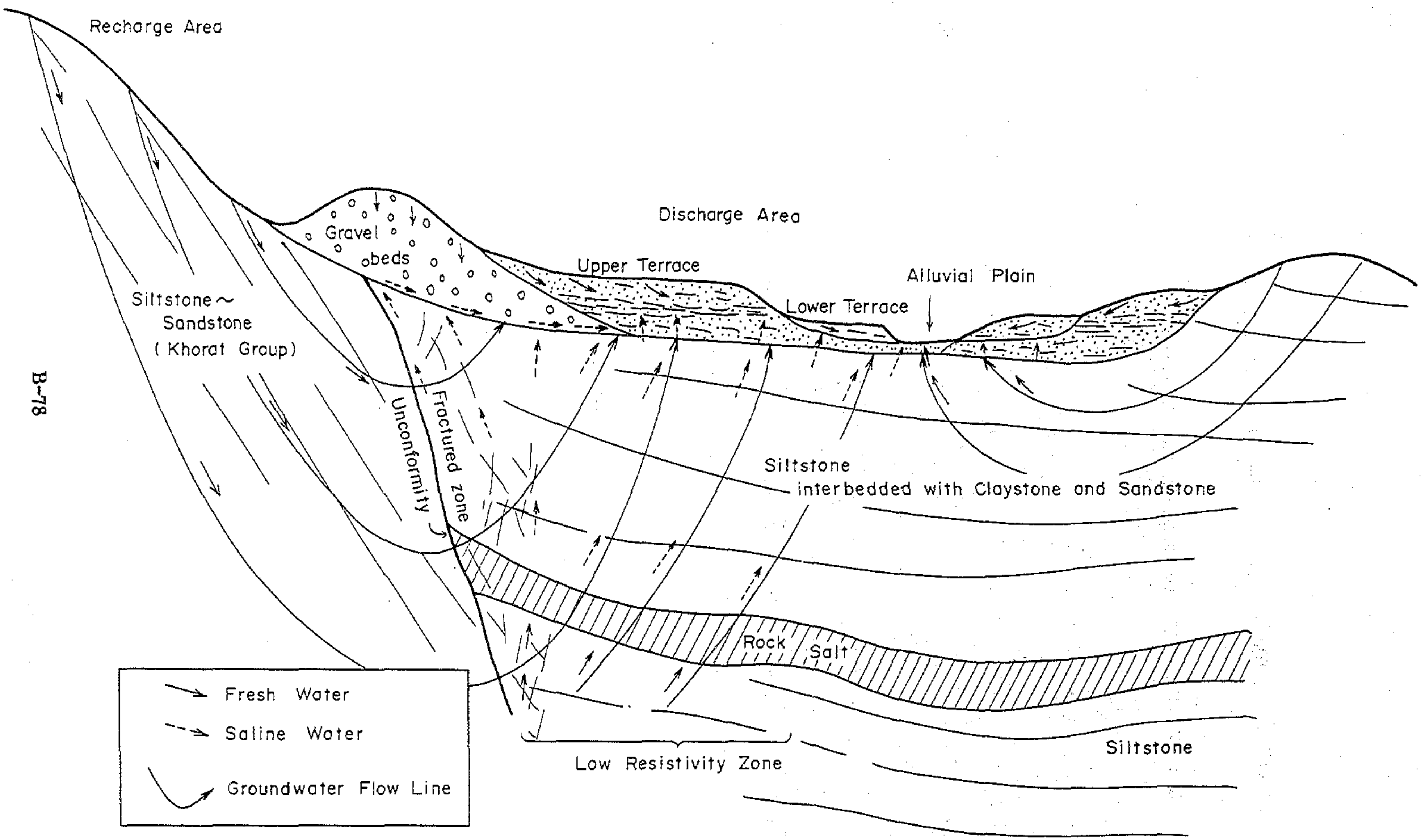
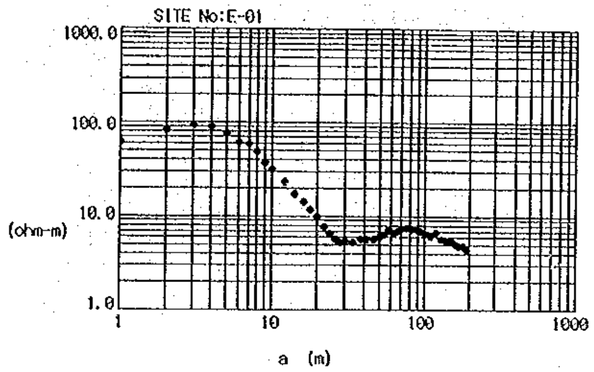
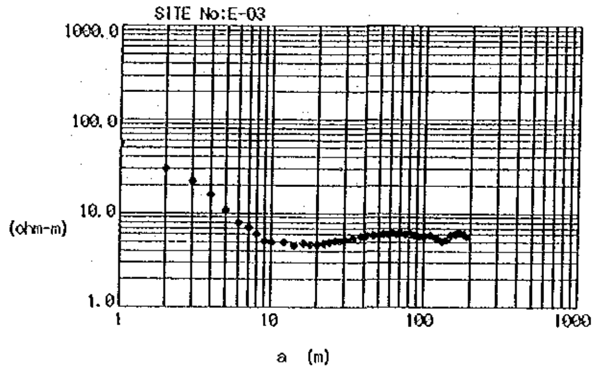
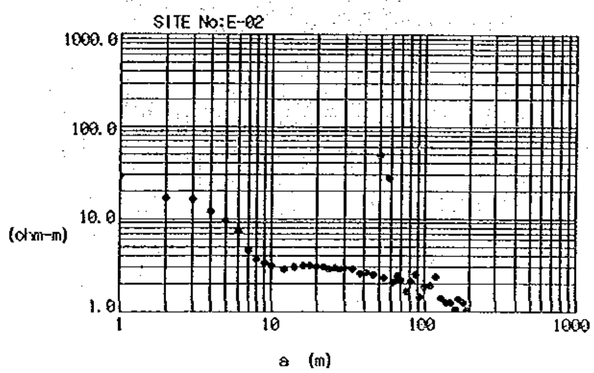
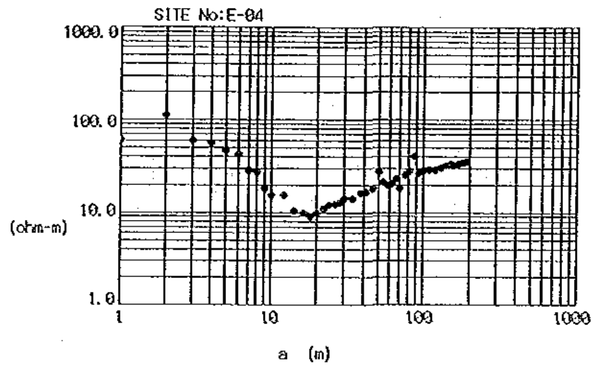


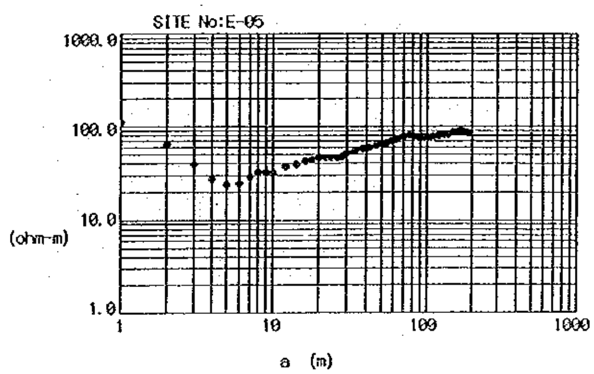
FIGURE B-45 ρ -a Curve (1)

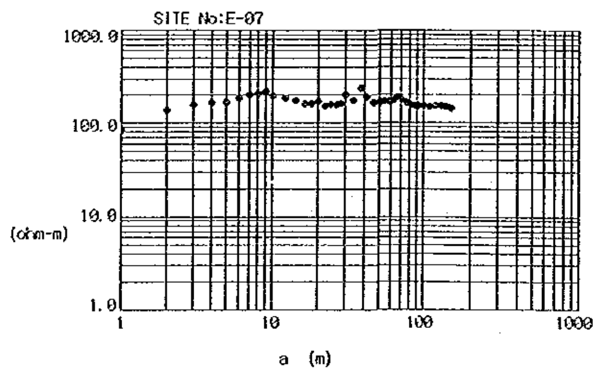


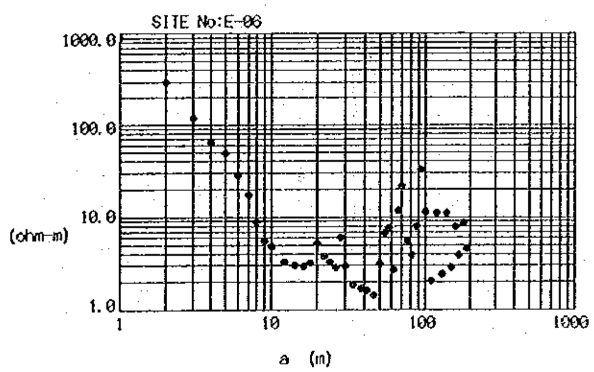












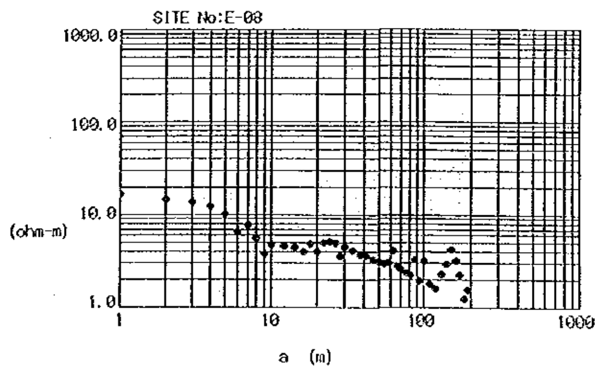


FIGURE B-45 ρ -a Curve (2)

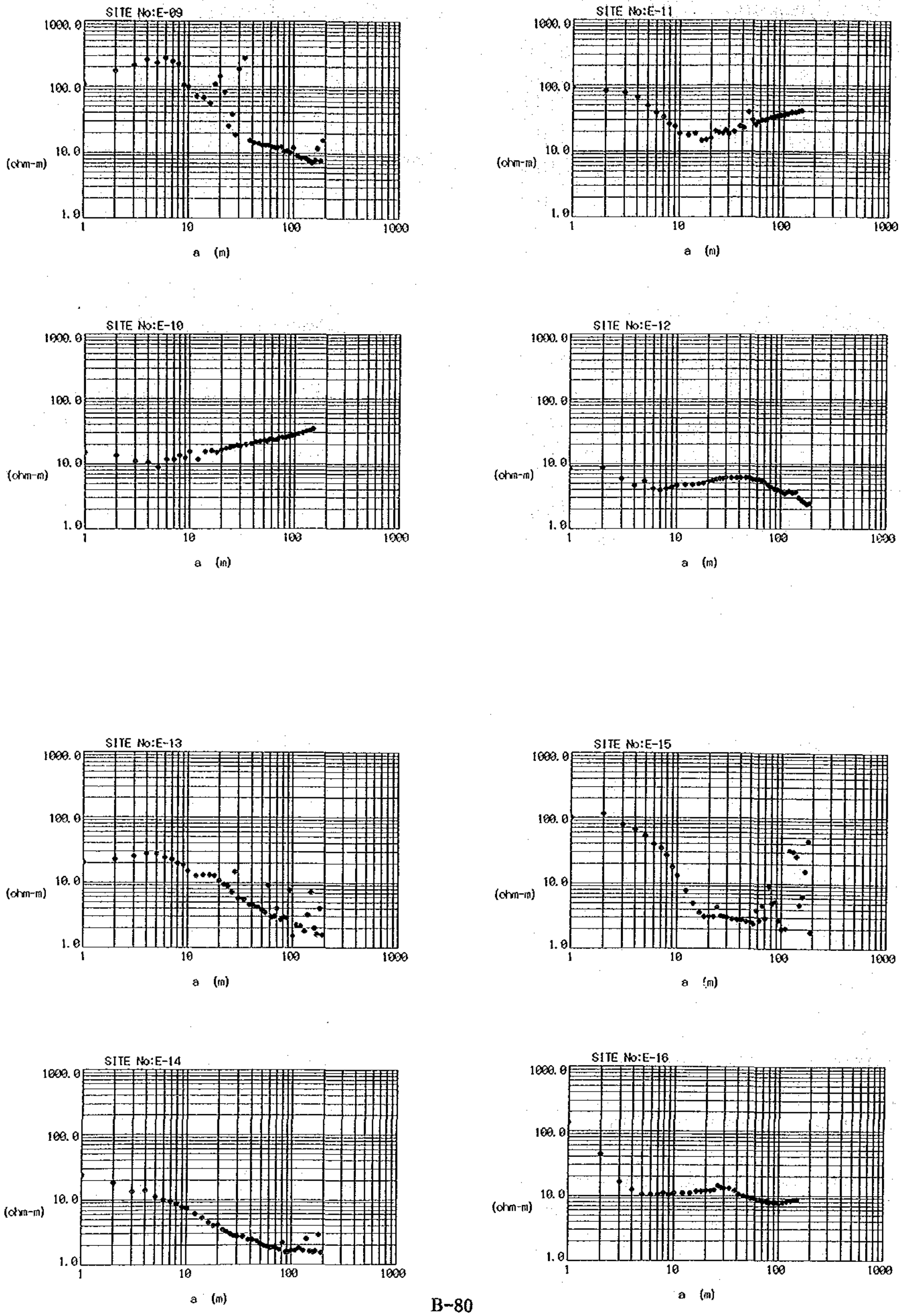
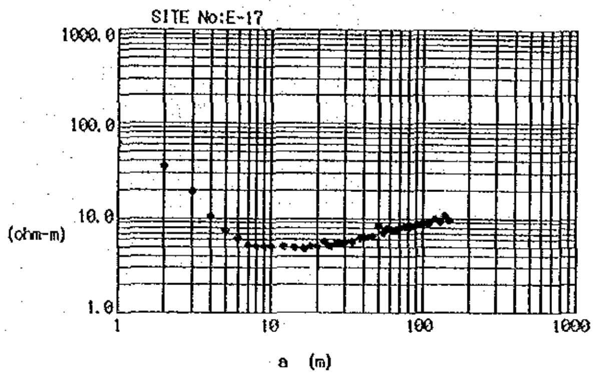
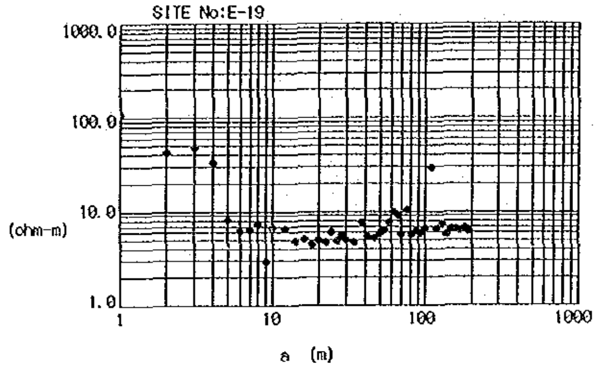
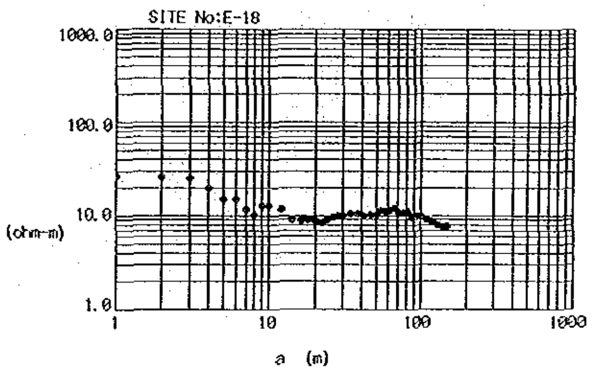
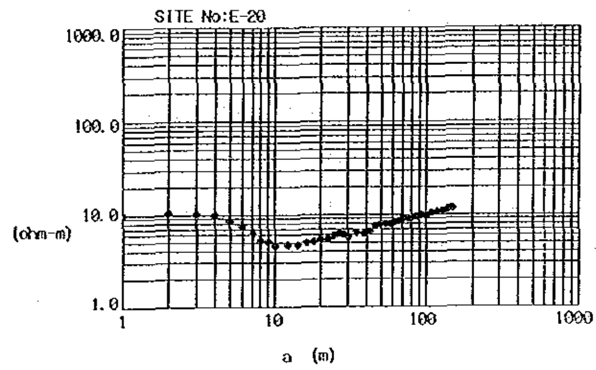


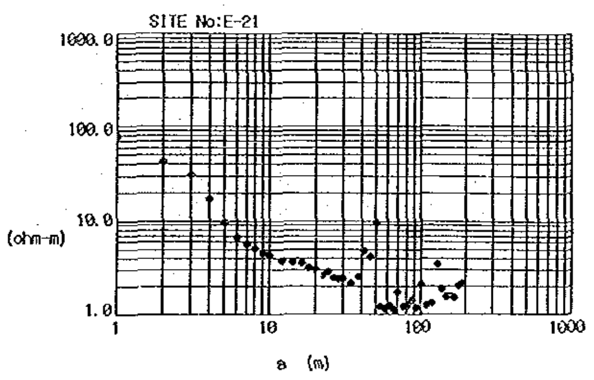
FIGURE B-45 ρ -a Curve (3)

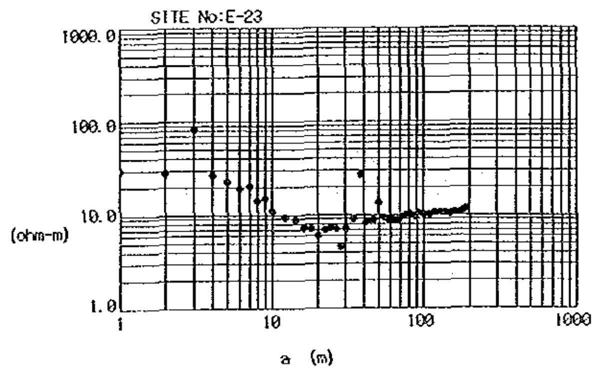


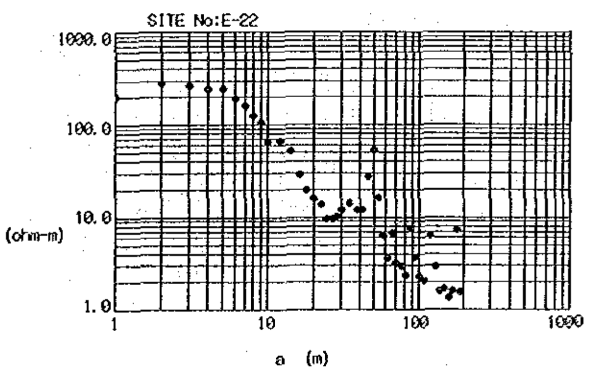












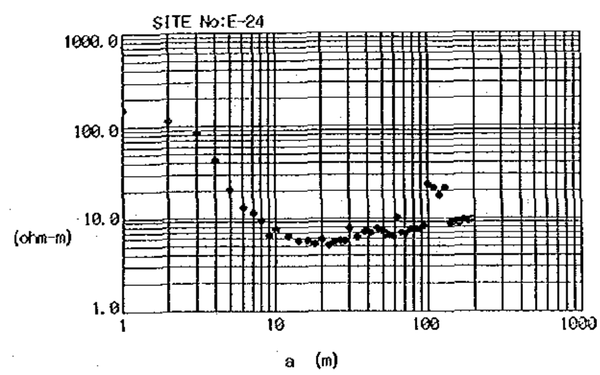
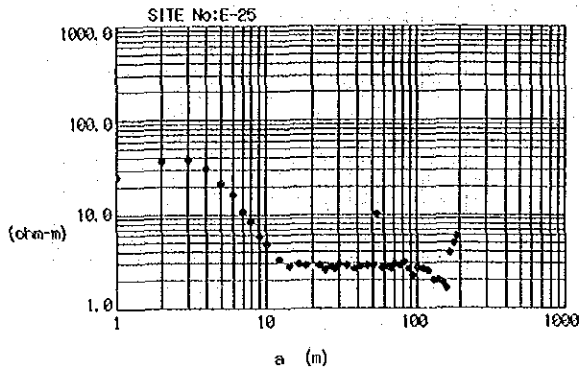
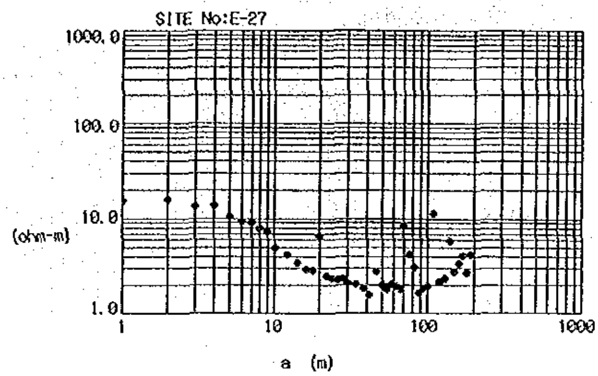
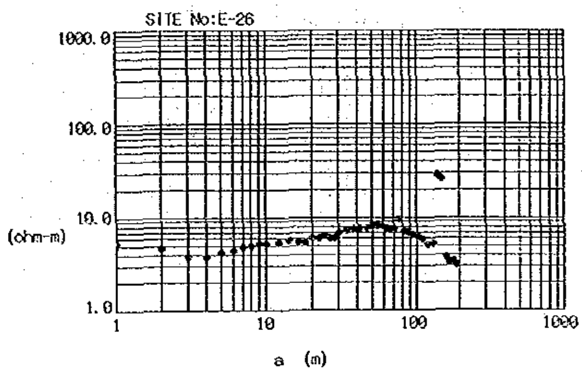
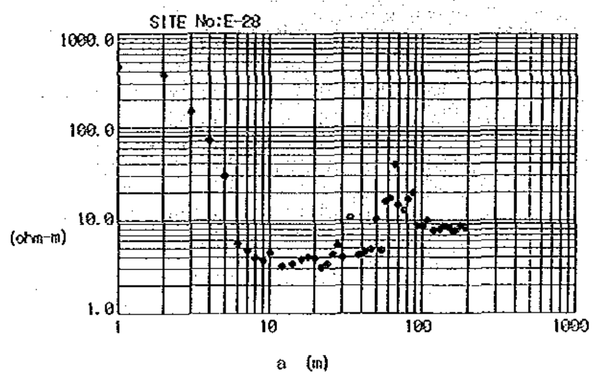


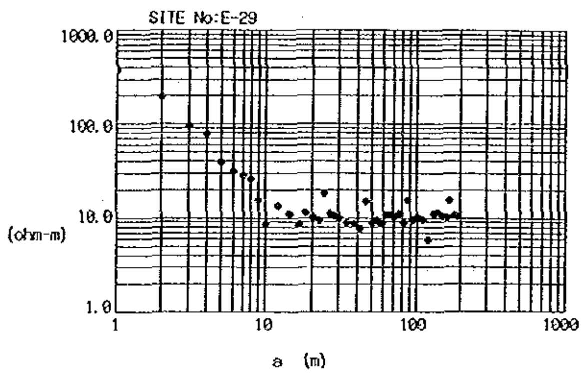
FIGURE B-45 ρ -a Curve (4)

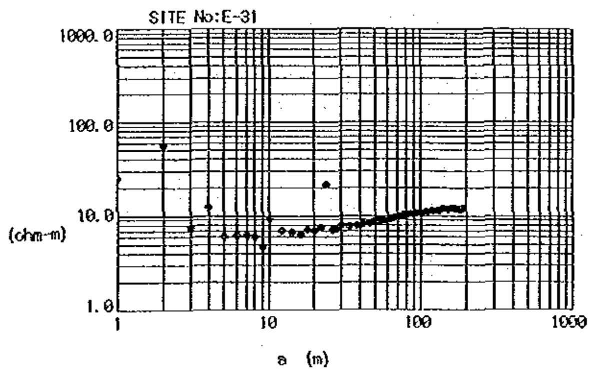


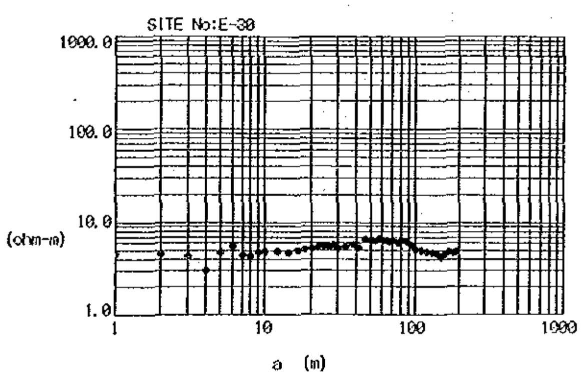












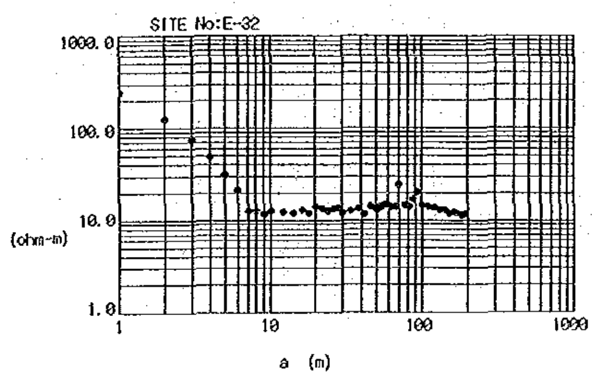
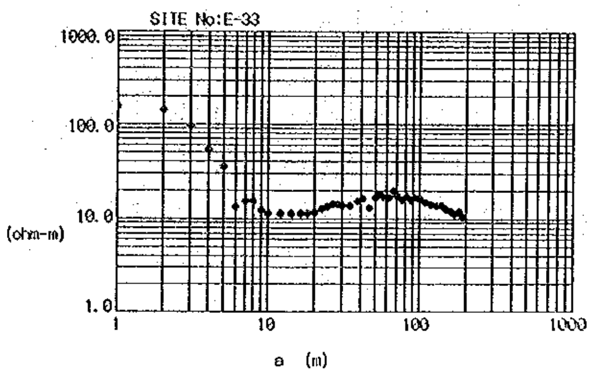
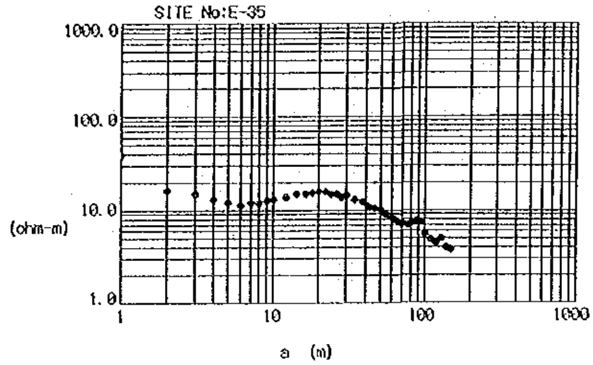
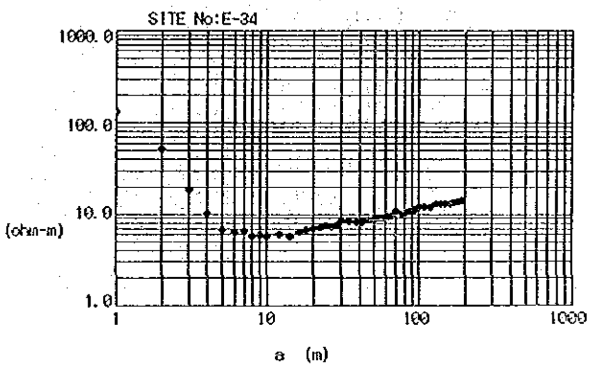
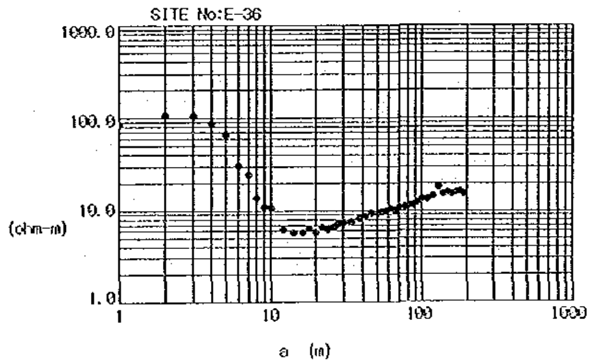


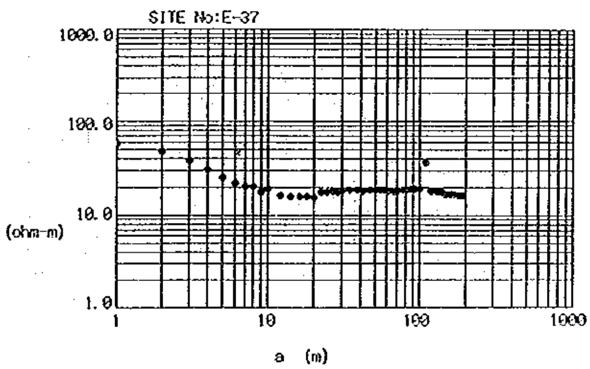
FIGURE B-45 ρ -a Curve (5)

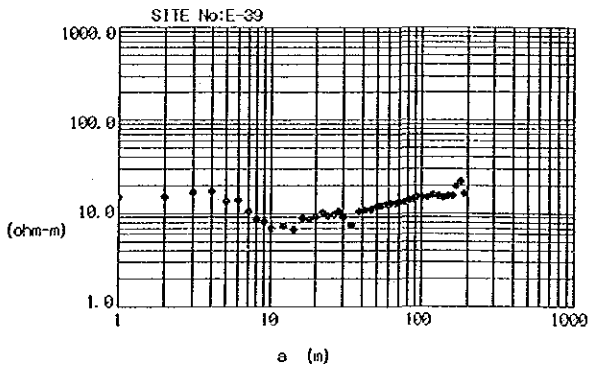


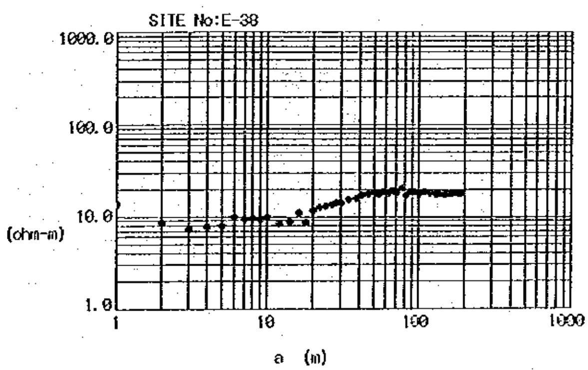












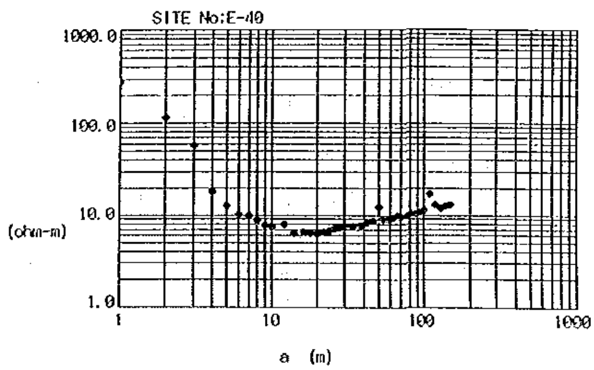
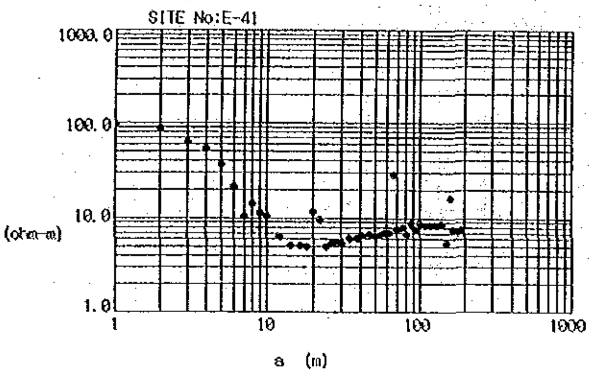
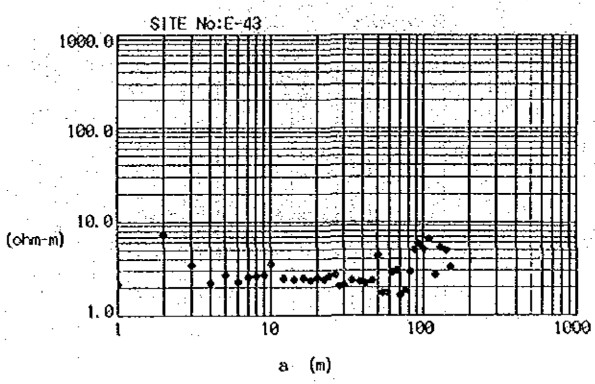
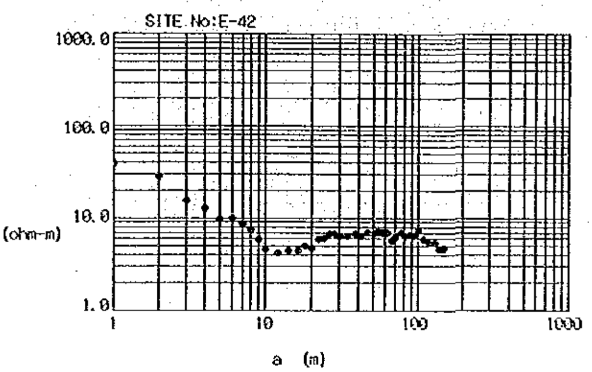
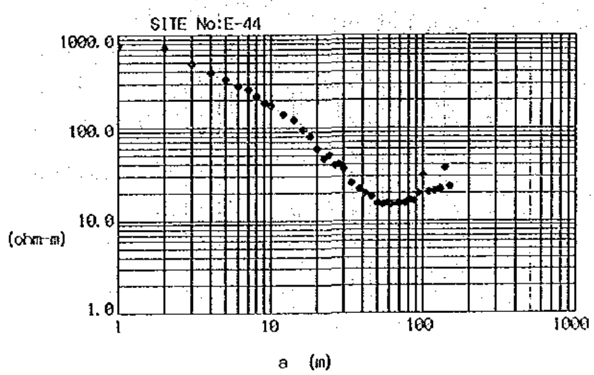


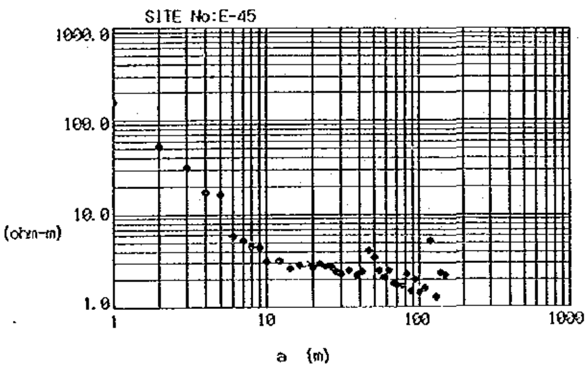
FIGURE B-45 ρ -a Curve (6)

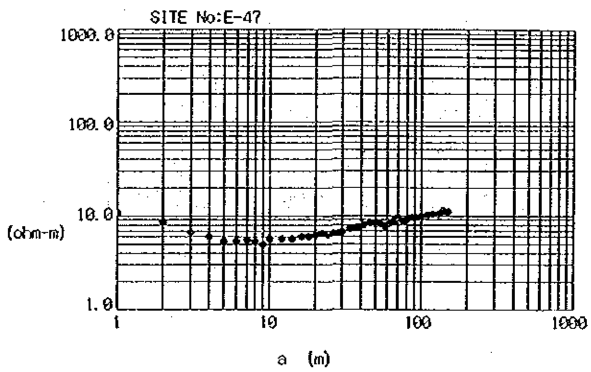


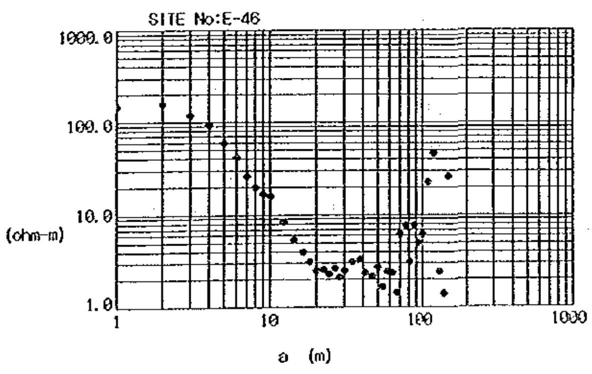












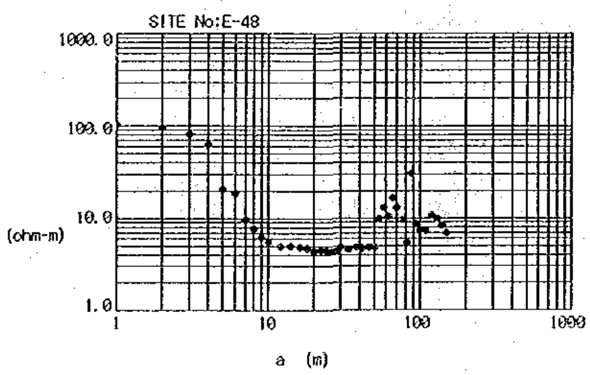
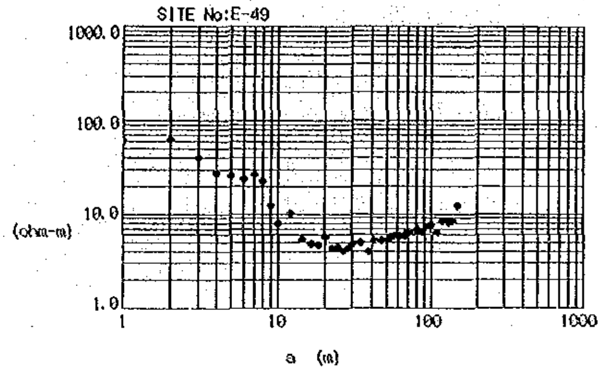
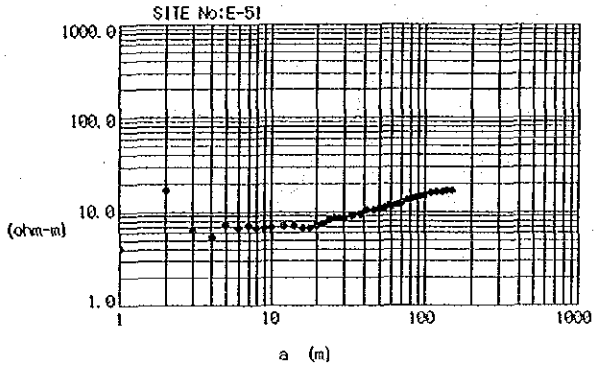
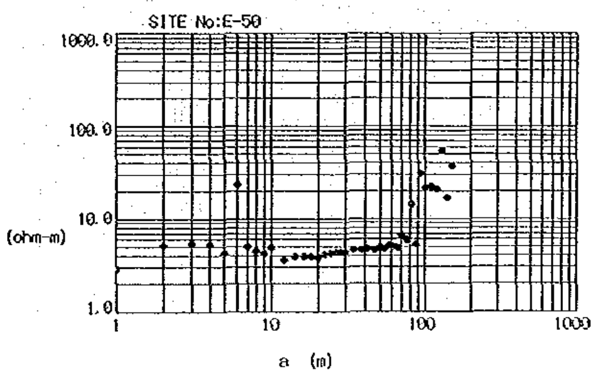
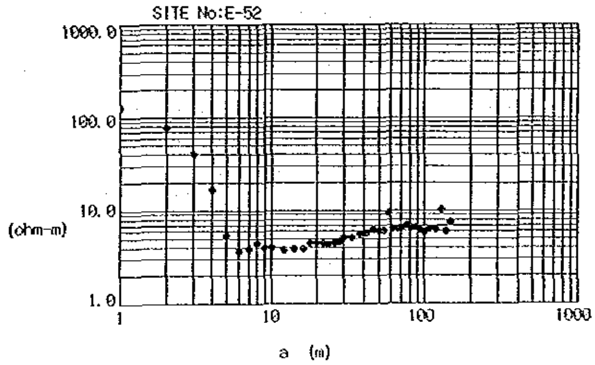


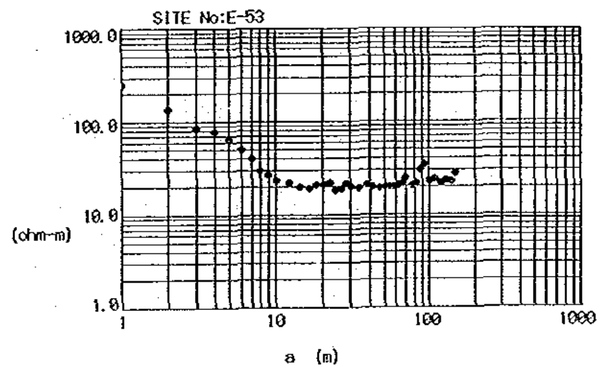
FIGURE B-45 ρ-a Curve (7)

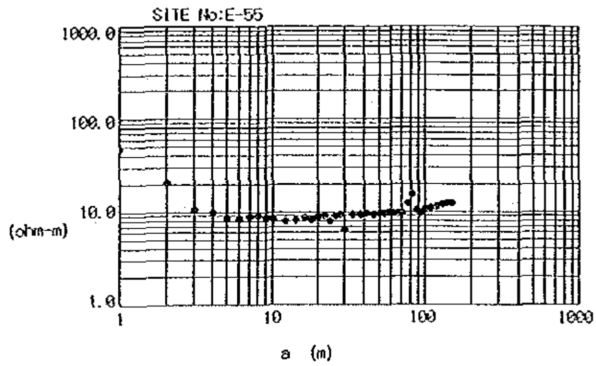


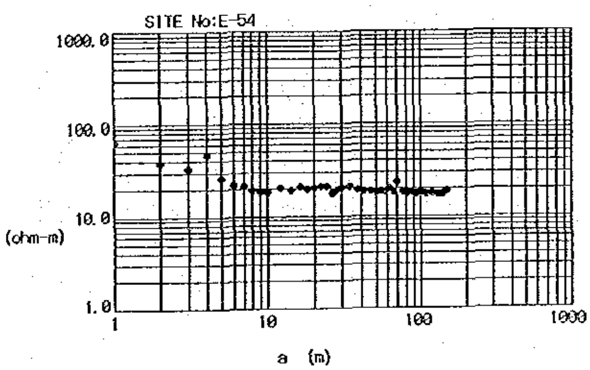












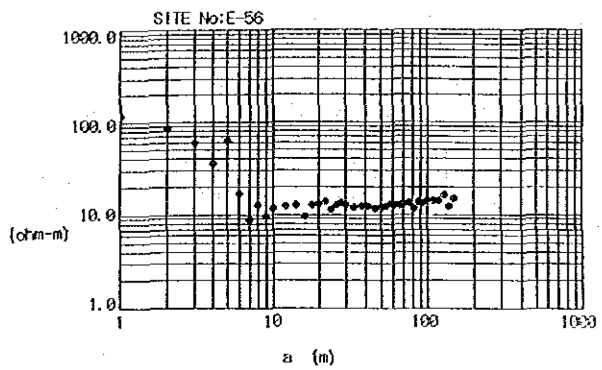
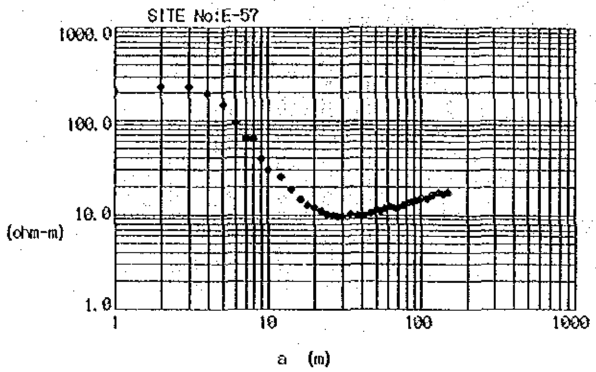
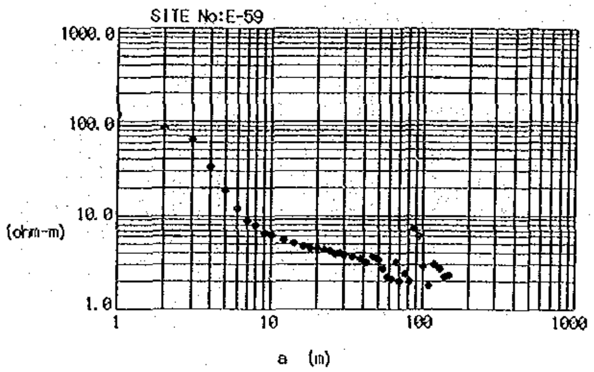
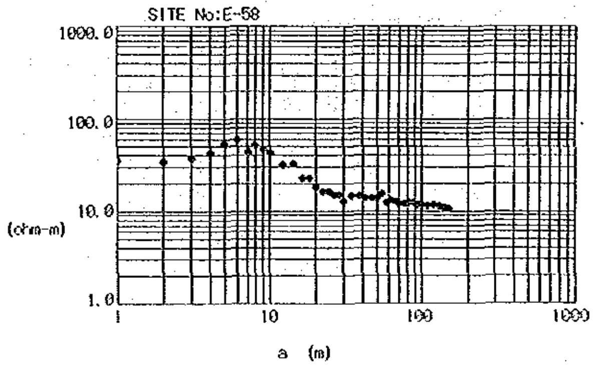
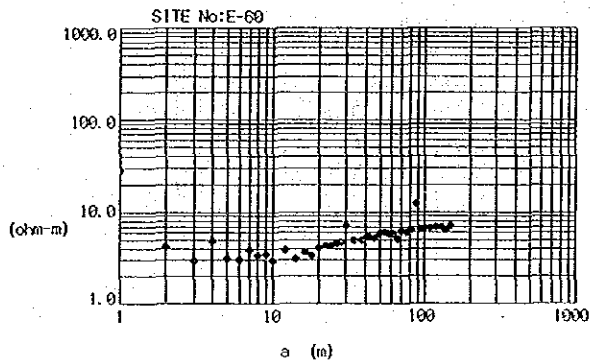


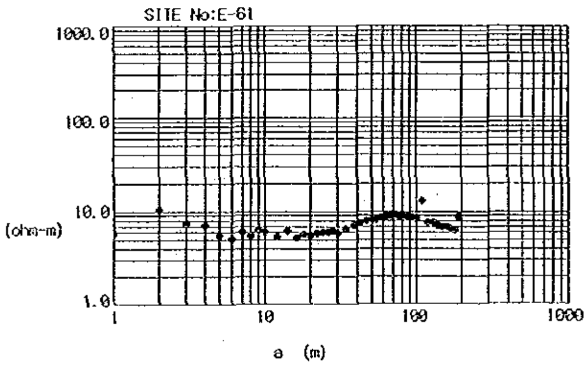
FIGURE B-45 ρ -a Curve (8)

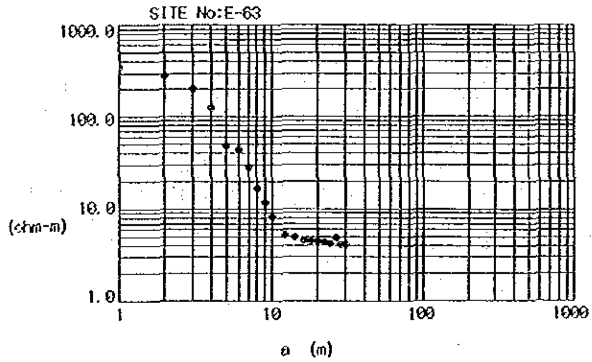


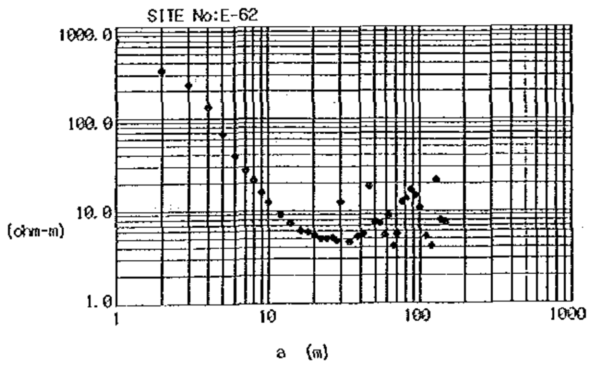












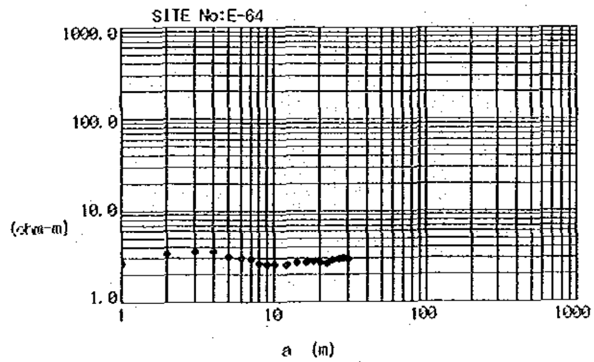
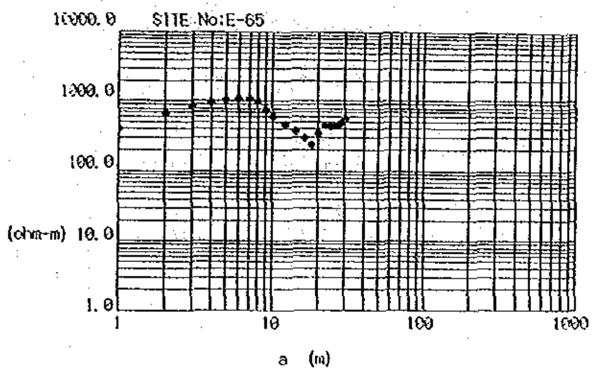
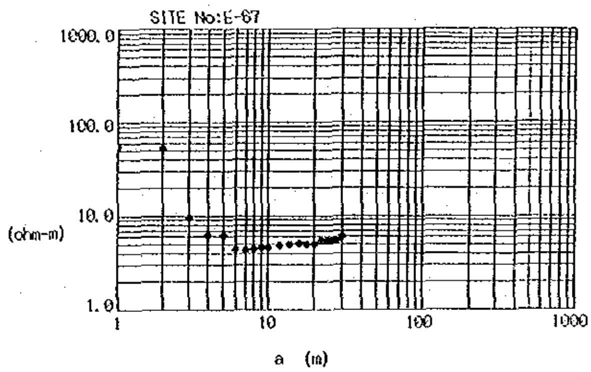
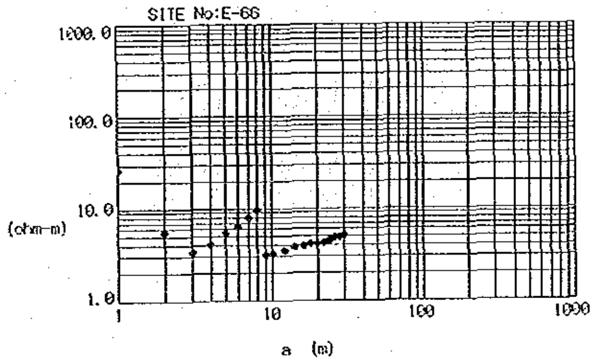
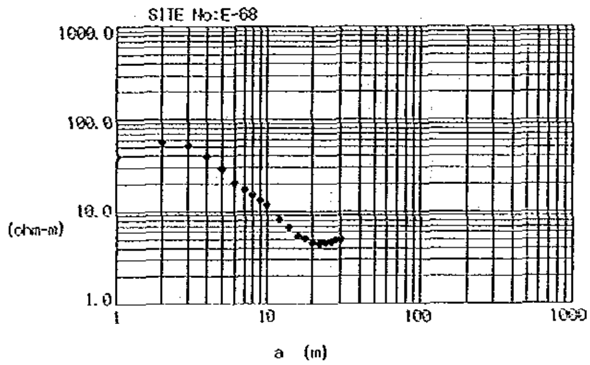


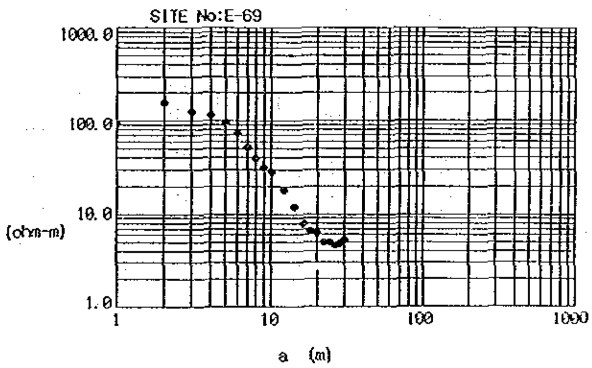
FIGURE B-45 ρ-a Curve (9)

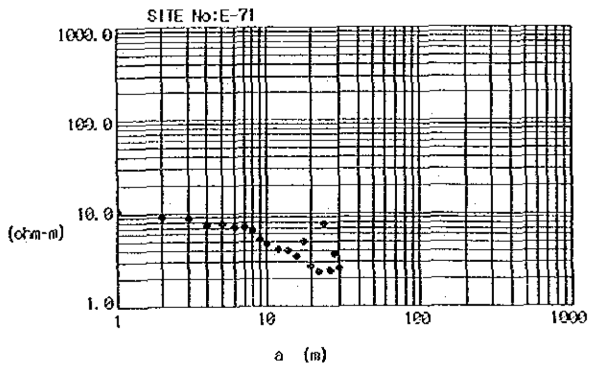


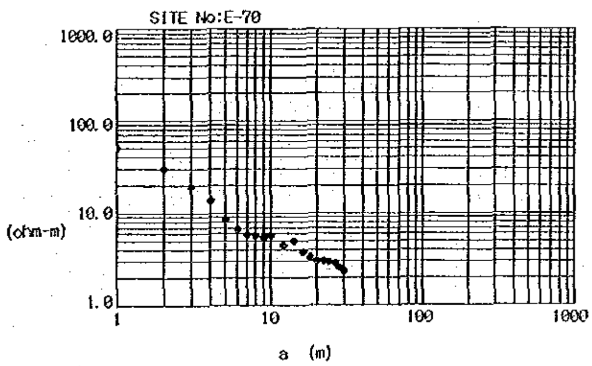












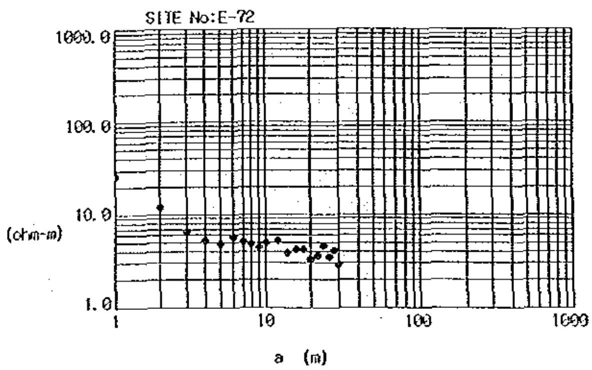
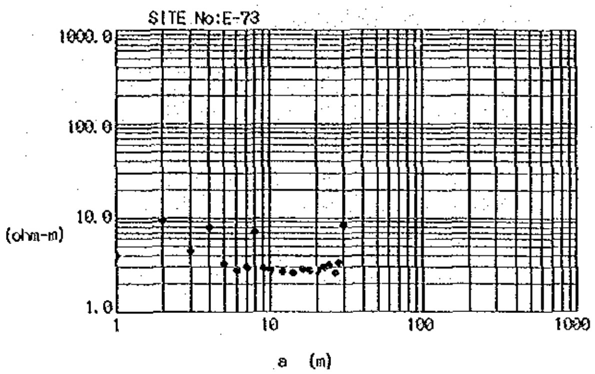
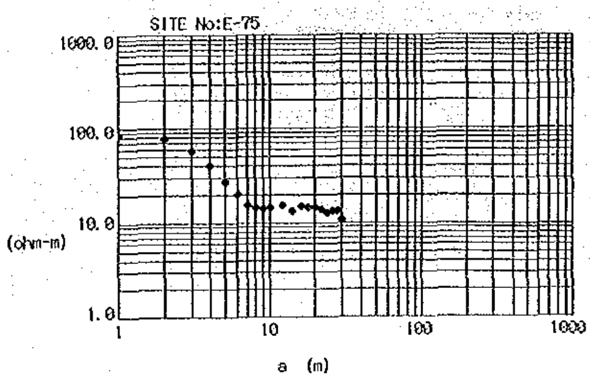
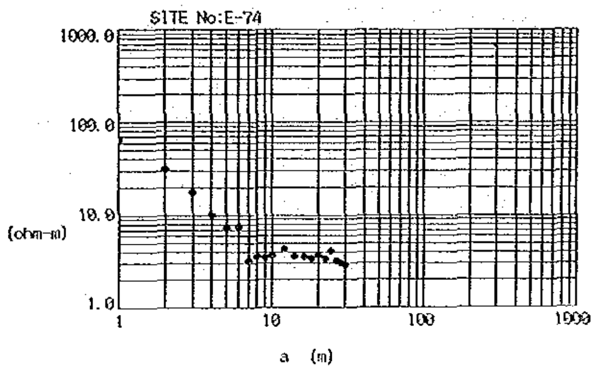
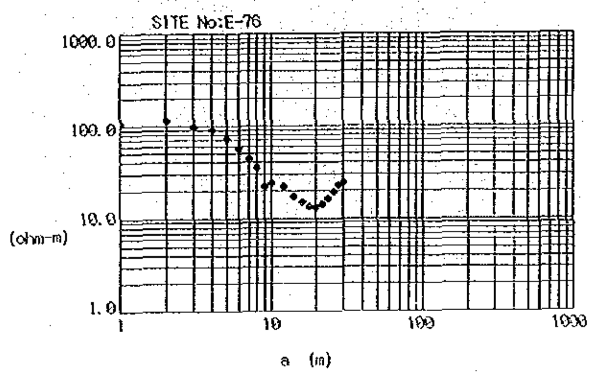


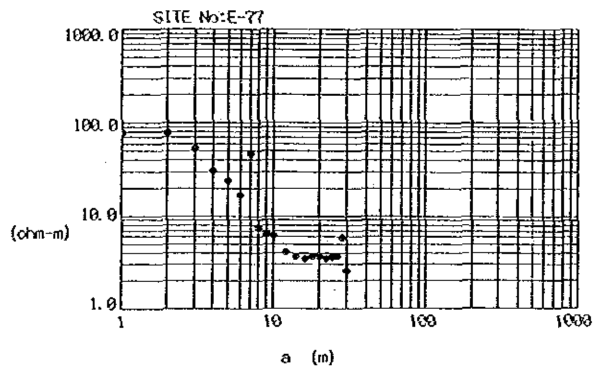
FIGURE B-45 ρ-a Curve (10)

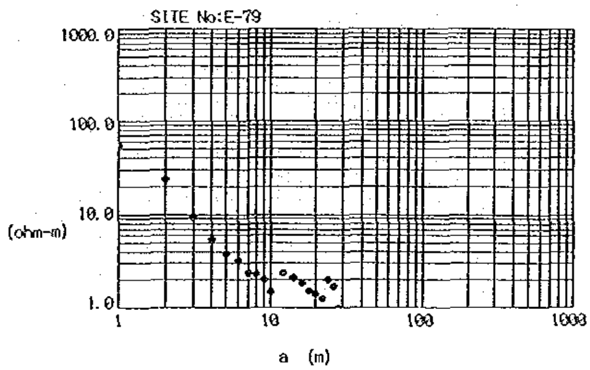


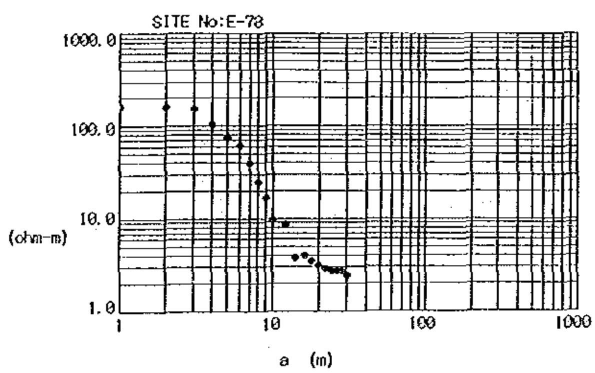












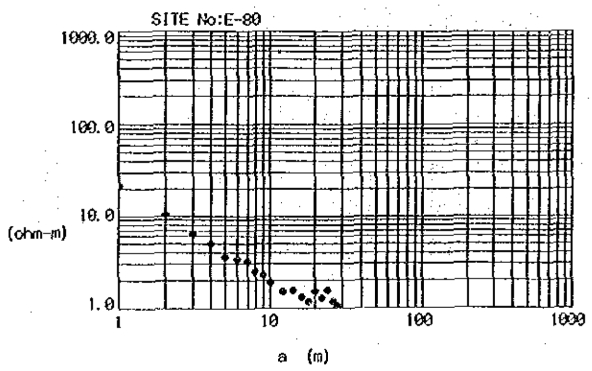
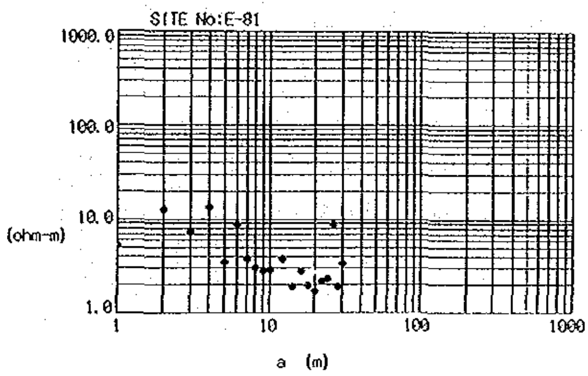
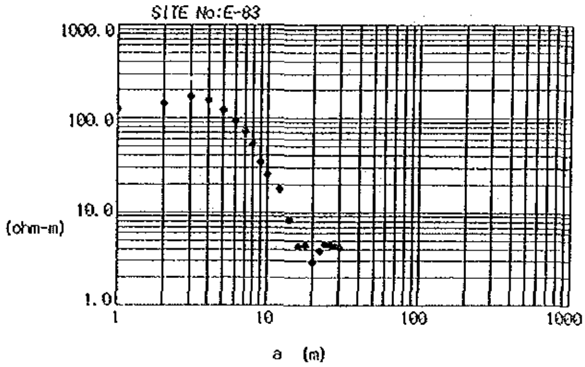
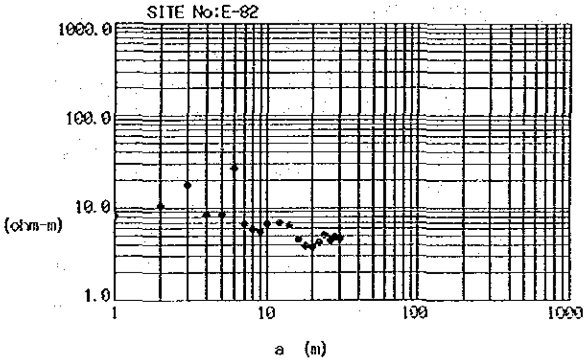
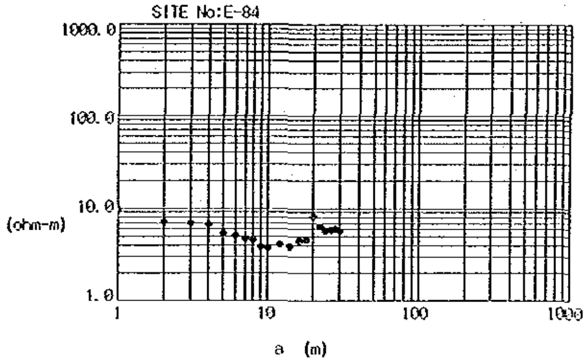


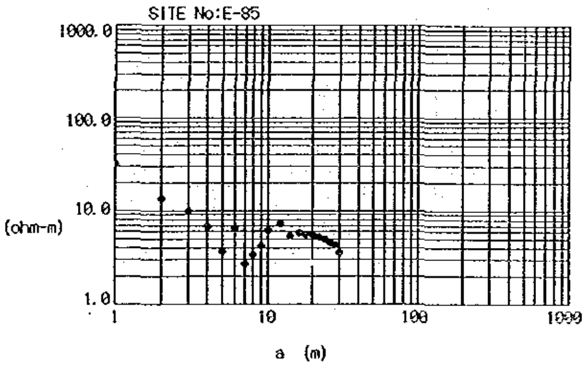
FIGURE B-45 ρ -a Curve (11)

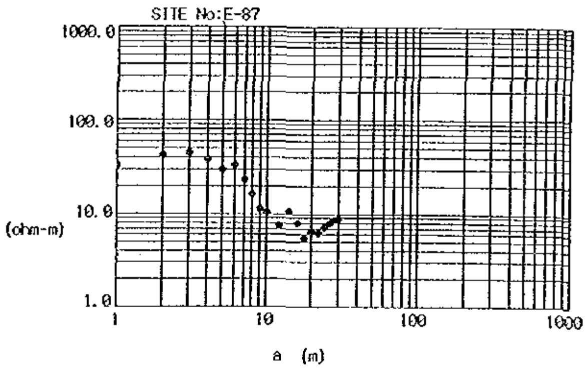


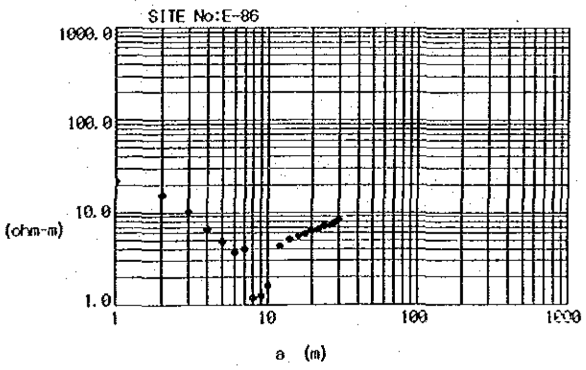












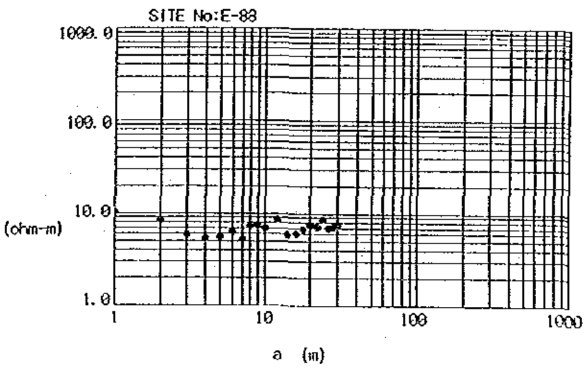
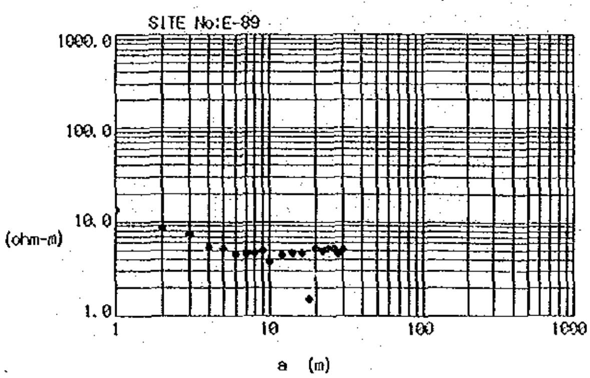
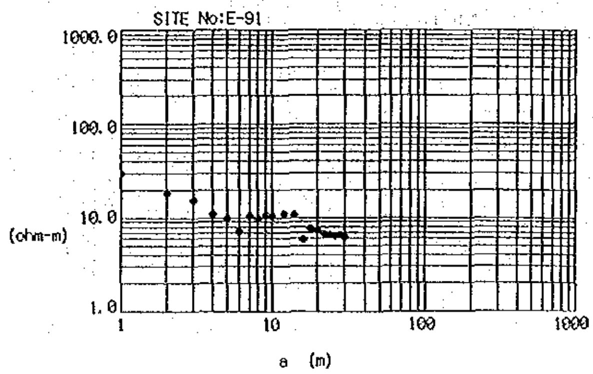
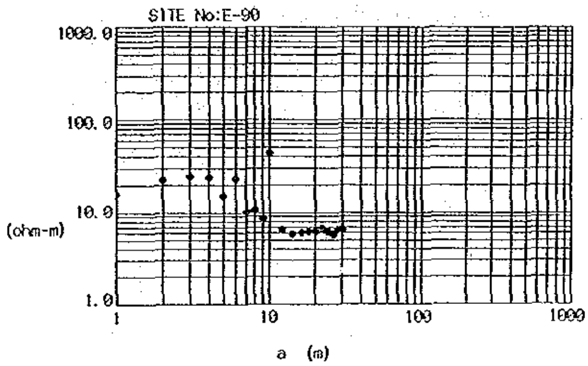
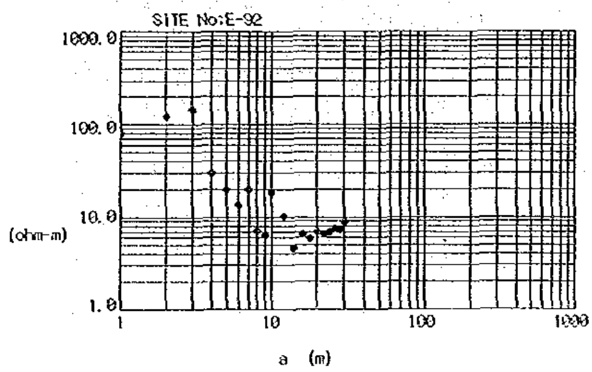


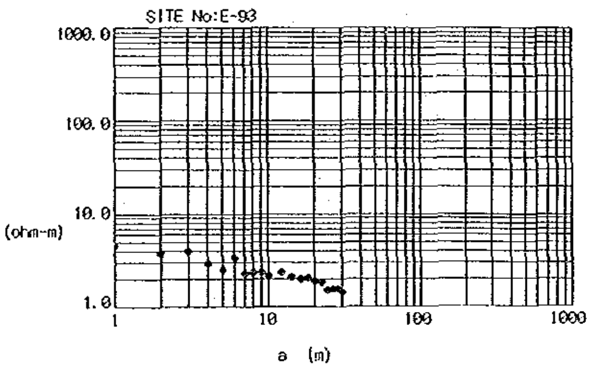
FIGURE B-45 ρ -a Curve (12)

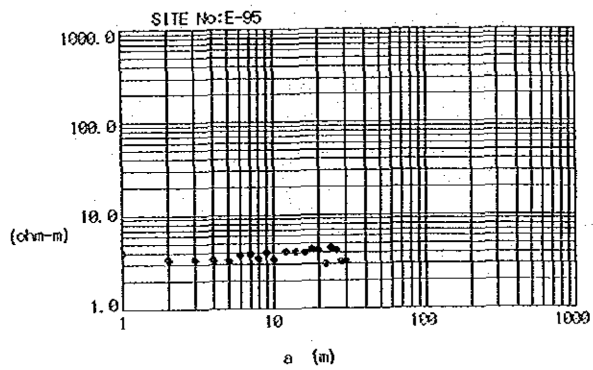


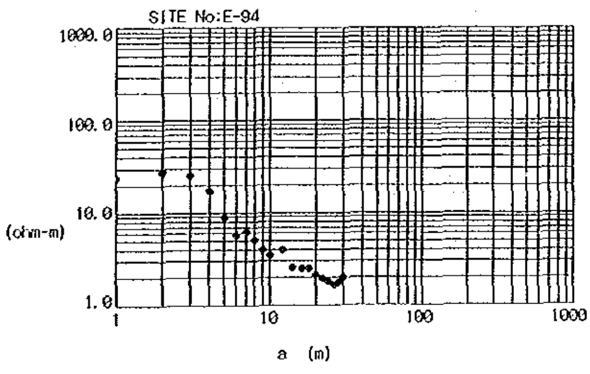












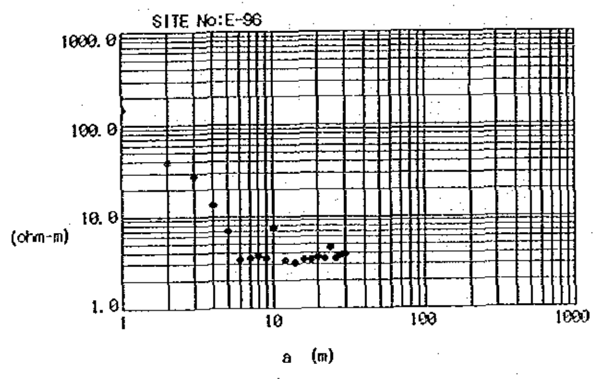
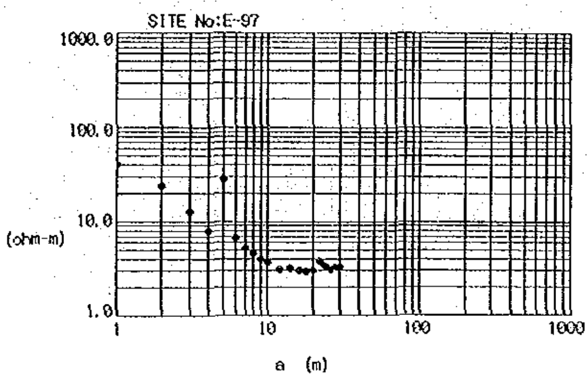
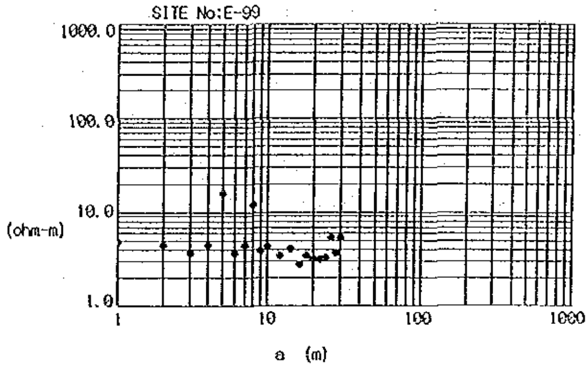
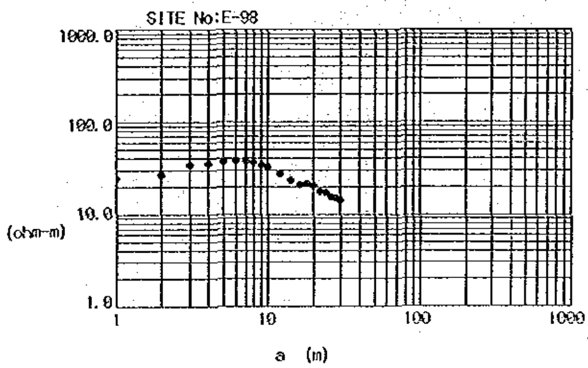
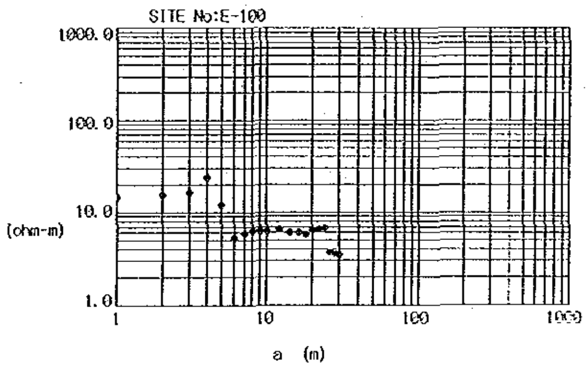


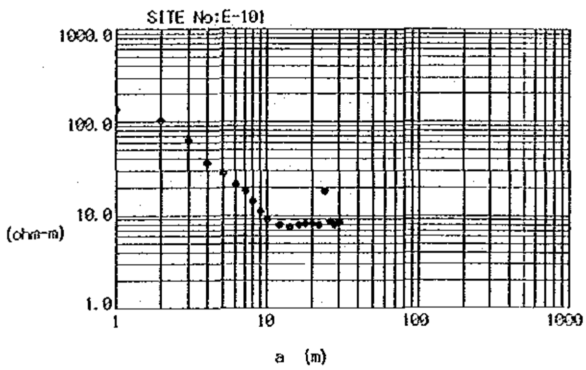
FIGURE B-45 ρ -a Curve (13)

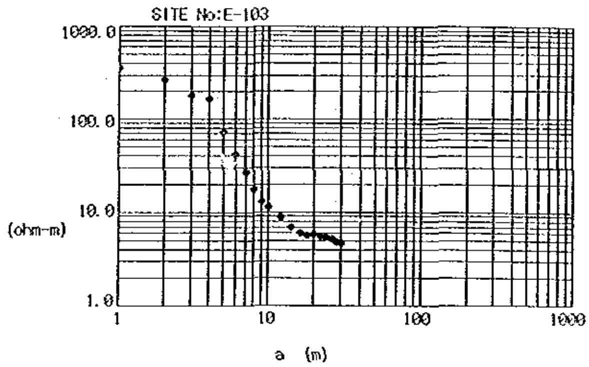


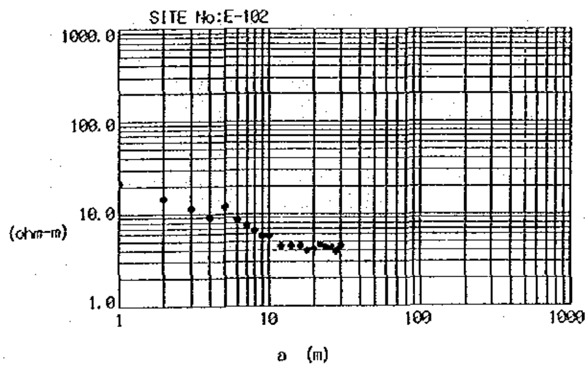












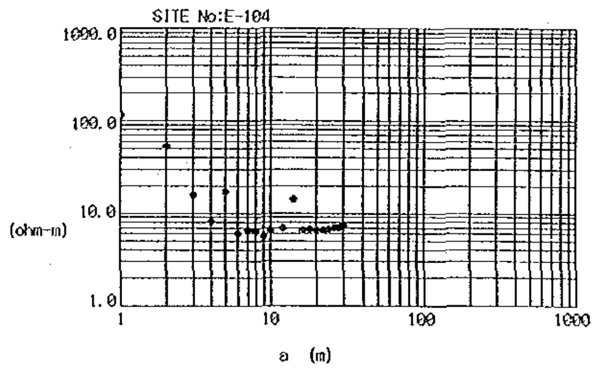
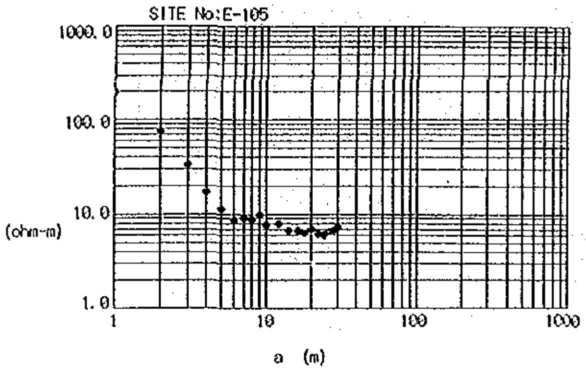
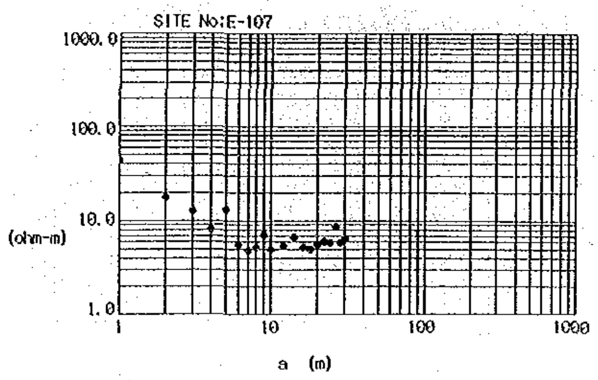
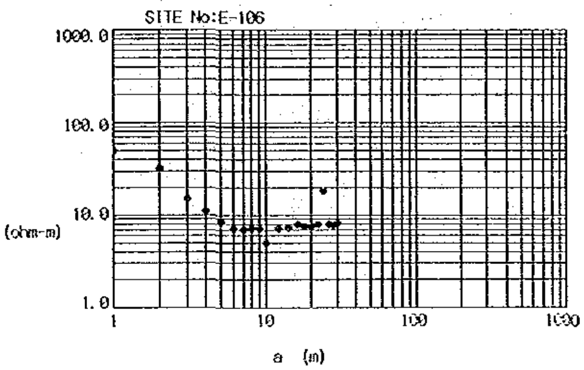
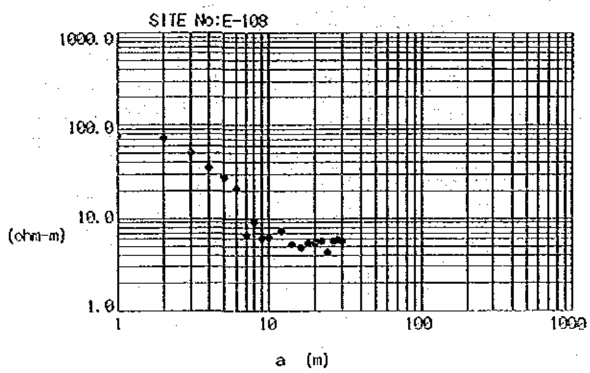


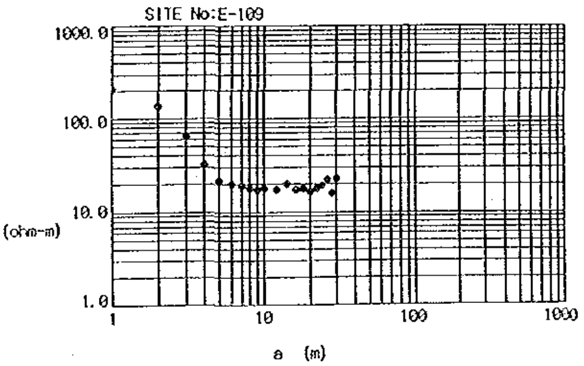
FIGURE B-45 ρ -a Curve (14)

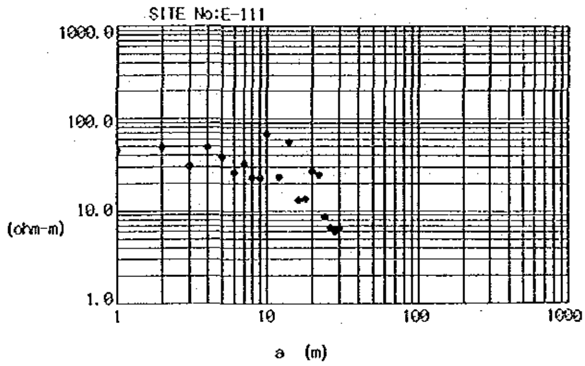


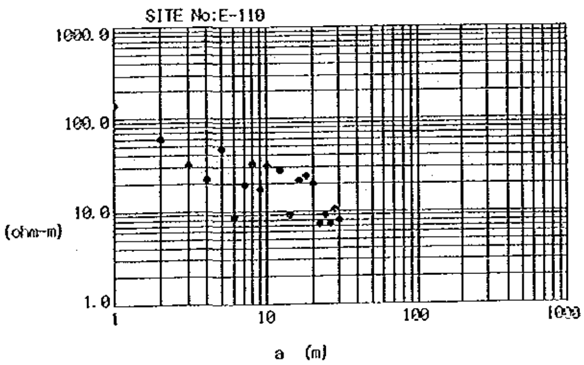












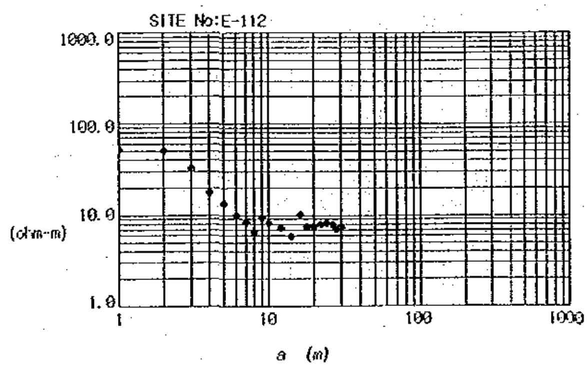
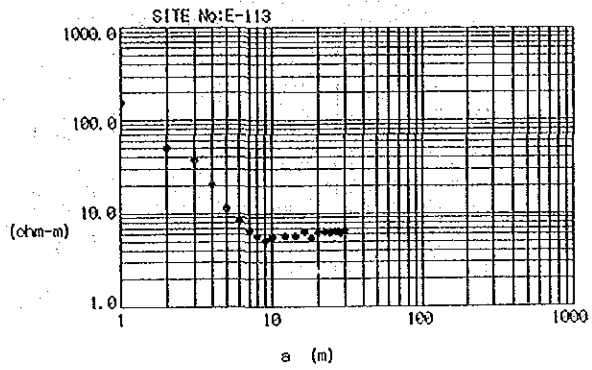
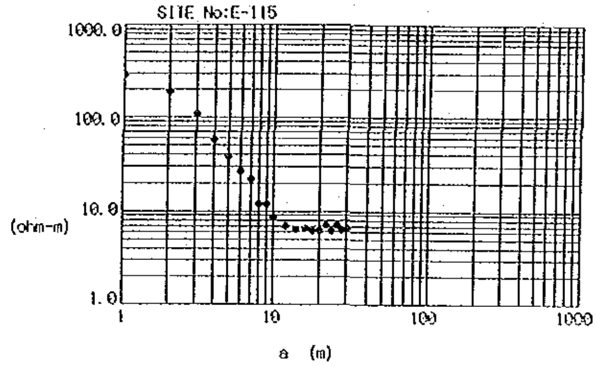
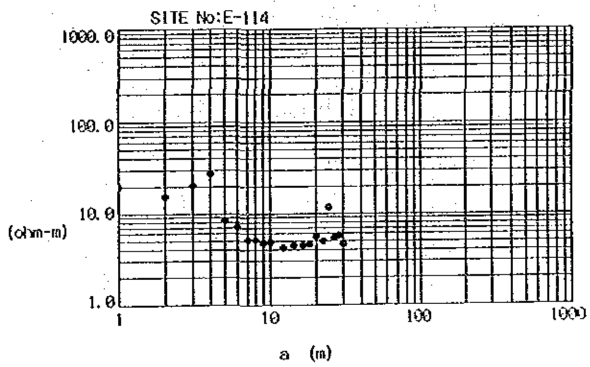
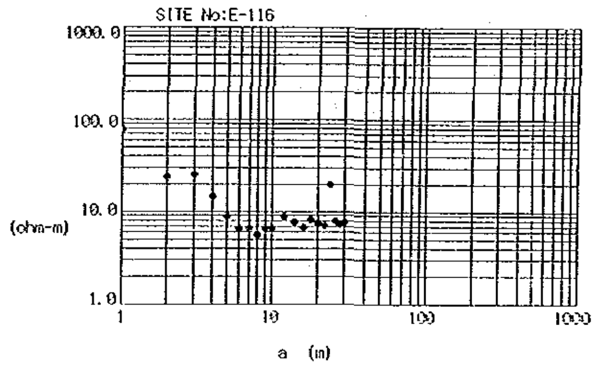


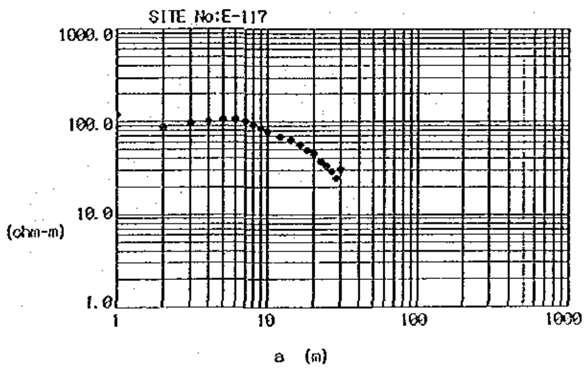
FIGURE B-45 ρ -a Curve (15)

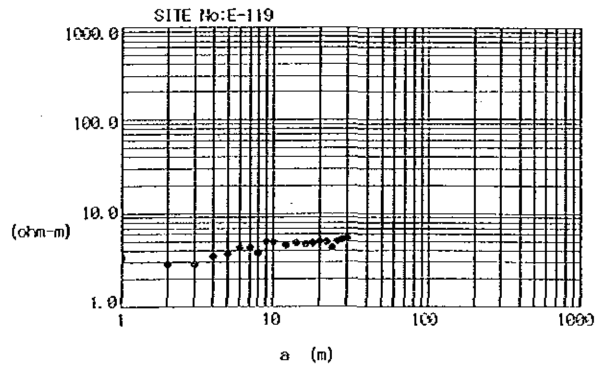


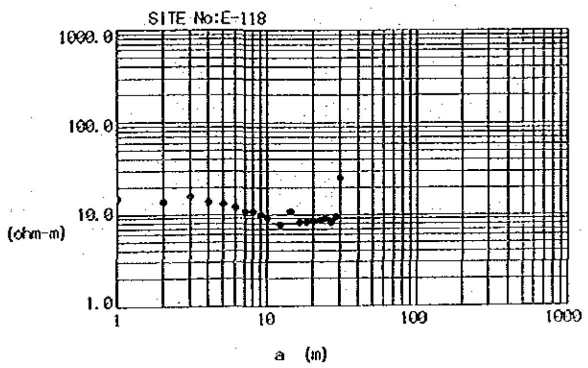


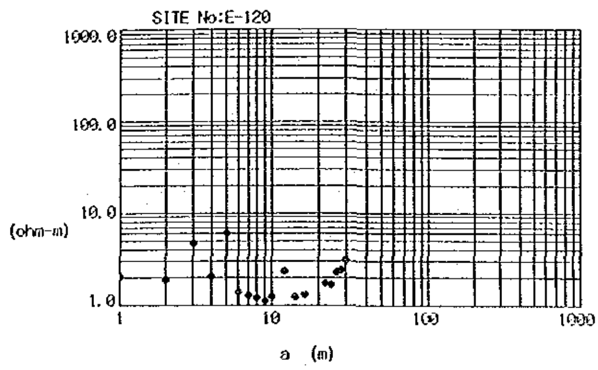












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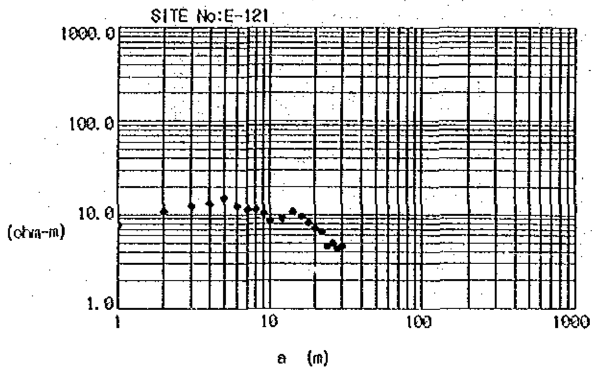
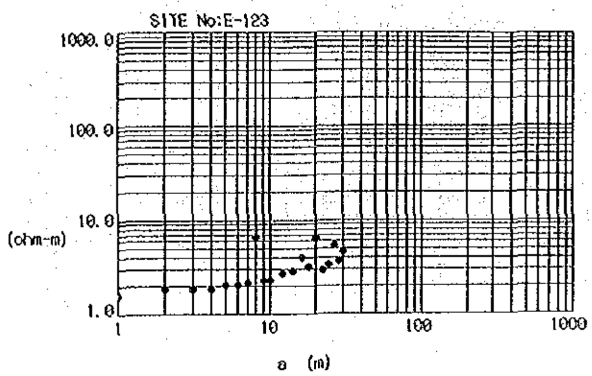
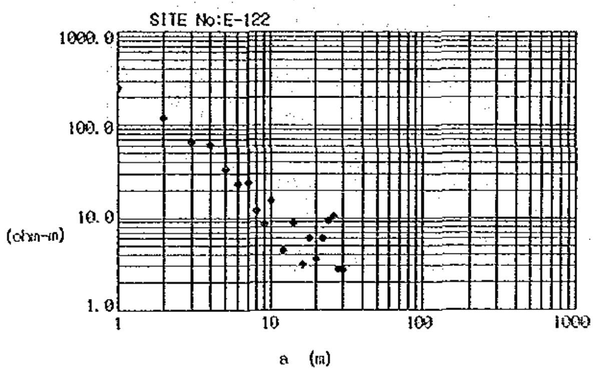
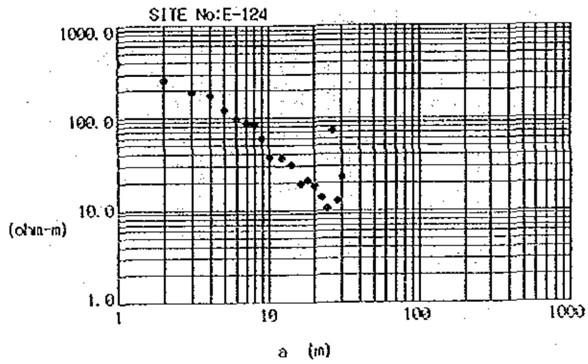
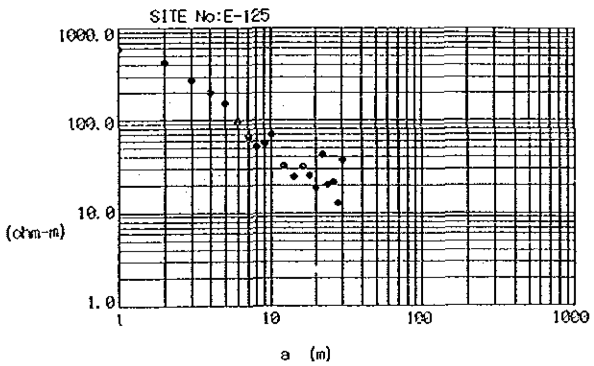
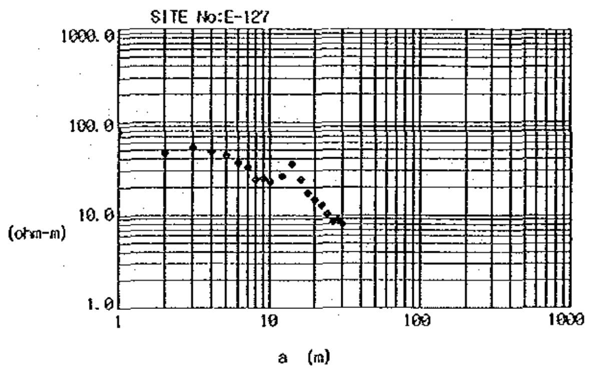


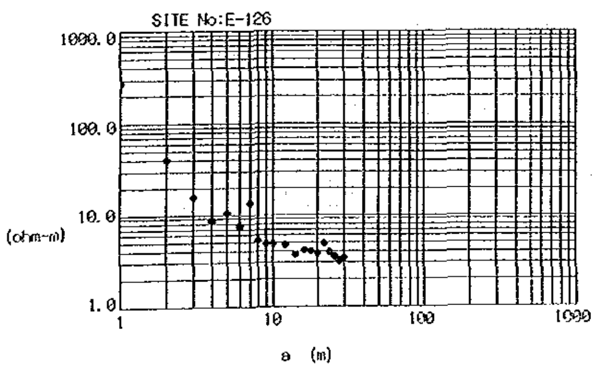












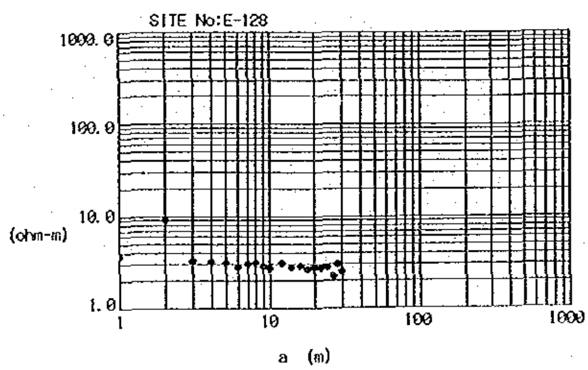
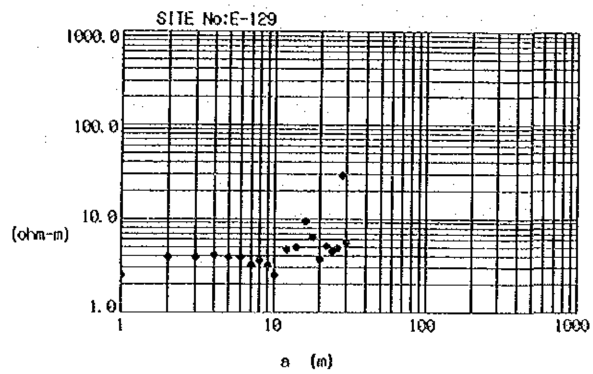
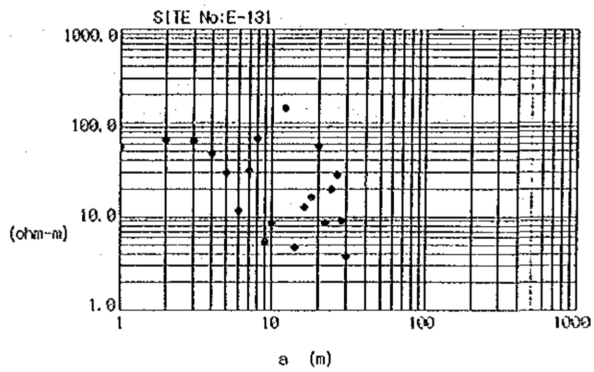
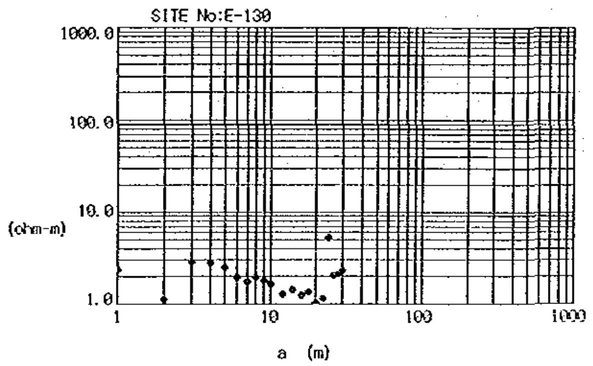
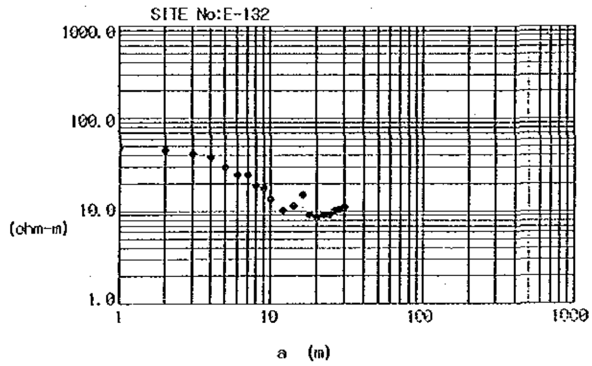


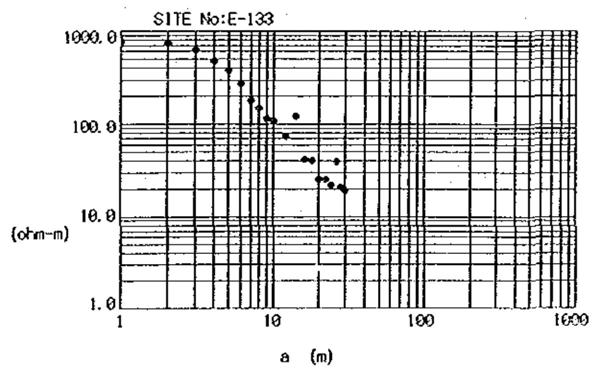
FIGURE B-45 ρ -a Curve (17)

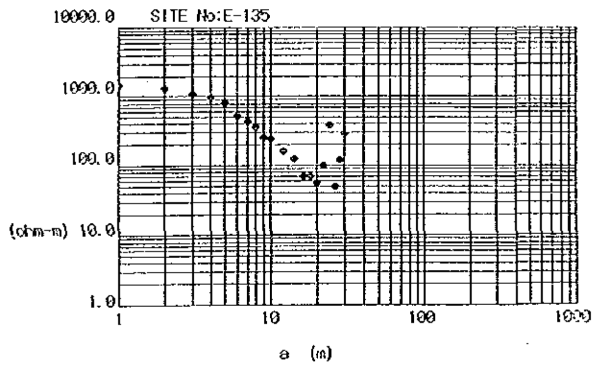


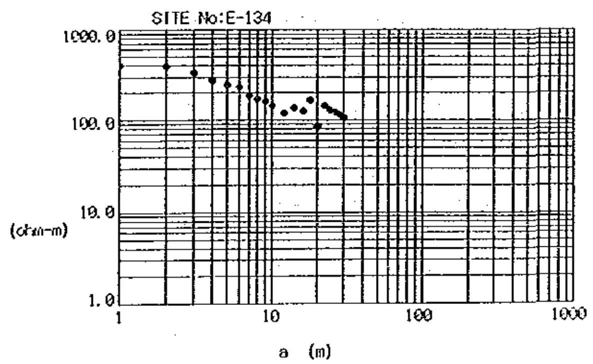


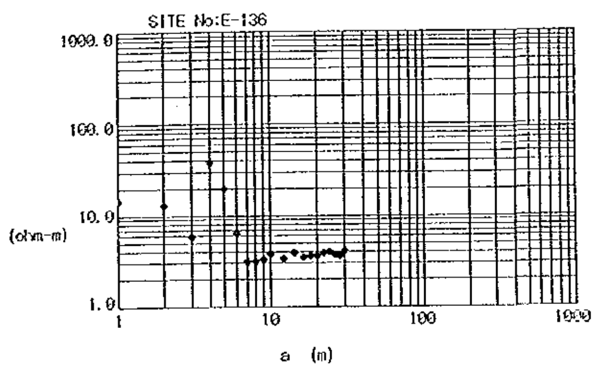












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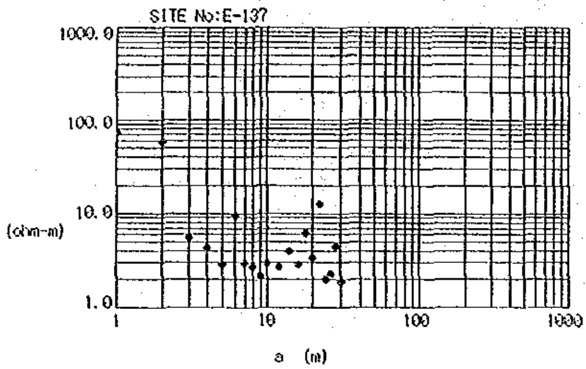

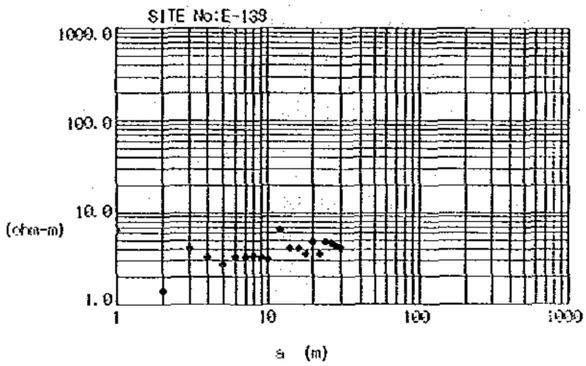

APPENDIX C SOIL AND LAND USE

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C-1. List of Maps, Aerophotos, and References

1) Maps
- Topographical Map, scale 1:50,000
- Detailed Reconnissance Soil Map of Khon Kaen Province scale 1:100,000, DLD (1973)
- Salt-Affected Area Map of Khon Kaen Province scale 1:100,000, DLD (1989)
- Land Form, Soil and Land Suitability Map for Agriculture of Khon Kaen Province scale 1:100,000, DLD (1989)
- Land Suitability Map for Small Reservoir Development in Amphoe Phra Yun, Khon Kaen Province scale 1:50,000
  Soil Survey Div, ADRC (1990)
- Forest Area Data from Remote Sensing 2528 in the Northeast Region, scale 1:250,000, RFD (1985)

2) Aerophotos and Satellite Imagery
- Aerophotos (scale 1:15,000) taken in April and August 1976
- Aerophotos (scale 1:15,000) taken in November 1983
- LANDSAT imagery (scale 1:200,000) 1978, 1984 and 1990
- SPOT imagery (scale 1:50,000) Sept. - Dec. 1988

3) Data and Publications
- Outline of Soils of the Northeast Plateau Thailand Their Characteristics and Constraints, M. Mitsuchi, Pichai Wichaidit, ADRC Tech Paper No. 1, 1986
- Distribution of Salt Affected Soils in the Northeast Region, Pichai Wichaidit
- Problems and Research Strategies of Cropping in the Problem Soils in the Northeast, ARDC (1987)

C-2 Methods of Soil Survey

The following works were carried out during the soil survey period:

- Data and maps collection and review
- Soil profile investigation (M/P and F/S)
- Soil analyses (F/S)

1) Data and Maps Collection and Review

Existing data and maps concerning soil and land use were collected at the Soil Survey Division of DLD at Bangkok and ADRC at Khon Kaen. And topographical maps, aerophotos, satellite imagery and soil maps were collected and analyzed in order to prepare the database maps.

2) Soil Profile Investigation

(1) For the Study Area

During the rainy season, soil survey for only upland area was conducted because most paddy fields were flooded for rice cultivation. The soil profiles were investigated by auger boring as deep as 7.5 m at 20 representative sites. For every soil profile, soil texture, color, moisture status, mottlings, concretions, gravels and pH were checked on the site in accordance with the FAO guidelines. Electrical conductivity (EC) of soil samples taken from each layer was measured at ADRC laboratory at Khon Kaen.

After rice harvest, soil survey for lowland area was carried out. The soil profiles mainly in paddy field were investigated by auger boring as deep as 4.0 m at 27 sites. The observation and description of soil profiles were made similarily to those for upland area.

(2) For the Pilot Area

During the dry season, soil survey for the pilot area was conducted. Firstly, 143 soil profiles were surveyed at a grid of 500 m apart. Soil profile survey were made by auger boring as deep as 1.8 m. For every soil profile, similar observation and description to those for the study area were made. Then, additional soil profile survey were made in order to collect soil samples for soil analyses at 16 representative sites.

3) Soil Analyses

Soil analyses on chemical and physical properties, and clay mineralogy were carried out at the DLD laboratories at Khon Kaen and Bangkok. Totally 75 disturbed soil samples for chemical analysis and 68 soil cores for physical analysis were delivered to the laboratories. Analytical method for each item is given in the following page.

Analytical Item		Method
Particle-size distribution		Sieving, hydrogen peroxide dispersion, Pipette method
pH (saturated paste)		pH meter with glass electrode
EC (saturation extract)		EC meter with direct indicating bridge
Cation exchange capacity (CEC)		Ammonium acetate extraction
Exchangeable cations		Ammonium acetate extraction
	Ca	- EDTA titration
	Mg	"
	Na	- Flame photometry
	K	"
Soluble ions	Ca	Atomic absorption
	Mg	"
	Na	"
	K	"
	Cl	Titration with silver nitrate
	HCO	Titration with acid
	SO	Precipitation as barium sulfate
Organic matter		Modified Walkley-Black wet oxidation
Extractable phosphate		Bray No.2 method
Total nitrogen		Semi-micro Kjeldahl distillation
Bulk density		Direct oven-drying of 100 cc soil core
Particle density		Pycnometer method
Moisture retention	1/3 bar	Pressure-plate method
	15 bar	Pressure-membrane method
Permeability of soil to water		Constant hydraulic head method

Exchangeable sodium percantage (ESP)

$$ESP = \frac{\text{Exchangeable sodium (meq/100g soil)}}{\text{Cation exchange capacity (meq/100g soil)}}$$

Sodic soil : ESP more than 15.

C-3 Soil Classification and Major Soil Characteristics in Khon Kaen Province

Table C-3-1 Soil Classification

No.	Soil Series	USDA Soil Taxonomy: Subgroups	USDA Soil Taxonomy: Families	National	Area: ha	Area: rai	Area: %
Flood Plain and Valley Flat							
5	Phimai	Vertic Tropaquepts.	very fine clayey, mixed, non acid	Hydromorphic Alluvial Soils	230	1,440	0.7
7	Ratchaburi	Aeric Tropaquepts.	Fine clayey, mixed, non acid	〃	420	2,620	1.2
9	Ratchaburi/Phimai				630	3,940	1.8
11	Alluvial Complex				1,350	8,440	4.0
					2,630	16,440	7.7
Low Terrace							
14	Roi Et	Aeric Paleaquults.	fine-loamy, Kaolinitic, acid	Low Humic Gley Soils	8,310	51,940	24.3
15	Roi Et, loamy variant	〃		〃	1,150	7,190	3.4
16	Roi Et, saline variant	Typic Natraqualfs		Solonchak	1,340	8,370	3.9
19	Ubon	Aquic Dystropepts.	coarse-loamy, siliceous	Hydromorphic Regosols (Aquic Arenic Paleustults)	130	810	0.4
21	Roi Et, high phase	Aeric Paleaquults		Low Humic Gley Soils	2,620	16,380	7.7
					13,550	84,690	39.7
Middle Terrace							
25	Korat	Oxic Paleustults.	fine-loamy, siliceous, acid	Gray Podzolic Soils	7,620	47,620	22.3
30	Phon Phisai	Plinthustults.	loamy-skeletal over clayey, mixed, acid	Red Yellow Podzolic Soils	2,600	16,250	7.6
32	Phen	Plinthaquults.	loamy skeletal over clayey, mixed, acid	Low Humic Gley Soils	170	1,060	0.5
33	Nam Phong	Ustoxic Quartzipsamments.	sandy, siliceous	Regosolic Soils (Arenic Paleustults)	420	2,630	1.2
					10,810	67,560	31.6
Middle to High Terrace							
37	Satuk	Oxic Paleustults.	fine-loamy, mixed	Red Yellow Podzolic Soils	4,080	25,500	11.9
38	Warin	Oxic Paleustults.	fine-loamy, siliceous, acid	〃	960	6,000	2.8
41	Yasothon	Oxic Paleustults.	fine-loamy, oxidic, acid	Red Yellow Latosol	910	5,690	2.7
55	Slope Complex				160	1,000	0.5
					6,110	38,190	17.9
W	Water				1,050	6,560	3.1
				Total	34,150	213,440	100.0

Table C-3-2 Major Soil Characteristics in Khon Kaen Province

Soil series, type phase, & variant	Mapping Unit No's	Classification 1. USDA 2. National 1/	Range of slope	Effective soil depth 2/	Textural profile	Color profile	Structure a. Upper A-horizon b. Subsoil 3/	a. Drainage b. Permeability c. Surface run-off 4/	Period of water saturation a. Surface b. Subsurface 5/	Organic matter (% carbon × 1.724) 0-30 cm 6/	Base saturation a. 0-30 cm b. >30 cm 7/	C.E.C (meq/100 %) a. 0-30 cm b. >30 cm 8/	Available phosphorus (ppm. of P) a. 0-30 cm b. >30 cm 9/	Available Potassium (ppm. of P) a. 0-30 cm b. >30 cm 10/	Reaction (pH 1 : 1 H2O) a. 0-30 cm b. >30 cm
Phimai	5	1. Vertic Tropaquepts 2. Hydromorphic Alluvial Soils	<1	very deep	clay throughout	dark grayish brown or dark gray over dark gray to gray; yellowish red or brownish yellow or dark reddish brown or gray mottles throughout	a. weak coarse prismatic and massive b. weak coarse prismatic at beginning of subsoil and weak fine to medium subangular blocky at lower	a. poorly b. slow c. slow	a. flooded by river water and rain water in the wet season, ground water table falls below 1.5 m in dry season b. groundwater table within 1 m, for at least 4 months and falls below 1.3 m, in the dry season	moderately low	a. medium b. medium	a. moderately low b. high	a. moderately low b. very low to low	a. high b. high to very high	a. 5.5 - 6.0 b. 5.5 - 6.0
Ratchaburi	7	1. Aeric Tropaquepts 2. Hydromorphic Alluvial Soils	<1	very deep	silty clay or clay over clay; some phanganese concretion below 60 cm	dark brown to brown over brown or reddish brown; dark yellowish brown or strong brown or dark gray or dark reddish brown or grayish brown or red mottles throughout	a. massive to weak fine and medium subangul blocky b. weak to moderate fine to medium subangular blocky	a. somewhat poorly b. slow c. slow	a. flooded by river water up to 50 cm, for 3 - 4 months b. groundwater table falls below 1.5 m, during the dry season	moderately low	a. medium b. medium	a. high b. high	a. low b. moderately low to low	a. high b. high to very high	a. 5.0 - 5.5 b. 5.5 - 6.0
Roi Et	14	1. Aeric Paleaquults 2. Low Humic Gley Soils	<2	very deep	sandy loam or loamy sand over loam or sandy clay loam or clay loam grading to clay	dark brown to brown or light gray to gray over brown grading to light gray or light brownish gray or reddish gray; yellowish red or light reddish brown or strong brown or light reddish brown to reddish brown mottles throughout	a. very weak fine subanlar blocky and massive b. moderate fine to medium subangular blocky and weak coarse prismatic	a. poorly b moderate c. slow	a. flooded by impounded rain water up to 30 cm, deep for 3 - 4 months b. groundwater table is below 3 m, during the peak of the dry season	very low to medium	a. medium b. medium	a. low b. moderately low to very low	a. very low to moderately high b. very low to high	a. high b. low	a. 5.0 - 5.5 b. 4.5 - 5.0
Roi Et, loamy variant	15	1. Aeric Paleaquults 2. Low Humic Gley Soils	<2	very deep	loam over clay loam grading to clay with few iron concretion in the subsoil	light gray to gray over brown or light brownish gray; brownish yellow or red mottles throughout	a. moderate fine to medium subangular blocky b. moderate medium to coarse subangular blocky	a. poorly b. moderate c. slow	a. flooded by impounded rain water up to 50 cm, for 4 - 5 months b. groundwater table within 1 m, for 5 months	low	a. medium b. medium	a. moderately low b. medium to moderately high	a. low b. low	a. low b. low	a. 5.5 - 6.0 b. 5.0 - 5.5
Roi Et, saline variant	16	1. Typic Natraqualfs 2. Solonchak ?	<2	very deep	sandy loam over heavy sandy loam or sandy clay loam with many gray and black concretions in subsoil	light brown to brown over light brown to light gray strong brown or reddish yellow mottles throughout	a. weak fine platy and weak fine subangular blocky b. weak fine to medium subangular blocky	a. poorly b. moderate c. slow	a. flooded by impounded rain water up to 20 cm deep for 2 - 3 months b. groundwater table drop to 1.5 meters in the dry season	very low	a. medium b. high	a. very low b. moderately low	a. very low b. very low	a. very low b. low	a. 6.5 - 7.5 b. 7.0 - 8.0
Ubon	19	1. Aquic Dystropepts 2. Hydromorphic Regosols	<2	deep	loamy sand over loamy sand or sandy loam or sand	light brownish gray over very dark gray or light brown intergrade to brown; yellowish red and dark brown to brown intergrade to strong brown and dark yellowish brown or brownish yellow and black mottles throughout	a. very weak fine subangular blocky b. weak fine granular; and weak fine subangular blocky	a. somewhat excessively or well b. rapid c. slow	a. flooded by impounded rain water up to 20 cm deep for 2 - 3 months b. groundwater level drops to 4 m, or more in the dry season	low	a. medium b. medium	a. low b. very low to low	a. very low b. very low	a. low b. very low	a. 5.0 - 5.5 b. 5.5 - 6.5
Roi Et, high phase	21	1. Aeric Paleaquults 2. Low Humic Gley Soils	1-3	very deep	sandy loam or sandy clay loam over sandy clay loam grading to clay	dark gray with dark brown and yellowish brown mottles over light brownish gray grading to pinkish gray with dark brown or yellowish brown mottles	a. moderate fine and medium subangular blocky b. moderate medium to coarse subangular blocky	a. poorly b. rapid over moderate c. slow	a. rain water is impounded up to 25 cm, for 3 - 4 months b. groundwater level falls below 3 m, during dry season	very low	a. medium b. low	a. very low b. moderately low	a. very low b. very low	a. low b. high	a. 5.0 - 5.5 b. 5.5 - 6.0
Korat	25	1. Oxic Paleustults 2. Gray Podzolic Soils	2-6	very deep	sandy loam over loam to sandy clay loam	dark brown or dark grayish brown over brown grading to strong brown in very deep subsoil with few fine gray mottles below 60 cm	a. weak fine to medium subangular blocky b. weak to moderate fine to medium subangular blocky	a. moderately well b. moderate c. rapid	a. none b. groundwater table within 1.5 m, during the peak of wet season	moderately low to medium	a. medium b. low	a. low to moderately low b. low to moderately low	a. low b. low	a. medium to high b. low	a. 5.0 - 6.0 b. 4.5 - 5.5
Phon Phisai	30	1. Plinthustults 2. Red Yellow Podzolic Soils	2-6	shallow to lateritic concretion layer	sandy loam or loam over sandy clay loam which inturn overlies gravelly sandy clay loam grading to mottled clay	brown to dark brown over strong brown or yellowish red which inturn over lies light gray or light brownish gray with reddish, brownish or yellowish mottles	a. weak fine granular and/or subangular blocky b. weak to moderate fine to medium subangular blocky	a. moderately well b. moderate over slow c. rapid	a. none b. groundwater table within 1 m, during the wet season	very low to medium	a. low to medium b. low	a. low to moderately low b. low to moderately low	a. low to moderately low b. very low to low	a. low to medium b. low to medium	a. 6.0 - 6.5 b. 4.5 - 5.0
Phen	32	1. Plinthaquults 2. Low Humic Gley Soils	1-3	shallow to lateritic concretion layer	sandy loam or loam over gravelly sandy clay loam or gravelly clay loam which inturn overlies silty clay or clay	dark brown to brown over light brown or light reddish brown grading to light gray with strong brown or yellowish brown mottles at surface and yellowish red and some strong brown in the subsoil	a. weak fine to medium subangular blocky b. weak medium to coarse subangular blocky	a. poorly b. moderate over slow c. slow	a. water at surface up to 30 cm for 2 - 3 months in the wet season b. groundwater table falls below 1 m, during the dry season	very low to low	a. medium b. low to medium	a. moderately low to low b. very low to low	a. low b. low	a. medium b. very high	a. 5.0 - 6.0 b. 4.5 - 5.0
Nam Phong	33	1. Untoxic Quartzipsamments 2. Regosolic Soils	3-10	very deep	loamy sand or sand over sand or loamy sand grading to sandy loam	very dark brown or dark brown to brown over light brownish gray grading to very pale brown or pink or light reddish brown or reddish yellow	a. very weak very fine granular and weak fine subangular blocky b. weak fine to medium subangular blocky	a. somewhat excessively b. rapid c. rapid	a. none b. groundwater table falls below 4 m, during the dry season	low	a. medium to high b. medium to high	a. very low to low b. very low	a. moderately low to low b. very low to low	a. very low to low b. very low	a. 5.0 - 7.0 b. 5.0 - 6.5
Satuk	37	1. Oxic Paleustults 2. Red Yellow Podzolic Soils	3-3	very deep	loamy sand or sandy loam over sandy clay loam grading to sandy clay	brown to light brown over strong brown with yellowish red and pink to pinkish gray mottles in very deep subsoil	a. weak fine granular b. weak fine to medium subangular blocky	a. well b. moderate c. rapid	a. none b. groundwater table below 1.5 m for 12 months	moderately low	a. medium b. medium	a. low b. moderately low to low	a. low b. very low	a. medium b. low	a. 6.0 - 6.5 b. 5.0 - 5.5
Warin	38	1. Oxic Paleustults 2. Red Yellow Podzolic Soils	2-5	very deep	sandy loam or loamy sand over sandy loam grading to sandy clay loam	dark brown to brown over yellowish red or reddish yellow	a. weak fine subangular blocky b. weak to moderate fine subangular blocky	a. well b. rapid c. rapid	a. none b. groundwater table below 1.5 m for 12 months	low	a. medium b. low to medium	a. very low to low b. very low to low	a. moderately low b. very low to low	a. low b. very low	a. 5.5 - 6.0 b. 4.5 - 5.5
Yasothon	41	1. Typic Haplustox 2. Red Yellow Latosol	3-8	very deep	loamy sand to sandy loam over sandy loam to sandy clay loam	dark reddish brown over red	a. weak very fine subangular blocky and/or single grain b. weak fine subangular blocky	a. well b. rapid c. rapid	a. none b. groundwater table below 4 m, for 12 months	low	a. medium b. low to medium	a. very low b. very low	a. medium b. very low to low	a. low b. very low to low	a. 5.5 - 6.0 b. 4.5 - 5.5

1/ Classification

(1) USDA - 1970 : Soil Taxonomy of the National Cooperative Soil Survey - described to subgroup level where possible.

(2) National : Based on "Major Soils of Southeast Asia", by R. Dudal and F.R. Moormann, Jour of Trop. Geog. Vol 18. 1964.

2/ Effective Soil Depth : Refers to the rooting zone where the limiting depth is a lithic contact, paralithic contact, petroferric layer or hard pan, through which it is very difficult or impossible for roots to penetrate. Range of depth ratings is as follows :

Rating	Range (cm)
Very shallow	<25
Shallow	25 - 50
Moderately deep	50 - 100
Deep	100 - 150
Very deep	>150

3/ Structure

Structure is described following standard terms as defined in the USDA Soil Survey Manual, with one exception : the term 'blocky' is used for both angular blocky and subangular blocky.

4/ Drainage : Ratings are as described in the USDA Soil Survey Manual

Permeability : Based on field observations of the soil profile - least permeable horizon of the solum or immediate substratum determines permeability of the soil. Definition of ratings is as follows.

Slow : soils expected to have hydraulic conductivity of less than 0.5 cm/hour
Moderate : soils expected to have hydraulic conductivity of 0.5 to 15 cm/hour
Rapid : soils expected to have hydraulic conductivity of more than 15 cm/hour

Surface Runoff : Estimations based on characteristics of the soil profile, soil slope, climate and vegetation cover. Definition of ratings is as follows:

Slow : surface water flows away so very slowly that free water lies on the surface for considerable periods of time or immediately enters the soil. Much of the water either passes through the soil or is lost to evaporation. Soils with slow runoff are subject to little or no erosion hazard.

Medium : surface water flows away at such a rate that a moderate amount of water enters the soil profile and free water lies on the soil surface for only short periods. Most of the precipitation is (a) absorbed by the soil and used for plant growth, or (b) moved downwards into underground channels. With medium runoff the loss of water over the surface does not seriously reduce the supply available for plant growth. Erosion hazards can be expected to be slight or moderate if such soils are cultivated.

Rapid : A large or very large proportion of the precipitation moves rapidly over the surface of the soil and very little moves through the soil profile, Surface water moves as fast or almost or fast off the soil as it is added to the soil. Erosion hazard is moderate, high or very high.

5/ Period of Water Saturation : indicates the length of time that the soil surface and/or subsurface is at or above field capacity. Saturation by rainwater, seepage, river water or seawater; but not by irrigation water.

6/ Organic Matter (% carbon X 1.724) : Standard ratings are as follows : (USDA)

Rating	Range (%)
Very low	<0.5
Low	0.5 - 1.0
Moderately low	1.0 - 1.5
Medium	1.5 - 2.5
Moderately high	2.5 - 3.5
High	3.5 - 4.5
Very high	>4.5

7/ Base Saturation (%) $\frac{B \times 100}{B + A}$: Standard ratings are as follows : (SSD)

Rating	Range (%)
Low	<35
Medium	35 - 75
High	>75

8/ C.E.C. (me/100 gm soil) : Standard ratings are as follows : (SSD)

Rating	Range (me/100gm soil)
Very low	<3.0
Low	3.0 - 5.0
Moderately low	5.0 - 10
Medium	10 - 15
Moderately high	15 - 20
High	20 - 30
Very high	>30

9/ Available Phosphorus (ppm of P) Bray No. 2 : Standard ratings are as follows : (USDA)

Rating	Range (ppm)
Very low	<3
Low	3 - 6
Moderately low	6 - 10
Medium	10 - 15
Moderately high	15 - 25
High	25 - 45
Very high	>45

10/ Available Potassium (ppm of K) Ammon. Acetate : Standard ratings as follows : (USDA)

Rating	Range (ppm)
Very low	<30
Low	30 - 60
Medium	60 - 90
High	90 - 120
Very high	>120