THE REPUBLIC OF PARAGUAY

THE FEASIBILITY STUDY
ON
THE INTEGRATED RURAL INFRASTRUCTURE
IMPROVEMENT PROJECT
IN
LA COLMENA

ANNEX

MAY 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

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ANNEX A. Meteorology and Hydrology

A. 1 Meteorology

The meteorological stations around the study area are shown in Fig. A.1.1 and Table A.1.1. These stations were under the control of the Department of Meteorology, Ministry of National Defense. The meteorological records observed at the said stations are summarized in Table A.1.2 with the monthly basis. As for the rainfall record, there are data which have been observed by the Agricultural Cooperative in La Colmena since 1974. Application of the these data will be concluded after verification of its accuracy by using the observed record on the neighboring stations because data at La Colmena were not registered by the Department of Meteorology.

Thiessen method is employed among the neighboring six meteorological stations to clarify the meteorological conditions in the study area. As shown in Fig. A.1.2, the study area situates within the sphere of *influence in Villarrica and Carapegua. Correlation factor on the* mean monthly and annual rainfall among La Colmena, Villarrica and Carapegua is as follows:

Station	La Colmena	Villarrica	Carapegua
La Colmena	-	0.3460	0.2985
		0.8829	0.8954
Villarrica	0.3460	-	0.6986
	0.8829	-	0.8880
Carapegua	0.2985	0.6986	-
	0.8954	0.8880	-

. Rainfall data employed from 1974 to 1987
. Upper value shows correlation of annual rainfall
. Lower value shows correlation of mean monthly rainfall

From the above Table, signification of correlation on the annual rainfall between Carapegua and Villaricca is obviously found,however, there is no signification of correlation between La Colmena and other stations.

On the other hand, high significant levels of correlation on the monthly rainfall can be found among the three stations. These results show that the distribution of annual rainfall for each month develops a same trend among the three stations, however, rainfall record of La Colmena could not be handled with other stations in view of total amount of annual rainfall.

Rainfall record at La Colmena is shown prominently larger values than the other 2 stations when daily rainfall of more than 150 mm is compared with other stations.

Year	Carapegua	La Colmena	Villarrica
1974/ 5/23	71.5	-	26.8
24	112.3	246	87.4
25	10.0	13	8.6
26	2.0	-	0.7
27	-	-	0.4
Total	195.8 mm	259 mm	123.9 mm
1980/ 5/17	18.9	-	20.4
18	6.6	9	7.8
19	58.9	158	98.8
20	84.5	33	46.9
21	2.4	14	-
22	-	20	-
Total	195.8 mm	234 mm	173.9 mm
1982/11/25	52.4	-	-
26	66.4	98	12.6
27	51.2	50	92.9
28	6.3	163	12.6
29	-	-	71.4
Total	176.3 mm	311 mm	189.5 mm

As shown in Table A.1.1, mean annual rainfall during the observed period is as follows:

Carapegua : 1,619 mm
La Colmena : 1,755 mm
Villarrica : 1,592 mm

Mean annual rainfall of La Colmena is also shown larger values than 1,600 mm of annual isohytal graph in "Mapa Hidrogeologico" which has been published in 1986.

Topographical conditions around the presaid observation stations are

- Elevation of each station varies from 100 to 150 m above mean sea water level
- Distance interval of each station is every 40 km from west to east
- A mountain which elevation is ranging from 400 m to 500 m exists behind the all stations in south and/or east.

It is considered that there are no particular conditions to occur the difference of daily or annual rainfall among the three stations.

Rainfall record to be used for the project will be decided taking the following view points into account:

- Conservative values should be employed for estimation of water requirement
- Long term record is preferable for the analysis.

Therefore, areal rainfall estimated by the area ratio of Villarrica and Carapegua on the basis of Thiessen Polygon is used for the analysis instead of the data on La Colmena.

The missing data of Carapegua station is complemented by the following regression equation constructed on the basis of monthly rainfall of Villarrica:

$$y = 1.846x - 11.7628$$

y: Carapegua daily rainfall
x: Villarrica daily rainfall

Areal rainfall is estimated using the following equation based on the area ratio of 0.33 for Carapegua and of 0.67 for Villarrica:

$$Ra = 0.67\ Rv + 0.33\ Rc$$

Ra: Daily rainfall in study area, mm
Rv: Daily rainfall in Villarrica, mm
Rc: Daily rainfall in Carapegua, mm

A. 2 Hydrology

The hydrological stations in Paraguay are shown in Fig. A.1.1 together with the meteorological stations. Due to the lack of hydrological data available in and around the study area, new automatic water level gauging stations were established by the project at the three major streams named Rory-Mi, Rory and Tranquera in the study area. River basin diagram in and around the study area and locations of new gauging stations are shown in Tables A.2.1 and A.2.2, respectively.

To estimate the discharge available of pre-said three major streams, runoff analysis is carried out by using the water level record on its commanded streams. The tank model method is employed for analysis because low water discharge is mainly required for the project formulation. The parameters on the model are constructed on the stream basis with the discharge record, daily rainfall and water level record obtained from September to November, 1988. Data employed for calculation and its computed results are shown in Tables A.2.1 to A.2.3 and illustrated in Fig. A.2.3, respectively.

Calculations on each stream model were performed on the daily basis and presented high co-relation with its observating results as follows :

	co-relation factor
Tranquera	0.9833
Rory	0.9809
Rory-Mi	0.9876

Consequently, parameters of the models will be concluded as shown in Fig. A.2.4.

To clarify the stream regimen in the study area, runoff analysis of pre-said three major streams with the tank model is carried out on the daily basis at the duration from 1978 to 1987. Low water flow in each year,thus, estimated and summarized in main report.

A. 3 Water Quality

Water quality analysis is executed by the INTN (INSTITUTO NACIONAL DE TECNOLOGIA Y NORMALIZACION) during the study period at the streams, wells and pond in the study area. Location and number of samples is as follows:

No.	Location	Sample
1.	Tranquera middle stream reach	1
2.	Rory middle stream reach	1
3.	Rory-Mi middle stream reach	1
4.	Rory-Mi upstream reach	1
5.	Rory upstream reach	1
6.	Tranquera upstream reach	1
7.	Shallow well at Miyamoto,s house	1
8.	Deep well at Miyamoto,s house	1
9.	Pond near the Miyamoto,s house	1

Physical and chemical analysis were performed on the abovementioned samples. Items of analysis and its results are shown in Table A.3.1.

Analyzed results show that the water can be used as the drinking water with the water quality criteria in Paraguay, however, colon bacilli were detected in some samples though values show in allowable range. With these, utilization of these water sources will be made after chlorination.

Table A.1.1 Meteorological Stations Around the Study Area

No.	Station	Coordination Lat.	Lon.	EL.	Duration	Remarks
1	Asuncion					
	Sajonia	25°16'	57°38'	63	1881 - 1970	
	Aeropuerto	25°15'	57°31'	85	1971 - present	
2	Paraguari	25°36'	57°09'	-	1981 - present	
3	Carapegua	25°48'	57°14'	116	1970 - present	
4	Villarrica	25°45'	56°26'	161	1941 - present	
5	San Juan B. Mios	26°40'	57°09'	126	1956 - present	
6	San Lorenzo	25°22'	57°34'	120	1957 - 1981	
7	Caacupe	25°24'	57°06'	228	1961 - present	
8	Barrerito-Caapucu	26°17'	57°03'	-	1975 - 1979	
9	Caazapa	26°11'	56°22'	-	1973 - present	
10	Eusebio Ayala	25°26'	56°58'	-	1937 - 1949	Rainfall only
11	San Bernardino	25°18'	57°17'	-	1940 - 1951	〃
12	Altos	25°16'	57°14'	-	1940 - 1949	〃
13	San Salvador	25°28'	56°54'	-	1940 - 1968	〃
14	Col. Carlos Pfamul	25°28'	56°55'	-	1940 - 1966	〃
15	Maciel	26°08'	56°30'	-	1940 - 1968	〃
16	Isla Saca	26°28'	56°24'	-	1940 - 1958	〃
17	Sapucai	25°39'	56°56'	-	1940 - 1968	〃
18	Yaguaron	25°34'	57°17'	-	1940 - 1949	〃
19	Guarambare	25°28'	57°28'	-	1972 - 1976	〃
20	Copiata	25°16'	57°30'	-	1940 - 1976	〃

Note: 1 - 9 Registrated meteorological stations
10 - 20 Registrated rainfall observation stations

Table A.1.2 Mean Monthly Values on Each Meteorological Stations

RAINFALL RECORD — MEAN MONTHLY — UNIT: mm

STATION	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
VILLARRICA	162	126	158	160	136	113	78	80	108	174	164	133	1592
CARAPEGUA	162	124	137	195	140	106	62	89	77	130	207	145	1619
PARAGUARI	156	144	81	220	86	81	63	72	59	103	218	130	1455
CAACUPE	176	144	143	174	123	95	55	74	99	146	200	162	1590
SAN JUAN B.M.	162	146	146	155	126	104	77	79	100	177	161	134	1607
CAAZAPA	143	132	114	199	138	80	89	85	118	156	192	106	1533
LA COLMENA	172	148	127	198	162	103	60	119	97	159	250	161	1755

RELATIVE HUMIDITY RECORD — MEAN MONTHLY — UNIT: %

STATION	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVE.
VILLARRICA	73	76	77	83	85	84	80	75	71	72	73	73	75
CARAPEGUA	71	74	76	83	83	80	76	75	71	71	70	70	74
PARAGUARI	77	79	78	82	80	81	77	72	79	74	79	77	78
CAACUPE	64	64	65	70	78	77	74	68	64	62	62	59	63
SAN JUAN B.M.	67	70	72	74	75	76	74	71	69	67	67	64	71
CAAZAPA	66	66	69	75	79	80	78	78	77	71	68	66	73

TEMPERATURE RECORD — MEAN MONTHLY — UNIT: ℃

STATION	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVE.
VILLARRICA	26.4	26.0	24.6	22.9	20.1	17.8	18.6	17.8	19.5	22.0	23.7	25.4	21.7
CARAPEGUA	27.3	26.8	25.3	22.1	19.3	17.0	17.7	18.0	23.1	22.5	24.4	26.1	22.5
PARAGUARI	27.1	26.6	25.0	22.6	21.6	17.1	18.2	18.5	19.9	23.0	24.9	26.0	22.5
CAACUPE	26.6	26.3	25.0	21.3	19.8	17.4	17.6	18.6	20.2	22.8	24.3	26.1	22.0
SAN JUAN B.M.	27.0	26.5	24.9	21.6	18.2	16.6	16.8	17.4	19.5	22.3	24.2	26.4	21.8
CAAZAPA	25.7	25.5	24.1	20.5	18.1	15.7	16.8	16.8	18.3	21.5	22.8	24.8	20.9

SUNSHINE RECORD — MEAN MONTHLY — UNIT: Hr

STATION	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVE.
VILLARRICA	251	229	226	220	199	163	190	200	181	223	261	257	259
CAACUPE	253	240	228	218	195	171	180	181	185	206	213	243	210
SAN JUAN B.M.	255	226	231	185	179	168	162	175	205	221	246	249	275

EVAPORATION ARECORD — MEAN MONTHLY — UNIT: MM

STATION	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVE.
VILLARRICA	82	68	67	50	47	48	65	77	75	75	77	87	817
CARAPEGUA	104	102	85	75	64	52	71	85	101	116	113	112	1057
CAACUPE	156	130	124	110	108	102	126	149	163	177	168	174	1731(PICHE)
SAN JUAN B.M.	102	79	83	62	55	54	70	85	90	95	101	111	987

Table A.2.1 Results of Runoff Calculation on Rory-Mi

RORY-MI TANK MODEL

DATE	STRAGING PREVIOUS DAY mm	RAINFALL PREVIOUS DAY mm	STRAGING PREVIOUS DAY mm	STRAGING PREVIOUS DAY mm	STRAGING PREVIOUS DAY mm	STRAGING mm	OUTFLOW TOTAL mm	DISCHARGE m3/sec	OBSERVATION m3/sec	DIFFERENCE m3/sec
9/20	0.000	0.000	20.000	100.000	400.000	427.729	1.252	0.041	0.040	0.001
21	0.000	0.000	14.630	71.735	427.729	446.602	1.188	0.038	0.038	0.000
22	0.000	0.000	10.141	51.415	446.602	459.087	1.131	0.037	0.038	-0.001
23	0.000	0.000	6.388	36.740	459.087	466.945	1.079	0.035	0.038	-0.003
24	0.000	0.000	3.250	26.089	466.945	471.434	1.034	0.034	0.040	-0.006
25	0.000	0.000	0.627	18.315	471.434	473.542	1.020	0.033	0.038	-0.005
26	0.000	0.000	0.000	12.802	473.542	473.994	1.015	0.033	0.038	-0.005
27	0.000	0.000	0.000	8.949	473.994	473.294	1.010	0.033	0.039	-0.006
28	0.000	0.000	0.000	6.255	473.294	471.797	1.004	0.033	0.037	-0.004
29	0.000	0.000	0.000	4.372	471.797	469.749	0.998	0.032	0.037	-0.005
30	0.000	0.000	0.000	3.056	469.749	467.324	0.991	0.032	0.036	-0.004
10/1	0.000	0.000	0.000	2.136	467.324	464.643	0.985	0.032	0.035	-0.003
2	0.000	0.000	0.000	1.493	464.643	461.788	0.978	0.032	0.035	-0.003
3	0.000	16.000	0.000	1.044	461.788	459.018	1.663	0.054	0.051	0.003
4	9.661	0.000	3.687	1.192	459.018	456.374	1.049	0.034	0.036	-0.002
5	5.013	0.000	4.878	1.445	456.374	453.816	1.041	0.034	0.034	0.000
6	1.759	0.000	4.708	1.601	453.816	451.170	0.987	0.032	0.034	-0.002
7	0.000	0.000	1.846	1.350	451.170	448.369	0.950	0.031	0.034	-0.003
8	0.000	0.000	0.000	0.944	448.369	445.466	0.943	0.031	0.033	-0.002
9	0.000	0.000	0.000	0.660	445.466	442.500	0.937	0.030	0.033	-0.003
10	0.000	0.000	0.000	0.461	442.500	439.496	0.930	0.030	0.033	-0.003
11	0.000	57.000	0.000	0.322	439.496	437.218	10.185	0.330	0.320	0.010
12	29.966	0.000	13.970	1.977	437.218	435.695	4.037	0.131	0.050	0.081
13	16.427	0.000	18.567	3.711	435.695	434.723	1.743	0.056	0.038	0.018
14	9.251	0.000	19.015	4.979	434.723	434.060	1.221	0.040	0.035	0.005
15	4.726	0.000	17.590	5.686	434.060	433.487	1.181	0.038	0.034	0.004
16	1.558	0.000	15.263	5.889	433.487	432.734	1.102	0.036	0.032	0.004
17	0.000	0.000	10.670	5.455	432.734	431.651	1.034	0.034	0.032	0.002
18	0.000	0.000	6.830	4.669	431.651	430.171	0.976	0.032	0.031	0.001
19	0.000	32.000	3.620	3.718	430.171	428.798	4.441	0.144	0.120	0.024
20	18.141	0.000	10.726	3.944	428.798	427.617	1.915	0.062	0.055	0.007
21	10.160	0.000	12.890	4.373	427.617	426.562	1.121	0.036	0.040	-0.004
22	5.362	0.000	12.697	4.649	426.562	425.524	1.096	0.036	0.036	0.000
23	2.003	13.000	11.332	4.671	425.524	424.584	1.581	0.051	0.035	0.016
24	9.133	0.000	12.911	4.884	424.584	423.690	1.112	0.036	0.027	0.009
25	4.643	11.000	12.457	4.977	423.690	422.913	1.705	0.055	0.050	0.005
26	9.472	0.000	14.011	5.236	422.913	422.190	1.126	0.036	0.035	0.001
27	4.880	0.000	13.462	5.348	422.190	421.419	1.097	0.036	0.032	0.004
28	1.666	0.000	11.851	5.225	421.419	420.401	1.027	0.033	0.032	0.001
29	0.000	0.000	7.817	4.633	420.401	419.033	0.966	0.031	0.033	-0.002
30	0.000	0.000	4.445	3.796	419.033	417.276	0.914	0.030	0.031	-0.001
31	0.000	115.000	1.626	2.857	417.276	416.761	34.840	1.129	0.925	0.204
11/1	46.206	0.000	29.809	5.744	416.761	417.431	7.769	0.252	0.220	0.032
2	25.034	0.000	35.169	8.515	417.431	418.877	4.072	0.132	0.055	0.077
3	13.813	0.000	34.429	10.349	418.877	420.675	1.743	0.056	0.035	0.021
4	7.866	0.000	31.366	11.199	420.675	422.498	1.371	0.044	0.030	0.014
5	3.756	0.000	27.568	11.286	422.498	424.108	1.304	0.042	0.028	0.014
6	0.879	0.000	23.362	10.819	424.108	425.252	1.205	0.039	0.028	0.011
7	0.000	0.000	17.440	9.750	425.252	425.804	1.122	0.036	0.027	0.009
8	0.000	0.000	12.490	8.382	425.804	425.724	1.050	0.034	0.026	0.008
9	0.000	0.000	8.352	6.906	425.724	425.020	0.989	0.032	0.025	0.007
10	0.000	0.000	4.892	5.441	425.020	423.730	0.935	0.030	0.023	0.007

Table A.2.2 Results of Runoff Calculation on Rory

RORY TANK MODEL

DATE	STRAGING PREVIOUS DAY mm	RAINFALL PREVIOUS DAY mm	STRAGING PREVIOUS DAY mm	STRAGING PREVIOUS DAY mm	STRAGING PREVIOUS DAY mm	STRAGING mm	OUTFLOW TOTAL mm	DISCHARGE m3/sec	OBSERVATION m3/sec	DIFFERENCE m3/sec
9/20	0.000	0.000	0.000	100.000	300.000	328.746	0.579	0.078	0.080	-0.002
21	0.000	0.000	0.000	69.850	328.746	348.372	0.559	0.075	0.078	-0.003
22	0.000	0.000	0.000	48.790	348.372	361.630	0.545	0.073	0.076	-0.003
23	0.000	0.000	0.000	34.080	361.630	370.441	0.535	0.072	0.075	-0.003
24	0.000	0.000	0.000	23.805	370.441	376.147	0.527	0.071	0.077	-0.006
25	0.000	0.000	0.000	16.628	376.147	379.687	0.520	0.070	0.075	-0.005
26	0.000	0.000	0.000	11.614	379.687	381.716	0.516	0.069	0.076	-0.007
27	0.000	0.000	0.000	8.113	381.716	382.690	0.512	0.069	0.078	-0.009
28	0.000	0.000	0.000	5.667	382.690	382.929	0.508	0.068	0.078	-0.010
29	0.000	0.000	0.000	3.958	382.929	382.657	0.505	0.068	0.076	-0.008
30	0.000	0.000	0.000	2.765	382.657	382.029	0.503	0.067	0.075	-0.008
10/1	0.000	0.000	0.000	1.931	382.029	381.154	0.500	0.067	0.065	0.002
2	0.000	0.000	0.000	1.349	381.154	380.109	0.498	0.067	0.067	0.000
3	0.000	16.000	0.000	0.942	380.109	379.408	0.986	0.132	0.140	-0.008
4	9.957	0.000	2.712	1.736	379.408	379.003	0.673	0.090	0.085	0.005
5	5.220	0.000	3.044	2.423	379.003	378.690	0.635	0.085	0.078	0.007
6	1.904	0.000	2.374	2.636	378.690	378.039	0.497	0.067	0.073	-0.006
7	0.000	0.000	0.000	1.841	378.039	377.153	0.495	0.066	0.073	-0.007
8	0.000	0.000	0.000	1.286	377.153	376.104	0.493	0.066	0.070	-0.004
9	0.000	0.000	0.000	0.898	376.104	374.943	0.491	0.066	0.067	-0.001
10	0.000	0.000	0.000	0.627	374.943	373.706	0.489	0.066	0.067	-0.001
11	0.000	57.000	0.000	0.438	373.706	374.165	6.531	0.877	0.560	0.317
12	33.542	0.000	10.277	4.391	374.165	376.104	2.997	0.402	0.200	0.202
13	19.926	0.000	12.047	7.856	376.104	378.830	1.698	0.228	0.120	0.108
14	11.620	0.000	10.624	9.711	378.830	381.690	0.987	0.133	0.105	0.028
15	6.384	0.000	8.216	10.049	381.690	384.224	0.850	0.114	0.095	0.019
16	2.719	0.000	5.770	9.313	384.224	386.158	0.725	0.097	0.095	0.002
17	0.153	0.000	3.589	7.932	386.158	387.175	0.556	0.075	0.076	-0.001
18	0.000	0.000	0.670	5.806	387.175	387.439	0.514	0.069	0.076	-0.007
19	0.000	32.000	0.000	4.056	387.439	388.142	2.613	0.351	0.600	-0.249
20	19.717	0.000	5.664	5.085	388.142	389.320	1.460	0.196	0.190	0.006
21	11.492	0.000	6.660	6.199	389.320	390.672	0.852	0.114	0.120	-0.006
22	6.295	0.000	5.755	6.618	390.672	391.886	0.766	0.103	0.105	-0.002
23	2.656	13.000	4.239	6.308	391.886	393.176	1.128	0.151	0.115	0.036
24	9.747	0.000	5.256	6.495	393.176	394.400	0.788	0.106	0.090	0.016
25	5.073	11.000	4.570	6.353	394.400	395.742	1.185	0.159	0.155	0.004
26	10.002	0.000	5.536	6.639	395.742	397.037	0.805	0.108	0.118	-0.010
27	5.251	0.000	4.789	6.541	397.037	398.070	0.729	0.098	0.105	-0.007
28	1.926	0.000	3.453	5.941	398.070	398.432	0.563	0.076	0.090	-0.014
29	0.000	0.000	0.586	4.383	398.432	398.228	0.526	0.071	0.080	-0.009
30	0.000	0.000	0.000	3.061	398.228	397.630	0.523	0.070	0.078	-0.008
31	0.000	115.000	0.000	2.138	397.630	400.326	26.905	3.612	3.400	0.212
11/1	54.422	0.000	20.978	9.833	400.326	405.567	6.146	0.825	0.620	0.205
2	32.182	0.000	22.341	15.805	405.567	412.017	3.353	0.450	0.350	0.100
3	19.096	0.000	19.216	18.678	412.017	418.565	1.937	0.260	0.220	0.040
4	11.114	0.000	14.880	18.962	418.565	424.468	1.203	0.161	0.145	0.016
5	6.029	0.000	10.740	17.514	424.468	429.323	1.006	0.135	0.130	0.005
6	2.471	0.000	7.256	15.118	429.323	432.708	0.756	0.102	0.117	-0.015
7	0.000	0.000	2.925	11.723	432.708	434.611	0.600	0.081	0.113	-0.032
8	0.000	0.000	0.262	8.292	434.611	435.438	0.581	0.078	0.110	-0.032
9	0.000	0.000	0.000	5.792	435.438	435.515	0.577	0.077	0.100	-0.023
10	0.000	0.000	0.000	4.046	435.515	435.069	0.574	0.077	0.096	-0.019

Table A.2.3 Results of Runoff Calculation on Tranquera

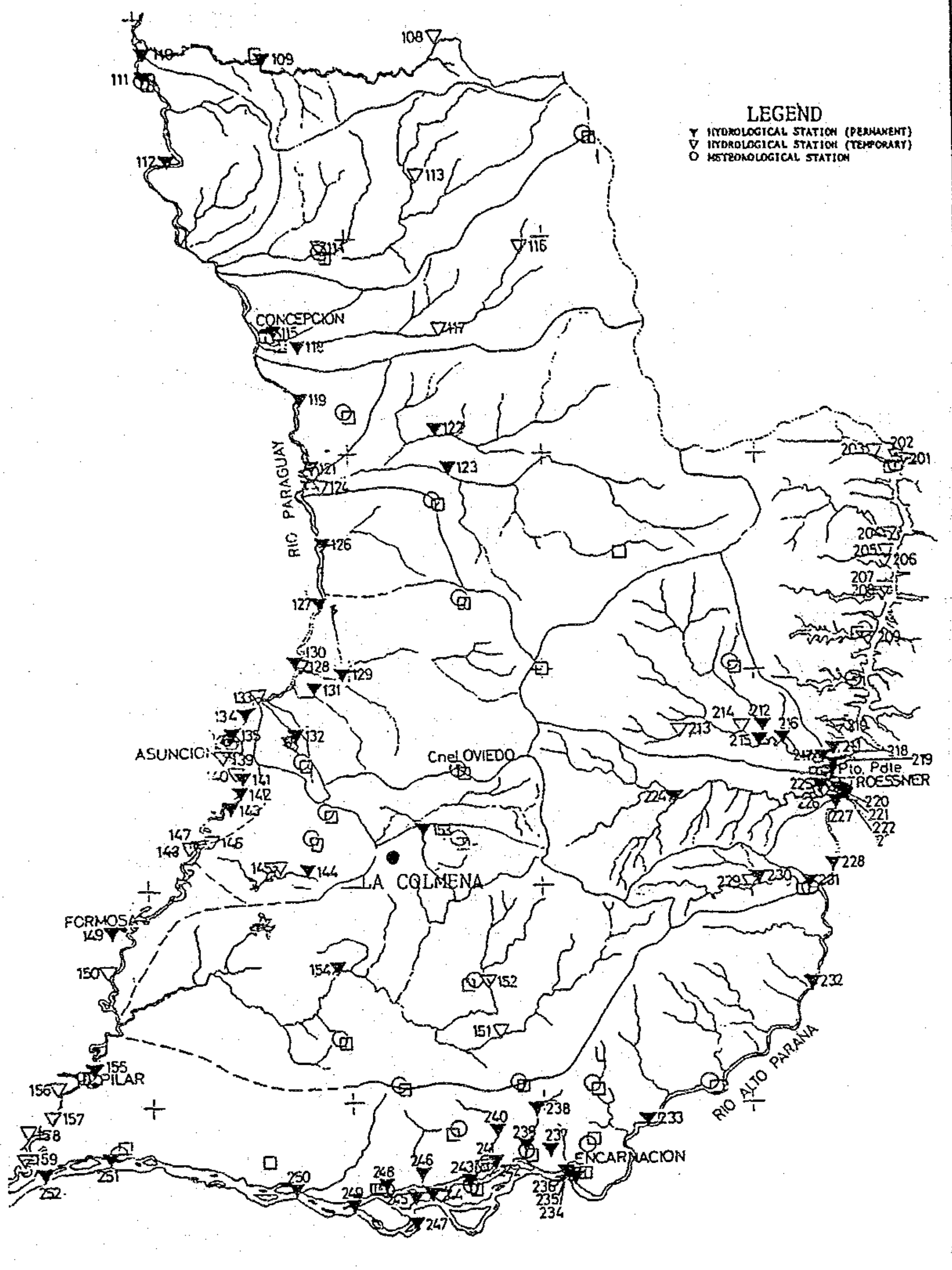
TRANQUERA TANK MODEL

DATE	STRAGING PREVIOUS DAY mm	RAINFALL PREVIOUS DAY mm	STRAGING PREVIOUS DAY mm	STRAGING PREVIOUS DAY mm	STRAGING PREVIOUS DAY mm	STRAGING mm	OUTFLOW TOTAL mm	DISCHARGE m3/sec	OBSERVATION m3/sec	DIFFERENCE m3/sec
9/20	0.000	0.000	0.000	100.000	300.000	328.944	0.496	0.034	0.034	0.000
21	0.000	0.000	0.000	69.900	328.944	348.794	0.490	0.033	0.034	-0.001
22	0.000	0.000	0.000	48.860	348.794	362.289	0.485	0.033	0.034	-0.001
23	0.000	0.000	0.000	34.153	362.289	371.343	0.481	0.033	0.034	-0.001
24	0.000	0.000	0.000	23.873	371.343	377.294	0.478	0.033	0.034	-0.001
25	0.000	0.000	0.000	16.687	377.294	381.077	0.475	0.032	0.035	-0.003
26	0.000	0.000	0.000	11.664	381.077	383.345	0.473	0.032	0.035	-0.003
27	0.000	0.000	0.000	8.153	383.345	384.557	0.471	0.032	0.034	-0.002
28	0.000	0.000	0.000	5.699	384.557	385.031	0.469	0.032	0.034	-0.002
29	0.000	0.000	0.000	3.984	385.031	384.990	0.467	0.032	0.034	-0.002
30	0.000	0.000	0.000	2.785	384.990	384.591	0.466	0.032	0.033	-0.001
10/1	0.000	0.000	0.000	1.946	384.591	383.942	0.464	0.032	0.031	0.001
2	0.000	0.000	0.000	1.361	383.942	383.120	0.463	0.032	0.031	0.001
3	0.000	16.000	0.000	0.951	383.120	382.376	0.894	0.061	0.070	-0.009
4	9.920	0.000	3.687	1.127	382.376	381.755	0.544	0.037	0.039	-0.002
5	5.194	0.000	4.943	1.408	381.755	381.212	0.542	0.037	0.036	0.001
6	1.886	0.000	4.808	1.587	381.212	380.571	0.492	0.034	0.031	0.003
7	0.000	0.000	1.930	1.351	380.571	379.757	0.459	0.031	0.031	0.000
8	0.000	0.000	0.000	0.945	379.757	378.824	0.457	0.031	0.031	0.000
9	0.000	0.000	0.000	0.660	378.824	377.809	0.455	0.031	0.031	0.000
10	0.000	0.000	0.000	0.462	377.809	376.738	0.454	0.031	0.030	0.001
11	0.000	57.000	0.000	0.323	376.738	376.379	6.585	0.450	0.430	0.020
12	33.095	0.000	13.970	1.978	376.379	376.804	2.743	0.187	0.100	0.087
13	19.457	0.000	19.352	3.809	376.804	377.834	1.400	0.096	0.055	0.041
14	11.274	0.000	20.431	5.225	377.834	379.222	0.788	0.054	0.047	0.007
15	6.142	0.000	19.281	6.071	379.222	380.738	0.753	0.051	0.040	0.011
16	2.549	0.000	17.032	6.379	380.738	382.192	0.708	0.048	0.040	0.008
17	0.035	0.000	14.251	6.247	382.192	383.364	0.634	0.043	0.039	0.004
18	0.000	0.000	9.824	5.599	383.364	384.140	0.572	0.039	0.035	0.004
19	0.000	32.000	6.123	4.681	384.140	384.998	2.655	0.181	0.180	0.001
20	19.520	0.000	12.818	4.880	384.998	386.029	1.325	0.090	0.080	0.010
21	11.312	0.000	14.985	5.290	386.029	387.167	0.721	0.049	0.050	-0.001
22	6.168	0.000	14.737	5.546	387.167	388.297	0.697	0.048	0.047	0.001
23	2.568	13.000	13.240	5.537	388.297	389.496	1.049	0.072	0.060	0.012
24	9.661	0.000	14.647	5.708	389.496	390.710	0.714	0.049	0.045	0.004
25	5.013	11.000	14.041	5.751	390.710	392.007	1.110	0.076	0.074	0.002
26	9.928	0.000	15.428	5.955	392.007	393.325	0.729	0.050	0.042	0.008
27	5.199	0.000	14.761	6.014	393.325	394.564	0.701	0.048	0.040	0.008
28	1.889	0.000	13.017	5.836	394.564	395.518	0.631	0.043	0.040	0.003
29	0.000	0.000	8.792	5.182	395.518	396.084	0.571	0.039	0.036	0.003
30	0.000	0.000	5.260	4.282	396.084	396.221	0.520	0.036	0.034	0.002
31	0.000	115.000	2.308	3.283	396.221	397.568	27.320	1.866	1.750	0.116
11/1	53.395	0.000	30.318	6.113	397.568	400.169	6.299	0.430	0.260	0.170
2	31.413	0.000	37.157	9.053	400.169	403.651	3.910	0.267	0.100	0.167
3	18.448	0.000	37.340	11.133	403.651	407.578	2.234	0.153	0.075	0.078
4	10.669	0.000	34.575	12.199	407.578	411.583	1.214	0.083	0.065	0.018
5	5.718	0.000	30.771	12.409	411.583	415.400	0.962	0.066	0.060	0.006
6	2.253	0.000	26.532	12.002	415.400	418.738	0.856	0.058	0.057	0.001
7	0.000	0.000	20.090	10.909	418.738	421.449	0.767	0.052	0.050	0.002
8	0.000	0.000	14.706	9.470	421.449	423.480	0.692	0.047	0.047	0.000
9	0.000	0.000	10.204	7.899	423.480	424.832	0.628	0.043	0.042	0.001
10	0.000	0.000	6.440	6.329	424.832	425.542	0.574	0.039	0.042	-0.003

Table A.3.1 Results of Water Quality Analysys

Location		1	2	3	4	5	6	7	8	9
Temperature (Water)	℃	20	22	22	20	21	22	23	22	23
Turbidity (SiO_2)	mg/l	5	2.5	5	2	2	0	0	45	35
pH		6.9	6.9	6.7	6.7	6.5	6.5	6.6	7.2	6.5
Alkalinity ($CaCO_3$)	mg/l	25	23	19	15	15	15	18	45	15
Hardness ($CaCO_3$)	mg/l	26	20	20	16	12	10	60	32	14
Solid Total (ST)	mg/l	24.5	25.5	25.5	3	41	26	164	147	46.5
Cl^-	mg/l	7.1	8.8	7.1	7.1	7.1	7.1	8.8	9	7
SO_4^{--}	mg/l	0.5	1	0.5	1	2	1	2.1	0.7	1
N^-NH_4	mg/l	0.1	0.1	0.1	0.3	0.1	0.1	0.04	0.02	0.4
EC	micromhos/cm	55	40	30	28	29	22	70	80	30
DO	mg/l	8.4	6	8	7.5	7.3	6.7	–	–	8.5
BOD	mg/l	0.8	0.4	0.6	0.6	0.9	0.6	–	–	5
Na	mg/l	0.7	0.6	0.5	0.3	0.3	0.3	0.4	3	0.8
K	mg/l	2.0	1.9	1.4	1.5	1.5	0.3	3.3	10	3
Ca	mg/l	0.5	1	0.6	0.0	0.0	2.8	2.2	1.8	2.2
Cu	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zn	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fe	mg/l	0.5	0.2	0.1	0.0	0.1	0.0	0.0	3	0.0
Mn	mg/l	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.1
Colon Bacilli	M.P.N	0	4	9	4	23	0	0	0	0

Fig. A.1.1 Hydrological and Meteorological Stations



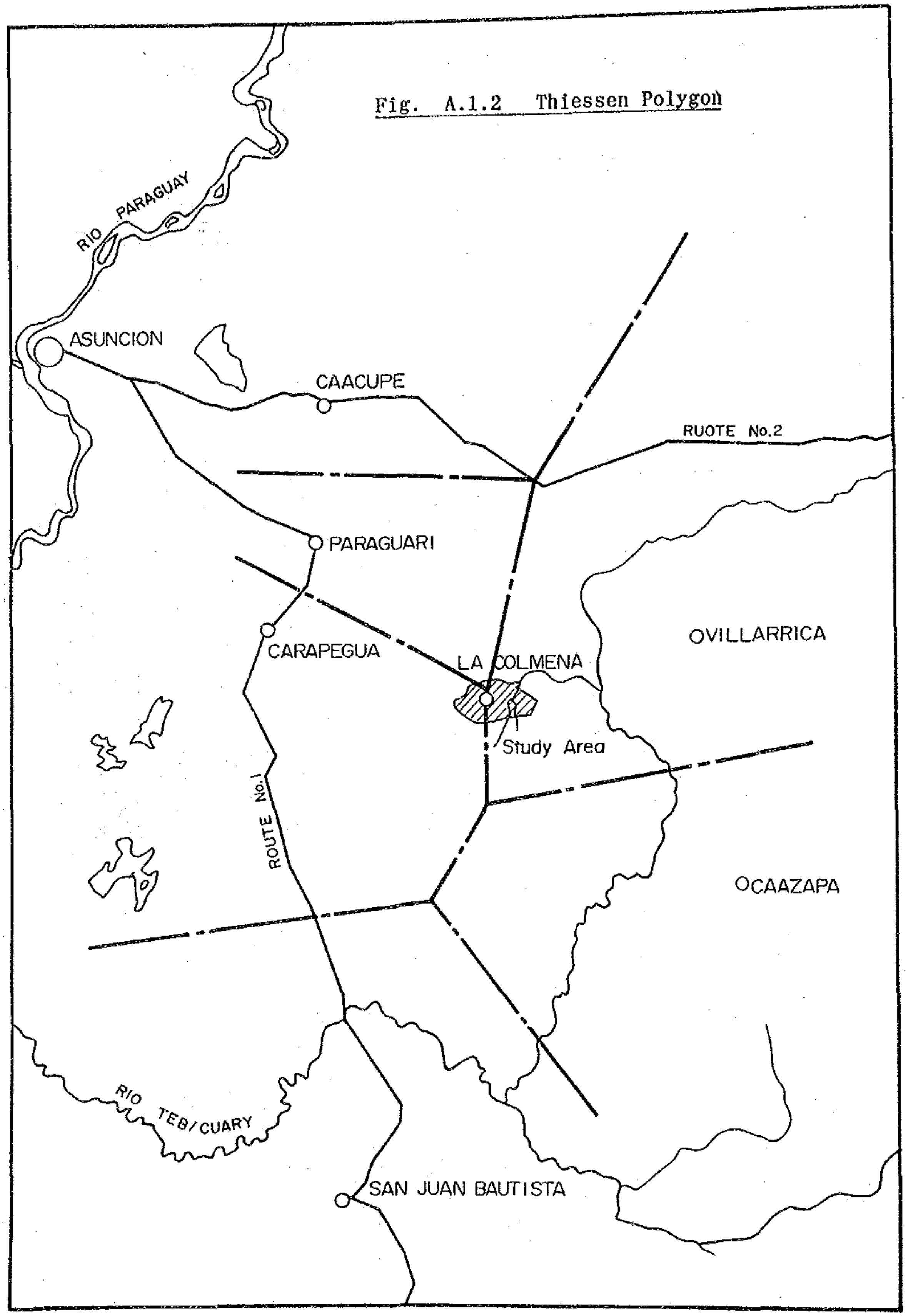


Fig. A.1.2 Thiessen Polygon

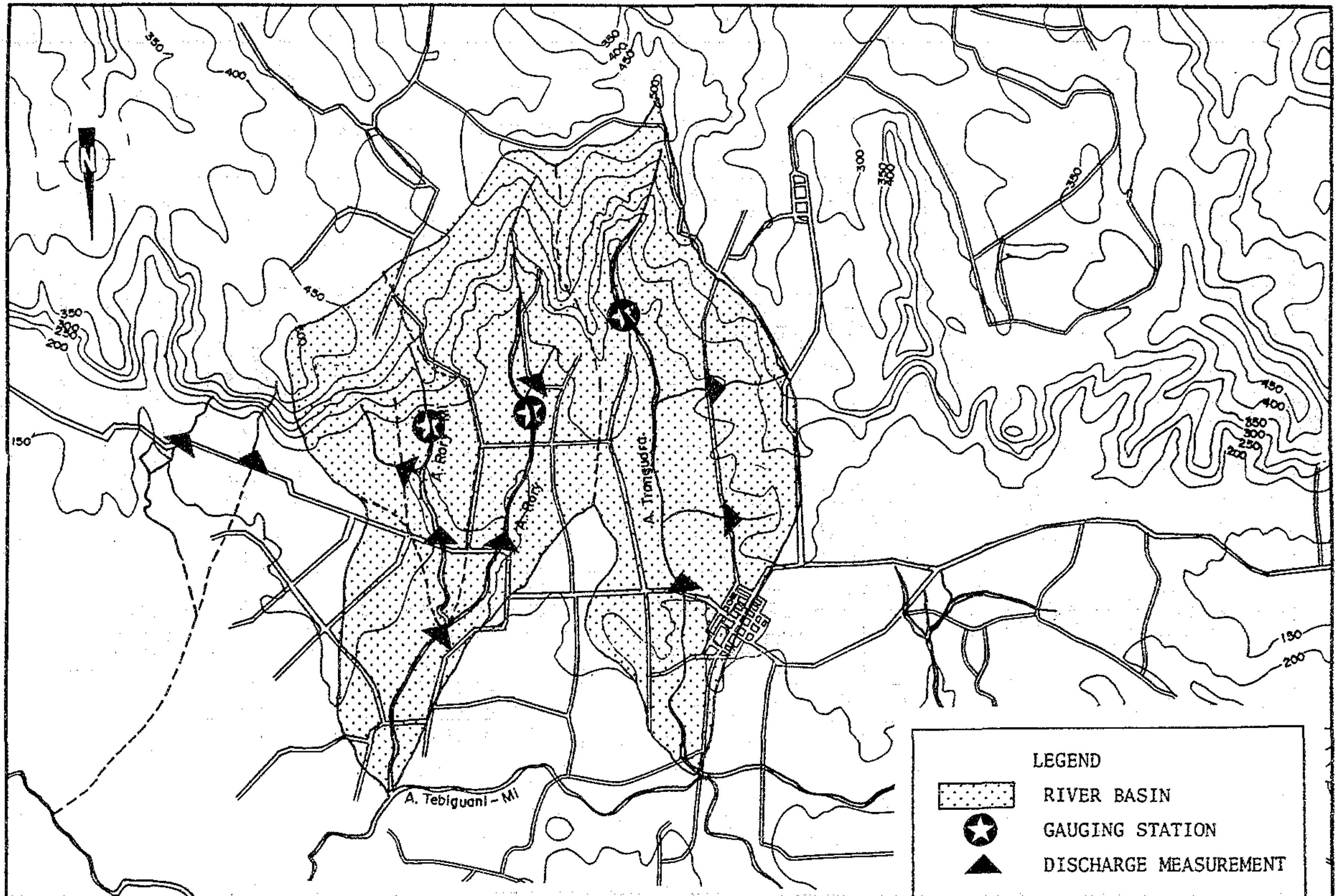


Fig. A.2.1 Location of Gausing Station

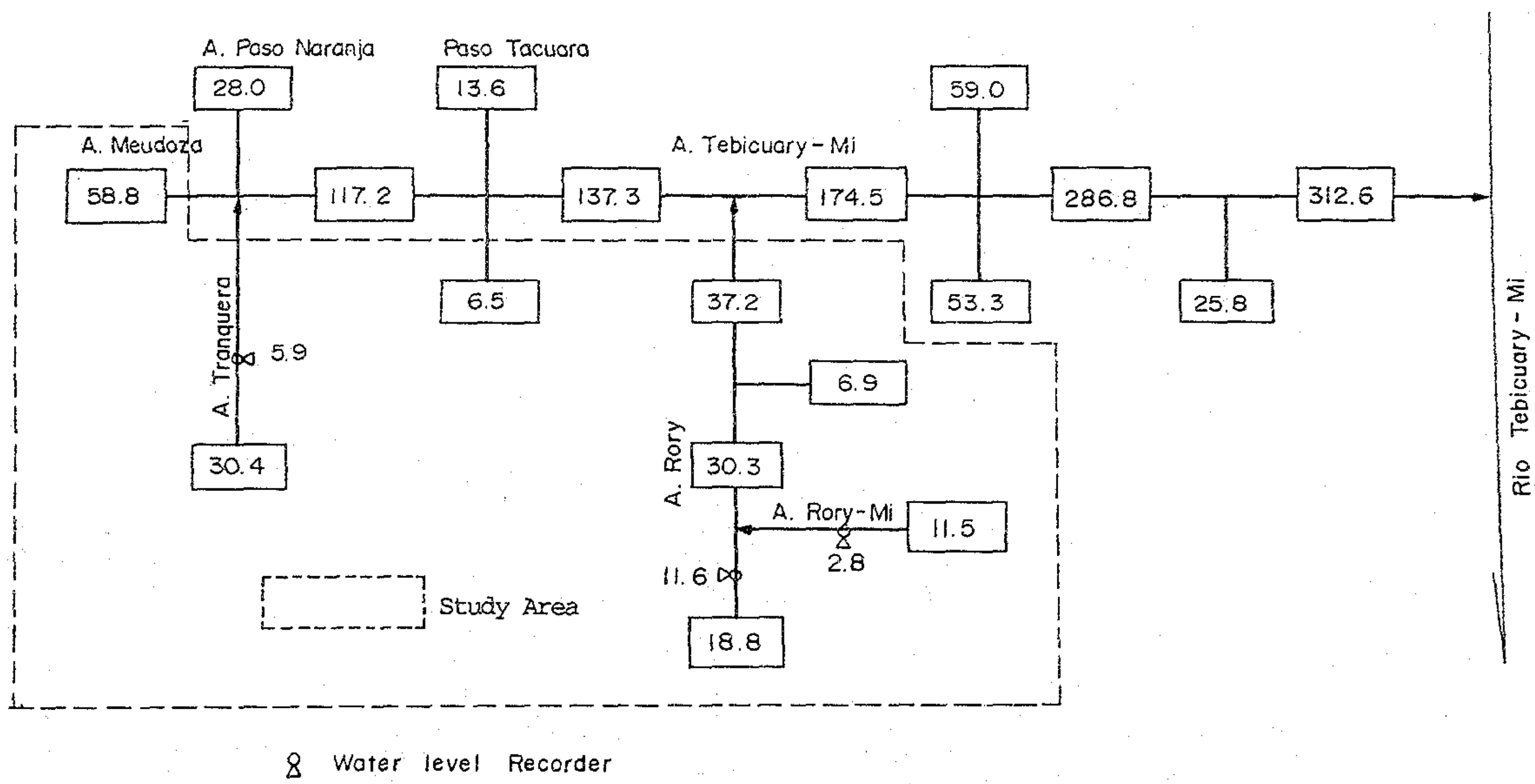


Fig. A.2.2 River Basin Diagram

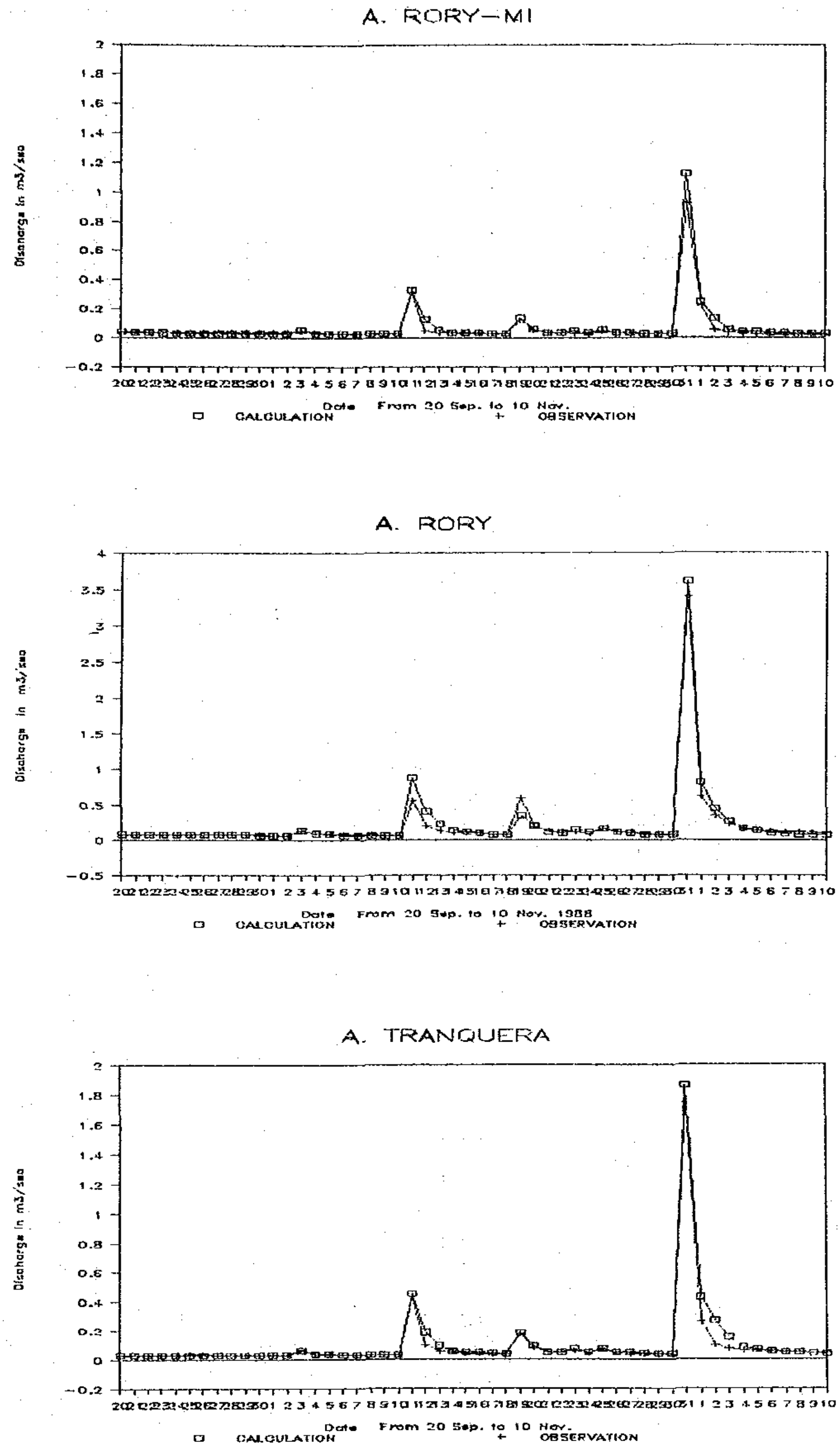


Fig. A.2.3 Verified Results on Tank Model

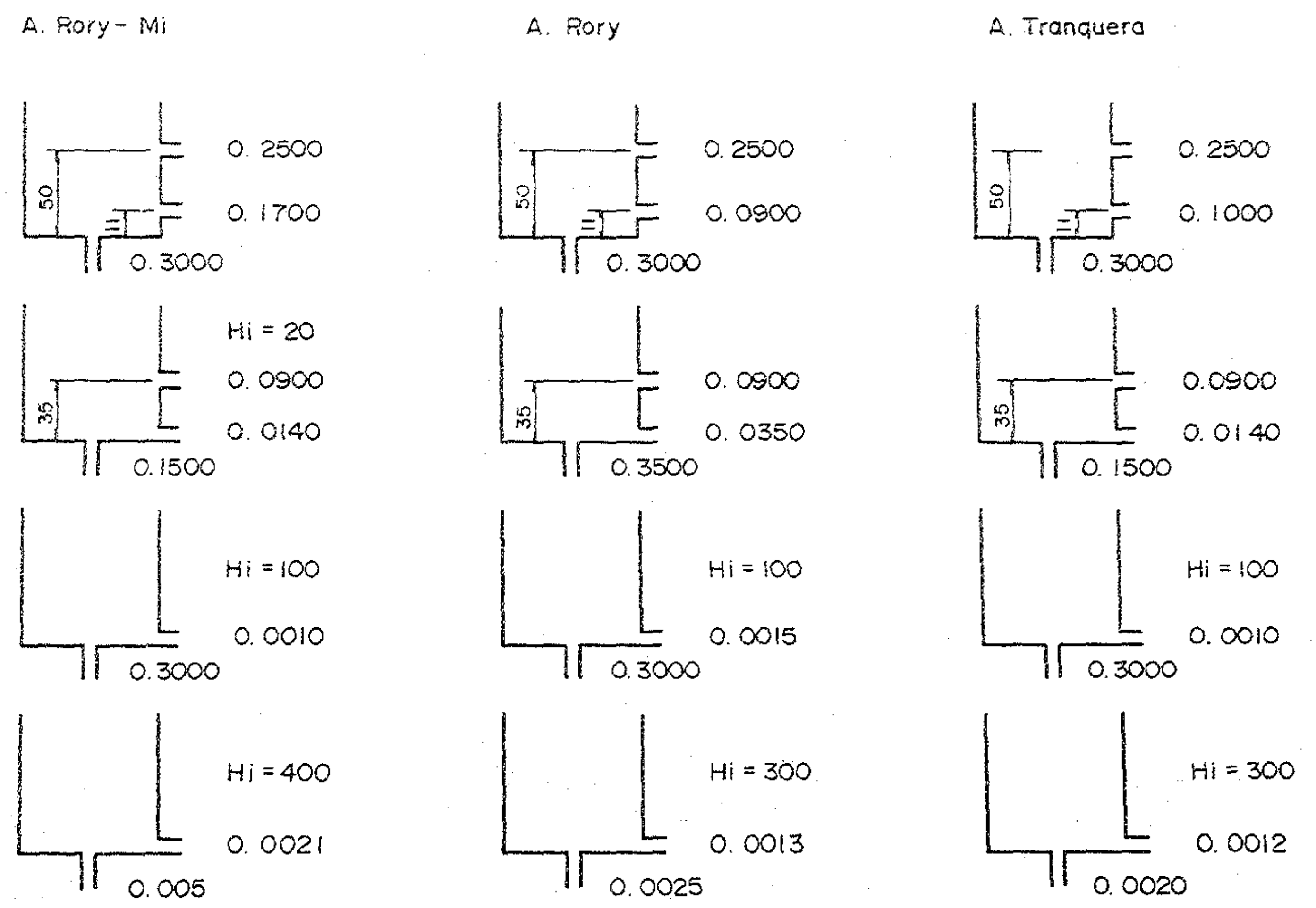


Fig. A.2.4 Coefficient of Tank Model

ANNEX B GEOLOGY AND GROUNDWATER

ANNEX B Geology and Groundwater

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ANNEX B. Geology and Groundwater

B.1 Introduction

The following surveys were carried out in the Study Area to understand its geological and ground water characteristics.

- Geographical and geological surveys of the locations where construction of water-intake dams, regulating ponds and reservoirs is planned in the project.

- Electrical prospecting of the ground and well-digging surveys concerning ground-water development in the Study Area.

B.2 Surveys on Geography and Geology

2.1 Upper Reaches of Arroyo Tranquera, Arroyo Rory and Arroyo Rory-mi

The area's geology is typified by the alternation of conglomerate and sand stone of the Paleozoic period, with the strike running about N30^{o} E and a very gentle gradient of 3-5^{o} to the east or west.

The land appears to have a wavy pattern from west to east.

The streams are rather rapid down to an altitude of 250 meters and their valleys are narrow and shaped like a letter V. The river bed is covered with thin layers of boulders 20-100 cm in size, and rough and medium sand, but no granules. Many small waterfalls are observed, most of them are 1.5 - 5.0 m in height, but very occasionally there are those with a height of up to 7 - 8 m.

The land is an alternation of conglomerate and sand stone strata (30 - 50 cm in thickness, maximum of 1.0 m). The conglomerate consists mostly of well-polished pebbles of chart and quartz. Matrixes comprise about 70 - 80% of the sand stone.

The small water falls are considered a kind of cuesta and are believed to have been formed as a result of the selective erosion of the hard conglomerate. The rock easily crumbles on impact of a hammer and readily becomes sandy without experiencing the granule state.

The valleys of Arroyo Rory and Arroyo Rory-mi are also v-shaped and exhibit rougher terrain than Arroyo Tranquera. This is because of the strong influence of the fault and crushing zones. The streams are rapid and construction of a dam 20 -30 m high will not be economically feasible as the reservoir capacity of such a dam will be too small for its size. On the other hand, construction of a water-intake (small dam) should not pose any problems, provided that such a dam is located at a certain altitude. Any place with exposed rock will be adequate to serve as a foundation of the dam.

The extension of digging will merely get larger or smaller depending on whether the valley walls have exposed rock or talus cone. If it is the latter, only a 1.0 - 2.0 m trench cut needs to be made at the exposed rock for installation. 0.5 -1.0 m form treatment of the foundation which also serves as a cut off is considered adequate for the lower part of the bank. Others such as curtain grout and contact grout are not necessary.

2.2 Middle Reaches of Arroyo Tranquera

According to the plan, it is possible to construct a small dam 5.0 - 7.0 m (max. 10.0 m) in height with a capacity of 1.5 -2.0 million cubic meters of water at the east of the La Colmena urban area where the valley close to the upper stream becomes narrow. Electrical prospecting were conducted to understand the geological characteristics of the place..

The rock bed is made of hard conglomerate of the Paleozoic period and should pose no problems as to the required strength of the foundation for a dam of the proposed size. Outcrops of the conglomerate strata are observed over about 100 m up and down the stream on the right side of the dam site, but no faults or crushing zones could be found.

The river bed is covered with sedimentary layers 2 - 3 m in thickness, or a little thicker in some parts. No outcrops are observed, an indication that the conglomerate strata is distributed over all the site.

Electrical prospecting conducted at five points to a depth of 50 - 60 m suggested the existence of a foundation which mainly consists of dry, thin surface soil and conglomerate on both sides.

B.3 Ground Water Survey

3.1 Electrical Prospecting

Electrical prospecting, which is one of the many physical surveys, is used to measure natural electric potential or find out the geological structure of the area by carefully studying changes in the electric current which is made to flow in the ground.

The Wenner method, a kind of specific resistance method, was used to conduct electrical prospecting in La Colmena. Here, electric current electrodes and potential electrodes are symmetrically placed above the point of measurement. The distance between the electrodes is gradually made greater and apparent resistivity is measured each time to determine apparent resistivity directly above the point.

The equation expressed as:

$$\rho = 2 \times 3.14 \times aR$$

where ρ : specific resisting
a : interval of electrode
R : electrical resistance

3.2 Equipment Used in the Electrical Prospecting

Various devices are used in the electrical prospecting. In this case, highly functional devices most suited to the specific resistance method were employed. Their specifications are shown below.

(1) Transmitter

a. Output voltage	:	400 VP-V
b. Output current	:	1, 2, 5, 10, 50, 100, 200 mA
c. Operation voltage	:	12 VDC

(2) Receiver

a. Input impedance	:	1M
b. Measurement potential	:	± 0.6V, ± 6V (AUTO RANGE)
c. Resolution	:	10 V
d. Stack frequency	:	1, 4, 16, 64 (can be stopped as desired)
e. Cycle time	:	3.5 sec.

(3) Data Memory

a. File registration	:	max. 128 files
b. Data point	:	max. 1100 data
c. 1 file	:	max. collected 110 data

(4) Interface : RC-232C

(5) Power Source : DC12V (built in um 1x8)
External power sources can be used

(6) Dimensions : 206(W) x 181(H) x 200(D) mm

(7) Weight : 10 kg

3.3 Survey Outline

The survey was conducted to a level 150 - 200 m below the ground by taking into account the depth (150 m) of the planned wells. As the Wenner's four electrode method was employed, the max. measurement depth of 200 m requires a total length of 600 m (200 m x 3) of C1 and C2 electrodes on a nearly straight line. For ease of measurement, the areas along the main roads were chosen to carry out the approx. 1.0-km square preliminary surveys. In the actual measurement, the key curves were obtained at two places in the urban La Colmena where deep wells are located and near the deep wells owned by Mr. Miyamoto and Mr. Mitsui.

3.4 Survey Results

Only the Paleozoic conglomerate and sand stone layers in the south of the area near the urban La Colmena show rather high resistivity of several 100 Ωm or more. It is about 200 Ωm for the alternation of the very weathered layer of the conglomerate and sand stone of the Mesozoic era, 80 - 100 Ωm for a little fresher rock and mere 10 - 20 Ωm for the fresh foundation rock.

In particular, the specific resistivity is extremely low at 7 -15 Ωm in the vicinity of the urban area, suggesting that the geology of the area contains a mixture of shale and mud stone, or a thick accumulation, forming impermeable layers.

The electrical prospecting started near the deep wells of La Colmena and the measurement points were gradually expanded into the surrounding area. As a result, the Study Area has been divided into the following five blocks according to the specific resistance characteristics: the urban area, west of the urban area, east, south and east of Arroyo Rory-mi.

(1) The mountains in the south with the highest specific resistivity. This thinly layered block has very few strata which might contain ground water.

(2) The thick weathered layer to the level of a few dozen meters below the ground of the east block shows relatively high specific resistivity and is considered to contain ground water.

(3) In this urban block, the sandy layers of the surface weather-eroded zone, which contain ground water, are believed very thin, and the specific resistivity of the foundation rock is extremely low.

(4) This west block is thought to have relatively thin surface sandy layers but contain a large amount of conglomerate and sand stone with high specific resistivity.

(5) This block in the east of Arroyo Rory-mi exhibits about the same amount of specific resistivity as case 1. above, but is thought to have thick weather-eroded layers which might contain ground water.

3.5 Analysis of the Survey Results

Brief explanations of each of the above-mentioned five blocks will be given below. First, the relationship between each block and the specific resistivity is as follows.

a. The mountains in the south	:	more than 2,000 Ω m
b. The hilly areas in the east	:	100-300, more than 20 Ω m
c. Near the urban area	:	10-20, 50-200 Ω m
d. The flat land in the west	:	100-500, 40 Ω m
e. Near Arroyo Rory-mi	:	15-30, 100-800 Ω m

(1) The mountains in the south

Conglomerate and sand stone of the Paleozoic era predominate in the mountains in the south. The surface layer is soft due to erosion by strong winds and belongs to the CL or D class in terms of rock bed strength.

In the valley, some hard rock in the CM class appears. Although no faults and crushing zones are visible, possibility is high that they are hidden behind the foot of the mountains or talus cone of the sloping areas. Faults and crushing zones may appear in the northern part such as EPNo. 13, 14, but this is not clear. Likewise, there are few joints or cracks and the foundation rock is not likely to contain much ground water (excluding the part of the mountains south of Rory-mi). The surface soil covers a limited area of land and the accumulation of talus cone is thin and also limited in its distribution. With these geological characteristics, the ground in this block can only temporarily retain water after rainfalls, but will quickly lose it after some consecutive sunny days.

However, some part of the mountains have sand layers 5 - 10 m in thickness such as arose in texture, and are capable of holding water in the form of free underground water. Such water can be used for rural water supply on a limited scale.

(2) Hills in the east

The Paleozoic conglomerate and sand stone in the south are distributed below the hills between EPNo. 10 and EPNo. 9 at an angle of about 30^{0} (this angle has been determined from examples of the other areas). ON top of these are the nonconforming strata of conglomerate and sand stone of the Mesozoic period.

The area bordering Arroyo Tranquera up to EL 140 m north of this block shows higher specific resistivity than the urban district. At any measurement point, this weather-eroded Mesozoic conglomerate layer which mostly consists of sand stone is found to contain clayish sand strata 30 - 40 m in thickness. This result has been confirmed by the survey conducted at the present No. 1 well. It is also learned that the ground enters the strata of mostly less-method sand stone about 40 m from the surface.

The results of the electrical exploration show that the high-erosion zones often have a specific resistivity of about 300 m, suggesting the existence of a large pool of water, but 80 - 100 Ω m in some part. The value of resistivity becomes smaller as the measurement point enters the fresh rock bed. It is about 30 - 50 Ω m at the depth of 50 - 60 m, then furthers declines to approx. 20 Ω m, which changes very little to a depth of 150 - 200 meters.

It can be easily understood that the ground 50 - 60 meters from the surface and below has experienced less erosion and had fewer cracks and joints, and therefore does not contain much ground water. For this reason, it does not make sense to dig. a well deep into these strata. At the moment, there are two wells, each providing a pumping capacity of approx. 100 m3/day (max.150 m3/day).

(3) Vicinity of the urban area

This block west of Arroyo Tranquera is located in the hills extending north from EPNo. 14, 30 and has basically the same geological characteristics as the other blocks. Conglomerate and sand stone of the Paleozoic era are believed to be distributed between EPNo. 14 and EPNo. 30 at an angle of 30^{0} in nonconformity. The surface layers mainly consist of conglomerate and sand stone of the Mesozoic period and are thinner than those in the east block (only several meters in thickness, max. 20 m).

(4) Flat land in the west

The block can be geographically further divided into three zones: northern, central and southern part. The p-a curve of the central and the southern zones exhibits the tendency similar to that of the east. On the other hand, the situations in EPNo. 55, 56 (near the graveyard) are similar to those in the urban La Colmena; the heavily weather-eroded sandy surface layer is thin and the specific resistivity declines to 12 -15 Ω m at a depth of about 10 m, which later rises to about 20 m at a depth of 50 m and deeper.

It has been judged that ground water is very difficult to obtain near the graveyard and the area extending to north. The foundation rock shows sings of alteration of conglomerate and sand stone, but the absence of geological data in the area concerning ground water, such as records of deep wells, makes it impossible to make a valid comparison.

The flat land near the national roads and the south exhibits characteristics that are basically similar to the mixture of the data of various places of the urban area; it consists of the very weather-eroded layer of sand and clay 20 - 30 m below the surface, the less weather-eroded and firmer strata up to a depth of 50 - 60 m, and the fresh alterations of conglomerate and sand stone from there.

Such pieces of information suggest that not much can be expected in obtaining water from under ground with such geological characteristics. The stratigraphic column of a survey well shows that the ground is clayish to the depth of 6.0 m, sandy clay to 29.0 m in depth, loose sand to 37.0 m where underground water is stored, medium-hard sand stone and very hard sand stone strata at the depth of 55 m and deeper.

This data almost completely corresponds to the analysis of the above-mentioned ρ-a curve, proving that the overall analysis results are correct.

(5) East of Arroyo Rory-mi

Layers of conglomerate and sand stone of the Paleozoic period appears at the depth of about 12 m in EPNo. 73 in the south, as in the case of No. 10, 13, 14. Naturally, very little ground water can be expected from such strata, but a well can be dug in the area to get water for home use from the eroded sand layers in the upper part.

EPNo. 75, 79 and 80, which are north of the national roads, have a ρ-a curve very close to that in the urban area; therefore, it cannot be expected at all to obtain water form under the ground. However, strongly weather-eroded sandy layers exist to a depth of 40 m at the other measurement points and water can be obtained from these strata in the same manner as in the eastern part of the urban area.

3.6 Summary

(1) In the southern mountains, the only available form of underground water is the free ground water contained in the arose sand 5 - 10 m in thickness. Therefore, it is next to impossible to use it for agricultural irrigation.

(2) Underground water resources are extremely poor near the foot of the mountains a little to the north.

(3) It will be possible to pump 200 m^3/day of water form a large-diameter well to be dug to a depth of 40 - 50 m, or a very large well with a bore of 2.0 m or more can be dug to the depth of 10 - 15 m to obtain the same amount of water. In the latter case, more water can be obtained by boring the ground radially from the lower levels.

(4) Large-scale development of the underground water in the urban area cannot be expected. It is possible to pump 50 m^3/day of water from a well with a depth of 30 - 50 m, but that amount of water can also be obtained from a shallow large-bore well with a depth of 10 - 15 m.

(5) Construction of a small dam 5 -10 m high at Arroyo Tranquera is expected to greatly enhance recharging of the free underground water. Moreover, large numbers of large-diameter wells and conduits can be constructed to serve as reservoirs.

(6) It is difficult to secure large volumes of underground water in the western part of the area. However, water contained in the weather-eroded sand stone and the clayish sand layers to the depth of 5 - 10 m can be utilized.

(7) The summary above can be further condensed into the following:

- It is not possible to obtain free underground water contained in the loose sand stone of the weather-eroded surface layers.

- Pooling of this underground water should be actively promoted.

- It will be very difficult to obtain ground water from the foundation rock bed 50 m or more below the surface. Water can be obtained if a well happens to encounter faults or crushing zones, but another survey must be made to confirm their existence.

3.7 Groundwater Level of the Project Area

Surveys were conducted on the distribution of ground water in shallow strata, mainly at farmers' shallows scattered over most of La Colmena area. The actual places of measurement, a total of 176 points were shown in Fig. B.1.8. However, wells at 26 points were excluded from the measurement because of the following reasons.

(1) Discarded wells
(2) Drained up wells about which measurement cannot be performed
(3) Use of streams to obtain water and therefore cannot be classified as well

The strata which contain water, located 5 - 10 m below the ground, consist mainly of sandy clay, sandy clay with gravels or weather-eroded sand stone and conglomerate. Distribution of such water-containg atrata is uneven over the area, with layers running as thick as 20 m in some places where there are thick weather-eroded strata.

The wells are on average 5 - 10 m in depth, excluding the extremely shallow ones in some part of the flat land in the north, each containing

0.5 - 1.5 m of water. Quite a few wells were found short of water as the survey was conducted in August 1988 after more than 40 consecutive days of dry days. However, they can adequately serve as a source of water during the wet season. It has been learned during the field survey that the water level in the well drops 1.5 - 2.0 m throughout a year. Fig. B.1.9 shows the contour line of the water level in the shallow wells.

Groundwater levels have been found to follow the land contours, indicating distribution of the water-containg shallow strata with relatively uniform thickness. On the other hand, the permeability coefficient is judged to be 10^{-3} - 10^{-4}cm/s and much water cannot be expected from the wells.

It has been learned that as many as one third of the wells in the area run short of water during the dry season. Therefore, it is necessary to construct facilities to obtain water from rivers and deep wells in order to secure supply of water.

B.4 Reference Data of Well-Digging Surveys

- Bodegas "La Colmenita"
- Propiedad de Hayashi
- Propiedad de Seki
- Propiedad de Chavez

1. INTRODUCCION

De acuerdo a las indicaciones recibidas de los interesados en la construcción de dos pozos tubulares profundos, se ha trasladado la máquina perforadora INGERSOLL RAND, hasta el sitio indicado por los mismos. Atendiendo, al parecer, los resultados de SEV (sondeos eléctricos verticales) practicados en la zona por técnicos japoneses.

Los trabajos tenían por objetivo perforar hasta 100 m. de profundidad (cada pozo), encamisarlo y realizar pruebas de suficiencia de los acuíferos alumbrados.

Hubiera resultado de gran valor contar con los resultados de los SEV para orientar con mayor efectividad los trabajos de perforación.

2. PERFORACION

Las experiencias anteriores de perforaciones realizadas en la zona indicaban la conformación de un subsuelo bastante difícil, con gravas y cantos rodados en matríz arcilloso y arenoso, lo cual significa un medio sumamente inestable. Razón por la cual,se decidió iniciar los trabajos en el sistema de rotación con broca tricórnica de 12 1/4" de diámetro, utilizando "bentonita" para contener las paredes.

2.1. Pozo de la Bodega

Los trabajos con el sistema de rotación avanzaron con muchas dificultades hasta los 16 m. de profundidad, cuando la herramienta dejó de avanzar, por lo cual se decidió cambiar al sistema de percusión, utilizando martillo de fondo (DHD 16 A, INGERSOLL RAND) con broca de botones de 8 1/2" de diámetro, llegando hasta los 87,00 m. de profundidad.
La perforación no pudo continuar debido a las dificultades ocasionadas por la alta inestabilidad de las paredes del pozo

que produjeron el contínuo atascamiento de la herramienta, con el consiguiente peligro para hombres y máquina operando en el lugar.

Después de varios días de intentos fallidos se decidió, con acuerdo de los Interesados, encamisar la longitud perforada, previa realización del perfilaje eléctrico del pozo.

El encamisado no alcanzó a cubrir toda la columna perforada, lográndose entubar hasta los 60 m. de profundidad, debido al derrumbamiento de las paredes del pozo en su longitud inferior.

Características del pozo

Durante los trabajos de perforación del pozo ya se tuvo conocimiento de su rendimiento debido al trabajo de la máquina, que utiliza un martillo de fondo para romper la roca y aire a presión para el desalojo de los detritos. Si se detecta un acuífero, el aire empieza a desalojar agua en forma contínua, en caudales casi igual al rendimiento del acuífero alumbrado.

En el pozo de referencia no se logró captar ningún aporte de importancia, apenas el acuífero libre de los 20 m. y otros de menor importancia más abajo. Este hecho fue profusamente informado a los Interesados de manera a evitar gastos mayores con el encamisado y terminado del pozo. No obstante los mismos decidieron continuar los trabajos hasta su completa terminación.

2.2. Pozo 2 de Hayashi

La perforación realizada en este sitio no ha variado substancialmente en relación al anterior pozo. Sin embargo, existió mejor cementación de la formación que permitió perforar 57.4 m. en el sistema de rotación y por supuesto utilizando tiempos mucho mayores que los normales.

Se decidió terminar el pozo en la profundidad de 57,4 m., para lo cual se realizó el perfilaje eléctrico correspondiente.

Posteriormente se procedió al encamisado y engravado del po - zo para iniciar la limpieza y desarrollo del mismo.

3. PRUEBAS DE BOMBEO

. Equipo utilizado: Compresor portátil SPIRO FLO de INGERSOLL RAND.

. Medidor de nivel de agua

. Cronómetro.

3.1. Pozo 1 de la Bodega

Como ya se adelantara, este pozo no tiene un rendimiento importante.

Durante el bombeo el agua se mantuvo turbia durante unas 5 ho - ras y posteriormente ya se mantuvo limpia hasta la completa ter minación de la prueba, es decir, hasta 24 hs.

El caudal de bombeo fue de 2.000 lts/h.

Posteriormente se realizó la prueba de recuperación del nivel del agua del pozo.

3.2. Pozo 2 Hayashi

El rendimiento de este pozo fue superior al anterior. En efecto, durante la limpieza y desarrollo del mismo ya se midió un caudal de 6.000 lts./h., utilizando el compresor de la máquina.

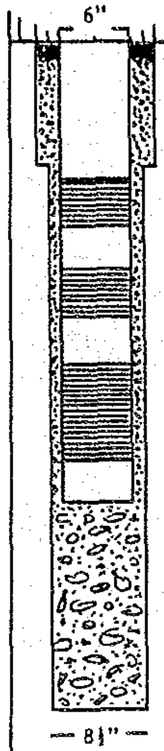
Posteriormente, utilizando el equipo de prueba de bombeo, se realizó un ensayo durante 24 hs.

El caudal de bombeo fue de 4.000 lts./h.

Al parar el equipo de bombeo se realizaron mediciones de la recuperación del nivel de agua del pozo.

PERFIL DE POZO PERFORADO

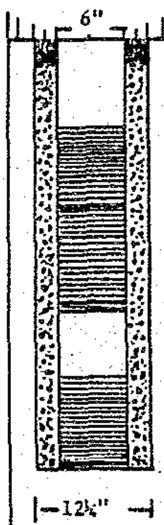
Nombre: LA COLMENA - POZO DE LA BODEGA



PROF (m)	SIMBOLO	DESCRIPCION	FORM
		ARENA ARCILLOSA COLOR ROJIZA	
		ARENISCA ARCILLOSA, GRANO FINO A GRUESO COLOR AMARILLENTO	
		CONGLOMERADO ARCILLOSO, BLANCO AMARILLENTO.	
		CONGLOMERADO, RODADOS DE CUARZOS, CUARCITAS Y ARENISCAS, MATRIZ ARCILLOSA MARRON ROJIZO.	
		CONGLOMERADO, GRIS CLARO A AMARILLENTO	
		CONGLOMERADO DE CUARZO Y CUARCITAS, CON MATRIZ ARCILLOSA, MARRON ROJIZO	
		CONGLOMERADO MARRON CLARO A OSCURO ARCILLOSO	
		CONGLOMERADO, MARRON VIOLACEO, MUY ARCILLOSO	

PROF (m): 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

Nombre: LA COLMENA - POZO N° 2 DE HAYASHI



PROF (m)	SIMBOLO	DESCRIPCION	FORM
		ARENA ARCILLOSA, ROJA, PLASTICA	
		ARCILLA ARENOSA, PLASTICA, CON NODULOS DE GRAVILLA, ROSADO AMARILLENTO.	
		CONGLOMERADO ARCILLOSO, COLOR ROJO.	
		CONGLOMERADO CON MATRIZ ARENA ARCILLOSO, COLOR PARDO ROJIZO.	

PROF (m): 10, 20, 30, 40, 50, 60, 70, 80

PLANILLA DE BOMBEO

POZO Nº 2 : HAYASHI
PROFUNDIDAD : 57 m.
NIVEL ESTATICO : 19,55 m.
HORAS DE BOMBEO : 24 hs.
EQUIPO UTILIZADO : COMPRESOR INGERSOLL RAND

DIAMETRO: 6"
FECHA DE PRUEBA: 22 - 23 - XII - 88

TIEMPO (min)	NIV. EST. (m)	NIV. DINAM. (m)	ABATIM. (m)	CAUDAL l/h.	CARACT. DEL AGUA
	19,55				
1		23.67	4.12		
2		24.00	4.45		
3		24.28	4.73		Turbio
4		24.48	4.93		"
6		24.58	5.03		"
8		24.71	5.16		"
10		24.98	5.43	4.000	"
15		25.40	5.85	"	"
20		25.61	6.06	"	"
30		25.77	6.22	"	"
60		25.90	6.35	"	"
90		26.08	6.53	"	"
120		26.10	6.55	"	Aclarando
150		26.12	6.57	"	"
180		26.14	6.59	"	Claro
240		26.20	6.65	"	"
300		26.25	6.70	"	"
360		26.32	6.77	"	"
420		26.38	6.83	"	"
480		26.42	6.87	"	"
540		26.47	6.92	"	"
600		26.50	6.95	"	"
660		26.52	6.97	"	"
720		26.50	6.95	"	"
780		26.50	6.95	"	"
840		26.51	6.96	"	"
900		26.50	6.95	"	"
960		26.50	6.95	"	"
1020		26.51	6.96	"	"
1080		26.51	6.96	"	"
1140		26.51	6.96	"	"
1200		26.50	6.95	"	"
1260		26.51	6.96	"	"
1320		26.51	6.96	"	"
1380		26.51	6.96	"	"
1440		26.51	6.96	"	"

PLANILLA DE RECUPERACION

POZO Nº 2 : HAYASHI
NIVEL DINAMICO: 26.51 m

TIEMPO (min.)	RECUPERACION (m)	NIVEL DINAMICO (m)
		26.51
0.5	1.95	24.56
1.0	2.51	24.00
2.0	2.72	23.79
3.0	3.53	22.98
5.0	4.45	22.06
7.0	4.92	21.59
9.0	5.30	21.21
11	5.48	21.03
14	5.58	20.93
17	5.67	20.84
20	5.76	20.75
23	5.81	20.70
26	5.84	20.67
30	5.89	20.62
35	5.93	20.58
40	5.97	20.54
45	6.03	20.48
55	6.09	20.42
65	6.16	20.35

GRAFICO ABATIMIENTO - BODEGA

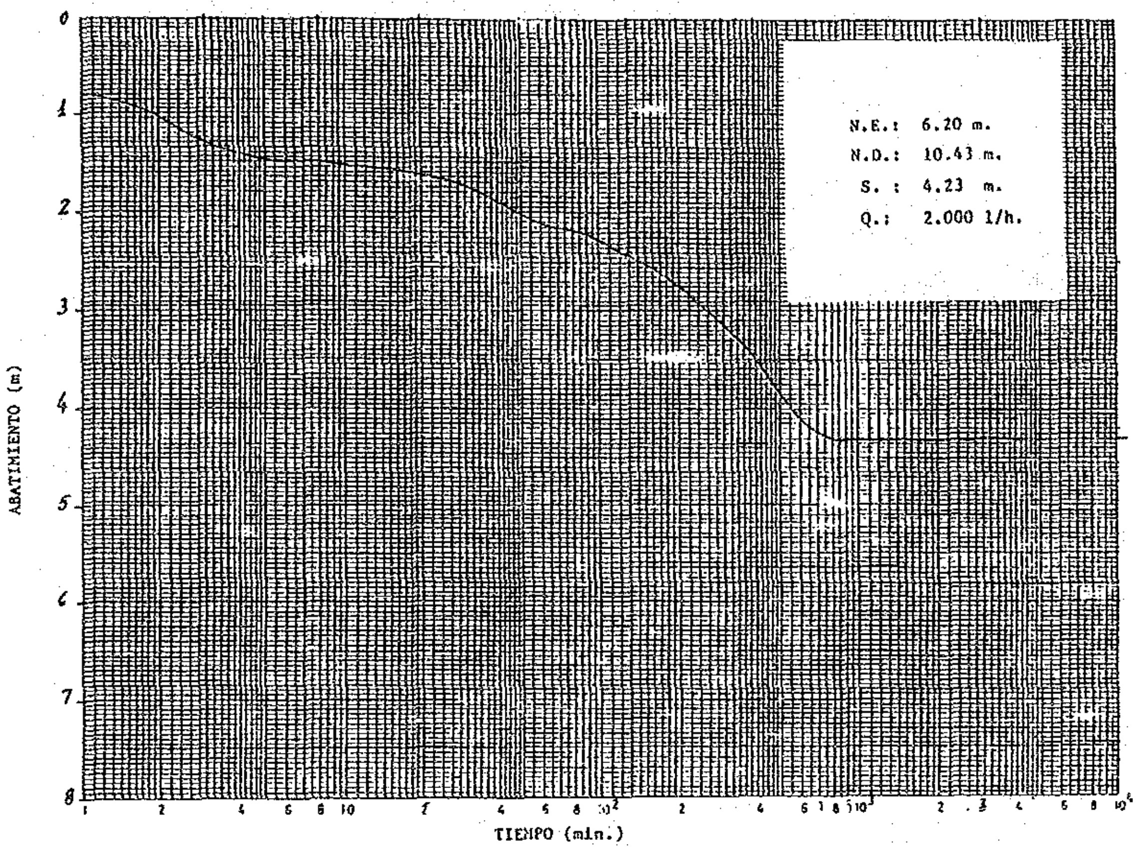
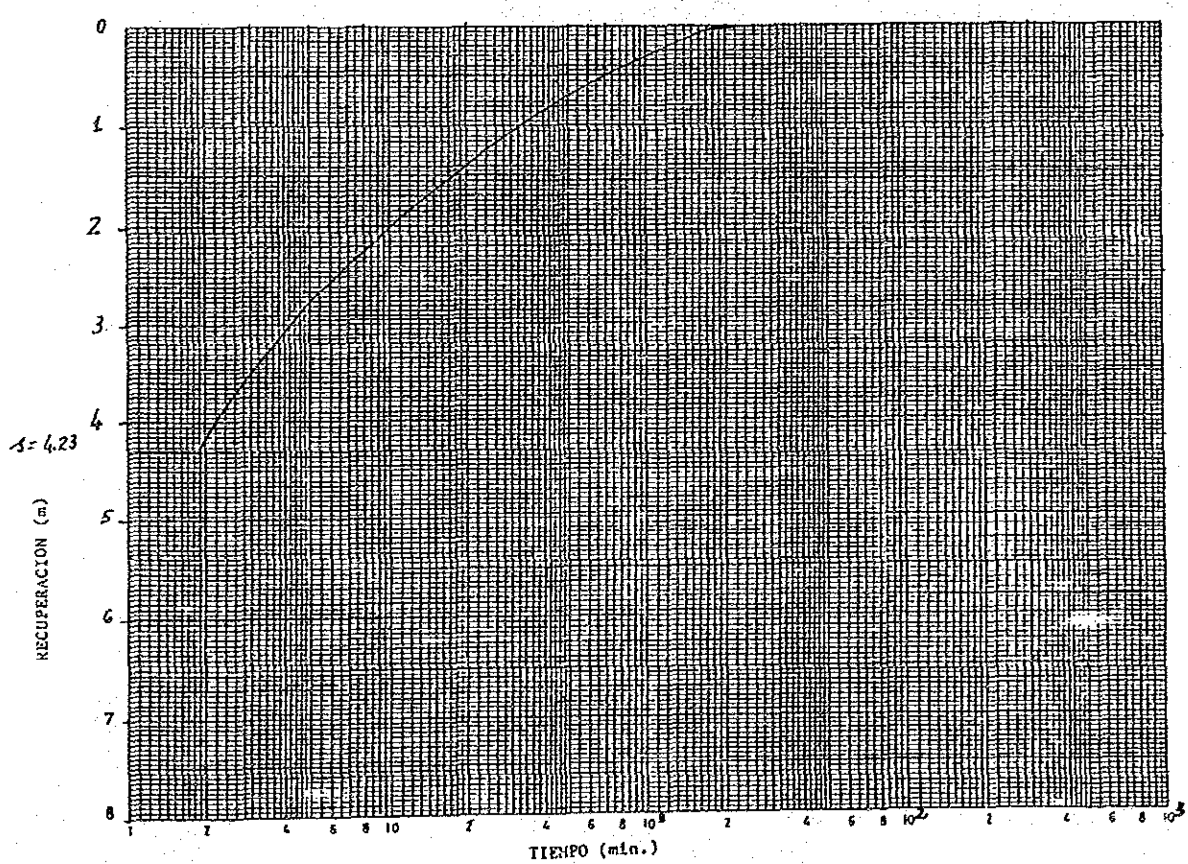


GRAFICO RECUPERACION - BODEGA



PLANILLA DE BOMBEO

POZO Nº 1 : BODEGA

PROFUNDIDAD : 60 M. DIAMETRO: 6"

NIVEL ESTATICO : 6.20 m. FECHA DE PRUEBA: 20 - 21 - XII - 88

HORAS DE BOMBEO : 24 hs.

EQUIPO UTILIZADO : COMPRESOR INGERSOLL RAND

TIEMPO MIN.	NIV. EST. (m)	NIV. DINAM. (m)	ABATIM. (m)	CAUDAL l/h.	CARACT. DEL AGUA
	6.20				
1		7.00	0.80		
2		7.20	1.00		
3		7.50	1.30		Turbio
4		7.60	1.40		"
6		7.66	1.46		"
8		7.68	1.48		"
10		7.70	1.50		"
15		7.75	1.55	1.800	"
20		7.81	1.61		"
30		7.89	1.69		"
60		8.32	2.12		"
90		8.53	2.33		"
120		8.66	2.46		"
150		8.76	2.56	1.800	"
180		8.85	2.65		"
240		9.10	2.90		"
300		9.30	3.10	1.800	Aclarando
360		9.50	3.30		Claro
420		9.75	3.55	2.000	"
480		10.00	3.85	"	"
540		10.20	4.05	"	"
600		10.32	4.12	"	"
660		10.42	4.22	"	"
720		10.42	4.22	"	"
780		10.43	4.23	"	"
840		10.43	4.23	"	"
900		10.43	4.23	"	"
960		10.42	4.22	"	"
1020		10.43	4.23	"	"
1080		10.44	4.24	"	"
1140		10.43	4.23	"	"
1200		10.43	4.23	"	"
1260		10.43	4.23	"	"
1320		10.43	4.23	"	"
1380		10.42	4.22	"	"
1440		10.43	4.23	"	"

PLANILLA DE RECUPERACION

POZO Nº 1 : BODEGA

NIVEL DINAMICO : 10.43

TIEMPO (min.)	RECUPERACION (m)	NIVEL DINAMICO (m)
		10.43
0.5	1.43	9.00
1.0	2.18	8.25
1.5	2.48	7.95
2.0	2.76	7.67
2.5	2.96	7.47
3.5	3.18	7.25
4.5	3.42	7.01
6.5	3.79	6.64
8.5	3.89	6.54
10.5	3.97	6.46
12.5	4.02	6.41
14.5	4.07	6.36
16.5	4.19	6.24
18.5	4.21	6.22

GRAFICO RECUPERACION - HAYASHI

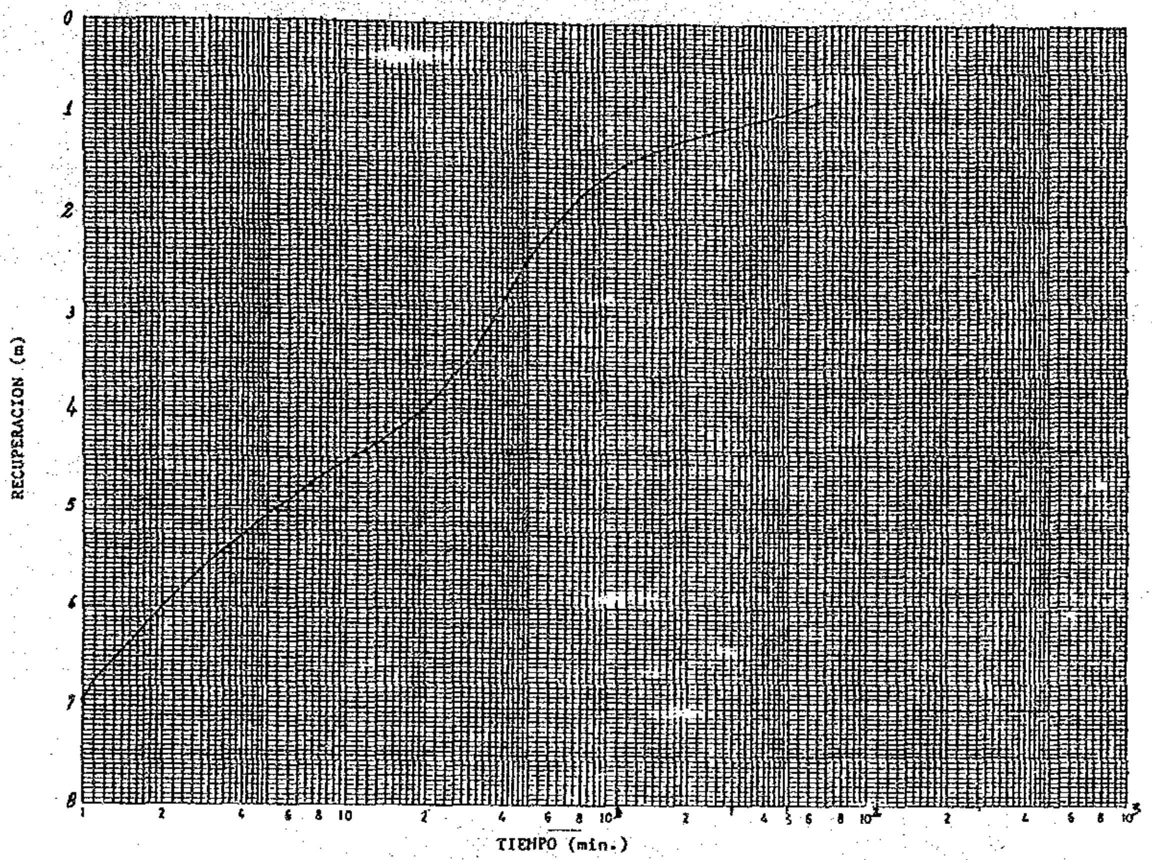
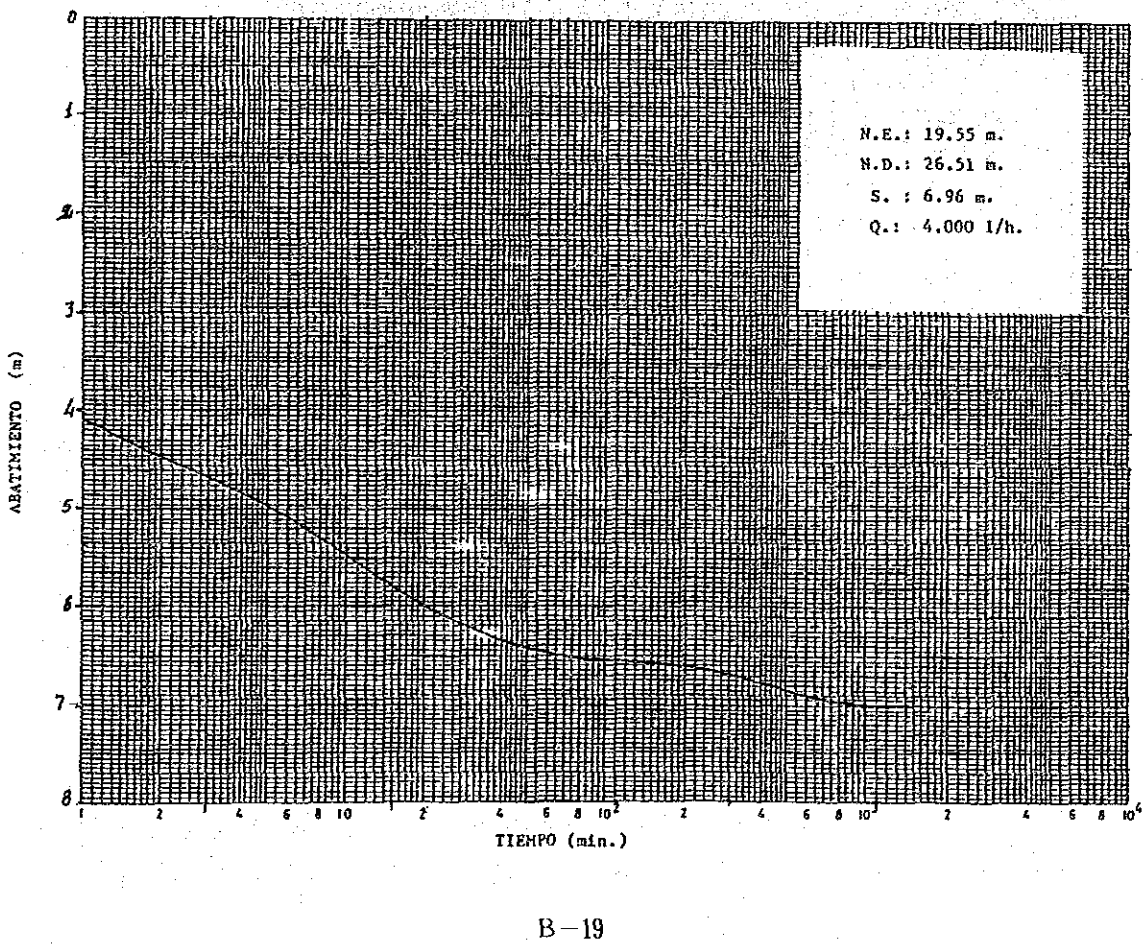
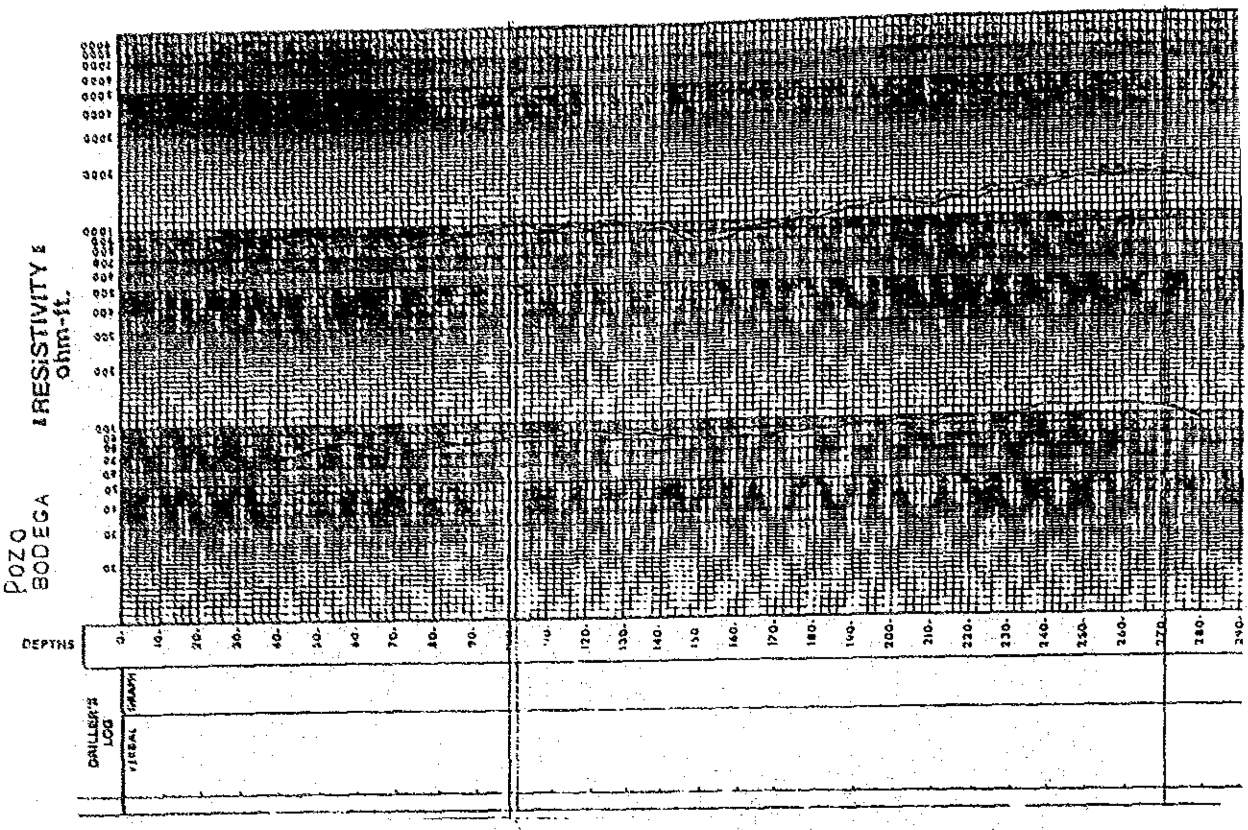
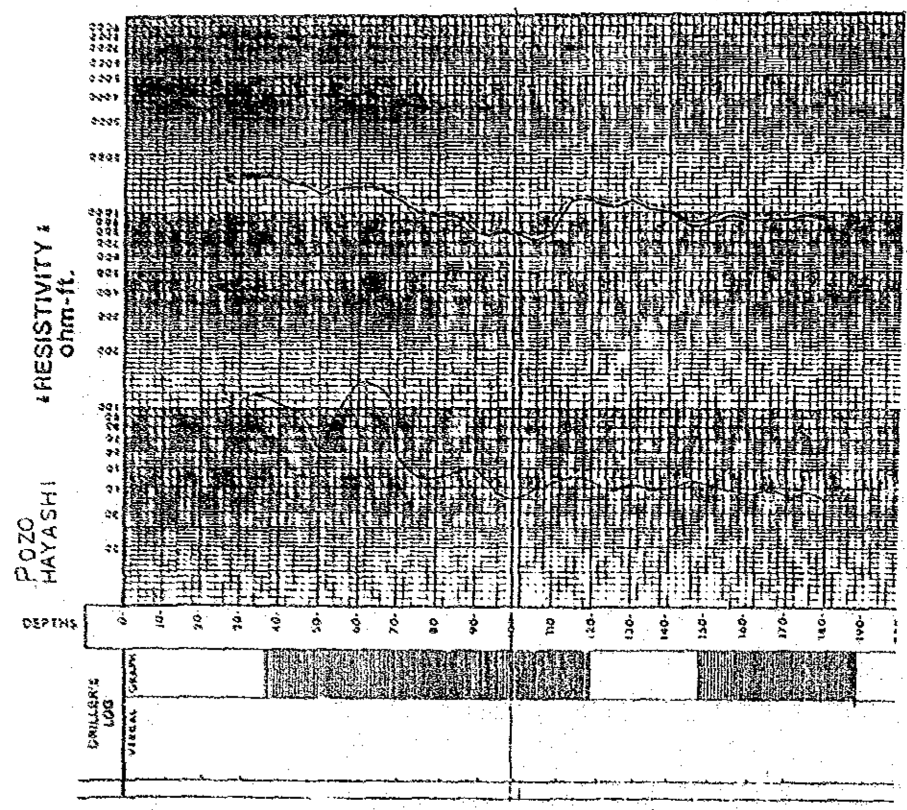


GRAFICO ABATIMIENTO - HAYASHI




POZO
BODEGA
RESISTIVITY
ohm-ft.
DEPTHS
DRILLER'S LOG
GRAPH
VERBAL


POZO
HAYASHI
RESISTIVITY
ohm-ft.
DEPTHS
DRILLER'S LOG
GRAPH
VERBAL

POZO SEKI

El primer pozo a ser perforado en la propiedad del señor Seki fue iniciado el dia 1° de septiembre de 1988 con una máquina a percusión. El dia antes fue realizada la limpieza del terreno para la introducción a la misma de la máquina perforadora.
El dia 3 de septiembre del mismo año la perforación se encontraba en 8 metros de profundidad y se presentaban problemas de estabilidad del suelo perforado, por lo tanto hubo necesidad de utilizar bentonita para contrarrestar el desmoronamiento del terreno que estaba siendo perforado.
El dia 6 de septiembre del mismo año la perforación se encontraba en 20 metros de profundidad pero continuaban los problemas de desmoronamiento.
Hasta el dia 14 de septiembre del mismo año no se habían podido superar los problemas de desmoronamiento en el pozo y el mismo continuaba en 20 metros.
Debido a todos los problemas anteriormente citados se decidió avanzar la máquina perforadora unos 10 metros al frente e iniciar una nueva peoración a percusión, tampoco se tuvo éxito.
Finalmente el dia 20 de octubre de 1988 con otra máquina esta vez rotativa se consigue perforar hasta los 42 metros encontrandose grandes cantos rodados que aprisionaban la herramienta de perforación por lo cual no fue posible continuar la perforación.
Cuando se decidió el encamisado del pozo de 42 metros de profundidad la sorpresa fue que peones mal intencionados echaron madera de grandes dimensiones dentro del pozo y por lo tanto fue necesario perforar otro pozo, el tercero en la misma propiedad, el cual se inició con una máquina rotativa a las 06;00 horas del dia 3 de diciembre concluyéndose a las 18;00 horas del dia 4 de diciembre de 1988.
El bombeo del mismo fue realizado los dias 5, 6 y 15 de diciembre de 1988 y los resultados son los siguientes:

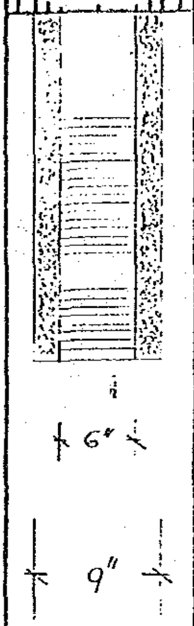
Pozo Seki (continuación)

Caudal de Ensayo:	10.000 litros/hora = 2,78 l/s
Profundidad:	40 metros
Tiempo de Ensayo:	26 horas + 7 horas
Nivel Estático:	9,40 metros
Nivel Dinámico 1 hora:	15,40 metros
Nivel Dinámico 2 horas:	15,80 metros
Nivel Dinamico 3 horas:	15,80 metros
Nivel Dinámico 4 horas:	15,80 metros
....	
Nivel Dinamico 26 horas:	15,80 metros
Abatimiento:	6,40 metros
Caudal Específico:	1.563 l/hxm = 0,43 l/sxm
Recuperación:	5 minutos 15 segundos

Como en las cercanías de este pozo no existían otros pozos de agua no fue posible hacer la medición de los descensos de nivel de los mismos.
Cuando fue realizada la segunda perforación, la cual no pudo ser encamisada, la arenisca recién fue encontrada a los 30,50 metros y sin embargo en la tercera perforación ella fue hallada desde los 24,30 metros en adelante.
En la segunda perforación a los 42 metros se encontraron grandes cantos rodados que atrapaban la herramienta y en la tercera perforación se halló CONGLOMERADO hacia el final del pozo.
Los pozos no encamisados fueron sellados con hormigón armado para evitar posibles accidentes y además se instaló una alambrada con un cartel indicador de la expresa prohivición de ingresar a la propiedad donde se encuentra el pozo ordenado por LA MISION.

PERFIL DE POZO PERFORADO

Nombre: S E K I



PROF (m)	SIMBOLO	DESCRIPCION	FORM
		Arcilla limosa, color rojizo. Cuat.	
		Arenisca limosa, parda amarillenta, granos brechosos de cuarzo.	
		Arenisca, grano fino a medio.	
		Arenisca con predominio de cristales brechosos de silice. Color claro a oscuro. CONGLOMERADO.	

PROF (m): 10 – 20 – 30 – 40 – 50 – 60 – 70 – 80 – 90 – 100 – 110 – 120 – 130 – 140 – 150 – 160 – 170

Seccion Tecnica
ASUNCION - PARAGUAY

SISTEMA DE PERFILAJE ELECTRICO MANUAL
(Johnson - Keck SR 3?)

POZO Nº

UBICACION . " LA COLMENA "

FECHA DE LA PERFORACION 3-XII-88

INICIO 3-XII-88 FIN 4-XII-88

OPERADOR DEL PERFILAJE

FECHA DE PERFILAJE 4-XII-88

NIVEL ESTATICO 9,40 m

PROFUNDIDAD DE LA PERFORACION 40 m

PROFUNDIDAD PERFILADA 40 m

PROPIEDAD Seki

MAQUINA QUE PERFORO FAILING 250

OPERADOR Edgar Elio Franco

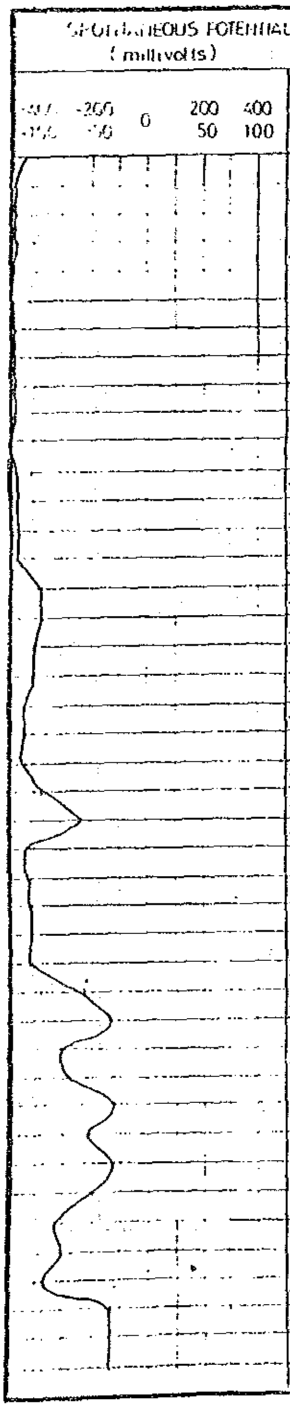
DIAMETRO DE LA PERFORACION 9"

INYECCION USADA DURANTE LA PERFORACION Arcilla Natural (Nai-G)

RESISTIVIDAD DEL LODO :

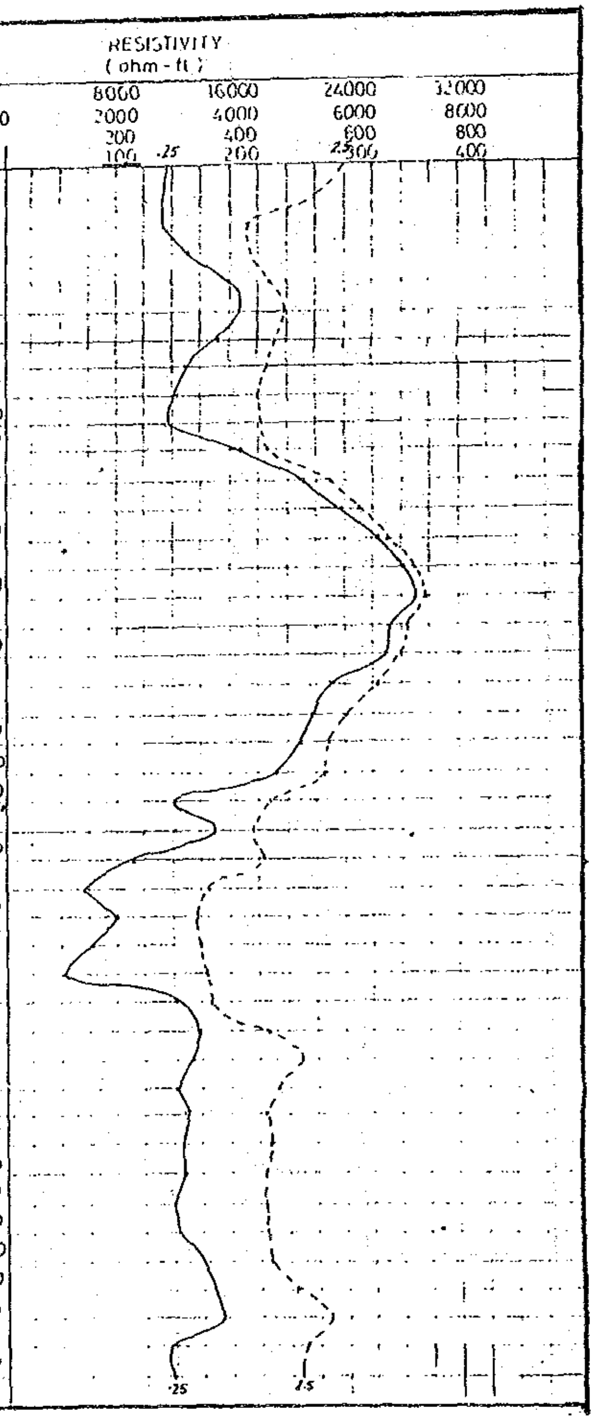
METODO DE PERFORACION . Rotativo

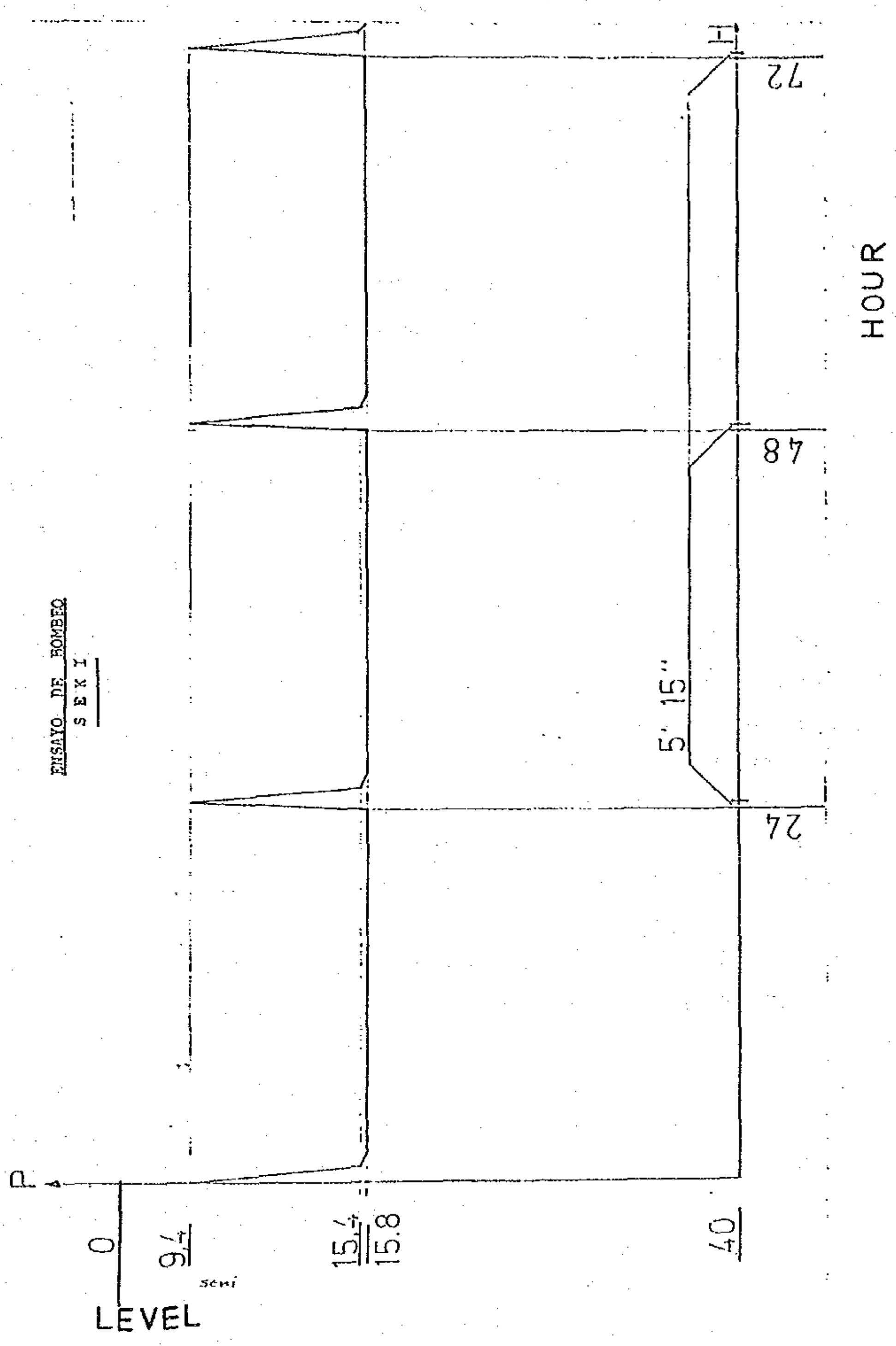
SPONTANEOUS POTENTIAL (millivolts)



Depth (ft) (1" = 10' / 1" = 20' / 1" = 40')	SP	NORMAL · LATERAL (Circle one) .25	2.5	10
27.5	-212	118	700	.0
30.0	-212	118	460	.0
32.5	-206	126	470	.0
35.0	-211	140	540	.0
37.5	-211	143	590	240
40.0	-211	136	560	200
42.5	-211	125	530	200
45.0	-211	122	500	280
47.5	-205	118	510	400
50.0	-208	144	530	280
52.5	-206	166	750	240
55.0	-206	179	850	280
57.5	-204	192	950	360
60.0	-204	204	1050	480
62.5	-198	205	1090	520
65.0	-198	196	1020	520
67.5	-200	195	1000	600
70	-200	176	920	600
72.5	-202	158	800	640
75	-202	155	750	6.40
77.5	-202	167	730	400
80	-198	111	540	200
82.5	-192	135	480	240
85	-202	107	520	200
87.5	-201	89	330	240
90.0	-201	100	290	300
92.5	-201	91	300	360
95.0	-201	81	320	160
97.5	-192	121	340	40
100.0	-187	129	530	160
102.5	-195	127	650	160
105.0	-194	121	570	240
107.5	-187	125	520	400
110.0	-191	123	530	240
112.5	-187	124	520	280
115.0	-190	120	520	400
117.5	-196	122	530	360
120.0	-195	132	540	480
122.5	-198	136	620	320
125.0	-187	138	730	360
127.5	-187	118	660	320
130.0	-187	119	640	360

RESISTIVITY (ohm - ft)



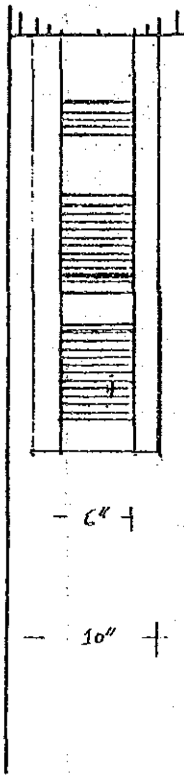

ENSAYO DE BOMBEO
S E K I
P
H
0
9.4
15.4
15.8
40
seni
LEVEL
HOUR
24
48
72
5' 15"

POZO CHAVEZ

El dia 23 de septiembre de 1988 fue marcado en el terreno el lugar de la perforación, el 26 de septiembre fue instalada en el lugar la máquina perforadora a percusión que haría los trabajos de perforación.
Iniciada la perforación en el dia 28 de septiembre esta se encontraba en 3 metros y para el dia 30 alcanzaba los 7 metros.
El dia 11 de octubre del mismo año la perforación se encontraba en 52 metros y a esa profundidad se cortó la barra de perforación. Inmediatamente se inició la tarea de pesca de la barra la cual fue extraida del pozo el dia 23 de octubre de 1988.
El dia 29 de octubre del mismo año la perforación alcanzaba 57 metros y la herramienta quedó atrapada en el pozo a causa de los cantos rodados que había en el mismo. Esta herramienta no pudo ser recuperada pese al esfuerzo que fue realizado y recién el dia 22 de noviembre se inició un nuevo pozo el cual fue concluido el dia 9 de diciembre de 1988 con una profundidad de 52 metros y con el siguiente resultado: el pozo no tiene agua y por lo tanto se ordenó el encamisado del pozo viejo para realizar los estudios de acuífero correspondiente. El encamisado del pozo viejo se hizo el dia 12 de diciembre de 1988 y en una longitud de 28 metros.
Fueron realizados los ensayos correspondientes con resultados totalmente negativos ya que ninguno de los dos pozos contenían agua.
El agua que fluía a los pozos respondía al de un estero que se encuentra a 17,50 metros de distancia de los pozos y solamente a los 3 metros de profundidad se detectó una pequeña entrada de agua y analizada esta agua resultó ser filtración del agua del estero hacia los pozos.
En el pozo de 52 metros fluían 400 litros/hora.
En el pozo de 28 metros fluían 700 litros/hora.
En ningún momento el agua de ninguno de los dos pozos adquirío transparencia, siempre tuvo el color GRIS del agua del estero adyacente a los pozos.
La recuperación del nivel de los pozos era de 25 horas 10 minutos y el nivel estático es de 1,00 metros.

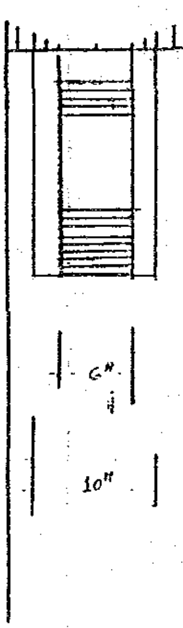
PERFIL DE POZO PERFORADO

Nombre: C H A V E Z



PROF (m)	SIMBOLO	DESCRIPCION	FORM
		Suelo sin descripción	
10		Arena rosada de granos finos a medios	
20		Arena blanquesina de granos finos a gruesos	
30		Arena fina con intercalaciones de arcilla	
40		Arena blanquesina con granos finos a gruesos	
50			
60			
70			
80			
90			

Nombre: C H A V E Z



PROF (m)	SIMBOLO	DESCRIPCION	FORM
		Suelo sin descripción	
10		Arena rosada de granos finos a medios	
20			
30			
40			
50			
60			
70			

POZO ... 3

UBICACION La Colmena

FECHA DE LA PERFORACION

INICIO FIN

OPERADOR DEL PERFILAJE

FECHA DE PERFILAJE 8-diciembre-1988

NIVEL ESTATICO 1,00 metro

PROFUNDIDAD DE LA PERFORACION 52 m

PROFUNDIDAD PERFILADA

PROPIEDAD Chávez

MAQUINA QUE PERFORO Failing 250

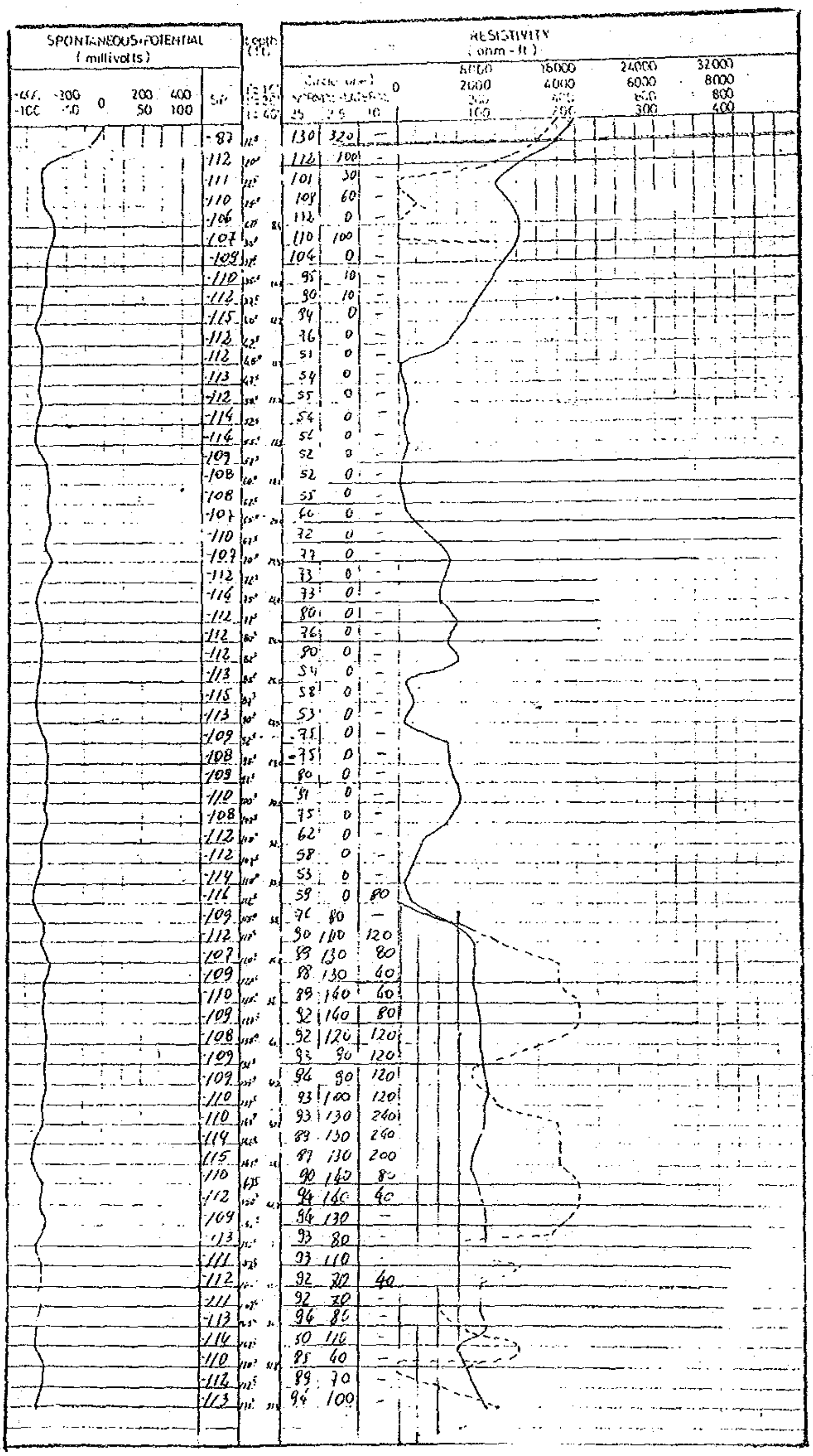
OPERADOR Edgar Elio Franco

DIAMETRO DE LA PERFORACION 10"

INYECCION USADA DURANTE LA PERFORACION

RESISTIVIDAD DEL LODO

METODO DE PERFORACION Combinado



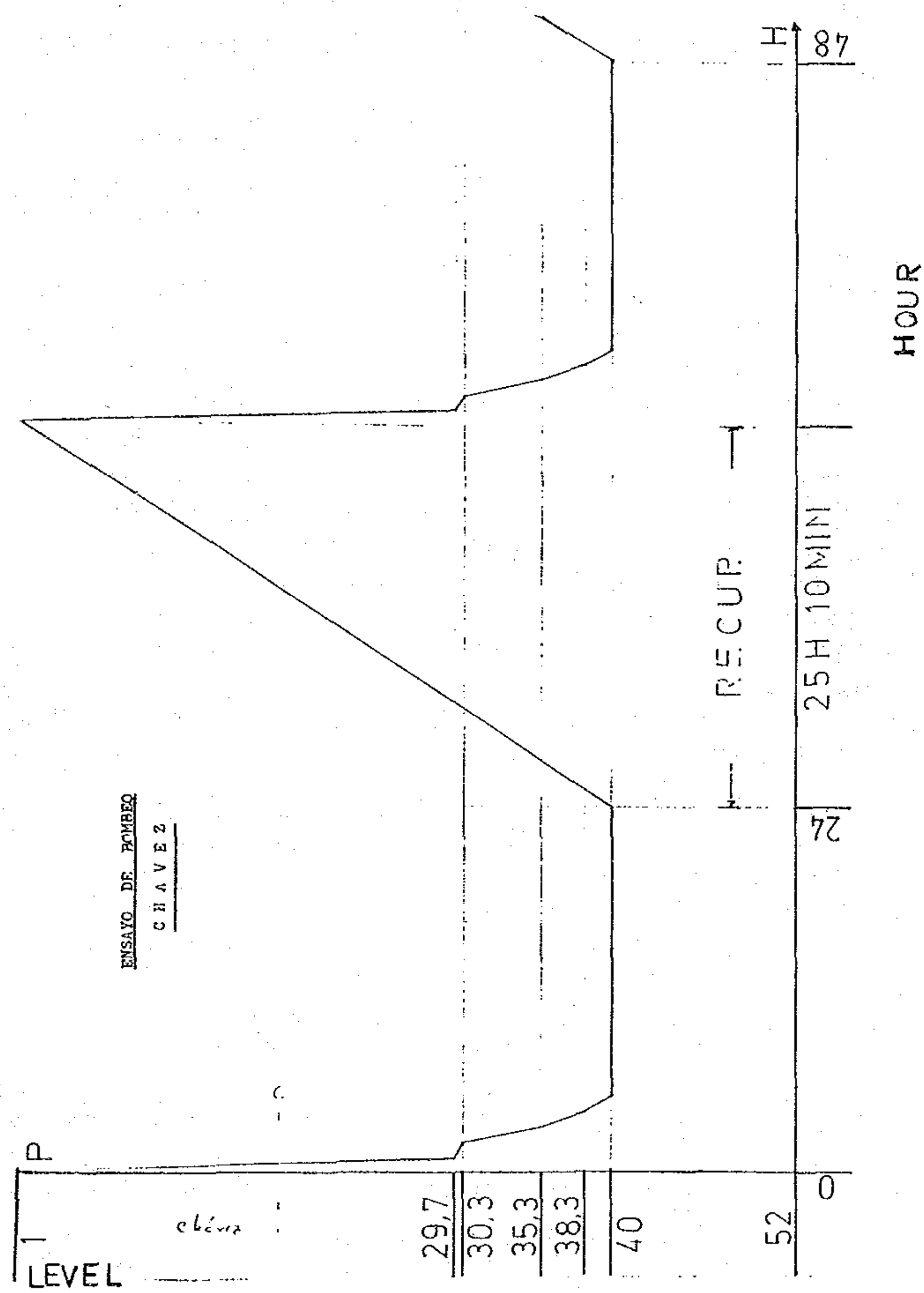

ENSAYO DE BOMBEO
CHAVEZ
LEVEL
P
29,7
30,3
35,3
38,3
40
52
0
24
48
H
RECUP
25H 10MIN
HOUR

Table B.1.1 Data of Electrical Prospecting Survey (1)

a(m)	2πa	1	2	3	4	5	6	7	8	9	10
1	6.28	176.935	836.293	304.860	160.850	123.025	124.533	215.388	227.451	210.990	80.739
2	12.57	67.230	466.852	255.475	122.585	110.358	163.363	53.746	185.857	138.733	103.534
3	18.85	54.720	316.484	282.555	104.804	87.990	197.355	29.424	182.747	106.500	114.153
4	25.13	58.735	291.289	300.839	81.179	50.064	204.003	18.950	198.549	90.428	114.279
5	31.42	58.339	282.649	323.898	62.769	32.139	230.405	12.661	210.173	78.854	117.841
6	37.70	58.170	272.075	345.362	41.130	23.750	252.697	10.895	218.391	70.120	115.736
7	43.98	57.221	280.695	318.564	27.841	20.892	273.350	9.588	221.407	63.291	112.111
8	50.27	56.247	154.768	285.759	25.032	19.252	308.530	9.249	219.660	58.509	109.126
9	56.55	57.680	153.190	247.683	20.697	17.756	257.919	9.048	233.546	54.965	106.990
10	62.83	57.554	151.174	211.618	19.918	16.650	265.088	9.048	236.688	52.527	107.631
11	69.12	60.061	151.984	185.228	19.214	15.758	267.683	8.709	242.732	51.076	-
12	75.40	61.902	155.697	153.511	17.945	14.326	270.981	9.349	247.005	47.953	113.927
13	81.68	64.855	156.257	136.326	16.581	13.151	266.690	8.985	245.289	44.271	-
14	87.96	63.071	158.688	123.942	15.658	11.963	259.936	8.796	241.903	40.992	114.442
15	94.25	65.408	161.729	106.406	13.760	12.346	253.715	9.331	240.144	37.888	-
16	100.53	71.176	160.749	95.907	11.863	12.064	246.201	9.349	233.131	34.382	112.796
17	106.81	75.304	159.474	87.054	13.459	11.750	240.439	9.293	228.689	31.190	-
18	113.10	79.734	160.259	80.865	12.441	11.310	237.278	9.274	224.725	32.572	117.621
19	119.38	83.925	159.254	70.673	13.968	12.057	237.209	9.550	221.809	30.323	-
20	125.66	85.577	168.264	65.848	13.949	11.310	238.007	9.802	223.430	28.400	120.260
22	138.23	81.832	156.062	50.730	13.132	10.782	239.276	9.953	217.436	23.361	-
24	150.80	86.105	159.543	48.255	12.064	11.008	239.917	10.405	194.678	19.754	135.114
26	163.36	78.251	152.418	43.781	13.069	9.965	236.059	11.272	186.397	18.297	-
28	175.93	68.788	148.133	41.695	12.139	10.380	242.079	11.787	170.476	18.473	147.957
30	188.50	65.597	143.445	33.552	10.744	10.367	237.128	12.064	151.174	16.022	-
32	201.06	60.118	135.516	33.175	11.259	10.656	228.407	12.064	138.934	-	160.850
34	213.63	52.980	128.604	30.122	13.245	12.604	216.833	13.031	132.450	15.381	-
36	226.19	47.049	122.145	31.441	10.857	11.988	207.873	13.572	124.181	-	176.206
38	238.76	48.946	115.799	29.368	11.461	11.699	202.708	12.893	116.277	16.236	-
40	251.33	46.758	109.328	28.149	11.561	12.566	193.271	14.828	111.087	-	192.266
42	263.89	41.959	103.183	25.598	12.931	13.986	181.823	14.250	103.974	17.945	-
44	276.46	38.704	98.696	22.946	11.888	12.164	177.211	13.823	96.208	-	215.363
46	289.03	36.706	95.090	23.122	12.139	11.850	173.416	14.740	90.465	19.076	-
48	301.59	33.477	94.700	22.318	14.175	11.461	168.289	16.286	83.240	-	234.036
50	314.16	33.615	92.991	21.677	14.137	11.938	162.420	15.394	77.597	14.451	-
52	326.73	33.326	89.196	21.074	13.069	11.762	155.195	15.356	73.513	-	254.193
54	339.29	30.876	85.162	20.358	14.590	12.215	146.235	15.947	65.144	15.268	-
56	351.86	30.964	81.983	20.056	13.371	11.611	137.577	15.482	51.371	-	270.931
58	364.43	29.154	79.080	20.408	13.119	9.839	130.100	16.399	53.206	14.577	-
60	376.99	27.143	77.660	21.112	12.441	12.441	126.669	15.457	47.501	-	273.319
64	402.12	28.149	75.197	19.302	15.281	14.074	117.420	15.683	49.863	15.683	304.006
68	427.26	38.453	69.216	22.645	13.672	12.390	109.805	16.663	40.589	15.381	320.443
72	452.39	39.810	65.144	22.619	13.119	12.215	104.050	17.643	35.739	14.476	335.673
76	477.52	37.724	65.376	22.444	-	11.938	96.937	18.146	31.516	16.713	350.024
80	502.66	32.673	62.832	20.609	-	12.566	87.462	18.096	35.186	16.588	364.928
84	527.79	32.723	59.112	20.056	-	12.667	79.168	18.473	36.945	20.056	380.535
88	552.92	22.670	58.057	20.458	-	12.164	72.433	18.246	34.834	18.246	397.550
92	578.05	24.856	54.915	19.076	-	13.295	69.944	17.920	35.261	16.185	412.152
96	603.19	21.715	51.874	-	-	12.064	66.350	17.492	25.334	17.492	427.056
100	628.32	21.991	47.752	-	-	11.938	63.460	17.593	21.991	16.965	438.567
110	691.15	-	-	-	-	11.750	54.601	-	17.970	-	-
120	753.98	-	-	-	-	17.342	45.239	-	19.604	-	-
130	816.81	-	-	-	-	20.420	36.757	-	17.153	-	-
140	879.65	-	-	-	-	11.435	30.788	-	15.834	-	-
150	942.48	-	-	-	-	12.252	30.159	-	17.907	-	-
160	1005.31	-	-	-	-	14.074	27.143	-	-	-	-
170	1068.14	-	-	-	-	13.886	21.363	-	-	-	-
180	1130.97	-	-	-	-	-	22.619	-	-	-	-
190	1193.81	-	-	-	-	-	21.489	-	-	-	-
200	1256.64	-	-	-	-	-	20.106	-	-	-	-
210	1319.47	-	-	-	-	-	19.792	-	-	-	-
220	1382.30	-	-	-	-	-	-	-	-	-	-

UNIT: Ωm

a(m)	2πa	11	12	13	14	15	16	17	18	19	20
1	6.28	87.902	381.390	219.597	221.608	98.081	264.836	9.720	434.734	225.315	249.129
2	12.57	79.985	249.317	149.540	266.155	90.729	97.364	9.148	334.014	169.018	294.682
3	18.85	92.627	218.090	102.466	278.597	104.200	38.491	7.540	242.405	136.094	175.339
4	25.13	103.044	179.951	77.459	259.675	108.850	23.474	7.213	194.628	104.050	163.288
5	31.42	113.412	150.922	74.047	242.154	125.224	16.619	6.535	173.290	79.011	140.492
6	37.70	123.540	153.096	70.196	217.449	130.137	13.836	6.635	161.051	60.319	139.298
7	43.98	131.155	109.384	64.786	192.467	128.780	15.218	7.125	151.563	50.580	96.629
8	50.27	132.701	94.198	64.742	169.495	132.349	11.109	6.736	145.318	41.720	88.668
9	56.55	133.229	68.707	67.010	155.848	139.562	10.066	7.125	136.395	35.626	90.761
10	62.83	126.858	57.491	65.785	146.775	136.974	10.304	7.414	127.800	32.673	57.554
11	69.12	-	51.905	-	-	-	-	7.741	124.269	29.719	52.458
12	75.40	110.911	45.842	67.557	135.114	129.987	11.159	7.464	118.149	27.897	47.049
13	81.68	-	-	-	-	-	-	9.230	112.067	24.504	42.638
14	87.96	92.891	33.515	60.344	133.794	125.965	11.435	8.445	105.470	21.991	38.704
15	94.25	-	-	-	-	-	-	8.482	100.280	18.850	35.343
16	100.53	78.113	26.741	71.075	133.706	122.145	11.561	8.646	92.690	17.090	31.567
17	106.81	-	-	-	-	-	-	8.866	87.054	16.022	30.335
18	113.10	69.668	20.131	79.734	133.455	118.865	12.554	10.066	82.222	14.703	28.727
19	119.38	-	-	-	-	-	-	9.431	78.791	13.132	38.441
20	125.66	64.968	16.462	87.588	132.073	111.966	16.588	9.425	75.650	12.566	23.750
22	138.23	-	14.514	-	-	-	-	10.091	68.009	13.132	23.361
24	150.80	47.501	13.722	99.224	136.320	91.383	15.080	10.254	59.715	13.572	21.866
26	163.36	-	13.559	-	-	-	-	10.945	54.563	12.579	30.549
28	175.93	40.464	12.315	105.206	140.392	92.187	15.482	11.347	50.140	12.667	30.436
30	188.50	-	12.252	-	-	-	-	12.064	45.239	12.252	32.233
32	201.06	32.773	-	114.404	149.389	72.181	16.487	-	40.615	12.466	25.535
34	213.63	-	11.536	-	-	-	-	10.895	37.812	12.390	25.849
36	226.19	30.310	-	122.598	159.015	65.144	20.584	-	35.060	13.119	18.548
38	238.76	-	12.893	-	-	-	-	9.789	32.710	12.893	18.385
40	251.33	29.908	-	151.551	165.625	53.533	22.368	-	30.913	13.572	18.598
42	263.89	-	11.875	-	-	-	-	11.347	29.292	13.459	21.903
44	276.46	26.540	-	192.969	173.894	46.998	24.605	-	29.028	13.547	26.540
46	289.03	-	12.139	-	-	-	-	12.139	26.590	13.584	17.531
48	301.59	26.540	-	176.734	183.369	41.921	23.826	-	25.937	14.778	20.508
50	314.16	-	11.624	-	-	-	-	12.252	32.044	14.137	20.420
52	326.73	25.811	-	193.748	192.115	34.960	23.851	-	26.138	14.703	19.277
54	339.29	-	13.911	-	-	-	-	11.875	25.786	15.268	19.340
56	351.86	27.797	-	188.948	195.985	28.501	20.760	-	25.686	15.130	19.704
58	364.43	-	11.662	-	-	-	-	12.026	24.781	14.577	20.772
60	376.99	21.112	-	215.262	202.067	29.782	26.389	-	24.504	14.703	21.866
64	402.12	-	14.476	226.396	206.290	-	-	12.868	24.127	15.281	24.127
68	427.26	25.208	-	221.319	211.919	35.462	16.663	-	22.217	14.954	25.635
72	452.39	-	17.191	230.266	219.409	25.334	-	-	22.167	14.476	28.048
76	477.52	38.679	18.146	261.682	226.823	-	20.056	13.848	21.966	14.803	20.056
80	502.66	-	12.566	258.867	235.243	24.630	19.504	-	21.614	15.582	22.619
84	527.79	39.584	12.139	272.339	244.366	-	-	11.611	23.223	14.250	31.667
88	552.92	-	15.482	283.648	252.132	34.834	18.799	-	23.223	15.482	30.411
92	578.05	20.810	14.856	289.027	263.014	-	-	12.139	22.544	15.029	19.654
96	603.19	-	13.873	299.180	273.243	21.715	20.508	-	27.143	15.683	18.699
100	628.32	21.991	14.451	294.053	282.744	-	18.850	12.566	22.619	15.080	19.478
110	691.15	-	11.750	316.547	301.342	28.959	-	-	-	-	17.970
120	753.98	-	9.802	315.919	330.245	27.143	-	-	-	-	19.604
130	816.81	-	11.435	349.597	351.230	28.589	-	-	-	-	17.153
140	879.65	-	14.074	380.007	385.285	19.352	-	-	-	-	-
150	942.48	-	-	404.323	419.403	23.562	-	-	-	-	-
160	1005.31	-	-	-	-	-	-	-	-	-	-
170	1068.14	-	-	-	-	-	-	-	-	-	-
180	1130.97	-	-	-	-	-	-	-	-	-	-
190	1193.81	-	-	-	-	-	-	-	-	-	-
200	1256.64	-	-	-	-	-	-	-	-	-	-
210	1319.47	-	-	-	-	-	-	-	-	-	-
220	1382.30	-	-	-	-	-	-	-	-	-	-

UNIT: Ωm

Table B.1.1 Data of Electrical Prospecting Survey (2)

a(m)	2πa	21	22	23	24	25	26	27	28	29	30
1	6.28	256.794	162.735	85.828	221.482	46.527	305.677	220.226	113.977	750.841	80.048
2	12.57	135.466	112.218	91.860	119.506	48.883	295.059	139.487	70.598	317.301	73.149
3	18.85	117.433	70.120	105.369	95.379	40.150	279.539	131.740	65.088	186.799	84.785
4	25.13	112.092	54.789	123.176	82.435	37.950	256.605	136.848	70.523	105.708	91.031
5	31.42	110.584	42.412	131.758	82.624	25.133	234.363	140.272	81.179	60.947	100.971
6	37.70	103.296	37.322	138.695	84.069	18.397	216.770	147.027	91.835	36.907	112.080
7	43.98	96.321	35.626	147.077	82.687	14.734	191.323	143.031	99.796	23.882	115.805
8	50.27	92.489	31.165	148.032	80.425	12.566	170.903	140.140	108.423	17.291	115.761
9	56.55	84.823	29.405	153.699	75.775	12.158	158.336	135.660	114.398	14.137	97.433
10	62.83	78.540	28.903	157.897	75.398	12.064	144.513	133.078	120.700	13.320	111.652
11	69.12	73.262	27.646	155.855	73.953	11.611	133.392	130.904	123.854	13.132	111.690
12	75.40	68.612	26.389	152.908	73.136	11.762	119.129	125.538	125.086	12.215	111.665
13	81.68	63.712	26.138	151.111	72.697	12.497	108.636	122.686	123.339	11.599	108.065
14	87.96	57.177	24.630	138.192	73.890	12.315	100.280	115.937	122.359	11.435	102.655
15	94.25	51.836	24.504	129.120	75.398	12.441	95.190	108.197	122.616	12.158	95.190
16	100.53	47.250	22.117	123.452	75.398	12.868	89.473	100.632	123.854	11.561	90.277
17	106.81	41.658	22.431	110.766	75.838	12.284	83.315	94.637	124.225	11.322	85.451
18	113.10	37.322	21.489	103.597	75.775	12.554	79.168	87.990	124.294	11.762	80.299
19	119.38	25.070	21.489	97.295	75.210	12.416	82.970	82.970	126.424	11.938	76.642
20	125.66	25.133	21.363	94.374	75.398	11.938	66.476	74.896	128.931	11.435	73.262
22	138.23	29.028	17.970	87.500	78.791	13.547	63.586	63.171	132.010	12.579	68.562
24	150.80	25.635	18.096	68.160	81.430	13.119	55.946	54.136	129.233	12.818	65.295
26	163.36	21.237	17.970	71.553	78.414	13.232	48.355	47.375	128.077	12.906	56.033
28	175.93	19.352	17.417	66.501	75.650	14.426	42.927	43.630	124.558	12.667	49.788
30	188.50	18.473	17.342	59.942	71.628	13.949	38.265	40.904	120.449	12.629	39.773
32	201.06	16.688	16.487	54.488	70.372	14.879	39.006	33.778	119.833	12.667	35.789
34	213.63	16.449	17.090	49.135	68.361	14.527	32.685	35.676	119.846	12.818	33.112
36	226.19	15.834	15.607	46.144	67.858	14.476	30.536	32.346	116.264	13.345	30.989
38	238.76	13.848	16.236	42.022	59.690	14.564	29.606	30.323	119.619	13.132	29.129
40	251.33	15.331	15.582	39.458	60.319	14.074	27.897	28.400	112.343	12.566	26.892
42	263.89	14.778	16.098	38.001	60.696	14.514	26.126	28.501	104.502	13.195	24.014
44	276.46	17.417	16.588	37.875	49.763	12.994	26.540	27.370	99.802	12.717	21.287
46	289.03	15.029	16.764	35.839	49.135	14.451	25.434	27.169	95.957	13.584	21.388
48	301.59	18.699	15.984	33.175	45.239	14.778	20.207	25.937	91.081	13.873	19.905
50	314.16	14.451	18.850	31.416	43.982	15.080	21.677	24.504	88.279	14.451	19.164
52	326.73	18.950	19.277	33.979	39.207	15.029	17.970	23.851	84.295	14.049	17.643
54	339.29	19.679	16.965	29.179	37.322	15.268	15.947	25.786	83.127	13.232	16.965
56	351.86	14.778	15.834	29.908	34.130	15.482	15.834	24.278	77.761	13.722	16.185
58	364.43	13.848	19.315	27.332	32.798	15.306	15.670	24.416	68.147	14.213	16.764
60	376.99	15.080	16.588	26.389	29.782	15.457	15.834	23.373	68.235	14.326	16.211
64	402.12	15.281	17.291	25.334	27.344	16.889	14.879	25.334	68.361	14.074	16.085
68	427.26	17.090	17.518	24.354	23.499	15.809	15.809	26.063	56.398	14.099	15.809
72	452.39	14.929	16.286	21.715	23.977	16.738	14.929	25.786	52.025	14.476	15.834
76	477.52	17.668	17.191	21.489	20.533	16.236	15.758	21.966	45.842	14.803	15.758
80	502.66	14.074	17.593	20.609	19.101	15.582	16.085	22.117	41.720	15.080	14.577
84	527.79	19.528	15.834	20.056	19.528	15.834	16.889	21.112	40.112	15.834	15.834
88	552.92	17.693	18.799	16.035	18.799	16.035	16.975	20.458	38.704	15.482	16.588
92	578.05	20.232	16.185	17.920	17.342	15.607	12.717	20.232	34.683	15.029	16.764
96	603.19	15.080	18.096	18.096	18.096	16.286	11.461	19.905	31.969	15.080	16.286
100	628.32	15.080	20.106	16.965	17.593	15.080	9.425	18.850	29.531	15.080	16.965
110	691.15	15.205	17.970	16.588	16.588	17.279	11.750	16.588	26.955	14.514	15.896
120	753.98	14.326	15.080	15.834	16.588	16.588	15.834	18.096	22.619	15.080	18.096
130	816.81	14.703	18.787	17.153	17.562	15.519	15.519	17.153	21.237	15.519	17.970
140	879.65	15.834	21.991	18.473	18.912	15.834	12.315	17.593	22.871	15.834	17.593
150	942.48	13.195	16.965	15.080	18.755	17.907	17.907	15.080	17.907	16.965	17.907
160	1005.31	-	-	-	-	-	-	-	-	-	-
170	1068.14	-	-	-	-	-	-	-	-	-	-
180	1130.97	-	-	-	-	-	-	-	-	-	-
190	1193.81	-	-	-	-	-	-	-	-	-	-
200	1256.64	-	-	-	-	-	-	-	-	-	-
210	1319.47	-	-	-	-	-	-	-	-	-	-
220	1382.30	-	-	-	-	-	-	-	-	-	-

UNIT: Ωm

a(m)	2πa	31	32	33	34	35	36	37	38	39	40
1	6.28	619.271	83.943	20.885	256.417	158.839	487.576	964.470	460.432	96.887	176.306
2	12.57	525.903	108.548	16.588	142.126	108.460	176.935	261.004	259.998	96.359	132.575
3	18.85	360.592	122.522	18.114	141.334	102.014	100.845	144.237	136.188	116.189	144.350
4	25.13	313.908	144.036	18.121	133.706	104.301	97.389	130.640	114.932	132.902	160.322
5	31.42	220.383	151.739	18.473	119.758	113.883	105.903	142.000	121.297	139.141	173.950
6	37.70	120.034	152.644	18.586	100.242	124.030	110.308	138.130	131.155	143.898	180.503
7	43.98	90.296	154.686	18.561	85.194	135.554	117.081	132.695	142.767	160.799	181.911
8	50.27	67.909	159.744	19.252	69.216	145.368	115.761	133.555	145.619	178.493	179.951
9	56.55	54.513	157.375	19.227	56.492	152.229	118.978	135.151	152.455	195.037	178.694
10	62.83	45.993	155.760	19.289	47.501	157.394	119.569	141.058	154.755	148.472	180.516
11	69.12	41.815	159.034	19.352	40.156	157.928	119.431	144.934	156.684	205.479	185.021
12	75.40	37.775	159.694	19.000	37.398	155.471	116.038	148.082	158.412	208.099	190.984
13	81.68	34.715	159.769	19.113	31.039	154.950	114.354	147.435	160.667	213.107	193.912
14	87.96	32.019	159.040	19.264	27.709	156.225	108.548	145.582	160.448	212.875	188.948
15	94.25	30.442	160.504	19.415	25.635	154.943	104.992	144.105	158.902	212.812	188.213
16	100.53	29.958	163.966	19.402	24.027	153.209	101.938	145.267	160.448	213.930	185.178
17	106.81	28.306	165.028	19.013	21.897	156.162	101.153	143.772	160.542	211.279	181.477
18	113.10	28.274	164.670	18.548	19.566	150.080	101.561	146.122	157.884	204.933	179.373
19	119.38	28.054	164.865	18.265	18.265	151.733	100.399	147.315	154.359	199.007	181.339
20	125.66	26.138	168.138	18.221	16.839	150.168	96.007	148.660	153.059	192.517	177.312
22	138.23	25.711	163.250	17.693	15.896	153.021	91.785	144.865	147.353	180.252	175.138
24	150.80	24.580	159.543	16.738	14.627	147.479	91.081	140.542	150.344	169.043	170.551
26	163.36	23.688	159.606	16.336	14.213	141.636	91.157	135.591	151.111	161.729	162.873
28	175.93	22.871	140.919	16.361	14.074	143.734	86.205	138.456	148.308	153.938	156.577
30	188.50	22.431	140.429	16.399	13.760	140.429	82.750	138.921	143.445	149.854	148.535
32	201.06	20.910	136.521	15.884	13.672	137.929	84.044	138.934	138.130	147.177	142.151
34	213.63	20.722	127.109	15.809	13.886	130.954	82.033	134.800	135.440	146.685	130.100
36	226.19	20.810	128.252	16.286	13.798	127.574	79.621	134.812	132.324	129.157	121.240
38	238.76	20.772	124.633	16.475	13.371	124.156	75.687	134.661	127.976	119.381	112.934
40	251.33	20.358	115.359	16.336	13.069	121.140	76.404	135.968	125.161	112.595	110.081
42	263.89	20.056	115.849	16.361	13.459	116.641	73.099	132.211	120.336	107.405	102.655
44	276.46	20.458	114.731	16.311	13.547	110.308	70.221	129.660	118.601	98.696	97.038
46	289.03	20.521	106.940	16.764	13.295	111.564	67.343	126.016	115.900	95.090	92.778
48	301.59	20.207	103.748	16.286	12.667	108.875	64.239	122.748	113.399	91.684	82.335
50	314.16	20.420	98.646	16.965	13.509	109.013	60.319	120.323	112.155	87.965	80.425
52	326.73	20.257	97.364	16.336	13.396	104.552	57.177	121.542	110.760	81.355	78.741
54	339.29	20.358	92.627	16.965	13.911	102.127	53.608	121.806	112.645	75.662	77.019
56	351.86	19.704	87.965	17.241	14.074	99.576	51.020	121.039	106.613	68.964	74.946
58	364.43	19.679	84.911	16.764	14.577	99.852	50.291	118.438	103.132	65.597	72.156
60	376.99	19.604	78.414	16.965	13.572	95.002	50.894	109.705	100.280	62.204	67.858
64	402.12	20.508	77.208	17.291	14.074	94.097	45.038	110.182	102.542	55.493	58.710
68	427.26	20.508	68.788	17.518	13.245	90.578	43.153	102.542	93.997	48.707	55.971
72	452.39	19.905	62.430	17.643	13.119	86.406	38.001	97.264	85.502	42.977	50.215
76	477.52	19.578	59.213	16.236	13.848	80.701	37.247	92.639	77.359	39.634	44.887
80	502.66	18.598	57.303	18.096	14.577	76.906	34.181	86.457	72.885	35.186	43.731
84	527.79	19.528	51.195	17.945	14.250	67.557	31.667	78.113	72.307	33.778	37.473
88	552.92	19.352	51.975	18.246	13.823	58.610	30.964	77.409	66.350	30.964	35.387
92	578.05	18.498	45.088	18.498	14.451	58.383	28.903	72.835	60.696	27.747	33.527
96	603.19	18.699	42.223	17.492	15.080	56.096	26.540	69.970	57.303	27.747	31.366
100	628.32	18.850	38.956	17.593	14.451	54.664	26.389	63.460	54.035	24.504	30.159
110	691.15	20.043	31.793	16.588	13.823	53.219	24.190	56.674	-	24.190	24.190
120	753.98	19.604	29.405	17.342	14.326	41.469	22.619	47.501	-	23.373	20.358
130	816.81	19.604	26.138	17.153	14.703	37.573	19.604	46.558	-	22.871	18.787
140	879.65	19.352	23.750	16.713	14.954	36.945	19.352	38.704	-	20.232	15.834
150	942.48	18.850	21.677	17.907	16.022	32.044	19.792	41.469	-	18.850	13.195
160	1005.31	-	-	-	-	-	-	-	-	-	-
170	1068.14	-	-	-	-	-	-	-	-	-	-
180	1130.97	-	-	-	-	-	-	-	-	-	-
190	1193.81	-	-	-	-	-	-	-	-	-	-
200	1256.64	-	-	-	-	-	-	-	-	-	-
210	1319.47	-	-	-	-	-	-	-	-	-	-
220	1382.30	-	-	-	-	-	-	-	-	-	-

UNIT: Ωm

Table B.1.1 Data of Electrical Prospecting Survey (3)

a(m)	2πa	41	42	43	44	45	46	47	48	49	50
1	6.28	463.322	367.190	192.266	965.098	334.831	56.486	494.864	165.248	108.197	158.902
2	12.57	220.037	113.474	178.945	440.829	177.940	80.802	400.742	155.195	50.730	187.239
3	18.85	156.244	100.129	198.297	216.205	95.775	107.348	311.395	151.928	33.646	219.786
4	25.13	153.586	110.257	211.316	165.826	85.652	131.218	252.333	149.791	22.594	254.595
5	31.42	153.059	127.769	216.456	157.425	67.890	147.938	236.311	133.298	17.530	258.805
6	37.70	159.505	129.459	237.354	162.069	50.253	155.924	217.675	115.095	15.306	257.221
7	43.98	171.223	137.489	213.886	167.529	37.561	158.732	183.582	95.090	13.854	226.069
8	50.27	179.548	143.408	219.107	174.974	32.572	161.101	156.074	78.263	12.969	224.687
9	56.55	189.042	144.312	238.014	181.521	29.009	160.598	135.151	69.216	12.497	202.218
10	62.83	195.533	148.597	238.887	181.207	26.515	157.143	120.135	56.674	11.938	181.207
11	69.12	199.674	153.366	220.201	175.552	24.743	153.988	114.040	45.962	11.888	184.399
12	75.40	205.837	151.324	214.282	177.940	23.298	149.892	108.272	37.247	11.536	175.753
13	81.68	207.308	160.259	213.352	177.330	22.217	158.054	106.023	31.121	11.272	169.244
14	87.96	207.773	170.124	198.448	176.721	21.815	142.679	105.558	27.797	11.523	147.517
15	94.25	206.780	176.997	189.344	172.285	20.923	134.586	107.537	24.127	11.310	136.377
16	100.53	206.591	186.887	184.575	168.792	21.011	131.796	109.478	23.323	11.762	129.987
17	106.81	203.374	194.402	181.157	170.048	20.936	128.070	111.300	20.936	10.895	112.689
18	113.10	203.688	194.641	177.902	166.366	20.810	123.955	113.663	19.227	10.970	94.549
19	119.38	204.738	197.097	178.952	164.029	20.653	121.171	118.545	18.623	10.744	97.653
20	125.66	207.974	198.674	172.662	161.478	19.981	118.375	121.894	17.216	10.304	87.588
22	138.23	199.604	195.181	159.379	153.574	19.767	104.087	128.139	16.173	10.229	75.303
24	150.80	198.147	200.861	140.392	142.654	19.302	85.954	131.645	15.683	10.254	63.636
26	163.36	182.493	199.303	128.893	140.492	19.113	76.617	134.611	15.683	10.455	53.256
28	175.93	184.022	202.847	121.743	134.234	18.121	62.983	137.929	15.834	9.676	47.149
30	188.50	173.039	199.428	105.181	133.266	17.153	54.098	141.372	15.645	10.744	40.904
32	201.06	165.474	198.448	90.476	127.272	16.487	51.271	139.135	15.281	11.058	36.593
34	213.63	162.571	195.684	82.461	127.323	15.809	47.212	133.304	15.809	10.895	30.976
36	226.19	160.825	190.230	74.644	113.776	14.703	40.941	126.443	16.060	11.310	23.524
38	238.76	150.897	180.742	75.210	107.920	14.564	37.486	121.529	15.997	10.983	17.907
40	251.33	144.513	175.678	72.885	101.285	14.828	34.432	117.873	16.085	11.058	16.839
42	263.89	141.183	169.684	67.293	100.280	14.778	27.709	106.877	15.570	11.084	16.625
44	276.46	137.677	162.559	62.480	90.955	14.652	26.264	110.861	16.311	11.611	17.141
46	289.03	131.796	158.387	58.961	86.419	15.029	23.989	109.252	16.475	11.850	15.896
48	301.59	126.368	152.908	52.477	80.224	14.175	22.016	105.558	15.984	11.159	18.699
50	314.16	117.496	146.398	47.124	78.540	14.137	21.677	100.531	16.336	10.996	18.850
52	326.73	108.800	137.552	43.455	76.781	13.722	21.237	95.404	16.010	12.089	17.643
54	339.29	100.770	127.235	35.965	68.198	14.250	20.018	96.698	14.250	12.554	17.643
56	351.86	95.354	122.799	39.056	67.557	14.778	19.352	94.650	16.537	11.963	17.945
58	364.43	88.555	119.896	35.714	65.232	14.941	17.492	92.928	15.670	11.297	17.857
60	376.99	87.839	122.145	33.929	64.089	15.080	17.342	91.609	16.588	12.441	15.457
64	402.12	82.838	102.542	32.572	59.112	15.281	16.487	88.869	16.487	12.868	16.085
68	427.26	76.906	101.260	28.626	52.553	15.381	17.090	86.733	16.663	13.672	16.663
72	452.39	67.858	89.573	26.691	52.477	14.929	18.096	80.978	17.191	14.476	17.191
76	477.52	59.690	82.134	25.309	49.662	15.758	17.668	74.971	17.191	13.848	17.668
80	502.66	55.795	74.896	21.614	45.239	15.582	18.096	71.880	16.588	13.069	17.593
84	527.79	50.668	70.196	20.584	41.167	15.834	16.889	63.862	16.361	14.250	16.361
88	552.92	48.104	63.586	18.799	37.599	16.035	17.141	62.480	15.482	14.929	16.588
92	578.05	47.978	57.805	18.498	35.839	16.185	16.185	57.227	16.185	15.029	16.764
96	603.19	41.017	53.684	16.889	31.969	16.889	16.286	51.271	16.286	14.476	18.096
100	628.32	35.814	51.522	15.708	31.416	16.336	16.965	52.779	15.708	15.080	16.965
110	691.15	30.411	42.160	14.514	25.573	16.588	17.279	49.763	-	13.132	-
120	753.98	27.143	38.453	14.326	24.127	16.588	18.096	43.731	-	13.572	-
130	816.81	24.504	-	14.703	26.138	17.153	17.970	38.390	-	13.886	-
140	879.65	22.871	-	14.074	26.389	16.713	18.473	35.186	-	12.315	-
150	942.48	20.735	-	15.080	20.735	16.022	18.850	30.159	-	16.022	-
160	1005.31	-	-	-	-	-	-	27.143	-	-	-
170	1068.14	-	-	-	-	-	-	24.567	-	-	-
180	1130.97	-	-	-	-	-	-	22.619	-	-	-
190	1193.81	-	-	-	-	-	-	22.682	-	-	-
200	1256.64	-	-	-	-	-	-	-	-	-	-
210	1319.47	-	-	-	-	-	-	-	-	-	-
220	1382.30	-	-	-	-	-	-	-	-	-	-

UNIT: Ωm

a(m)	2πa	51	52	53	54	55	56	57	58	59	60
1	6.28	472.182	169.458	239.955	484.560	242.845	2037.010	220.603	66.665	4075.910	64.466
2	12.57	156.954	162.106	157.457	211.618	170.903	886.558	92.928	75.398	2062.140	94.474
3	18.85	50.140	182.784	91.929	69.875	130.043	275.958	67.632	88.423	1005.810	125.180
4	25.13	29.908	154.139	86.130	24.907	87.537	105.181	64.993	88.065	438.818	147.630
5	31.42	18.064	137.759	84.415	15.739	60.633	42.035	65.597	87.274	251.171	157.174
6	37.70	14.967	150.683	84.258	14.326	44.900	23.298	67.331	85.087	143.898	154.717
7	43.98	11.655	107.053	84.754	14.118	33.207	17.021	69.888	82.951	102.435	158.292
8	50.27	12.818	98.420	87.010	13.622	26.440	12.064	69.417	79.872	82.184	149.037
9	56.55	10.179	94.549	91.043	13.006	21.715	11.253	73.740	77.076	74.757	134.812
10	62.83	9.613	88.907	87.965	13.760	18.284	11.812	70.812	74.581	73.011	119.883
11	69.12	10.229	83.007	86.947	13.201	16.380	10.436	68.078	70.774	-	107.336
12	75.40	10.405	85.728	84.597	13.119	17.794	10.330	62.430	69.366	70.950	96.359
13	81.68	10.210	87.236	82.172	13.151	16.091	10.619	56.360	67.142	-	89.033
14	87.96	10.468	81.103	83.742	12.843	13.810	10.556	51.107	69.228	66.853	80.840
15	94.25	9.425	78.791	75.210	12.818	14.514	10.839	51.459	60.601	-	73.042
16	100.53	10.053	74.695	74.996	13.672	13.773	10.355	45.138	55.694	67.456	71.478
17	106.81	10.041	68.254	70.711	13.993	13.993	10.788	44.852	58.748	-	68.361
18	113.10	9.839	63.108	66.954	14.476	13.345	10.857	41.394	48.519	64.692	65.710
19	119.38	10.147	61.720	63.749	14.564	13.251	11.461	40.948	44.051	-	64.227
20	125.66	10.430	58.685	62.958	15.080	14.074	11.058	37.950	44.108	59.816	63.335
22	138.23	10.644	52.113	57.504	15.896	13.685	12.026	36.078	38.843	60.130	60.960
24	150.80	10.857	44.937	56.850	16.286	14.476	11.008	30.461	35.191	86.859	58.951
26	163.36	11.109	40.187	52.603	16.500	14.213	12.089	28.589	37.083	87.563	59.464
28	175.93	10.204	35.010	48.205	18.473	15.482	13.547	28.149	31.667	86.557	58.409
30	188.50	10.179	31.290	47.689	19.227	14.703	12.818	28.274	30.913	80.111	61.450
32	201.06	10.656	28.953	43.429	19.704	14.879	12.064	25.535	29.154	72.784	61.525
34	213.63	10.681	26.490	42.085	20.081	15.168	12.818	26.490	29.908	54.262	56.184
36	226.19	11.084	26.012	39.810	19.453	16.060	14.024	27.822	29.179	58.811	56.096
38	238.76	10.744	23.637	37.963	21.489	16.475	14.564	25.547	30.323	56.348	50.140
40	251.33	10.556	23.122	37.196	21.363	16.839	14.577	26.138	28.149	57.554	54.789
42	263.89	10.820	21.639	36.417	22.167	16.889	13.986	25.862	28.237	-	49.084
44	276.46	10.782	19.076	34.834	22.117	17.141	14.929	28.199	28.199	70.774	53.910
46	289.03	10.983	19.943	32.949	22.833	17.342	13.873	28.325	28.614	-	54.337
48	301.59	11.159	18.699	34.080	22.921	17.794	15.984	29.858	28.046	57.906	51.874
50	314.16	11.310	18.535	33.615	23.248	17.279	14.765	30.473	27.960	-	47.124
52	326.73	11.435	18.623	32.999	23.851	17.643	16.336	31.366	28.752	54.563	48.029
54	339.29	11.536	18.322	30.536	24.429	18.322	15.268	32.911	28.840	-	46.483
56	351.86	11.259	17.241	30.612	24.278	18.649	16.889	33.778	29.556	58.760	47.149
58	364.43	11.297	17.492	31.341	24.416	18.221	16.764	34.620	29.518	-	43.367
60	376.99	10.933	16.965	32.044	25.635	18.473	16.588	35.814	29.028	65.974	45.239
64	402.12	11.662	16.889	32.572	26.138	16.487	17.291	37.398	28.551	60.721	45.842
68	427.26	12.390	16.663	30.335	26.917	18.799	16.236	38.880	30.335	65.798	44.007
72	452.39	12.215	17.191	30.763	28.501	18.548	15.834	41.620	28.953	63.787	43.429
76	477.52	12.416	16.713	31.039	28.651	19.578	14.803	44.410	28.651	61.600	44.887
80	502.66	12.566	16.085	31.165	29.154	19.101	15.080	46.244	29.154	54.789	42.223
84	527.79	12.667	16.361	32.195	29.028	19.000	15.306	47.501	29.028	64.918	44.334
88	552.92	12.717	17.141	31.516	28.752	17.693	14.376	49.763	29.305	63.033	45.892
92	578.05	13.873	17.342	32.371	30.059	18.498	14.451	49.713	29.481	76.881	43.354
96	603.19	14.476	16.286	32.572	29.556	18.096	15.080	53.080	28.953	47.049	42.826
100	628.32	13.195	16.336	32.673	-	18.850	15.708	51.522	28.903	40.212	41.469
110	691.15	-	-	32.484	-	16.588	15.896	56.674	29.719	44.234	34.558
120	753.98	-	-	33.175	-	18.850	17.342	58.057	31.667	49.763	37.699
130	816.81	-	-	33.489	-	17.153	18.787	60.444	31.039	80.048	37.573
140	879.65	-	-	32.547	-	16.713	20.232	70.372	31.667	47.501	40.464
150	942.48	-	-	31.102	-	16.965	21.677	60.319	34.872	64.089	40.527
160	1005.31	-	-	-	-	-	-	-	-	-	-
170	1068.14	-	-	-	-	-	-	-	-	-	-
180	1130.97	-	-	-	-	-	-	-	-	-	-
190	1193.81	-	-	-	-	-	-	-	-	-	-
200	1256.64	-	-	-	-	-	-	-	-	-	-
210	1319.47	-	-	-	-	-	-	-	-	-	-
220	1382.30	-	-	-	-	-	-	-	-	-	-

UNIT: Ωm

Table B.1.1 Data of Electrical Prospecting Survey (4)

a(m)	2πa	61	62	63	64	65	66	67	68	69	70
1	6.28	389.621	181.710	78.666	441.960	434.420	75.084	312.966	4010.560	302.724	338.036
2	12.57	135.717	172.034	74.230	131.319	121.404	90.164	332.255	1463.980	122.912	243.662
3	18.85	103.013	141.089	81.675	80.921	71.006	105.746	230.719	458.799	82.542	227.703
4	25.13	97.063	108.800	77.158	70.799	59.163	110.584	151.827	195.106	80.877	183.268
5	31.42	94.970	90.698	62.612	66.225	59.250	107.348	97.358	98.301	86.991	173.636
6	37.70	97.565	70.196	73.400	62.656	59.112	102.919	67.218	74.192	88.367	141.862
7	43.98	97.641	61.531	68.085	61.355	58.101	100.280	48.073	64.302	80.708	121.787
8	50.27	99.677	51.020	65.094	58.057	56.348	89.975	36.493	60.972	73.890	97.364
9	56.55	97.886	49.197	62.769	56.266	53.665	68.424	32.968	58.471	68.820	68.141
10	62.83	97.892	47.752	60.884	55.606	54.852	66.476	26.264	57.177	62.266	71.314
11	69.12	96.139	47.344	65.383	61.029	52.597	-	24.812	54.255	61.167	63.448
12	75.40	96.284	46.068	64.767	60.469	53.231	60.168	23.298	54.890	60.620	57.076
13	81.68	93.607	46.232	60.853	51.133	52.031	-	22.217	57.340	63.221	53.583
14	87.96	87.789	43.982	62.543	49.084	50.052	52.251	21.375	56.297	62.367	52.339
15	94.25	86.237	41.846	63.052	48.349	50.328	-	19.981	53.816	62.109	50.517
16	100.53	83.139	43.630	63.435	45.842	49.763	48.456	20.709	56.700	60.419	52.075
17	106.81	81.499	44.648	59.175	44.862	49.669	-	20.936	55.864	55.543	51.805
18	113.10	81.091	42.298	57.906	43.882	49.650	42.412	18.887	55.644	53.043	51.346
19	119.38	79.866	44.410	54.438	43.096	51.453	-	17.310	56.706	48.588	51.095
20	125.66	77.535	45.239	53.910	42.349	48.506	40.212	17.342	55.795	48.506	52.025
22	138.23	76.027	42.298	54.048	40.916	44.510	38.152	16.588	56.674	45.063	52.527
24	150.80	71.930	44.033	50.064	37.699	42.977	34.985	18.096	54.739	39.961	50.064
26	163.36	75.310	42.474	47.049	36.430	41.331	32.346	17.970	54.400	41.984	50.806
28	175.93	81.807	40.112	45.566	38.177	37.473	31.843	17.241	55.946	41.167	49.436
30	188.50	87.274	41.281	42.977	36.568	35.814	32.044	19.981	56.737	35.437	49.763
32	201.06	70.573	43.630	43.832	35.387	34.181	31.366	21.313	54.890	34.985	45.440
34	213.63	57.720	38.667	38.239	35.676	34.608	30.762	20.081	55.330	29.694	46.357
36	226.19	70.347	38.001	37.548	35.060	33.024	31.215	23.298	54.965	30.310	45.691
38	238.76	70.912	37.963	35.575	35.098	31.994	29.845	23.160	56.348	26.502	44.648
40	251.33	69.869	37.196	36.694	35.940	31.919	29.405	21.866	50.517	26.138	44.736
42	263.89	68.085	36.681	36.153	34.570	29.028	29.292	18.736	54.098	25.598	43.279
44	276.46	66.074	37.599	33.452	32.069	29.858	29.028	18.799	52.804	24.052	42.851
46	289.03	68.499	32.949	32.949	30.926	28.903	29.192	19.076	50.580	22.833	41.331
48	301.59	66.350	34.683	32.572	31.969	29.556	28.953	19.302	54.287	26.239	40.715
50	314.16	58.434	34.872	32.358	31.102	28.589	29.845	18.850	54.035	24.504	39.898
52	326.73	66.979	34.633	32.346	30.386	28.425	-	20.257	55.870	25.158	38.227
54	339.29	64.805	35.286	31.554	30.536	29.179	30.197	20.018	52.251	24.429	38.001
56	351.86	61.223	36.241	31.667	31.315	28.501	-	20.408	54.186	21.463	37.297
58	364.43	60.495	33.527	31.705	30.976	27.332	30.247	21.137	52.113	23.323	36.807
60	376.99	58.434	35.060	30.913	30.913	27.143	-	20.735	54.287	19.981	37.322
64	402.12	59.112	32.572	32.572	30.561	27.344	30.561	22.519	51.472	21.715	37.398
68	427.26	56.398	31.617	29.481	31.190	27.344	30.335	21.363	52.980	23.499	34.181
72	452.39	57.906	32.120	30.310	31.667	27.143	29.858	22.619	52.930	24.429	33.929
76	477.52	52.527	32.949	30.561	31.994	28.174	30.084	22.921	50.617	23.399	33.904
80	502.66	52.779	33.175	29.657	32.673	28.651	29.657	24.127	49.763	27.143	32.673
84	527.79	52.779	28.501	31.139	31.667	27.973	29.556	23.750	48.029	24.806	31.667
88	552.92	51.422	34.281	32.069	32.069	29.858	29.858	24.329	50.316	27.093	32.069
92	578.05	48.556	34.683	31.215	31.793	30.637	30.637	24.278	47.978	25.434	29.481
96	603.19	50.668	36.794	32.572	31.366	29.556	31.969	24.127	48.858	24.731	28.953
100	628.32	50.266	33.929	33.301	31.416	30.159	32.044	25.761	47.752	25.761	34.558
110	691.15	51.836	34.558	35.940	31.793	33.175	-	-	50.454	26.264	15.205
120	753.98	53.533	33.929	39.207	33.175	33.929	-	-	43.731	27.897	12.064
130	816.81	52.276	32.673	36.757	35.123	34.306	-	-	42.474	29.405	29.405
140	879.65	54.538	33.427	35.186	34.306	34.306	-	-	40.464	31.667	24.630
150	942.48	55.606	30.159	34.872	32.044	35.814	-	-	40.527	32.044	35.814
160	1005.31	-	-	-	-	-	-	-	-	-	-
170	1068.14	-	-	-	-	-	-	-	-	-	-
180	1130.97	-	-	-	-	-	-	-	-	-	-
190	1193.81	-	-	-	-	-	-	-	-	-	-
200	1256.64	-	-	-	-	-	-	-	-	-	-
210	1319.47	-	-	-	-	-	-	-	-	-	-
220	1382.30	-	-	-	-	-	-	-	-	-	-

UNIT: Ωm

a(m)	2πa	71	72	73	74	75	76	77	78	79	80	81	82
1	6.28	892.841	390.689	1938.360	220.791	398.543	164.305	115.422	360.027	1710.910	765.921	170.714	131.947
2	12.57	499.765	181.207	1357.170	163.237	421.225	144.513	92.024	112.343	1825.900	474.255	147.404	101.411
3	18.85	298.766	109.007	751.344	161.183	368.321	162.069	96.566	73.344	1323.050	333.637	134.567	106.330
4	25.13	136.773	93.293	497.629	170.953	299.080	161.754	104.728	73.187	976.659	112.670	116.138	106.312
5	31.42	100.028	79.451	265.842	187.616	213.911	166.536	110.521	77.880	540.354	56.266	115.674	121.862
6	37.70	67.972	68.198	233.018	195.508	165.612	157.997	114.153	82.599	330.546	28.501	115.548	128.215
7	43.98	53.790	65.314	192.994	195.282	125.438	153.850	115.058	85.326	201.087	25.070	124.338	129.660
8	50.27	49.160	58.308	169.696	186.183	100.129	151.701	113.902	87.462	132.450	17.442	127.272	132.701
9	56.55	45.522	55.248	156.979	212.962	86.350	152.173	169.307	89.064	101.788	18.661	127.574	130.232
10	62.83	43.040	53.784	147.969	179.888	75.210	147.655	120.009	86.771	90.604	17.530	134.900	123.716
11	69.12	41.400	52.873	147.077	172.857	63.517	133.185	107.958	84.666	78.377	17.348	132.217	101.945
12	75.40	40.112	53.608	145.594	166.479	54.965	128.252	102.240	82.109	72.759	16.889	131.872	110.986
13	81.68	30.876	54.155	147.190	158.789	49.091	133.468	100.141	79.884	71.308	17.888	131.997	106.431
14	87.96	34.922	52.955	153.586	152.619	42.839	136.345	97.201	79.080	69.932	16.449	128.692	102.215
15	94.25	37.322	54.004	159.750	150.985	40.055	102.165	95.379	74.833	73.042	17.719	145.519	99.149
16	100.53	39.107	52.276	162.458	149.389	35.689	99.526	90.981	72.282	72.483	16.789	128.881	96.409
17	106.81	38.239	51.271	166.096	149.113	41.444	96.987	85.238	69.002	71.886	16.343	137.577	93.997
18	113.10	37.096	52.364	170.777	145.669	39.584	93.532	83.579	68.198	69.216	15.042	117.848	89.234
19	119.38	38.202	52.289	176.564	143.734	31.039	85.238	81.418	68.883	69.241	14.803	112.815	87.625
20	125.66	38.327	50.266	182.966	142.251	26.641	91.358	69.618	63.209	72.257	14.074	106.814	84.069
22	138.23	41.746	49.901	190.619	142.515	24.052	81.418	69.115	67.180	68.424	15.067	108.787	74.368
24	150.80	39.961	47.199	208.702	146.273	22.469	83.089	65.446	57.303	66.200	14.778	105.407	71.327
26	163.36	43.455	45.415	223.480	123.992	19.440	79.558	62.568	56.033	63.548	15.029	102.919	64.692
28	175.93	39.936	45.390	238.736	119.632	16.889	76.881	57.881	54.538	61.047	15.834	96.761	61.575
30	188.50	40.527	43.919	251.642	117.244	17.907	69.178	50.894	52.213	58.057	16.022	94.059	56.172
32	201.06	40.615	42.223	266.809	110.986	19.101	67.356	51.472	46.646	55.091	16.487	91.081	53.684
34	213.63	38.880	38.880	261.054	111.300	16.877	64.729	49.135	49.135	50.630	14.740	86.092	49.348
36	226.19	40.715	40.263	282.517	104.954	15.607	61.073	47.501	47.501	45.239	14.703	73.061	46.370
38	238.76	41.783	39.396	295.825	99.802	15.758	56.109	45.603	46.081	46.558	15.281	75.449	42.738
40	251.33	42.474	37.448	308.128	100.531	16.839	58.559	43.228	46.496	46.244	15.331	71.880	41.720
42	263.89	42.223	39.056	319.312	92.627	16.098	55.154	40.376	41.431	43.279	15.042	74.418	39.320
44	276.46	42.575	37.875	336.452	74.368	16.864	50.039	40.640	39.534	41.469	14.652	70.221	39.534
46	289.03	43.065	37.284	344.809	74.280	17.631	43.643	38.152	37.573	38.441	14.740	66.765	38.730
48	301.59	43.429	38.001	360.705	73.890	18.096	46.144	35.890	34.382	39.810	15.080	62.128	37.096
50	314.16	42.412	38.956	363.483	61.889	16.965	43.354	34.243	39.584	39.584	14.765	60.947	34.872
52	326.73	44.435	37.247	383.576	65.999	16.336	39.861	32.019	37.573	37.573	15.356	59.464	33.326
54	339.29	41.054	36.644	393.579	66.841	16.965	40.715	31.215	33.929	37.322	15.607	49.197	32.911
56	351.86	41.167	34.834	409.915	53.131	14.426	38.353	28.149	33.778	32.723	15.834	51.020	30.612
58	364.43	40.087	35.349	409.249	58.672	16.399	37.171	26.603	30.976	36.443	15.306	51.020	29.883
60	376.99	39.584	34.306	422.607	56.549	16.588	36.945	28.274	27.897	33.552	15.457	49.386	28.651
64	402.12	41.017	36.191	447.564	51.070	15.683	32.974	25.334	26.540	33.778	15.281	50.668	25.736
68	427.26	38.880	33.326	460.156	44.007	15.381	30.762	23.499	26.917	34.181	-	42.298	23.499
72	452.39	38.453	33.477	458.723	39.810	14.929	27.596	20.358	25.786	33.024	-	41.167	23.072
76	477.52	39.634	34.382	467.972	38.679	16.236	26.741	22.921	25.786	29.129	-	39.157	20.533
80	502.66	40.212	34.683	496.121	37.699	16.085	24.630	23.122	24.630	25.635	-	38.202	20.609
84	527.79	41.695	33.778	485.037	33.778	16.361	24.278	21.112	24.278	26.917	-	36.417	20.584
88	552.92	40.363	34.281	489.888	33.175	16.035	23.223	21.564	22.670	23.776	-	34.834	19.352
92	578.05	39.886	35.839	501.750	30.059	15.029	20.810	20.232	21.966	26.590	-	33.527	18.498
96	603.19	41.017	35.588	509.692	30.159	16.286	19.905	19.302	20.508	22.921	-	34.985	18.699
100	628.32	38.956	36.443	529.673	26.389	15.080	19.478	18.850	20.735	15.080	-	35.814	17.593
110	691.15	40.087	35.249	543.245	25.573	-	16.588	20.043	18.661	17.279	-	32.484	16.588
120	753.98	36.945	-	544.376	19.604	-	18.096	18.850	18.850	18.850	-	32.421	15.834
130	816.81	37.573	-	566.869	22.054	-	17.970	16.336	22.054	18.787	-	25.321	-
140	879.65	38.704	-	575.289	17.593	-	17.593	17.593	-	-	-	27.269	-
150	942.48	40.527	-	579.624	16.022	-	16.022	17.907	-	-	-	28.274	-
160	1005.31	-	-	-	-	-	-	-	-	-	-	-	-
170	1068.14	-	-	-	-	-	-	-	-	-	-	-	-
180	1130.97	-	-	-	-	-	-	-	-	-	-	-	-
190	1193.81	-	-	-	-	-	-	-	-	-	-	-	-
200	1256.64	-	-	-	-	-	-	-	-	-	-	-	-
210	1319.47	-	-	-	-	-	-	-	-	-	-	-	-
220	1382.30	-	-	-	-	-	-	-	-	-	-	-	-

UNIT: Ωm

Table B.1.1 Data of Electrical Prospecting Survey

a(m)	2πa	Ao. TRANQUERA 101	102	103	104	105	Ao. RORY 201	202	203	204	205
1	6.28	1528.070	1034.840	60.394	177.626	826.239	1086.990	2554.120	260.061	2585.530	9424.780
2	12.57	1683.900	491.345	41.431	153.938	321.071	1864.850	4330.370	279.225	1641.170	9872.150
3	18.85	1310.420	266.156	37.077	157.300	170.853	2177.130	3604.040	289.341	642.016	9096.800
4	25.13	781.880	176.181	38.906	137.476	118.979	2073.700	2651.510	274.701	560.712	9241.320
5	31.42	562.031	133.298	40.841	105.620	99.714	1685.470	1728.510	332.695	454.589	5881.070
6	37.70	242.028	121.994	40.263	91.458	82.486	1541.140	1152.840	433.163	346.116	4339.170
7	43.98	111.803	331.451	38.177	74.110	67.821	1073.170	972.010	454.337	346.449	3637.340
8	50.27	72.282	100.531	41.670	66.149	55.946	1136.000	890.202	476.819	367.743	2463.510
9	56.55	48.179	87.424	41.337	63.674	47.840	1124.190	838.052	478.628	394.314	1859.890
10	62.83	33.866	75.901	40.087	54.224	42.726	1105.210	764.036	507.745	415.507	1502.940
11	69.12	26.264	70.359	39.603	43.681	33.244	1045.710	697.371	534.882	436.531	1273.790
12	75.40	19.830	62.807	38.604	34.382	34.457	919.105	670.592	506.752	460.307	1074.430
13	81.68	15.765	56.769	37.492	28.262	30.467	830.701	682.694	474.161	469.342	939.337
14	87.96	14.866	52.603	36.066	25.598	24.102	807.340	677.240	432.434	502.542	879.647
15	94.25	15.645	50.423	36.097	23.656	22.242	790.457	658.604	429.016	507.619	779.995
16	100.53	14.778	48.054	35.487	22.418	23.323	759.311	632.340	439.421	541.963	676.473
17	106.81	13.352	37.171	35.035	20.722	20.508	702.197	573.058	423.198	509.077	719.394
18	113.10	15.155	33.138	34.608	20.131	18.887	628.030	535.969	431.240	523.641	512.218
19	119.38	15.758	30.800	33.546	20.414	18.623	583.652	510.472	443.738	519.783	499.847
20	125.66	14.451	28.526	31.919	19.352	19.352	530.804	484.811	432.535	473.124	454.777
22	138.23	15.620	25.987	31.240	18.938	20.182	478.553	-	435.702	-	445.931
24	150.80	18.095	22.770	29.858	18.397	17.945	-	-	-	-	477.723
26	163.36	16.663	21.401	28.262	18.623	17.643	-	-	-	-	456.926
28	175.93	15.482	19.880	26.917	18.297	15.834	-	-	-	-	459.703
30	188.50	14.703	19.981	25.070	17.719	17.530	-	-	-	-	465.207
32	201.06	13.873	18.900	23.926	17.895	15.080	-	-	-	-	471.491
34	213.63	14.740	17.945	23.926	18.799	14.099	-	-	-	-	-
36	226.19	13.119	17.417	25.334	18.096	14.703	-	-	-	-	-
38	238.76	-	16.713	-	18.385	15.042	-	-	-	-	-
40	251.33	-	16.085	-	20.609	15.331	-	-	-	-	-
42	263.89	-	-	-	20.584	15.306	-	-	-	-	-
44	276.46	-	-	-	19.076	14.652	-	-	-	-	-
46	289.03	-	-	-	16.764	14.740	-	-	-	-	-
48	301.59	-	-	-	17.492	15.080	-	-	-	-	-
50	314.16	-	-	-	16.022	14.765	-	-	-	-	-
52	326.73	-	-	-	16.663	-	-	-	-	-	-
54	339.29	-	-	-	14.250	-	-	-	-	-	-
56	351.86	-	-	-	16.185	-	-	-	-	-	-
58	364.43	-	-	-	14.577	-	-	-	-	-	-
60	376.99	-	-	-	15.080	-	-	-	-	-	-
64	402.12	-	-	-	14.476	-	-	-	-	-	-

unit: ρ= Ω

Table B.1.2 Relationship between Specific Resistance and Permeable/Impermeable Layers

	Rock	Specific Resistance Dry(- m)	Wet(- m)
Permeable layer	Gravel I	1,000 - 15,000	200 - 10,000
	Gravel & Sand	1,000 - 7,000	200 - 5,000
	Sand	300 - 7,000	100 - 700
	Conglomerate	300 - 1,800	100 - 500
	Sand Stone	200 - 2,500	100 - 500
Difficult permeate layer(A)	Loam	500 - 5,000	100 - 1,000
	Tuff	100 - 1,000	
Difficult permeate layer(B)	Silt		100
	Clay		100
	Marlstone		100
	Oil shale		100
Implerable layer	Granite	1,000 - 10,000	
	Andesite	200 - 10,000	
	Basalt	20,000	
	Crystalline schist	200 - 20,000	
	Gneiss	200 - 20,000	
	Lava	1,000 - 20,000	
	Linestone	60 -500,000	

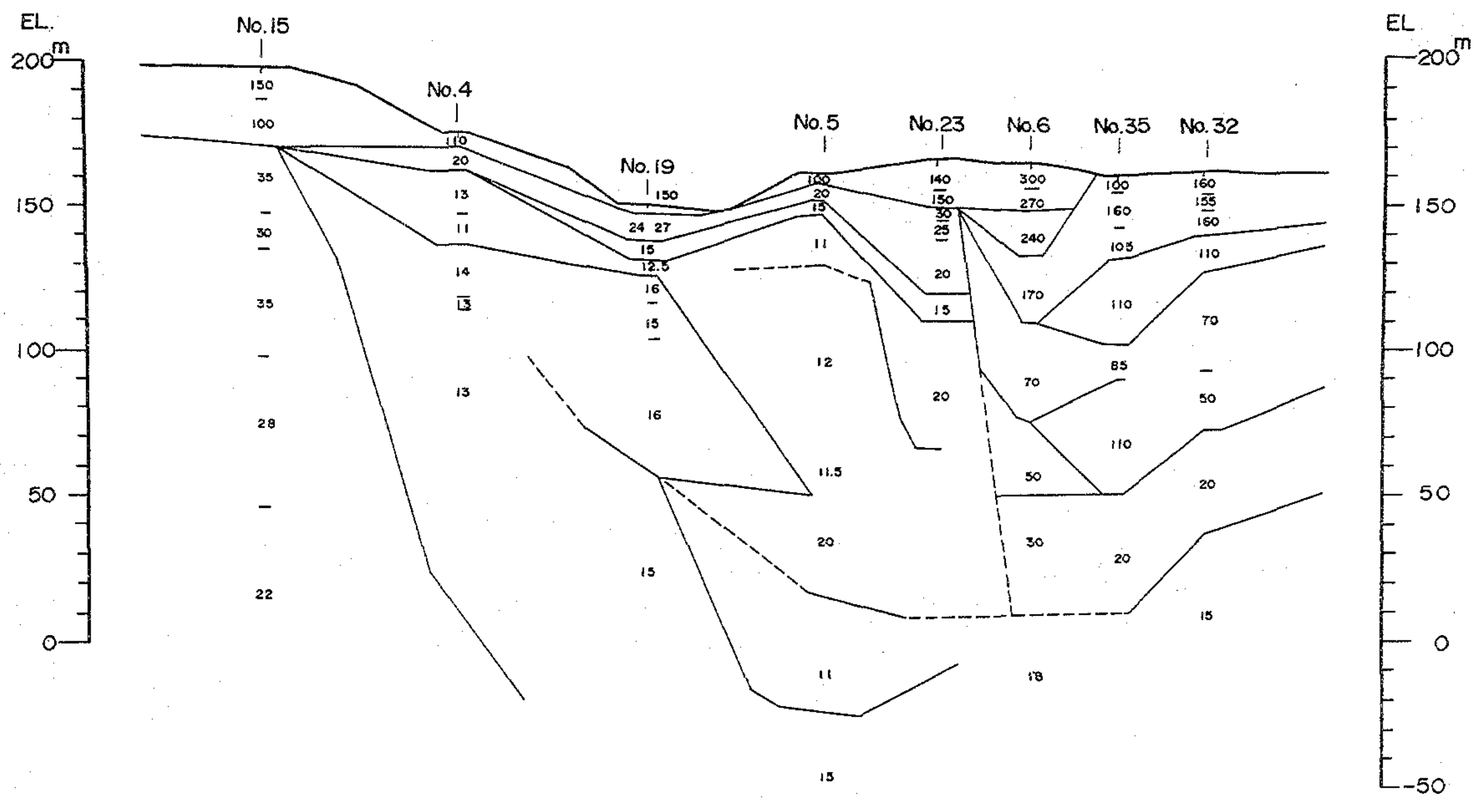


Fig. B 1.1 Profile of Specific Resistance (East-West)

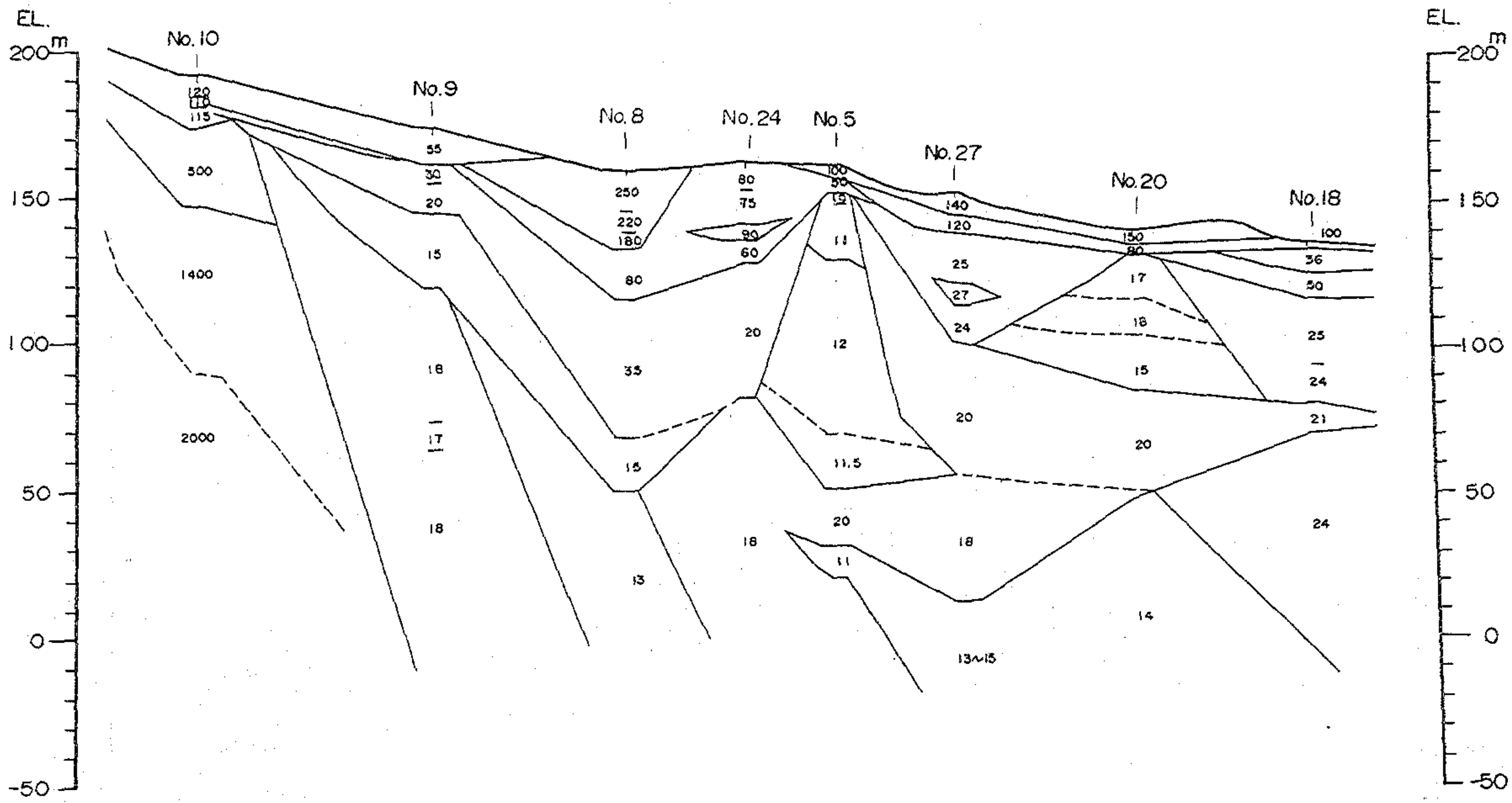


Fig. B.1.2 Profile of Specific Resistance (South-North)

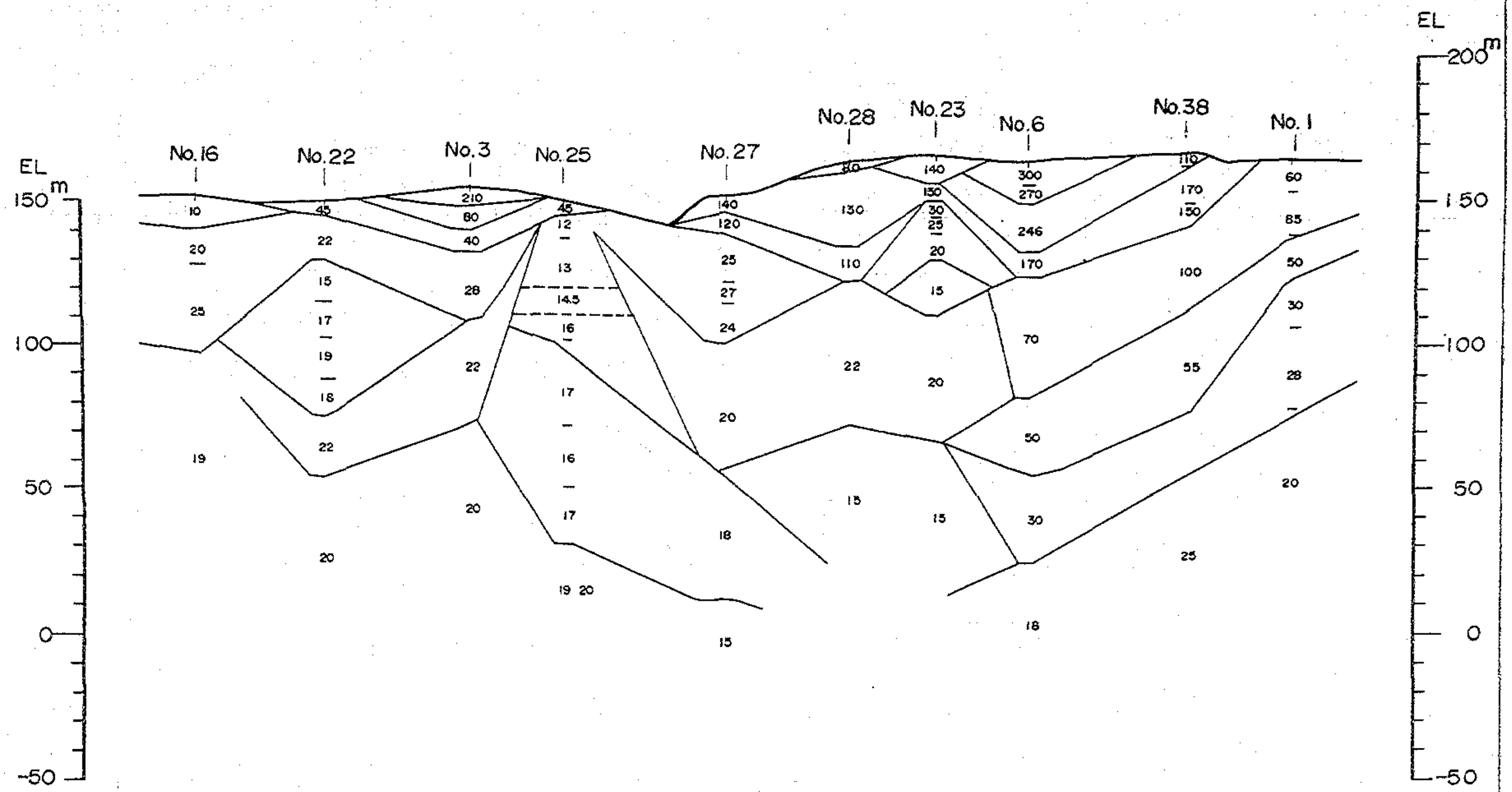


Fig. B.1.3 Profile of Specific Resistance (North & South - East & West)

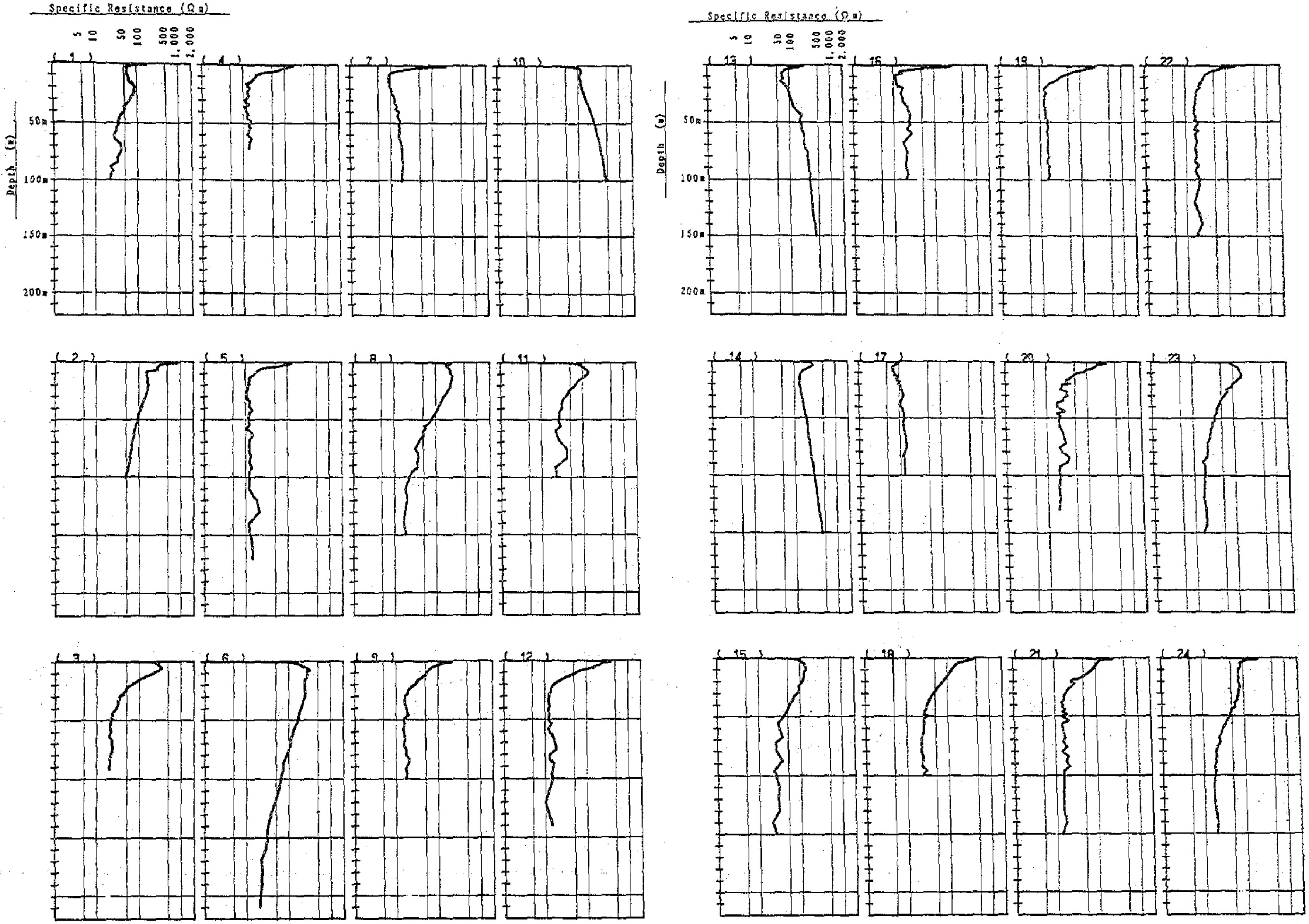


Fig. B.1.4 ρ-a Curve of Electric Potential (1)

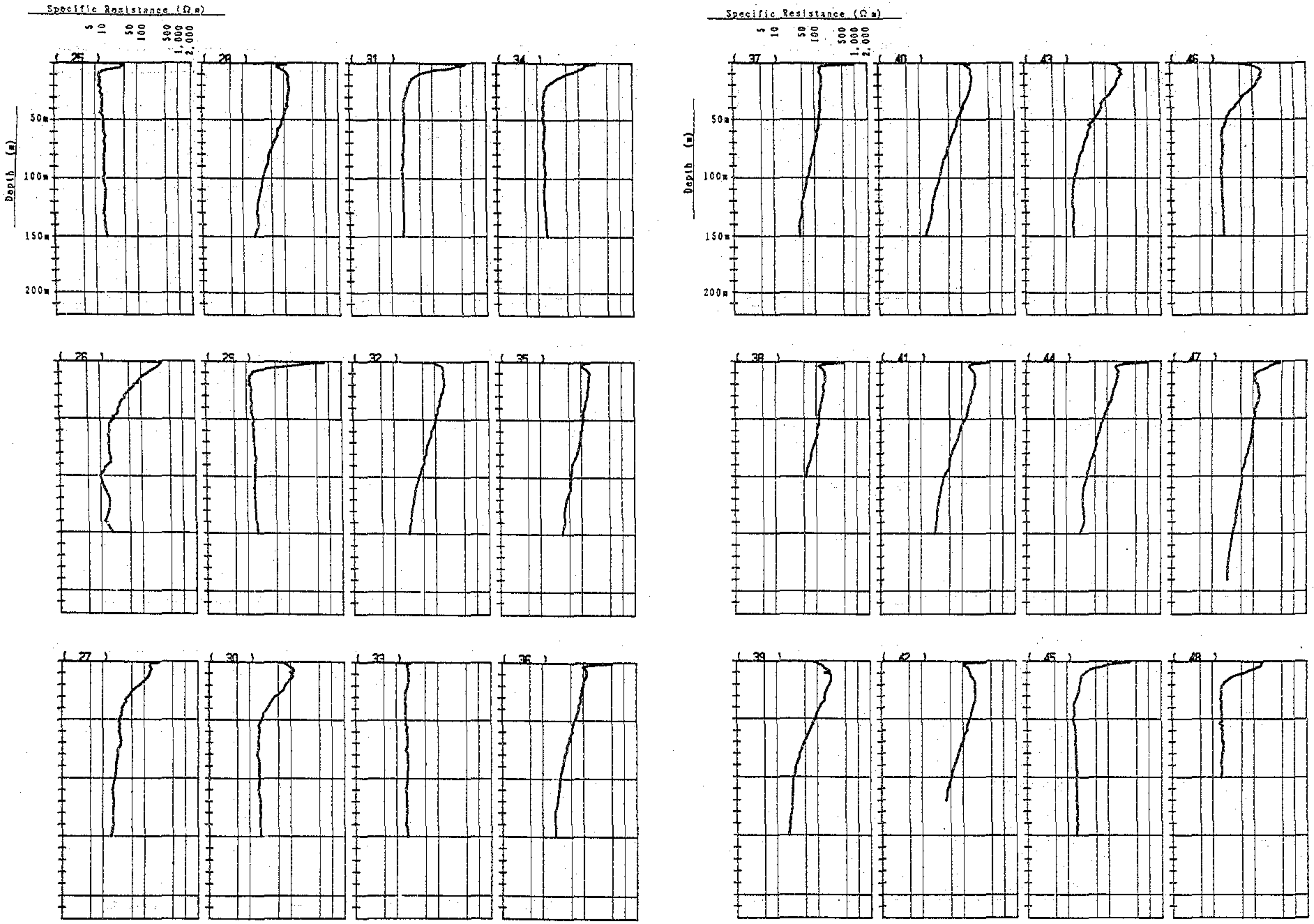


Fig. B.1.4 ρ-a Curve of Electric Potential (2)

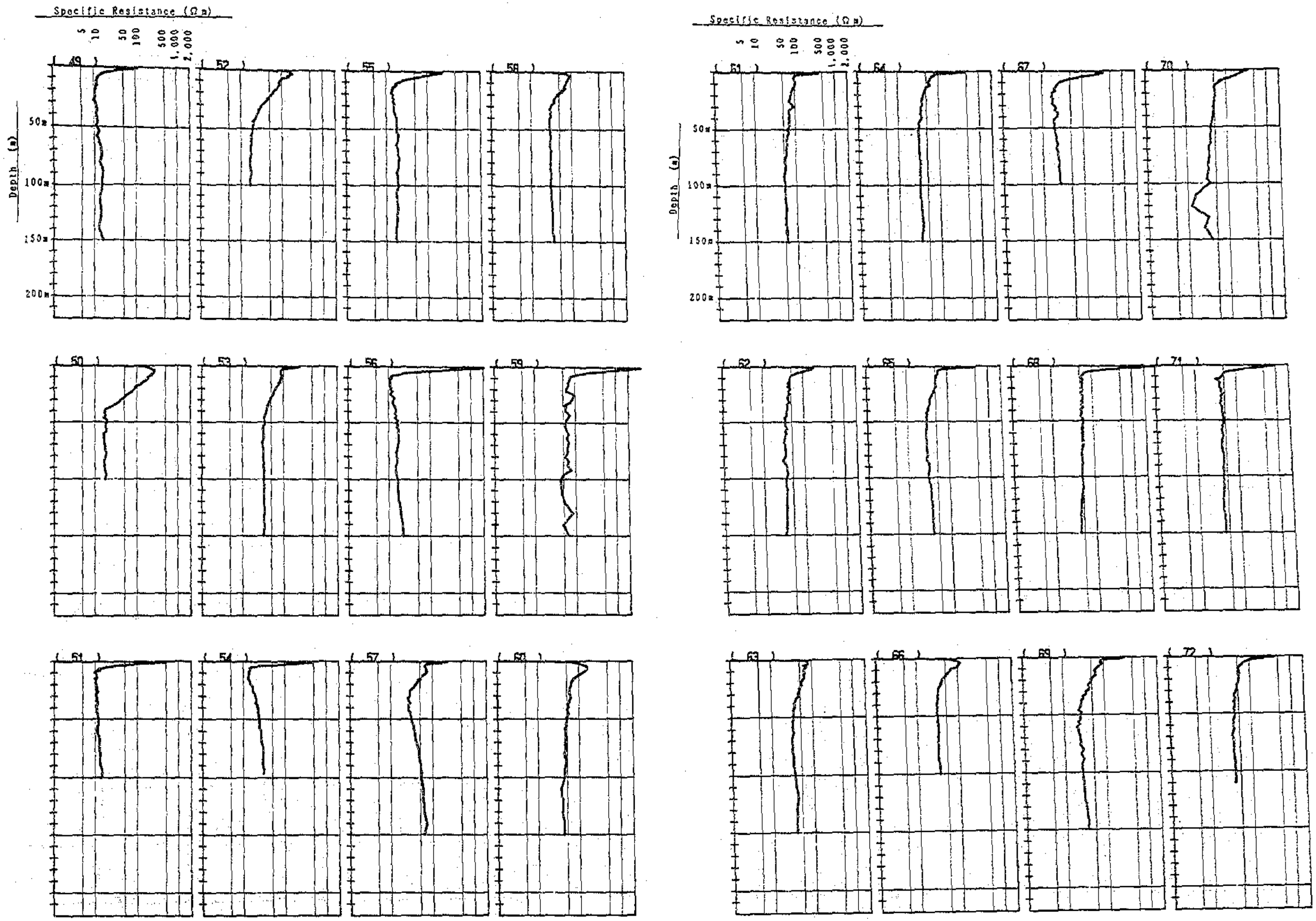


Fig. B.1.4 ρ-a Curve of Electric Potential (3)

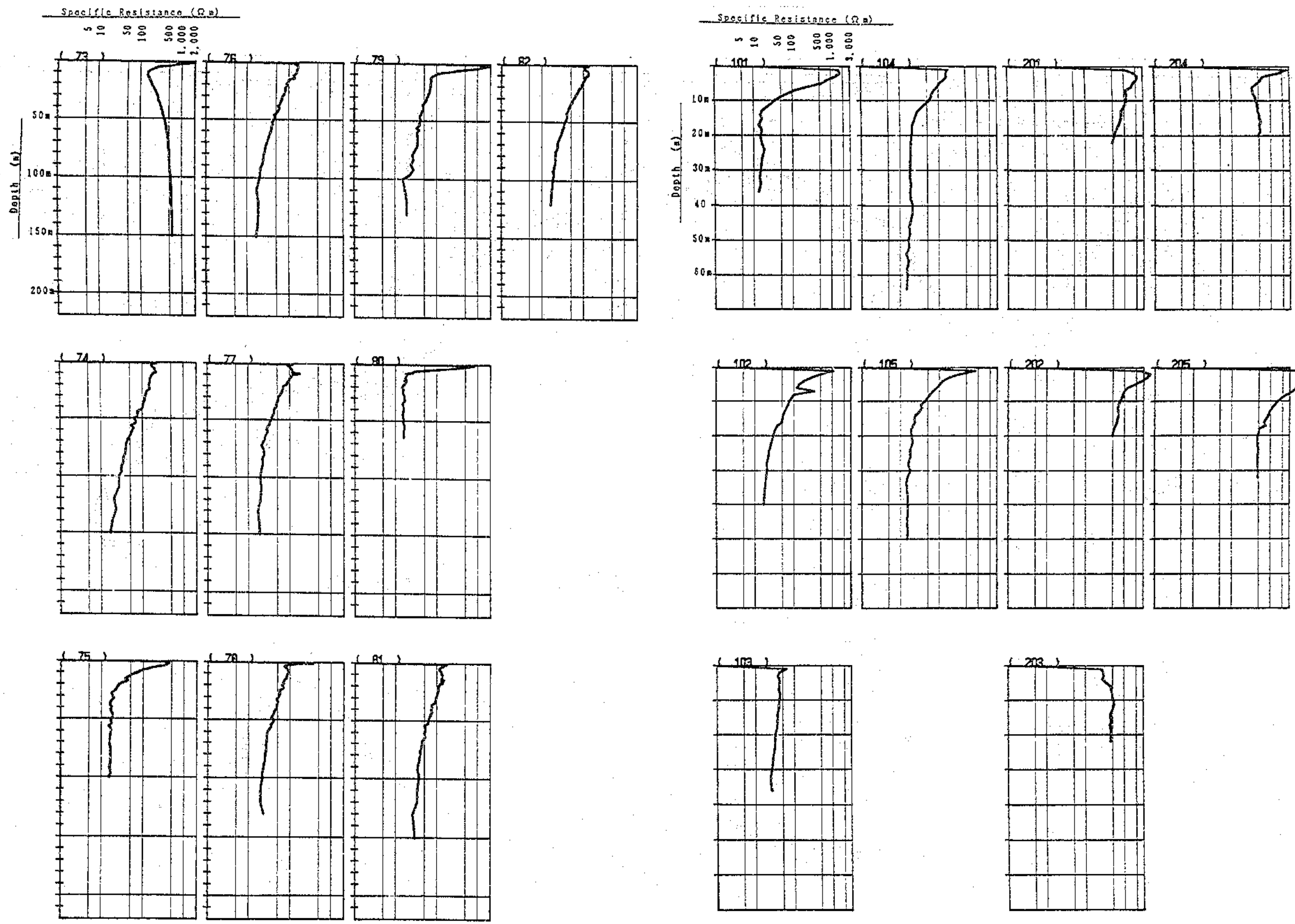


Fig. B.1.4 ρ-a Curve of Electric Potential (4)

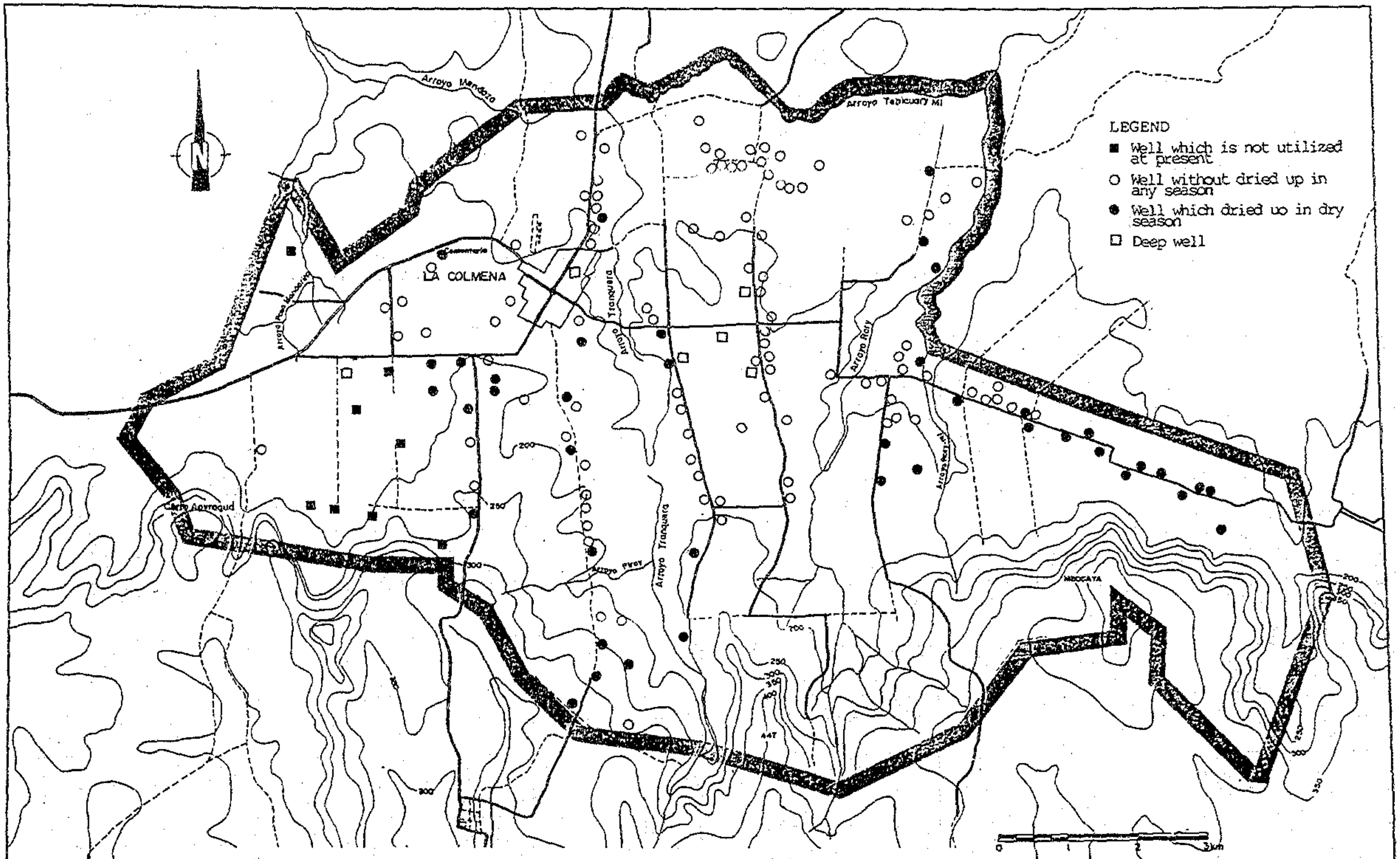


Fig. B.1.7 Location Map of Well Point (shallow and deep)

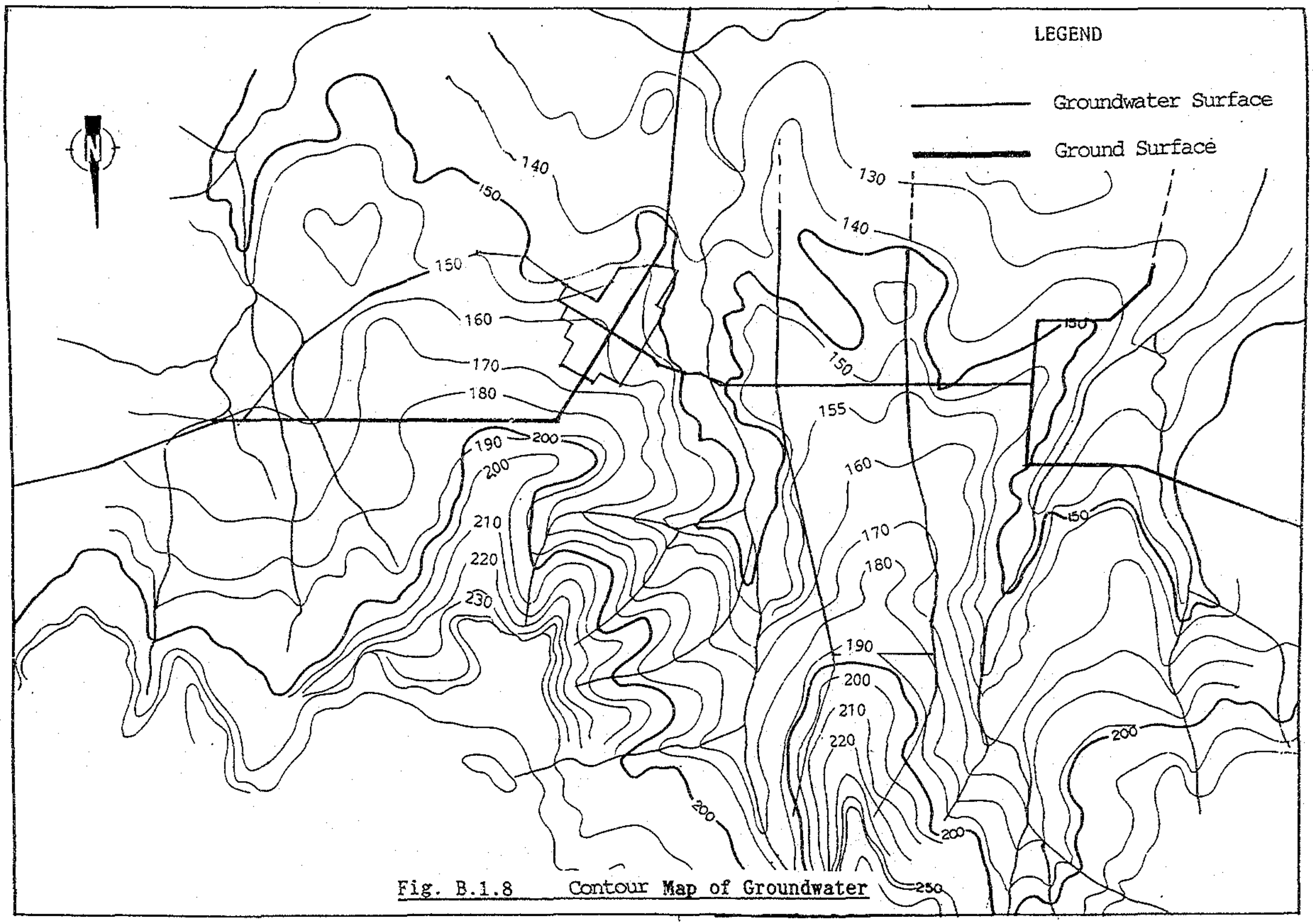


Fig. B.1.8 Contour Map of Groundwater

ANNEX C SOIL AND LAND USE

ANNEX C Soil and Land Use

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ANNEX C. SOIL AND LAND USE

C.1 General

As the preliminary survey had found that the contents of the water soluble salts and the exchangeable sodium in the soils are remarkably low, the measurements about them were omitted after that.

Distribution of the pits are given in Fig. C.1.1.

C.2 Soil Classification

The typical profiles of each series are shown as monoliths in Fig. C.2.1 and the brief description on them are given as below.

The distribution area of the soil types at each basin and administrative section is given in Table C.2.1, C.2.2 (1) and (2) respectively.

Description of the Soil Profiles

The U.CM series

Pit No. 4 : Located in Fatima, hillside with gentle slope with 240 m in elevation, upland field (cotton).

Ap: 0-24 cm : Sand, very fine gravel common, dull reddish brown (5YR 4/3.5). Organic matter (OM) few, no structure (NS) friable, hardness (16) gradual boundary, 0 - 8 cm: extremely dry.

Bt: 24-140 + cm : Sandy loam, very fine gravel common, dark red (10R 3/6), O.M. few, weakly subangular blocky (W.s AB) friable, hardness (19). Increasing very fine gravel and fine particles gradually with depth below 140 cm, gravely layer and at 190 cm, rock bed.

Pit No. 21 : Located in Rory, flate land with 140 m in elevation, upland field (no cropping).

Ap: 0-31 cm : Sand, no gravel, dull reddish brown (5YR 5/2.5 - 5YR 5/4). O.M. common, N.S., friable, hardness (16 - 22).

0 - 5 cm : extremely dry
16 - 31 cm: harder than upper and below layers gradual boundary.

Bt_1: 31-61 cm : Sandy loam, no gravel, dull reddish brown (5YR 5/4), O.M. common, W.s AB, friable, hardness (16), gradual boundary.

Bt_2 61-115 + cm : Sandy loam, no gravel, reddish brown (2.5YR 4/5), O.M. common, moderate (M) s AB, friable, hardness (10), fine particles increase gradually with depth, below about 135 cm clay layer appears.

<u>The U.Fa series</u>

<u>Pit No. 10</u> : Located in Ybaroty, flate grassland with 180 m in elevation.

A_1: 0-15 cm : Sandy loam, no gravel, dull reddish brown (5YR 4/3), O.M. few, W. s AB, friable, hardness (10), very fine - fine root many, gradual boundary.

ABt_1:15-33 cm : Loamy sand, no gravel, dark reddish brown (5YR 4/4), O.M. few, M. s AB very firm, hardness (28) obviously harder than upper and below layers, very fine root many, gradual boundary.

Bt_1: 33-90 : Loamy sand, no gravel, dark reddish brown (10R 3/3.5), O.M. few, M. s AB, firm, hardness (20) very fine root common, gradual boundary.

Bt_2: 90-128 + cm: Sandy clay loam, no gravel, dark red (10R 3/5), O.M. few, strong (S) s AB, very firm, sticky, hardness (28), fine particles and sticky increase with depth.

<u>Pit No. 20</u> : Located in Rory, flate land with 130 m in elevation, orchard (orange).

A_1: 0-19 cm : Sandy loam, no gravel, grayish brown (7.5YR 4/2), O.M. few, N.S., very friable, hardness (25), fine root common, gradual boundary.

A_2: 19-60 cm : Sandy loam, no gravel, almost similar to A_1 except color, brown (7.5YR 4/5).

Bt: 60-115 cm : Clay loam, no gravel, dark red (10R 3/4), O.M. few,