Table B-III, 2.5 Estimation of Groundwater Storage

<Estimacion de Reservas de Agua Subterraneas>

DEPTH (mBSL)	ZONE 1 (Sect. A-B) (x million m3)		ZONE2 (SECT. B-C) (x million m3)		ZONE 3 (Sect. C-D) (x million m3)		ZONE4 (Sect.D-E) (x million m3)		ZONE 5 (Sect. E-F) (x million m3)		ZONE 6 (Sect. F-G) (x million m3)		ZONE 7 (Sect. G-H) (x million m3)		ZONE 8 (Sect. H-I) (x million m3)		ZONE 9 (Sect. I-J) (x million m3)		ZONE 10 (Sect. J-K) (x million m3)		ZONE 11 (Sect. K-L) (x million m3)		ZONE 12 (Sect.L-C.Gordo) (x million m3)		TOTAL (Whole Area) (x million m3)	
		SUM		SUM		SUM		SUM		SUM		SUM		SUM		SUM		SUM		SUM		SUM		SUM		SUM
10	537	537	128	128	163	163	161	161	175	175	68	68	113	113	229	229	74	74	153	153	351	351	161	161	2,316	2,316
20	502	1,039	120	248	154	317	154	315	169	344	67	135	110	223	224	453	116	190	218	371	321	672	160	321	2,317	4,633
30	460	1,499	109	357	144	461	147	462	163	507	65	200	107	330	221	674	116	306	209	580	305	977	156	477	2,204	6,837
40	425	1,924	99	456	130	591	135	597	156	663	64	264	105	435	218	892	116	422	205	785	294	1,271	152	629	2,102	8,939
50	404	2,328	92	548	110	701	115	712	147	810	62	326	103	538	215	1,107	116	538	198	983	281	1,552	148	777	1,991	10,930
60	365	2,693	86	634	78	779	83	795	136	946	60	386	101	639	213	1,320	115	653	193	1,176	271	1,823	145	922	1,848	12,778
70	330	3,023	80	714	43	822	49	844	126	1,072	58	444	99	738	211	1,531	115	768	191	1,367	262	2,085	140	1,062	1,704	14,482
80	249	3,272	71	785	33	855	47	891	119	1,191	56	500	98	836	207	1,738	115	883	188	1,555	251	2,336	132	1,194	1,567	16,049
90	163	3,435	50	835	12	867	44	935	111	1,302	54	554	96	932	205	1,943	114	997	185	1,740	235	2,571	122	1,316	1,393	17,442
100	123	3,558	31	866	0	867	41	976	104	1,406	53	607	94	1,026	203	2,146	114	1,111	181	1,921	214	2,785	108	1,424	1,268	18,710
110	80	3,638	20	886	0	867	37	1,013	96	1,502	51	658	93	1,119	202	2,348	114	1,225	177	2,098	193	2,978	94	1,518	1,157	19,867
120	0	3,638	0	886	0	867	31	1,044	88	1,590	49	707	92	1,211	200	2,548	113	1,338	171	2,269	173	3,151	50	1,568	967	20,834
130	0		0	886	0	867	13	1,057	69	1,659	48	755	90	1,301	198	2,746	113	1,451	154	2,423	133	3,284	41	1,609	859	21,693
140	0	0	0	886	0	867	0	1,057	56	1,715	47	802	88	1,389	195	2,941	112	1,563	137	2,560	62	3,346	15	1,624	714	22,407
150	0	0	0	886	0	867	0	1,057	54	1,769	46	848	86	1,475	193	3,134	111	1,674	131	2,691	26	3,372	0	1,624	647	23,054
160	0	0	0	886	0	867	0	1,057	52	1,821	45	893	84	1,559	189	3,323	109	1,783	123	2,814	19	3,391	0	1,624	621	23,675
170	0	0	0	886	0	867	0	1,057	50	1,871	43	936	82	1,641	183	3,506	106	1,889	112	2,926	7	3,398	0	1,624	586	24,261
180	0	0	0	886	0	867	0	1,057	48	1,919	42	978	80	1,721	178	3,684	103	1,992	104	3,030	0	3,398	0	1,624	556	24,817
190	0	0	0	886	0	867	0	1,057	46	1,965	41	1,019	78	1,799	171	3,855	100	2,092	101	3,131	0	3,398	0	1,624	537	25,354
200	0	0	0	886	0	867	0	1,057	43	2,008	37	1,056	71	1,870	163	4,018	95	2,187	98	3,229	0	3,398	0	1,624	508	25,862
210	0	0	0	886	0	867	0	1,057	40	2,048	30	1,086	61	1,931	153	4,171	88	2,275	91	3,320	0	3,398	0	1,624	464	26,326
220	0	0	0	886	0	867	0	1,057	29	2,077	22	1,108	52	1,983	134	4,305	70	2,345	67	3,387	0	3,398	0	1,624	374	26,700
230	0	0	0	886	0	867	0	1,057	0	2,077	8	1,116	38	2,021	80	4,385	28	2,373	24	3,411	0	3,398	0	1,624	178	26,878
240	0	0	0	886	0	867	0	1,057	0	2,077	0	1,116	10	2,031	20	4,405	0	2,373	0	3,411	0	3,398	0	1,624	30	26,908
	3,638		886		867		1,057		2,077		1,116		2,031		4,405		2,373		3,411		3,398		1,624		26,908	

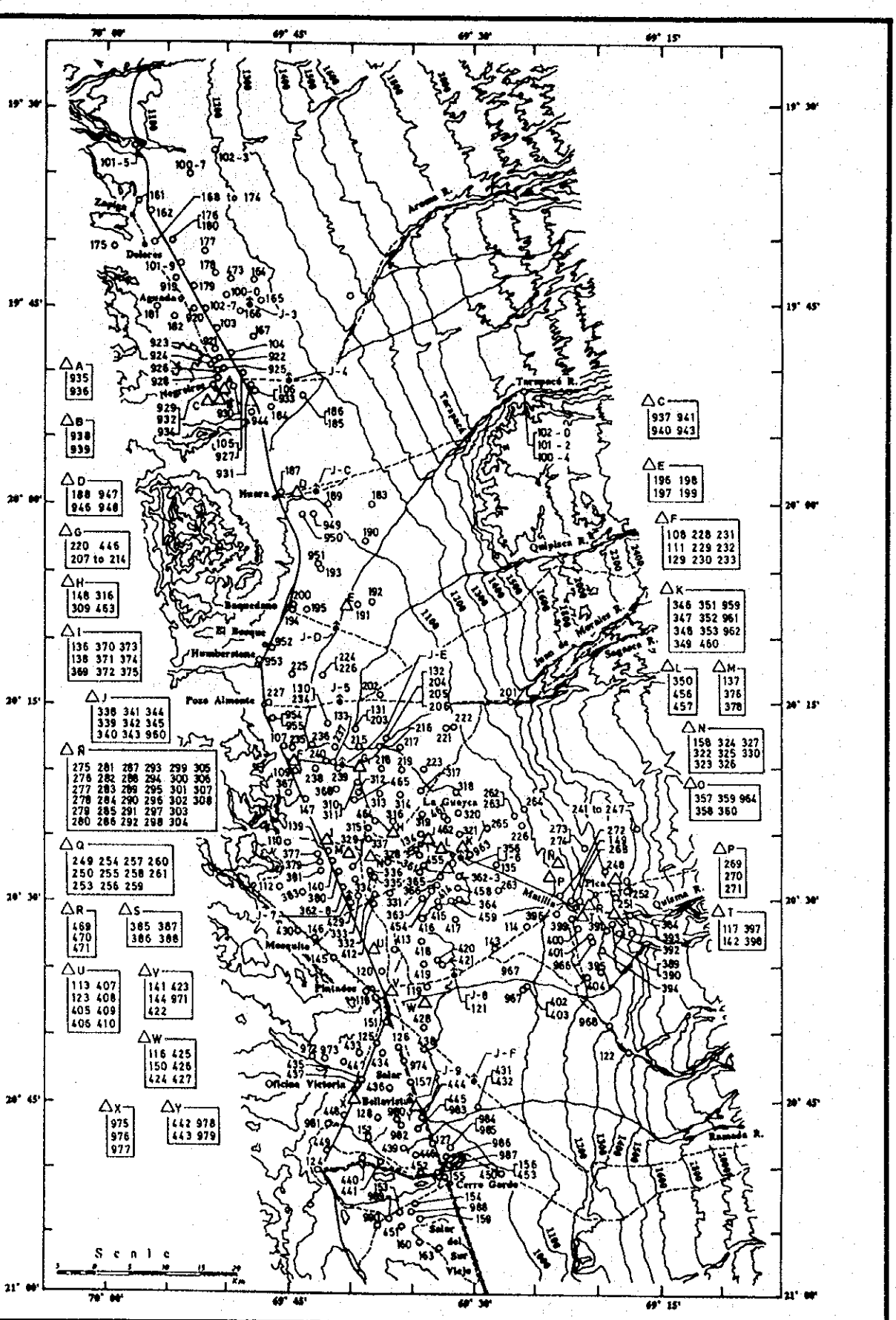


Fig. B-III. 2.1 (1) Well Location (Pampa del Tamarugal)

< Ubicación de Sondajes (Pampa del Tamarugal)>

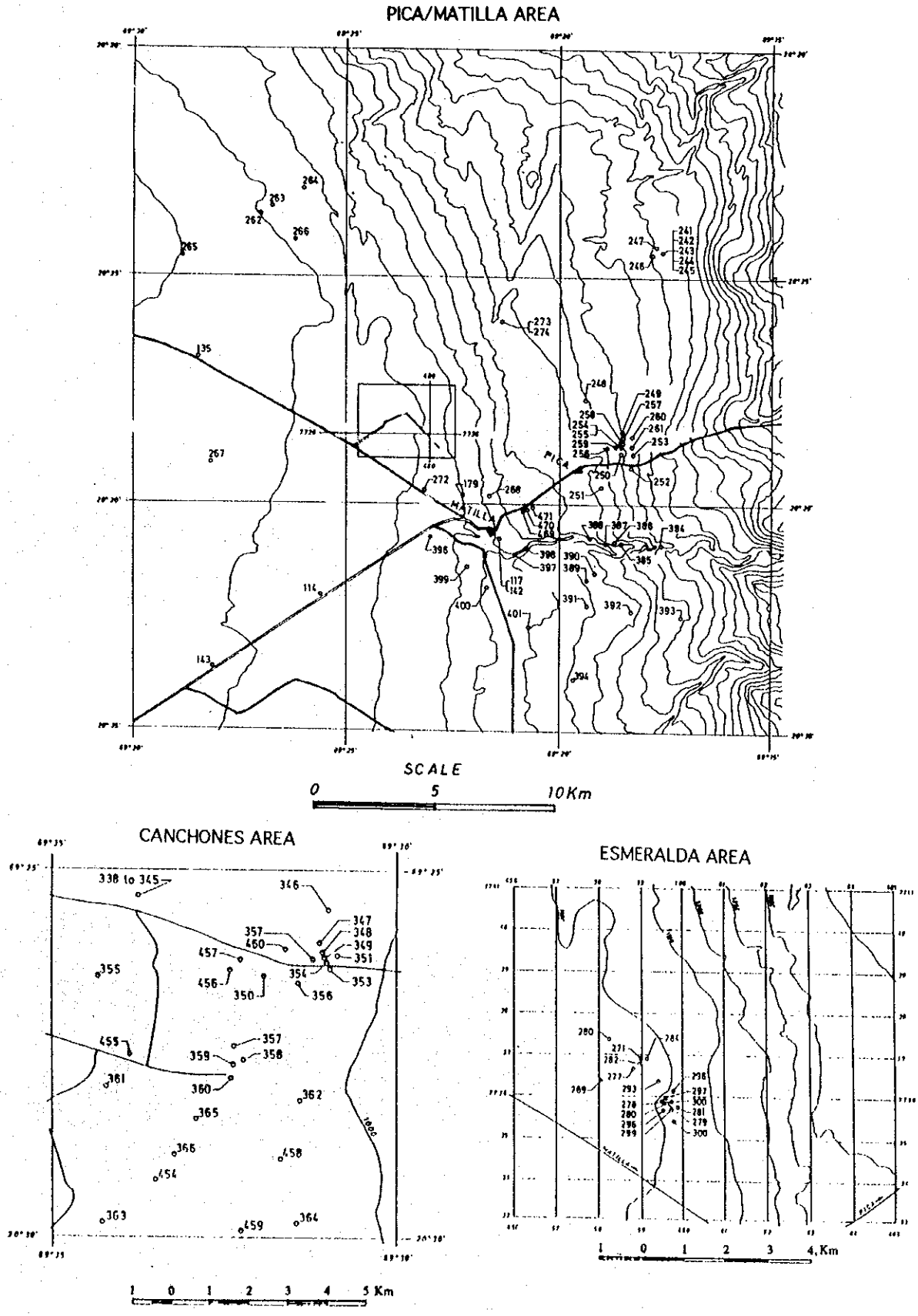
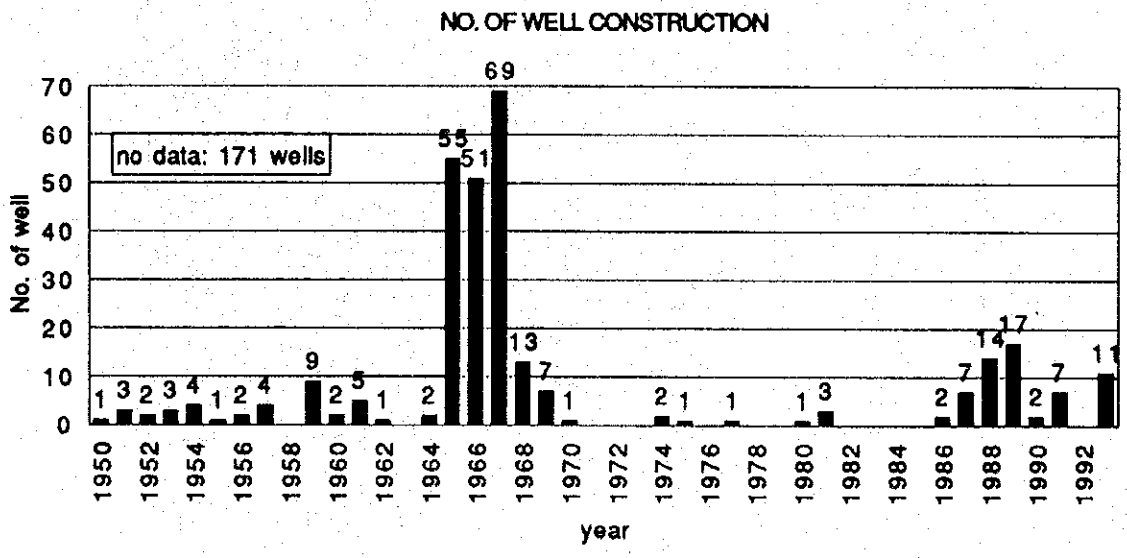


Fig. B-III. 2.1 (2) Well Location (Canchones and Pica Area)

< Ubicación de Sondajes (Area de Canchones y Pica)>



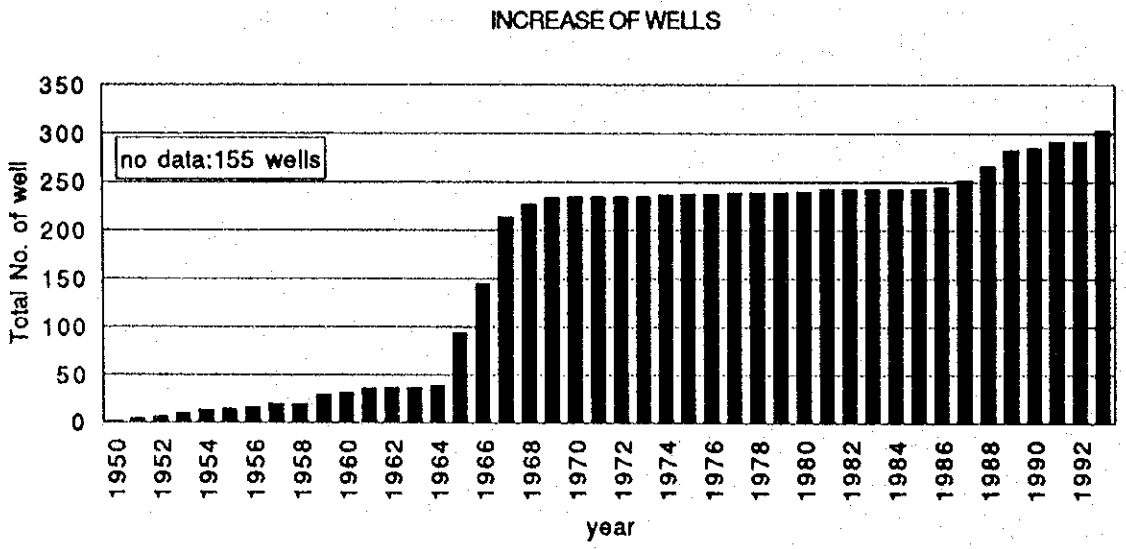


Fig. B-III. 2.2 Well Construction (Pampa del Tamarugal)

< Construcción de Sondajes (Pampa del Tamarugal)>

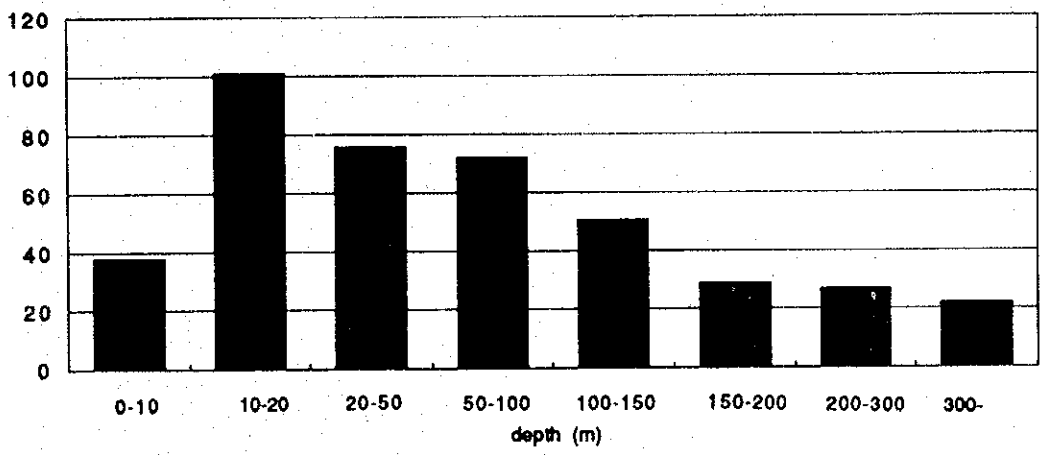


Fig. B-III, 2.3 Depth of Well (Pampa del Tamarugal)

<Profundidad de Pozos (Pampa del Tamarugal)>

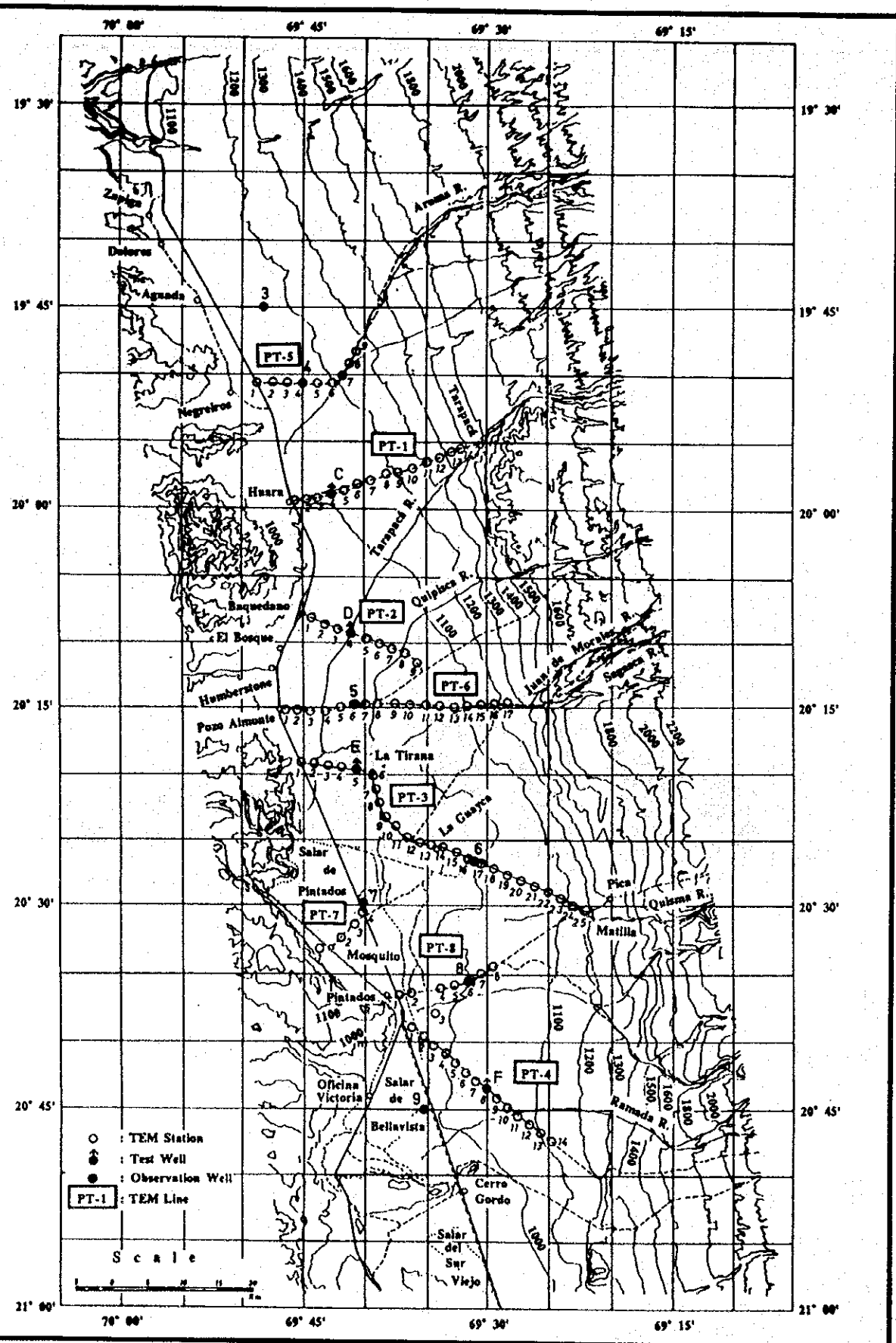


Fig. B-III, 2.4 Location of TEM Station and Test/Observation Well (Pampa del Tamarugal)

< Ubicación de las Estaciones TEM y pozos de Prueba y Observación (Pampa del Tamarugal)>

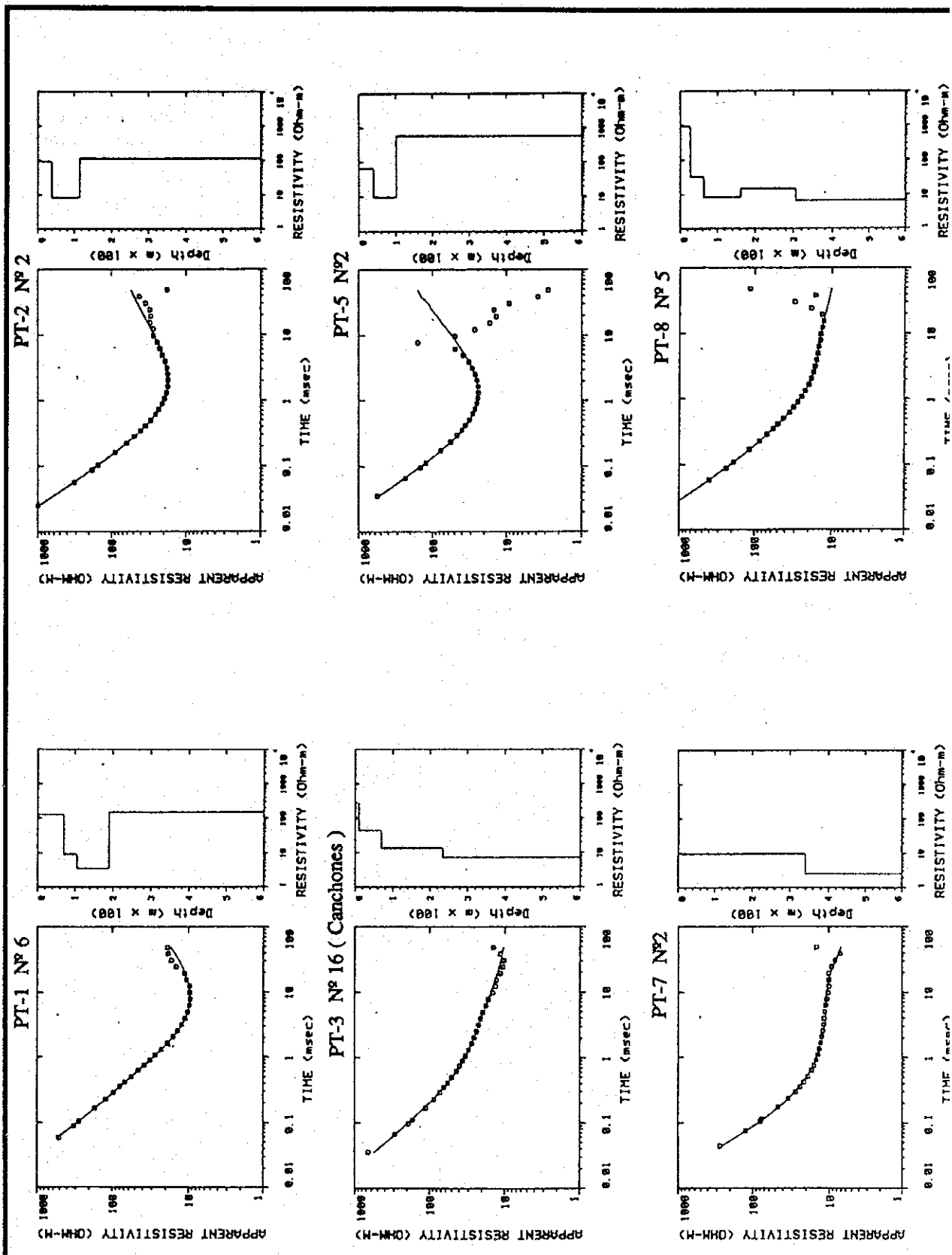


Fig. B-III, 2.5 Measured Apparent Resistivity Curves and Inverted Geoelectrical Section in Pampa del Tamarugal Area

< Curvas de Resistividad Aparente Medidas y Secciones Geoeléctricas Invertidas en el Area de la Pampa del Tamarugal >

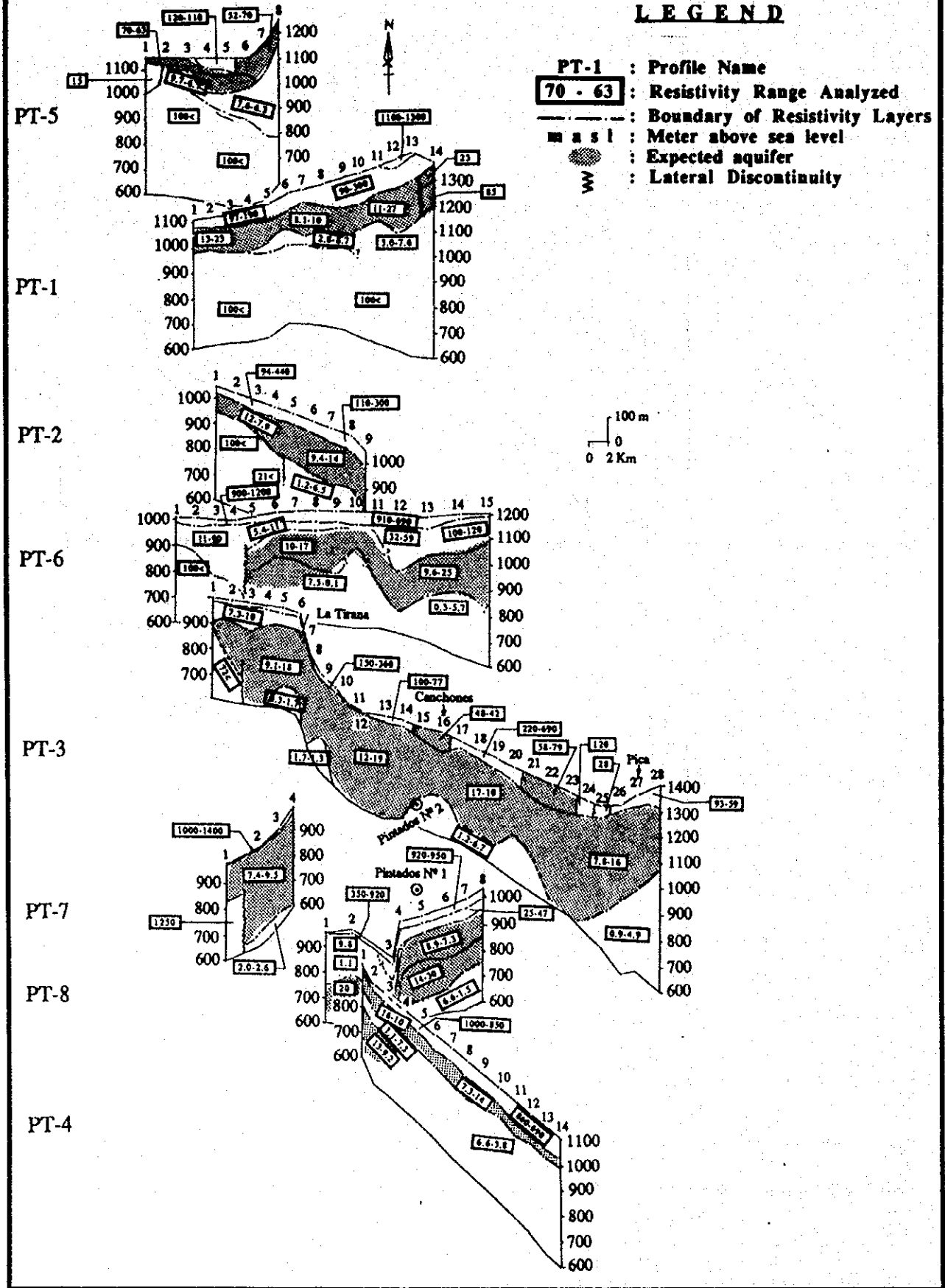


Fig. B-III, 2.6 Geoelectric Profiles Contructed from all TEM Soundings in Pampa del Tamarugal Area

< Perfiles Geoeléctricos Construídos de todos los Sondeos TEM del Area de la Pampa del Tamarugal >

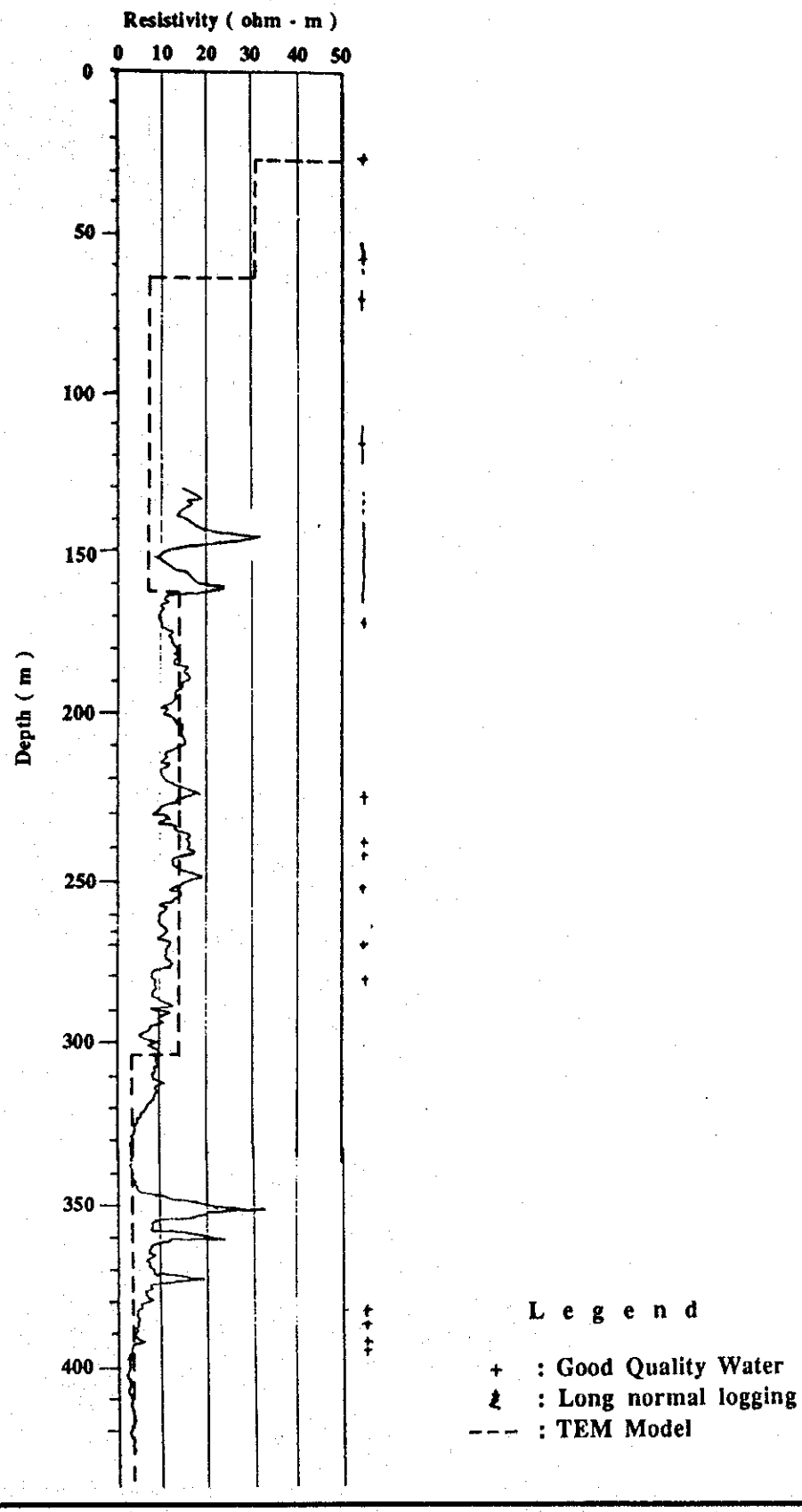
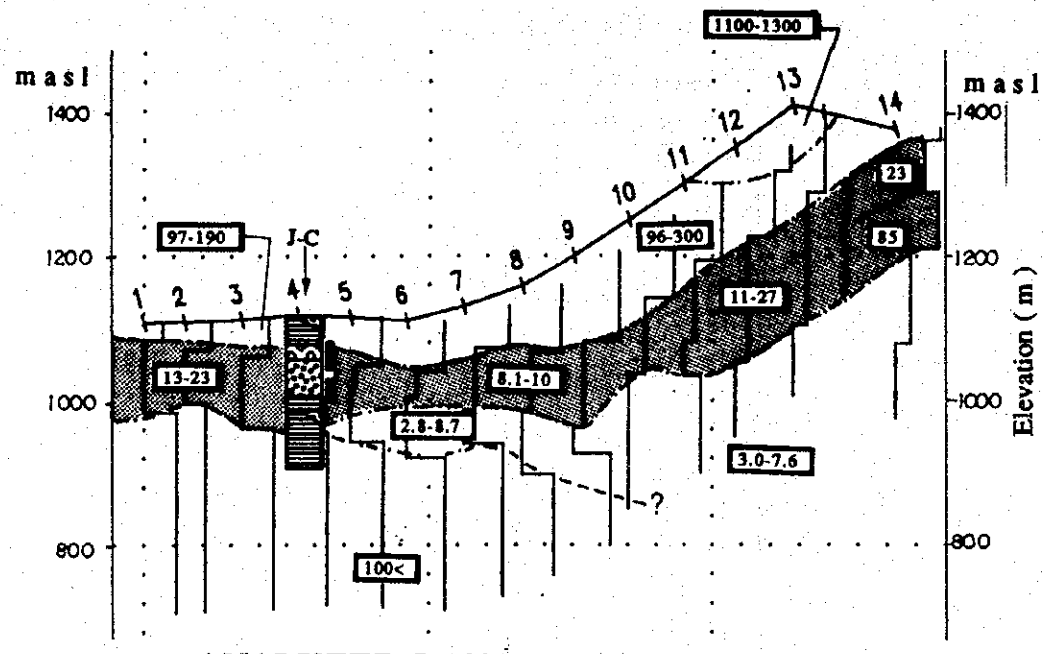
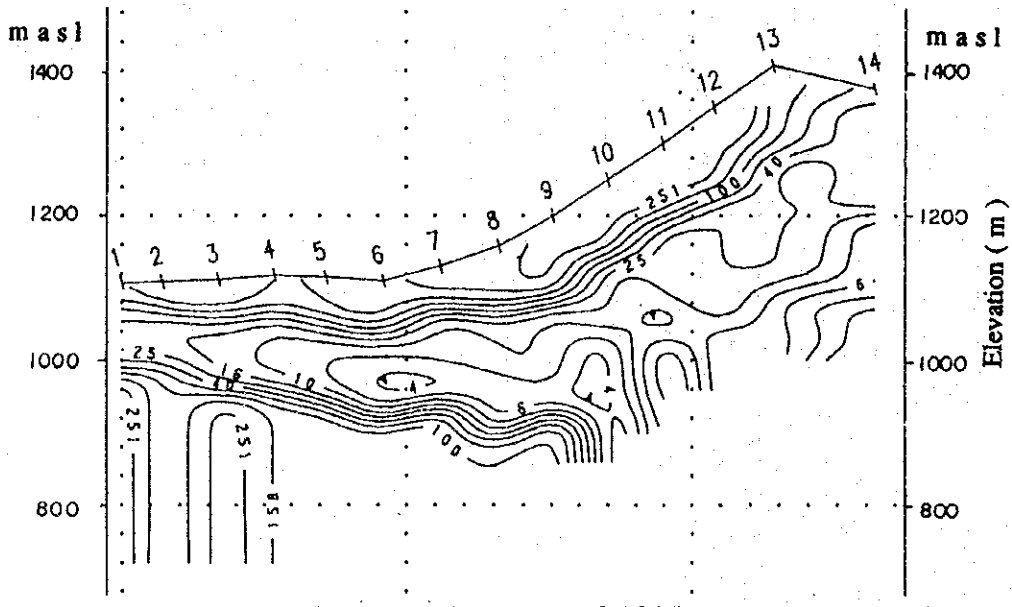


Fig. B-III, 2.7 Comparison of Geoelectric Section Derived from Well and TEM Sounding

< Comparación de la Sección Geoeléctrica derivada de Sondeo de Pozo y Sondeo TEM >



ANALYZED LAYERED MODEL



RESISTIVITY INVERSION

LEGEND

1, 2, 3	: TEM Station Nº
11 - 27	: Resistivity Range Analyzed
——·——·——	: Boundary of Resistivity Layers
m a s l	: Meter above sea level
	: Expected aquifer
J-C	: Well Constructed by JICA

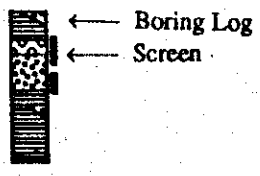
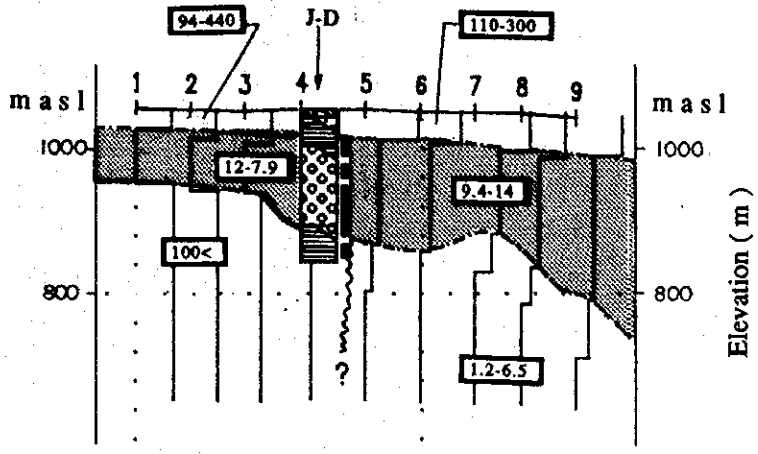
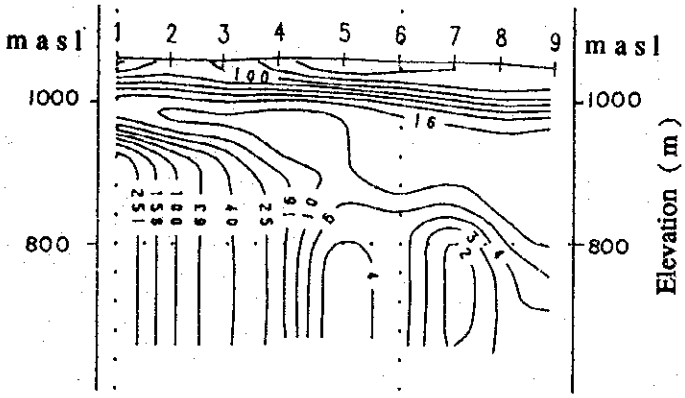


Fig. B-III, 2.8 Analyzed Resistivity Profile of PT-1 in Pampa del Tamarugal Area

< Perfil de Resistividad Analizado del PT-1 en el Area de la Pampa del Tamarugal >



ANALYZED LAYERED MODEL



RESISTIVITY INVERSION

LEGEND

1, 2, 3	: TEM Station Nº
12 - 9.9	: Resistivity Range Analyzed
——·——·——	: Boundary of Resistivity Layers
m a s l	: Meter above sea level
	: Expected aquifer
J-D	: Well Constructed by JICA
	: Lateral Discontinuity

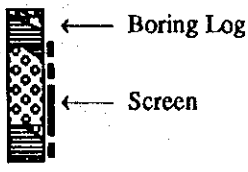


Fig. B-III, 2.9 Analyzed Resistivity Profile of PT-2 in Pampa del Tamarugal Area

< Perfil de Resistividad Analizado del PT-2 en el Area de la Pampa del Tamarugal >

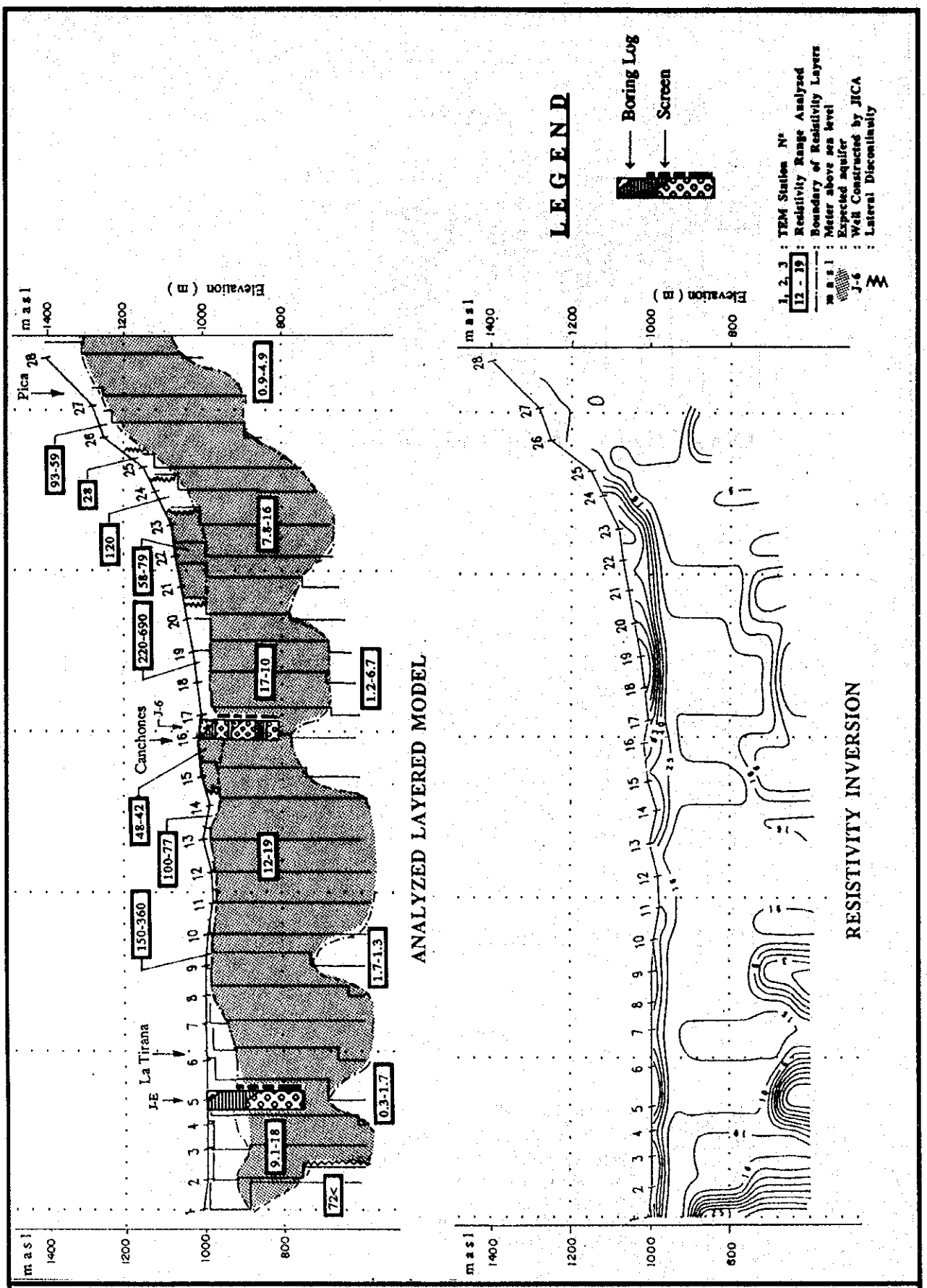
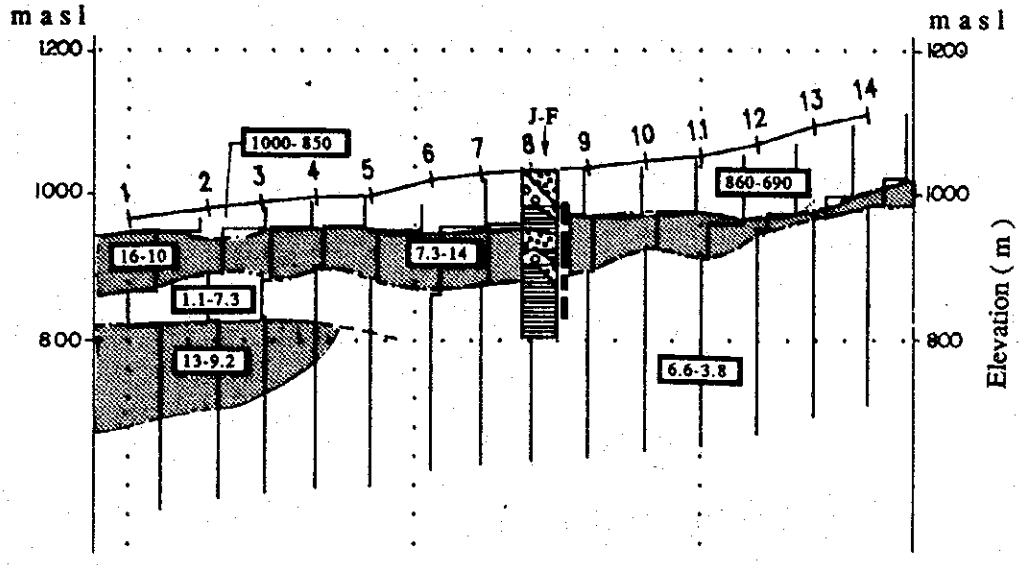
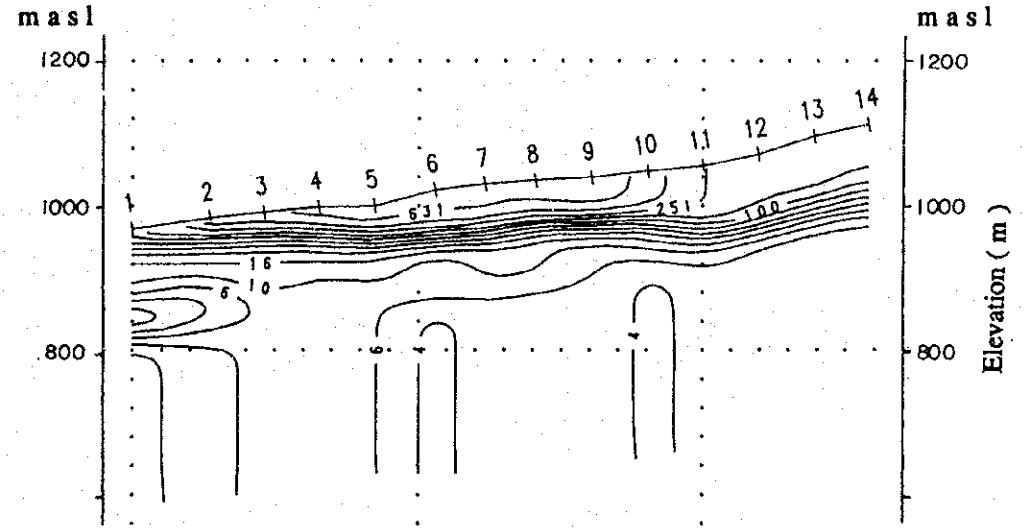


Fig. B-III, 2.10 Analyzed Resistivity Profile of PT-3 in Pampa del Tamarugal Area

< Perfil de Resistividad Analizado del PT-3 en el Area de la Pampa del Tamarugal >



ANALYZED LAYERED MODEL



RESISTIVITY INVERSION

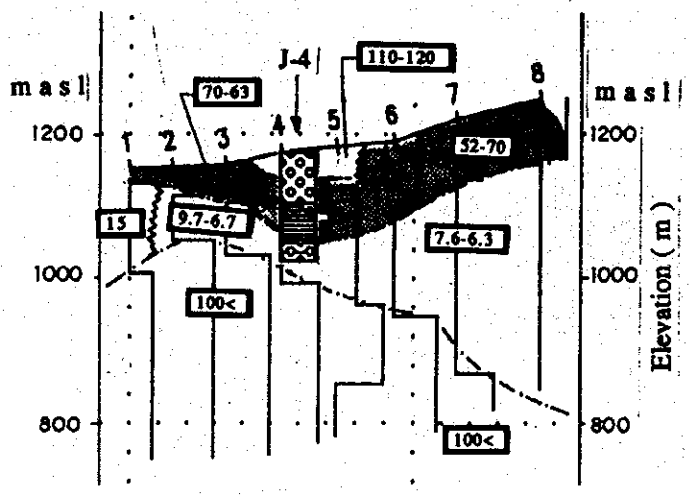
LEGEND

1, 2, 3 : TEM Station Nº
16 - 10 : Resistivity Range Analyzed
: Boundary of Resistivity Layers
m a s l : Meter above sea level
: Expected aquifer
J-F : Well Constructed by JICA
: Lateral Discontinuity

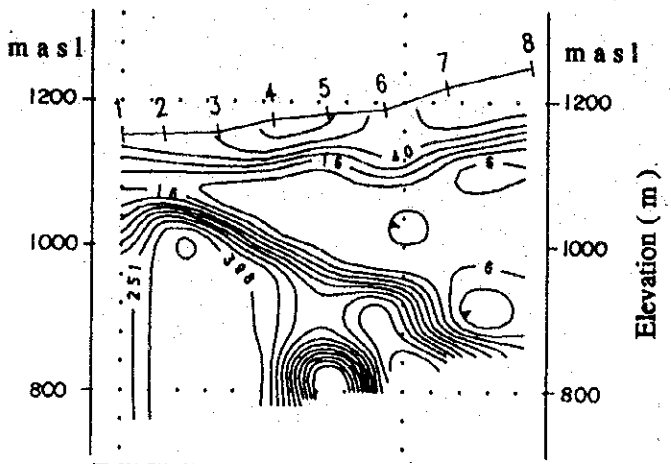
← Boring Log
← Screen

Fig. B-III, 2.11 Analyzed Resistivity Profile of PT-4 in Pampa del Tamarugal Area

< Perfil de Resistividad Analizado del PT-4 en el Area de la Pampa del Tamarugal >



ANALYZED LAYERED MODEL



RESISTIVITY INVERSION

L E G E N D

1, 2, 3	: TEM Station Nº
90 - 63	: Resistivity Range Analyzed
——·——·——	: Boundary of Resistivity Layers
m a s l	: Meter above sea level
	: Expected aquifer
J-4	: Well Constructed by JICA
	: Lateral Discontinuity

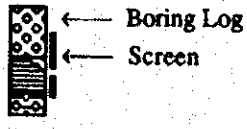
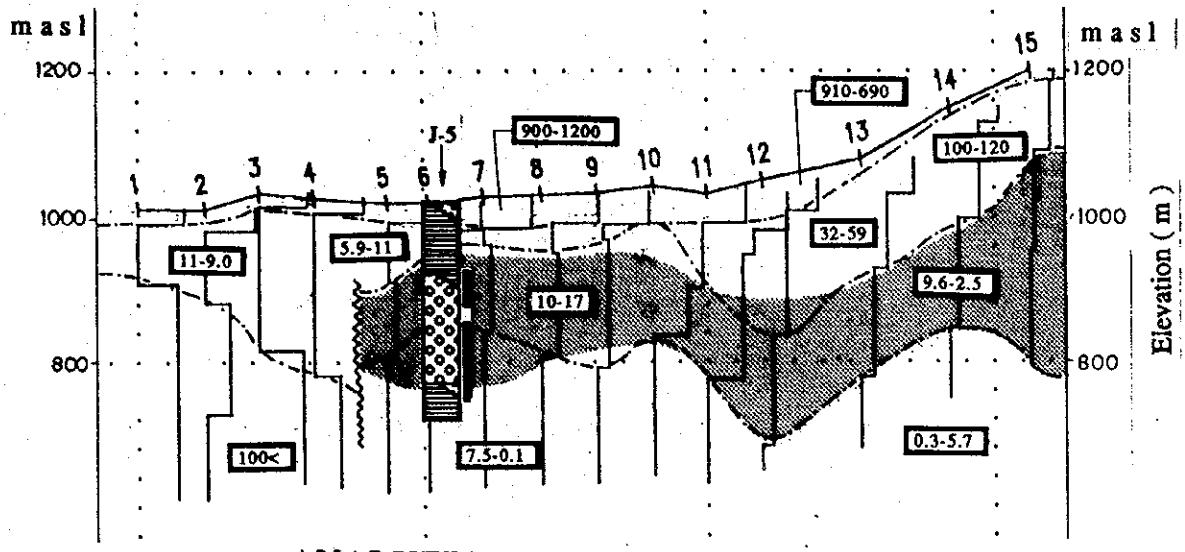
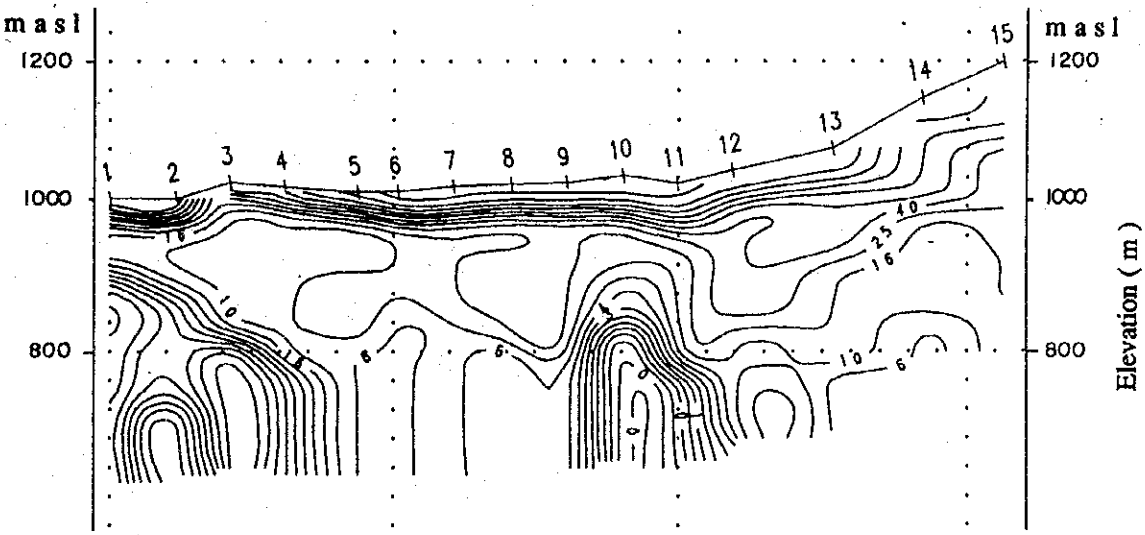


Fig. B-III, 2.12 Analyzed Resistivity Profile of PT-5 in Pampa del Tamarugal Area

< Perfil de Resistividad Analizado del PT-5 en el Area de la Pampa del Tamarugal >



ANALYZED LAYERED MODEL



RESISTIVITY INVERSION

LEGEND

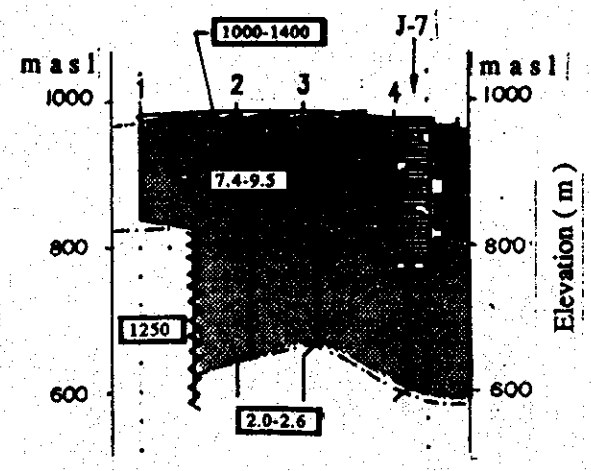
1, 2, 3	: TEM Station Nº
10 - 17	: Resistivity Range Analyzed
——·——·——	: Boundary of Resistivity Layers
masl	: Meter above sea level
	: Expected aquifer
J-5	: Well Constructed by JICA
	: Lateral Discontinuity

← Boring Log

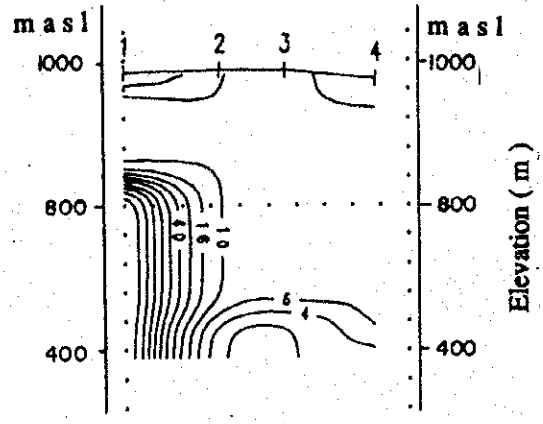
← Screen

Fig. B-III, 2.13 Analyzed Resistivity Profile of PT-6 in Pampa del Tamarugal Area

< Perfil de Resistividad Analizado del PT-6 en el Area de la Pampa del Tamarugal >



ANALYZED LAYERED MODEL



RESISTIVITY INVERSION

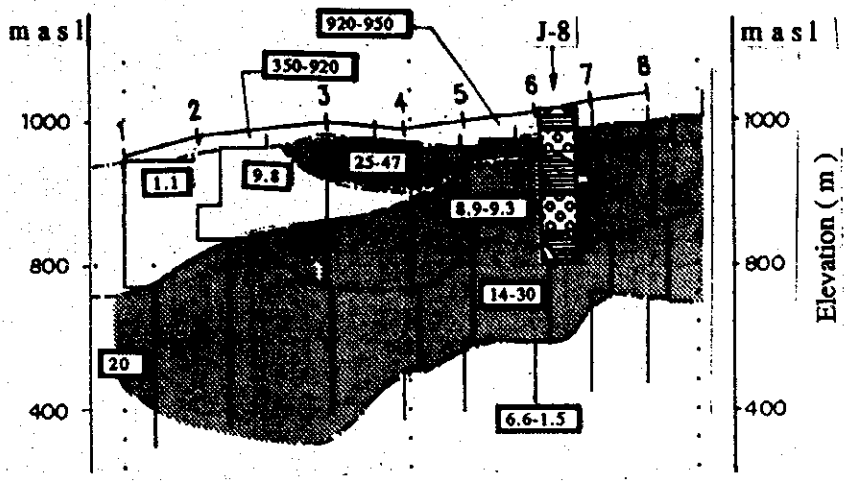
L E G E N D

1, 2, 3	:	TEM Station Nº
7.4 - 9.5	:	Resistivity Range Analyzed
——·——·——	:	Boundary of Resistivity Layers
m a s l	:	Meter above sea level
	:	Expected aquifer
J-7	:	Well Constructed by JICA
	:	Lateral Discontinuity

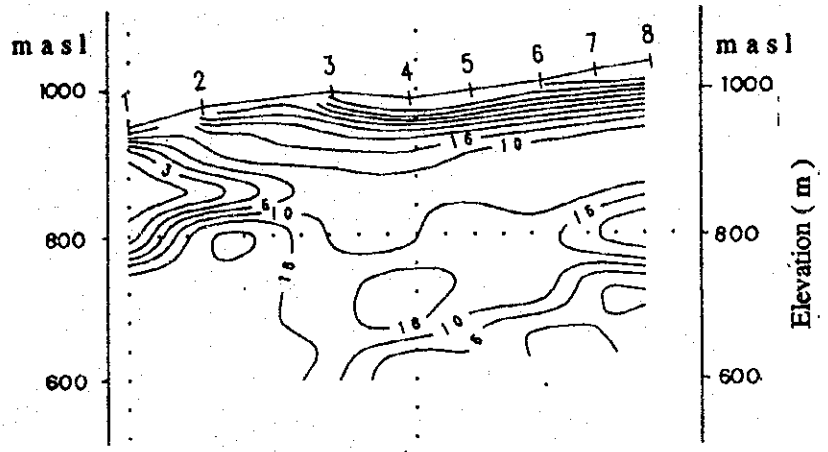
← Boring Log
← Screen

Fig. B-III, 2.14 Analyzed Resistivity Profile of PT-7 in Pampa del Tamarugal Area

< Perfil de Resistividad Analizado del PT-7 en el Area de la Pampa del Tamarugal >



ANALYZED LAYERED MODEL



RESISTIVITY INVERSION

LEGEND

1, 2, 3	: TEM Station Nº
8.9-9.3	: Resistivity Range Analyzed
———	: Boundary of Resistivity Layers
m a s l	: Meter above sea level
	: Expected aquifer
J-8	: Well Constructed by JICA
	: Lateral Discontinuity

← Boring Log
← Screen

Fig. B-III, 2.15 Analyzed Resistivity Profile of PT-8 in Pampa del Tamarugal Area

< Perfil de Resistividad Analizado del PT-8 en el Area de la Pampa del Tamarugal >

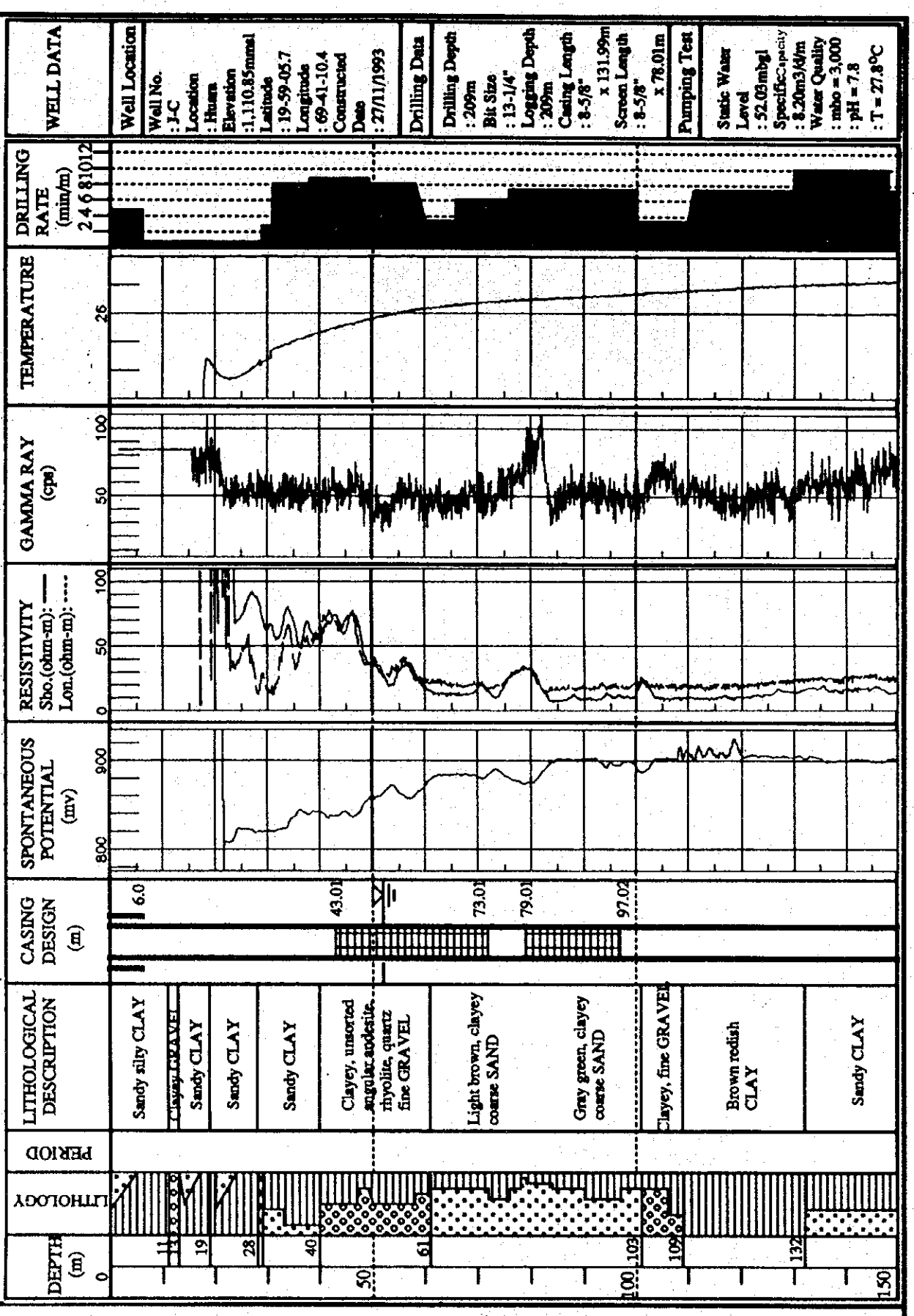


Fig. B-III, 2.16 Well Data for J-C (Sheet No. 1)

< Información del Pozo J-C (Hoja Nº 1) >

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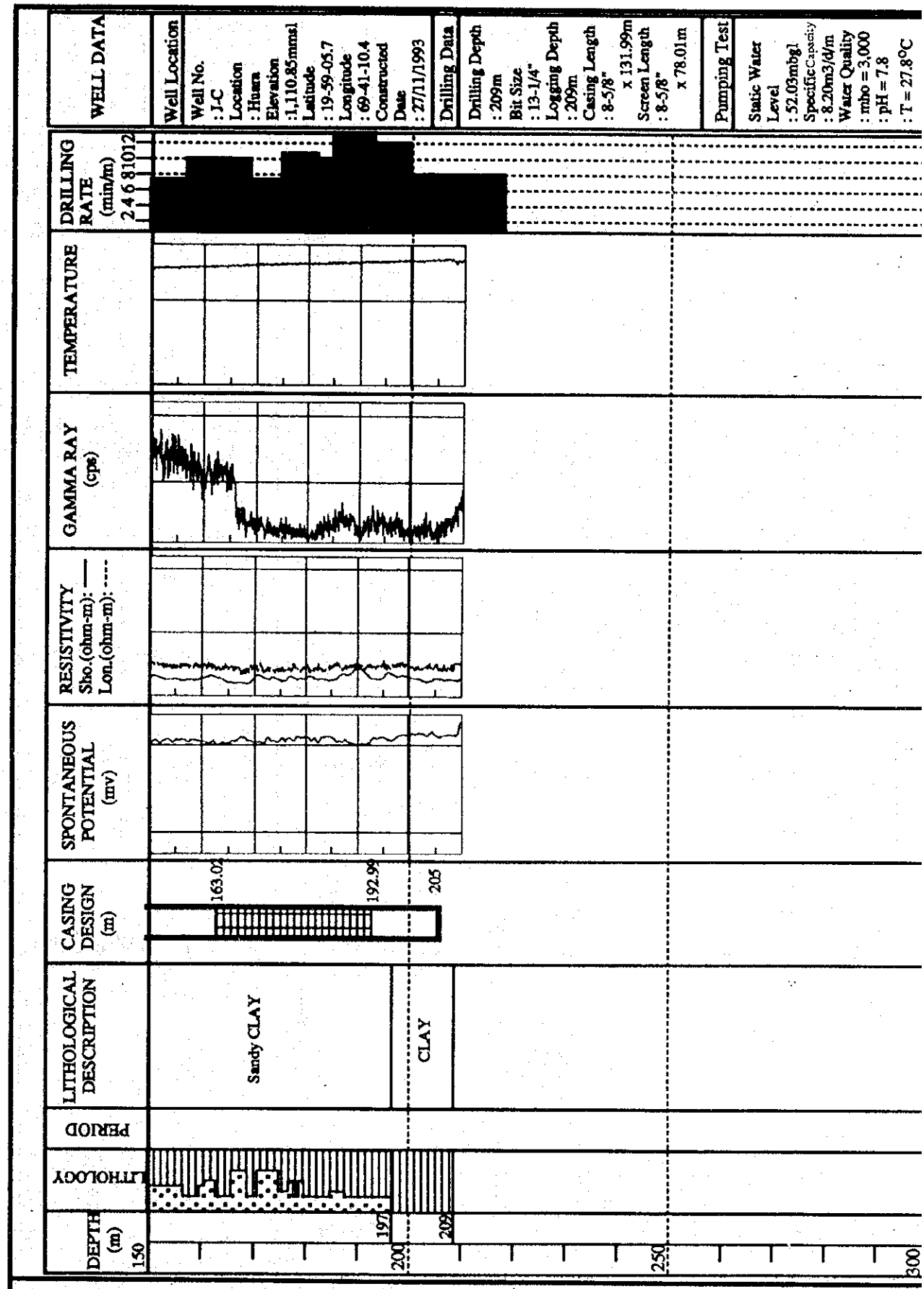

Fig. B-III, 2.16 Well Data for J-C (Sheet No. 2)

< Información del Pozo J-C (Hoja Nº 2) >

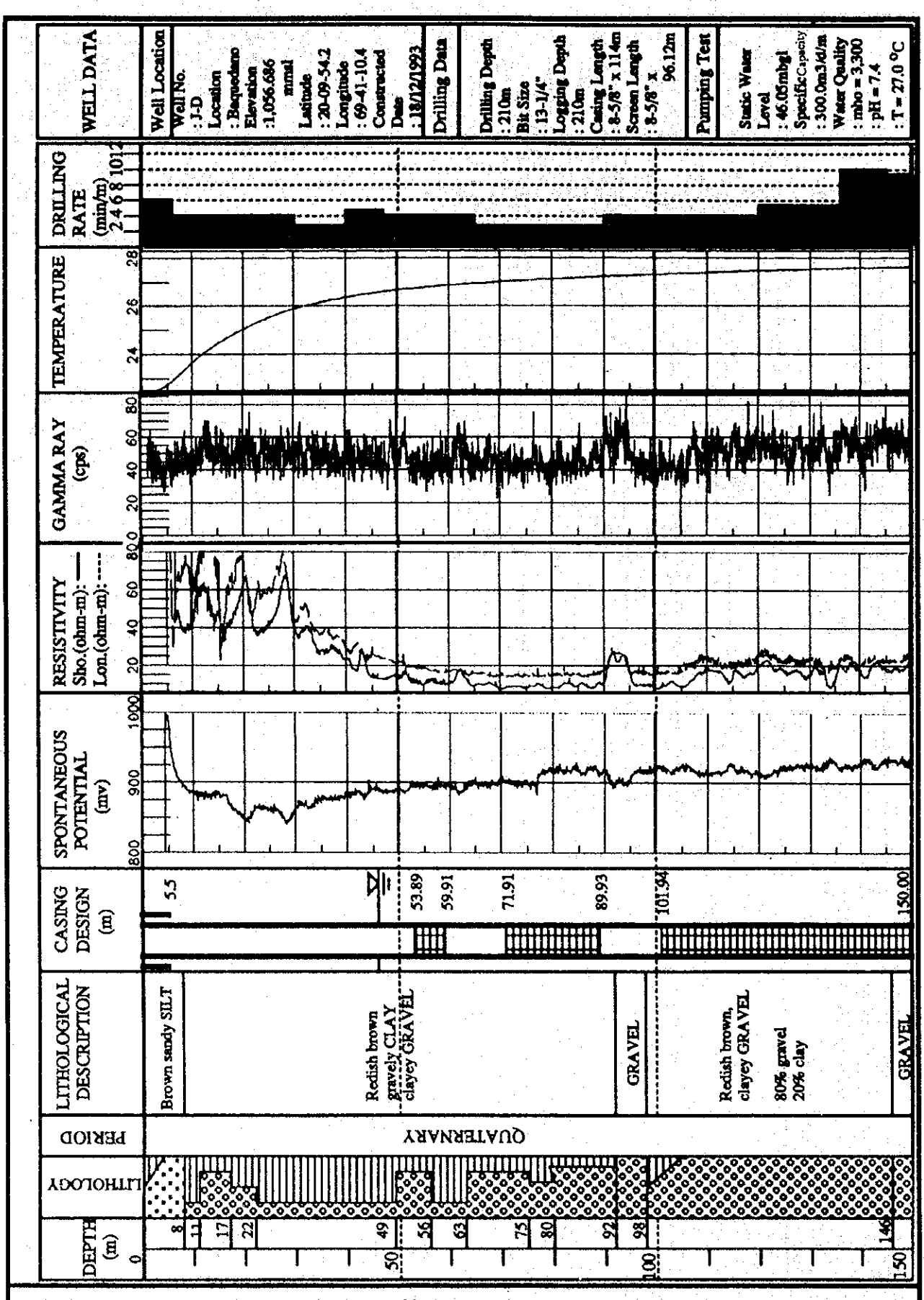

Fig. B-III, 2.17 Well Data for J-D (Sheet No. 1)

< Información del Pozo J-D(Hoja Nº 1) >

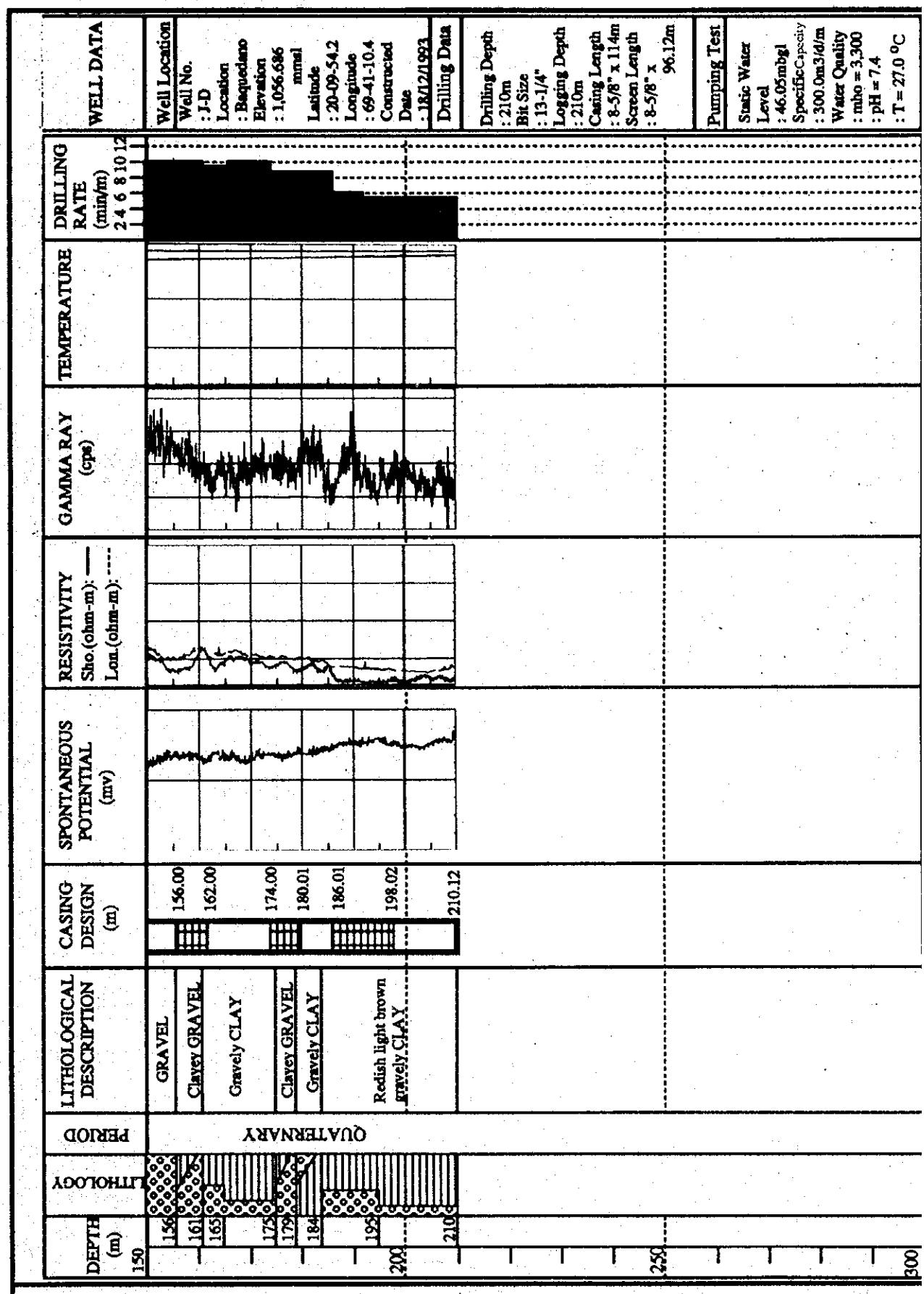

Fig. B-III, 2.17 Well Data for J-D (Sheet No. 2)

< Información del Pozo J-D (Hoja Nº 2) >

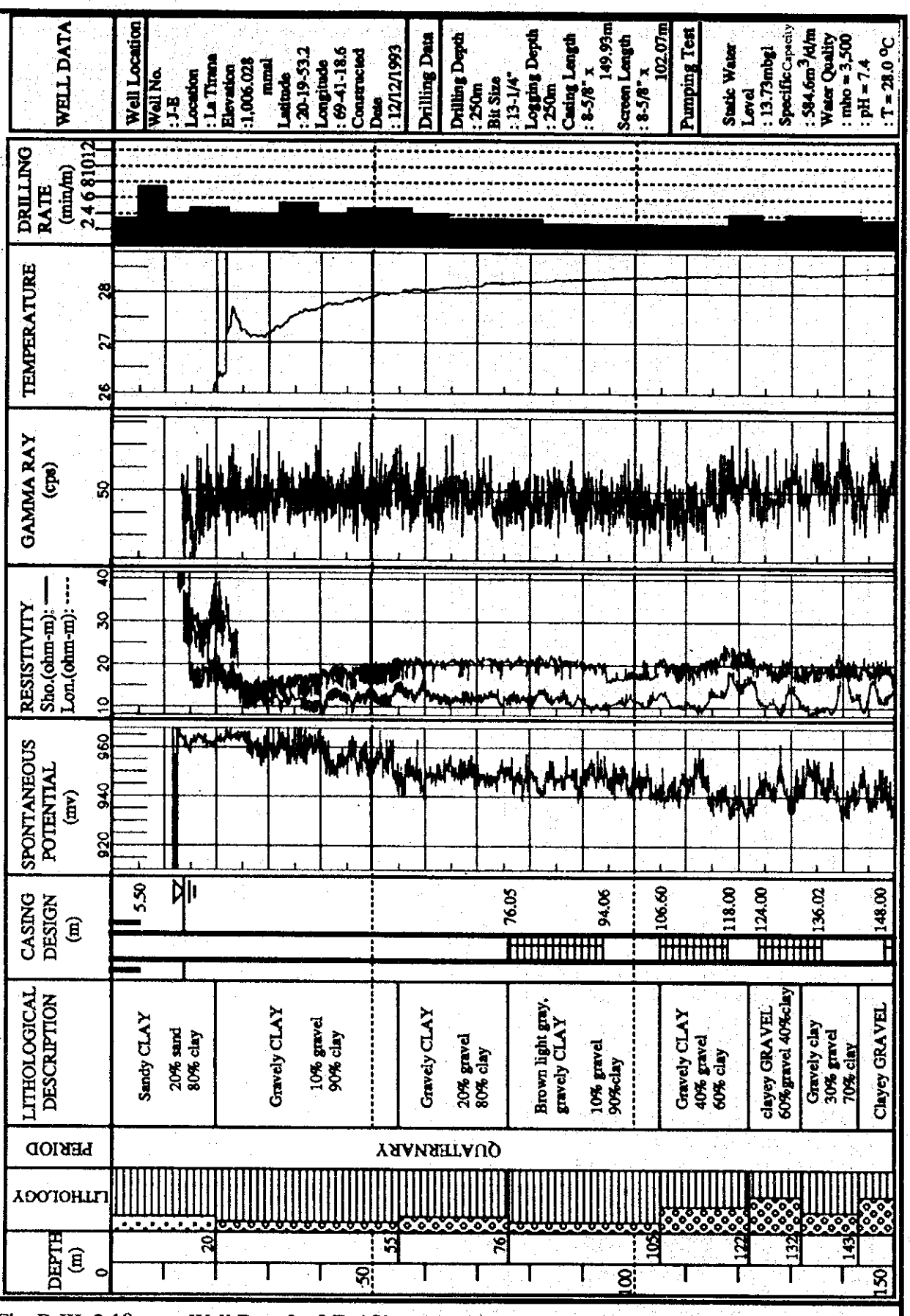

Fig. B-III, 2.18 Well Data for J-E (Sheet No. 1)

< Información del Pozo J-E (Hoja Nº 1) >

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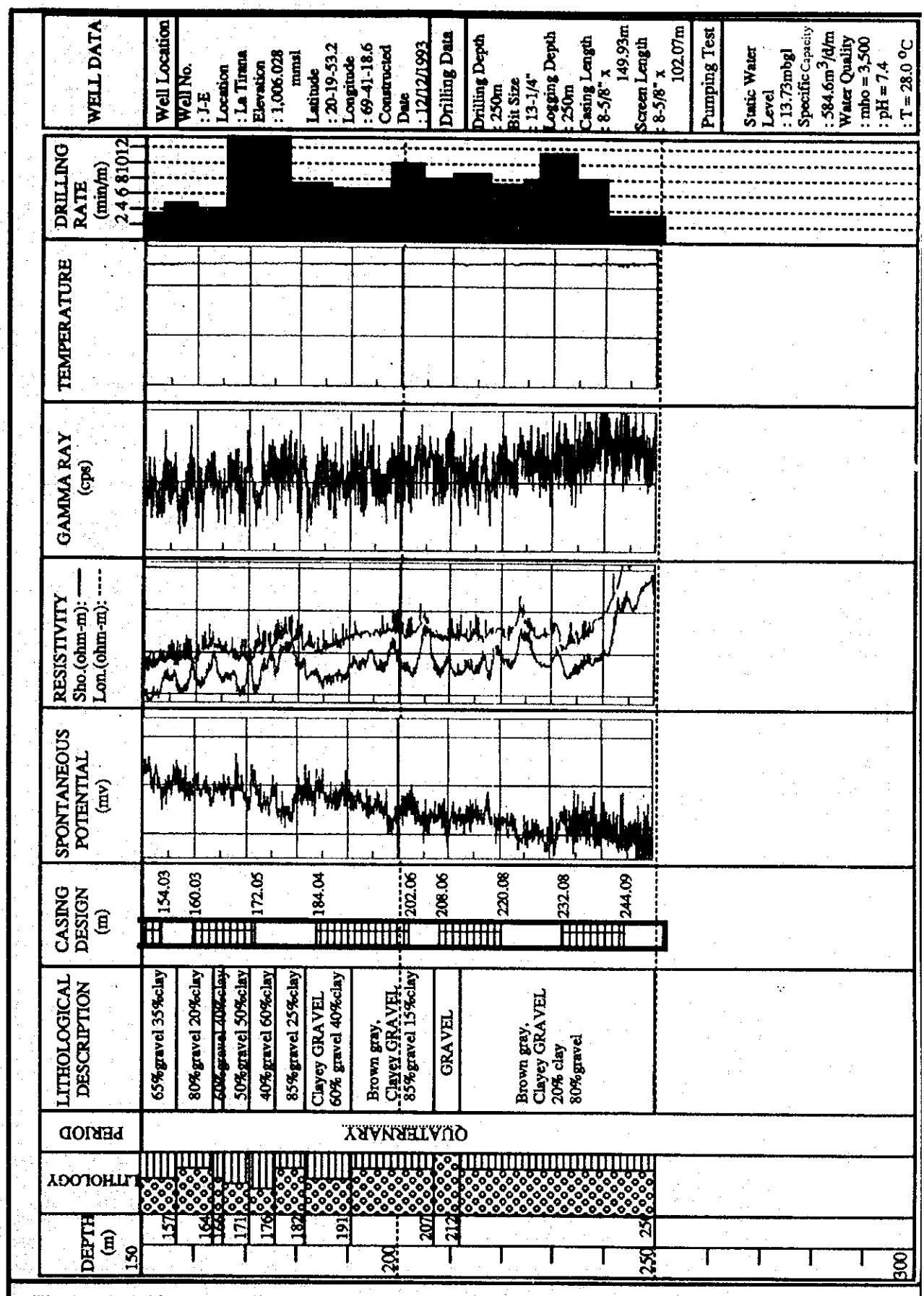

Fig. B-III, 2.18 Well Data for J-E (Sheet No. 2)

< Información del Pozo J-E(Hoja Nº 2) >

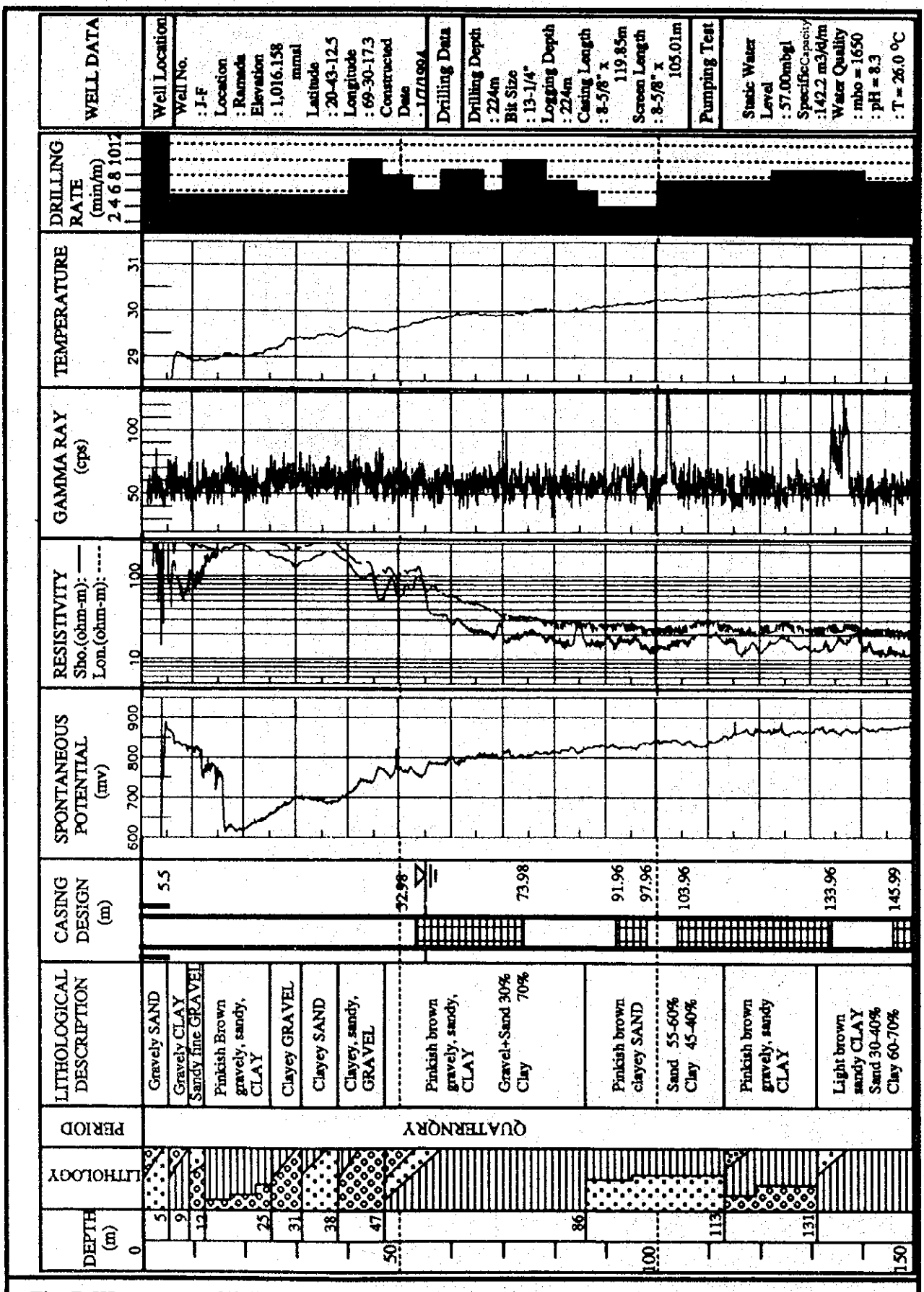

Fig. B-III, 2.19 Well Data for J-F (Sheet No. 1)

< Información del Pozo J-F (Hoja Nº 1) >

THE STUDY ON THE DEVELOPMENT OF WATER RESOURCES IN NORTHERN CHILE | JICA

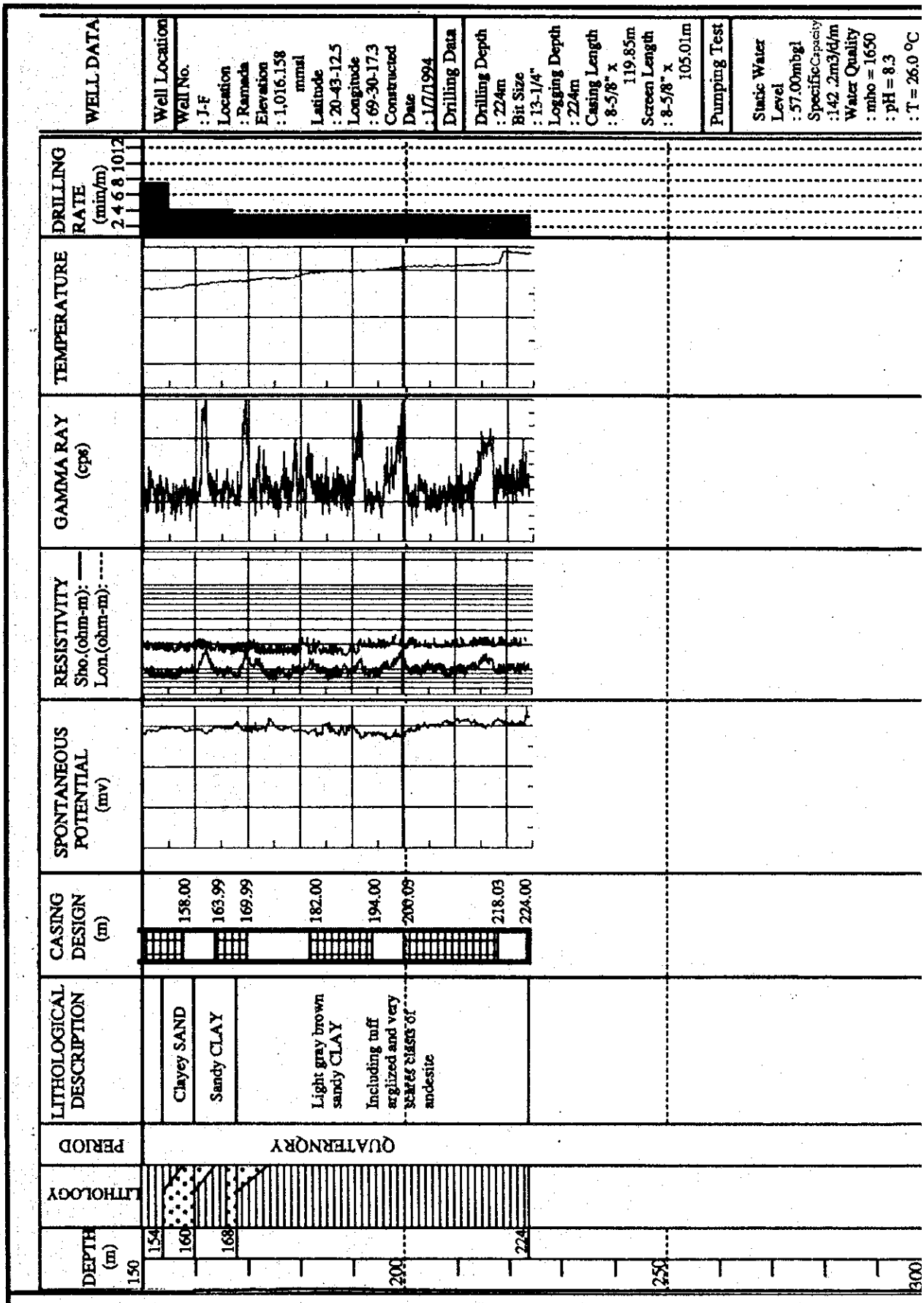

Fig. B-III, 2.19 Well Data for J-F (Sheet No. 2)

< Información del Pozo J-F (Hoja Nº 2) >

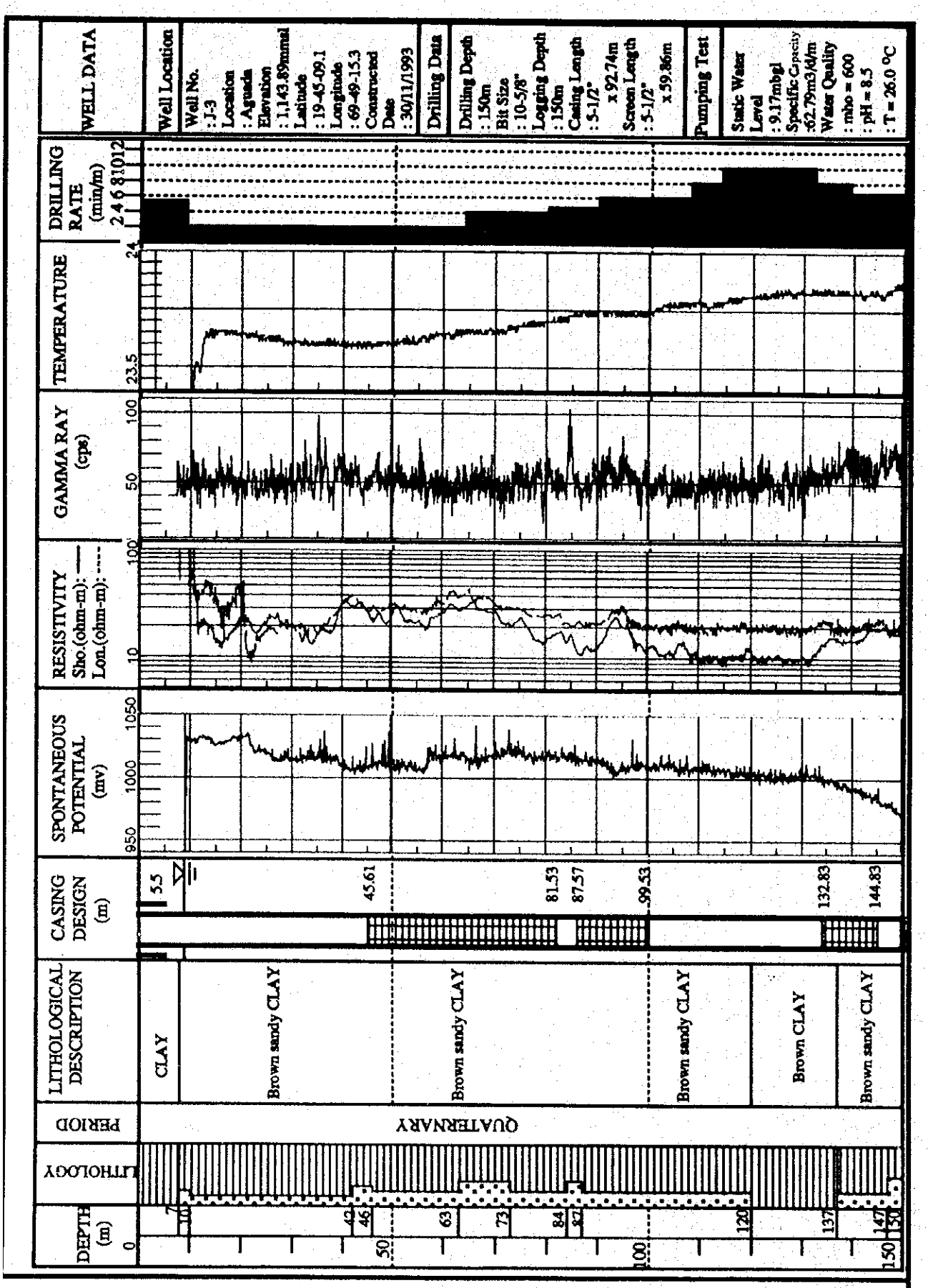

Fig. B-III, 2.20 Well Data for J-3

< Información del Pozo J-3 >

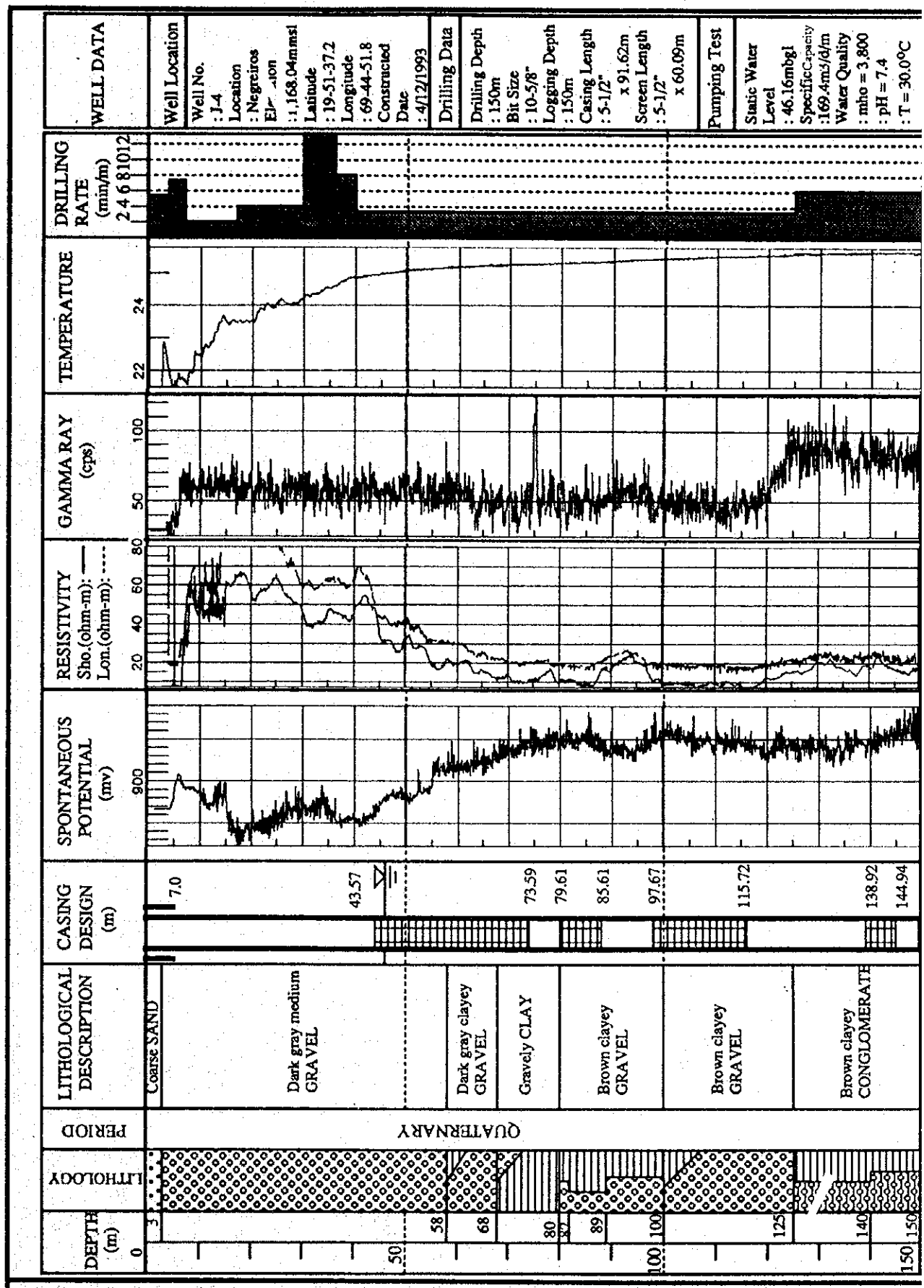

Fig. B-III, 2.21 Well Data for J-4

< Información del Pozo J-4 >

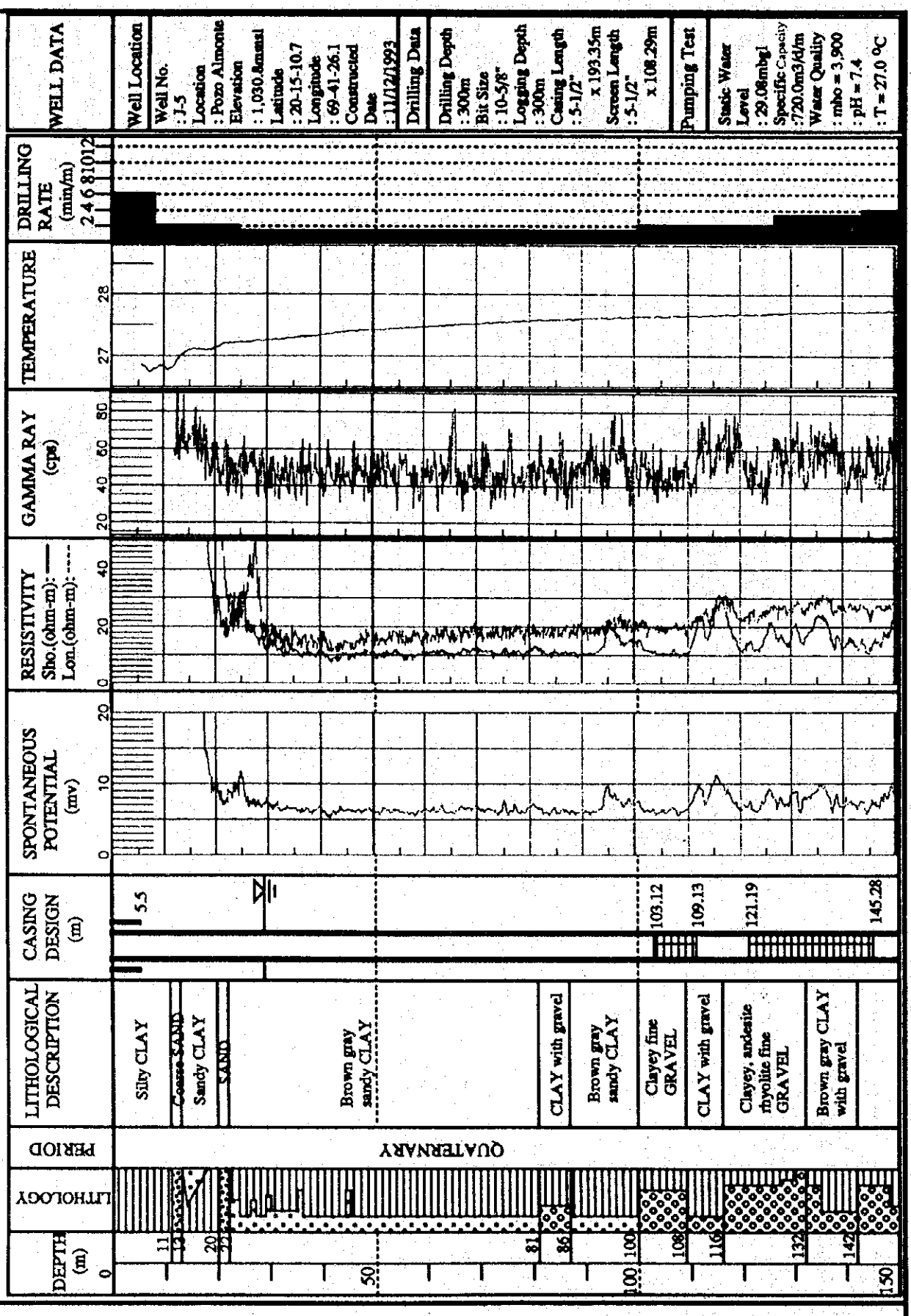

Fig. B-III, 2.22 Well Data for J-5 (Sheet No. 1)

< Información del Pozo J-5 (Hoja Nº 1) >

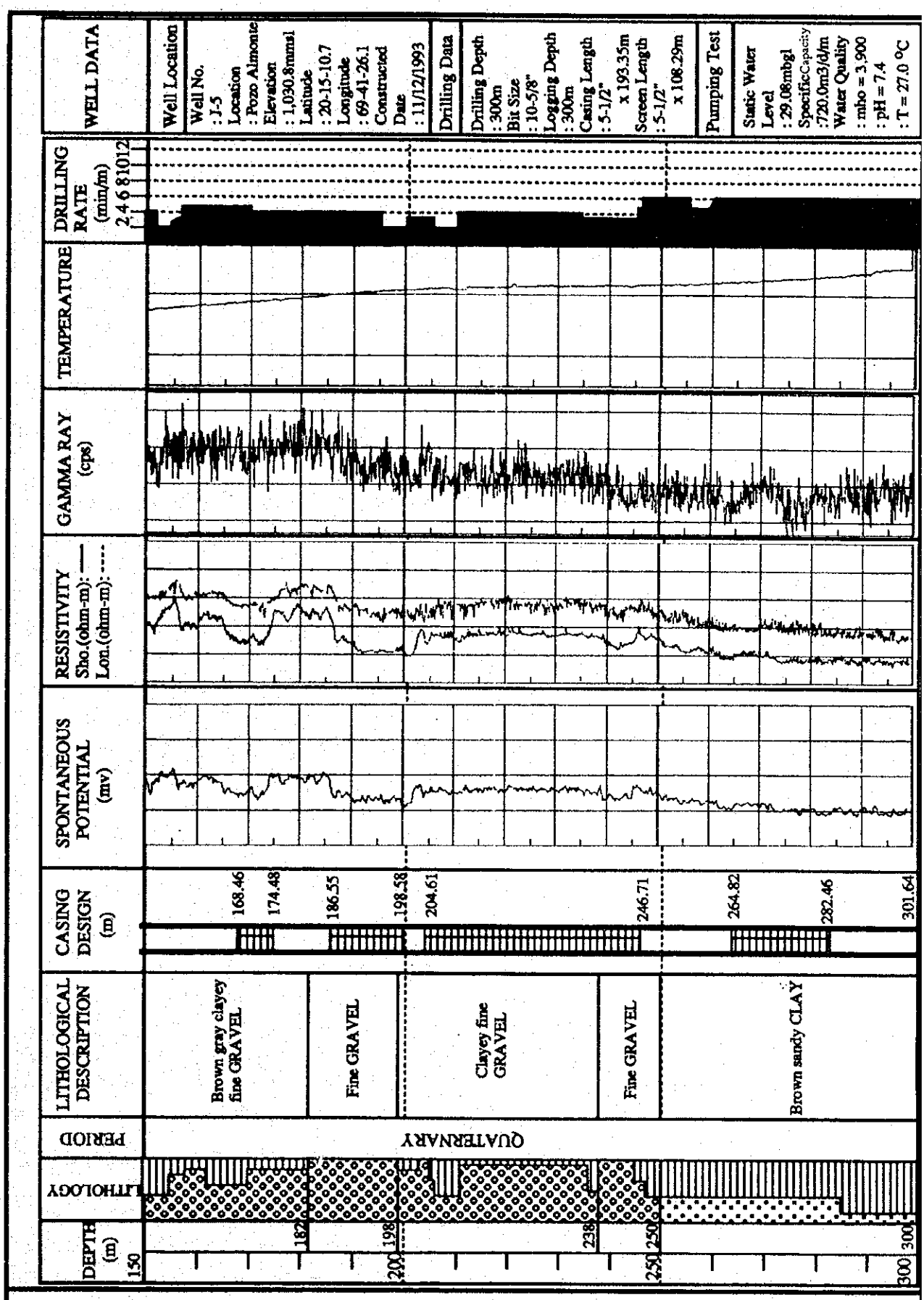

Fig. B-III, 2.22 Well Data for J-5 (Sheet No. 2)

< Información del Pozo J-5 (Hoja Nº 2) >

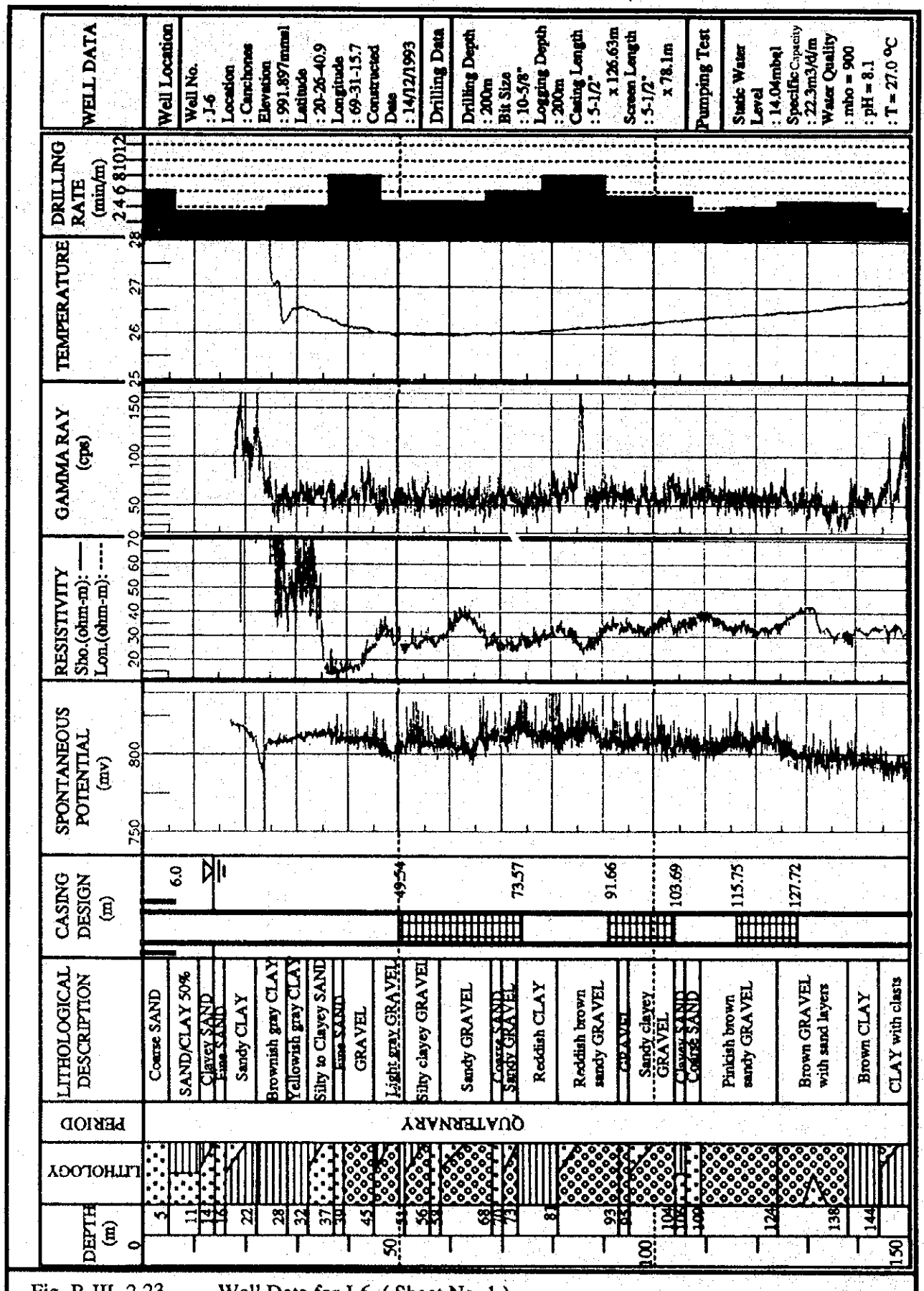

Fig. B-III, 2.23 Well Data for J-6 (Sheet No. 1)

< Información del Pozo J-6 (Hoja Nº 1) >

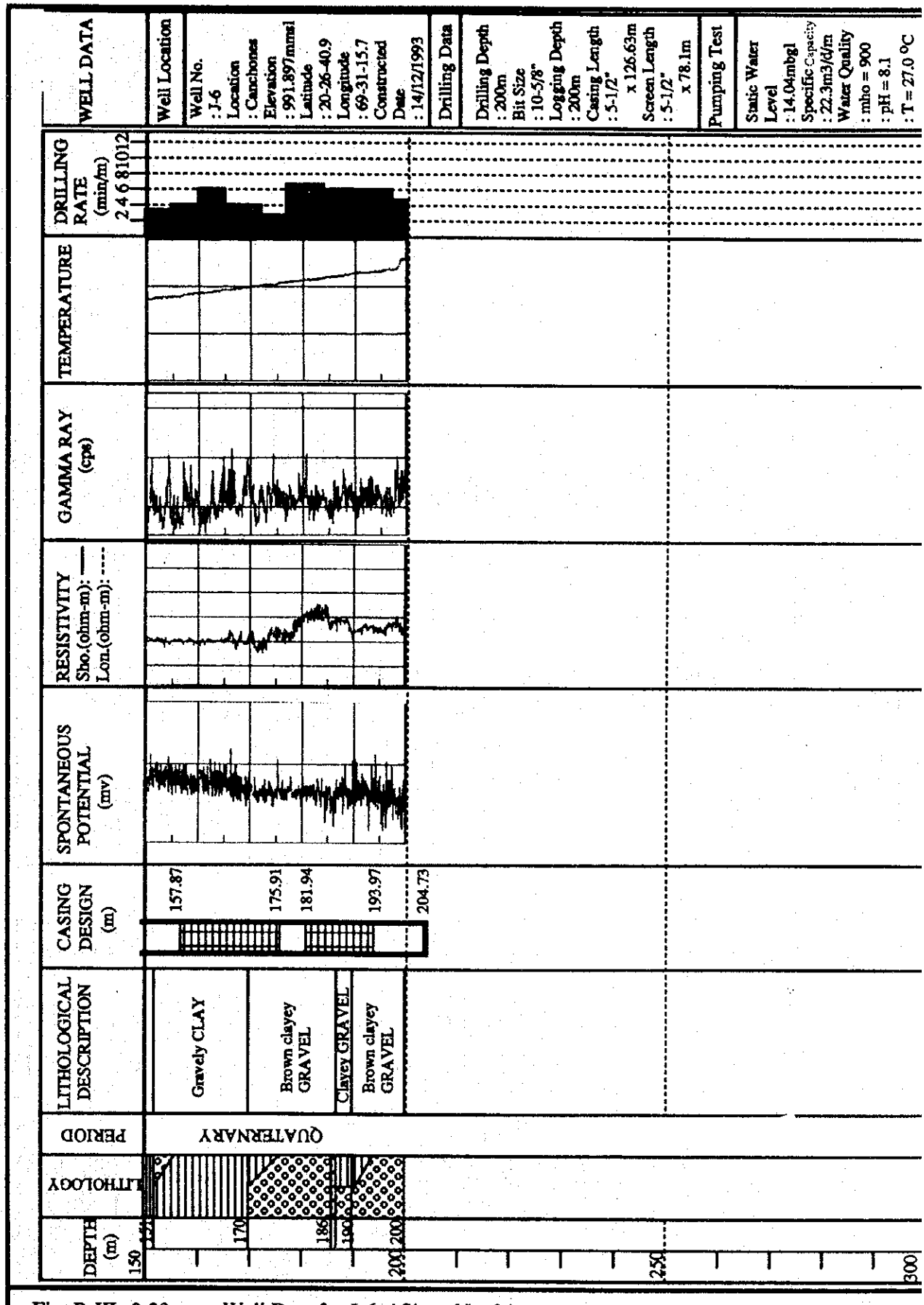

Fig. B-III, 2.23 Well Data for J-6 (Sheet No. 2)

< Información del Pozo J-6 (Hoja Nº 2) >

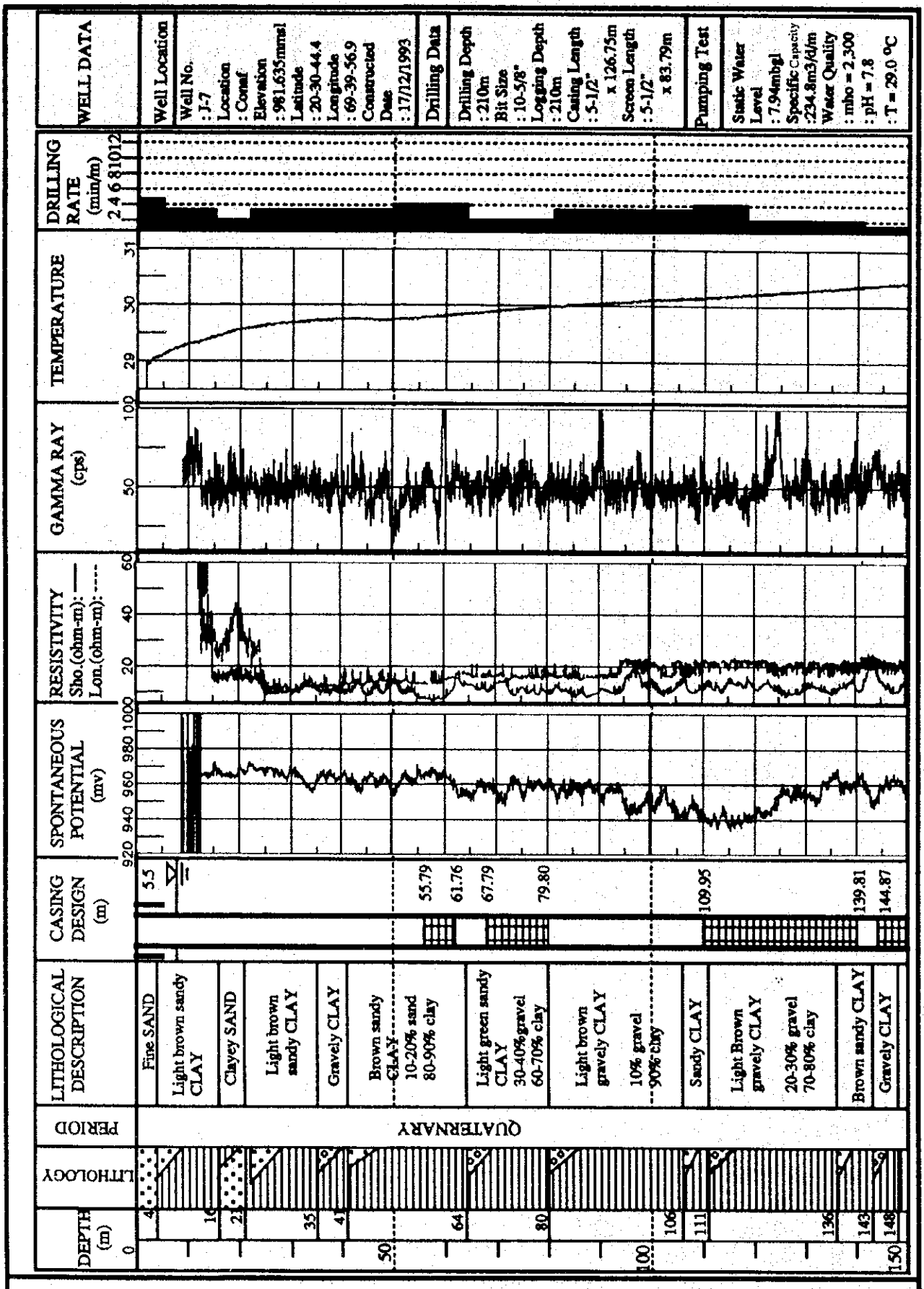

Fig. B-III, 2.24 Well Data for J-7 (Sheet No. 1)

< Información del Pozo J-7 (Hoja Nº 1) >

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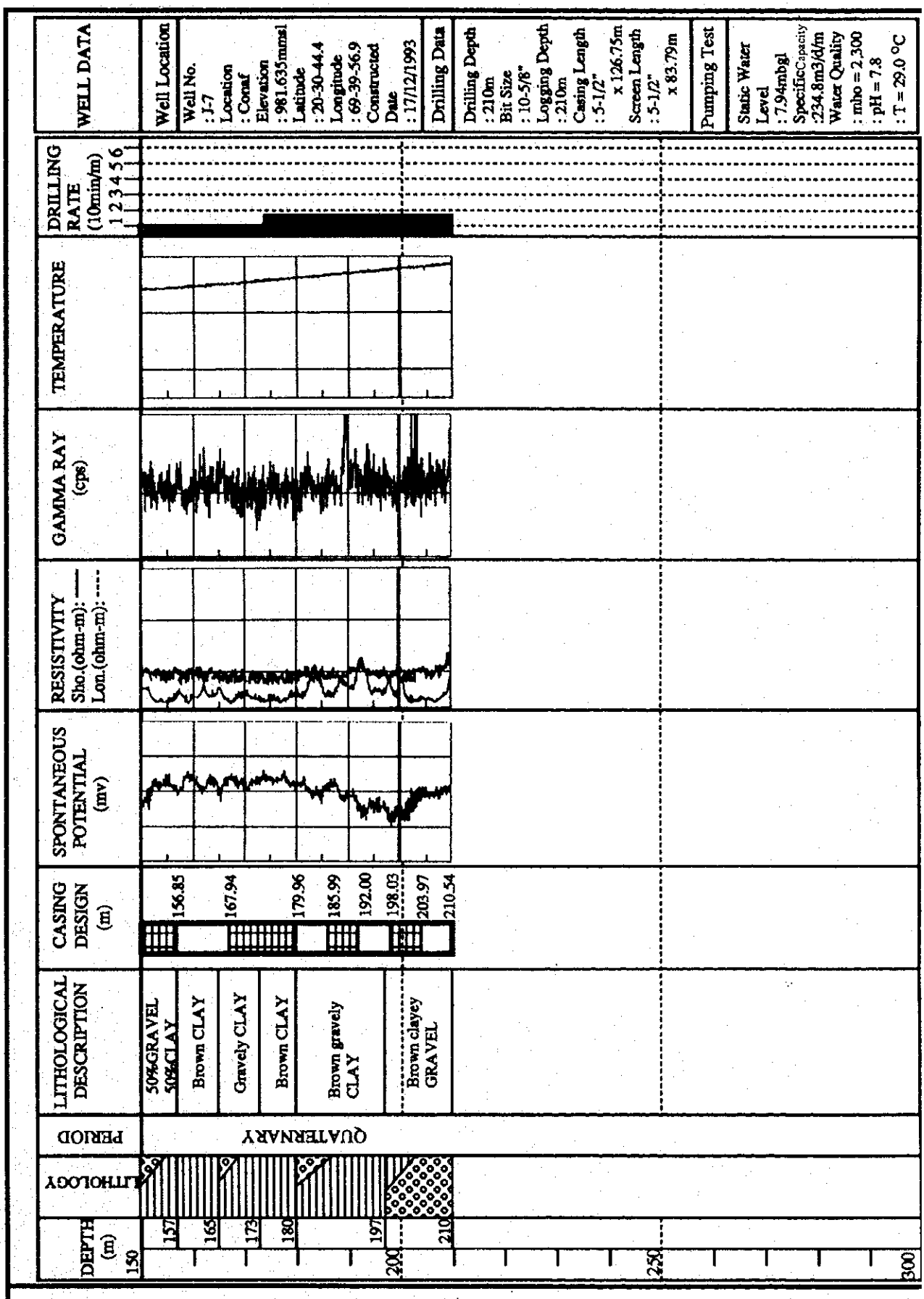


Fig. B-III, 2.24 Well Data for J-7 (Sheet No. 2)

< Información del Pozo J-7 (Hoja Nº 2) >

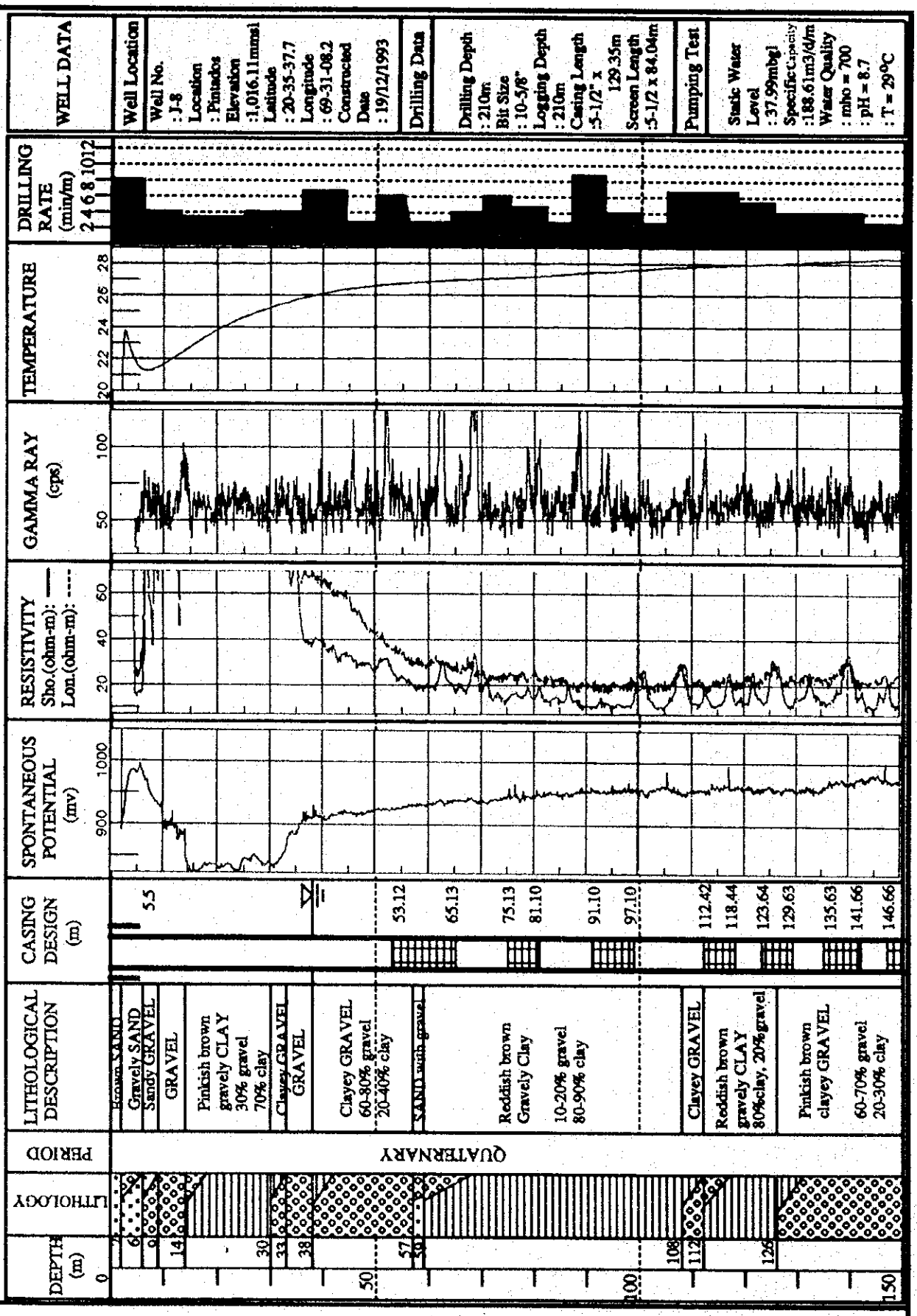


Fig. B-III, 2.25 Well Data for J-8 (Sheet No. 1)

< Información del Pozo J-8 (Hoja Nº 1) >

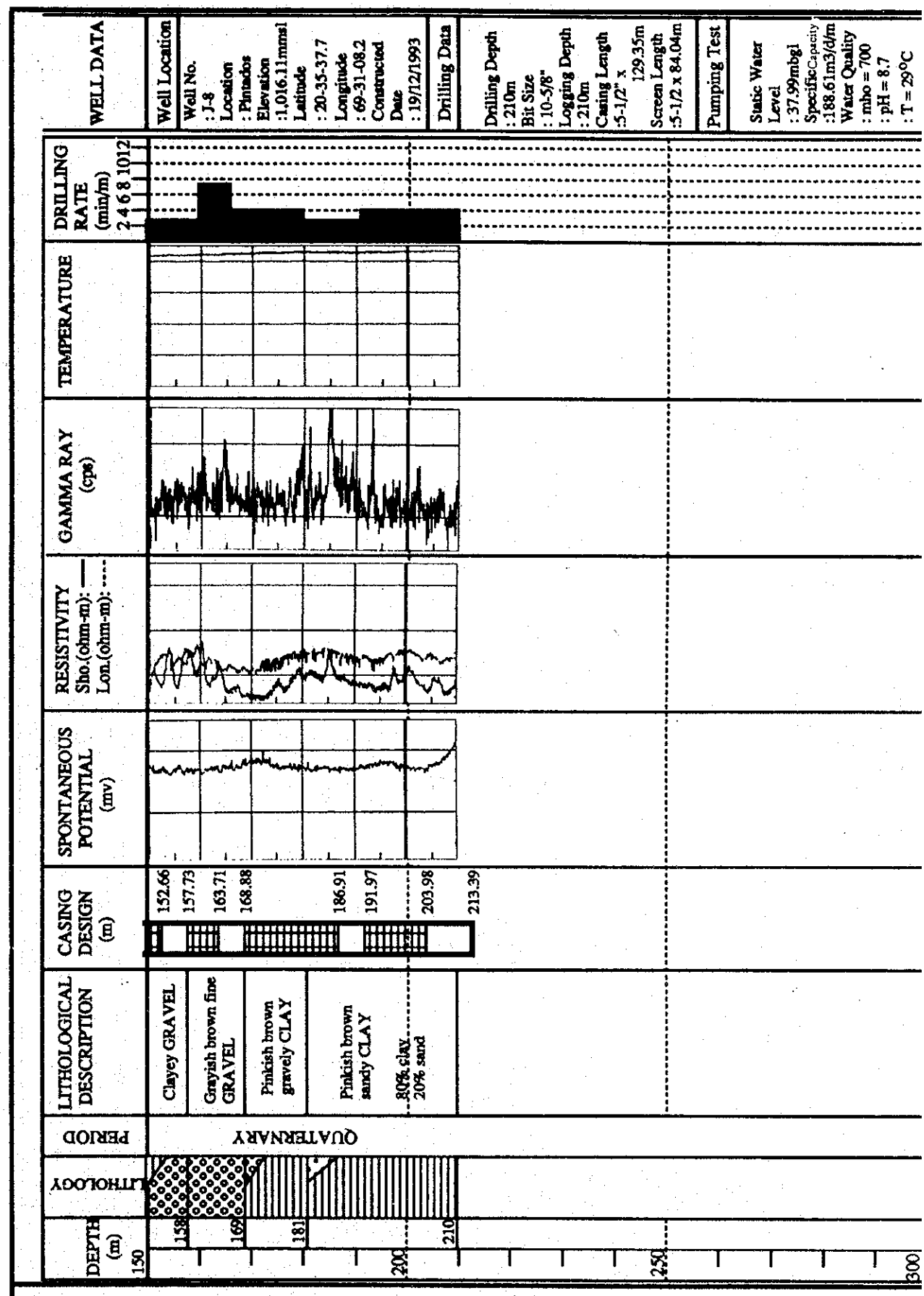


Fig. B-III, 2.25 Well Data for J-8 (Sheet No. 2)

< Información del Pozo J-8 (Hoja Nº 2) >

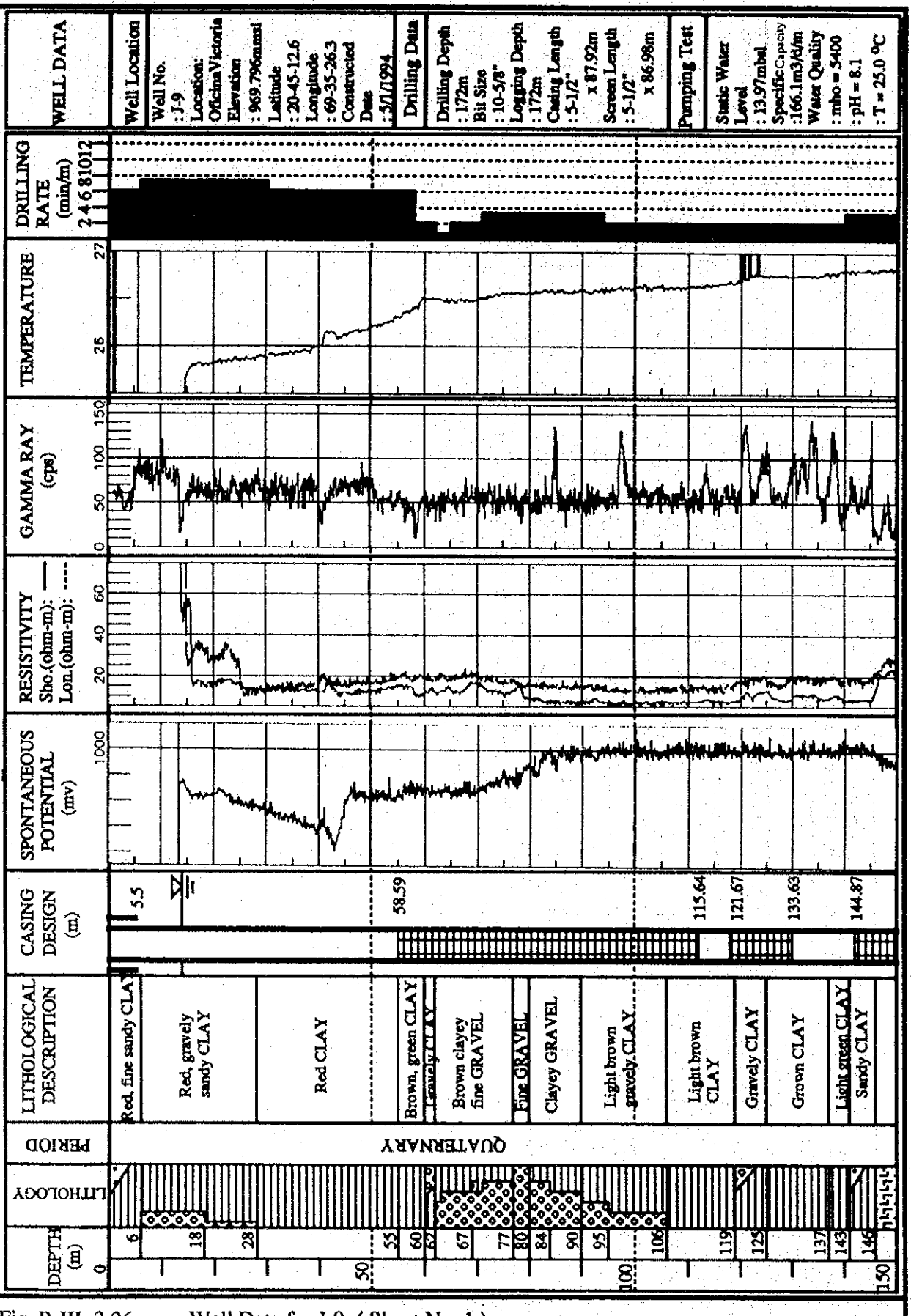


Fig. B-III, 2.26 Well Data for J-9 (Sheet No. 1)

< Información del Pozo J-9 (Hoja Nº 1) >

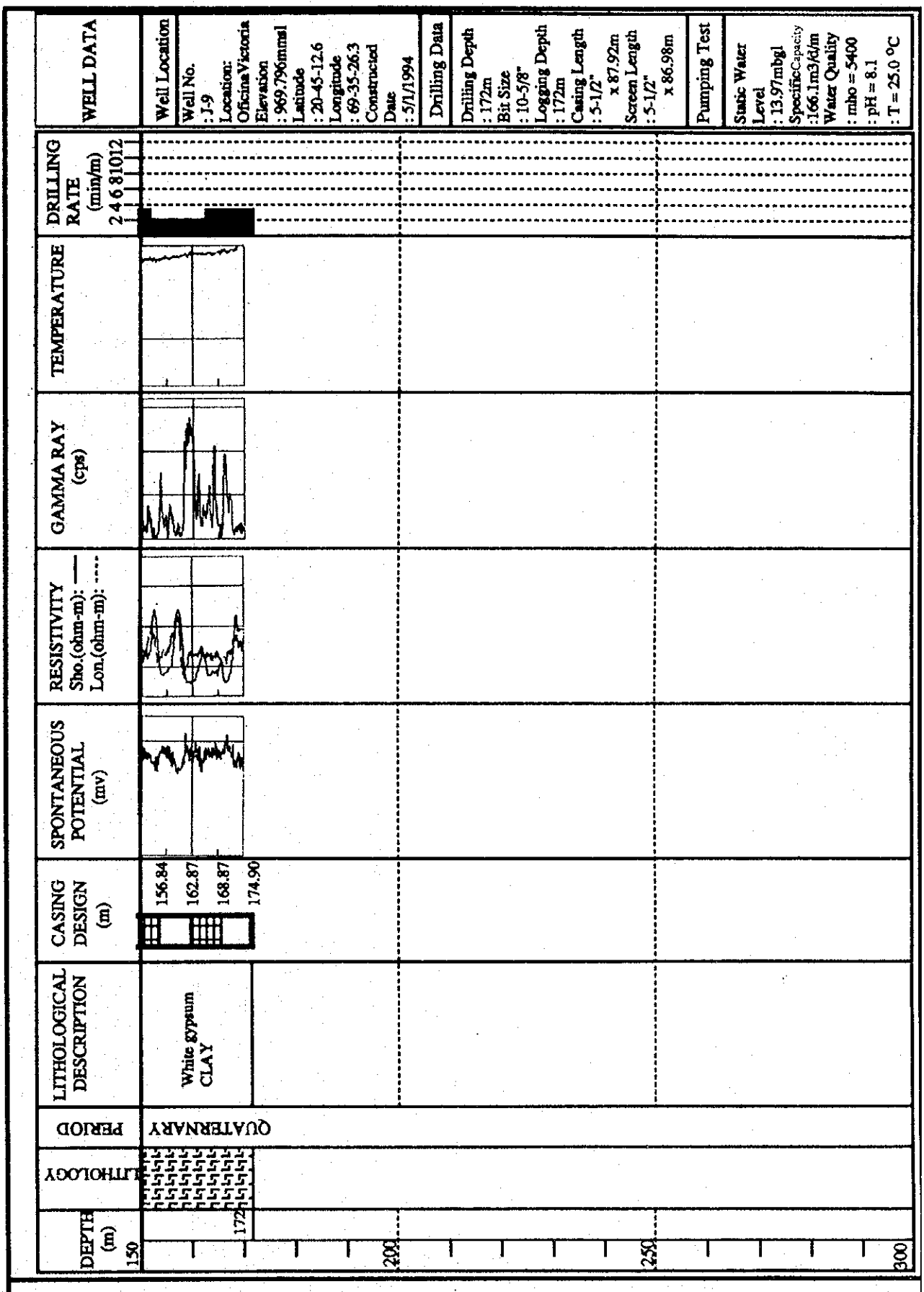


Fig. B-III, 2.26 Well Data for J-9 (Sheet No. 2)

< Información del Pozo J-9 (Hoja Nº 2) >

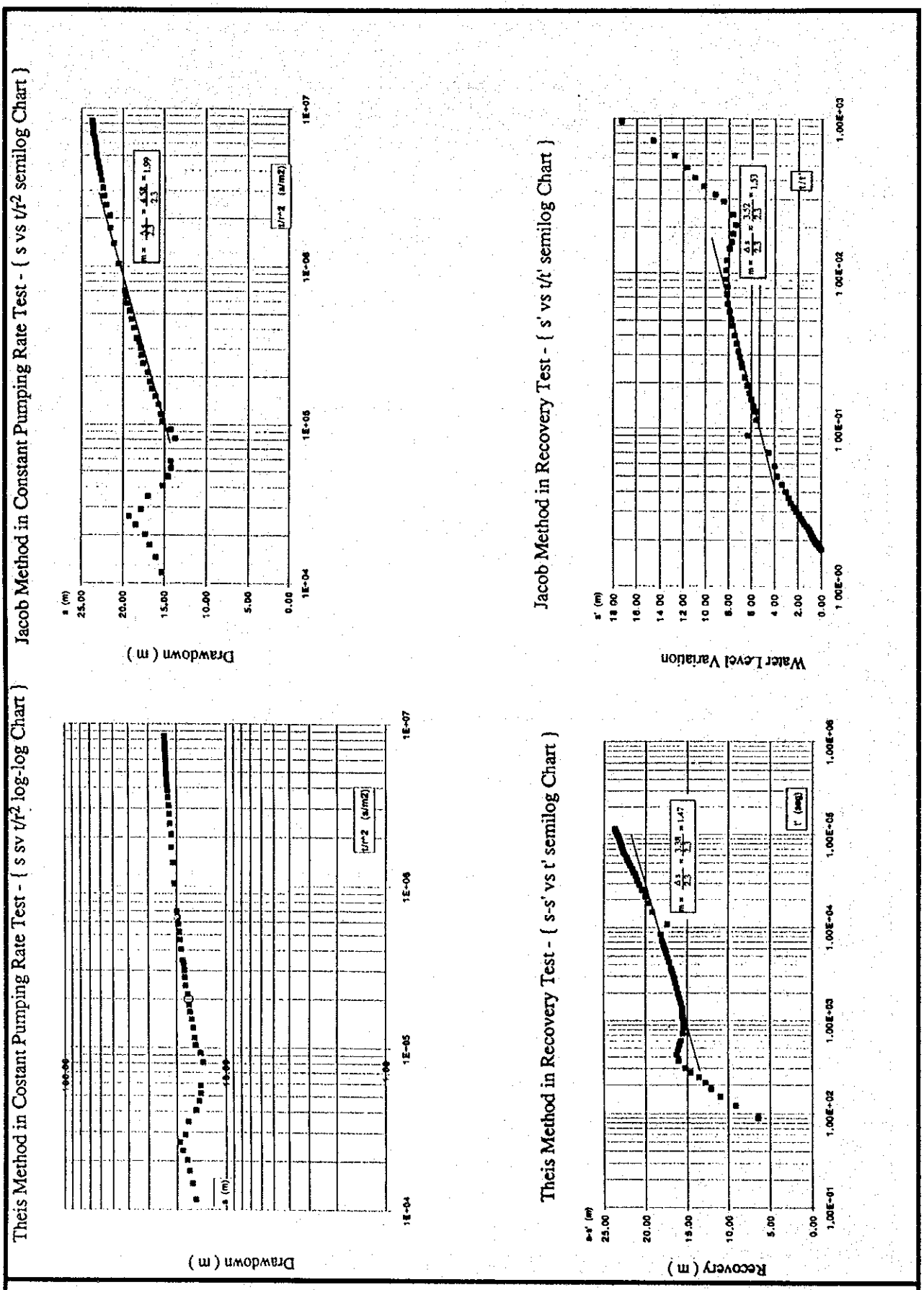


Fig. B-III, 2.27 Graphs for Theis and Jacob Method Analysis (Well No.J-C)

< Gráficos para los Métodos de Análisis Theis y Jacob (Pozo Nº J-C) >

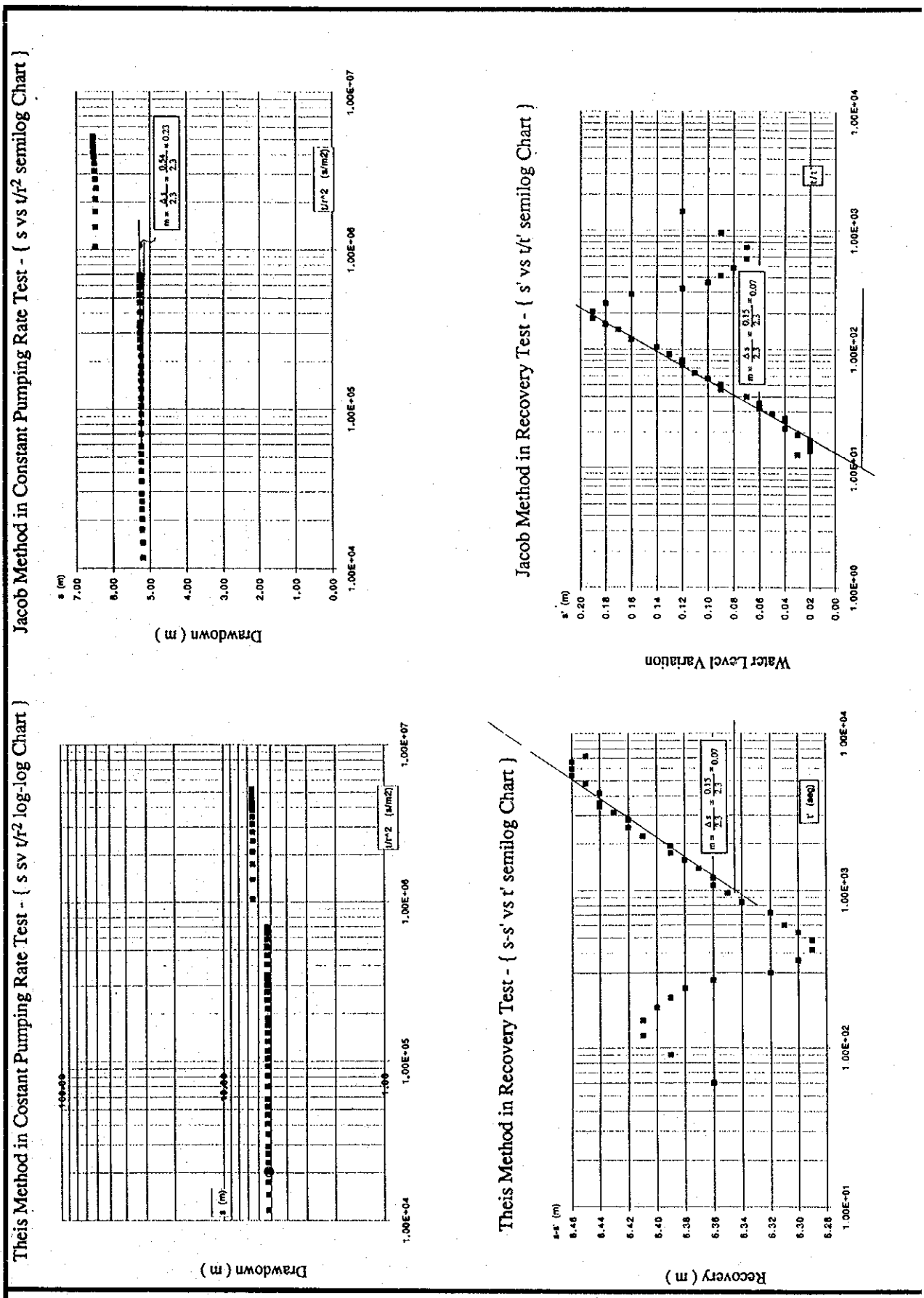


Fig. B-III, 2.28 Graphs for Theis and Jacob Method Analysis (Well No.J-D)

< Gráficos para los Métodos de Análisis Theis y Jacob (Pozo Nº.J-D) >

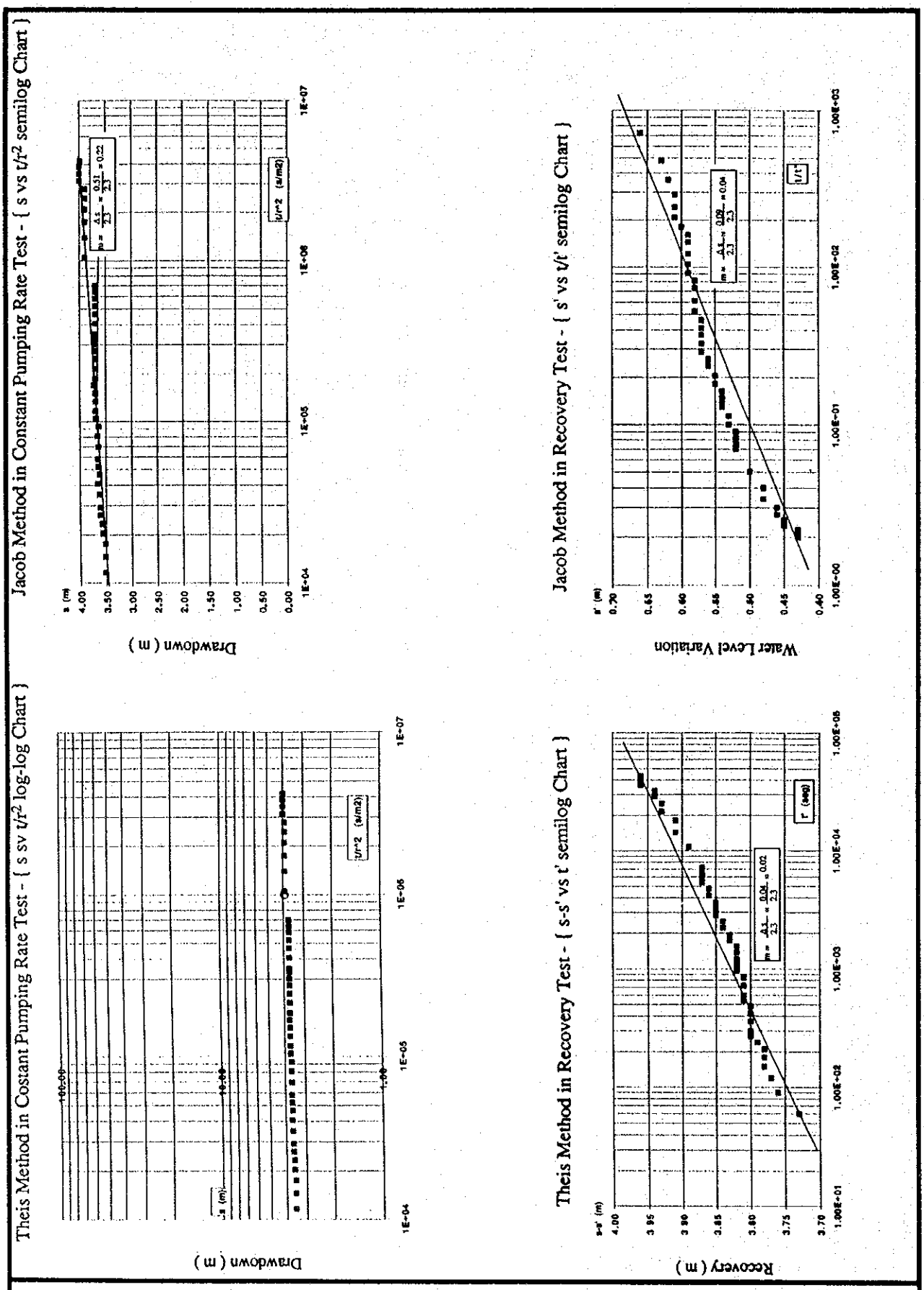


Fig. B-III, 2.29 Graphs for Theis and Jacob Method Analysis (Well No.J-E)

< Gráficos para los Métodos de Análisis Theis y Jacob (Pozo Nº J-E) >

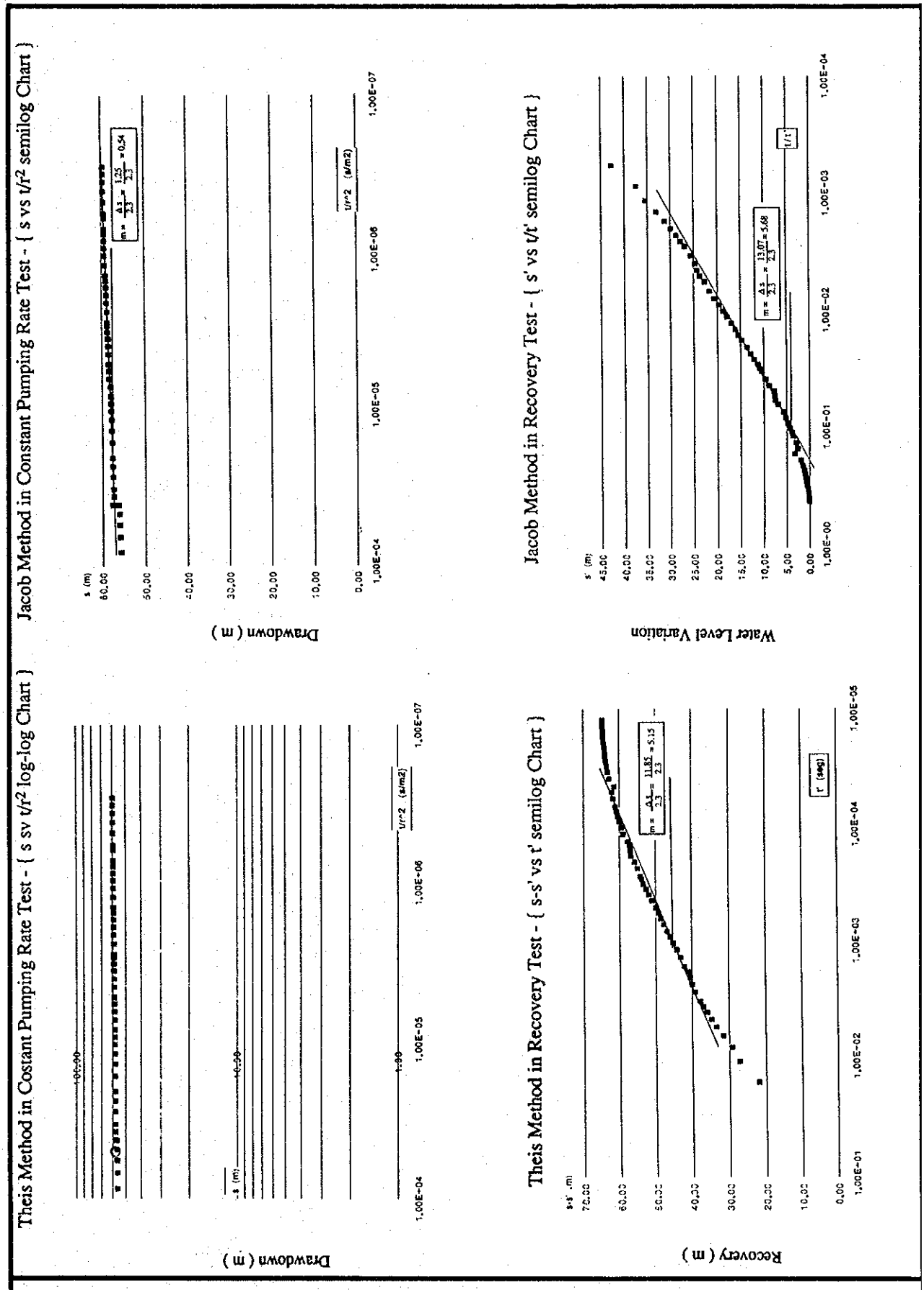


Fig. B-III, 2.30 Graphs for Theis and Jacob Method Analysis (Well No.J-F)

< Gráficos para los Métodos de Análisis Theis y Jacob (Pozo Nº J-F) >

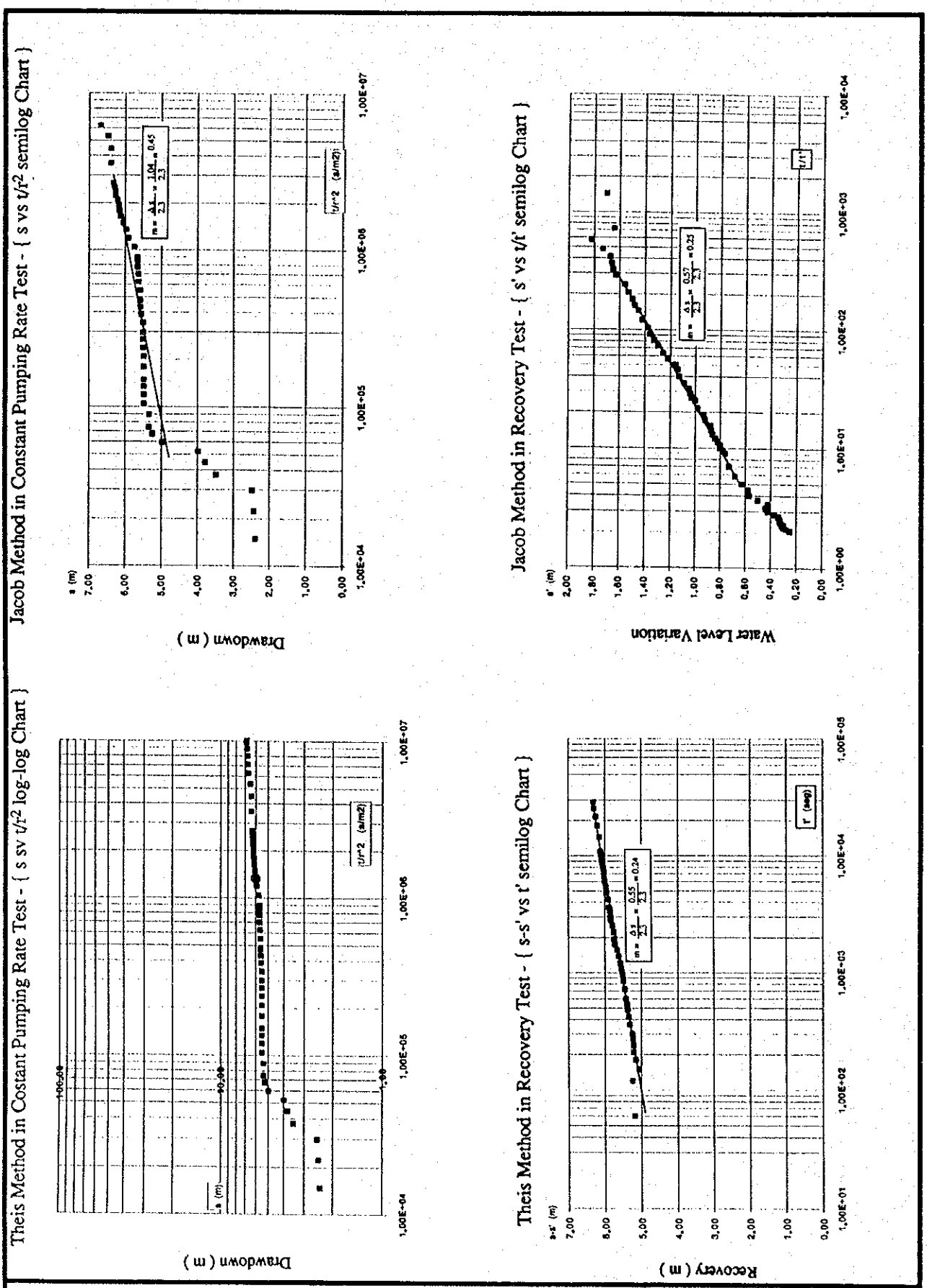


Fig. B-III, 2.31 Graphs for Theis and Jacob Method Analysis (Well No.J-3)

<Gráficos para los Métodos de Análisis Theis y Jacob (Pozo Nº J-3) >

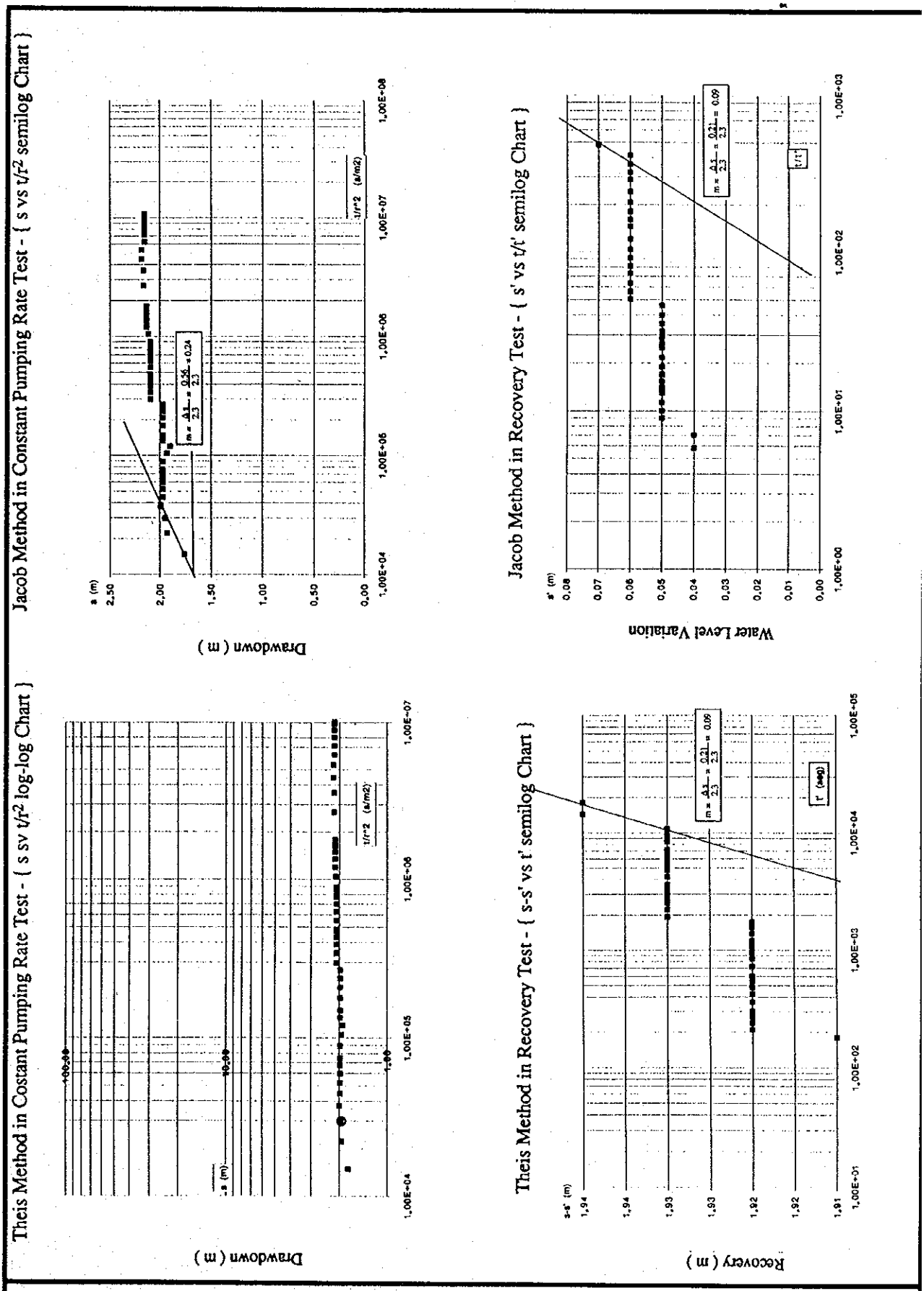


Fig. B-III, 2.32 Graphs for Theis and Jacob Method Analysis (Well No.J-4)

< Gráficos para los Métodos de Análisis Theis y Jacob (Pozo Nº J-4) >

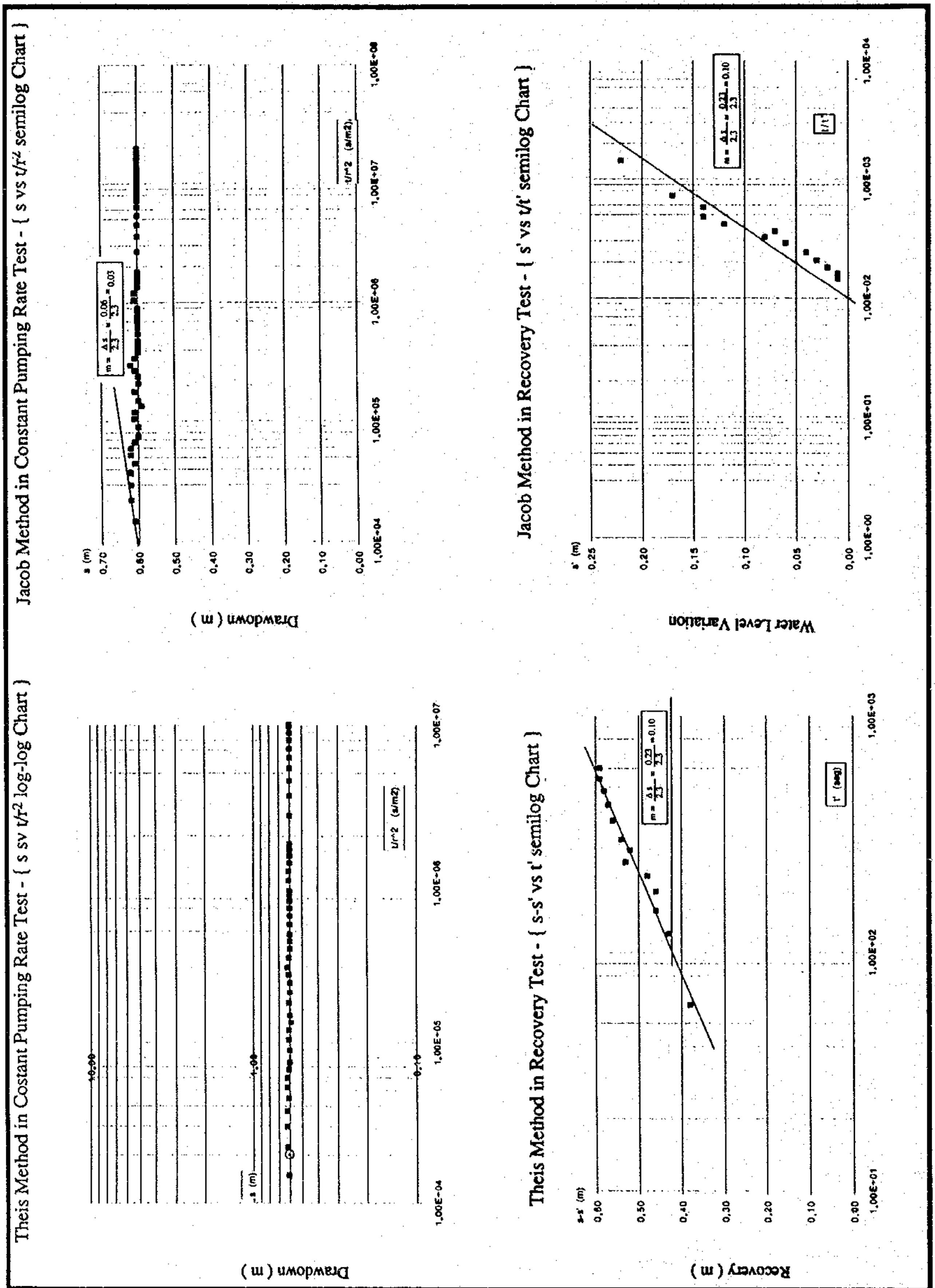


Fig. B-III, 2.33 Graphs for Theis and Jacob Method Analysis (Well No.J-5)

< Gráficos para los Métodos de Análisis Theis y Jacob (Pozo Nº J-5) >

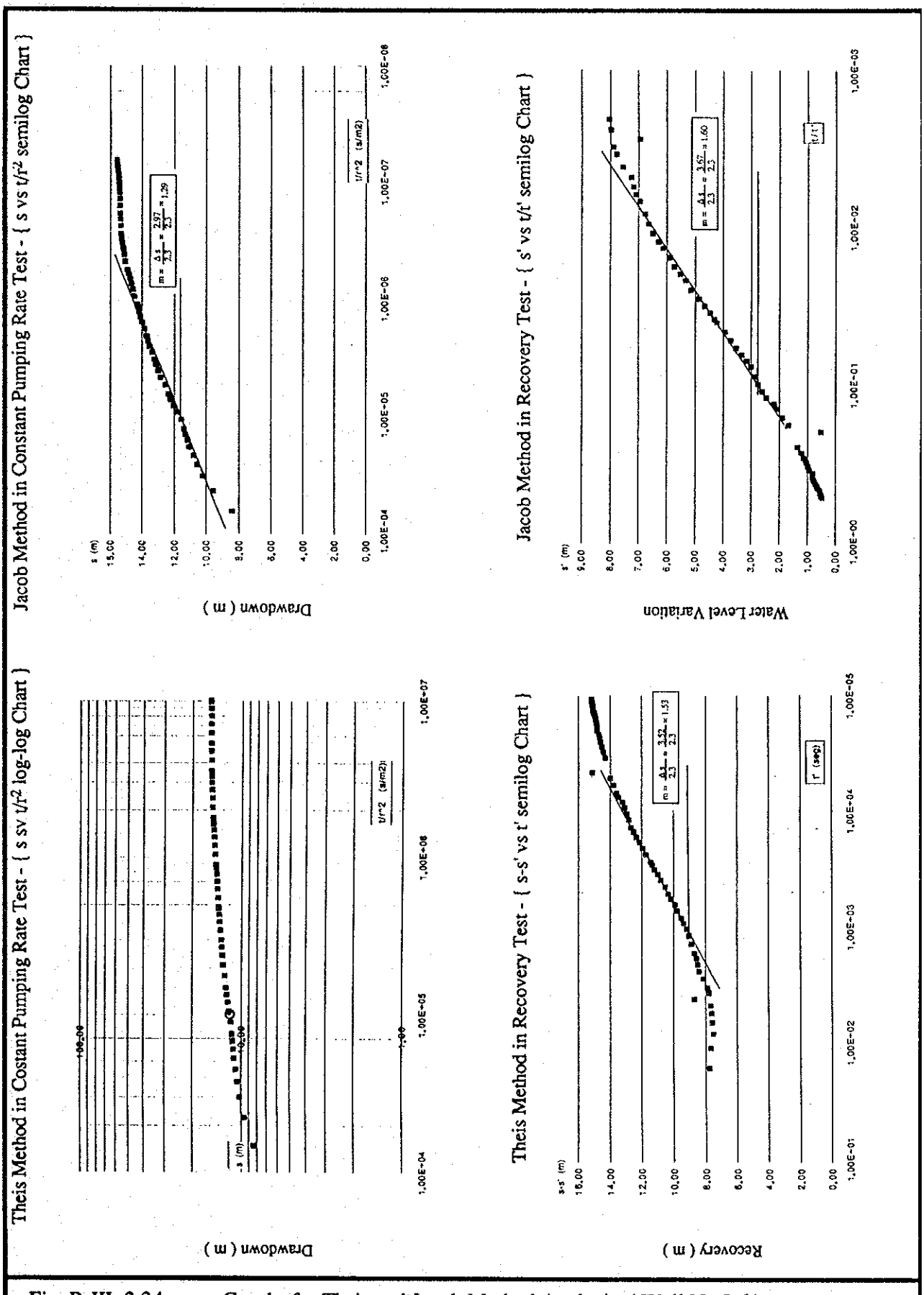


Fig. B-III, 2.34 Graphs for Theis and Jacob Method Analysis (Well No.J-6)

< Gráficos para los Métodos de Análisis Theis y Jacob (Pozo Nº J-6) >

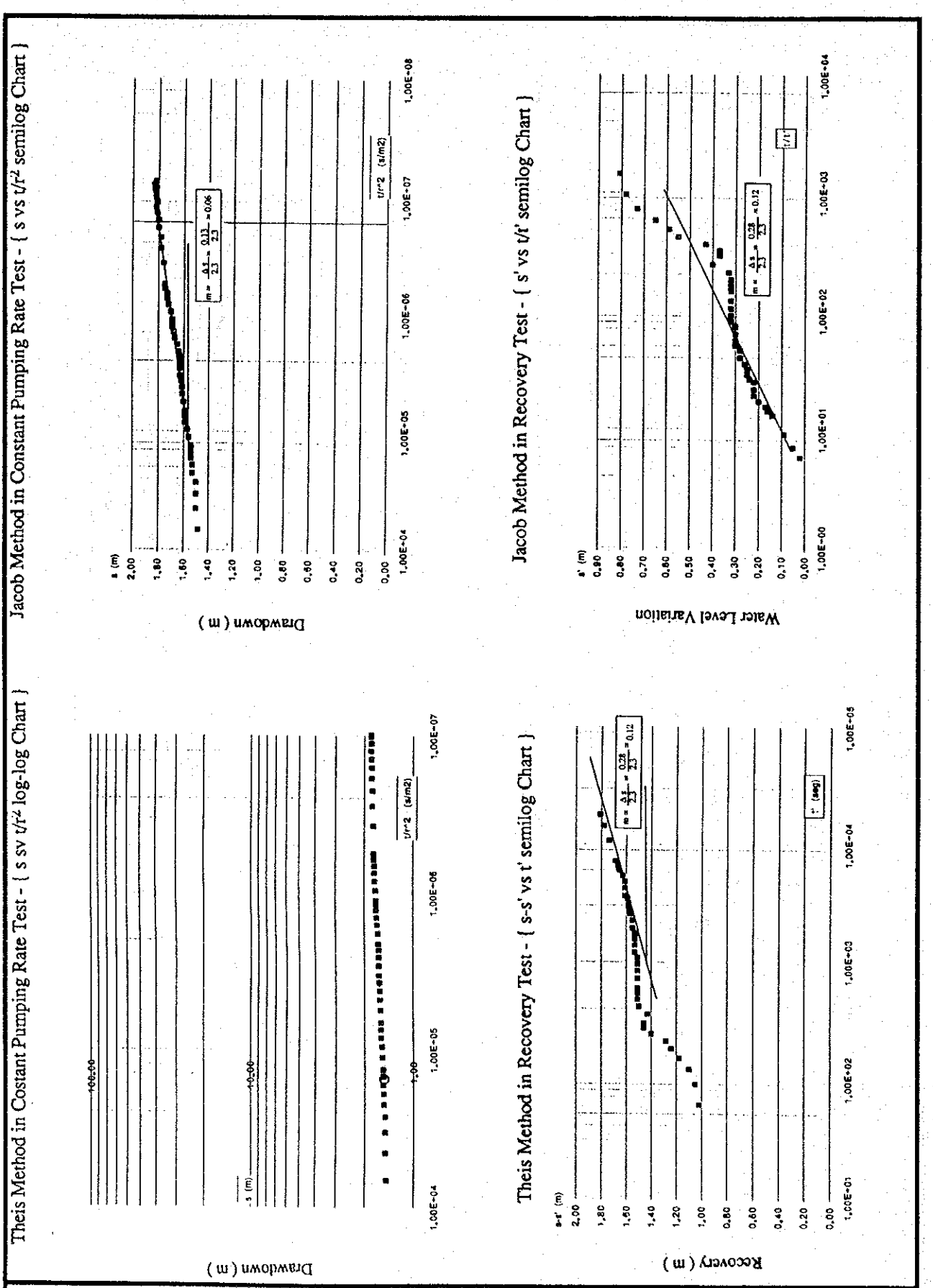


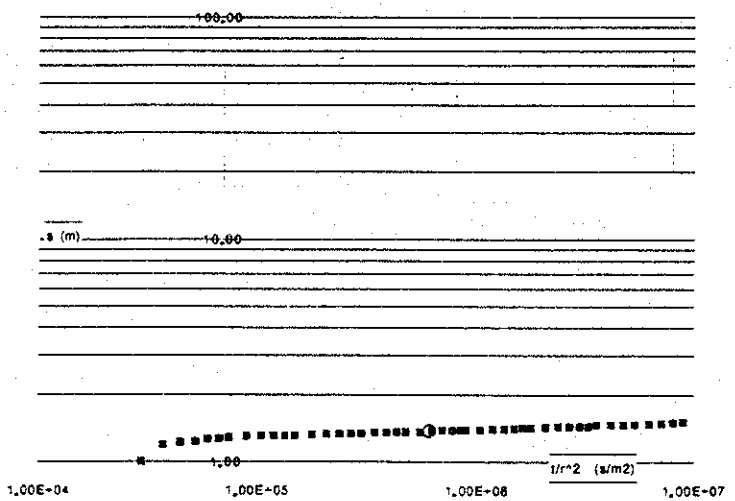
Fig. B-III, 2.35 Graphs for Theis and Jacob Method Analysis (Well No.J-7)

< Gráficos para los Métodos de Análisis Theis y Jacob (Pozo Nº J-7) >

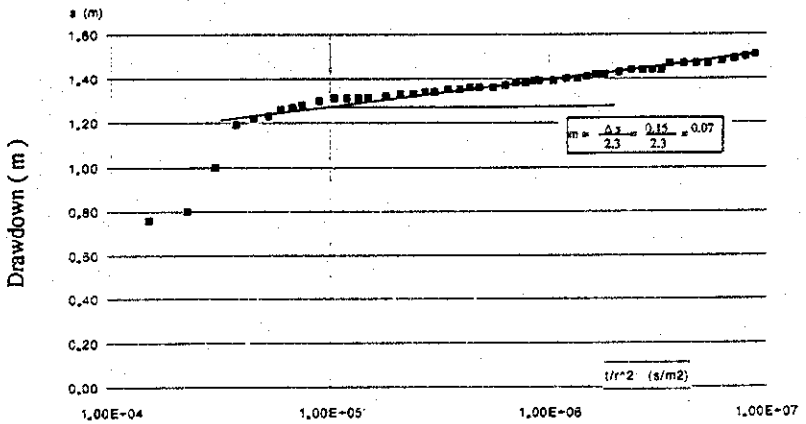
Fig. B-III, 2.36 Graphs for Theis and Jacob Method Analysis (Well No.J-8)

< Gráficos para los Métodos de Análisis Theis y Jacob (Pozo Nº J-8) >

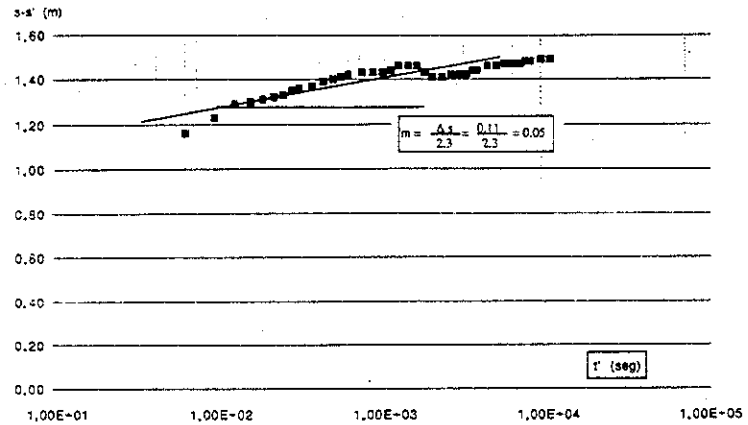
Theis Method in Costant Pumping Rate Test - { s sv t/r^2 log-log Chart }



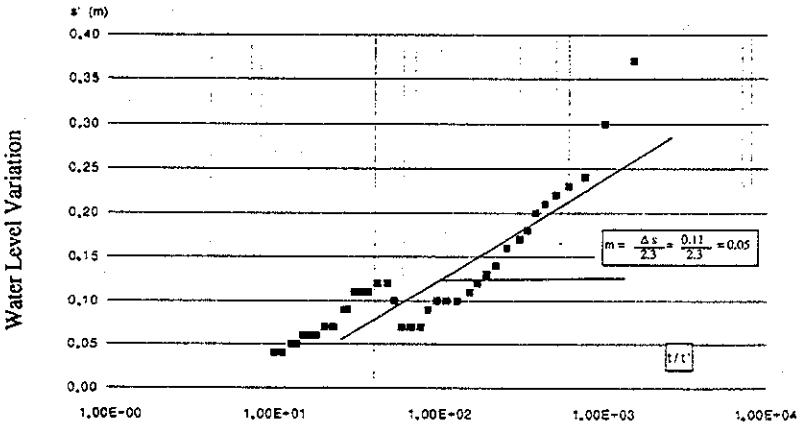
Jacob Method in Constant Pumping Rate Test - { s vs t/r^2 semilog Chart }



Theis Method in Recovery Test - { s-s' vs t' semilog Chart }



Jacob Method in Recovery Test - { s' vs t/t' semilog Chart }



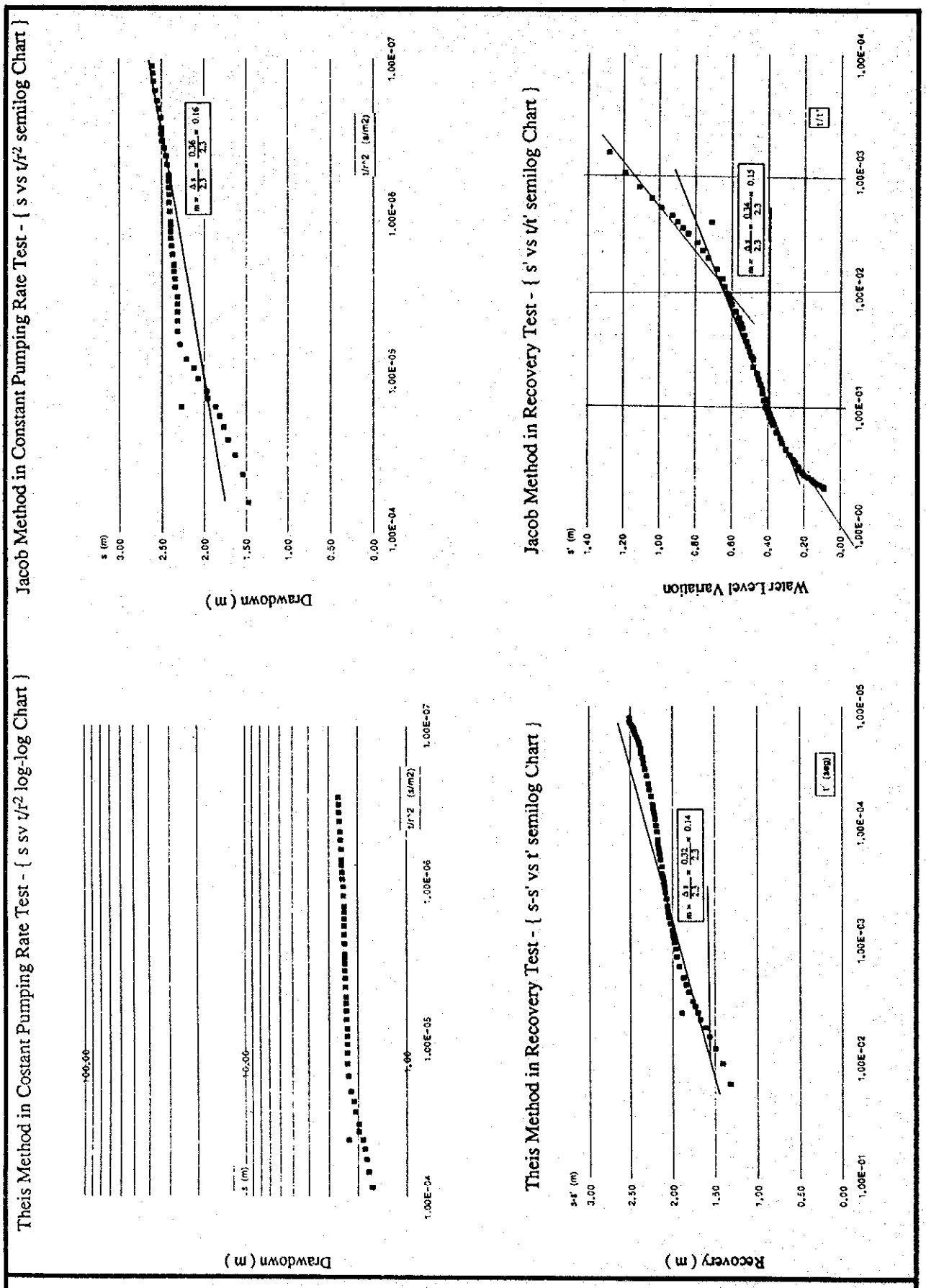
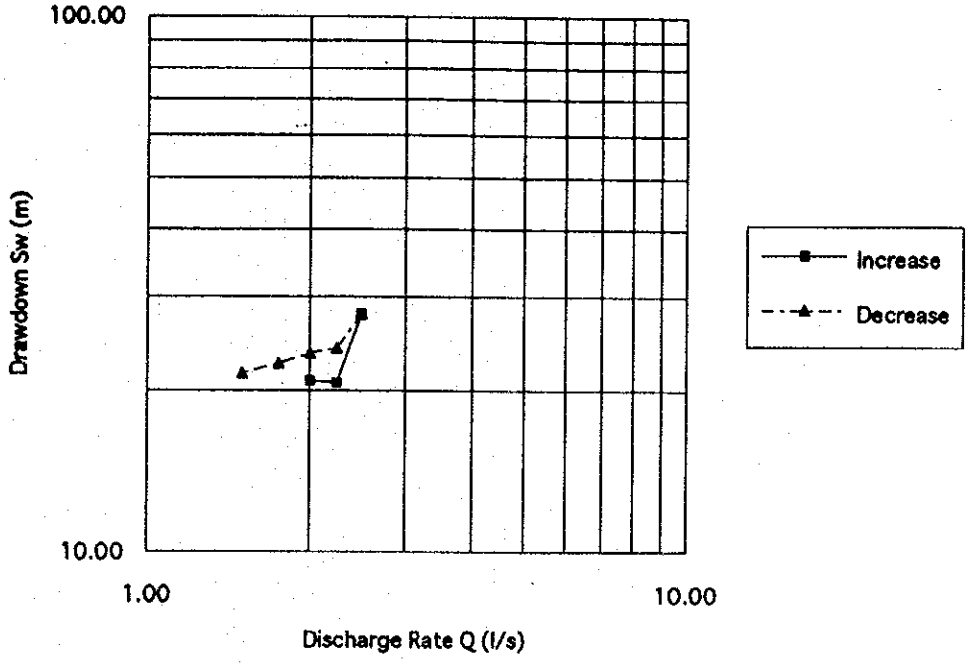


Fig. B-III, 2.37 Graphs for Theis and Jacob Method Analysis (Well No.J-9)

< Gráficos para los Métodos de Análisis Theis y Jacob (Pozo Nº J-9) >

Q - Sw Chart



Q - s/Q Chart

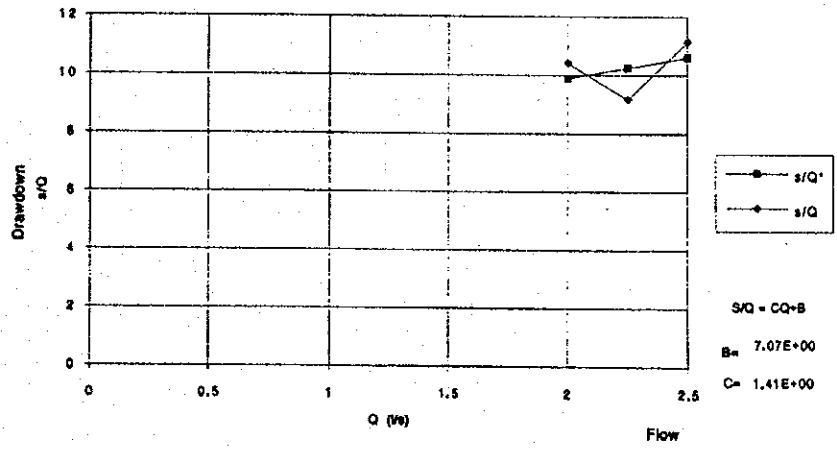
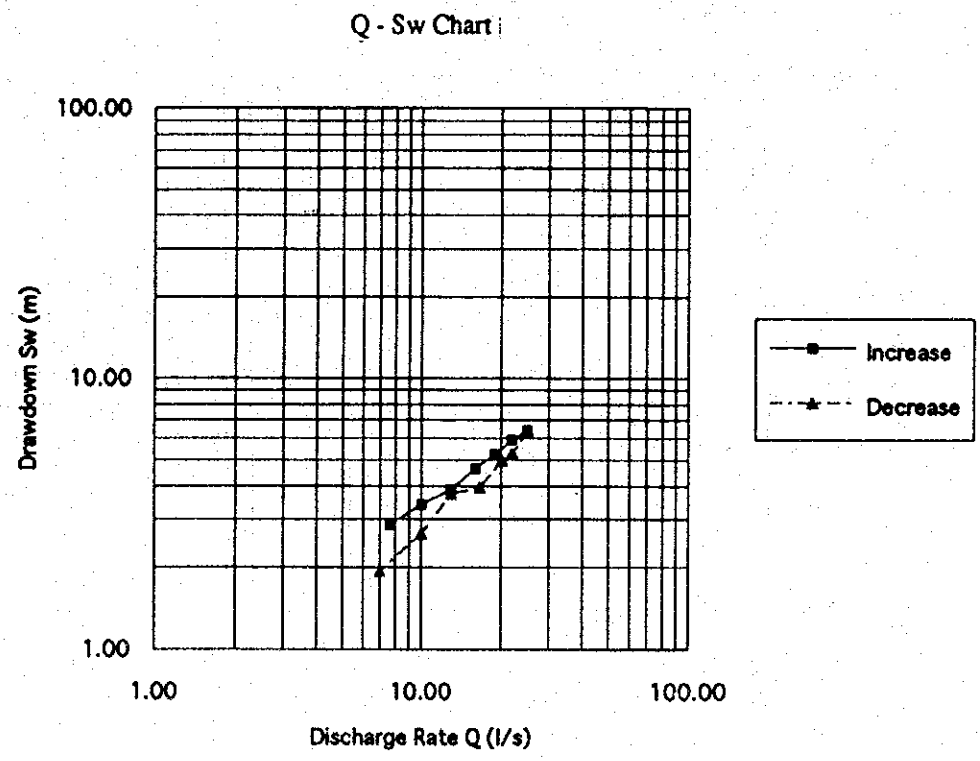


Fig. B-III, 2.38 Graphs for Step Drawdown Test (Well No.J-C)

< Gráficos Prueba de Gasto Variable (Pozo Nº J-C) >



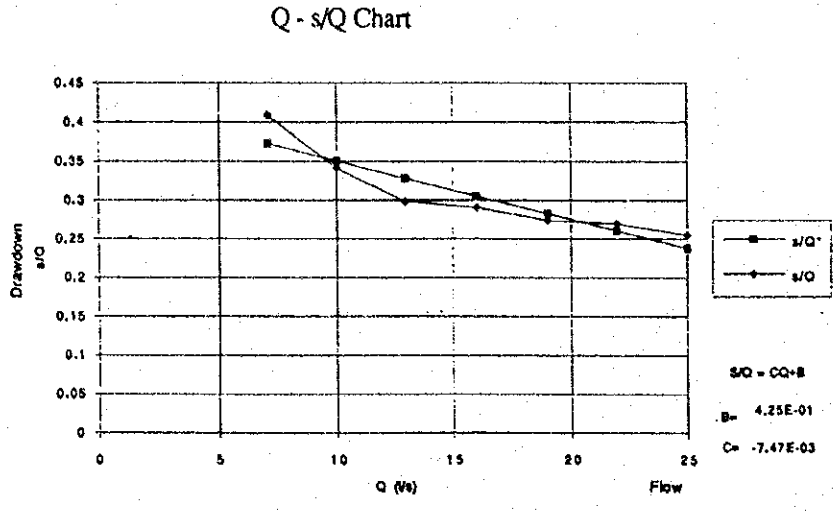
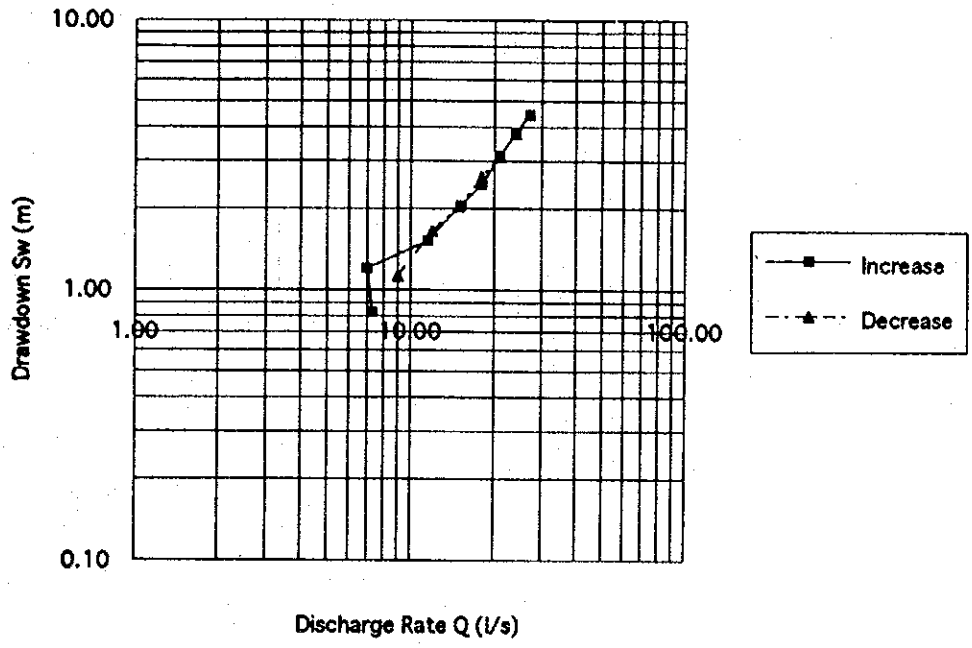


Fig. B-III, 2.39 Graphs for Step Drawdown Test (Well No.J-D)

< Gráficos Prueba de Gasto Variable (Pozo Nº J-D) >

Q - Sw Chart



Q - s/Q Chart

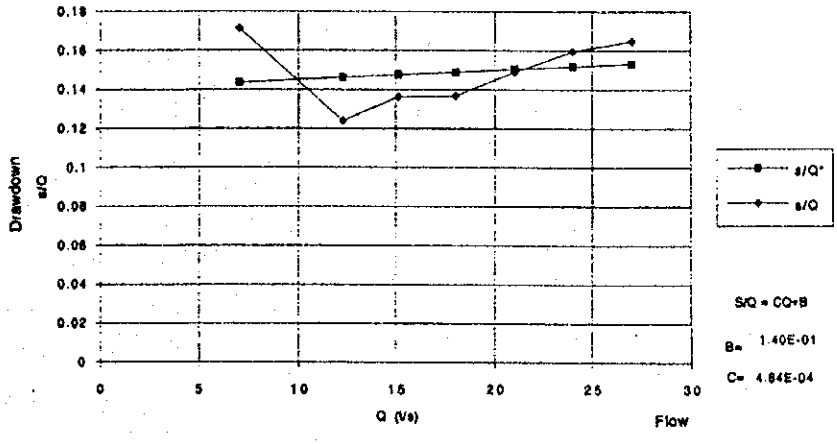
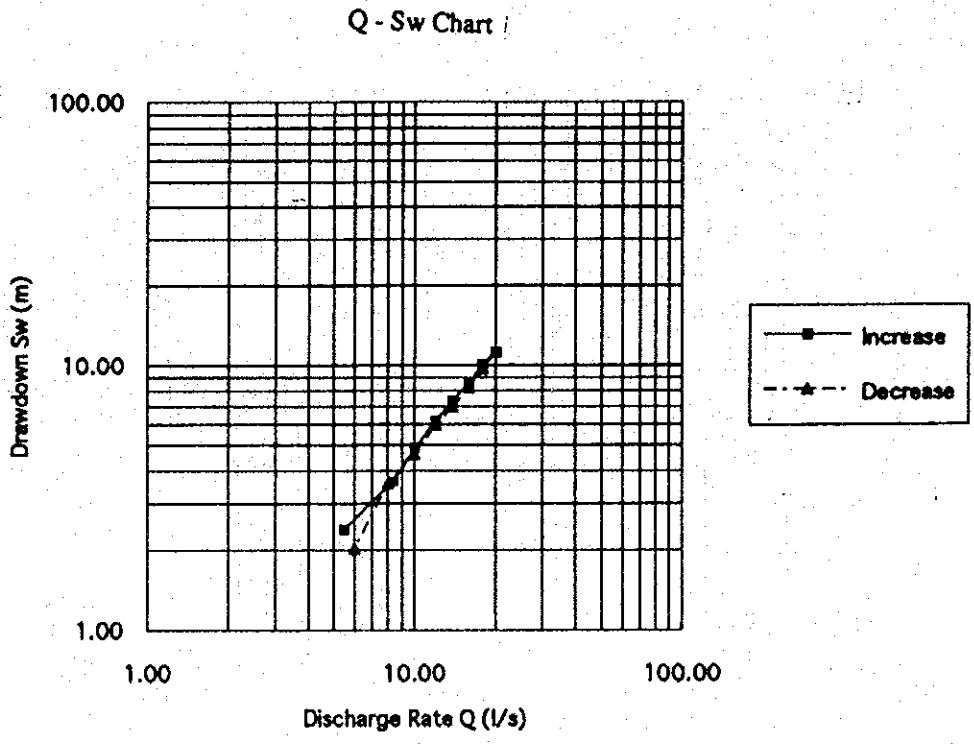


Fig. B-III, 2.40 Graphs for Step Drawdown Test (Well No.J-E)

< Gráficos Prueba de Gasto Variable (Pozo Nº J-E) >



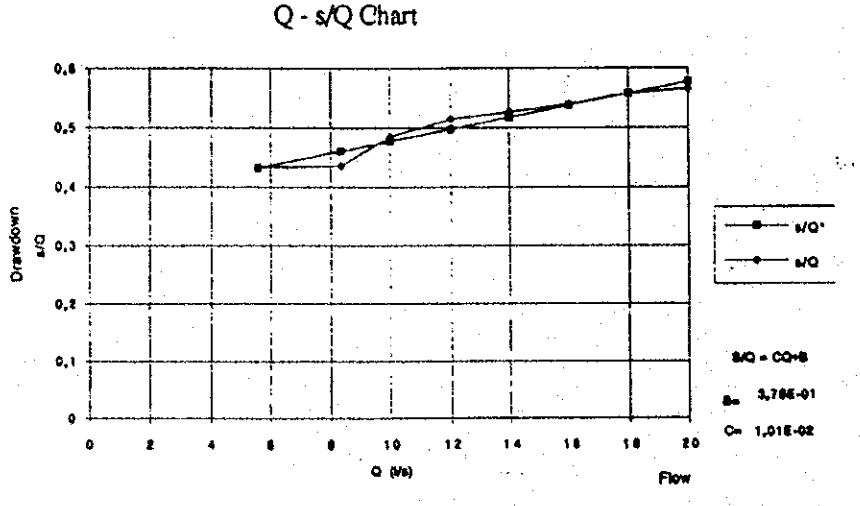
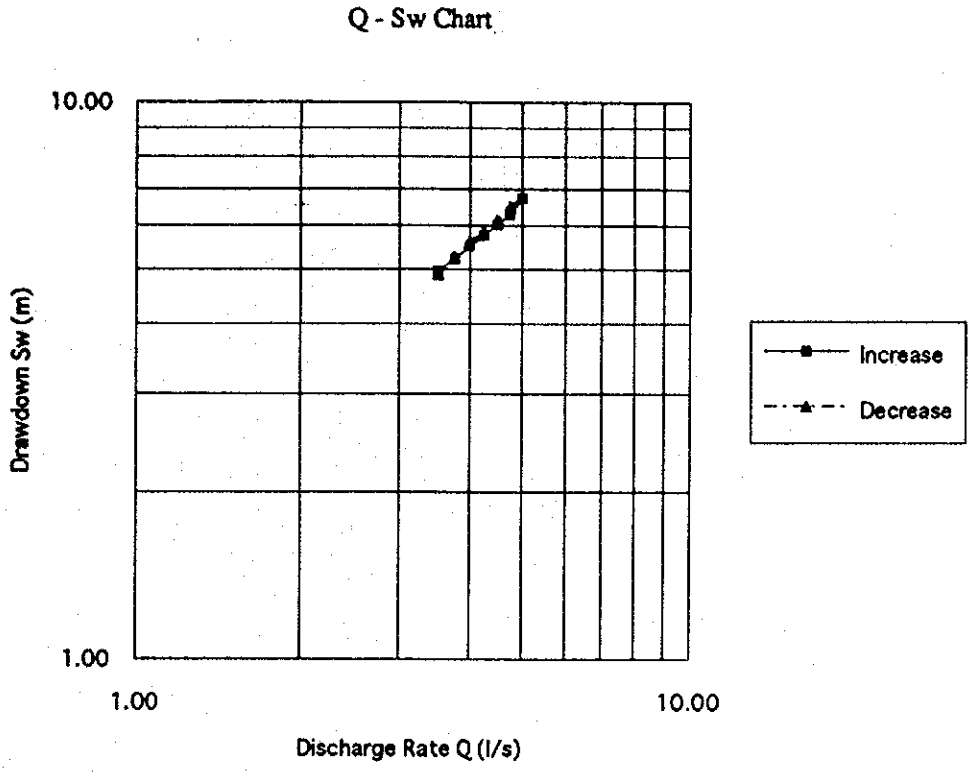


Fig. B-III, 2.41 Graphs for Step Drawdown Test (Well No.J-F)

< Gráficos Prueba de Gasto Variable (Pozo Nº J-F) >



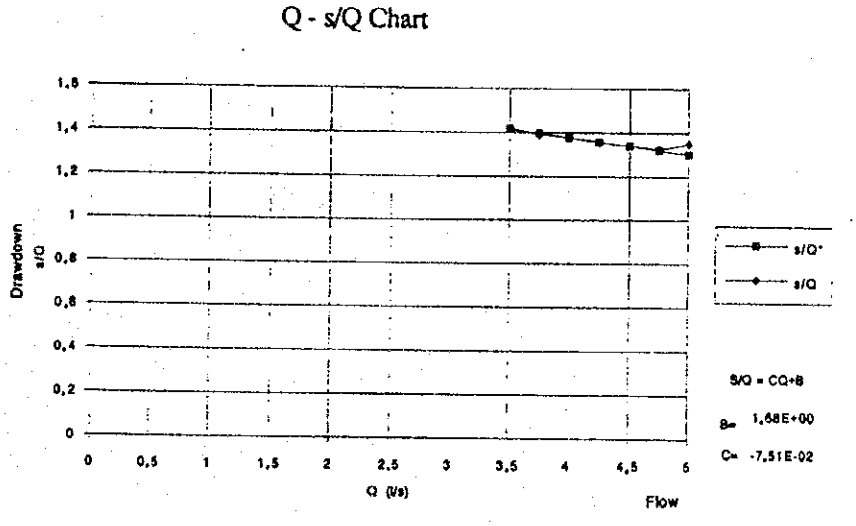
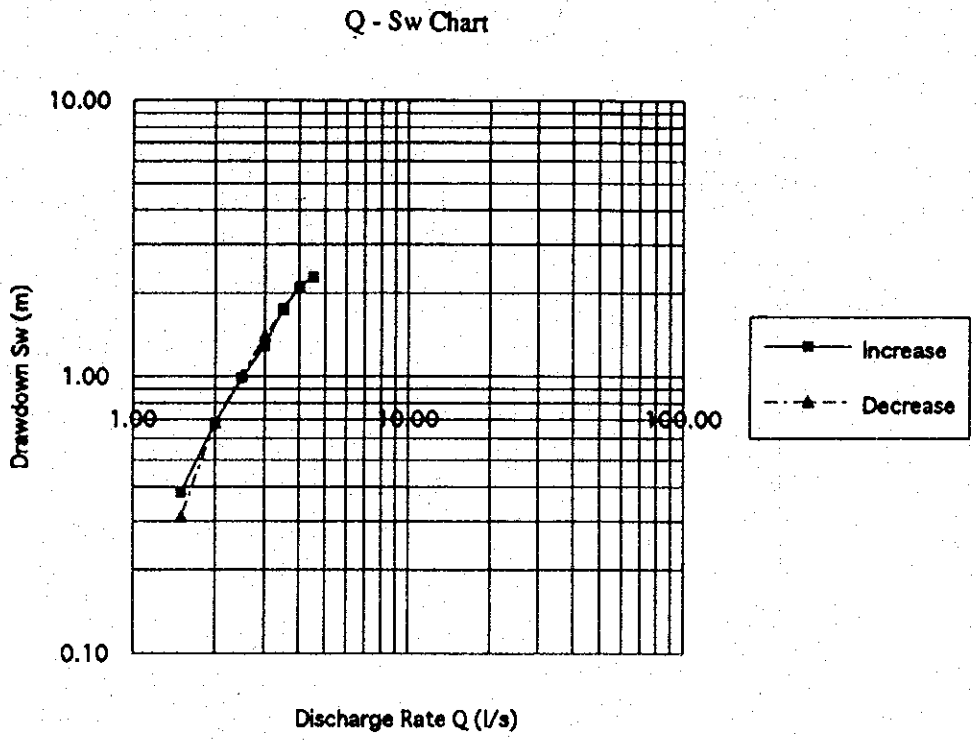


Fig. B-III, 2.42 Graphs for Step Drawdown Test (Well No.J-3)

< Gráficos Prueba de Gasto Variable (Pozo Nº J-3) >



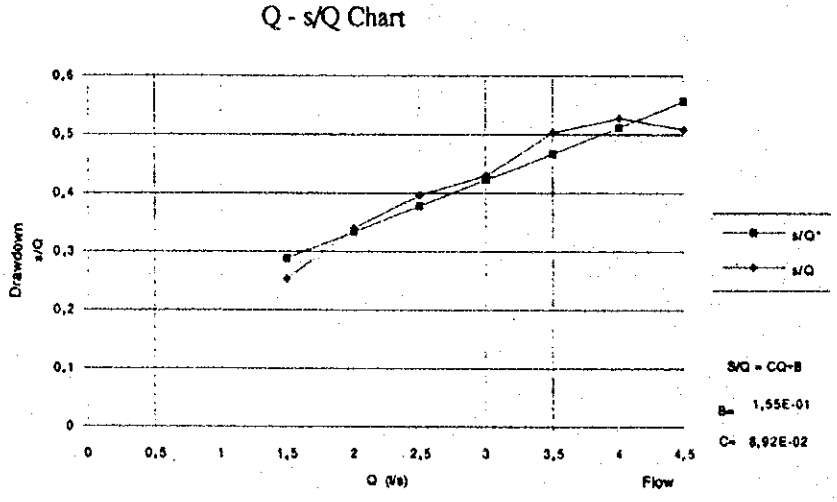
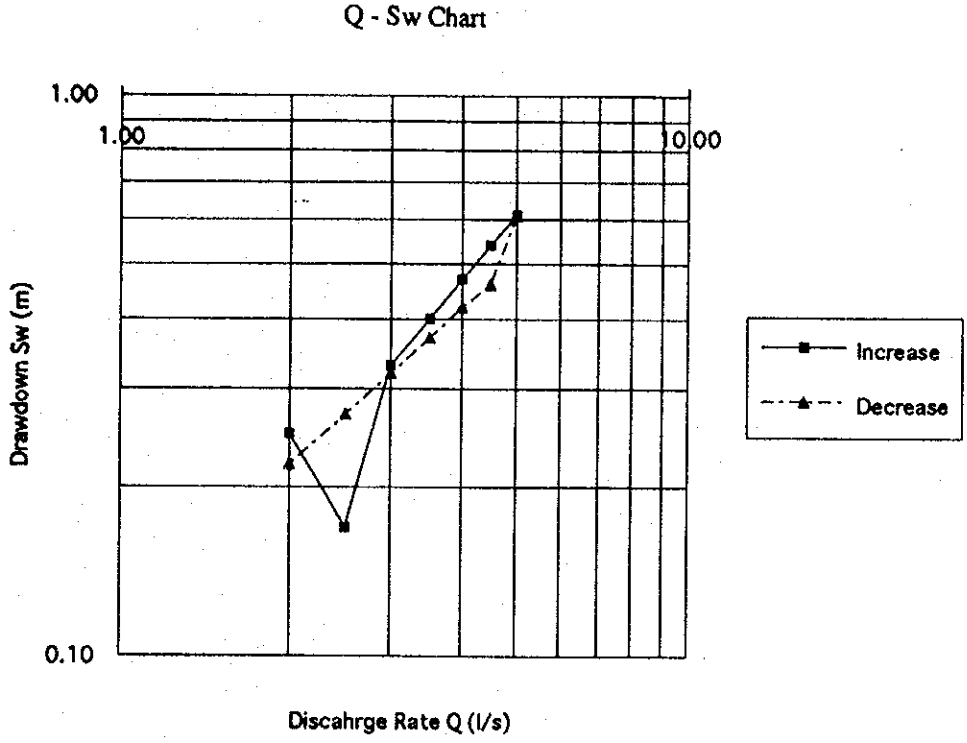


Fig. B-III, 2.43 Graphs for Step Drawdown Test (Well No.J-4)

< Gráficos Prueba de Gasto Variable (Pozo Nº J-4) >



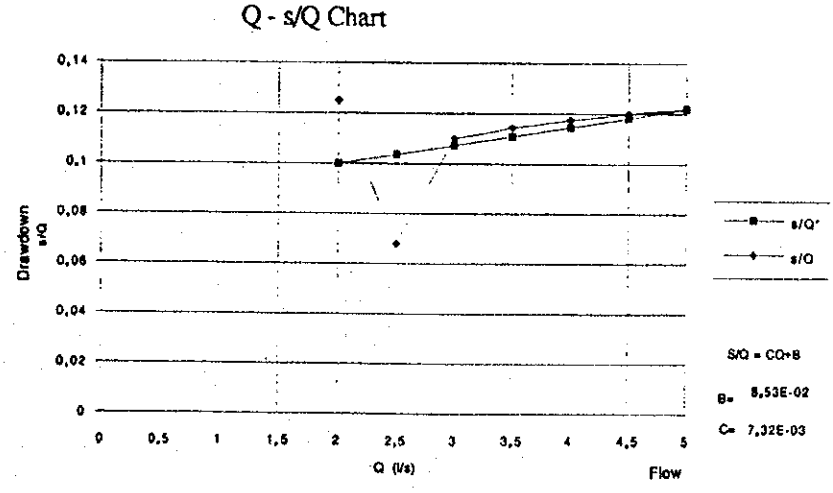
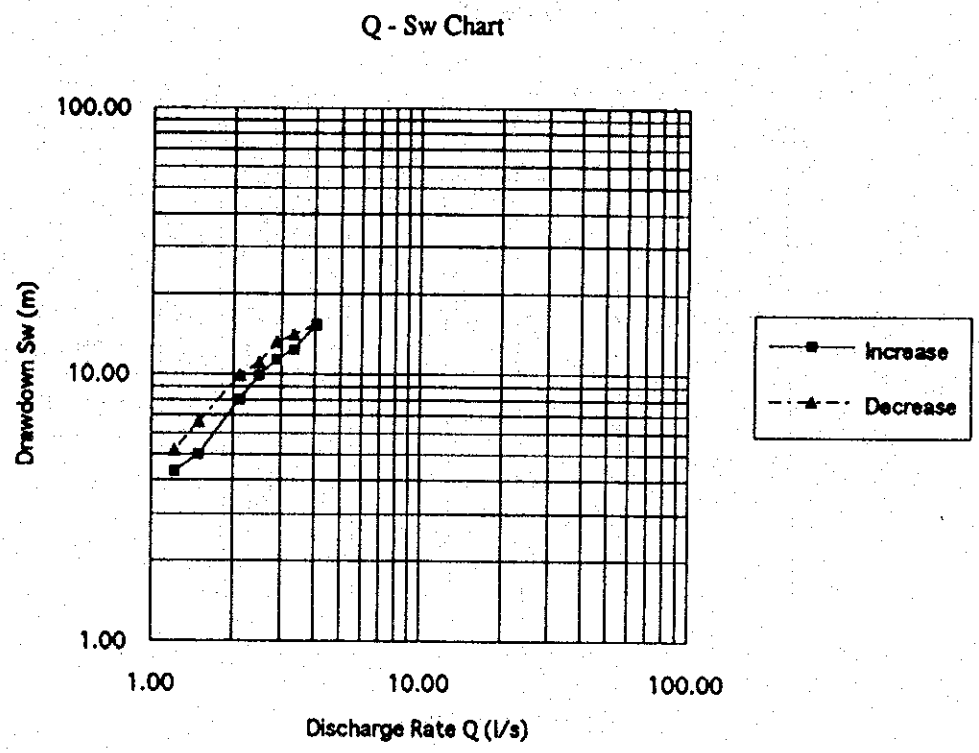


Fig. B-III, 2.44 Graphs for Step Drawdown Test (Well No.J-5)

< Gráficos Prueba de Gasto Variable (Pozo Nº J-5) >



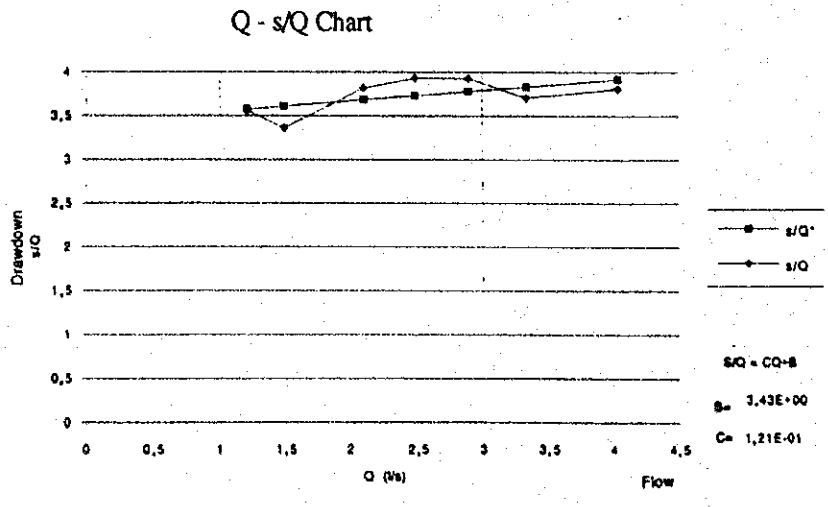


Fig. B-III, 2.45 Graphs for Step Drawdown Test (Well No.J-6)

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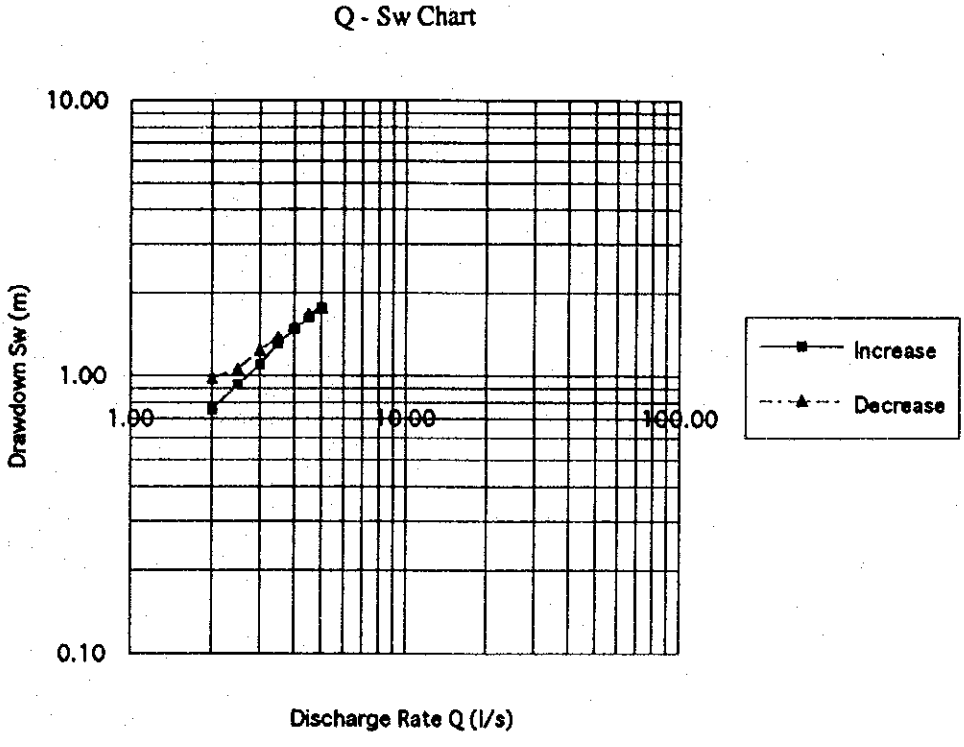


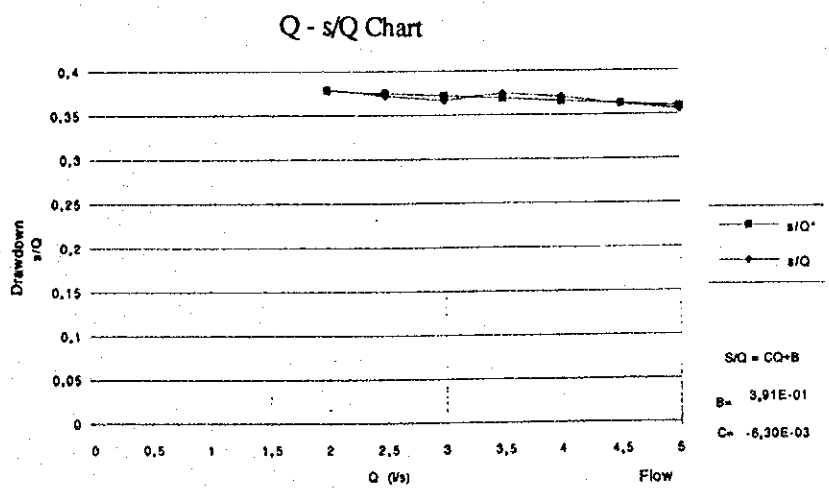
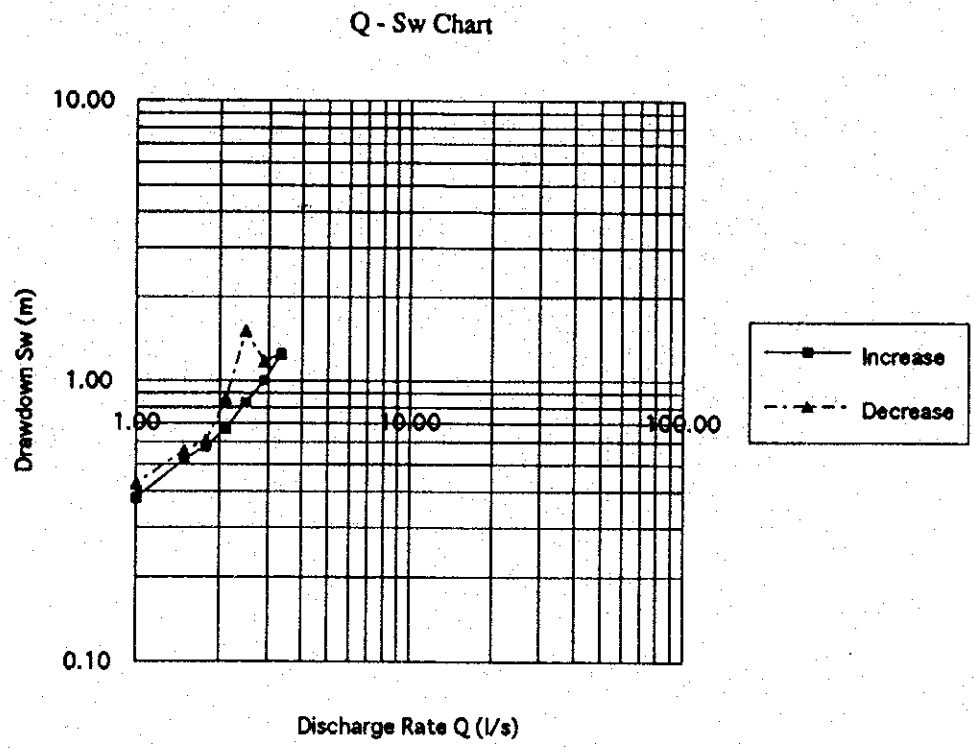


Fig. B-III, 2.46 Graphs for Step Drawdown Test (Well No.J-7)

< Gráficos Prueba de Gasto Variable (Pozo Nº J-7) >



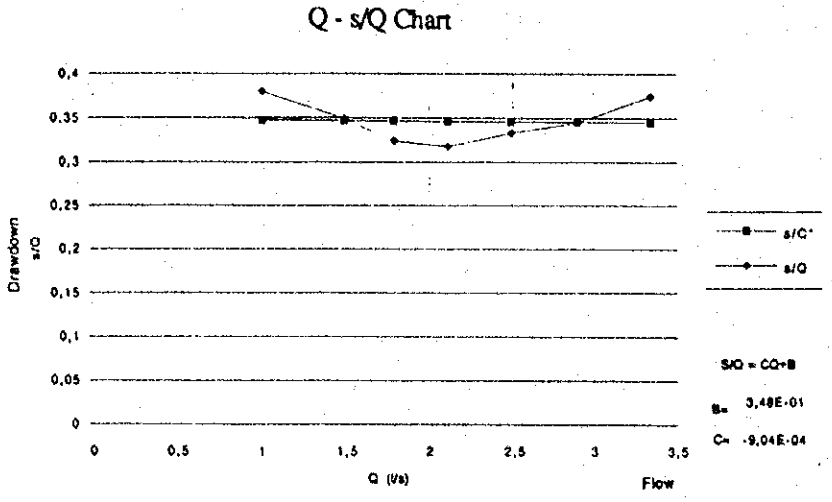
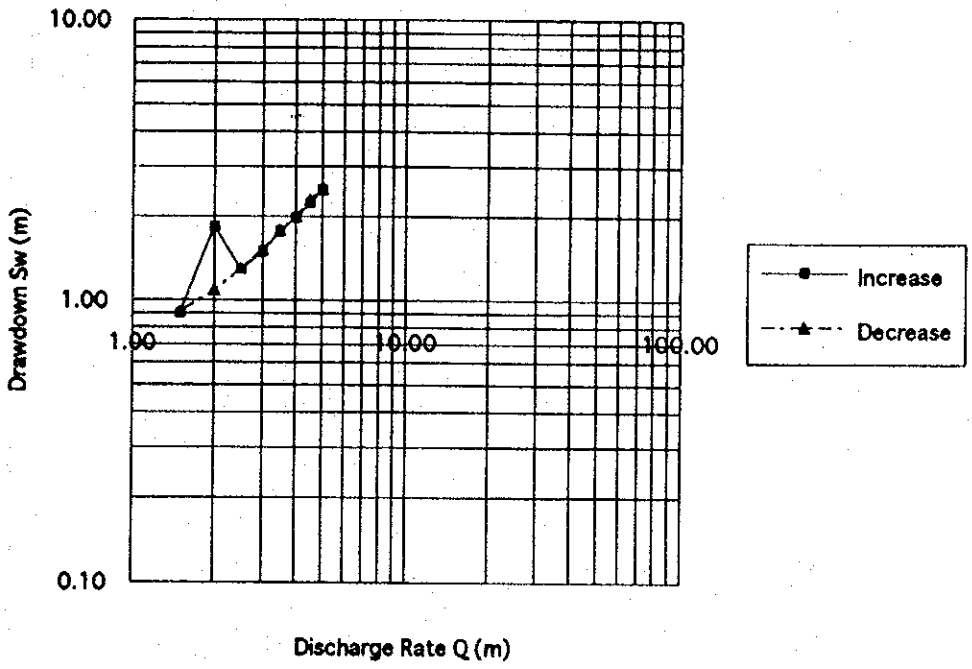


Fig. B-III, 2.47 Graphs for Step Drawdown Test (Well No.J-8)

< Gráficos Prueba de Gasto Variable (Pozo Nº J-8) >

Q - Sw Chart



Q - s/Q Chart

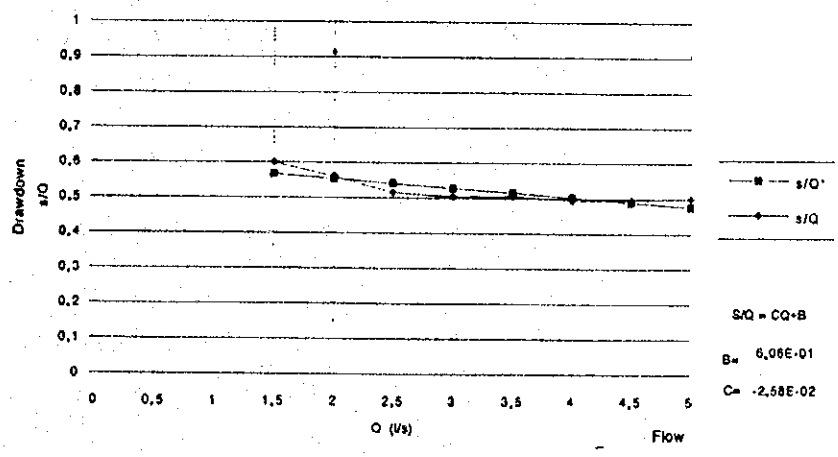


Fig. B-III, 2.48 Graphs for Step Drawdown Test (Well No.J-9)

< Gráficos Prueba de Gasto Variable (Pozo Nº J-9) >

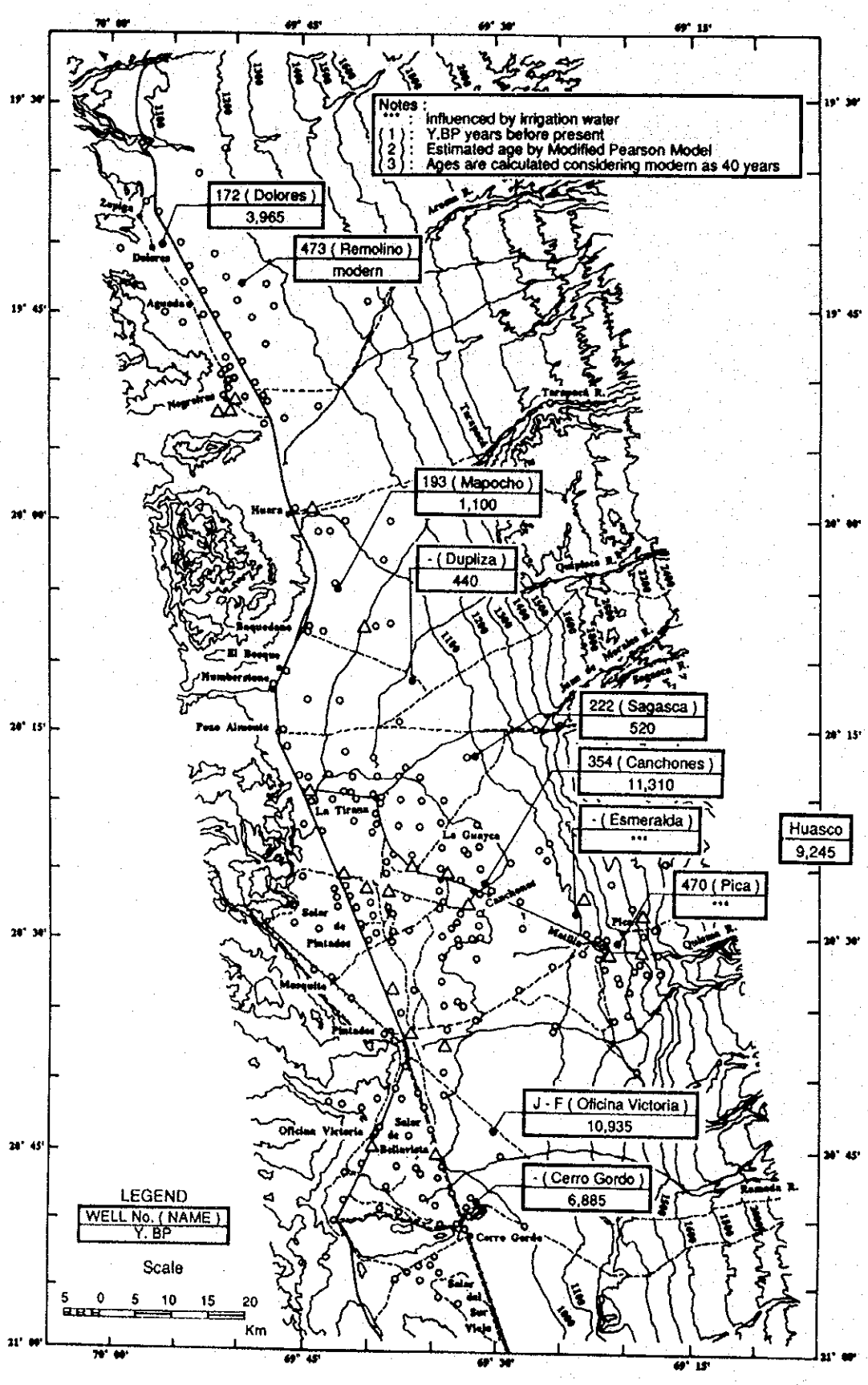


Fig. B-III, 2.49 Groundwater Age (by C - 14)

< Edad Agua Subterránea (por C - 14) >

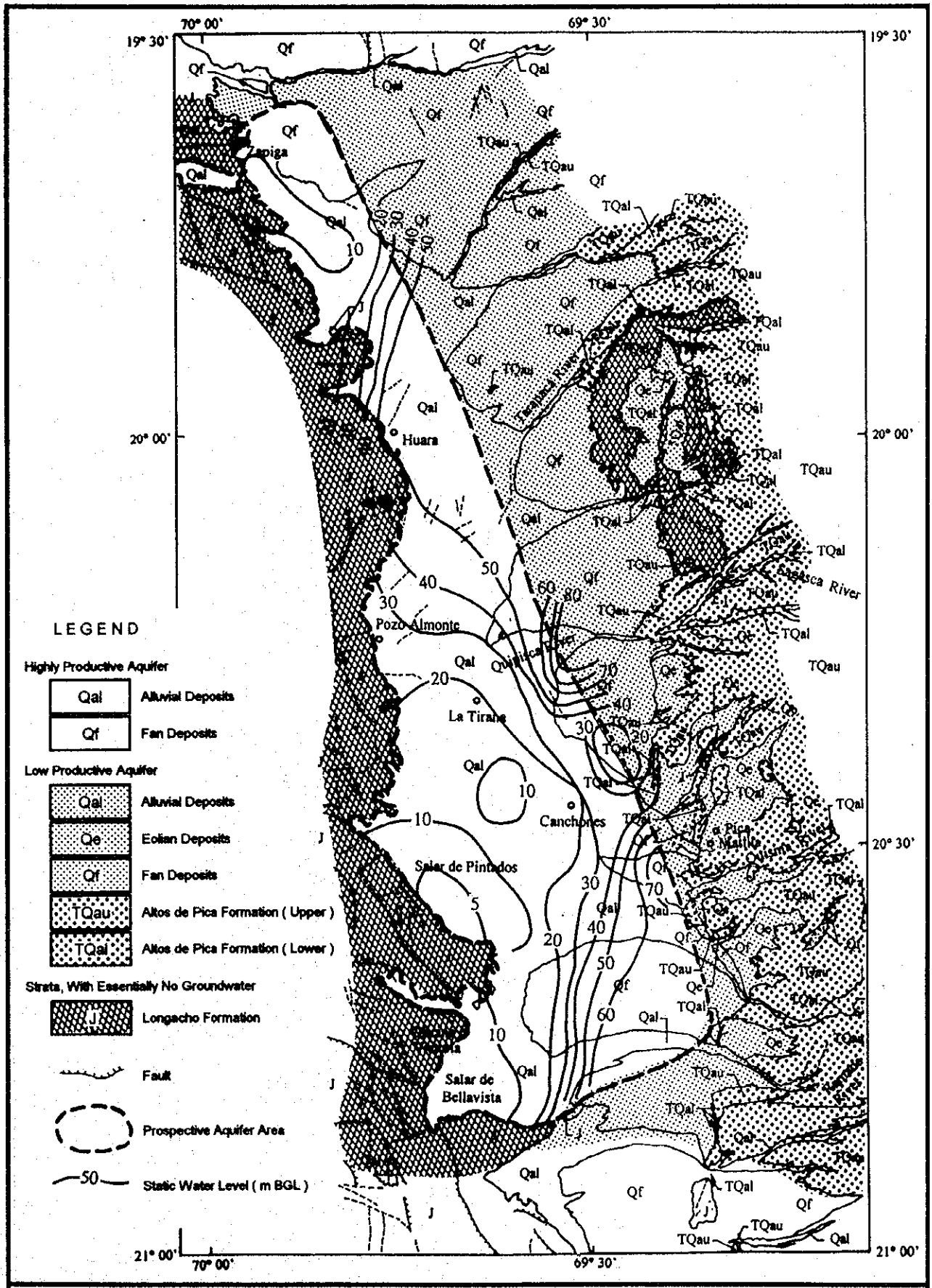


Fig. B-III, 2.50 Hydrogeological Map (Pampa del Tamarugal)

< Mapa Hidrogeológico (Pampa del Tamarugal) >

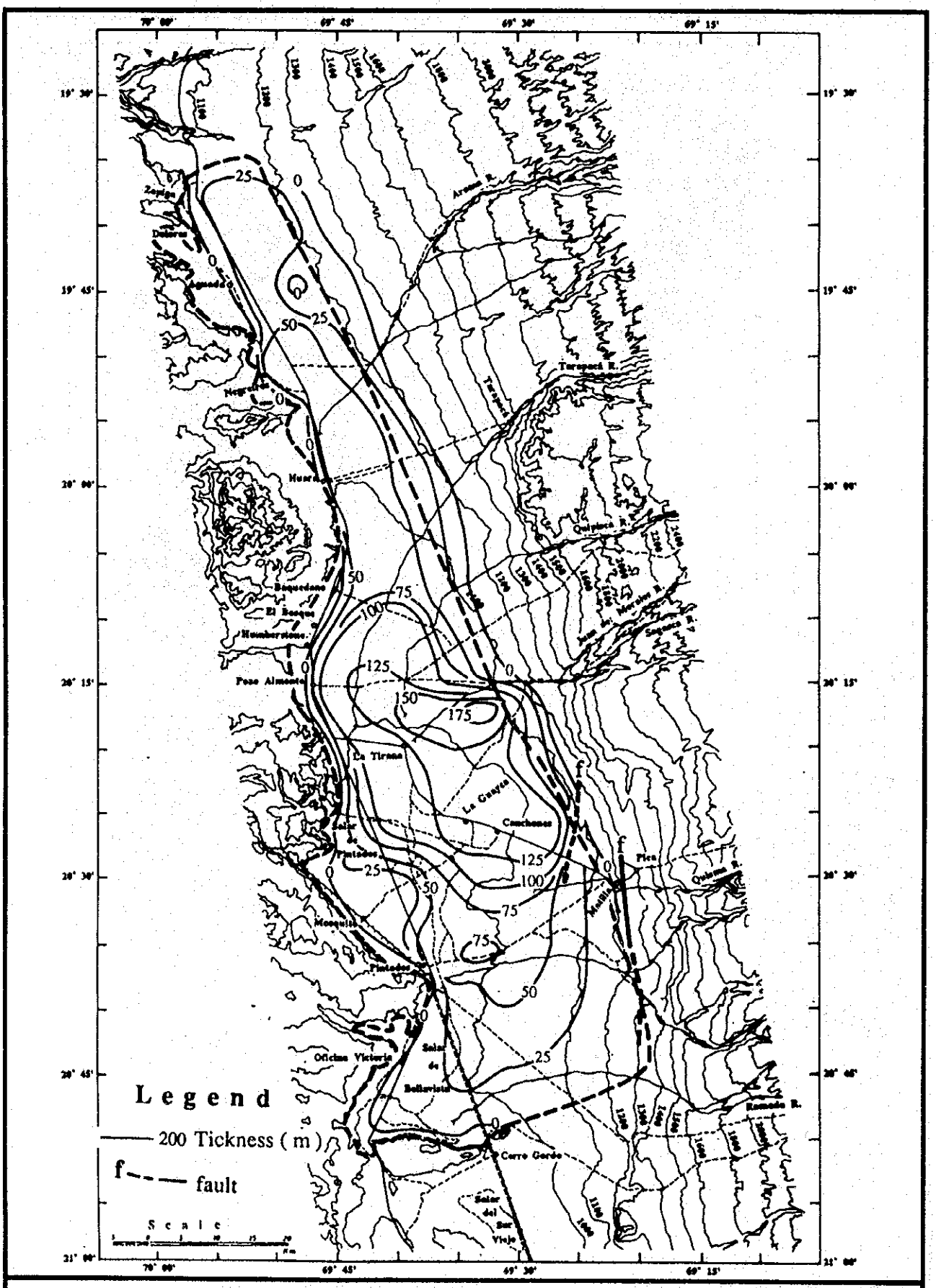


Fig. B-III, 2.51 Isopach Map of Aquifer (Pampa del Tamarugal)

< Mapa Isopaca Acufero (Pampa del Tmarugal) >

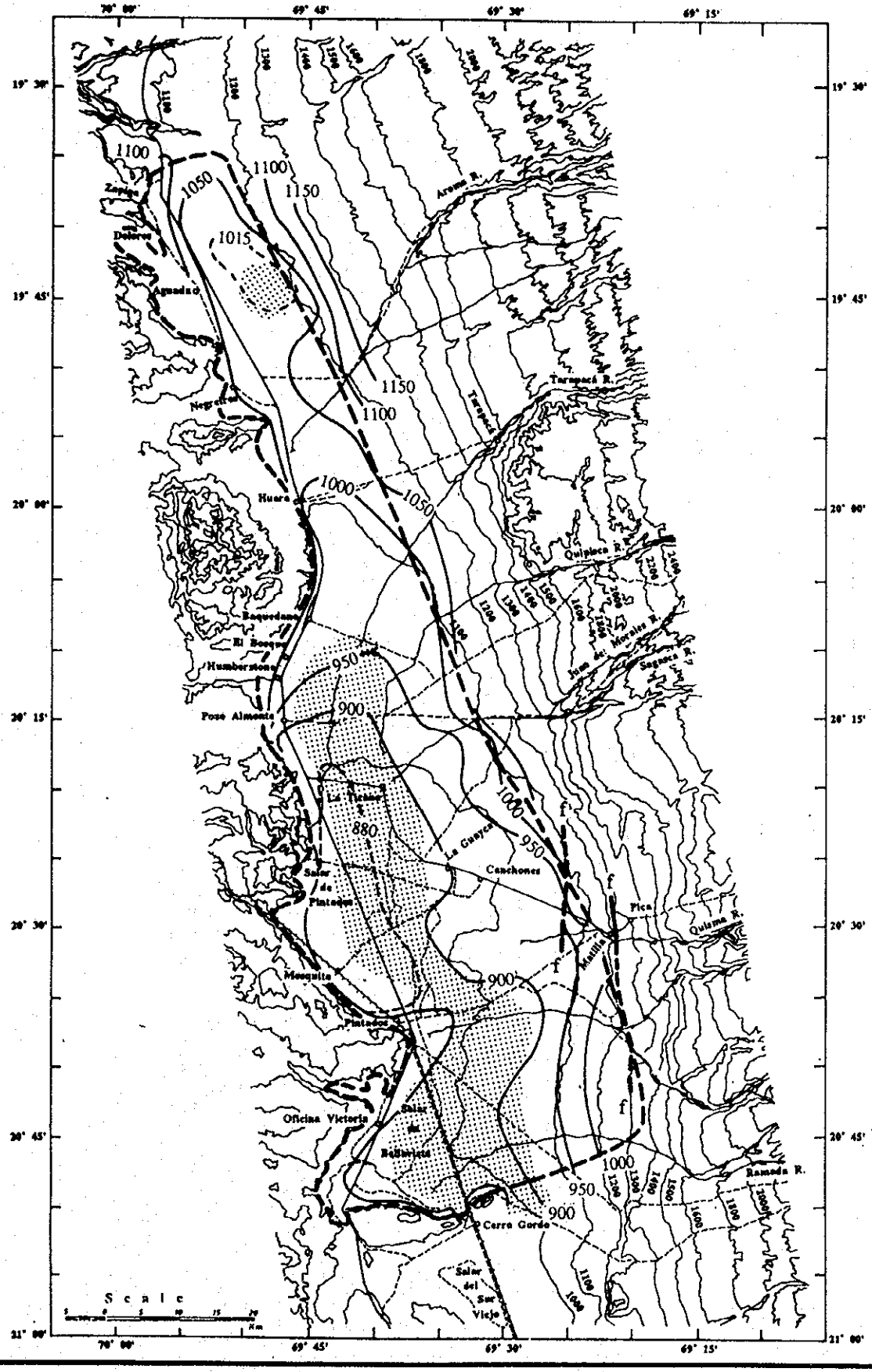


Fig. B-III, 2.52 Top of Aquifer (Pampa del Tamarugal)

< Superficie del Acuífero (Pampa del Tamarugal) >

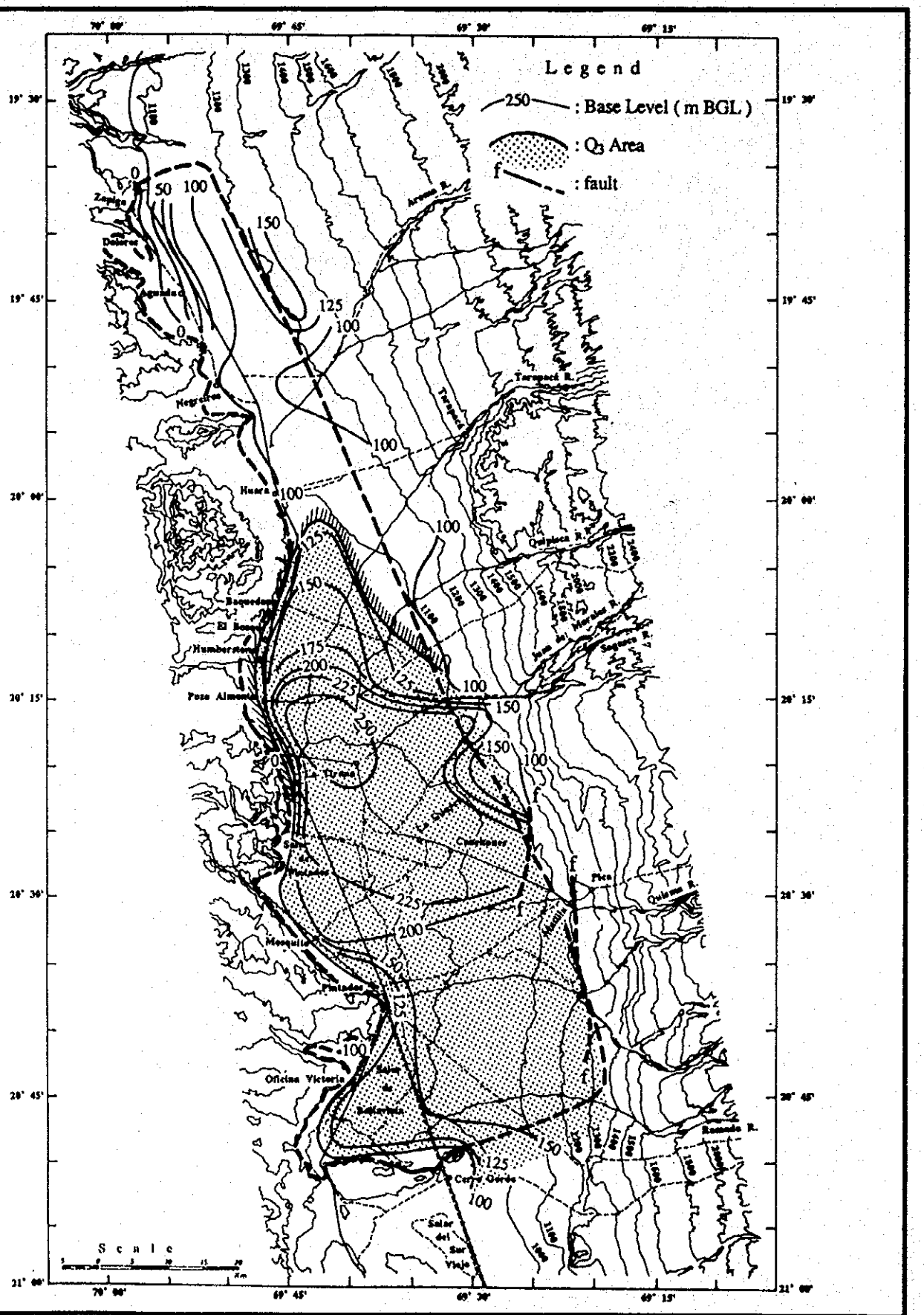


Fig. B-III, 2.53 Base of Aquifer (Pampa del Tamarugal)

< Fondo del Acuífero (Pampa del Tamarugal) >

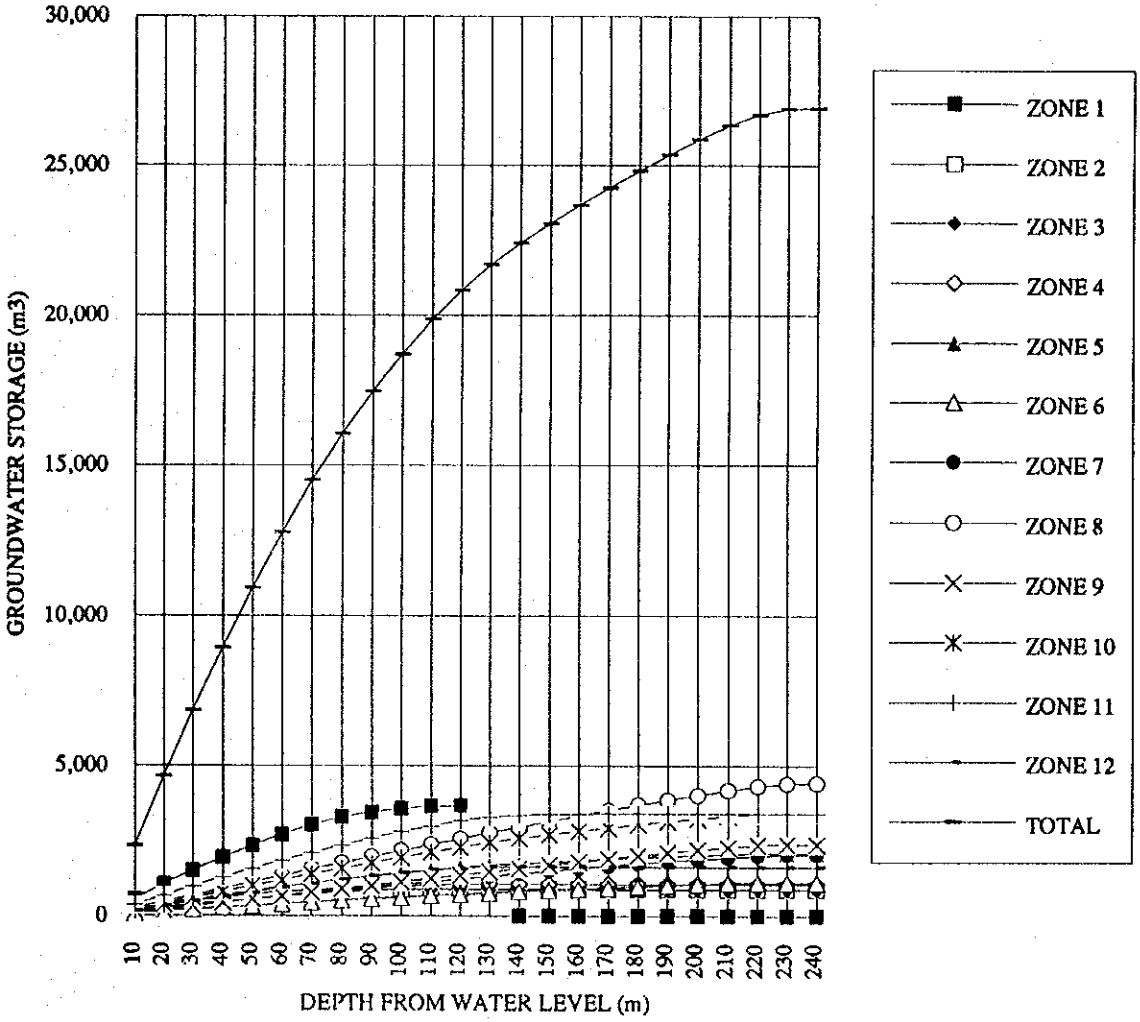


Fig. B-III, 2.54 Groundwater Storage (Pampa del Tamarugal)

<Reservas de Agua Subterráneas (Pampa del Tamarugal)>

Chapter III. GROUNDWATER EXTRACTION

3.1 Existing Groundwater Extraction

Groundwater is used for potable water supply, irrigation, mining and industry in Pampa del Tamarugal. Available pumping data were limited to that of potable water supply by ESSAT in phase 1 study. Therefore, DGA and the JICA Study Team carried out inteviews survey in the area.

Atotal number of 156 wells are surveyed during the study covering most of the wells which are actually extracting groundwater in Pampa except Pica, Matilla and Esmeralda area. The number of wells in actual use is 12 excluding ESSAT wells. The survey results are given in following table (see, Table B-III, 3.1 for more detailed information).

Water Use	Extraction (l/sec)
Domestic	
ESSAT	600.24
Other than ESSAT	60.41
(Sub-Total)	660.65
Mining	35.00
Irrigation	0.35
Total	696.00

note: interviews survey by DGA and the Study Team in Oct. to Nov., 1993.

Groundwater production of ESSAT increased by 1,518,500 m^3/year in 1993 compared to the production of 16,355,900 m^3/year (<3) in 1990. The University of Chile estimated groundwater extraction in Pampa to be 716 l/sec in 1980's (<4). However, actual extraction of ESSAT is 599.78 l/sec at Canchones and 0.46 l/sec at Dolores.

Groundwater extraction is also operating at Pica/Matilla area and Sagasca area, although the aquifers are separated from that of Pampa. At Pica area, water use is for irrigation and domestic water supply. Groundwater is extracted 111 l/sec. for irrigation use in Pica and Matilla area to towns in Pampa such as Pozo Almonte.

Extraction for mining use is 35 l/sec. Most of extraction is by a company, ACF Minera, located in the southern part of Salar Bellavista; the rate is 30 l/sec. Other mining use is at Oficina Mapocho, between Huara and Baquedano; the rate is 5 l/sec.

Groundwater for rrigation use is extremely small in Pampa; total rate is 0.35 l/sec.

3.2 Groundwater Level

3.2.1 Static Water Level

Static water level has been periodically measured by DGA on approximately 40 wells every month in the Pampa. In addition to these measurements, the Study Team and DGA conducted a static water level measurement on approximately 160 wells in 1993. Following two (2) water table contour maps were constructed on the basis of the results. One is a map of depth to water from the ground level (Fig. B-III, 3.1). Other is a map of water level above MSL (Fig. B-III, 3.2).

1) Depth of Water Level (below the ground level: BGL)

The depth of water level from the ground level is shown in Fig. B-III, 3.1. Water level is generally shallow in the central to western part of the Pampa, especially in Salar de Pintados and Salar de Bellavista, and the depth increases toward the east, because thick deposits are accumulated as the Fan Deposits in the eastern part of the Pampa. Characterristics of water level by area are described below;

(1) Zapiga, Dolores and Negreiros area

In the Zapiga and Dolores area, the water level is less than 10 BGL and the depth increases to the east reaching 20m BGL. The Negreiros area shows rather deeper water level, 10 m to 20 m. The water level becomes more deep to the east; the water level in the end of the fan is estimated to reach 50 m. The shallowest level was measured at the well No. ZP-1 (4.7 m) and the deepest one at the well No. 106 (more than 28 m).

(2) Huara to Pozo Almonte area

Although scarce data are available in the Huara area, the water table is generally the deepest in the Pampa except Pica area. The water level is deeper than 50 m in the most of Huara area.

The depth of water level decrease toward the Pozo Almonte from Huara; about 50 m in Huara, 40 m at Baquedano, 30 m at Bosque and 20 m in Pozo Almonte. In the Pozo Almonte area, gradual increase of water level is recognized; the water level is about 30 m at the cross point of the roads, to Mamiña and Sascada, about 12 km east from Pozo Almonte.

(3) Salar de Pintados

There is a large salt lake, Salar de Pintados, formed in a depression in this area. Elevation of ground level is slightly lower than surrounding area. The water level continuously becomes shallower from the Pozo Almonte to this area. The shalllowest area is 6 m mlower than the Mosquito area. The area of 10 m depth is widespreading from Pintados to Canchones and Huayca area. There exist pumping stations of ESSAT in Cnachones where 13 wells are operating. Total yield reaches to approximately 600 l/sec. No remarkable decrease of water table is recognized in the surrounding area of Canchones in spite of these pumping.

The water level abruptly increases toward the Pica, Matilla and Chacarilla area reaching to 90 m.

(4) Salar de Bellavista area

The shallowest water level of 2m was measured at the well No. 448 located western side of Salar de Bellavista which is disappeared. The area from Panamerican to the railroad has water level within 20 m; for most cases, it is less than 15 m. The water level in this area also increases toward the Chacarilla area.

2) Water Level (above the mean sea level: MSL)

Water level distribution is shown in Fig. B-III, 3.2. Water level is high in Salar de Zapiga (1,150 m MSL), north of the Pampa and the lowest level appears in Salar de Bellavista (909 m MSL). It shows a tendency to decline generally from north to south; from Zapiga to Salar de Bellavista through Salar de Pintados. Judging from the distribution of static water level, it is suggested that groundwater flows into the Pampa from eastward, then, slowly moves to southward. The gradient of groundwater is approximately 2/1000 from Zapiga to the southern end of Salar de Bellavista.

No remarkable influence is observed by pumpng at Canchones well field of ESSAT is recognized, although a limited area may be influenced by pumping groundwater in Canchones. There is a well in the experimental farm of Arturo Prat University located near the Canchones well field, approximately 1 km west from Canchones. Static water level of the well is sometimes measured; the data shows no influence by pumping of groundwater in Canchones well field. This fact shows that the radius of influence by pumping is less than 1 km in the vicinity of the Canchones well field.

There is a significant difference of water level between that of Pampa del Tamarugal Basin and Pica area; the difference is about 60 m. Because of this and the result of geological survey, the groundwater basin is divided into two basins, Pampa del Tamarugal and Pica basins.

Characteristics of water level by area are described as below;

(1) Zapiga, Dolores and Negreiros area

Water level ranges from 1,150 m to 1,110 m MSL, decreasing from east to west. The water level at Dolores is 1,112 m MSL. There is a ridge like form of 1,120 m contour line between Dolores and Negreiros. Judging from this, it seems that the groundwater recharged in the east flow down to the west, and diverges its stream to north towarding Dolores and to south.

(2) Huara to Pozo Almonte area

From Huara to northeastwars, the gradient of water table is steep, from 1,050 m to 1,150 m MSL; gradient of groundwater table is 9/1,000. In contrast to this, the gadient of groundwater table becomes gentle from Huara to Baquedano; the gradient is 4/1,000. The water table becomes almost flat toward the south from Baquedano; gradient between Baquedano and Salar de Bellavista is less than 1/1,000. This change of water table gradient is caused by the structure of the aquifer (See, Fig. B-III, 1.5).

(3) Pozo Almonte and Salar de Pintados area

The water level is about 1,000 m MSL at Humberstone, 990 m MSL at La Tirana, 980 m MSL at cnachones and 970 m MSL at the southern end of Salar de Bellavista. Contour lines of water table are generally straight and run in parallel to the north from Pozo Almonte. However, the contour lines gentelly curve toward the northeast forming a gentle valley like figure. The valley reaches to the southern end of Salar de Bellavista.

The contour lines show that groundwater flows to Pintados from not only north but also Pica and Chacarilla area.

(4) Oficina Victoria and Salar de Bellavista area

The water level ranges from 970 to 944 m MSL in this area. The lowest level was observed at the southwestern side of the Salar. The contour lines show that the groundwater flows from northeast to southeast.

(5) Pica area

Although aquifers of the Pampa receive a certain degree of groundwater recharge from the Pica area, aquifers of the Pica area are independent from that of the Pampa as shown in Chapter I, 1.1.

The number of available data is 12 in the Pica area. The highest water level (1,185.1 mMSL) is observed at the well No. 404 located apart from Pica, about 10 km south of the town. Thus, this well is an exceptional one.

Water level ranges from 1,063 to 1,091 m MSL except well No. 404. Depth to water level is different from place to place ranging 9 to 86 m. Averaged depth is 36 m. Water level in this area is around 100 m higher than that of Salar de Pintados area located to the west of Pica.

3.2.2 Dynamic Level

In the Pampa del Tamarugal area, the dynamic water level op most well has not been observed. Data on the dynamic water level are obtained only during the pumping test.

Although the dynamic water level changes corresponding to the yield, draw-down ranges from 1 to 52 m in Pampa del Tamarugal and from 8 to 55 m in Pica area.

Magnitude of draw-down is generally small in Huara area and relatively large value appears in Pozo Almonte area. In Huara area, yield is also small; less than 10 l/s in general. In contrary to this, yield is rather large in Pozo Almonte area; most of well has yield more than 20 l/s(max. 120 l/s). This difference may be due to the difference of the aquifer tapping the water. Depth of well is generally within 50 m in Huara area and most wells are more than 100 m deep.

Wells in Pica area show large draw-down as mentioned above. No matter how large is the draw-down, productivity is very small which is less than 10 l/s as a whole. So

far as concerned to the results of pumping test (yield, draw-down and specific yield), there is a remarkable difference between the Pampa area and Pica area.

Dynamic level is measured only on the wells of ESSAT in the Canchones well field. As the pumping for water supply has been continued, it is difficult to measure the static water level of each well. Therefore, the static water level of well No. H (observatory well) is considered as the static water level in the Canchones well field. Draw-down is estimated based on this assumption with the proviso that exact elevation of each well is unknown. Results are shown in Table B-III, 3.2.

When pumping is in succession, water level of each production well generally declines to a range from about 10 to 25 m against the static water level of the well No. H. This draw-down range is ordinary, compared with that of pumping test results shown in Table B-III, 2.2.

3.2.3 Historical Variation

Maps of static water level in 1993 (both BGL and MSL) are shown in Fig. B-III, 3.1 and 3.2. Furthermore, same kind of contour maps were constructed for the static water level in 1960s (Fig. B-III, 3.3 and 3.4).

Comparing two (2) maps, Fig. B-III, 3.1 and 3.3, major difference identified between the maps is a decrease of the area of 10 m contour line. It appears at areas surrounding the Canchones well field and the Dolores well field.

About 20 wells have long terms of information on static water level. Figures B-III, 3.5 (1) to 3.5 (6) show the historical variation of static water level in the Pampa del Tamarugal Basin.

Observation of static water level has been made since 1981. Characteristics of the result are as follows;

a) Water level has been gently declined at extremely small rate; the rate of draw-down is not more than 2 m between 1982 and 1993 (about 14 to 29 cm/year).

b) No seasonal change is recognized, while small oscillation is sometimes observed.

c) No influence of the production of groundwater around the Canchones well field is recognized so far as concern the available data.

d) Only well No. 122 shows the increase of static water level since 1989 in contrary to the general tendency. This well is located beside the Queb. de Chacarilla which is beyond the border of the western border of the basin. The reason of the increase of water table is unclear.

3.3 Groundwater Quality

Since data of groundwater quality is very scarce, DGA and the Study Team executed groundwater sampling and analysis in Pampa del Tamarugal. A total number of 50 samples are taken from the existing wells and the JICA Wells in November, 1993 and February, 1994. Results of water quality analysis are shown in Table B-III, 3.3.

Groundwater quality is generally characterized by high B and Mn contents, and relatively high TDS , As and Cl contents. The aquifers are generally uniform in the area except Salar de Pintados and Bellavista. Thus, there is no difference in water quality of shallow wells and deep wells. In contrary to this, impermeable clayey beds separate the aquifer of shallow wells and that of deep wells in Salar de Pintados and Bellavista area. Water quality of shallow wells show high concentration of ions. Such phenomena appeared in the well No. 113 in Salar de Pintados, and the wells No. 440 and 447 in Salar de Bellavista. Even in the deep wells, TDS is generally high in the Salar area.

Fig. B-III, 3.6 to 3.12 show the distribution of TDS, Cl, As, B, Mn, Fe and Cd contents respectively. Characteristics of major ion's distribution are as follows;

1) TDS

Fig. B-III, 3.6 shows the distribution of TDS value. The area of TDS value less than 250 mg/l is divided into two (2) areas; the northern area near Zapiga and Dolores, and the southern wide area with Canchones as a center. The Aroma River reches to Pampa at the eastward from Negreiros. The area of high TDS value is widespread along the stream of the Aroma. TDS value is generally low in the down streams of the Juan de Morales, Sagasca, Quisma, Chacarilla and Ramada.

2) Cl

Cl content is higher than standard of 250 mg/l in more than half of the total area as shown in Fig. B-III, 3.7. The area of high Cl content is distributed along the Aroma, Tarapaca and Quipisca Rivers, and the Salar area.

3) As

The area of high As content (more than 0.05 mg/l) is rather narrow as shown in Fig. B-III, 3.8. The western half of the area from Dolores to Salar de Pintados through Negreiros, Huara and Pozo Almonte. These areas correspond to the down stream of the Aroma, the Chacarilla and the Ramada Rivers. Along the other rivers, As content is less than standard.

4) B

Fig. B-III, 3.9 shows the distribution of B content. Distribution of high B content (more than 5 mg/l) area is almost similar with that of Cl content. The area of high content is distributed along the Aroma and the Tarapaca Rivers, and Salar area. Entrance to Pampa from the Chacarilla and the Ramada Rivers shows higher content.

5) Mn

Fig. B-III, 3.10 shows the distribution of Mn content. Distribution of high content area (more than 0.1 mg/l) is scattered separating five (5) areas. The widest area is from Humberstone to the south of Dolores. Others are as follows;

a) Area near La Tirana, elongating NE-SW direction
b) Area from Canchones to Pintados
c) Area southern margin of Salar de Bellavista
d) Area between Cerro Gordo and south of Matilla

Distribution of those areas seems to have no relation with rivers.

6) Fe

Fig. B-III, 3.11 shows the distribution of Fe content. High content areas (more than 0.30 mg/l) are wide spread in the following area;

a) Total area from Zapiga to Negreiros
b) Western half area from Negreiros to Humberstone
c) Area from La calera and Pica to Pintados and Bellavista

7) Cd

Fig. B-III, 3.12 shows the distribution of Cd content. High content area (more than 0.01 mg/l) is widespread in the area from Negreiros to Pozo Almonte along the Aroma and the Tarapaca Rivers. Salar area of Pintados and Bellavista is also high content area.

3.4 Identification of Groundwater Potential Area

Groundwater potential areas are identified referring the river network (Fig. B-III, 1.1), geological maps and geological profile (Fig. B-III, 1.2 to 1.6). Following factors are listed for the identification of potential development area;

(1) Extension of aquifer
(2) Thickness of aquifer
(3) Yield
(4) Water Quality
(5) Depth to water table (earth covering depth)

Item (1) and (2) decide the productivity of groundwater. They are mentioned in 2.4, Chapter II of B-III. The aquifers show enough extension and thickness.

Yield is represented by specific yield which is mentioned in 2.5, Chapter II of B-III. Specific yield is high in Huara, Pozo Almonte and Pintados area.

Water quality is the most important item to be considered in the Pampa. Water quality distribution is mentioned in 3.5, chapter III of B-III and is shown in Fig. B-III, 3.6 to 3.12. The areas which exceed the drinking water standard are indicated by dotted pattern in the maps. In Pampa, two (2) areas are within the standard of TDS, Cl, As, B(5 ppm is applied as a temporary standard in this Study) and Cd; the first one is the area east from La Tirana and the second is located between Matilla and Pintados as shown in Fig. B-III, 3.14.

The eastern part of the Pampa is covered by the Fan Deposits. The thickness of the deposits increase toward the east. Earth covering is generally thick in such area. It influences the cost of pumping of groundwater.

Furthermore, the adjacent area of the Canchones Well Field should be avoid, because the influence of groundwater extraction is observed in the area (<3).

Taking all these factors into consideration, the area east from La Tirana and the area between Matilla and Pintados are identified as groundwater potential areas as shown in Fig. B-III, 3.14.

Radius of influence was analyzed to determine the spacing of production wells to be constructed. Formulas applied are mentioned in Chapter III of this report.

Diameter of well	: 17-1/2" (444.5 mm)
Diameter of casing	: 12" (318.5 mm)
Production rate	: 50 l/sec
Allowable drawdown	: 30 m
Drilling depth	: 200 m

Pumping period considered in the calculation of influence radius is 0.5 day, 1 day, 15 days, 30 days, 180 days and 1 year. Aquifer constants applied are as follows;

Transmissibility	: 9.56 x 10^{-3} m3/sec/m
Effective porosity	: 0.3

Results are shown in following table.

	R (m)	Q (m3/sec)	T (m3/sec/m)	S	t (sec)	Period
1	155	0.05	9.56E-03	0.3	43200	0.5 day
2	190	0.05	9.56E-03	0.3	64800	0.75 day
3	219	0.05	9.56E-03	0.3	86400	1 day
4	849	0.05	9.56E-03	0.3	1E+06	15 days
5	1200	0.05	9.56E-03	0.3	3E+06	30 days
6	2940	0.05	9.56E-03	0.3	2E+07	180 days
7	4186	0.05	9.56E-03	0.3	3E+07	1 year

Above results suggest that 24 hours operation will cause a o.oo1 m of dradown along the circle which is 219 m in radius (428 m in diameter). Therefore, spacing of production wells are determined to be 500 m considering the safety side.