JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

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MINISTRY OF PUBLIC WORKS
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THE STUDY ON THE DEVELOPMENT OF WATER RESOURCES IN NORTHERN CHILE

SUPPORTING REPORT B : GEOLOGY AND GROUNDWATER

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PACIFIC CONSULTANTS INTERNATIONAL, TOKYO

B-I SAN JOSE RIVER BASIN

TABLE OF CONTENTS

B-1 SAN JOSE RIVER BASIN

LIST OF TABLES

B-I SAN JOSE RIVER BASIN

LIST OF FIGURES

B-I SAN JOSE RIVER BASIN

Chapter I. TOPOGRAPHY AND GEOLOGY

1.1 Topography

The JICA Study Team conducted a LANDSAT image analysis, aerial photographs interpretation and field survey in the area, and constructed a Topographical Map (Fig. B-I, 1.1) and a map of River Network (Fig. B-I, 1.2).

The northern part of Chile is divided into five (5) characteristic regions in topography, as shown in Fig. B-I, 1.1.

(1) Littoral Platform (A)

It was formed by the erosion in the western foothills of the coastal hills. It is a narrow region and extend from Iquique up to Morro de Arica, where the hills directly fall into the sea.

(2) Coastal Range (B)

The height and width of the region gradually decrease from Iquique to the north and extinct at Morro de Arica. Beyond this area, the plains of the Andes Mountains directly descend towards the sea.

(3) Intermediate Depression (C)

It is located between the Coastal Range and the Andes Mountains with 1,000 to 2,000 m in height and has gentle slope. It was formed by subsidence of the basement and was filled up by the eroded materials derived from the Andes Mountains to Pampa del Tamarugal. The filling materials of the Pampa are porous and seep the water proceeding from the Andes Mountains. Because of the evaporation of groundwater, saline deposits are widely spreading in the Pampa.

(4) Precordillera (D)

It corresponds to the west foothill of the Andes Mountains, grooved by several deep canyons, some of which have springs. It constitutes the location of many small villages, prehispanic in origin, with terrace cultivation in the foothills.

(5) Altiplano (E)

It forms an almost flat plateau at the top of the Andes Mountains, with 3,500 to 4,500 m in height, where very high and isolated volcanoes are also located. This region was filled up by the thick volcanic materials.

The San José River Basin consists of the parts of Altiplano, Precordillera and above mentioned Intermediate Depression. Drainage patterns of the basin extracted from LANDSAT images which were generated for this study are shown in Table B-I, 1.1. According to the Figures of B-I, 1.1 and 1.2, the San José River is originated at the Altiplano and has a large catchment at the upper stream, and it flows down into the regions of Precordillera and Intermediate Depression. It has a characteristically small catchment at the middle stream.

1.2 Geology

1.2.1 Methodology of Geological Analysis

Geological analysis was carried out by using LANDSAT images and aerial photographs, and field survey in order to clarify the regional hydrogeological conditions of the region. The results of both interpretations were compiled on the maps. They are shown in Fig. B-I, 1.3 and 1.4.

1) Interpretation of LANDSAT Images

For the present study, seven (7) scenes of LANDSAT false color images are used, which were generated using bands of 1, 4 and 5 of Thematic Mapper (TM) data, assigned to blue, green and red, respectively. This band combination has the advantage of emphasizing the color variation of rocks and soils. Details of used LANDSAT TM data are shown in Table B-I, 1.1.

Interpretation of these images which were enlarged to a 1:500,000 scale was conducted in order to extract lithological and structural characteristics on the hydrogeology and to understand large scaled geological structure and regional distribution of each rock units. As for the San José River Basin, four (4) scenes of false color images were used, whose path and row are 001-072, 001-073, 002-072 and 002-073.

2) Interpretation of aerial photographs

Interpretation of Black and white aerial photographs at 1:60,000 scale was followed by the above LANDSAT images interpretation. It allowed to clarify the detailed lithological distribution and geological structures. As for the San José River Basin, 25 sheets of aerial photographs were used, which were acquired in 1976 or 1977.

1.2.2 General Geological Features of the Basin

1) General geology of the Basin

Geology of the San José River Basin is composed of Precambrian (?), Mesozoic and Cenozoic rocks. The interpretation for the basin resulted in the classification of the 12 geological units shown in Fig. B-I, 1.3. Lithology of each units interpreted were discussed with published references which are mainly from Sonia Vogel and Thomas Vila (1980) and Salas, R. et al (1966). Lithological characteristics of each units and their ages are as follows:

Geologic Age	Formation	Lithology	Units
Quaternary	Recent Deposits	alluvial, fluvial, eolian, fan, terrace, beach, recent fluvial and detrital deposits	Qal, Qfl, Qe, Qf, Qt, Qb, Qrf, Qd
	Quaternary Volcanic Rocks	andesitic and trachyandesitic lava and pyroclastics	Qv
	Concordia Formation	unconsolidated gravel, sand, mud and volcanic ash marine deposits	Qc
	El Diablo Formation	Upper: greyish-black conglomerate, consisting mostly of andesite gravel Lower: an alternating bed of greyish-brown fine to coarse grained sandstone with greenish-grey siltstone	Qed,(d)--diatomaceous horizon
Tertiary	Oxaya Formation	Upper: grey, brown and white to pink ignimbritic tuff, rhyolitic and dacitic in composition Middle: greyish breccia intercalated with tuffaceous sandstone Lower: grey andesite intercalated with tuff and ignimbritic tuff	To, (ig)--predominant in ignimbrite
	Azapa Formation	light brown fine to medium grained sandstone intercalated with dark brown claystone, grey siltstone, conglomerate, calcareous rocks, pinkish tuff	Ta
	Chapiquiña Diorite	gray massive diorite. holocrystalline porphyritic	Ti
	(Chapiquiña Group) Lupica Formation	andesitic breccia, tuff, lava: alternated with conglomerate and arkose sandstone, affected by hydrothermal alteration	K-T
	Lluta Diorite	gray diorite with granite, granodiorite. holocrystalline granular	Kil
Cretaceous	(Vilacollo Group) Atajana Formation Sausine Formation	Atajana F.: conglomerate, sandstone, red sandstone and andesitic volcanic rocks Sausine F.: andesitic lava and breccia	J-K
Jurassic	(Arica Group) Los Tarros F. Camaraca F.	Los Tarros F.: brown-grey shale, limestone, grey quartzite, with brown andesite Camaraca F.: andesitic volcanic rocks with marine sedimentary rocks	
Pre-Cambrian (?)	Esquitos de Belen Formation	gneiss and mica schist	PC

(1) Precambrian Unit (PC)

It is distributed in the environs of Belen and Tignamar, and is called the Esquistos de Belen Formation inferred to be Precambrian. The Formation consists of gneiss and mica schists.

(2) Jurassic to Lower Cretaceous Unit (J-K)

It corresponds to Jurassic Arica Group and the Lower Cretaceous Vilacollo Group.

The Arica Group crops out only in the Coastal Range region and is divided into two formations: Camaraca Formation (Middle Jurassic), and Los Tarros

Formation (Upper Jurassic). The lithology of these formations are composed of andesitic volcanic rocks and marine sedimentary rocks.

The Vilacollo Group crops out along the main stream and is constituted by the Atajana Formation and the Sausine Formation. The Atajana Formation consists of conglomerate, sandstone, red siltstone deposited in a continental environment and andesitic volcanic rocks. The Sausine Formation is mainly composed of andesitic lava and breccia.

These formations are intruded by the acidic to basic plutonic rocks of same age in many parts.

(3) Lluta Diorite

It is composed mainly of grey granular holocrystalline diorite accompanied by granite and granodiorite. Phenocrysts are of plagioclase, orthoclase, biotite, amphibole, quartz, sphene, zircon and apatite. Orthoclase and biotite are altered. The rock was formed during the Upper Cretaceous period, because this rock intruded to the Arica Group and the Vilacollo Group and is overlain by the Oxaya Formation.

(4) Upper Cretaceous to Lower Tertiary Unit (K-T)

It corresponds to the Lupica Formation of Chapiquiña Group. Lupica Formation is constituted by a sequence of andesitic volcanic rocks alternated with conglomerate and arkose sandstone. Wide zones of hydrothermal alteration have been developed in this formation.

(5) Chapiquiña Diorite

The Chapiquiña Diorite is composed of porphyritic holocrystalline diorite. Phenocrysts consist of plagioclase, pyroxine and opaque minerals. Alteration of minerals is rare. This rock intrudes to the Lupica Formation of Chapiquiña Group. Thus, the intrusion was occurred during Early Miocene.

(6) Azapa Formation (Lower to Middle Tertiary) (Ta)

It is mainly formed of light-brown fine to medium grained sandstone with intercalation of dark-brown claystone, grey siltstone, conglomerate, calcareous sedimentary rocks and pinkish tuff. The thickness of the formation is variable, and the maximum reaches to 510 m.

(7) Oxaya Formation (Middle to Upper Tertiary) (To, To (ig))

According to Sonia Vogel and Tomas Vila (1980), it is divided into three members with maximum thickness reaching 550 m. It shows a large variation in lithology, both vertical and lateral. The lithology of Oxaya Formation at type-locality in the Pampa is as follows;

The lower member consists of grey andesite with intercalation of tuff and ignimbritic tuff.

The middle member consists of greyish breccia with intercalation of tuffaceous sandstone and tuff. In the San José River, however, conglomerate beds are well developed.

The upper member consists of grey, brown and white to pink ignimbritic tuff, rhyolitic and dacitic in composition, showing a different degree of welding.

(8) El Diablo Formation (Upper Tertiary to Lower Quaternary) (Qed,Qed (d))

According to Sonia Vogel and Tomas Vila (1980), it is divided into following two members;

The lower member consists of an alternating bed of greyish-brown fine grained to coarse sandstone with greenish-grey siltstone. Diatomaceous horizons are intercalated near the base of this member.

The upper member is represented by thick and continuous strata of greyish-black conglomerate which predominantly contains andesite gravels.

(9) Huaylas Formation (Lower Quaternary) (Qhu)

It is distributed in the area between the Altiplano regions and Precordillera and consists of rhyolitic ignimbritic tuff and lacustrine deposits.

(10) Concordia Formation

The Concordia Formation is of marine deposits and distributes in the lower reaches of the San José River and the city area of Arica. The formation is composed of unconsolidated gravel, sand, mud and volcanic ash. The formation never crops out because it is completely overlain by the Recent Units represented by the Fluvial Deposits. The Fluvial deposits has a interfinger relation with this formation in the Azapa Valley.

(11) Quaternary Volcanic Rocks (Qv)

These are widely distributed in the Altiplano region, most of which are andesitic and trachyandesitic in composition.

(12) Recent (Upper Quaternary) Units (Qt, Qf, Qe, Qfl, Qal, Qb, Qrf, Qd)

These are constituted by eight (8) units; terrace deposits (Qt), fan deposits (Qf), eolian deposits (Qe), fluvial deposits (Qfl), alluvial deposits (Qal), beach deposits (Qb), recent fluvial deposits (Qrf) and detrital deposits (Qd). Among the Recent Units, some units are called the Concordia Formation which constitutes the marine terraces. They are supposed to appear in the coastal plain and the lower reaches of rivers such as the San José River and the Lluta River. Beach Deposits appears along the beach from the river mouth of the San José River to the international border with Peru.

Small fans are formed at the outlets of quebradas such as Qda. del Diablo and Qda. de Llosyas. The deposits are rich in fine materials such as tuff and mud.

2) General Geological Structure of the Basin

Many faults of NW-SE direction were extracted from both, LANDSAT images and aerial photographs over the ignimbrite of the Oxaya Formation at the middle part of the basin, located within the Precordillera (Fig. B-I, 1.4). Those faults are probably of Cretaceous or lower Tertiary age and would have been reactivated in upper Tertiary to possibly Quaternary.

On the contrary, in the Intermediate Depression, the Mesozoic and Cenozoic formations form a stable monoclinal structure with gentle dipping towards the west.

1.2.3 Hydrogeology in Azapa Valley

The Study Team constructed a detailed geological map of Azapa Valley (Fig. B-I, 1.5) and a geological profile (Fig. B-I, 1.6) reviewing the existing data (< 1 to <4).

Geology of the Azapa Valley are classified into following seven (7) units;

Recent Fluvial Deposits (Qal)
Recent Beach Deposits (Qb)
Marine Terrace Deposit (Qt)
Fluvial Deposits (Qal)
Fan Deposits (Qf)
Detrital Deposits
Basement Rocks (J-K, K-T, Ta, To)

Six (6) units other than Basement Rocks and Detrital Deposits are considered to be permeable, therefore, aquifers are formed in these units. The Concordia Formation and the Fluvial Deposits are in a relation of interfinger; the former occupies the coastal plain and the lower reaches of the Azapa Valley, and the latter appears in the subsurface of middle to upper reaches of the Valley. Both are the principal aquifers in the area.

Distribution of the aquifers are limited in the coastal plain and the valley of the San José River up to Bocatoma (namely the Azapa Valley). It is considered that the extension of aquifers in the upstream of Bocatoma is small even if the aquifers appear, because the valley decreases its width toward the upstream of Bocatoma.

The aquifers are deposited filling the valley in the impermeable Basement Rocks. Thus, groundwater flows in the aquifers from the upstream to downstream without leaking to the outside of the valley.

Although river system is developed in the San José River basin, no surface water is recognized in the quebradas in the middle to lower reaches except the main stream of the San José River. Therefore, the groundwater is recharged mainly from the surface water of the San José River. In addition to this, fissures developed in the Basement Rocks may supply a certain measure of water to the aquifers.

Hydrogeological descriptions of each geological unit distributed in the area are given below;

1) Basement Rocks

Basement Rocks consist of the Arica Group (Camaraca Formation and Los Tarros Formation), Vilacollo Group (Sausine Formation and Atajana Formation), Chapiquiña Group (Lupica Formation), Azapa Formations, Oxaya Formation and plutonic rocks. These units are lumped together as the basement rocks from the hydrogeological point of view because of their impermeability.

Matrix of the sedimentary rocks in the Basement Rocks are generally filled by the fine materials such as silt, clay and volcanic ash. Fissures and joints are less developed in both sedimentary rocks and igneous rocks (volcanic rocks and plutonic rocks), while they are developed and weathered near the surface of rocks. Considering these conditions, the Basement Rocks are thought to be impermeable in general.

2) Marine Deposits

Marine Terrace was formed on the coastal plain by the eustatic movement. The Marine Terrace Deposits were piled on the terrace and are composed of mainly sand and gravels sometimes intercalated with silts. This unit is one of the aquifers in the city area of Arica. This Marine Terrace Deposits may be included in the Concordia Formation.

3) Fluvial Deposits

The San José River formed the fluvial plain along the both sides of the river. The Fluvial Deposits are piled in this plain and are composed of gravels, sands and silts. The unit is highly permeable, therefore, it is the most important aquifer in the Azapa Valley.

A geological profile (Fig. B-I, 1.6) from Saucache to San Miguel through Pago de Gomez was constructed based on the existing drilling logs. According to this profile, the geological characters of this unit are as follows;

(1) The area from San Miguel to Pago de Gomez

Sand and gravel beds distribute from the surface to a depth of 40 to 50 m. These beds are underlain by mud beds of which thickness is 20 m to 40 m and 60 m in maximum. The mud beds are underlain by fine grained volcanic ash of which thickness is more than 20 m.

(2) The area from San Miguel to Pago de Gomez

Sand and gravel beds distribute from the surface to a depth of 80 to 90 m intercalating with mud bed. The mud bed increases its thickness toward the downstream from Saucache. A more than 20 m thick of mud bed appears under the sand and gravel beds. The bottom of the mud bed has not been confirmed by drilling.

4) Detrital Deposits

Detrital Deposits consist mainly of talus deposits and others formed by land collapses and land slides. Principle units of this talus deposits are formed by gigantic scale of landslide occurred in the Oxaya Formations and deposited keeping their original sedimentary structure; the hydrogeological characteristics are considered same as that of the Oxaya Formation. Other deposits are formed by the land collapse. Matrix of the deposits are filled with very fine sand, silt and clay. Thus, the Detrital Deposits are less permeable.

5) Fan Deposits

The Qda. del Diablo, Qda. de Llosyas, and Qda. de Acha formed the fans at their confluences with the San José River. The Fan Deposits are composed mainly of sand, gravels and silt. Thus, this unit is usually permeable. However, the deposits formed by the Qda. del Diablo are abundant in very fine materials in the matrix and occupy wide and thick impermeable parts in the aquifer. The impermeable parts act as a underground dam which retards the water infiltrated in flood of the San José River.

6) Recent Beach Deposits

Along the coast of the Pacific Ocean, the Recent Beach Deposits are distributed. The deposits consist of sand and gravels. Fine materials are less in the matrix. Thus the permeability is high.

7) Recent Fluvial Deposits

The Recent Fluvial Deposits are distributed along the river channel of the San José River and the Qda. de Acha. The Deposits consist of volcanic ash, mud, gravel and sand. Therefore, it is a important aquifer in the Azapa Valley because of its high permeability.

References

<1: Cuadrangulos Arica y Poconchile, Region de Tarapacá, Carta Geologica de Chile (Escala 1:1,000,000), 1980 for Institute de Investigaciones Geologicas by Sonia Vogel and Thomas Vila

<2: Cuadrangulos Camaraca y Azapa, Provincia de Tarapaca, Carta Geologica de Chile (Escala 1:50,000), 1968 for Institute de Investigaciones Geologicas by Alvaro Tobar B, Ivan Salar Y y Rene F. Kast

<3: Geologia y Recursos Minerales del Departmento de Arica, Provincia de Tarapaca, for Institute de Investigaciones Geologicas, 1966 by Raul Salas O., Rene F. Kast, Francisco Montecinos P. e Ivan Salas Y.

<4: Modelo de Simulacion de las Agua Subterraneas del Valle de Azapa, January 1989 for DGA by Ayala, Cabrera y Asociados Ltda. con la assesoria de IPLA Ltdea.

Table B-I, 1.1 List of Used LANDSAT TM Data.
<Lista de Datos LANDSAT TM Utilizados>

No.	PATH-ROW	ACQUIRED DATE	CLOUD COVER	SCENE CENTER
1	001-072	02/AUG/1987	0 %	S17-21/W068-19
2	001-073	30/MAY/1987	0 %	S18-47/W068-43
3	001-074	27/MAR/1987	0 %	S20-14/W069-04
4	001-075	20/APR/1990	0 %	S21-40/W069-23
5	001-072	10/NOV/1986	0 %	S17-21/W069-55
6	002-073	28/MAR/1985	4 %	S18-47/W070-12
7	002-074	28/APR/1990	8 %	S20-14/W070-31

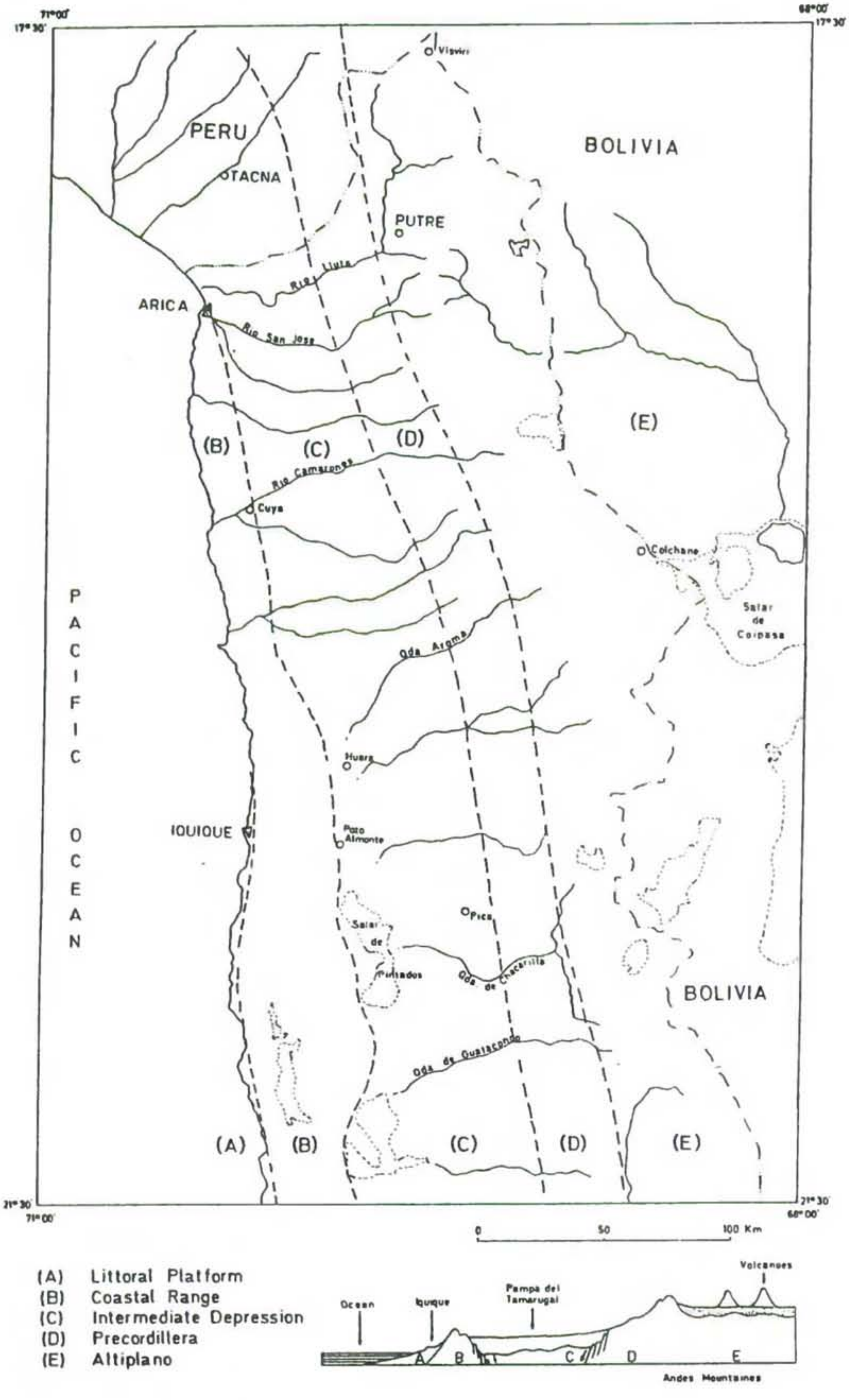


Fig. B-I. 1.1 Topographical Map

< Mapa Topográfico>

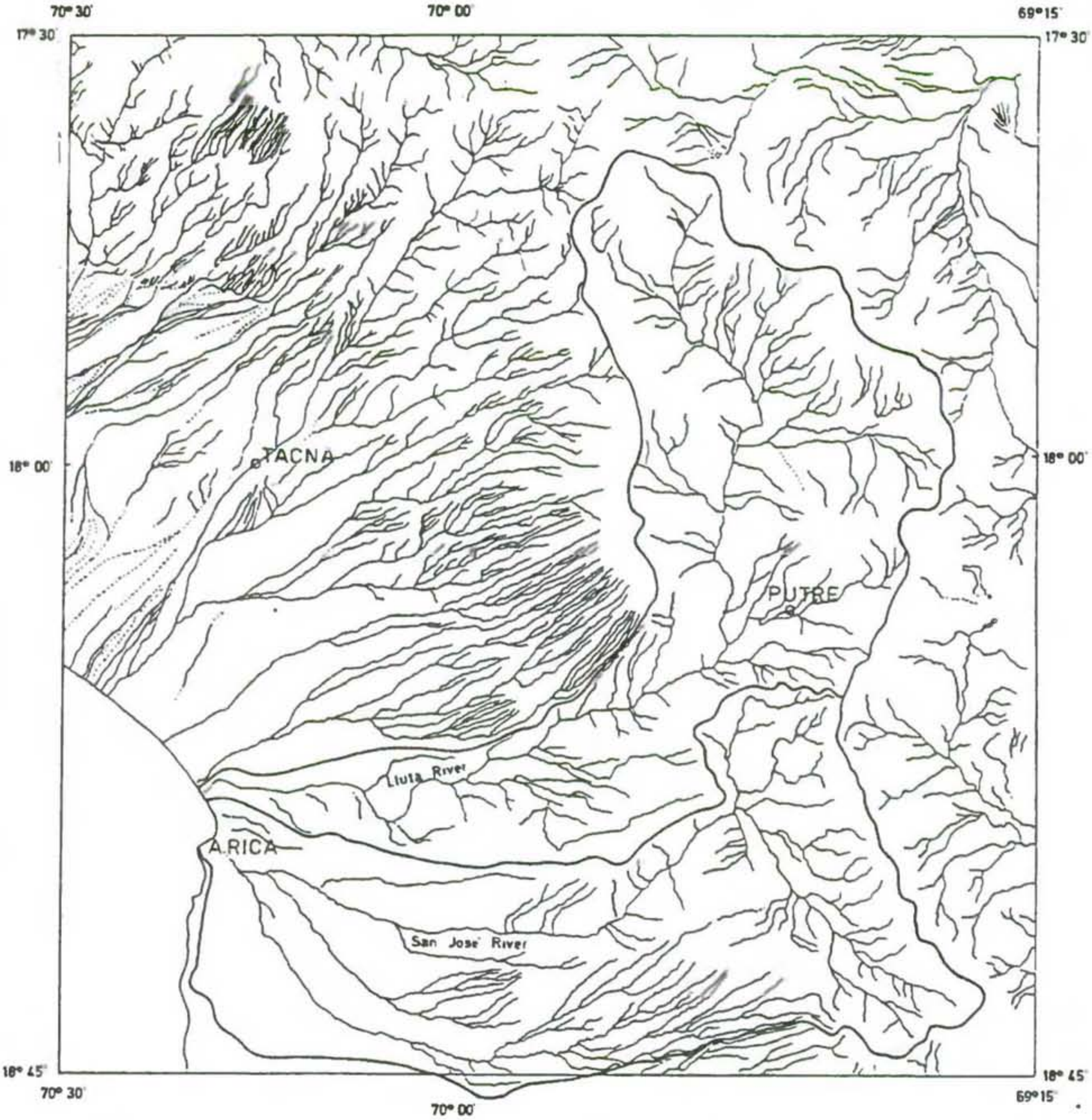


Fig. B-I. 1.2 River Network (Arica Area)

<Sistema Fluvial (Area de Arica)>

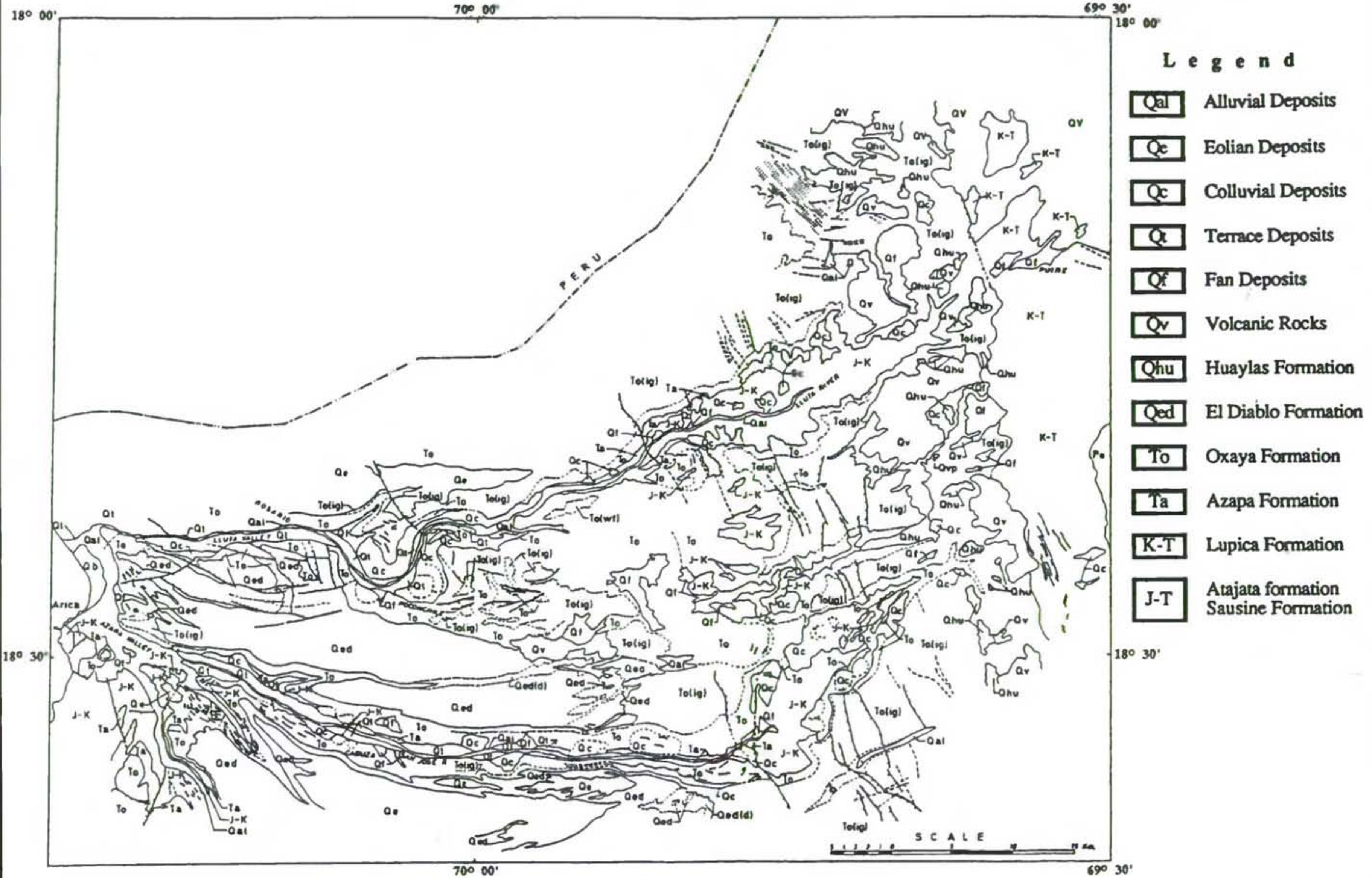


Fig. B-I. 1.3 Geological Map (Arica Area)

< Mapa Geológico (Area de Arica)>

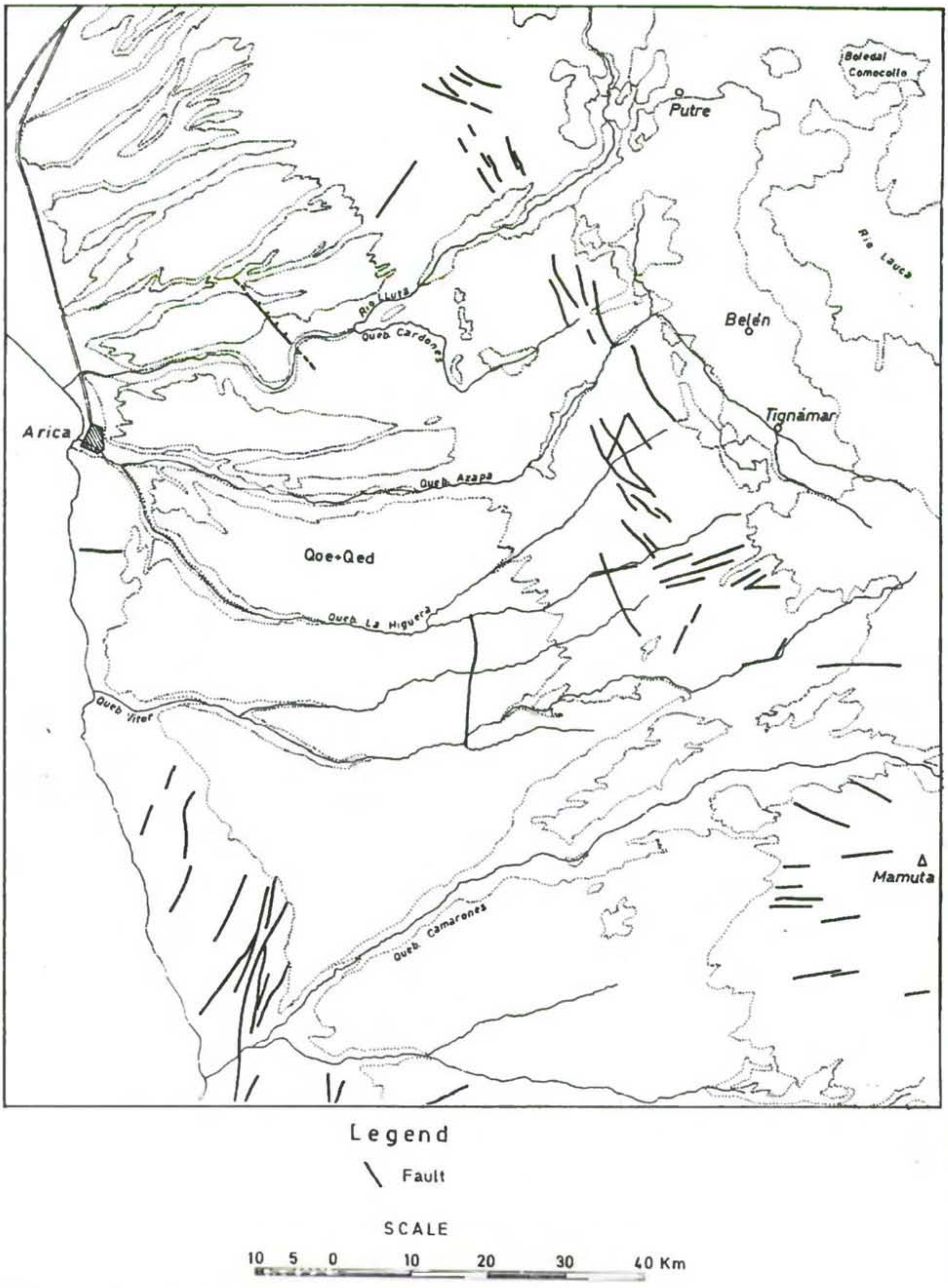


Fig. B-I. 1.4 Geological Structure (Arica Area)

< Estructura Geológica (Area de Arica) >

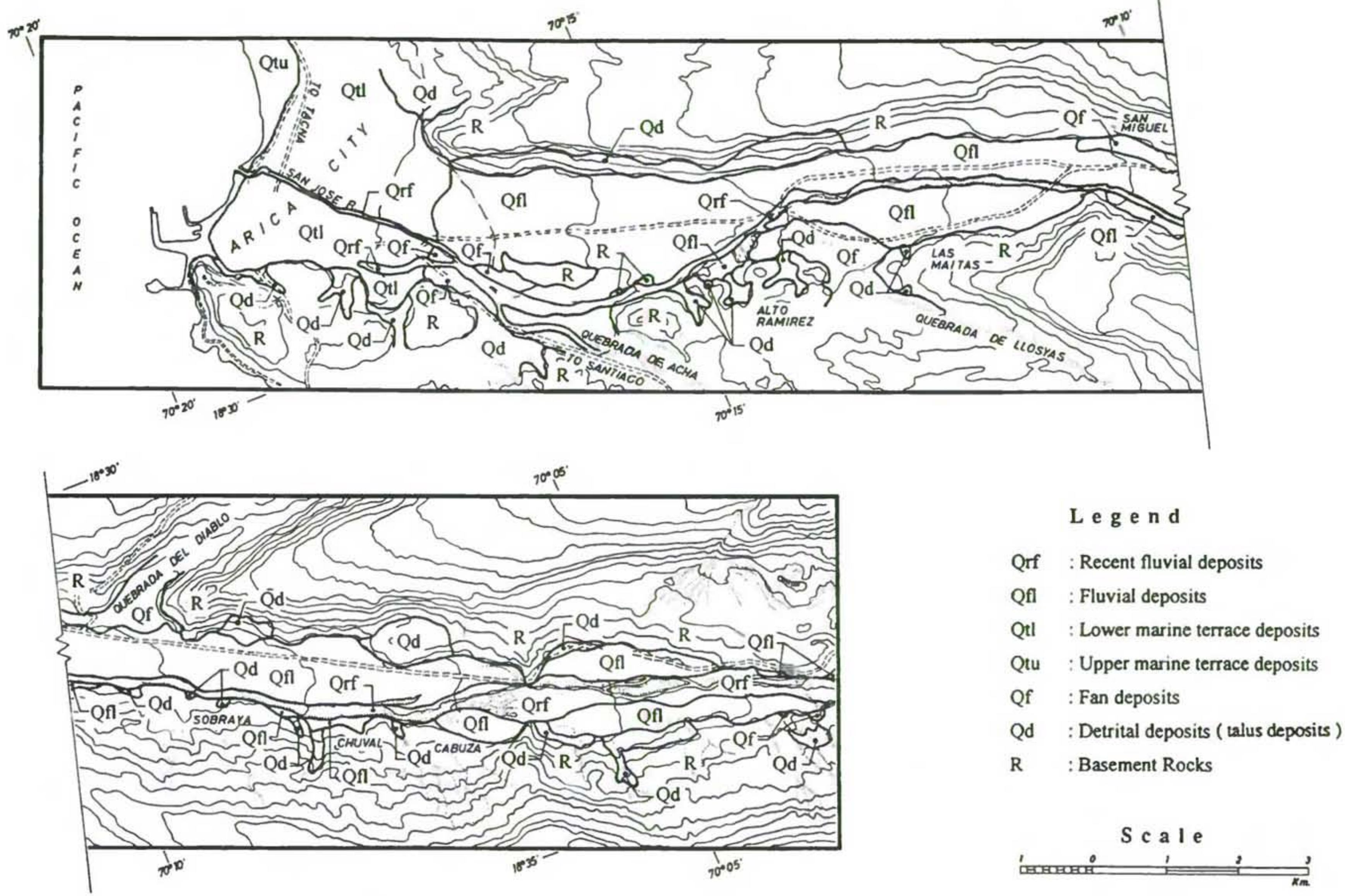


Fig. B-I. 1.5 Geological Map (Azapa Valley)

< Mapa Geológico (Valle de Azapa) >

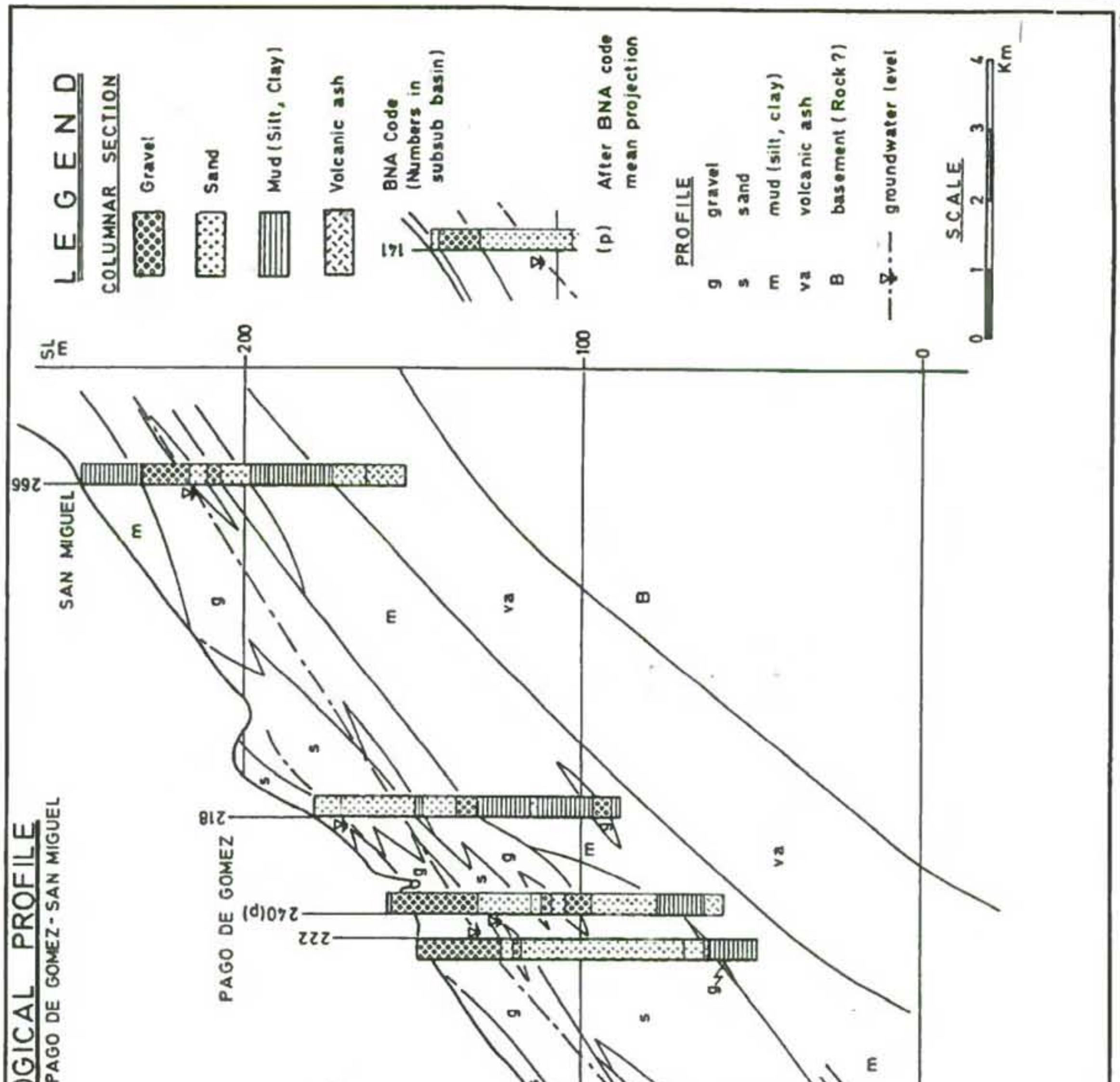


Fig. B-I. 1.6 Geological Profile (Azapa Valley)

< Perfil Geógico (Valle de Azapa)>

Chapter II. AQUIFER OF AZAPA VALLEY

2.1 Inventory of Existing Wells

2.1.1 Well Inventory

Most of the wells existing in the Azapa valley are officially registered to DGA and each well has respective registered number. However different four (4) numbering system were applied to register the wells in past; CORFO code (1969), CORFO code(1975) (<1), DGA code and BNA code (<2). Primarily CORFO code (1969) was used. This system was succeeded to the new system, CORFO code (1975). These systems express the wells by the combination of the coordinates (longitude and latitude) and numbers; for example, "1820-7010 CC-15". Although once DGA made DGA code which expresses the wells by only consecutive numbers such as "DGA-112", this code was not applied to the wells in the Azapa Valley. BNA code is the latest numbering system. This system expresses the wells by consecutive number using the hydrographic basin and sub-basin as follows; "013 10 108-6" (013: hydrographic basin, 10: sub-basin, 108: well No., -6: suffix). At present, DGA has applied both systems, CORFO code (1975) and BNA code, to register and control the wells.

In this report, the wells are expressed by three (3) digits of consecutive numbers using the last three (3) digits of the BNA code like "108" (this No. means "013 10 108-6".

The JICA Study Team established well lists and inventories (as of 1989) based on reviewing existing inventories and field survey (Table B-I, 2.1 and 2.2). The well inventory was prepared in sheets for each well, which gives necessary well data mentioned below to evaluate the groundwater potential around the well. The reviewed inventories are attached to the following reports;

(1) Analisis Critico de la Red de Medición de Niveles de Agua Subterránea 1 Region, October 1987 for DGA by Alamos y Peralta Ingenieros Consultores Ltda.

(2) Modelo de Simulación de las Aguas Subterráneas del Valle de Azapa, January 1989 for DGA by Ayala, Cabrera y Asociados Ltda. Ingenieros Consultores con la asesoris de IPLA Ltda.

(3) Stratigraphic columns prepared by DGA, RIEGO and ESSAT.

There are 371 deep wells and 14 springs (as of 1989) in the Azapa Valley consisting 166 deep wells (sondajes) and 205 dug wells (norias). The wells drilled by the Study Team during phase 2 study are also added. The well lists are shown in Table B-I, 2.1 for deep wells and 2.2 for dug wells. The well inventory is shown in Data Book. The locations of wells are shown in Fig. B-I, 2.1. The well inventories present following items;

(1) Well No.
  a. BNA code No.
  b. CORFO code No. (1975) (Dug wells and springs have not any code No.)
(2) Community name of well location
(3) Location name
(4) Name of owner
(5) Name of constructor
(6) Elevation
  Elevation of well is expressed by the height from the mean sea level (m MSL)
(7) Drilling depth
(8) Depth of well
(9) Specific yield
(10) Date of construction
(11) Static water level (as of De. to Nov., 1993)
  a. BGL (m below the ground level)
  b. MSL (m above the mean sea level)

In addition to these, well inventory cites the following data;

(1) Geostratigraphic column
(2) Well specification (casing & screen design)
(3) Pumping test results (Aquifer constants)
(4) Water quality

2.1.2 Deep Well (Sondaje)

Out of 166 deep wells, 121 deep wells have information on the date of construction and remaining 45 deep wells have no information. The oldest record of deep well is in the year of 1946. The number of deep well started to increase in 1940s, and significant increase of deep well number occurred between 1950 and 1967 as shown in Fig. B-I, 2.2. In this period, 57 deep wells were constructed. Total number of constructed deep wells reached to 100 in 1975 since 1946.

166 deep wells are listed in the list and inventory, however, 14 are abandoned. The purpose of deep well construction (as of 1989) is summarized as follows;

Purpose	No. of wells	Abandoned wells	Total No. of wells
Investigation	8	8	16
Potable	50	2	52
Irrigation	58	3	61
Industry	4	0	1
Others	20	1	21
No data	12	0	11
Total	152	14	166

2.1.3 Dug Well (Noria)

According to the inventory of dug wells, total number of dug wells comes to 205 distributing along the San José river; most dug wells locate between Chugal and Saucache. There are also ten (10) dug wells in the city area of Arica. Nine (9) wells(sondajes) are included in the inventory. Dug wells are used for following purposes (as of 1989);

Purpose	No. of dug wells
potable	37
irrigation	30
industry	2
potable/irrigation	2
potable/industry	1
capped or dried up	25
out of use	74
abandoned	9
no data	25
total	205

Total number of 180 dug wells has information on the date of construction and no information is available on the remaining 25 wells. Information is not available about the construction in 1970s. The oldest dug well in the record was constructed in 1920. Fig. B-I, 2.3 presents the number of construction in each year and increase of dug wells. Dug wells have been continuously constructed since 1920s; several dug wells increased every year.

2.2 Existing Boring Data

2.2.1 Boring Logs

Total of 22 boring logs are available in the area; two (2) logs are for San Miguel area, six (6) logs for Las Animas, seven (7) logs for Pago de Gomez area, seven (7) logs for Saucache area. These data are cited in the Data Book. In addition to these, several data are shown in the existing report <3, although the data present only permeability of strata without lithology.

2.2.2 Pumping Test

Although pumping test was executed on 48 wells at the completion of each deep well, aquifer constants were analyzed for only 10 wells. Therefore, in addition to these data, specific yield was calculated on 48 wells. They are expressed in the Well List (see, Table B-I, 2.1) and Well Inventory of Azapa Valley. Specific yield is given by following formula;

$$Sy = Q / (Ls - Ld)$$

where Sy : specific yield (m^3/day/m or m^2/day)
Q : yield (m^3/day)
Ls : static water level (m)
Ld : dynamic water level (m)

2.3 Configuration of Aquifer

A hydrogeological profile (Fig. B-I, 2.4) and hydrogeological cross sections (Fig. B-I, 2.5 (1) to (4) are provided in addition to the Geological Profile (Fig. B-I, 1.6). They present the figure of aquifers. The aquifer is occurred in the Recent Fluvial deposits, the Lower marine terrace deposits, the Upper marine terrace deposits, the Fluvial deposits and the Fan deposits. They are distributed in the coastal plain and the Azapa Valley up to Cabuza as described in Chapter I, 1.2.2 and 1.2.3. The distance from the coastal area to Cabuza is approximately 25 km.

In the Azapa Valley, the principle aquifers are transferred to the Fluvial Deposits as mentioned above. The estimated total thickness of the aquifer attains a maximum of more than 60 m. However, the aquifer varies markedly in thickness as a result of fluviatile deposition. The extent of the aquifer is controlled by the width of the valley.

Description of aquifers by area are as follows;

(1) Cabuza area

The width of the valley is about 1,200 m. However it becomes narrower at a part and its width is about 600 m. The aquifer is about 50 to 60 m in thickness. Intercalation of permeable layers such as silt and clay are less. As no impermeable layers cover the aquifer in this area, the groundwater is unconfined.

(2) San Miguel area

The width of the valley is about 1,200 m. The total thickness of aquifer is about 50 m including intercalation of impermeable layer due to which the actual thickness decreases to about 35 m. It seems that the aquifer is divided into two (2) parts, upper and lower, by the impermeable layer. However, it is quationable whether the lower part of aquifer is confined or not, because the aquifer is not saturated by groundwater.

(3) Pago de Gomez area

The width of the valley is about 1,200 m. The thickness of the aquifer is about 45 m. Although, impermeable layers appear irregularly in the aquifer, the aquifer is covered by no impermeable layer.

(4) Saucache area

The valley spreads its width up to more than 1,700 m. The aquifer is about 55 m in thickness. Intercalation of impermeable layers are rare. The groundwater in the area is considered to be unconfined.

(5) City area of Arica

The coastal plain is widespread in the area. The impermeable layers are predominant in the deposits of this area. The aquifer is divided by the impermeable layers which reduces its thickness. The lower aquifer is distributed under the sea level, therefore, the aquifer seems to be deteriorated by the sea water.

2.4 Hydrogeological Characteristics of Aquifers

2.4.1 General

As mentioned in 1.2 and 2.3, the aquifer of the Azapa Valley is composed mainly of sand and gravel bed in the different units. The field survey by the Study Team revealed that no hydrogeological discontinuity is recognized among the permeable units and the aquifer of the area is formed by the sequence of the permeable units. The groundwater stored in the aquifer is considered to be originally unconfined.

2.4.2 Pumping Test Result

1) Aquifer Constants

The existing data are concentrated in three (3) areas; San Miguel, Pago de Gomez and Saucache area. A total number of 10 data is available in the Azapa valley, which is shown in the following table.

Area	BNA Code	Test Date	Transmissibility (m3/d/m)	Permeability (cm/sec)	Storativity
San Miguel	266-	20, Jun.,1992	30	7.62 x 10-4	6.09 x 10-1
	265-	21, Aug.,1992	44	1.14 x 10-3	3.68
	Average		37	9.51 x 10-4	2.14 x 10-1
Pago de Gomez	187-6		3,160	9.26 x 10-3	3.22 x 10-4
	157-4		2,820	7.09 x 10-2	3.22 x 10-4
	161-2		3,526	9.72 x 10-2	3.28 x 10-5
	242-	31, Mar, 1992	43	1.11 x 10-1	3.38
	240-	28, May,1992	123	3.18 x 10-3	1.72
	Average		1,934	5.83 x 10-2	1.02
Saucache	166-3		2,075	6.00 x 10-2	6.23 x 10-3
	165-5		1,550	4.98 x 10-2	4.32 x 10-1
	141-B		69	2.12 x 10-3	2.02
	Average		1,231	3.73 x 10-2	8.19 x 10-1
Average (total area)			1,344	3.22 x 10-2	1.18

Note: BNA code of the Azapa Valley is formally expressed as 013 10 xxx-x.

The characteristics of aquifer constants distribution are as follows;

Transmissibility has a wide range from 30 to 3,526 m^3/d/m averaging 1,344m^3/d/m. Transmissibility is rather low in the upper reaches of the valley (San Miguel to Pago de Gomez), 30 to 44 m^3/d/m, and high in the lower reaches of the valley (Pago de Gomez to the city area of Arica), 1,550 to 3,526 m^3/d/m except the well 141-B.

Permeability varies between 7.62×10^{-4} and 1.11×10^{-1} m^3/d/m, having average of 3.5×10^{-2} m^3/d/m. There is a tendency that Permeability has rather high in Saucache area in the order of 10^{-2}.

Storativity ranges from 3.28×10^{-5} to 3.68, averaging 1.18. The area from San Miguel to Pago de Gomez has high Storativity.

2) Specific Yield

Specific yield is an important factor for evaluation of aquifer, therefore, that of each deep well was calculated based on the pumping test data shown in the Table B-I, 2.1. The results are shown in Table B-I, 2.3 (summarization is shown in the following table) and are presented on a map showing distribution of specific yield (Fig. B-I, 2.6).

unit: $m^3/d/m$

Area	Max.	Min.	Average
Cabuza	786	168	452
Las Riveras	1,080	206	643
San Miguel	2,991	69	722
Pago de Gomez	461	109	243
Saucache	1,080	41	335
City	364	22	158
Total area	2,991	22	351

The average of specific yield is 351 $m^3/d/m$. This value is of ordinary order for the silty sand and gravel bed. The maximum value of 2,991 $m^3/d/m$ is rather high. The values of specific yield vary from place to place reflecting the characteristics of the aquifer. Characteristics of the distribution of specific yield by area are as follows;

(1) Cabuza area

Large values appear in the central part of the valley. It shows that the groundwater mainly flows in the central part of the valley.

(2) Las Riveras to San Miguel area

Contrary to the Cabuza area, large values are unevenly distributed in the southern margin of the valley and are extremely high (2,991 and 1,080 $m^3/d/m$). According to the geological map (Fig. B-I, 1.5), a fan was formed at the outlet of the Qda. del Diablo. This fact suggests that the stream center of groundwater flow is in the southern margin of the valley concentrating towards the narrow part. It is considered that this is caused by the southward spurring of the fine materials derived from the Qda. del Diablo. In addition to this, high specific yield is due to the concentration of groundwater.

(3) Pago de Gomez to Saucache area

Distribution of specific yield shows the ordinary flow pattern; values are large in the center and small in the margin of the valley.

(4) City area of Arica

Specific yield is small in the western part of the city area. However, detail is unclear because of lack of existing data.

2.5 Estimation of Groundwater Storage

Groundwater storage of the Azapa Valley is shown in Table B-I, 2.4 and Fig. B-I, 2.7. These present the estimated groundwater storage in the area from Cabuza to the river mouth of the San José River. Total volume of groundwater storage is estimated as follow;

$$S_{\text{Total Storage}} = 302 \times 10^6 \text{ m}^3.$$

The estimation was made based on the one (1) geological profile and seven (7) geological sections dividing the area into seven (7) zones. Each profile represents following zone;

Zone	Geological section	Major community in the zone
1	(coast line) to sect. A-A	coastal area of Arica city
2	sect. A-A' to B-B'	central area of Arica city
3	sect. B-B' to C-C'	Saucache
4	sect. C-C' to D-D'	Pago de Gomez
5	sect. D-D' to E-E'	Pago de Gomez, Las Maitas
6	sect. E-E' to F-F	San Miguel
7	sect. F-F' to G-G'	Las Riveras, Cabuza

Conditions applied in the estimation are as follows;

(1) Climate condition will be constant during the estimated period.

(2) The extent of the estimation is limited to the area from the city area of Arica to Cabuza, because no stratigraphic column of well is available toward the upper reaches from Cabuza.

(3) Groundwater stored below the sea level is not included in the storage.

(4) Estimation is made on the groundwater stored in permeable and semi-permeable beds. Although groundwater is stored in impermeable beds, it is not considered as prospective one.

(5) Effective porosity of aquifer is assumed to be 30 % as a whole, considering the materials which compose the aquifer.

References

<1: Catastro de Pozos de la Pampa del Tamarugal, 1975 by CORFO.

<2: Banco Nacional de Aguas, 1983 for DGA by Cristian Juricic V., Dario Mosca R. and Brahim Nazarala G.

<3: Análisis Crítico de la Red de Medición de Niveles de Agua Subterránea 1 Region, October 1987 for DGA by Alamos y Peralta Ingenieros Consultores Ltda.

<4: Modelo de Simulación de las Aguas Subterráneas del valle de Azapa, January 1989 for DGA by Ayala, Cabrera y Asociados Ltda. Ingenieros Consultores con la asesoris de IPLA Ltda.

Table B-I, 2.1 (1) List of Deep Well (Azapa Valley)

<Lista de Sondajes (Valle de Azapa)>

BNA CODE	CORFO CODE (1975) LAT.-LONG.	CORFO CODE (1975) NO	COMMUNITY	LOCATION NAME	NAME OF OWNER	CONSTRUCTOR	ELEVATION (mASL)	DRILLING DEPTH (m)	WELL DEPTH (m)	SPECIFIC YIELD (m2/d)	DATE OF CONSTRUCTION
013 10 136-1	1820 7010	CA 1	ARICA	CHINCHORRO NORTE	CORFO	CORFO - 414	10.00	390	-		63/08
013 10 139-6	1820 7010	CC 1	ARICA	AP SAUCACHE	DOS	-	40.00	-	-	206.3	65/11
013 10 140-K	1820 7010	CC 2	ARICA	ESTADIO MUNICIPAL	JUNTA ADELANTO	CORFO-399	38.86	67	67	92.6	72/12
013 10 141-8	1820 7010	CC 3	ARICA	AP RETEN ESTADIO	DOS 714	CORFO-525	37.00	136	136	165.2	65/10
013 10 142-6	1820 7010	CC 4	ARICA	AP CANCHA TUCAPEL	DOS 715	CORFO-543	29.00	110	110	230.1	65/10
013 10 143-4	1820 7010	CC 5	ARICA	AP ESTADIO LIGA EMPL	DOS	DOS-	24.00	109	109	168.1	65/11
013 10 135-3	1820 7010	CC 6	ARICA	CEMENTERIO ARICA	CORFO	CORFO-476	23.68	33	33		73/12
013 10 144-2	1820 7010	CC 7	ARICA	EMBOTELLADORA ANDINA	EMBOT ANDINA	BONACI-	26.00	-	-		64/04
013 10 145-0	1820 7010	CC 8	ARICA	ENDESA	ENDESA	CORFO-386	22.91	45	45	39.0	61/05
013 10 146-9	1820 7010	CC 9	ARICA	CHINCHORRO	CORFO	CORFO-472	4.10	30	30		64/01
013 10 147-7	1820 7010	CC 10	ARICA	PLANTA AP SAN JOSE	DOS	DOS-	8.00	-	94	98.4	
013 10 148-5	1820 7010	CC 11	ARICA	REGIMIENTO RANCAGUA	EJERCITO CHILE	CORFO-363	21.23	36	36	22.3	73/01
013 10 149-3	1820 7010	CC 12	ARICA	UNIVERSIDAD DE CHILE	CORFO	CORFO-475	6.00	30	30		64/01
013 10 150-7	1820 7010	CC 13	ARICA	CASINO ARICA	CORFO	CORFO-471	5.58	30	30		63/12
013 10 151-5	1820 7010	CC 14	ARICA	HOTEL PACIFICO	DIREC DE RIEGO	RIEGO-	4.00	30	30		54/09
013 10 133-7	1820 7010	CC 15	ARICA	AVDA. TARAPACA	JUNTA ADELANTO	CORFO-1232	23.54	50	50		73/05
013 10 126-4	1820 7010	CC 16	ARICA	AVDA AZOLA	JUNTA ADELANTO	CORF-1233	33.47	50	50		73/05
013 10 227-	1820 7010	CC 17	ARICA	ACDA. P. AGUIRRE CERDA	JUNTA ADELANTO	CORFO-1234	30.15	60	60		73/06
013 10 152-3	1820 7010	CC 18	ARICA	AVDA. CHACABUCO	JUNTA ADELANTO	CORFO-1236	14.64	50	50		73/06
013 10 131-0	1820 7010	CC 19	ARICA	LOS DUENDES	JUNTA ADELANTO	CORFO-1237	46.80	60	60		73/06
013 10 213-9	1820 7010	CC 20	ARICA	UNIVERSODA DE NORTE		D.R.	49.50	-	-		
013 10 214-7	1820 7010	CC 21	ARICA	HOSPITAL			25.00	-	-		
013 10 153-1	1820 7010	CD 1	ARICA	PAGO DE GOMEZ	MARIO FIGUEROA	-	117.00	-	50		55/
013 10 154-K	1820 7010	CD 2	ARICA	PAGO GOMEZ ALGODONAL	S.NADER JORRAT	-	108.97	-	47		58/
013 10 155-8	1820 7010	CD 3	ARICA	PAGO GOMEZ ALGARROBA	S NADER JORRAT	-	109.84	-	50		67/
013 10 156-6	1820 7010	CD 4	ARICA	CONSULADO ITALIANO	JANIS KANEPA	-	109.96	-	39		68/
013 10 157-4	1820 7010	CD 5	ARICA	AP. ALSODONAL	DOS 491	DOS-491	106.69	105	105	83.4	62/05
013 10 158-2	1820 7010	CD 6	ARICA	AP. AZAPA	DOS 492	DOS-492	111.03	-	-		
013 10 159-0	1820 7010	CD 7	ARICA	AP. AZAPA	DOS 49	RIEGO-	108.30	57	57	102.0	47/09
013 10 160-4	1820 7010	CD 8	ARICA	AP. AZAPA	DOS 48	RIEGO-	110.25	55	55	562.1	47/09
013 10 161-2	1820 7010	CD 9	ARICA	AP.AZAPA	DOS 434	-	103.83	62	62	170.4	60/04
013 10 162-0	1820 7010	CD 10	ARICA	PAGO DE GOMEZ	SUC NEVERMAN		100.19				
013 10 163-9	1820 7010	CD 11	ARICA	AP AZAPA	DOS 186	CAS	103.00	79	79	115.5	
013 10 106-K	1820 7010	CD 12	ARICA	PARCELA ALGODONAL	J W HULES	CORFO-452	99.44	96	96		70/09
013 10 164-7	1820 7010	CD 13	ARICA	MOTEL AZAPA	UHRCEK		66.00				60/
013 10 165-5	1820 7010	CD 14	ARICA	AP SAUCACHE	DOS 568	CORFO-408	54.99	110	110	448.0	62/04
013 10 166-3	1820 7010	CD 15	ARICA	AP SAUCACHE	DOS 650	DOS 650	54.40	85	85	1080.0	63/10
013 10 167-1	1820 7010	CD 16	ARICA	AP SAUCACHE	DOS 569	CORFO-407	50.00	110	110	505.5	62/05
013 10 138-8	1820 7010	CD 17	ARICA	AP SAUCACHE	DOS	CORFO-434	47.23	69	69		60/
013 10 128-0	1820 7010	CD 18	ARICA	OLIVARERA AZAPA	SOCOAGRO	CORFO-512	46.25	83	83	41.1	71/01
013 10 130-2	1820 7010	CD 19	ARICA	OLIVARERA AZAPA	SOCOAGRO	CORFO-334	44.31	78	78	227.4	72/11
013 10 132-9	1820 7010	CD 20	ARICA	VIDRIERIA ARGENTINA	CORFO	CORFO-1084	31.82	59	59		71/
013 10 168-K	1820 7010	CD 21	ARICA	REFINADORA DE AZUFRE	CORFO	CORFO-1081	35.00	58	58		71/
013 10 169-8	1820 7010	CD 22	ARICA	QUEBRADA ACHA	JUNTA ADELANTO	CORFO-1214	71.28	110	110		73/10
013 10 170-1	1820 7010	CD 23	ARICA	LA VERBENA	JUNTA ADELANTO	CORFO-1236	59.56	70	70		73/06
013 10 110-8	1820 7010	CD 24	ARICA	SAUCACHE	JUNTA ADELANTO	CORFO-1203	67.35	110	110		73/06
013 10 111-6	1820 7010	CD 25	ARICA	AVDA. BALMACEDA	JUNTA ADELANTO	CORFO-1229	57.72	50	50		73/07
013 10 118-3	1820 7010	CD 26	ARICA	AVDA. LOA	JUNTA ADELANTO	CORFO-1230	41.03	50	50		73/07
013 10 119-1	1820 7010	CD 27	ARICA	AVDA. GONZALO CERDA	JUNTA ADELANTO	CORFO-1231	43.08	50	50		73/07
013 10 171-K	1820 7010	CD 28	ARICA	QUEBRADA ACHA	JUNTA ADELANTO	CORFO-1273	74.43	100	100	474.1	73/09
013 10 172-8	1820 7010	CD 29	ARICA	QUEBRADA ACHA	JUNTA ADELANTO	CORFO-1274	67.46	105	105		73/09
013 10 137-K	1820 7010	CD 30	ARICA	QUEBRADA ACHA	JUNTA ADELANTO	CORFO-1262	67.83	106	106	388.8	73/12
013 10 108-8	1820 7010	CD 31	ARICA	QUEBRADA ACHA	JUNTA ADELANTO	CORFO-1252	73.99	100	100	167.8	73/12
013 10 109-4	1820 7010	CD 32	ARICA	ALGODONAL	JUNTA ADELANTO	CORFO-1298	92.26	102	102	90.0	74/04
013 10 229-	1820 7010	CD 33	ARICA	AP AZAPA	DOS	HIDROSAM	112.00	90	90	293.9	87/
013 10 230-	1820 7010	CD 34	ARICA	AP AZAPA	DOS	HIDROSAM	109.38	90	90	137.4	87/
013 10 231-	1820 7010	CD 35	ARICA	AP AZAPA	DOS	HIDROSAM	103.53	90	90	238.3	87/
013 10 232-	1820 7010	CD 36	ARICA	AP AZAPA	DOS	HIDROSAM	110.89	90	90	490.9	87/
013 10 244-	1820 7010	CD 37	ARICA	LOTEO ALGODONAL	YUSEFF M. BU-ANTUM		106.11	45			81/
013 10 245-	1820 7010	CD 38	ARICA	PARCELA 26 ALGODONAL	P. CESPEDES		108.75				84/
013 10 246-	1820 7010	CD 39	ARICA	PARCELA 13 ALGODONAL	K. JOOMG K.		101.25	48			73/
013 10 247-	1820 7010	CD 40	ARICA	PARCELA 16 ALGODONAL	ENRIQUE BORQUEZ		105.00				87/
013 10 248-	1820 7010	CD 41	ARICA	PARCELA 24 ALGODONAL	JORGE BORQUEZ		104.50				
013 10 249-	1820 7010	CD 42	ARICA	PARCELA 30 ALGODONAL	BARBATO-NUNEZ-QUINT		101.39				
013 10 250-	1820 7010	CD 43	ARICA	PARCELA 20 ALGODONAL	PETRONEO GRECO		100.00				
013 10 251-	1820 7010	CD 44	ARICA	ALGODONAL	MARIO KOTESKY		91.36	50			83/
013 10 252-	1820 7010	CD 45	ARICA	SAUCACHE	MARIO CHANG	CHANG	80.80	50			83/
013 10 253-	1820 7010	CD 46	ARICA	EL PEDREGAL-ACHA	EJERCITO DE CHILE		71.43	100			73/
013 10 254-	1820 7010	CD 47	ARICA	AZAPA 3190	SOTO		56.67				
013 10 255-	1820 7010	CD 48	ARICA	SAUCACHE	MARIO CHANG	CHANG	72.70	40			
013 10 256-	1820 7010	CD 49	ARICA	SAUCACHE	MARIO CHANG	CHANG	80.30	50			83/
013 10 257-	1820 7010	CD 50	ARICA	AZAPA 4120	A. WORM		76.67				
013 10 258-	1820 7010	CD 51	ARICA	OCURICA Y LEOMOR	NEVERMAM	NEVERMAM	98.00	37.6			85/
013 10 261-	1820 7010	CD 52	ARICA	LA PORTROA	T. NUNEZ		117.50				
013 10 262-	1820 7010	CD 53	ARICA	TOURIST RANCH	H. LAGOS		117.50	30			65/
013 10 263-	1820 7010	CD 54	ARICA	ACEITUNAS PUCARA	PRIETO		93.43	43			87/
013 10 264-	1820 7010	CD 55	ARICA	PARCELA JUAN MARCELO	JULIO PANIAGUA		85.71				87/
013 10 173-6	1820 7010	DC 1	ARICA	PAGO GOMEZ STA LUCIA	SUC YANULAQUE	-	126.86	60	-		58/
013 10 174-4	1820 7010	DC 2	ARICA	PAGO GOMEZ	HUGO MOZO	-	128.22	51	51		52/
013 10 175-2	1820 7010	DC 3	ARICA	PAGO GOMEZ	S. NADER JORRAT	RIEGO-1082	126.95	73	73		56/07
013 10 121-3	1820 7010	DC 4	ARICA	CINCO OLIVOS	JUNTA ADELANTO	CORFO-1306	126.70	110	110	108.0	74/07
013 10 122-1	1820 7010	DC 5	ARICA	CINCO OLIVOS	JUNTA ADELANTO	CORFO-1317	127.60	110	110		74/07
013 10 215-5	1820 7010	DC 6	ARICA	LAS PALMERAS	E. YANULAQUE		151.71	40	-		64/
013 10 242-	1820 7010	DC 7	ARICA	PAGO DE GOMEZ	ABILIO GUTIERREZ		130.00	36			
013 10 129-9	1830 7000	AA 1	ARICA	CHUNGAL SANTA PABLA	ISIDORO ANDIA	RIEGO-	323.21	52	-		58/03
013 10 115-9	1830 7000	AA 2	ARICA	CERRO MORENO	AMADEO CARBONE	RIEGO-	314.54	45	45		56/05
013 10 112-4	1830 7000	AA 3	ARICA	DIRECCCION DE RIEGO	DIREC DE RIEGO	RIEGO-	305.01	31	30		
013 10 113-2	1830 7000	AA 4	ARICA	LAS RIVERAS MADRID	DIREC DE RIEGO	RIEGO-	291.65	-	-	1080.0	73/04
013 10 101-9	1830 7000	AA 5	ARICA	LAS RIVERAS MADRID	DIREC DE RIEGO	RIEGO	289.49	195	-		
013 10 216-3	1830 7000	AA 6	ARICA	LAS RIVERAS	D.O.S.	CELZAC-1676	280.00	25	25	205.7	80/03
013 10 233-	1830 7000	AA 7	ARICA	CHUNGAL SANTA PABLA	ISIDORO ANDIA		324.14				
013 10 176-0	1830 7000	AC 1	ARICA	CHUNGAL SANTA GEMA	SUC BARRIENTOS	RIEGO-1073	345.08	24	-	23.7	56/03
013 10 225-	1830 7000	AC 2	ARICA	FACUMDO GUITERREZ		RIEGO-1072	365.30	36	36		56/01
013 10 177-9	1830 7000	AD 1	ARICA	CABUZA 1C	DIREC DE RIEGO	RIEGO-	440.00	-	-	403.2	53/05
013 10 178-7	1830 7000	AD 2	ARICA	CABUZA 5E	DIREC DE RIEGO	RIEGO-	432.00	52	52		

Table B-I, 2.1 (2) List of Deep Well (Azapa Valley)

<Lista de Sondajes (Valle de Azapa)>

BNA CODE		CORFO CODE (1975) LAT.-LONG.		CORFO CODE (1975) NO	COMMUNITY	LOCATION NAME	NAME OF OWNER	CONSTRUCTOR	ELEVATION (mASL)	DRILLING DEPTH (m)	WELL DEPTH (m)	SPECIFIC YIELD (m2/d)	DATE OF CONSTRUCTION
013 10	100-0	1830	7000	AD 3	ARICA	CABUZA 1A	DIREC DE RIEGO	RIEGO-	432.67	57	-	785.5	73/05
013 10	116-7	1830	7000	AD 4	ARICA	CABUZA 3F	DIREC DE RIEGO	RIEGO-	433.81	71	71	777.6	
013 10	117-5	1830	7000	AD 5	ARICA	CABUZA 2B	DIREC DE RIEGO	RIEGO-	434.03	137	137	168.0	53/10
013 10	179-5	1830	7000	AD 6	ARICA	CABUZA G	DIREC DE RIEGO	RIEGO-	433.23	55	-		57/05
013 10	180-9	1830	7000	AD 7	ARICA	CABUZA 6H	DIREC DE RIEGO	RIEGO-	434.34	-	-		
013 10	181-7	1830	7000	AD 8	ARICA	CABUZA 4D	DIREC DE RIEGO	RIEGO-	434.82	39	39		54/01
013 10	182-5	1830	7000	AD 9	ARICA	CHUNGAL	S. QUINA TRUFFA	RIEGO-	382.04		-		
013 10	183-3	1830	7000	AD 10	ARICA	SOBRAYA	CORFO	CORFO-470	-	300	-		64/10
013 10	184-1	1830	7000	AD 11	ARICA	SOBRAYA	CORFO	CORFO-573	-	90	-		
013 10	185-K	1830	7000	AD 12	ARICA	SOBRAYA	CORFO	CORFO-594	-	84	84		66/10
013 10	226-	1830	7000	AD 13	ARICA	ESCUELA CHITITA M 28	I. MUNICIPALIDAD ARICA		-		-		
013 10	186-8	1830	7010	AB 1	ARICA	AP AZAPA	DOS 184	CAS-	112.18	67	67	183.8	59/11
013 10	187-6	1830	7010	AB 2	ARICA	AP AZAPA	DOS 47	RIEGO-	111.50	45	45	363.8	47/09
013 10	188-4	1830	7010	AB 3	ARICA	AP AZAPA	DOS 185	CAS-	112.75	53	53	182.3	
013 10	189-2	1830	7010	AB 4	ARICA	HACIENDA BUENA VISTA	R DERLIPPIES	CORFO-394	-	83	-		
013 10	190-6	1830	7010	AB 5	ARICA	HACIENDA BUENA VISTA	R DERLIPPIES	CORFO-552	97.97	110	110	52.3	66/01
013 10	191-4	1830	7010	AB 6	ARICA	HACIENDA BUENA VISTA	R DERLIPPIES	CORFO-415	100.00	36	-		62/02
013 10	192-2	1830	7010	AB 7	ARICA	HACIENDA BUENA VISTA	R DERLIPPIES	RIEGO-	97.74	52	39		46/06
013 10	193-0	1830	7010	AB 8	ARICA	HACIENDA BUENA VISTA	R DERLIPPIES	CORFO-416	80.00	105	70	84.4	73/01
013 10	217-1	1830	7010	AB 9	ARICA	HACIENDA BUENA VISTA	R DERLIPPIES	RIEGO	92.00	29	-		56/04
013 10	224-4	1830	7010	AB 10	ARICA	HDA. S.JUAN DE OCURRIR			121.25		-		
013 10	267-	1830	7010	AB 11	ARICA	AP AZAPA	DOS	HIDROSAN	111.00	90	90		87/
013 10	228-	1830	7010	AB 12	ARICA	AP AZAPA	DOS	HIDROSAN	113.33	92	92		87/
013 10	243-	1830	7010	AB 13	ARICA	HACIEMOR BUENA VISTA	CONTRERAS		90.00				
013 10	194-9	1830	7010	AD 1	ARICA	QUEBRADA ACHA	CORFO	CORFO-459	-	98	-		63/10
013 10	195-7	1830	7010	BA 1	ARICA	LAS MAITAS VIOLETA	RICARDO FERNAN	-	192.95		-		
013 10	103-5	1830	7010	BA 2	ARICA	LAS MAITAS VIOLETA	CORFO	CORFO-378	188.00	341	341	26.1	73/01
013 10	196-5	1830	7010	BA 3	ARICA	LAS ANIMAS	HUGO MOZO	RIEGO-1097	178.69	51	51		58/04
013 10	197-3	1830	7010	BA 4	ARICA	FUNDO LAS ANIMAS	HUGO MOZO	CORFO-379	181.81	175	175	108.9	73/03
013 10	107-8	1830	7010	BA 5	ARICA	LAS ANIMAS	A GARDILCIC	RIEGO-1063	180.70	45	45		56/09
013 10	125-6	1830	7010	BA 6	ARICA	PAGO GOMEZ SAN ELIAS	JUSEFF NADER	RIEGO-1086	151.90	50	50		57/03
013 10	123-K	1830	7010	BA 7	ARICA	PAGO GOMEZ SAN ELIAS	JUSEFF NADER	RIEGO-	154.00	50	-		68/
013 10	198-1	1830	7010	BA 8	ARICA	PAGO GOMEZ SAN ELIAS	HUGO MOZO	RIEGO-1042	140.77	51	45		53/10
013 10	199-K	1830	7010	BA 9	ARICA	LAS PALOMAS	REINALDO ORDON	CORFO-1002	135.29	45	45	180.0	71/01
013 10	104-3	1830	7010	BA 10	ARICA	LAS VARGAS	CARLOS BUNEDER	CORFO-389	131.77	68	68	460.8	61/10
013 10	105-1	1830	7010	BA 11	ARICA	PAGO GOMEZ L. PALOMAS	CARLOS BUNEDER	RIEGO-1028	133.98	46	46		52/02
013 10	200-7	1830	7010	BA 12	ARICA	LAS MACHORRAS	REINALDO ORDON		128.26	46	46	288.0	73/04
013 10	201-5	1830	7010	BA 13	ARICA	COLONIA BELLAVISTA	COLO BELLAVISTA	RIEGO-1015	124.12		-		
013 10	202-3	1830	7010	BA 14	ARICA	REINALDO ORDONEZ	JUNT A ADELANTO	CORFO-1213	176.86	111	-		
013 10	203-1	1830	7010	BA 15	ARICA	PAGO GOMEZ SAN JUAN	ESTEBAN GARDIC	RIEGO-1080	127.64	50	-		56/08
013 10	210-4	1830	7010	BA 16	ARICA	PAGO GOMEZ LO ANDRADE	ERNESTO LOMBAR		-		-		
013 10	211-2	1830	7010	BA 17	ARICA	PAGO GOMEZ LA GONDOLA	RAIMUNDO CENTE		132.29		-		54/
013 10	218-K	1830	7010	BA 18	ARICA	LAS ANIMAS	D.O.S. 1216	CELZAC-1436	178.80	90	-		76/11
013 10	219-8	1830	7010	BA 19	ARICA	LAS CARMENES	R. BLAMEY		182.59		-		59/
013 10	220-1	1830	7010	BA 20	ARICA	PAGO GOMEZ L. PALOMAS	S. ORDONEZ		134.84		-		
013 10	221-K	1830	7010	BA 21	ARICA	PLANTA P. GOMEZ	DOS 1113	CELZAC-1365 P	148.64	87	-	256.9	
013 10	222-8	1830	7010	BA 22	ARICA	PLANTA P. GOMEZ	DOS 1114	CELZAC-1367 P	148.00	100	-	380.2	
013 10	223-6	1830	7010	BA 23	ARICA	PLANTA P. GOMEZ	DOS 1142	CELZAC-1372 P	150.95	97	-		75/
013 10	237-	1830	7010	BA 23	ARICA	VIDOVAGORA	BEZMALINOVIC		181.56				86/
013 10	238-	1830	7010	BA 23	ARICA	VIDOVAGORA	BEZMALINOVIC		173.93				86/
013 10	239-	1830	7010	BA 23	ARICA	PONGO	CARLOS MOZO		147.19				
013 10	240-	1830	7010	BA 23	ARICA	PAGO DE GOMEZ	A BUNEDER		158.00				
013 10	241-	1830	7010	BA 23	ARICA	OLIVO	DOS		160.00				
013 10	259-	1830	7010	BA 23	ARICA	SAN AGUSTIN	PALZA		198.13	50			
013 10	204-K	1830	7010	BB 1	ARICA	LAS RIVERAS	AMADEO CARBON	RIEGO-1076	279.00	45	45		56/06
013 10	134-5	1830	7010	BB 2	ARICA	COLONIA JUAN NOE	COLONIA J. NOE	CORFO-372	261.45	80	80	69.1	73/03
013 10	205-8	1830	7010	BB 3	ARICA	COLONIA JUAN NOE	COLONIA J. NOE	RIEGO-1016	249.05	50	50	2990.8	47/05
013 10	206-6	1830	7010	BB 4	ARICA	COLONIA JUAN NOE	COLONIA J. NOE	RIEGO-1023	248.46	48	48	762.4	51/10
013 10	207-4	1830	7010	BB 5	ARICA	COLONIA JUAN NOE	COLONIA J. NOE	RIEGO-1026	247.48	51	51	86.4	51/11
013 10	102-7	1830	7010	BB 6	ARICA	COLONIA JUAN NOE	COLONIA J. NOE	RIEGO-1029	247.97	49	49	275.9	52/03
013 10	208-2	1830	7010	BB 7	ARICA	COLONIA JUAN NOE	COLONIA J. NOE	RIEGO-1032	252.38	55	55	506.1	52/06
013 10	114-0	1830	7010	BB 8	ARICA	PARCELA 16	COLONIA J. NOE	RIEGO-1035	230.59	50	50	363.8	52/07
013 10	209-0	1830	7010	BB 9	ARICA	LAS MAITAS SANTA ANA	JUAN FOCACIC	BONACI-	218.87		-		
013 10	124-8	1830	7010	BB 10	ARICA	LAS MAITAS	F MARINI	RIEGO-1061	205.49	47	46		56/10
013 10	212-0	1830	7010	BB 11	ARICA	LAS MAITAS	EDO. CHONG		207.94	50	-		59/
013 10	265-	1830	7010	BB 12	ARICA	SAN MIGUEL	DOS 1472		248.00				
013 10	266-	1830	7010	BB 13	ARICA	SAN MIGUEL	DOS 1471		248.33				
013 10	234-	1830	7010	BB 14	ARICA	COLONIA JUAN NOE	COLONIA JUAN NOE		262.50				
013 10	235-	1830	7010	BB 15	ARICA	PUEBLO SAN MIGUEL	DOS	AP RURAL	255.00				86/
013 10	236-	1830	7010	BB 16	ARICA	VIVERO SAN MIGUEL	MANUEL CABRERA		251.67				86/
013 10	260-	1830	7010	BB 17	ARICA	LAS ANIMAS	ROXANA GANCILIC		199.57				

SOURCE: < 1 and <2

Table B-I, 2.2 (1) List of Dug Well (Azapa Valley)

<Lista de Noria (Valle de Azapa)>

NO.	LOCATION	NAME OF OWNER	CONSTRUCTOR	USE	ELEVATION (m ASL)	DEPTH (m)	STATIC LEVEL(m)	DYNAMIC LEVEL(m)	YIELD (l/sec)	DATE OF CONSTRUCTION
1	ARICA NORTE	PLAYA CHINCHORRO		AB	(10,0)		1,23			
2	ARICA NORTE	PLAYA CHINCHORRO		AB	8,9		0,80			
3	ARICA NORTE	PLAYA CHINCHORRO		P	(3,0)	2,00	1,02		M	
4	ARICA NORTE	PLAYA CHINCHORRO		P	(3,0)	3,00	2,09		M	
5	ARICA NORTE	PLAYA CHINCHORRO		P	(3,1)	1,90	1,23		M	
6 *	ARICA		GALLO	SU	3,0					
7 *	CERRO CHUNO	CHUNO	O.PEREZ	SU	(30,0)					1920
8 *	CERRO CHUNO	ENAMI	ENAMI	SU	(20,0)					
9	ARICA NORTE	BARRIO INDUSTRIAL	CORMET	SU	24,5	28,70	18,44			
10	ARICA NORTE	BARRIO INDUSTRIAL	EDELNOR	TA	2,3					
11	ARICA NORTE	RIO SAN JOSE	PAREDES	TA						1959
12	ARICA VELASQUEZ	HOTEL EL PASO	H.EL PASO	R	(7,0)	9,00	5,33			
13 *			MARIA GALINDO		(6,0)					
14	KM 4,0 P.GOMEZ	HIJUELA 14	ALVARADO	SU	(118,7)		S			1953
15	KM 4,0 P.GOMEZ	LA PORTADA	T.NUNEZ	SOND 261	(118,4)		23,33			
16	KM 4,0 P.GOMEZ	MARAVILLA	M.SALAS	SU	(115,7)	12,00	S			
17 *			CANEPA							
18	KM 3,3 P.GOMEZ	OCURICA Y LEONOR	NEVERMAN	TA	(102,2)					
19	KM 4,0 P.GOMEZ	LA PORTADA	T.NUNEZ	SU	(113,8)		S			1958
20	KM 2,5 SAUCACHE	SAN GABRIEL	S.CAVALAN	SU	95,8					1954
21	KM 2,5 SAUCACHE	ACEITUNAS PUCARA	PRIETO	SOND 263	(92,8)					
22	KM 2,5 SAUCACHE	COLCHAGUA	SUC. LY	SU	(90,5)	30,00	S			1957
23	KM 2,5 SAUCACHE	COLCHAGUA	SUC. LY	SU	(89,3)	20,00	S			
24	KM 2,5 SAUCACHE	ESTADIO ITALIANO	COM.ITALIANA	R	(86,9)					
25	KM 2,5 SAUCACHE	VILLA VERONA	H.PERI	TA						1964
26	KM 2,0 SAUCACHE	JUAN MARCELO	J.PANIAGUA	SOND 264	(83,7)		20,53			
27	KM 2,5 SAUCACHE	OCURICA Y LEONOR	NEVERMAN	TA	(90,0)					1958
28	KM 2,5 SAUCACHE	OCURICA Y LEONOR	NEVERMAN	TA	(88,0)					1944
29	KM 2,5 SAUCACHE	LOS MOLINOS	T.TORO	TA	(86,8)					1964
30	KM 2,5 SAUCACHE	LOS MOLINOS	T.TORO	AB						
31	KM 2,5 SAUCACHE	LOS MOLINOS	T.TORO	TA						
32	KM 1,5 SAUCACHE	PARCELA SAN LUIS	D.DEVOTO	SU	(76,1)		S			1940
33	KM 1,5 SAUCACHE	PARCELA SAN LUIS	D.DEVOTO	SU	(76,3)		S			1938
34	KM 1,0 SAUCACHE	PARCELA SAN LUIS	D.DEVOTO	TA	75,8					
35	KM 1,5 SAUCACHE	AZAPA 4120	A.WORM	SOND 257			28,40			
36	KM 1,5 SAUCACHE	AZAPA 4160	R.AGUIRRE	R	(76,6)	40,00	26,56		2,00	1970
37	KM 1,5 SAUCACHE		SUC.SANCHEZ	AB	(78,4)					1950
38	KM 2,0 SAUCACHE	CHABELITA	C.CRIGNOLA	SU	(82,5)	30,00	24,45			1960
39	KM 1,5 SAUCACHE		M.CHANG	SOND 256	81,3	50,00	25,09			
40	KM 2,0 SAUCACHE		CORA	TA						
41	KM 0,5 SAUCACHE		RUIZ							
42	KM 1,0 SAUCACHE	VILLA OLGUITA	COLEGIO ALEMAN	SU	(70,6)	50,00	33,88			1965
43	ARICA SAUCACHE	QUEBRADA LA HIGUERA	ALVARADO	SU	62,3	30,00	S			1960
44	CERRO CHUNO	RENATO ROCA 1999	YPFB	SU	36,0	27,00	18,86			1961
45	ARICA NORTE	BARRIO INDUSTRIAL	PEREZ		30,0					
46	KM 7,0 LAS ANIMAS	LAS CARMENES	RINA BLANEY	SU	(168,0)	18,00	7,79			
47	KM 6,5 PAGO GOMEZ	LOS ALAMOS	SUC.FERNANDEZ	SU	(152,6)	20,00	10,55			1925
48	KM 6,5 PAGO GOMEZ	EL GALLITO	J.CESPEDES	R	(153,5)	23,00	13,83			1958
49	KM 6,5 PAGO GOMEZ	PONGO	CARLOS MOZO	AB	(150,9)	15,00	S			1960
50	KM 6,5 PAGO GOMEZ	LAS PALMERAS	E.YANULAQUE	R-P	(157,2)	38,00	10,88		8,00	1964
51	KM 6,0 PAGO GOMEZ	EL TRIANGULO	A.CORVACHO	R	(140,1)	30,00	21,56		38,00	1960
52	KM 6,0 PAGO GOMEZ	EL SAUCE	J.CESPEDES	AB	138,1	44,00	21,04			1965

Table B-I, 2.2 (2) List of Dug Well (Azapa Valley)

<Lista de Noria (Valle de Azapa)>

NO.	LOCATION	NAME OF OWNER	CONSTRUCTOR	USE	ELEVATION (m ASL)	DEPTH (m)	STATIC LEVEL(m)	DYNAMIC LEVEL(m)	YIELD (l/sec)	DATE OF CONSTRUCTION
53	KM 5,0 PAGO GOMEZ	EL LAUREL	FERNANDEZ	SU	(133,4)	26,00	23,08			
54	KM 4,5 PAGO GOMEZ	EL LAUREL	FERNANDEZ	P	(130,8)	36,00				
55	KM 4,5 PAGO GOMEZ		A.GUTIERREZ	SOND 242			21,72		26,75	1936
56	KM 4,5 PAGO GOMEZ	JUAN DE C.	BRAZ							
57	KM 4,5 PAGO GOMEZ	SANTA HELEDINA	A. SALINAS	AB	(130,5)		22,57			
58	KM 4,0 PAGO GOMEZ	ALGODONAL	YUSSEF NADER BU-ANT.	SU	(123,2)		S			
59	KM 4,0 PAGO GOMEZ	MIRANDA	SUC.SALAS	SU	122,1	40,00	23,82			
60	KM 4,5 PAGO GOMEZ	STA JUANA	J.HENRIQUEZ	TA						
61	KM 4,5 PAGO GOMEZ	STA JUANA	J.HENRIQUEZ	SU	(122,6)	37,00	23,12			
62	KM 16,5 CHUGAL	ROCO	PASCUAL ROCO	R	334,1	29,00	9,49			1945
63	KM 16,0 CHUGAL	DAVID	RAMOS-MOLINA	I	330,1	20,00	11,20		19,20	1952
64	KM 15,5 LAS RIVERAS	CERRO MORENO	LIDO CARBONE	P	(311,6)	20,00	5,25		0,20	1965
65	KM 15,0 LAS RIVERAS	CERRO MORENO	S.LOMBARDI	TA	300,0				0,60	1936
66	KM 14,5 LAS RIVERAS	CERRO MORENO	H. ANDIA	SU	301,6		4,42			
67	KM 13,5 LAS RIVERAS	SAN FELIPE	TALENTE	TA	293,5					1960
68	KM 13,5 LAS RIVERAS	SAN EDUARDO	R.CENTELLA	TA	292,0		S			1960
69	KM 13,5 LAS RIVERAS	LAS RIVERAS	SAJAMA	TA	293,3		S			
70	KM 13,5 LAS RIVERAS	SAN FELIPE	KU	TA	296,7		S			1940
71	KM 18,0 CHUGAL	CHUGAL	BALUARTE	TA	371,8					1944
72	KM 18,0 CHUGAL	SAN JUAN	J.CHOVAN	TA	372,5					1955
73	KM 17,5 CHUGAL	SAN MANUEL	GUTIERREZ	SU	(366,1)		10,14			1961
74	KM 17,5 CHUGAL	LA TARA	A. ESTORAICA	SU	(359,4)		10,89			1964
75	KM 17,5 CHUGAL	LA TARA	M.MELGAR	R	(361,5)		11,49			
76	KM 17,5 CHUGAL	SAN MARCOS	H.ROJAS	SU	354,1	28,00	12,64			
77	KM 17,5 CHUGAL	EL OLIVO	J. LOMBARDI	R	(353,8)	32,00	10,82			1964
78	KM 18,0 CHUGAL	STA. INES	J. LOMBARDI	R	363,0		12,25		40,00	1949
79	KM 20,0 CABUZA	STA. FILOMENA	H.STAGNARO	P	392,9	25,00	23,18			
80	KM 8,5 ALTO RAMIREZ	LA CUCANA	CHONG	TA	196,9				M	
81	KM 8,5 LAS MAITAS	SAN AGUSTIN	PALZA	SOND 259			21,30			1959
82	KM 8,0 ALTO RAMIREZ	LA EXOTICA	SUC. OSORIO	SU	190,0	35,00	16,92			
83	KM 8,0 ALTO RAMIREZ	LAS CADENAS	ALICIA PONCE	P	(185,4)	20,00	13,61			1966
84	KM 7,5 LAS ANIMAS	CRUZ BLANCA	S. FLORES	TA						1940
85	KM 7,5 LAS ANIMAS	LAS ANIMAS	J. YUCRA	P	186,4	30,00	19,94			
86	KM 7,0 ALTO RAMIREZ	LAS CADENAS	ALICIA PONCE	SU	(166,5)	8,00	S			1958
87 *	LAS MAITAS	SAN FERNANDO	OSORIO							
88	KM 17,0 CHUGAL	LA YARA	ENRIQUE CHANG	P	(337,9)	23,00	11,45			
89	KM 7,0 ALTO RAMIREZ	LA AURORA	BUITANO	SU	158,6	35,00				1946
90	KM 6,5 PAGO GOMEZ	LAS ANIMAS	YANULAQUE	R-SU	(155,3)	20,00	9,64			1944
91	KM 6,5 PAGO GOMEZ	LA PALMA	SUC ZABALA	SU	157,7	18,00	8,88			1960
92	KM 6,5 PAGO GOMEZ	LAS ANIMAS	YANULAQUE	SU	(155,6)	17,00	9,52			1948
93	KM 6,5 PAGO GOMEZ		CARLOS MOZO	SOND 239			18,66			
94	KM 6,5 PAGO GOMEZ		CARLOS MOZO	TA						
95 *	PAGO GOMEZ	SAN ELIAS	Y. NADER BU-ANTUN							
96	KM 6,5 PAGO GOMEZ	HACIENDA PIEMONTE	LOMBARDI	SU	(153,7)	31,00	17,76			
97	KM 6,5 PAGO GOMEZ	HACIENDA PIEMONTE	LOMBARDI	TA						1954
98	KM 6,5 PAGO GOMEZ	HACIENDA PIEMONTE	LOMBARDI	R	153,5	55,00	23,67			
99	KM 6,5 PAGO GOMEZ	HACIENDA PIEMONTE	LOMBARDI	R	154,8	77,00	22,12		50,00	1967
100	KM 7,0 ALTO RAMIREZ	NOVA ITALIA	LOMBARDI	R	(145,2)	63,00	27,30		8,00	1948
101	KM 7,0 ALTO RAMIREZ	NOVA ITALIA	LOMBARDI	TA						1946
102	KM 6,0 PAGO GOMEZ	LA PALMA	IBARRA	P	142,9	42,00	30,85			
103	KM 5,8 PAGO GOMEZ	LO ANDRADE	LOMBARDI	SU	(138,5)	30,00	S		1,70	1945
104	KM 4,5 PAGO GOMEZ	SAN JUAN DE OCURRIR	M. GARDILIC	SU	(122,0)	25,00	S			1944
105	KM 13,0 SAN MIGUEL	AGRADECIDA	M. CARBONE	P	201,4	17,00	6,23			1950
106 *	LAS RIVERAS	BUEN RETIRO	LOMBARDI	TA					5,60	1959
107	KM 13,5 LAS RIVERAS	LAS RIVERAS	E. CHONG	SU	278,7		4,70			
108	KM 13,0 SAN MIGUEL	SAN FCO.DE ASIS	I.BALUARTE	TA	271,6		0,54			1950
109	KM 12,0 LOS ALBARRACI	SAN JUAN	FOCACCI	SU	270,3	37,00	4,38			

Table B-I, 2.2 (3) List of Dug Well (Azapa Valley)

<Lista de Noria (Valle de Azapa)>

NO.	LOCATION	NAME OF OWNER	CONSTRUCTOR	USE	ELEVATION (m ASL)	DEPTH (m)	STATIC LEVEL(m)	DYNAMIC LEVEL(m)	YIELD (l/sec)	DATE OF CONSTRUCTION
110	KM 12,0 LOS ALBARRACI		BERETTA							
111	KM 12,5 SAN MIGUEL	SAN FRANCISCO	DANTE NOCE	AB	266,8	20,00	30,00			1945
112	KM 12,5 SAN MIGUEL	PARCELA 36 Y 37	A. CENTELLA	SU	(269,0)	20,00	17,65			1963
113	KM 11,0 LOS ALBARRACI	SAN LORENZO	FOCACCI	AB	246,3	10,00	S			
114	KM 11,5 LOS ALBARRACI	LA RINCONADA	GUTIERREZ	SU	236,9	33,00	18,34			1966
115	KM 10,5 LAS MAITAS	LA HUERTA	FOCACCI	SU	(226,6)	67,00	26,33			1948
116	KM 10,5 LAS MAITAS	LA HUACA	E.ALMONTE	AB	225,2	20,00	S			1943
117	KM 10,5 LAS MAITAS	LA HUACA	SAUL OVIEDO	P	220,9	36,00	23,04		1,50	1967
118	KM 10,5 LAS MAITAS	SAN ISIDRO	SUC. ISHIHARA	SU	(221,0)	38,00	22,59			1942
119	KM 9,0 LAS ANIMAS	PARCELA 30	A. TORRES	SU	(203,8)	20,00	18,84			
120	KM 8,5 LAS ANIMAS		ROXANA GARDILIC	SONO 260	199,8		18,36			
121	KM 8,5 LAS ANIMAS		TORRES							
122	KM 12,0 SAN MIGUEL		COLONIA J. NOE		250,3					
123	KM 13,0 SAN MIGUEL	SAN FCO.DE ASIS	I. BALUARTE	P	274,9	12,00	4,56		1,70	1986
124	KM 15,0 LAS RIVERAS	QUEBRADA DEL DIABLO	M. CARBONE	R	302,4	11,00	9,52		4,00	
125	KM 14,0 LAS RIVERAS	PARCELA 1	MARIA SOTO	P	(286,1)	12,00	1,00			
126	KM 15,5 LAS RIVERAS	LAS RIVERAS	A. CARBONE	P	(317,8)	17,00	6,52			1983
127	KM 15,5 LAS RIVERAS	CHIRINOS	CHIRINOS	P	(317,9)		5,65			
128	ARICA CHINCHORRO	LAS DUNAS	DOROTEA SORTA	P	(4,5)		2,84			
129	ARICA CHINCHORRO	RESTAURANT G. COJO	DOROTEA SORTA	P	(4,5)	2,50	1,55			
130	ARICA CHINCHORRO	RESTAURANT G. COJO	DOROTEA SORTA	P	(4,5)	3,00	1,46			1958
131	ARICA CHINCHORRO	LAS DUNAS	DOROTEA SORTA	SU	(4,5)		1,40			
132	ARICA CHINCHORRO	LAS DUNAS	CLINICA VETERINARIA	SU	(4,5)		1,22			
133	KM 17,0 CHUGAL	PLANTA TOMATIN	LOMBARDI	I	(352,2)	14,00	12,84		7,00	
134	KM 17,0 CHUGAL	PLANTA TOMATIN	LOMBARDI	SU	(350,0)	10,00	S			
135	KM 16,0 CHUGAL	SAN ANTONIO		SU	(327,4)	12,00	9,62			1985
136	KM 2,5 SAUCACHE	COLEGIO SAN JORGE	COLEGIO	SU	(89,8)	50,00	22,70			1984
137	KM 2,5 SAUCACHE		R. OHACO	R	(92,7)		23,60			
138	KM 2,5 SAUCACHE			P	(94,6)					
139	KM 3,3 PAGO GOMEZ	OCURICA Y LEONOR	NEVERMAN	SU	(101,7)		24,73			
140	KM 3,5 ALGODONAL	PARCELA 25 Y 33	C. CESPEDES	R	(105,1)	48,00	24,77		8,50	
141	KM 3,5 ALGODONAL	PARCELA 43	C. FOCACCI	P	(107,7)	32,00		24,84	0,80	
142	KM 3,5 ALGODONAL	LOTEO ALGODONAL	PAUL BIRO	P	(107,6)	28,00	24,06		1,00	
143	KM 3,5 ALGODONAL	LOTEO ALGODONAL	PAUL BIRO	P	(108,0)	30,00	24,27		1,50	
144	KM 3,5 ALGODONAL	LOTEO ALGODONAL	VELEZ	SU	(105,1)		23,88			
145	KM 3,5 ALGODONAL	LOTEO ALGODONAL	S. DONOSO	P	(102,6)	38,00	23,10		1,70	
146	KM 3,0 ALGODONAL	PETORCA 5809	C. RAMIREZ	P	(98,5)	40,00	29,26		3,00	
147	KM 3,0 ALGODONAL	PARCELA 19	E. LEIVA	SU	(95,1)	25,00	S			
148	KM 3,5 ALGODONAL	PARCELA 48	D. CROSSA	SU	(104,6)	16,00	S			
149	KM 3,5 ALGODONAL	PARCELA 49	G. VICENCIO	R	(105,8)	35,00	24,70		1,00	
150	KM 3,5 ALGODONAL		P. BEOVIC	SU	(101,0)		24,76			
151	KM 3,5 ALGODONAL	PARCELA 28	R. CORTES	R	(95,0)	25,00	21,71			
152	KM 3,5 ALGODONAL				(100,1)		24,08			1988
153	KM 3,5 ALGODONAL	PARCELA 29	ANDRES	P	(99,0)					
154	KM 3,5 ALGODONAL		V. SABA	P	(101,8)					
155	KM 3,5 ALGODONAL	PARCELA 23	OTTO KOCH	SU	(104,8)	14,00	S			
156	KM 3,5 ALGODONAL	CENTRO ESPANOL	COM. ESPANOLA							
157	KM 3,0 ALGODONAL	LAS CANAS 2190	M. PEREZ	P	(94,9)	35,00	28,26		2,00	
158	KM 3,0 ALGODONAL	COMBARBALA 2036	PIO LOPEZ	R	(99,0)	35,00			1,50	
159	KM 3,0 ALGODONAL	PARCELA 2	A. SOLARI	R	(100,0)	35,00	30,45		5,50	
160	KM 2,5 SAUCACHE		R. CASTRO	R	(96,0)	34,00	25,40		1,50	
161	KM 2,5 SAUCACHE	LOS ITALIANOS 2090	MARCO A.AGUIRRE	R	(89,8)	32,00	22,41			
162	KM 2,5 SAUCACHE	LOS ITALIANOS 2110	E.AUTRAN	R	(88,2)	30,00		22,98	1,00	
163	ARICA SAUCACHE	PANAMERICANA 2831	M.CALVANESE	SU	(61,4)	25,00	S			
164	KM 2,0 CAMPO VERDE	PARCELA 419	C.NORAMBUENA	P	(82,0)		24,92			1986
165	KM 2,0 CAMPO VERDE	PARCELA 6	LOBERA	SU	(77,3)		25,65			1986
166	KM 2,0 CAMPO VERDE	PARCELA 8	NARDAKOLSKI	SU	(76,3)	28,00				1986

Table B-I, 2.2 (4) List of Dug Well (Azapa Valley)

<Lista de Noria (Valle de Azapa)>

NO.	LOCATION	NAME OF OWNER	CONSTRUCTOR	USE	ELEVATION (m ASL)	DEPTH (m)	STATIC LEVEL(m)	DYNAMIC LEVEL(m)	YIELD (l/sec)	DATE OF CONSTRUCTION
167	KM 2,0 CAMPO VERDE		F. BRITO	SU	(78,3)					1988
168	ARICA SAUCACHE	ROTONDA AZAPA	B. AROS	SU	(60,3)	16,00	S			
169	ARICA SAUCACHE	ROTONDA AZAPA	HOTEL P.DE ASTURIAS	SU	(59,5)		34,13			1987
170	ARICA SAUCACHE	CAMPUS SAUCACHE	U. DE TARAPACA	SU	(46,0)	28,00	S			
171	KM 45,0	ESCUELA ALGODONAL	SERME ARICA	P		53,00	S		0,80	
172	KM 30,0 CASAGRANDE	PARCELA AZAPA	EJERCITO DE CHILE	P		12,00	4,00		5,00	
173	KM 30,0 CASAGRANDE	PARCELA AZAPA	EJERCITO DE CHILE	SU			5,30			
174	ARICA NORTE	PLAYA CHINCHORRO		SU	(3,0)	2,00	1,00			
175	ARICA NORTE	BARRIO INDUSTRIAL	GENERAL MOTORS	P-I	(26,2)			22,54		
176	ARICA NORTE	BARRIO INDUSTRIAL	BOTTAI HMOS.	I	(28,3)		22,05		4,20	
177	ARICA VELASQUEZ	HOTEL EL PASO	HOTEL EL PASO	R	(5,9)		3,81			
178	ARICA VELASQUEZ	HOTEL EL PASO	HOTEL EL PASO	R	(6,0)	8,00	3,75			
179	ARICA CENTRO	LAVANDERIA MODERNA	LAVAND. MODERNA	I	(11,7)		7,95		2,00	
180	KM 2,5 SAUCACHE	SAN GABRIEL	S. CAVALAN	R-P	(96,0)		22,67		1,50	
181	KM 2,5 SAUCACHE	LOS MOLINOS	T. TORO	R	(82,1)	30,00	22,20		3,30	
182	KM 2,5 SAUCACHE	LOS MOLINOS	T. TORO	R	(86,0)	25,00	24,07			
183	KM 2,5 SAUCACHE	AVICOLA DONOSO	DONOSO	SU	(83,0)		24,72			
184	KM 1,5 SAUCACHE	PARCELA SAN LUIS	D. DEVOTO	R	(77,0)	39,40	29,44			
185	KM 2,5 SAUCACHE	VILLA PAULITA	S. PELISARE	SU	(85,5)	30,00	21,17			1986
186	KM 1,5 SAUCACHE	SAUCACHE	MONTALVO	SU	(77,6)		27,60			1980
187	KM 2,5 CAMPO VERDE	PARCELA 8-STA. CLARA	H. HERNANDEZ	SU	(85,5)	27,00	21,65			1986
188	KM 2,0 CAMPO VERDE	PARCELA 2	GERARDO DIAZ	R	(74,3)	32,00	25,09			1986
189	KM 4,5 PAGO GOMEZ	STA. HELEDINA	ABULEME	P	(130,6)	27,00	22,98		1,00	1987
190	KM 4,5 PAGO GOMEZ	LA HUERTECITA	J. HORTA	SU	(128,7)	27,00	23,02			1986
191	KM 4,5 PAGO GOMEZ	LA HUERTECITA	F. DURAN	R	(128,5)	27,00	22,80		1,00	1986
192	KM 15,0 LAS RIVERAS	CERRO MORENO	SERAFINA LOMBARDI	R	(301,3)		2,08		8,30	1984
193	KM 7,0 ALTO RAMIREZ	PARCELA 22	E. AVACA	P	(165,2)	10,80	4,05			
194	KM 7,0 LAS ANIMAS	LAS CARMENES	RIMA BLANEY	SU	(161,5)		7,65			
195	KM 20,0 CABUZA	STA.IRENE SUR	F. CONDORI	SU	(412,1)	25,00	19,52			1988
196	KM 5,5 PAGO GOMEZ	OLIVAR WEGUELIN	HUGO MOZO	SU	(140,6)	33,00	26,95			1987
197	KM 6,5 PAGO GOMEZ	ALAMEDA	SUC.FERNANDEZ	SU	(154,7)	10,00	S			
198	KM 5,0 PAGO GOMEZ	LAS PALMAS	F. ROQUE	P	(145,0)		4,90			
199	KM 4,5 PAGO GOMEZ		OVANDO	SU	(125,2)					
200	KM 4,5 PAGO GOMEZ		OVANDO	SU	(125,6)	18,00	S			
201	KM 13,0 SAN MIGUEL	SAN JOSE	A. CARBONE	SU	(279,0)	10,00	5,79			
202	KM 13,5 LAS RIVERAS	LADERA IZQUIERDA	M. CABRERA	SU	(285,0)		7,46			1988
203	KM 10,5 LAS MAITAS	ESCUELA 69	SERME ARICA	P	(226,7)	39,00	24,16		0,30	1983
204	KM 11,0 LOS ALBARRAC		E. CUESTA	P	(241,6)	30,00	18,07		3,00	1983
205	KM 15,0 LAS RIVERAS	LOTE AB	M. MADRID	R	(303,0)	18,00	1,52		12,00	1980

Nomenclature used :

*	Without location in the plan
P	Drinking
I	Industrial
SU	Out of use
AB	Abandoned
R	Irrigated
TA	Covered or fallen down
S	Dry
N	By hand / with bucket
( )	Interpolated elevation

(Modelo de Simulacion de las Aguas Subterraneas del valle de Azapa, January 1989 for DGA by Ayala, Cabrera y asociados Ltda. Ingenieros Consultores con la asesoris de IPLA Ltda.)

Table B-I, 2.3 Distribution of Specific Yield (Azapa Valley)

<Distribución de Escrrímiento Específico (Valle de Azapa)>

B.N.A CODE	POMPING RATE (l/s)	DYNAMIC WATER LEVEL(m)	STATIC WATER LEVEL(m)	SPECIFIC YIELD (m3/d/m)	DROW-DOWN (m)
135-3	-	25.2	22.7		2.5
145-0	6	29.9	16.6	39.0	13.3
147-7	45	54.0	14.5	98.4	39.5
148-5	2.4	29.8	20.5	22.3	9.3
157-4	22	49.9	27.1	83.4	22.8
159-0	24.8	39.0	18.0	102.0	21.0
160-4	52.7	22.3	14.2	562.1	8.1
161-2	29	35.7	21.0	170.4	14.7
163-9	11.5	33.1	24.5	115.5	8.6
186-8	20	30.4	21.0	183.8	9.4
187-6	40	25.3	15.8	363.8	9.5
188-4	23	31.4	20.5	182.3	10.9
190-6	23	59.8	21.8	52.3	38.0
193-0	24.7	64.0	38.7	84.4	25.3
106-K	-	33.1	31.7		1.4
165-5	70	38.0	24.5	448.0	13.5
166-3	50	37.0	33.0	1080.0	4.0
167-1	55	36.4	27.0	505.5	9.4
128-0	7	58.8	44.1	41.1	14.7
130-2	5	44.7	42.8	227.4	1.9
171-K	45	52.5	44.3	474.1	8.2
137-K	45	54.5	44.5	388.8	10.0
108-6	20	58.3	48.0	167.8	10.3
109-4	25	50.2	26.2	90.0	24.0
229-	50	40.2	25.5	293.9	14.7
230-	45	54.8	26.5	137.4	28.3
231-	40	39.0	24.5	238.3	14.5
232-	50	32.7	23.9	490.9	8.8
121-3	30	39.3	15.3	108.0	24.0
113-2	35	8.1	5.3	1080.0	2.8
216-3	20	14.8	6.4	205.7	8.4
177-9	28	42.0	36.0	403.2	6.0
100-0	40	36.2	31.8	785.5	4.4
117-5	35	48.0	30.0	168.0	18.0
103-5	19	73.3	10.3	26.1	63.0
197-3	30	34.3	10.5	108.9	23.8
199-K	20	37.8	28.2	180.0	9.6
104-3	32	37.0	31.0	460.8	6.0
200-7	27	31.1	23.0	288.0	8.1
221-K	55	36.0	17.5	256.9	18.5
222-8	55	31.0	18.5	380.2	12.5
134-5	20	45.0	20.0	69.1	25.0
205-8	45	18.3	17.0	2990.8	1.3
206-6	45	24.8	19.7	762.4	5.1
207-4	19	41.0	22.0	86.4	19.0
102-7	38	32.2	20.3	275.9	11.9
208-2	41	31.5	24.5	506.1	7.0
114-0	40	22.0	12.5	363.8	9.5

NOTE: COMPILED FROM WELL INVENTORY

Table B-I, 2.4 Estimation of Groundwater Storage (Azapa Valley)
<*Estimación de Reservas de Agua Subterraneas (Valle de Azapa)*>

DEPTH (m BSWL)	ZONE 1 (COAST-SECT.A) (x million m3)	SUM	ZONE2 (SECT. A-B) (x million m3)	SUM	ZONE3 (SECT. B-C) (x million m3)	SUM	ZONE4 (SECT. C-D) (x million m3)	SUM	ZONE5 (SECT. D-E) (x million m3)	SUM	ZONE6 (SECT. E-F) (x million m3)	SUM	ZONE7 (SECT. F-G) (x million m3)	SUM	TOTAL (COAST-SECTION G) (x million m3)	SUM
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.26	0.26	2.25	2.25	12.70	12.70	18.70	18.70	13.90	13.90	8.35	8.35	18.90	18.90	75.06	41.15
20	0.00	0.26	0.00	2.25	5.34	18.04	12.50	31.20	10.20	24.10	4.00	12.35	9.38	28.28	41.42	82.57
30	0.00	0.26	0.00	2.25	5.98	24.02	12.80	44.00	10.10	34.20	5.30	17.65	9.84	38.12	44.02	126.59
40	0.00	0.26	0.00	2.25	8.05	32.07	14.40	58.40	11.20	45.40	9.33	26.98	16.20	54.32	59.18	185.77
50	0.00	0.26	0.00	2.25	7.97	40.04	14.90	73.30	7.59	52.99	4.39	31.37	12.70	67.02	47.55	233.32
60	0.00	0.26	0.00	2.25	8.61	48.65	11.60	84.90	2.55	55.54	0.00	31.37	2.93	69.95	25.69	259.01
70	0.00	0.26	0.00	2.25	4.55	53.20	4.71	89.61	0.00	55.54	0.00	31.37	0.00	69.95	9.26	268.27
80	0.00	0.26	0.00	2.25	0.00	53.20	0.00	89.61	0.00	55.54	0.00	31.37	0.00	69.95	0.00	268.27
90	0.00	0.26	0.00	2.25	0.00	53.20	0.00	89.61	0.00	55.54	0.00	31.37	0.00	69.95	0.00	268.27
100	0.00	0.26	0.00	2.25	0.00	53.20	0.00	89.61	0.00	55.54	0.00	31.37	0.00	69.95	0.00	268.27
TOTAL	0.26		2.25		53.20		89.61		55.54		31.37		69.95		302.18	

NOTE: "BSWL" means below the static water level in 1993.

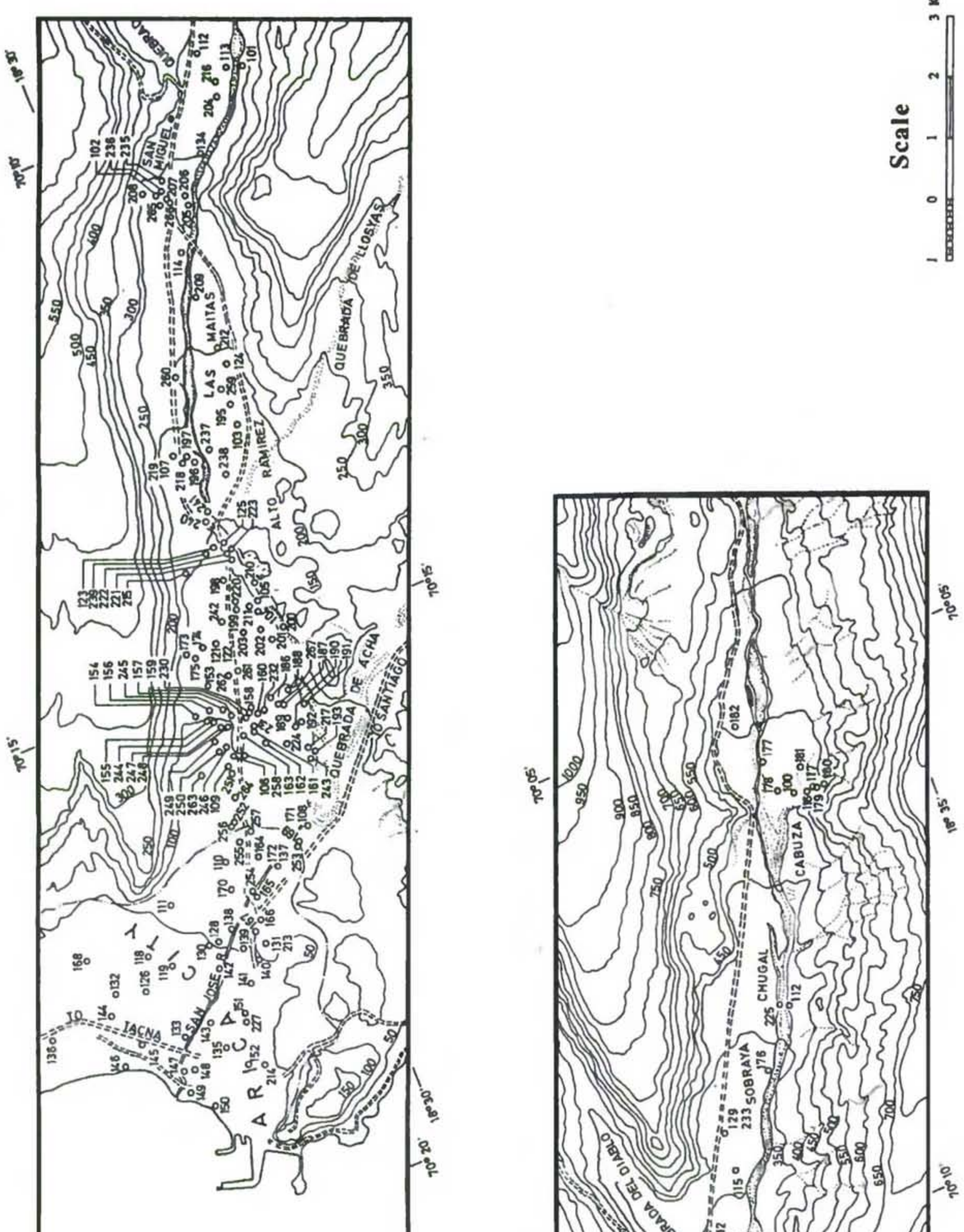
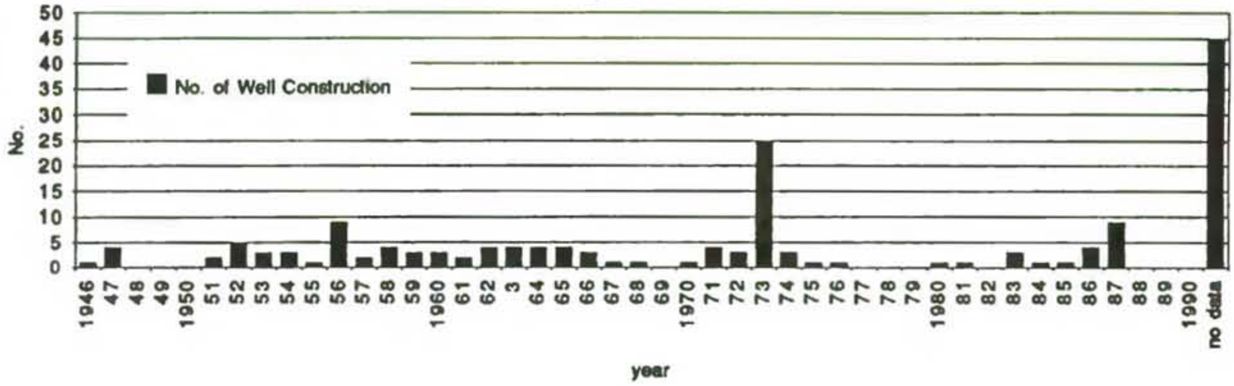


Fig. B-I. 2.1 Well Locations (Azapa Valley)

< Ubicación de Sondajes (Valle de Azapa) >



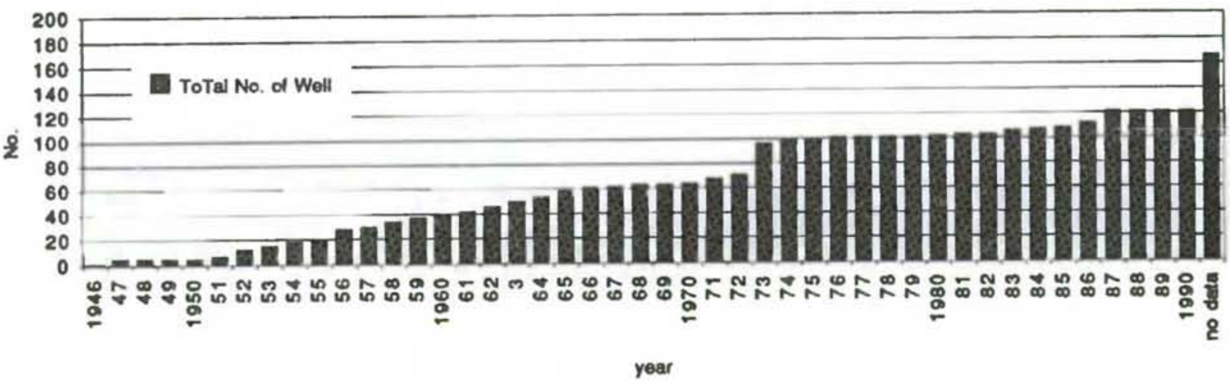
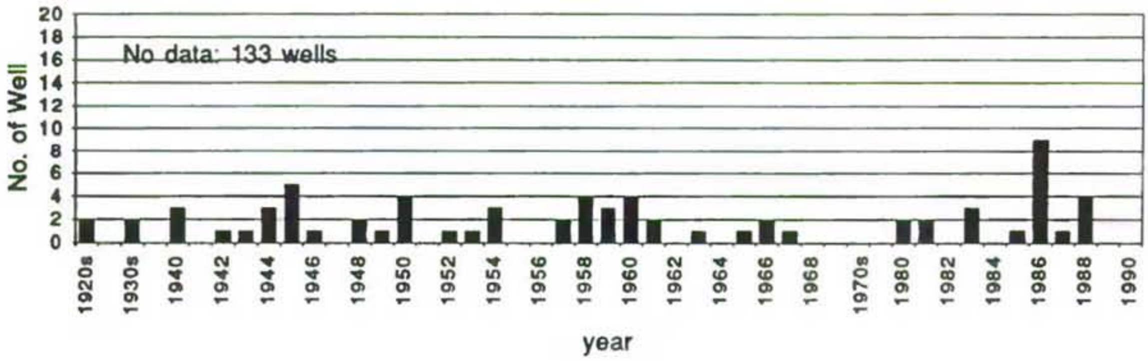


Fig. B-I. 2.2 Well Construction (Azapa Valley)

< Construcción de Sondajes(Valle de Azapa)>

DUG WELL CONSTRUCTION



INCREASE THE NUMBER OF DUG WELLS

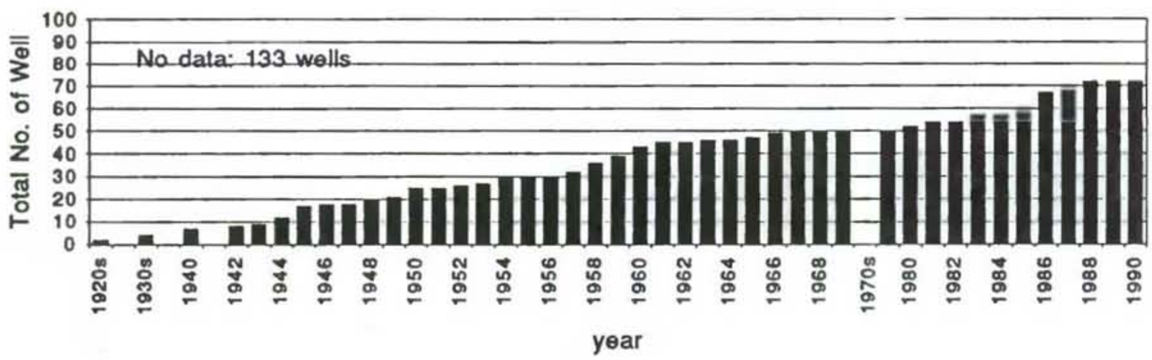


Fig. B-I. 2.3 Dug Well Construction (Azapa Valley)
< Construcción de Noria <Valle de Azapa)>

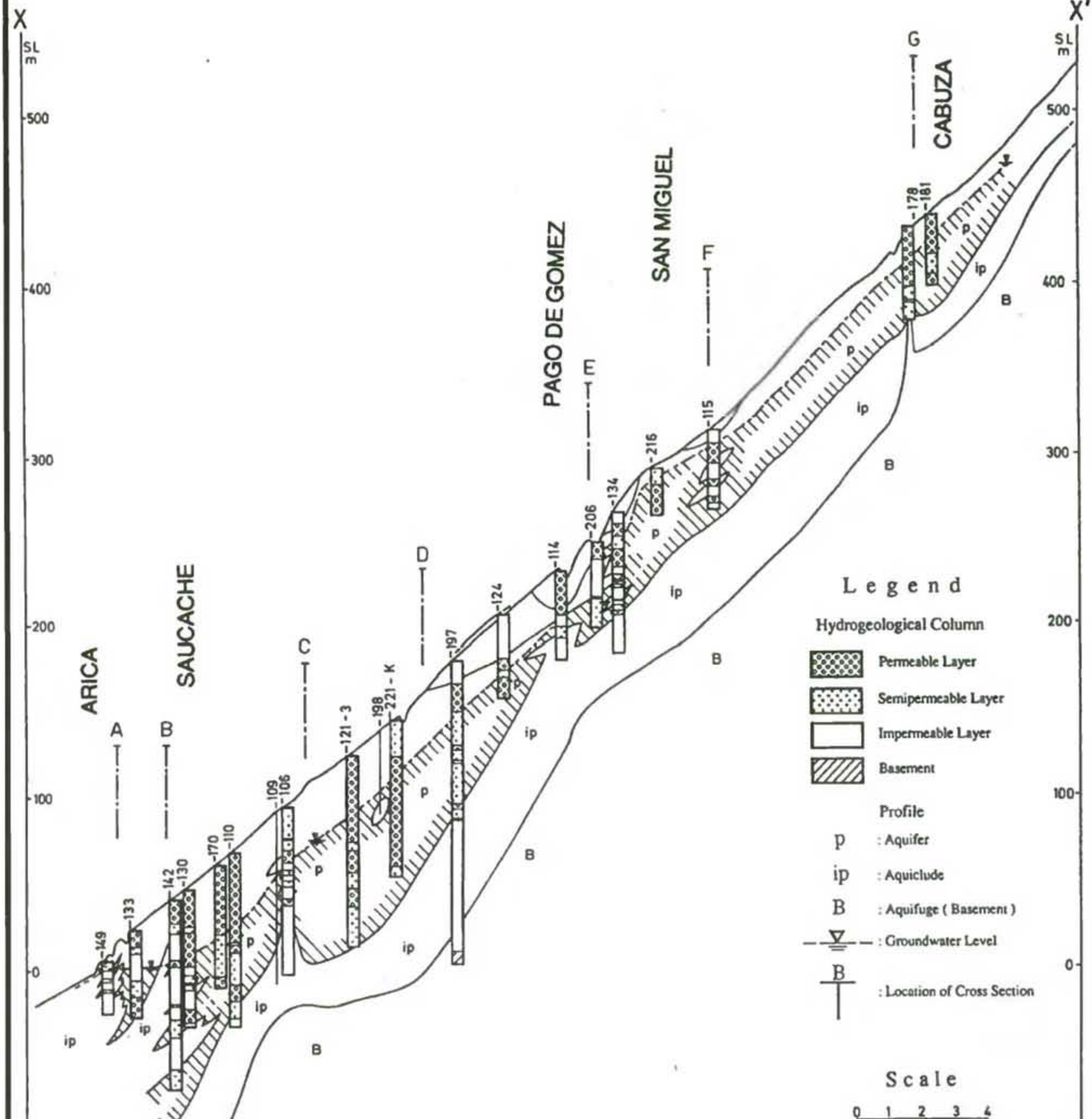


Fig. B-I. 2.4 Hidrogeological Profile (Azapa Valley) (X-X')

< Perfil Hidrogeológico(Valle de Azapa) (X-X')>

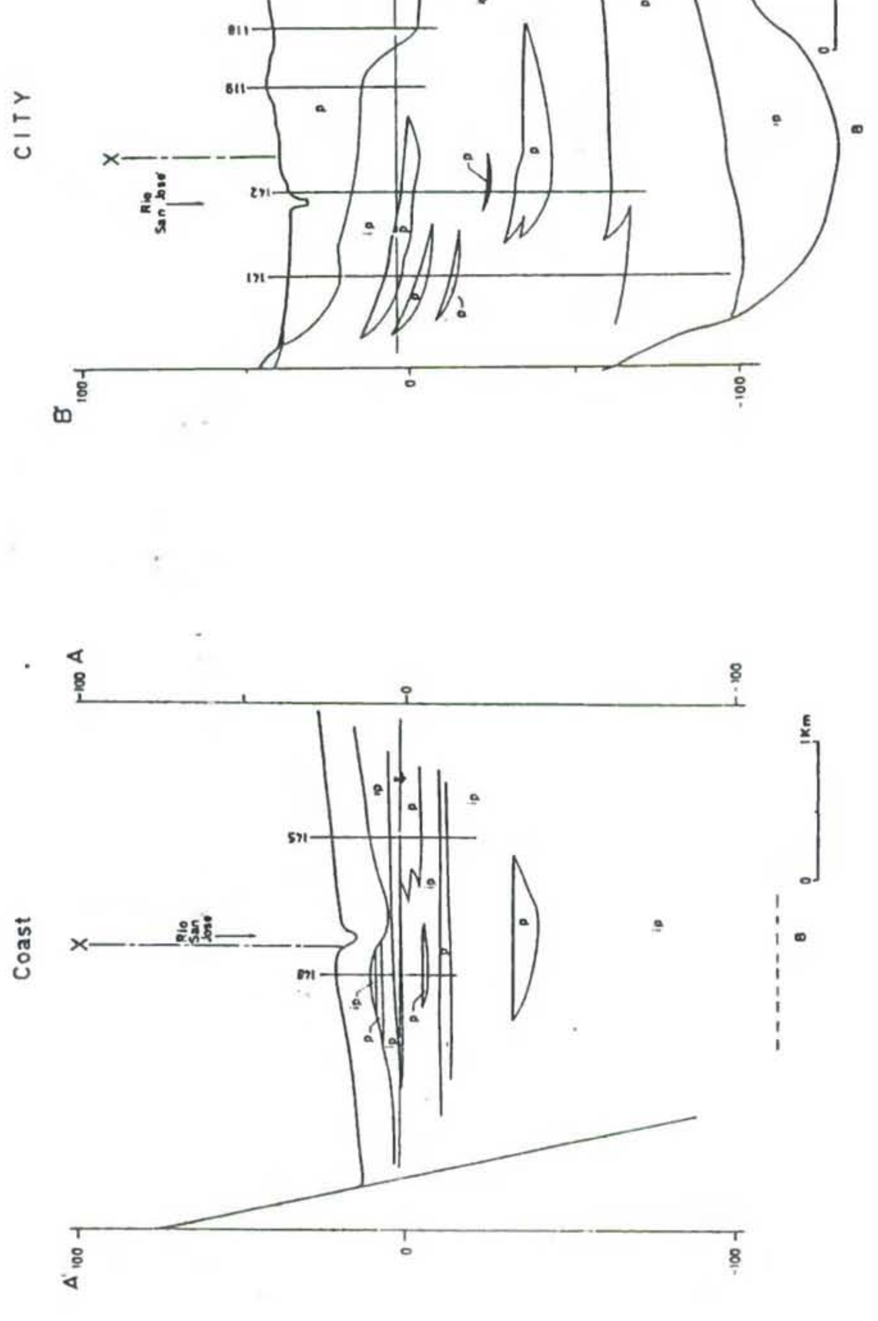


Fig. B-I. 2.5 (1) Hydrogeological Cross Section (Azapa Valley)

< Sección de Cruce Hidrogeológico (Valle de Azapa) >

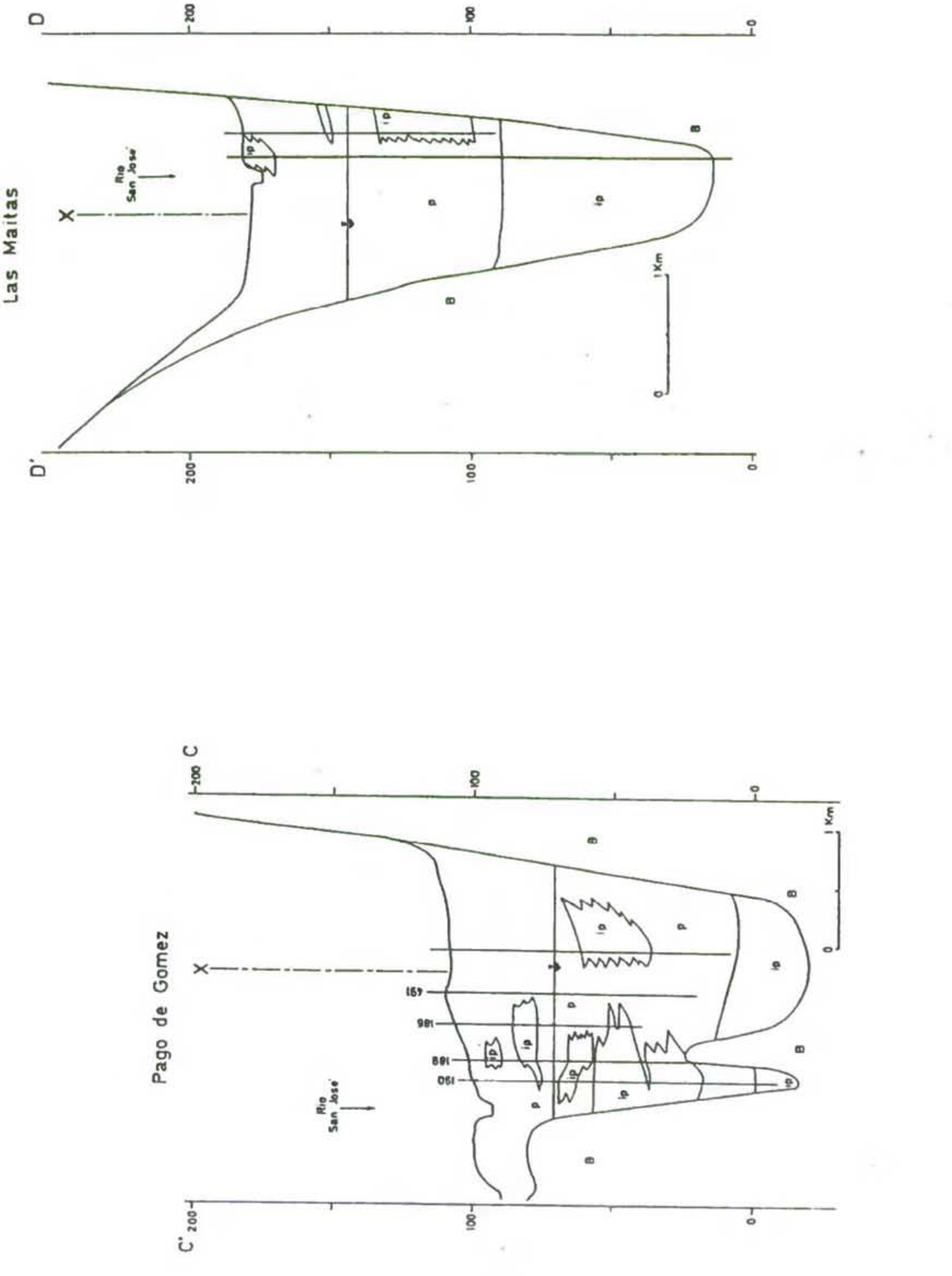


Fig. B-I. 2.5 (2) Hydrogeological Cross Section (Azapa Valley)

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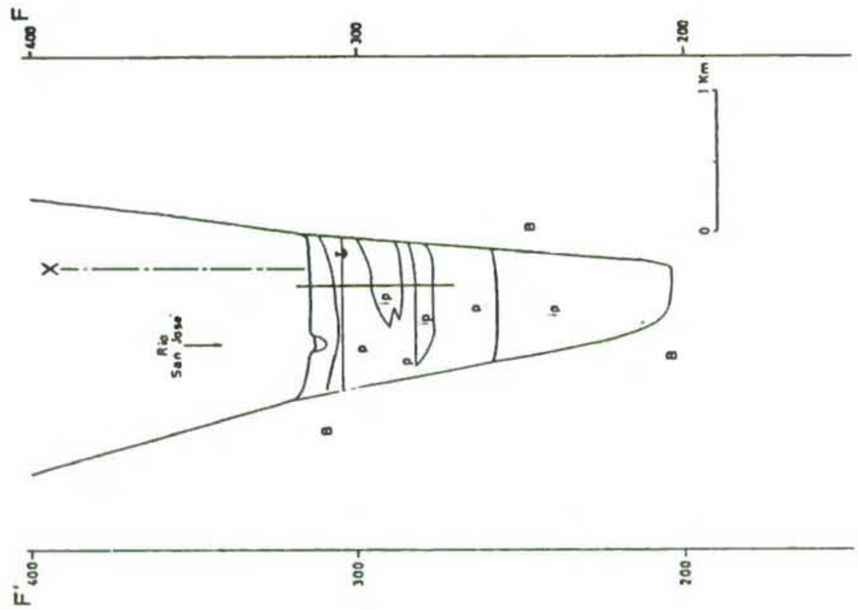

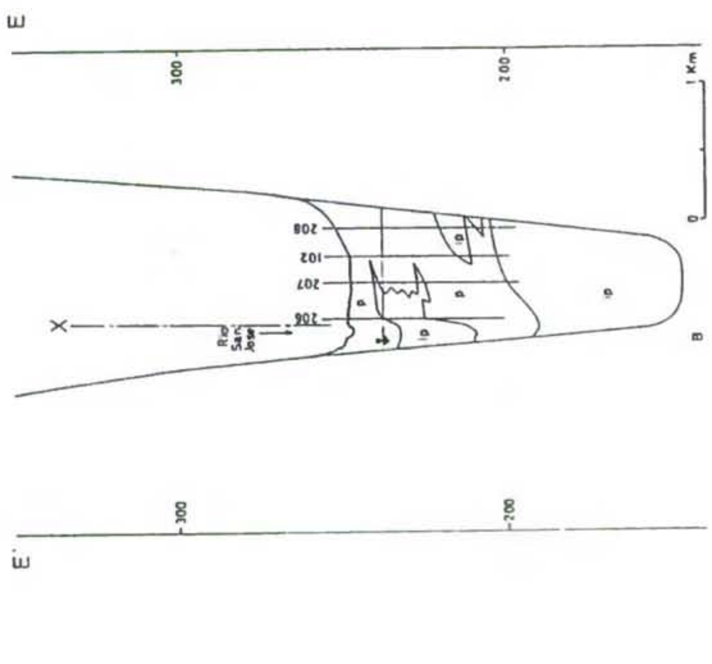

Fig. B-I. 2.5 (3) Hydrogeological Cross Section (Azapa Valley)

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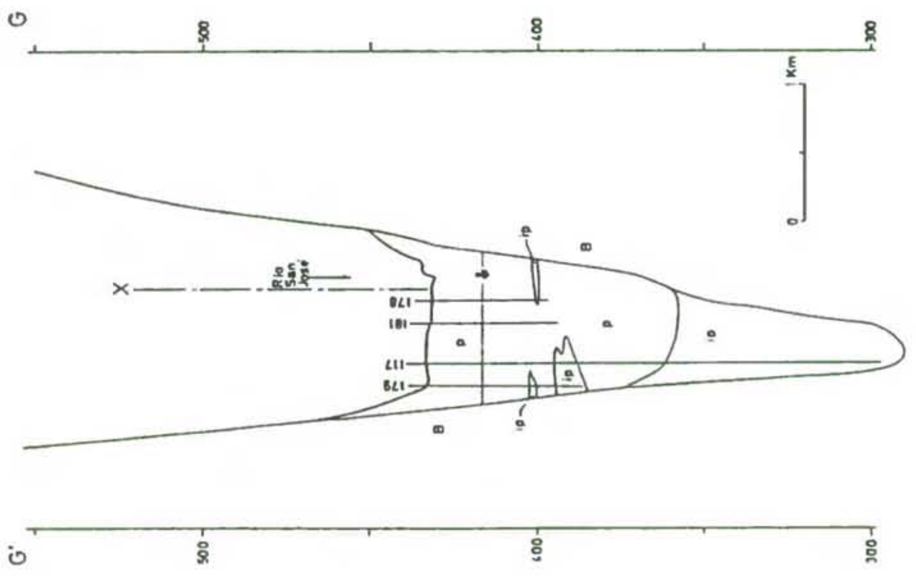

Fig. B-I. 2.5 (4) Hydrogeological Cross Section (Azapa Valley)

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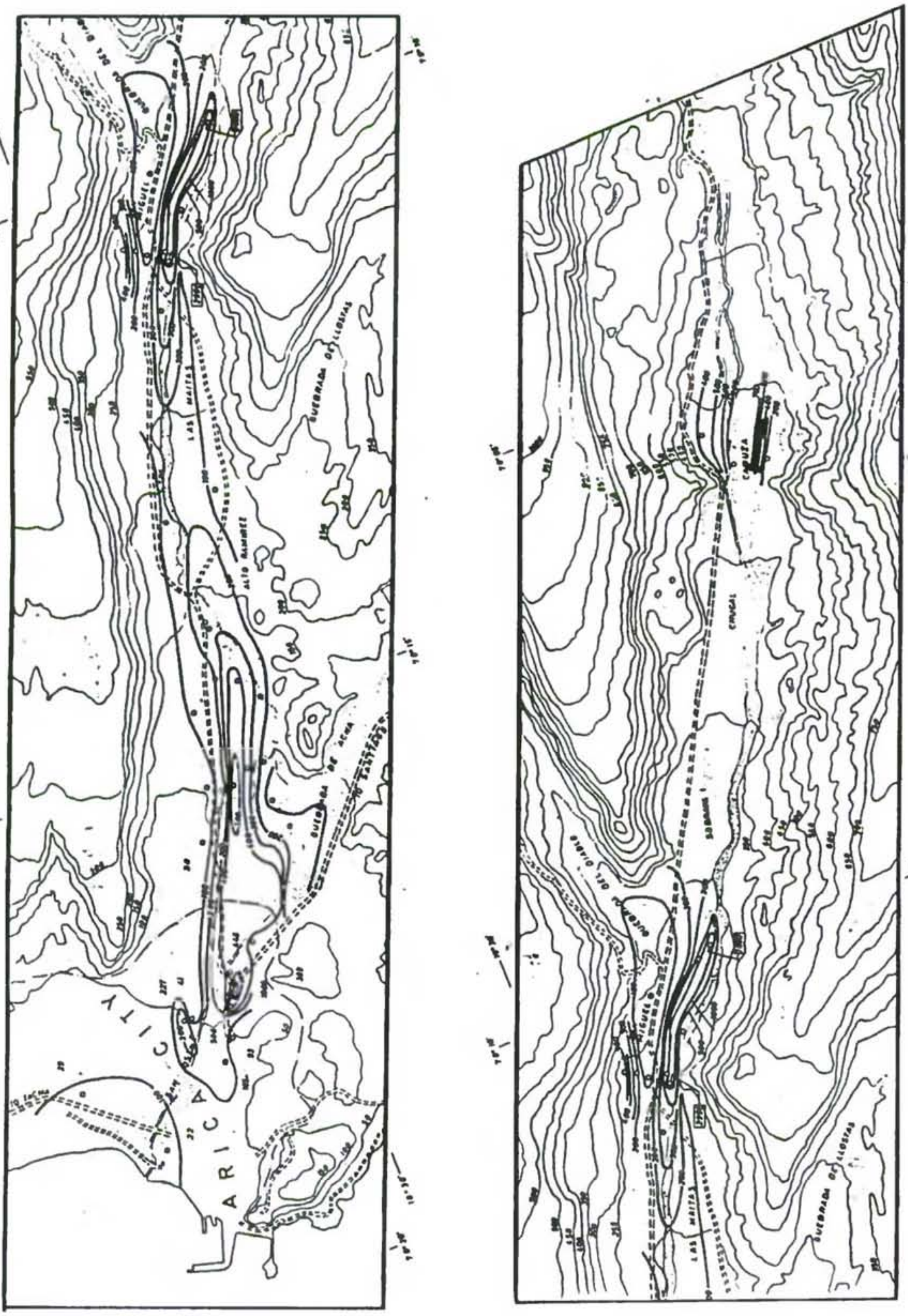


Fig. B-I. 2.6 Distribution of Specific Yield

<Distribución de Escurrímiento Específico>

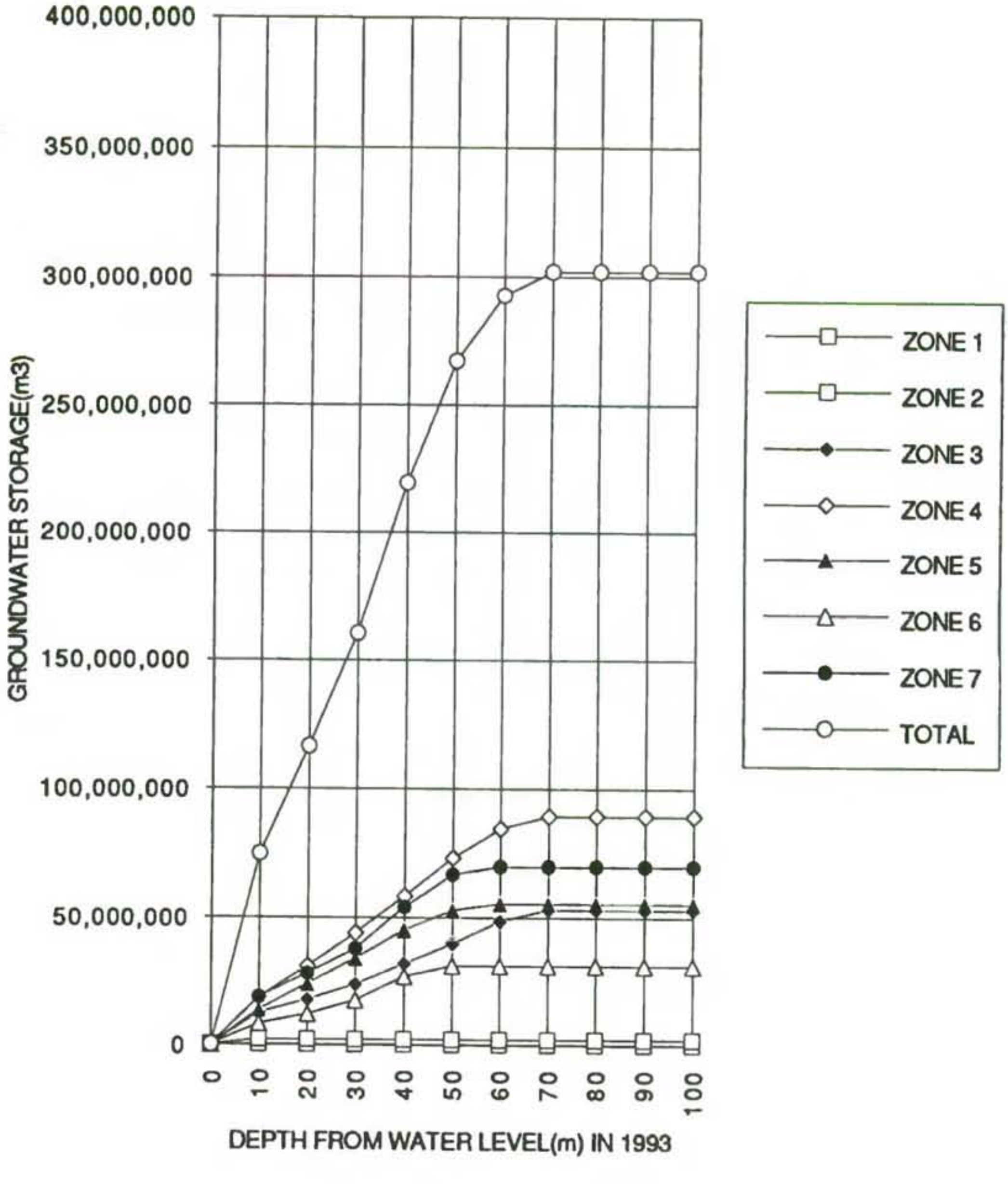


Fig. B-I. 2.7 Estimation of Groundwater Storage (Azapa Valley)

< Estimación de Reservas de Agua Subterránea (Valle de Azapa) >

Chapter III. GROUNDWATER EXTRACTION

3.1 Existing Groundwater Extraction

Groundwater in the Azapa Valley is extracted mainly from following three (3) types of wells including spring;

- ESSAT Well
- Other Wells
- Spring

3.1.1 ESSAT Wells

ESSAT extracted 17,292x10^3m^3 (503 l/sec) of groundwater in both Azapa Valley and Arica city area in 1992 (See Chapter I, Supporting Report C). In addition to this, 10 wells were drilled in 1993 to increase the groundwater production; six (6) wells in Arica city area and four (4) wells in the Azapa Valley, yielding 227 l/sec of groundwater. Thus, the total yield of ESSAT wells increased up to 730 l/sec by the end of 1993.

3.1.2 Other Wells

There was no data on the groundwater extraction through the wells in the area except ESSAT wells. Therefore, to clarify the groundwater extraction, field interviews were carried out in the area by the JICA Study Team and DGA during phase 2 study (1993). The result revealed that there are 343 wells; 167 wells are in operation and 176 wells are not in operation. Extraction rates from each wells are as follows;

Water Use	Number of Wells	Extraction Rate (m^3/yr)
Irrigation	122	9,536,336
Domestic	30	1,366,328
Industrial	3	125,691
Others	12	201,626
Total	167	11,229,981

source: field interview by DGA and the Study Team in 1993.

In addition to this, there are springs in the valley and a total yield of these reaches to 73.4 l/sec (2,302,128 m^3/yr).

3.1.3 Groundwater Extraction in Azapa Valley

As mentioned above, total groundwater extraction in the valley is summarized in the following table.

Water Use	Extraction Rate (l/sec)	Extraction Rate (m^3/yr)	%
ESSAT Wells (Q_E)	730	23,021,280	63.0
Irrigation (Q_R)	302	9,536,336	26.1
Domestic (Q_D)	43	1,366,328	3.7
Industrial (QI)	4	125,691	0.3
Others	6	201,626	0.6
Spring Water (Q_S)	73	2,302,128	6.3
Total	1,203	36,553,389	100.0

Source: ESSAT and field interview by DGA and Study Team.

Total extraction is estimated to be approximately 36.6 million m^3/year (1,203 l/sec). ESSAT wells yield a 63 % of groundwater and wells for irrigation yield 26 %. Other extractions are rather small.

3.2 Observed Groundwater Level of Existing Wells

3.2.1 Static Water Level

Observation of the static water level has been executed by DGA on selected wells. Based on this result, contour maps of static water level (as of Oct., 1993) is prepared as shown in Fig. B-I, 3.1 and 3.2. The maps show static water level above the mean sea level (MSL) and below the ground level (BGL), respectively.

Static water level is about 280 m at San Miguel and gently decreases toward the lower reaches of the San José River. The levels are 200 m at Las Maitas, 120 m at Pago de Gomez, 20 to 100 m at Saucache and less than 10 m in the city area.

Gradient of groundwater table is 22/1000 in the area between San Miguel and Las Maitas, and increases to 32/1000 at Pago de Gomez toward the city area. After reaching to the city area, water table becomes gentle, 4/1000.

Extraction of groundwater is large in Pago de Gomez and Saucache area, therefore, it causes change of groundwater table.

3.2.2 Dynamic Level

Dynamic water level of each well was examined by the pumping test at the completion of well construction. 48 data are available. The results are shown in Table B-I, 3.1 which presents static water level, draw-down and specific yield as well as dynamic water level. These wells are divided into three (3) categories by degree of drawdown as follows;

Drawdown (m)	Cabuza	Las Riveras	San Miguel	Pago de Gomez	Saucache	City	Total
less than 10	2	1	4	3	11	2	23
10 - 20	1	0	2	2	8	1	14
more than 20	0	0	1	3	6	1	11
total	3	1	7	8	25	4	48

Degree of draw-down is almost within 10 m in Cabuza and Las Riveras in the upper reaches of the valley. It increases toward the down stream. In Saucache, six (6) wells, out of 11 wells, show large degree of draw-down which are more than 20 m.

The wells of small drawdown generally show high specific yield except the city area. The wells of large drawdown is mainly located in the Pago de Gomez and Saucache area. It is supposed that high concentration of wells causes large degree of drawdown in these area.

3.2.3 Historical Variation

Historical variation of each well is shown in Table B-I, 3.2 (1) to (10) and Fig. B-I, 3.3 (1) to (4). Fig. B-I, 3.4 presents the variation of groundwater level of selected wells and flow rate of the San José River during flood period. Following characteristics are recognized on the variation of groundwater level;

a) Generally, the water levels have been decreased gradually, although the levels are recovered to a certain degree during the floods of the San José River. As shown in Fig. B-I, 3.4, the periods of the rising and declination of water level are in concordance with the periods of occurrence of floods in the San José River. Floods of the San José River cause the rising of the groundwater level in the area. After rising, the water level continues to fall down up to the next occurrence of flood.

b) Range of the water level variation is large in Cabuza area and it generally becomes smaller toward the lower reaches of the San José River; its range is about 20 m in Cabuza area and about 15 m in Saucache area.

c) Static water level shows different behavior in Las Riveras area; water level is shallow and its variation is small; once water level is risen by recharging from the flood water of the San José River, the water table keeps the risen level for a long period.

d) Variation of water level is not clear in the city area of Arica because of the lack of long term observation record. Static water level is high around 1964, 1977 and 1987, and is low around 1967, 1984 and present.

e) Rising of water level in 1987 is apparent in San Miguel area, however, it is not so clear in Pago de Gomez and Saucache area.

f) The degree of drawdown of water level is large in the lower reaches of the San José River.

Considering the hydrogeological characteristics of the area, the features described above suggest following;

a) The groundwater in the basin is recharged directly by the surface water of the San José River especially during the flood period.

b) The fact mentioned above b) is caused by fine materials such as silt and clay deposited in the valley. These fine materials are derived from the Qda. del Diablo and make the aquifer less permeable near the confluence area with San José River. These materials act like a dam constructed under the ground. It is like a dam up effect due to the spur of the Qda. del Diablo.

c) Apparent drawdown is caused by over exploitation of groundwater in the lower reaches of the San José River through a lot of wells and dug wells.

3.3 Groundwater Quality

3.3.1 Existing Data

Groundwater quality data are available on 61 wells in the Azapa Valley. Main data sources are the analysed data of ESSAT and the existing report entitled Analisis Critico de la Red de Medicion de Niveles de Agua Subterránea 1 Region, October 1987 for DGA by Alamos y Peralta Ingenieros Consultores Ltda. In addition to these, DGA reported the increase of salinity based on the conductivity data on the groundwater in the Azapa Valley (<3).

The number of well distribution by area (as of 1989) is as follows;

(1) Cabuza area	:	5
(2) Las Riveras area	:	4
(3) San Miguel area	:	4
(4) Pago de Gomez area	:	14
(5) Saucache area	:	22
(6) City area	:	12
Total	:	61

3.3.2 Groundwater Quality of Existing Wells

1) Results of Groundwater Quality Analysis

Table B-I, 3.3 (1) to (2) show the groundwater quality data after averaging to avoid the instability of data and to easily understand the tendency of water quality, because water quality analysis was not executed periodically. The characteristics of water quality are as follows;

a) Most TDS values exceed 500 ppm, therefore, groundwater in the Azapa Valley is classified as brackish water. 12 wells in total exceed the TDS value standard (WHO). Out of 12 wells, six (6) wells are in the city area of Arica. The number of well that exceeds the TDS standard decreases toward the upstream of the San José River. No well exceeds the standard in the Cabuza area.

b) TDS value shows extremely high at the well 168-K located in the Saucache area. This well is located downstream of the Qda. Encantada. There was a salt mine in the upper reaches of this quebrada. This fact suggests that the groundwater in downstream of the quebrada is influenced by the salty water derived from the salt mine.

c) The values of Boron (B) content are available on 24 wells. (B) contents are generally high.

d) Arsenic (As) contents are generally within the standard (0.01 ppm: WHO).

2) Composition of Major Ions

The composition of major anions and cations is plotted in the trilinear diagram (Fig. B-I, 3.5). Only one (1) well (No. 107) lies in the zone 1. This type of groundwater is classified as carbonate hardness type which is the normal type of groundwater. Most wells lie in the central part of zone 3 concentrating in a small area. This type of groundwater is classified as non carbonate hardness type which is deteriorated by the groundwater originated from volcanoes. The wells (149, 150 and 168) fall at the edge of zone 3. These wells show an increase of (Cl+SO4) contents. This means that the groundwater in these wells are deteriorated by saline water because well No. 149 and 150 are located near the coastal area and well No. 168 is located in the downstream side of the salt mine.

The groundwater in the Azapa Valley is generally influenced by the water of volcanic origin and the influence of saline water is added near the coastal area.

3) Relation between TDS Value and EC

Fig. B-I, 3.6 shows the relationship between TDS values analyzed by recurrence analysis and EC values measured by salinometer or other equipment. The both values have a good correlation expressed by the following formula;

$$Y = 0.6848\,X + 91.38 \qquad (A)$$

where, X: measured value of EC, Y: TDS value

4) Relation between Cl Content and EC Value

Fig. B-I, 3.7 shows the relationship between Cl contents analyzed in laboratories and EC values measured by equipment. The relationship is expressed by the following equation based on the result of recurrence analysis;

$$Y = 0.2653\,X - 158.7 \qquad (B)$$

where, X: measured value of EC, Y: Cl contents

3.3.3 Historical Variation

Salinity of groundwater shows historical variation as shown in Fig. B-I, 3.8 (1) to (3). Salinity is expressed by TDS values in this figure. TDS values increased as a whole, comparing the values in 1960s, 1970s and 1980s. Variations of the contents (increase and decrease) are recognized especially in 1970s. These variations are considered to be caused by the variation of groundwater level depending on the floods of the San José River.

Increase of conductivity in Azapa Valley is reported in <3 and <4 by DGA. Fig. B-I, 3.9 shows the variation of conductivity measured on the spring water and groundwater in the valley since 1960. Conductivity is less than 1,500 ms/cm in all the springs up to 1970; especially less than 1,000 ms/cm in San Miguel. Increase was suddenly occurred between 1985 and 1990 in the whole springs increasing to more than 1,500 ms/cm. The rate of increase is about twice during 1970 and 1990. The reports mentioned that these increase of salinity was caused by agricultural chemicals used in the Azapa Valley as well as the upper reaches of the San José River.

Although it is difficult to predict precisely the future increase of salinity in the groundwater, an estimation was made by correlative analysis on the average EC value under the assumption that the increase of salinity continues with the same condition as present. Increasing of salinity is given by following formula;

$$Y = 37.3\,X - 72{,}408$$

where, Y: EC , X : year

Results of estimation are shown in Fig. B-I, 3.10.

It shows that salinity will increase up to 2,200 ms/cm in 2000 and 2,600 ms/cm in 2010. These correspond to 425 mg/l and 530 mg/l respectively, converting into Cl contents by formula (B). It is a 10.5 mg/l/year of increasing rate. However, considering the decreasing of groundwater level in the valley, it will be happened in future that the increase of salinity will suddenly become much greater than the estimation.

Groundwater of the valley also indicates similar tendency to that of the springs.

3.3.4 Evaluation of Groundwater Quality

Groundwater quality is shown in Table B-I, 3.3 (1) to (2). Permissible value for drinking water is shown partly as follows;

	pH	Cl	SO_4	Mg	As	Cu	Fe	N-NO_3	N-NH_3
		(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Permissible Values	6.0-8.5	250	250	125	0.05	1.0	0.3	9.0	0.5

Water Quality Standard is referred in Appendix A, 5 of Supporting Report A.

The results are as follows;

a) Cl is higher than permissible values at several wells mainly in the lower reaches.

b) SO_4 and NO_3 sometimes exceed permissible values.

c) Boron (B) is higher than permissible values at most of well.

d) As is less than permissible values.

3.4 Evaluation of Groundwater Development Potential

Water balance of the Azapa Valley is estimated by equations as follows;

$$\Delta S = Q_{Ausipar} - (O + I + E)$$
$$E = D + E_{Others}$$

Here, ΔS stands for the groundwater storage increment/deficit, $Q_{Ausipar}$ for surface runoff at Ausipar, O for the surface water outflow to the sea, I for the consumption of irrigation use, E for the exploitation rate from the groundwater, D for the domestic use in Arica City and E_{Others} for the others consumption (such as industrial use and individual drinking use, etc.).

Each item in the equations are estimated as follows;

$Q_{Ausipar}$	:	34,721,000 m^3 (1,101 l/s : see Supporting Report A, Chapter 1)
O	:	4,699,000 m^3 (see Supporting Report A, Chapter 1)
I	:	24,810,000 m^3 (see Supporting Report C, Chapter 2)
D	:	18,330,000 m^3 (see Supporting Report C, Chapter 1)
E_{Others}	:	675,000 m^3 (see Supporting Report C, Chapter 2)

The water balance of the Azapa Valley is shown as below

$$\Delta S = Q_{Ausipar} - (O + I + D + E)$$
$$= 34{,}721{,}000 - (4{,}699{,}000 + 24{,}810{,}000 + 14{,}823{,}000 + 675{,}000)$$
$$= -10{,}286{,}000{,}000 \ (m^3)$$

This results indicate that groundwater exploitation in the area exceeds the recharge rate from the San José River and its deficit is balanced by consuming the groundwater storage. If this amount of groundwater is consumed every year, following equation comes into being;

$$S/\Delta S = n \text{ (years)}$$

where S : total storage of groundwater
n : life of aquifer

S is estimated to be 302 x 10^6 m^3 (see Chapter 2). Thus,

$$n = 302 \times 10^6 \, m^3/(10{,}286 \times 10^3 \, m^3) = \mathbf{29.4} \text{ (years)}$$

This means that most groundwater storage will be consumed within about 30 years if all the conditions continue during this period. The water balance in Azapa Valley was roughly estimated; the groundwater resources will be comsumed during about 30 years. However, the results show severe condition for future groundwater extraction in the Azapa Valley. Therefore, groundwater protection is necessary instead of further development in the Azapa Valley.

References

<1: Análisis Crítico de la Red de Medición de Niveles de Agua Subterránea I Región, October 1987 for DGA by Alamos y Peralta Ingenieros Consultores Ltda.

<2: Modelo de Simulación de las Aguas Subterráneas del Valle de Azapa, January 1989 for DGA by Ayala, Cabrera y Asociados Ltda. Ingenieros Consultores con la asesoría de IPLA Ltda.

<3: Estudio del Origen y Proceso de Salinización de las Aguas del Río San José, I Región, Chile, November 1991 for DGA by Peña, Pollastri, Salazar y Gutiérrez.

<4: Estudio Análisis de los Recursos de Agua de la Primera Región de Tarapacá, June 1991 for DGA by Ingeniería y Geotecnía Ltda.

Table B-I, 3.1 Dynamic Water Level (Azapa Valley)

<Nivel Dinámico (Valle de Azapa)>

B.N.A CODE	POMPING RATE (l/s)	DYNAMIC WATER LEVEL(m)	STATIC WATER LEVEL(m)	SPECIFIC YIELD (m3/d/m)	DROW-DOWN (m)
135-3	-	25.2	22.7		2.5
145-0	6	29.9	16.6	39.0	13.3
147-7	45	54.0	14.5	98.4	39.5
148-5	2.4	29.8	20.5	22.3	9.3
157-4	22	49.9	27.1	83.4	22.8
159-0	24.8	39.0	18.0	102.0	21.0
160-4	52.7	22.3	14.2	562.1	8.1
161-2	29	35.7	21.0	170.4	14.7
163-9	11.5	33.1	24.5	115.5	8.6
186-8	20	30.4	21.0	183.8	9.4
187-8	40	25.3	15.8	363.8	9.5
188-4	23	31.4	20.5	182.3	10.9
190-6	23	59.8	21.8	52.3	38.0
193-0	24.7	64.0	38.7	84.4	25.3
106-K	-	33.1	31.7		1.4
165-5	70	38.0	24.5	448.0	13.5
166-3	50	37.0	33.0	1080.0	4.0
167-1	55	36.4	27.0	505.5	9.4
128-0	7	58.8	44.1	41.1	14.7
130-2	5	44.7	42.8	227.4	1.9
171-K	45	52.5	44.3	474.1	8.2
137-K	45	54.5	44.5	388.8	10.0
108-6	20	58.3	48.0	167.8	10.3
109-4	25	50.2	26.2	90.0	24.0
229-	50	40.2	25.5	293.9	14.7
230-	45	54.8	26.5	137.4	28.3
231-	40	39.0	24.5	238.3	14.5
232-	50	32.7	23.9	490.9	8.8
121-3	30	39.3	15.3	108.0	24.0
113-2	35	8.1	5.3	1080.0	2.8
216-3	20	14.8	6.4	205.7	8.4
177-9	28	42.0	36.0	403.2	6.0
100-0	40	36.2	31.8	785.5	4.4
117-5	35	48.0	30.0	168.0	18.0
103-5	19	73.3	10.3	26.1	63.0
197-3	30	34.3	10.5	108.9	23.8
199-K	20	37.8	28.2	180.0	9.6
104-3	32	37.0	31.0	460.8	6.0
200-7	27	31.1	23.0	288.0	8.1
221-K	55	36.0	17.5	256.9	18.5
222-8	55	31.0	18.5	380.2	12.5
134-5	20	45.0	20.0	69.1	25.0
205-8	45	18.3	17.0	2990.8	1.3
206-6	45	24.8	19.7	762.4	5.1
207-4	19	41.0	22.0	86.4	19.0
102-7	38	32.2	20.3	275.9	11.9
208-2	41	31.5	24.5	506.1	7.0
114-0	40	22.0	12.5	363.8	9.5

NOTE: COMPILED FROM WELL INVENTORY

Table B-I, 3.2 (1) Variation of Groundwater Table (Azapa Valley)

< Variación de Nivel Estatico (Valle de Azapa)>

WELL	226-0	133-7	126-4	214-7	106-K	164-7	110-8	111-6	108-6	109-4	122-1	129-9	115-9	112-4	113-2
	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1830 7000	1830 7000	1830 7000	1830 7000
DATE	AD-13	CC-15	CC-16	CC-21	CD-12	CD-13	CD-24	CD-25	CD-31	CD-32	DC-5	AA-1	AA-2	AA-3	AA-4
62/1															
2															
3															
4															
5												25.30			
6												25.35			
7												25.14			
8															
9												24.61			
10												24.32			
11												24.12			
12												24.08			
63/1												24.10			
2												23.91			
3												23.74			
4												22.55			
5												19.83			
6												19.91			
7												18.30			
8												17.45			
9												16.20			
10												15.22			
11												14.97			
12												15.40			
64/1															
2												15.88			
3												15.80			
4												15.74			
5												16.05			
6												16.34			
7												16.05			
8												15.94			
9															
10												16.08			
11												16.70			
12												17.21			
65/1												17.58			
2												15.25			
3															
4												15.75			
5												17.72			
6												17.80			
7												17.97			
8															
9															
10															
11												18.69			
12															
66/1															
2															
3												19.70			
4															
5															
6												20.36			
7												20.44			
8												20.47			
9												20.63			
10															
11												20.95			
12												21.20			
67/1															
2															
3															
4												22.00			
5															
6															
7															
8															
9															
10												20.64			
11															
12															
68/1															
2															
3															
4															
5															
6															
7												17.50			
8															
9															
10												16.50			
11															
12															
69/1												20.58			
2															
3															
4															
5															

Table B-I, 3.2 (2) Variation of Groundwater Table (Azapa Valley)

< Variación de Nivel Estatico (Valle de Azapa)>

WELL	226-0	133-7	126-4	214-7	106-K	164-7	110-8	111-6	108-6	109-4	122-1	129-9	115-9	112-4	113-2
	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1830 7000	1830 7000	1830 7000	1830 7000
DATE	AD-13	CC-15	CC-16	CC-21	CD-12	CD-13	CD-24	CD-25	CD-31	CD-32	DC-5	AA-1	AA-2	AA-3	AA-4
6															
7															
8															
9															
10															
11															
12															
70/1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12												25.27			
71/1												25.38			
2												21.88			
3															
4															
5															
6															
7												20.98			
8															
9															
10															
11												20.95			
12															
72/1												21.78			
2												20.75			
3												19.20			
4															
5												17.84			
6															
7															
8												16.83			
9															
10												18.93			
11															
12															
73/1												17.78			
2															
3												14.15			
4															
5												13.79			
6												15.45			
7															
8															
9															
10												13.20			
11		24.20										13.20			
12												13.80			
74/1															
2		23.60										13.40			
3		23.60													
4															
5		23.60													
6		23.00													
7		22.50													
8		22.69										12.09			
9		22.97													
10		23.00										12.89			
11		23.10													
12		22.98										13.70			
75/1		22.51													
2		22.32													
3		22.76										12.93			
4		22.59										12.43			
5															
6															
7															
8															
9															
10															
11															
12					16.51		16.86		32.30	13.13		4.93			
76/1					16.44		16.70		31.33	13.14		4.93			
2					15.77		16.11		31.92	12.39		4.76			
3												4.34			
4		25.96			13.48		14.00			9.98	17.20	4.40			
5												4.40			
6		17.62			12.12		12.75		28.42	8.72		4.52			
7		16.92			12.87		12.07		25.96	9.62		4.55			
8		16.58			12.85		11,71		24.93	3.20		4.47			
9		16.57			12.02		11.34		24.71	8.50		4.58			
10		16.38			12.45		11.45		24.35	8.81		4.52			

Table B-I, 3.2 (3) Variation of Groundwater Table (Azapa Valley)

< Variación de Nivel Estatico (Valle de Azapa)>

WELL	226-0	133-7	126-4	214-7	106-K	164-7	110-8	111-6	108-6	109-4	122-1	129-9	115-9	112-4	113-2
	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1830 7000	1830 7000	1830 7000	1830 7000
DATE	AD-13	CC-15	CC-16	CC-21	CD-12	CD-13	CD-24	CD-25	CD-31	CD-32	DC-5	AA-1	AA-2	AA-3	AA-4
11												4.52			
12					15.29		12.30		23.87	10.80		4.51			
77/1		15.34			16.07		12.60			11.65	15.73	4.66			
2		14.77			15.48		13.26		24.30	12.02	14.99	4.58			
3		14.30			15.84		12.55			19.70	16.00	4.64			
4		14.02			14.28		13.50		21.98	11.[illegible]	16.10	4.20			
5		13.60			13.52		11.36		21.50	15.99	12.89	4.20			
6		13.03			12.55		10.34		20.75	9.35	12.60	4.24			
7		12.46			12.60		10.90		19.85	8.84	12.37	4.38			
8		12.40			11.75		10.79		19.47	8.56	12.75				
9		12.08					10.81		19.87	8.77	13.32	4.30			
10		11.85					10.97		20.00	9.27	13.93				
11		11.77					11.00		20.19	9.87	14.29	2.09			
12															
78/1															
2		10.56					12.02			11.58	15.38				
3															
4		11.52							21.15	12.22	16.00				
5		11.53							21.76	12.08	15.78				
6		11.88					12.00		21.73	12.00	16.00				
7		10.68					12.00		21.63	11.64	15.87				
8		10.80					12.30		21.53	11.80	16.00				
9		11.50					12.53		21.51	11.97	16.23				
10		11.66							10.96	13.10	16.20				
11		12.00							10.90	13.20	16.30				
12		11.67					13.90		22.30	14.34	16.13				
79/1											16.98				
2		11.72					14.57		22.66	15.08					
3		11.65					15.13		23.33	15.59	17.23				
4		11.70					15.52		23.40	15.65	17.49				
5		12.00					15.50		23.35	15.65	17.52				
6		21.77					15.61		22.37	15.67	17.50				
7		22.00					15.74		24.05	15.70	17.50				
8		12.00					16.00		24.11	15.65	17.60				
9															
10															
11		12.16					17.00		24.30	16.65	18.00				
12		12.05					17.12		24.35	16.75	18.00				
80/1		11.98					17.22		23.90	16.83	18.10				
2		12.41					17.30		25.67	16.83	18.35				
3		12.64					17.25		25.60	16.70	18.42				
4		12.67					19.19		26.40	17.78	18.79				
5		12.80					19.30		27.17	18.02	18.94				
6		12.70					19.20		27.25	19.00	18.90				
7		12.75					20.20		26.45	16.50	19.48				
8		12.75					20.15		26.40	16.95	20.38				
9		12.60					20.01		26.55	16.80	19.21				
10		12.00					21.34		28.72		19.02				
11		12.15					23.14		28.85		19.22				
12		12.20					22.64		28.02		21.02				
81/1									23.90						
2							22.91		28.51		21.83				
3									28.42		21.12				
4									25.52		21.07				
5									25.82		20.69				
6									25.92		20.82				
7							25.55		29.60		21.12				
8							25.79		29.97		20.28				
9							25.79		30.24		20.72				
10															
11															
12															
82/1							20.15		26.92		21.73				
2							20.04		27.14		21.73				
3							20.09		26.92		22.02				
4							20.15		26.61		22.14				
5							22.74		28.67						
6							26.86		33.90						
7							26.43		33.52	27.28					
8							28.52		33.72	27.24					
9							28.88		33.65	27.53					
10															
11															
12															
83/1															
2					31.41		30.45		35.09						
3					31.70		31.49		36.48						
4							31.11		31.30						
5					32.45		31.31		37.17						
6					32.51		31.55		36.44						
7					32.53		31.58		37.20						
8					32.53		32.20		37.33						
9					33.70		32.36		38.19			23.73			
10					32.67		32.40		38.02			23.95			
11					32.75		32.58		38.12			22.05			
12					33.35		33.21					23.93			
84/1					34.83		33.83		38.29			21.80			
2					33.60		33.76		38.32			21.71			
3							33.90		37.76			19.28			

Table B-I, 3.2 (4) Variation of Groundwater Table (Azapa Valley)

< Variación de Nivel Estatico (Valle de Azapa)>

WELL / DATE	226-0	133-7	126-4	214-7	106-K	164-7	110-8	111-6	109-6	109-4	122-1	129-9	115-9	112-4	113-2
	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1830 7000	1830 7000	1830 7000	1830 7000
DATE	AD-13	CC-15	CC-16	CC-21	CD-12	CD-13	CD-24	CD-25	CD-31	CD-32	DC-5	AA-1	AA-2	AA-3	AA-4
4					34.70		34.05		37.86			18.66			
5					33.25		34.29		38.42			18.61			
6							34.41		38.64			18.61			
7							34.44		38.92	29.42		18.24			
8							34.78		39.06	29.37		18.20			
9							35.00		39.30	29.42		18.40			
10							35.05		39.39	29.43		18.67			
11							35.22		39.66	29.52		18.51			
12							35.31		39.81	29.53		18.55			
85/1							35.56		40.00	29.66		18.61			
2							35.50		40.02	29.71		18.26			
3							35.73		40.11	29.69		18.08			
4												18.08			
5															
6															
7							35.51		40.71	29.16		13.46			
8										29.16		13.23			
9							35.34			28.80					
10							35.20			28.83					
11															
12							35.33			28.84					
86/1							35.42			28.72					
2							35.70			28.99					
3							35.64			28.66					
4							35.58			28.17					
5															
6							35.25			27.69					
7															
8							36.12			32.25					
9															
10							34.45			32.18					
11															
12							34.45			27.45					
87/1															
2							34.39	21.30		27.45				9.35	16.68
3															
4							34.48	21.01		27.19				9.04	16.59
5			25.62				34.40	20.70		27.01			8.80		16.59
6			25.46				34.33	20.04		26.71			8.77		16.66
7			25.37				34.00	20.11		26.35			8.69		16.69
8			25.38				33.77	19.46		26.18			9.05		16.67
9															
10			25.25				33.73	20.15		25.95			9.38		16.81
11			25.04				33.37	21.44		25.61			9.75		
12							33.26			25.44					
88/1			25.03				33.25	21.55		25.38			10.11		17.15
2			25.12				33.22	21.46		25.28			10.43		17.09
3			25.07				33.11	21.52		25.30			10.75		17.20
4			25.04				32.72	21.46		25.19			10.50		17.13
5															
6			25.04				32.40	20.66		25.41			11.35		17.36
7							32.30			25.38			11.53		17.40
8			24.70				31.99	19.12		25.57			11.88		17.43
9							31.88			25.71			11.99		17.56
10										25.97			12.15		17.58
11															
12			24.43				31.99	20.87		26.79			12.10		17.70
89/1							32.28			27.18			13.17		17.77
2							32.37			27.39			12.95		17.80
3															
4							32.70			27.90			13.34		18.15
5															
6	17.99		22.65	20.67			32.85	20.78		28.69			8.16		
7															
8															
9	17.94		22.70	20.37			32.69	20.45		29.30			8.40		
10															
11	18.05		22.73	19.77			33.28	20.09		29.63			9.27		
12															
90/1															
2															
3	18.23			20.43			34.98	21.09		30.49			10.50		
4															
5	18.37						36.00			31.03			11.37		
6															
7	18.45						36.53						11.94		
8															
9	18.49						36.96			31.62			11.76		
10															
11	18.57						37.69			32.72					
12															
91/1	18.69						38.22			31.42			7.57		
2	18.88									34.09			7.71		
3	19.12									34.40			7.67		
4						29.71	39.20	20.73		33.66			7.54	17.92	18.94
5						30.77	39.35	20.65		33.87				18.09	18.99
6															
7						29.69	39.48			34.50				18.65	19.13
8						29.78	39.57	20.61		34.03				18.70	19.08

Table B-I, 3.2 (5) Variation of Groundwater Table (Azapa Valley)

< Variación de Nivel Estatico (Valle de Azapa)>

WELL / DATE	226-0	133-7	126-4	214-7	106-K	164-7	110-8	111-6	108-6	109-4	122-1	129-9	115-9	112-4	113-2
	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1820 7010	1830 7000	1830 7000	1830 7000	1830 7000
	AD-13	CC-15	CC-16	CC-21	CD-12	CD-13	CD-24	CD-25	CD-31	CD-32	DC-5	AA-1	AA-2	AA-3	AA-4
9															
10															
11															
12							41.66			35.50					
92/1	19.67					40.42	41.48	21.91		35.34					
2	19.16					43.93	41.62	20.94		35.26					
3	19.19					43.97	41.42	21.06		35.50					
4	19.30							20.63							
5	19.34														
6															
7						45.90	43.12	20.77		35.61					19.49
8															
9	19.48					46.50	43.56	20.92		35.95					
10															
11															
12															
93/1															
2						47.90	45.00	20.93		37.45					
3	19.64					46.10	45.83	21.16		37.65					
4															
5															
6															
7															
8	19.62					46.97	46.76	22.00		39.97					
9															
10	20.22					48.00	47.14	20.19		40.60					
11	20.22					48.15	47.54	20.20		40.93					
12	19.95					48.48	47.93	20.13		41.08					

Table B-I, 3.2 (6) Variation of Groundwater Table (Azapa Valley)

< Variación de Nivel Estatico (Valle de Azapa)>

WELL / DATE	101-9	225-	100-0	116-7	117-5	224-4	104-3	103-5	220-1	198-5	125-6	199-K	134-5	102-7	114-0
	1830 7000	1830 7000	1830 7000	1830 7000	1830 7000	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010
	AA-5	AC-2	AD-3	AD-4	AD-5	AB-10	BA-10	BA-2	BA-20	BA-3	BA-6	BA-9	BB-2	BB-6	BB-8
62/1															
2															
3															
4														29.74	
5														29.65	
6	14.42													26.96	
7														28.87	
8	13.06													27.94	
9	12.94													26.18	
10	13.20													26.72	
11														29.43	
12														29.80	
63/1	13.68													19.55	
2	13.28													27.62	
3	10.26													29.49	
4	6.70													23.50	
5	6.74													23.50	
6	5.79													25.90	
7	4.18													27.70	
8	3.35													22.06	
9	2.70													21.44	
10	2.38													20.20	
11	2.44													13.90	
12															
64/1	2.51													16.62	
2	2.39													16.40	
3	2.35													19.15	
4	2.48													16.64	
5	2.69													16.47	
6	2.60													16.08	
7	2.55													17.66	
8															
9														17.75	
10	3.00													16.08	
11	3.32													18.36	
12	3.56													16.20	
65/1	3.69													18.00	
2															
3	3.67													19.00	
4	3.97													19.73	
5	4.25													19.60	
6	6.77													19.15	
7															
8															
9															
10														19.44	
11															
12															
66/1															
2														21.50	
3															
4															
5														21.60	
6	6.77														
7	6.67													20.80	
8	7.18													20.76	
9															
10														21.13	
11														22.43	
12															
67/1															
2															
3	8.92													24.74	
4	8.88													23.73	
5	8.78													23.90	
6	7.63													20.98	
7															
8	7.70													20.02	
9	7.38													19.93	
10	7.56													21.20	
11															
12														21.15	
68/1	6.66													20.00	
2	7.22													21.08	
3	5.45													16.72	
4															
5	3.17													17.08	
6	2.98													16.83	
7															
8	2.78													17.86	
9	2.20													17.57	
10	2.16													16.00	
11	2.74													17.57	
12	2.78													17.83	
69/1	2.65													17.91	
2	3.01													17.56	
3	2.84													17.02	
4	3.80													16.76	
5	3.89													16.56	

Table B-I, 3.2 (7) Variation of Groundwater Table (Azapa Valley)

< Variación de Nivel Estatico (Valle de Azapa)>

WELL / DATE	101-9	225-	100-0	116-7	117-5	224-4	104-3	103-5	220-1	196-5	125-6	199-K	134-5	102-7	114-0
	1830 7000	1830 7000	1830 7000	1830 7000	1830 7000	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010
	AA-5	AC-2	AD-3	AD-4	AD-5	AB-10	BA-10	BA-2	BA-20	BA-3	BA-6	BA-9	BB-2	BB-6	BB-8
6	3.36													16.40	
7	3.45													16.61	
8	3.39													16.41	
9	3.41													16.54	
10	3.54													16.35	
11	3.48													16.39	
12	3.72													16.41	
70/1	4.10													16.40	
2	3.98													16.41	
3	4.20													19.10	
4	4.09													16.48	
5	4.03													16.45	
6														16.42	
7															
8	4.18													16.46	
9	4.10													16.40	
10	4.08													19.78	
11	6.58													19.77	
12	6.37													21.42	
71/1	6.66													19.88	
2															
3															
4	5.14													18.45	
5	5.17													17.26	
6	5.19													17.82	
7	5.21													17.54	
8														17.47	
9	5.40													17.58	
10	5.56													17.62	
11															
12	6.56													17.90	
72/1	5.61													19.00	
2															
3	3.72													16.65	
4	3.43													16.40	
5	3.15													16.95	
6														17.18	
7	2.75														
8															
9	2.53													17.40	
10	2.60													17.36	
11														18.91	
12	2.93													18.58	
73/1															
2	1.92													16.75	
3															
4	1.43													16.52	
5	1.05													15.44	
6															
7															
8															
9															
10	0.81														
11	0.99														
12															
74/1	0.86														
2															
3	1.15														
4															
5	0.92														
6	0.82														
7	0.89														
8	1.02														
9	1.00														
10	1.50														
11	1.20														
12	1.10														
75/1	1.01														
2	1.00														
3	1.04														
4															
5															
6															
7															
8															
9															
10	1.95														
11	1.55							5.06					18.81	15.00	8.20
12	1.44			26.23	26.39								18.54		
76/1				26.17	26.22			4.99					18.57	15.70	
2	1.36			25.55	25.71			3.36					18.25	14.07	8.39
3															
4	1.46							2.81					18.23	12.68	
5															
6	1.46													14.24	
7	1.43													16.69	
8	1.63													14.92	
9	1.46							2.40					19.16	15.02	
10	1.47													15.00	

Table B-I, 3.2 (10) Variation of Groundwater Table (Azapa Valley)

< Variación de Nivel Estatico (Valle de Azapa)>

WELL	101-9	225-	100-0	116-7	117-5	224-4	104-3	103-5	220-1	196-5	125-6	199-K	134-5	102-7	114-0
	1830 7000	1830 7000	1830 7000	1830 7000	1830 7000	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010
DATE	AA-5	AC-2	AD-3	AD-4	AD-5	AB-10	BA-10	BA-2	BA-20	BA-3	BA-6	BA-9	BB-2	BB-6	BB-8
9															
10															
11															
12								14.99							
92/1								15.74				35.52			
2	4.30							15.76		31.11		32.74			
3	4.46					33.42		15.91		30.92		36.30			
4	4.74					33.81				31.49		34.90			
5															
6															
7								15.75	36.83	33.88					33.90
8															
9						34.23		15.78		32.87					
10															
11															
12															
93/1															
2	6.44					35.97		16.30		34.04		36.55			
3	6.58					36.34		16.72		34.14		36.51			
4															
5															
6															
7															
8	6.38					37.51		18.60		35.62		37.40			
9															
10	6.38					37.53		19.20		36.15		37.84			
11	6.41					38.75		19.33		36.25		38.10			
12	6.41					39.10		19.33		36.32		38.15			

Source : Observation by DGA.

Table B-I, 3.3 (1) Groundwater Quality (Azapa Valley)

<Calidad de Agua (Valle de Azapa)>

ITEM / WELL	pH	TDS	EC	Ca	Mg	Na	K	SO4	Cl	CO3	HCO3	NO3	SiO2	Li	B	Fe	Mn	As	Zn	Cu	F	Al
			m.mho/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
STANDARD	6.5-8.0	1000	-	-	125	200	-	250	250	-	-	10	-	-	1.00	0.30	0.10	0.05	5.00	1.00	1.50	0.20
136-1	7.1	1252	1500	195.8	12.8	158.8	21.1	300.0	214.9	0.0	349.0											
135-3	7.0	1453	1353	189.7	15.8	104.9	5.2	169.7	346.1	75.5	223.9	18.6	177.0	0.1	0.0			0.0				
139-6	7.4	873	1094	150.6	18.0	73.4	4.4	240.6	122.1	9.1	196.8		42.8	<0.2					0.0	<0.01		0.1
140-K	7.1	859	1200	135.5	18.5	89.7	8.0	240.3	190.9	0.0	215.4	2.1	41.7		1.4	0.0	0.0	0.0		0.0	0.5	
141-B	7.2	1073	1524	186.9	22.7	180.6	12.9	242.9	227.1	6.7	247.9	10.6	55.7	<0.2	1.2	0.3	0.4	<0.05	0.0	<0.01	1.5	
142-6	7.1	946	1575	171.8	17.1	72.6	4.2	222.8	173.2	0.0	178.5	10.0	38.0	<0.2	0.8	0.2	<0.1	<0.05	0.0	<0.01	0.3	0.1
143-4	7.2	1381	1779	223.8	23.4	92.1	4.4	230.7	288.7	6.4	194.2	23.1		<0.2	1.1	0.3	<0.1	<0.05	0.1	<0.01	0.2	0.1
145-0	7.3	948	1268	166.8	14.2	75.8	3.3	198.7	191.9	0.0	196.5	5.6	52.2	0.0	1.0	0.0	0.0	<0.05	0.0	0.0		
147-7	7.2	753	961	141.6	17.0	68.9	3.7	174.0	127.2	4.2	181.7	6.4	40.8	<0.2		<0.1	<0.1	<0.05	0.1	<0.01	0.3	<0.1
148-5	7.2	657	1092	113.7	14.7	49.0	6.0	199.0	95.0	0.0	198.0	4.6	45.0									
149-3	5.8	1929	2525	309.4	49.2	168.6	12.6	473.5	577.6	0.0	93.0	11.5	62.5									
150-7	7.2	2835	4113	496.6	44.8	205.6	10.9	861.3	532.4	0.0	211.0	113.1	94.2	0.2				0.0				
106-K	7.7	881	1090	133.7	8.9	97.5	13.8	225.9	158.0	0.0	225.2	0.0	110.3	0.0	0.5			0.0				
108-6	7.9	659	740	113.9	11.4	66.0	3.7	206.2	81.4	0.0	193.7				1.7							
128-0	7.2	658	1110	126.0	13.5	79.8	4.6	199.7	92.0	0.0	169.4	3.1	34.8	<0.2	0.9					<0.01		
130-2	7.2	717	884	130.7	16.5	73.2	15.3	208.8	118.0	8.3	183.8	20.0	49.0	<0.2	1.2	<0.1	<0.1	<0.05		<0.01	0.2	
137-K	8.3	950		115.3	36.6	80.0	3.8	214.8	85.1	72.0	206.4				1.1			0.0				
138-8	7.3	886	1135	201.4	20.3	85.0	1.5	244.1	147.4		204.4	5.0			1.3	<0.1	<0.1	<0.05			0.4	
154-K	7.3	1351	1520	271.3	29.2	84.5	16.3	483.5	220.8	0.0	251.1			<0.2								
155-8	7.1	1573	1695	299.8	32.7	140.5	6.4	525.3	251.7	0.0	255.9							0.0				
157-4	7.2	798	1080	145.3	15.5	68.0	3.6	214.0	123.4	17.3	190.5	2.6	40.0			<0.1	<0.1	<0.05	0.0	<0.01	0.3	<0.1
158-2	7.0	958	1469	183.6	17.4	72.3	4.5	265.3	150.1	21.3	209.2	5.7	38.4	<0.2		<0.1	<0.1	<0.05	0.0	<0.01	0.4	0.0
159-0	7.0	1089	1520	200.2	8.5	63.7	3.9	270.4	146.1	0.0	222.7											
160-4	7.2	897		171.0	18.7	101.0	6.0	273.8	144.5	0.0	290.7		45.3	<0.2						0.0		0.0
161-2	7.1	975	1173	184.4	19.3	96.7	3.2	279.6	153.2	0.0	209.5		42.7	<0.2						<0.01		
165-5	7.1	922	1172	176.8	22.7	77.9	3.5	243.2	147.0	4.4	177.3	4.8	41.4	<0.2		0.2	<0.1	<0.05	0.1	<0.01	0.5	<0.1
166-3	7.5	886	1131	164.0	15.5	92.1	4.6	250.2	151.6	0.0	219.7	4.2	49.9	<0.2		<0.1	<0.1	<0.05	0.0	<0.01	0.4	0.0
167-1	7.1	905	1240	170.2	19.1	86.0	17.0	266.0	151.5	0.0	266.0		45.5	<0.2					0.0	<0.01		0.0
168-K	7.3	5624	8100	566.0	21.1	305.8	214.3	1240.5	2149.4	0.0	209.4											
121-3	7.7	1219	1300	200.2	18.3	93.1	5.4	322.6	191.7	0.0	215.3				1.7			0.0				
112-4	7.2	949	1160	182.4	18.0	90.0	7.0	249.0	166.1	0.0	220.8		38.0	<0.2	1.6	0.1	<0.1	<0.05		<0.01	0.2	
113-2	7.4	843	960	153.6	17.3	70.0	3.8	296.3	108.5	0.0	212.1				1.8							
129-9	7.4	777	987	142.4	15.9	65.4	2.3	229.1	125.4	13.4	178.5	9.7	34.3	<0.2	1.6	0.1	<0.1	<0.05		<0.01	<0.2	
216-3	7.0	714		138.0	16.0	75.0	3.8	216.0	122.0	0.0	204.0		45.0			0.3	<0.1	<0.05				
100-0	7.0	779	1420	126.1	14.8	90.3	5.3	294.0	137.0	0.0	318.0	4.0	26.5	<0.1	1.8	0.4	<0.1	<0.05		<0.01	0.2	
117-5	8.1	776	860	88.2	9.4	40.0	2.5	166.3	79.8	34.0	133.8	0.0	299.7		1.3							
177-9	7.3	741	954	131.5	17.2	66.8	5.3	199.2	108.0	2.6	194.5							0.0				
183-3	7.3	636	870	119.3	12.7	62.0	5.0	213.8	82.6	4.1	198.0							0.0				
184-1	7.1	615		115.0	13.0	59.0	3.9	209.0	87.0	0.0	161.0											
186-8	6.9	989	1406	174.3	17.4	73.9	3.9	274.6	145.3	0.0	216.4	6.9	48.8	<0.2		<0.1	<0.1	<0.05	0.0	<0.01	0.3	0.0
187-6	7.2	1026	1527	194.0	20.4	98.3	5.4	304.3	161.6	0.0	304.3		49.0	<0.2						<0.01		0.0
188-4	7.2	790		128.0	17.0			230.0	126.0	0.0	229.0		120.0							0.0		
190-6	7.7	798	953	134.6	15.9	79.4	5.3	271.2	108.2	0.0	119.8											
103-5	7.3	670		104.0	12.0	87.0	5.4	212.0	104.0	0.0	184.0	0.0	46.0									

Table B-I, 3.2 (8) Variation of Groundwater Table (Azapa Valley)

< Variación de Nivel Estatico (Valle de Azapa)>

WELL	101-9	225-	100-0	116-7	117-5	224-4	104-3	103-5	220-1	196-5	125-8	199-K	134-5	102-7	114-0
	1830 7000	1830 7000	1830 7000	1830 7000	1830 7000	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010
DATE	AA-5	AC-2	AD-3	AD-4	AD-5	AB-10	BA-10	BA-2	BA-20	BA-3	BA-6	BA-9	BB-2	BB-6	BB-8
11														15.20	
12	1.42			25.90	26.15			4.00					19.16	14.70	8.10
77/1	1.45						17.21							14.51	
2	1.47			26.30	26.52		18.00	4.21					18.85	14.56	7.41
3	1.53						17.21							14.60	
4	0.48			24.37	24.35		17.20	3.74						12.44	5.47
5	1.50			24.32	24.20		15.78	2.51						13.10	6.23
6	1.51			24.24	24.19		15.61	2.40			16.40			13.84	6.96
7	1.52			24.17	25.89		15.47	2.46			17.46			14.12	7.30
8	0.56			24.15	24.13		15.63	2.56			16.40			14.67	7.80
9	1.48			23.48	23.39		15.35	2.56			17.77			13.23	7.80
10	0.57			23.96	24.06		16.39	2.28			17.77			13.94	7.45
11	1.37			23.80	24.15		17.28	2.35						13.70	7.22
12															
78/1															
2	1.62			24.70	25.20		18.31							13.20	7.04
3	1.60			25.00	25.10										
4	1.56			24.90	25.18		19.12	3.25						14.62	8.00
5	1.52			26.59	25.77		18.90	3.65							8.00
6	1.60			26.40	25.80		19.55	3.82						14.52	8.10
7	1.52			26.59	25.60		18.30	3.38							7.57
8	1.48			26.58	25.56			2.50						14.15	7.65
9	1.50			26.50	25.50		19.35	3.42							7.63
10	1.54			26.47	25.55		19.40	3.20						14.70	7.56
11				26.35	25.46		19.35	4.05						14.25	7.73
12				26.30	25.40		20.28	4.16						14.80	8.88
79/1															
2				27.62	27.66		20.32	4.47						15.42	8.85
3	1.79			28.22			20.56	5.21						17.11	10.11
4	1.52			23.87			20.84	4.28						16.68	10.18
5	1.53			23.84			20.79	4.26						16.74	10.00
6	1.44			23.82				5.14						15.55	10.02
7	1.42			23.96				5.07						15.45	10.10
8	1.42			23.90			21.23	5.00							9.01
9															
10	1.40			23.65			21.33	5.33						15.31	8.71
11	1.45				23.75		20.75	5.53						16.60	8.80
12	1.50						20.70	5.50						16.69	8.90
80/1	1.50						20.85	5.60						17.05	8.95
2	1.60						22.14	6.00						16.90	11.55
3	1.75						22.01	5.85							12.12
4	1.70						22.74	6.75						18.37	11.85
5	1.57						22.63	7.08						18.70	11.74
6	1.54						22.60	7.10						18.40	11.70
7							20.30	7.30						18.45	11.80
8							21.90	7.20						18.30	11.31
9							20.15	7.16						18.20	11.40
10								6.69						18.40	11.12
11								6.75						18.30	11.37
12	1.87							8.68			36.50			18.65	12.12
81/1															
2	1.94							8.72			36.62			18.80	12.54
3	1.55							8.56						18.55	12.33
4	1.62						24.20	9.55			25.79			18.49	12.92
5	1.55						23.90	9.68			25.80			18.40	13.02
6	1.74						24.90	9.73			25.62			18.12	12.94
7	2.42						25.20	9.23						20.35	
8							25.15	9.41						20.48	12.92
9							25.25	9.63							13.12
10															
11															
12															
82/1							25.10	9.71							
2							25.30	9.76							
3							25.30	9.74							
4							25.35	9.86						21.30	
5							29.10	10.15						24.00	
6							30.40	12.60						25.01	
7							30.29	12.64						25.04	
8							30.49	12.62			25.10			25.10	
9								12.68							
10															
11															
12															
83/1															
2	3.08						32.24	13.91						26.20	
3	3.37						33.74	14.28						24.79	
4	4.15						32.67	14.24						26.36	
5	4.47						32.80	15.09						26.75	
6	4.73						33.37	15.29						26.66	
7	5.21						33.39							26.72	
8	5.28						33.37							26.74	
9	5.93						33.07							27.31	
10	6.39													27.21	
11	6.75						34.01							27.55	
12	7.97						33.90							28.36	
84/1	7.26						34.64							28.45	
2	7.32						34.24							28.69	
3	5.10						33.10							27.73	

Table B-I, 3.2 (9) Variation of Groundwater Table (Azapa Valley)

< Variación de Nivel Estatico (Valle de Azapa)>

WELL	101-9	225-	100-0	116-7	117-5	224-4	104-3	103-5	220-1	196-5	125-6	199-K	134-5	102-7	114-0
	1830 7000	1830 7000	1830 7000	1830 7000	1830 7000	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010	1830 7010
DATE	AA-5	AC-2	AD-3	AD-4	AD-5	AB-10	BA-10	BA-2	BA-20	BA-3	BA-6	BA-9	BB-2	BB-6	BB-8
4	4.95						33.23							27.74	
5	4.97						32.98	15.78						28.06	
6	4.68						32.96	15.82						29.12	
7	4.08						32.94							28.69	
8	4.09						33.28							27.45	
9	4.28						33.27							26.10	
10							33.93							28.41	
11	4.49						33.59							28.45	
12	4.81						33.55							28.68	
85/1	5.23						33.50							28.91	
2	5.39						33.98							28.23	
3	3.26						33.60	15.92						27.17	18.67
4															
5															
6	2.03							15.15						25.37	
7	2.03						32.85	15.17						25.45	18.04
8	1.64							15.14						25.44	18.34
9	1.57						32.14	14.93						25.24	18.02
10	1.88						32.42							25.00	
11	1.33						31.88							25.05	
12	1.38						31.92							25.12	
86/1															
2	1.13						31.88	14.09						24.90	
3	1.23							13.40						23.16	
4							31.13	12.81						22.09	
5															
6	1.30						31.10	11.41						22.08	
7															
8							32.52	10.46						22.60	
9															
10							30.50							22.37	
11															
12							31.15							22.20	
87/1															
2	1.03		6.08				30.36	9.63						22.31	15.35
3															
4	1.22		5.53				30.17	9.68						22.50	15.52
5	1.20		5.71				28.90	9.54						22.55	
6	1.14		6.04				28.53	9.45						22.75	
7	1.13		6.40				28.10	9.13						22.04	
8	1.13		6.88				28.00	9.16						22.17	14.76
9															
10	1.01		7.35				28.04	9.51						22.08	14.82
11	1.03		8.13				27.29	9.49						22.06	15.31
12															
88/1	0.99		8.63				27.63	9.66		27.71				22.05	
2	1.01		9.25				28.28	9.91		28.22				21.84	
3	1.06		9.65				28.54	9.88						21.60	
4	1.12		9.88				28.52	10.12		25.44				21.42	
5															
6	1.13		10.33				28.88	10.29							
7	1.14		10.52				28.79	10.11						21.36	
8	1.26		10.84				29.53	10.00		25.89				21.30	
9	1.17		10.98				29.56	9.88		25.71				21.22	
10	1.18		11.24				29.63	9.96						21.01	
11															
12	1.77		12.95				30.07	10.23						20.82	
89/1	1.35		12.59				29.56	10.29						20.76	
2	1.26		12.58				30.21	10.24		26.92				20.73	
3															
4	1.25		12.48				30.46	10.28		26.36				20.50	
5															
6	1.17	13.34					30.61	10.70		27.65					
7															
8															
9	1.34	13.84					31.19	10.97		27.62					
10															
11	1.13	14.44					32.02	11.07		26.63					
12															
90/1															
2															
3	2.04	15.73					32.32	11.64		28.65					
4															
5	2.27	16.41					33.25	12.16		28.90					
6															
7		17.00					32.91	12.52		28.22					
8															
9	0.97	17.97					33.51	12.78		30.05					
10															
11	3.15	18.43					33.73	13.30		33.14					
12															
91/1	3.46	19.04					34.25	13.54		33.65					
2	3.51	19.23					35.29	13.86		32.58					
3	3.45	18.84					32.54	13.99		29.64					
4	3.63						35.35	14.16	33.48	36.34					32.38
5	3.54						35.65	14.26	32.79	30.13					32.44
6															
7	3.40						34.97	14.39							32.44
8	3.39						34.94	14.48	32.74	31.06					32.64

Table B-I, 3.3 (2) Groundwater Quality (Azapa Valley)

<Calidad de Agua (Valle de Azapa)>

ITEM / WELL	pH	TDS	EC	Ca	Mg	Na	K	SO4	Cl	CO3	HCO3	NO3	Si02	Li	B	Fe	Mn	As	Zn	Cu	F	Al
			m.mho/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
STANDARD	6.5-8.0	1000	-	-	125	200	-	250	250	-	-	10	-	-	1.00	0.30	0.10	0.05	5.00	1.00	1.50	0.20
104-3	7.4	626		114.0	14.0	58.0	5.5	187.5	81.0	0.0	208.0	5.6	50.5									
107-8	7.4	479	473	62.2	6.7	68.0	5.8	117.1	98.4	0.0	371.0	0.9	27.8		0.4							
123-K	7.5	828	1157	213.0	22.0	200.0		239.3	112.7	0.0	249.6	5.6			1.5			0.0				
125-6	7.1	750	1151	136.0	13.7	61.9	5.1	222.1	89.1	0.0	219.0	4.2	132.5									
195-7	7.3	778	1110	139.5	15.0	87.0	5.0	242.5	118.5	0.0	236.0	1.5	46.5	<0.2		<0.1	<0.1	<0.05		<0.01	0.3	
197-3	7.3	543	905	96.0	12.0	56.0	5.8	170.0	74.0	0.0	176.0	0.0	37.0									
202-3	7.3	519		93.5	8.7	54.7	4.4	151.0	71.3	0.0	166.5	9.5	40.3									
203-1	7.8	905	1100	181.3	21.9	88.0	4.5	286.4	126.1	0.0	255.3											
218-K	7.0	960		199.0	20.0	87.0	4.6	272.0	204.0	0.0	236.0	17.0	39.0	<0.2		0.1	0.3	<0.05		<0.01	0.2	
221-K	7.1	901		185.0	19.0	83.0	4.2	279.0	158.0	0.0	254.0	8.9	38.0	<0.2		<0.1	<0.1	<0.05		<0.01	0.2	
222-8	7.0	895	1150	172.0	18.3	77.2	4.1	240.5	141.0	0.0	222.5	8.6	37.5	<0.2		0.1	<0.1	<0.05	0.0	<0.01	0.3	0.1
223-6	6.9	763		155.0	16.0	69.0	3.0	244.0	111.0	0.0	242.0	6.7	38.0	<0.2		<0.1	<0.1	<0.05		0.1	0.2	
102-7	7.4	527	860	63.8	2.5	87.0	13.0	16.5	124.1	0.0	19.0	0.0	45.3		0.5							
134-5	7.5	562	744	104.2	12.4	54.2	3.1	175.8	75.5	2.7	223.6	4.2	30.5	<0.2	1.7		<0.1	<0.05		0.0	0.2	
206-6		929																				
300-	7.7	740	980	129.7	14.6	75.0	5.1	263.1	100.6	0.0	201.6				1.0			0.1				
301-	7.2	700	980	160.5	6.1	68.0	15.6	222.6	147.6	0.0	189.2				0.0							
Average(*)	7.27	913	1248.96	162.8	17.5	86.7	6.34	253.24	154.15	4.86	212	9.56	59	<0.2	1.13	<0.1	<0.1	<0.05	0.02	<0.01	0.36	<0.1

(*): except well No. 168-k.

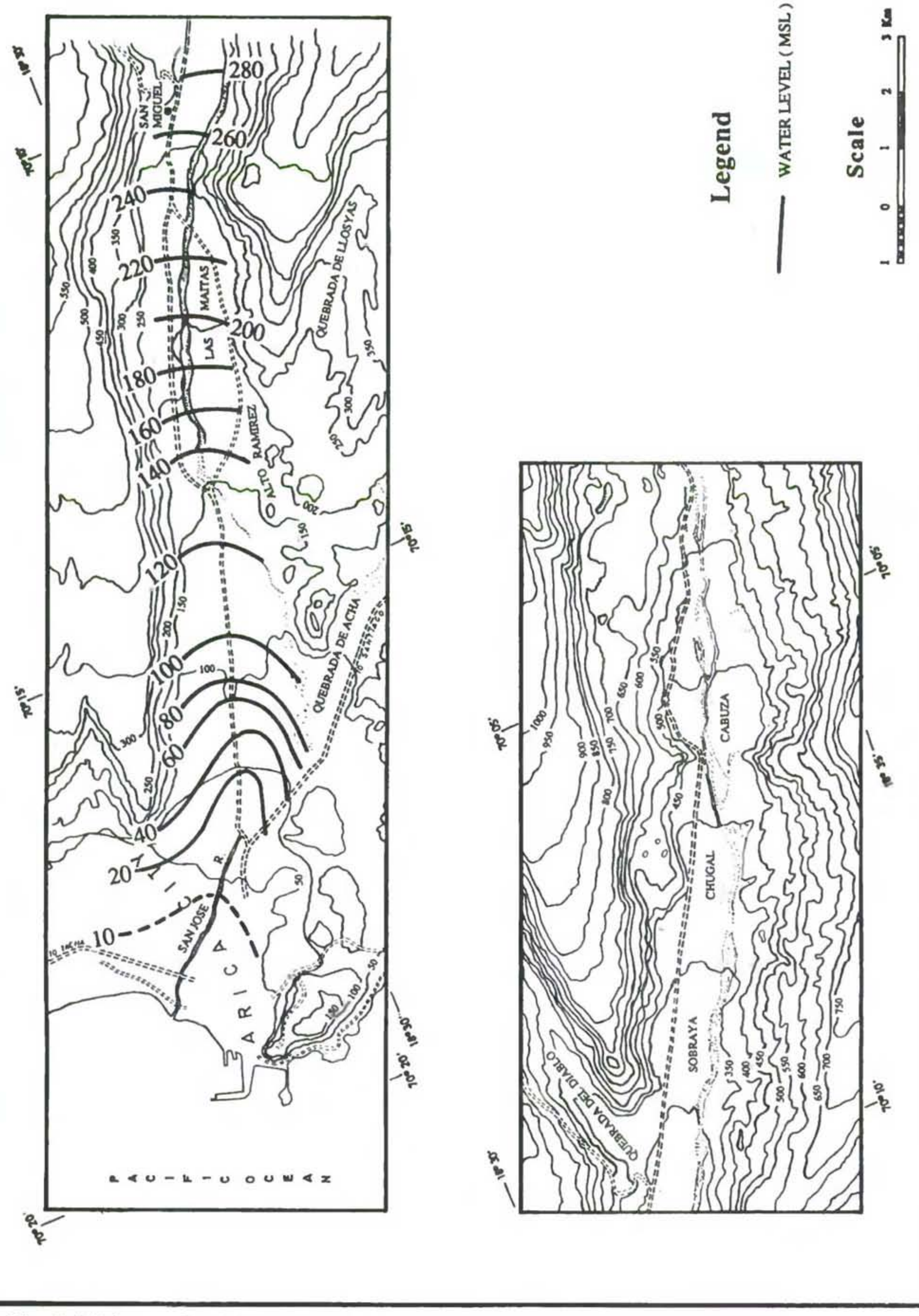


Fig. B-I. 3.1 Static Water Level (Azapa Valley) (Unit: mMSL)

< *Nivel Estático (Valle de Azapa)* >

Unit: m MSL

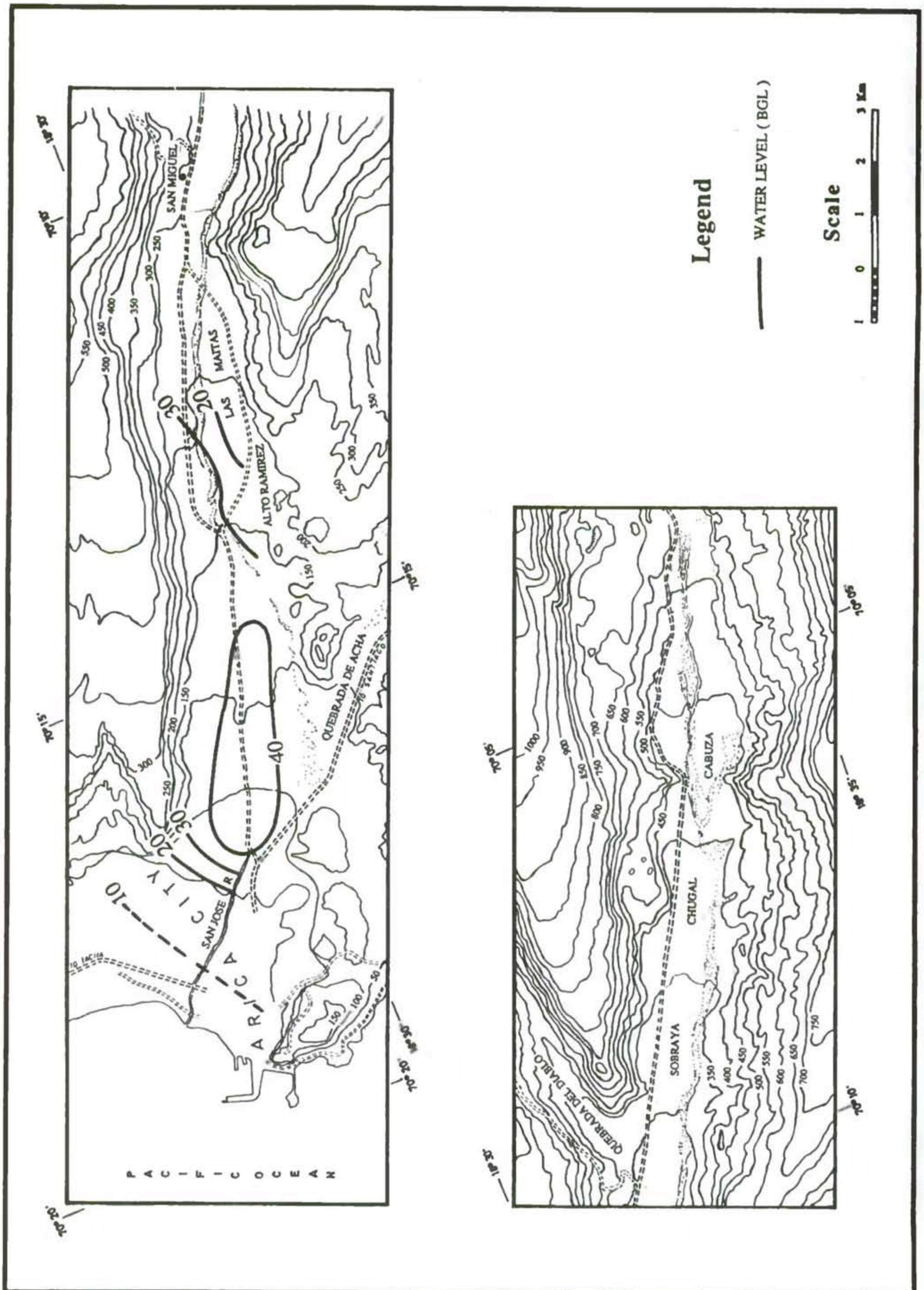


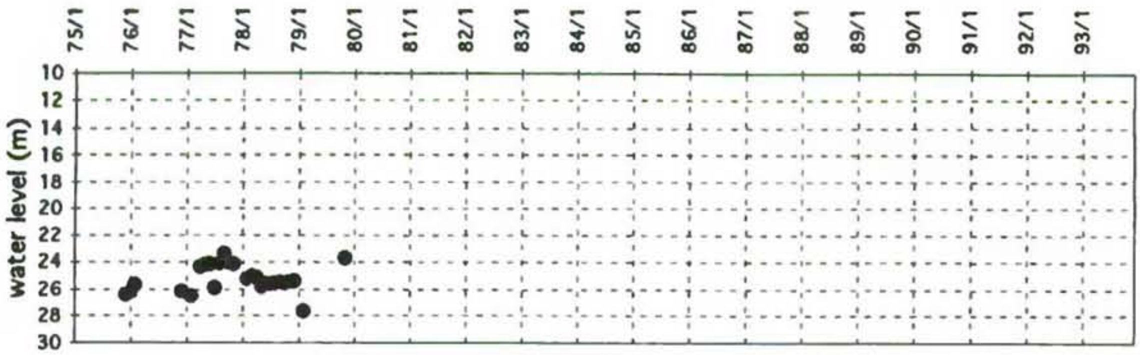
Fig. B-I. 3.2 Static Water Level (Azapa Valley)

< Nivel Estático (Valle de Azapa) >

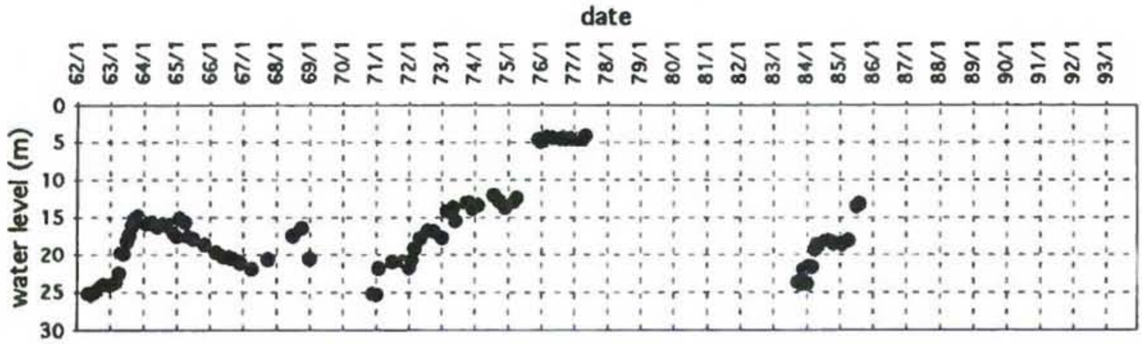
Unit: m BGL

Cabuza-Las Riveras

117-5 1830 7000 AD-5



129-9 1830 7000 AA-1



101-9 1830 7000 AA-5

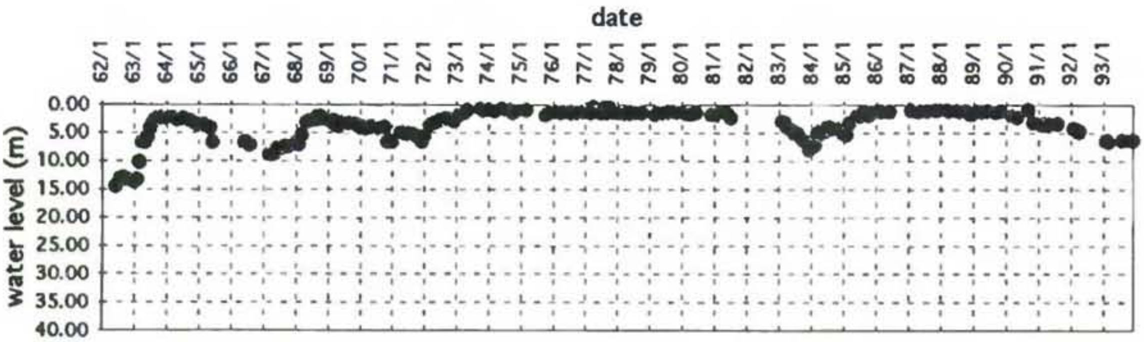
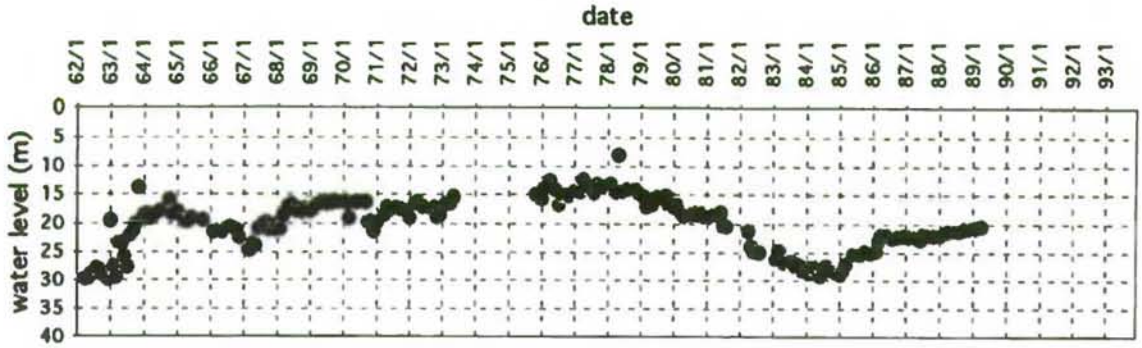


Fig. B-I. 3.3 (1) Variation of Groundwater Table (Azapa Valley)

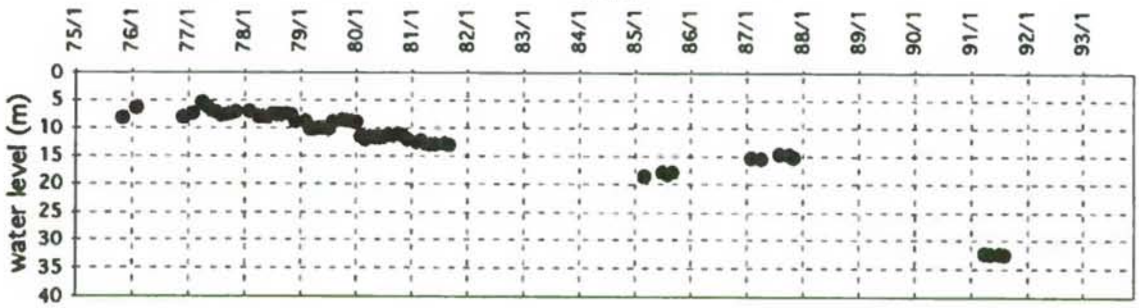
< Variación de Nivel Estatico (Valle de Azapa)>

San Miguel

102-7 1830 7010 BB-6



114-0 (1830-7010 BB-8)



103-5 (1830 7010 BA-2)

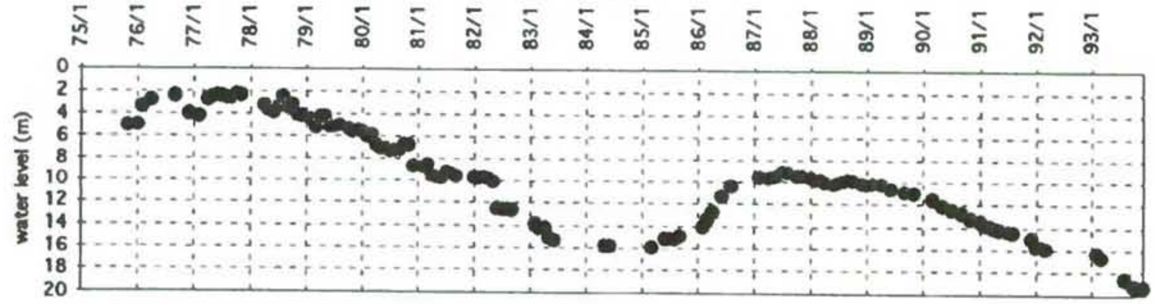


Fig. B-I. 3.3 (2) Variation of Groundwater Table (Azapa Valley)

< Variación de Nivel Estatico (Valle de Azapa)>

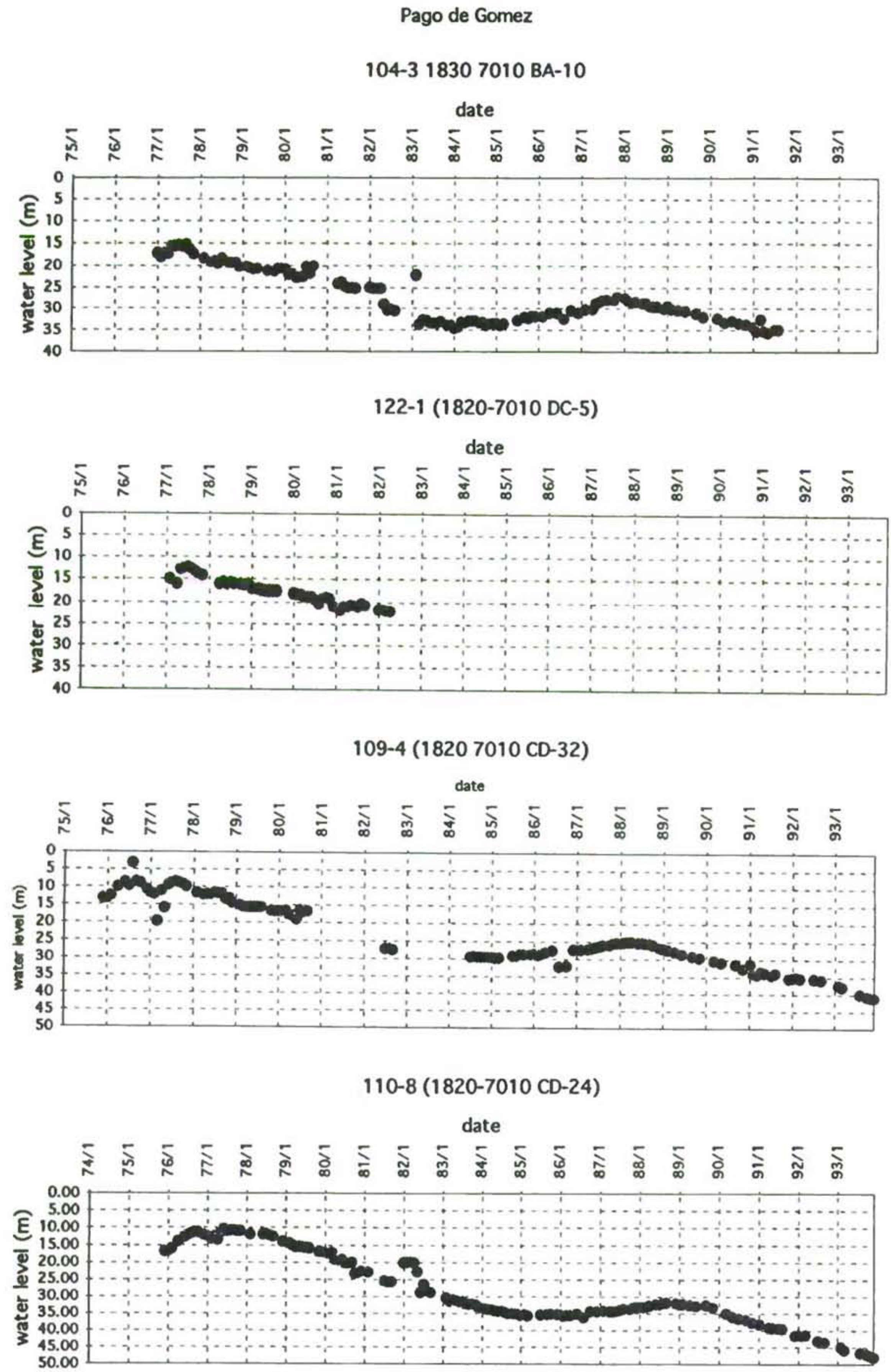
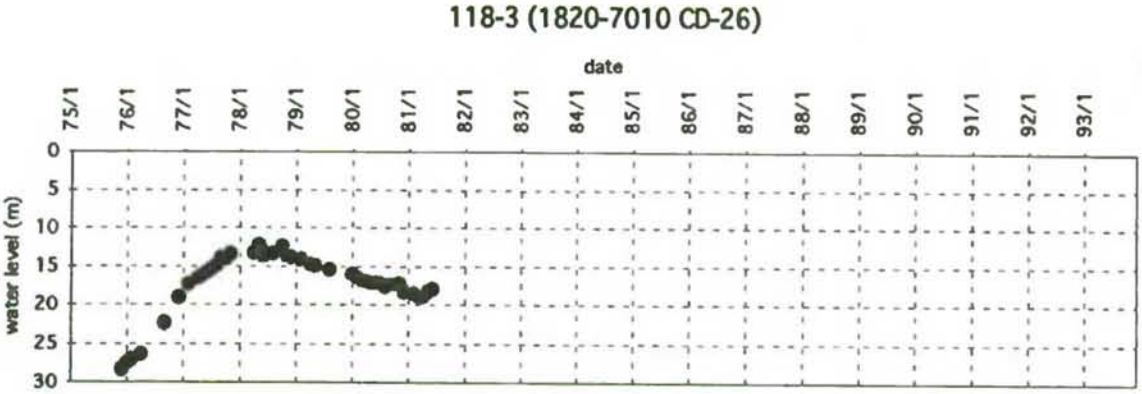


Fig. B-I. 3.3 (3) Variation of Groundwater Table (Azapa Valley)
< Variación de Nivel Estatico (Valle de Azapa)>

City Area of Arica



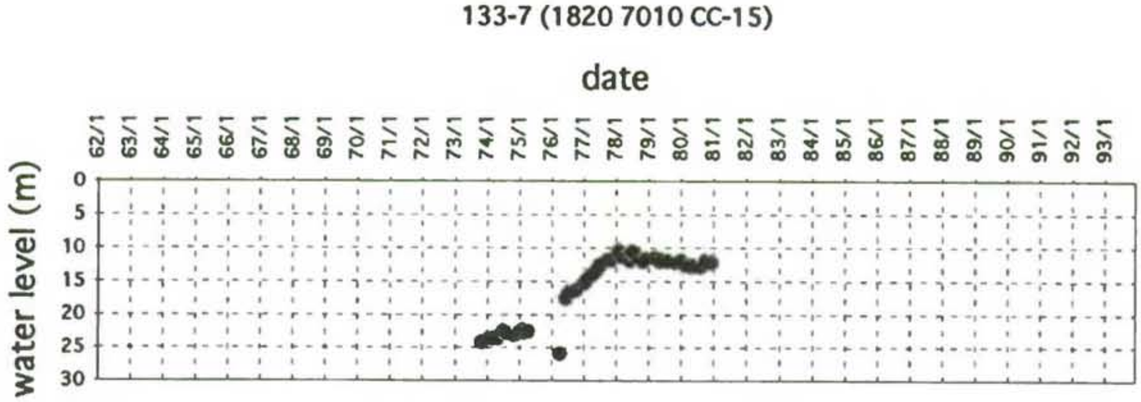
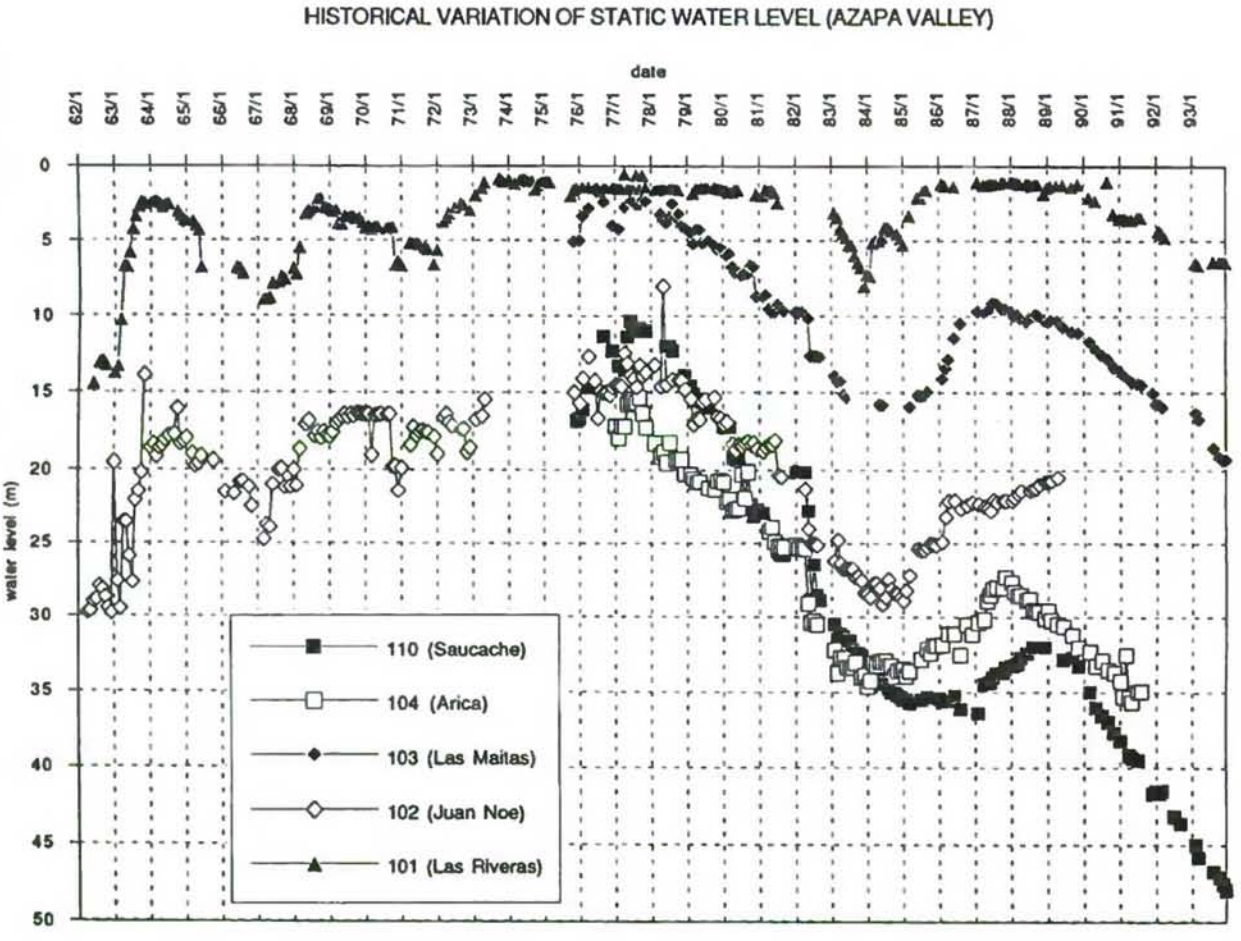


Fig. B-I. 3.3 (4) Variation of Groundwater Table (Azapa Valley)

< Variación de Nivel Estatico (Valle de Azapa)>



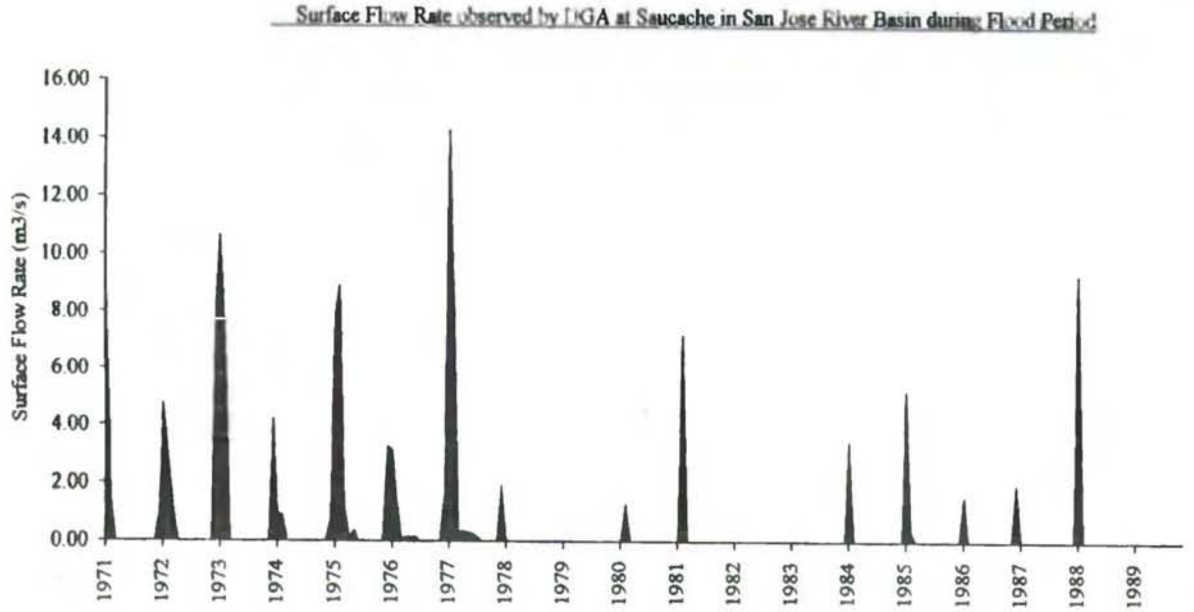


Fig. B-I. 3.4 Relation between Groundwater Level and Flood (Azapa Valley)

< Relación entre el Nivel Estático y Avenida (Valle de Azapa) >

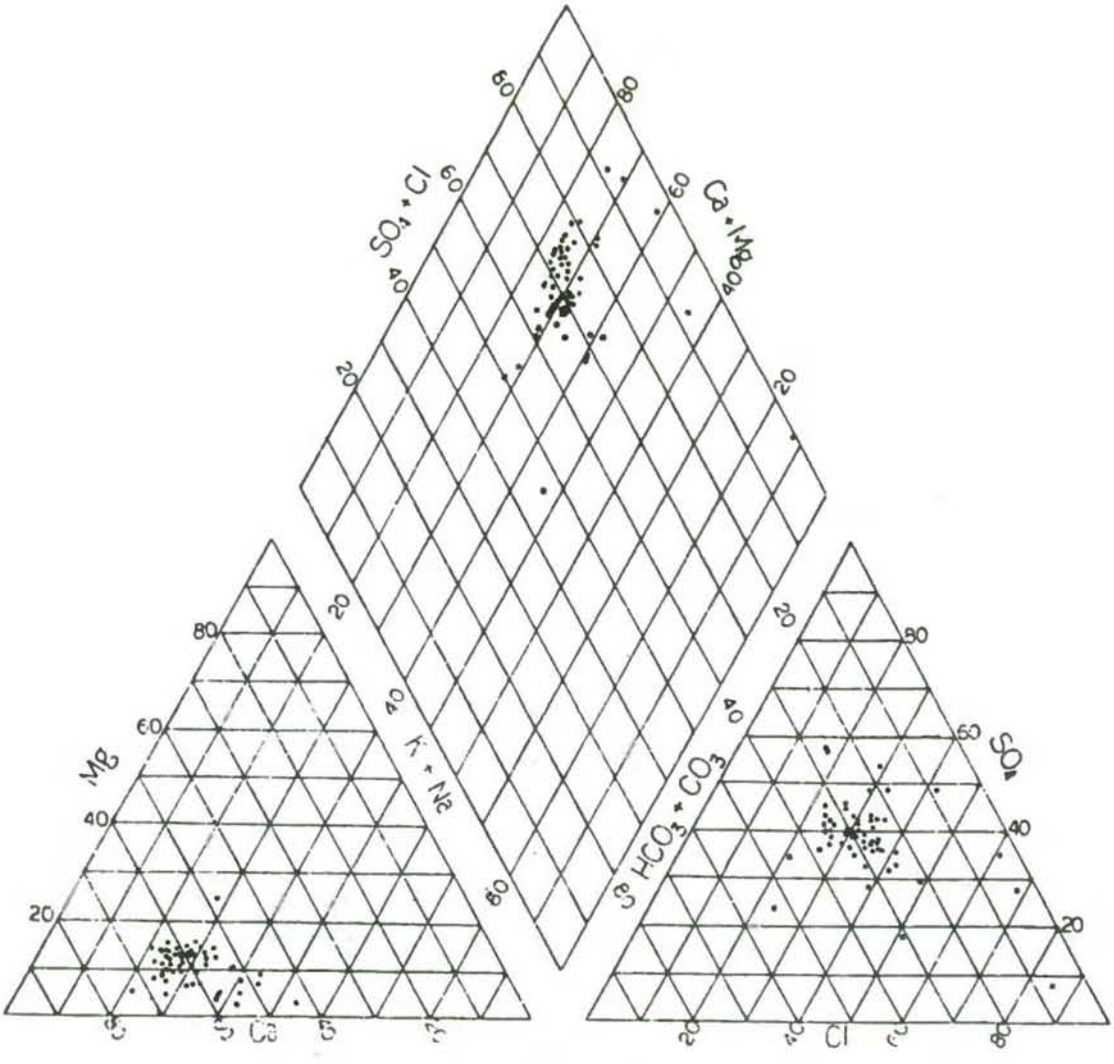


Fig. B-I. 3.5 Tri-linear Diagram of Major Ions (Azapa Valley)

< Diagrama Tri-Lineal de Iones Mayores (Valle de Azapa)>

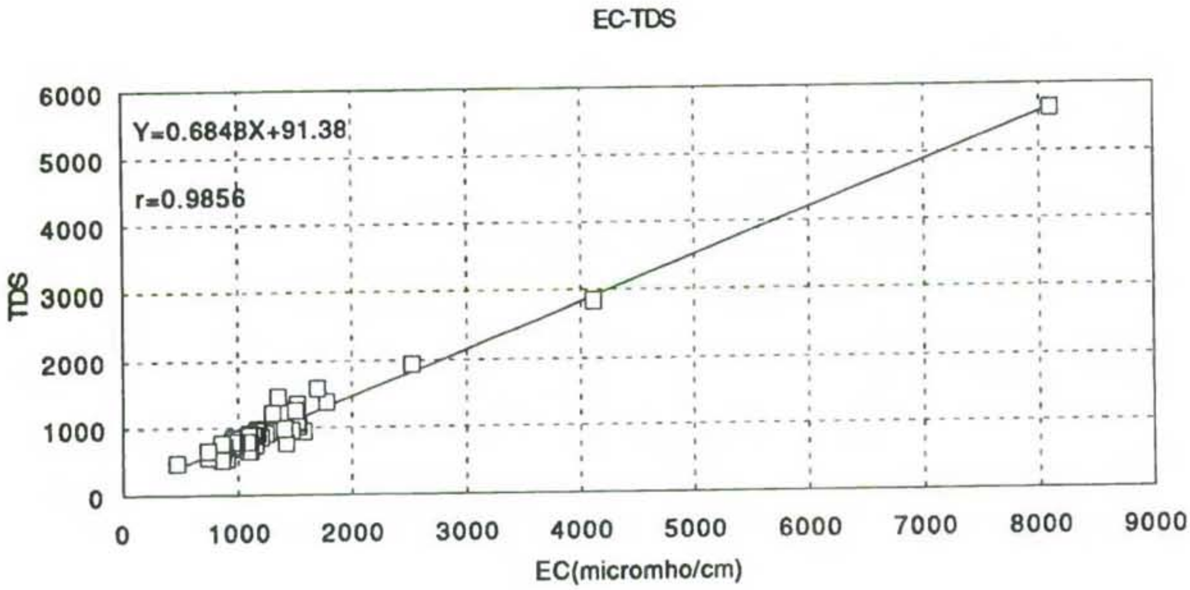


Fig. B-I. 3.6 Relation between TDS and EC (Azapa Valley)

< Relación entre TSD y CE (Valle de Azapa)>

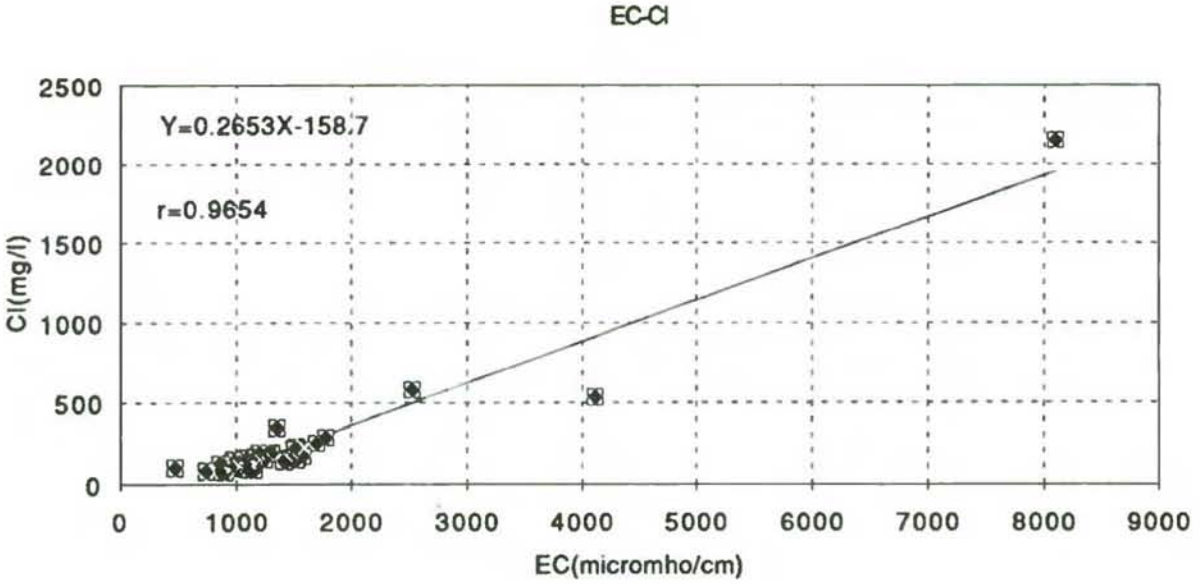


Fig. B-I. 3.7 Relation between Cl and EC (Azapa Valley)

< Relación entre Cl y CE (Valle de Azapa)>

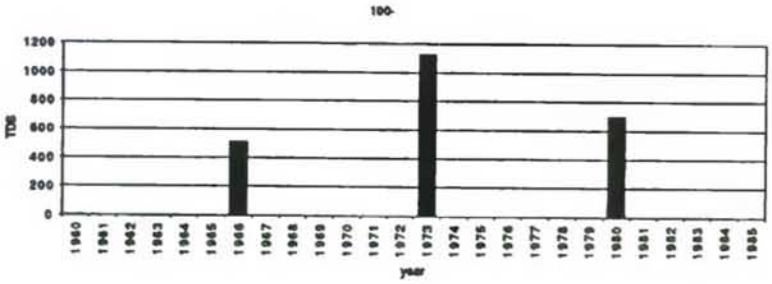


Fig. B-I. 3.8 (1) Variation of Salinity in Azapa Valley (Cabuza Area)

< Variación de Salinidad en Valle de Azapa (Zona Cabuza)>

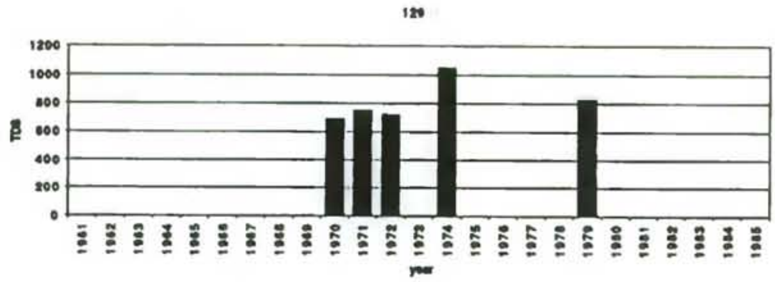


Fig. B-I. 3.8 (2) Variation of Salinity in Azapa Valley (Las Riveras Area)

< Variación de Salinidad en Valle de Azapa (Zona Las Riveras)>

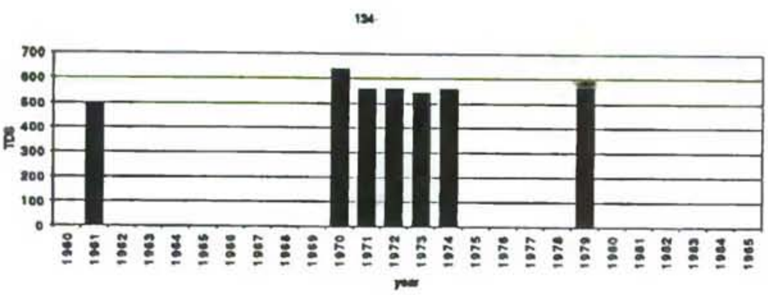


Fig. B-I. 3.8 (3) Variation of Salinity in Azapa Valley (San Miguel Area)

< Variación de Salinidad en Valle de Azapa (Zona San Miguel)>

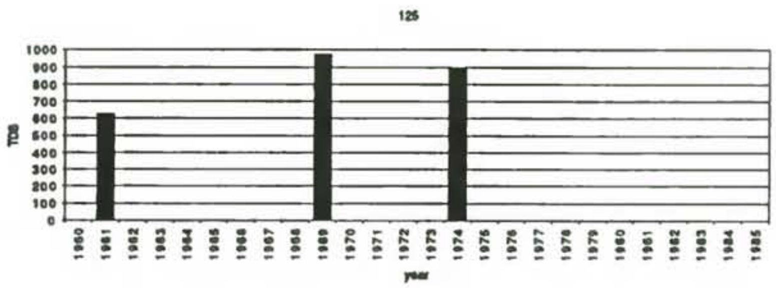


Fig. B-I. 3.8 (4) **Variation of Salinity in Azapa Valley (Pago de Gomez Area)**

< Variación de Salinidad en Valle de Azapa (Zona Pago de Gomez)>

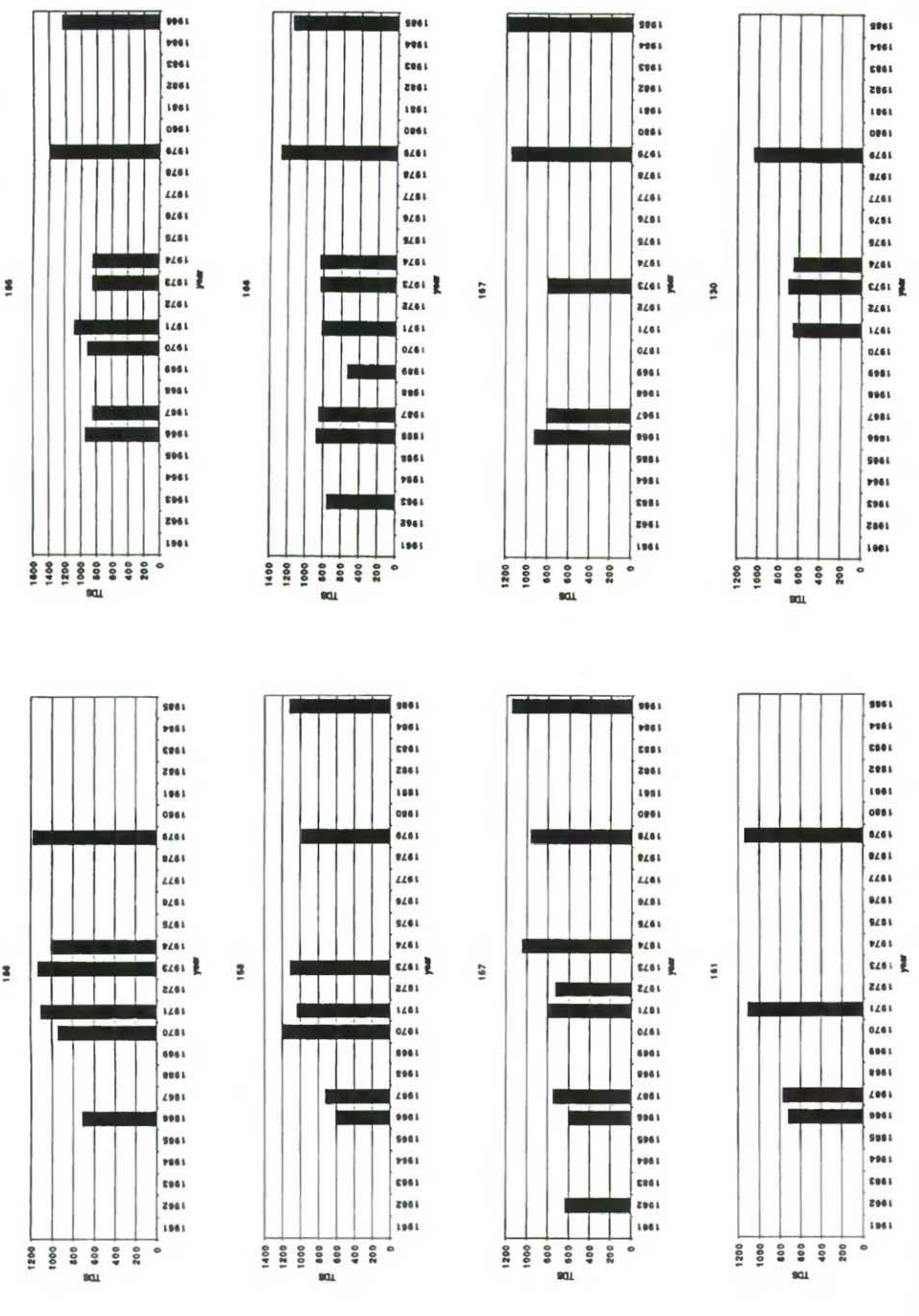
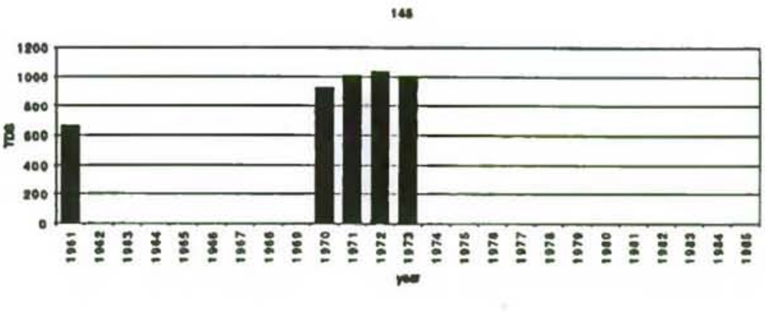
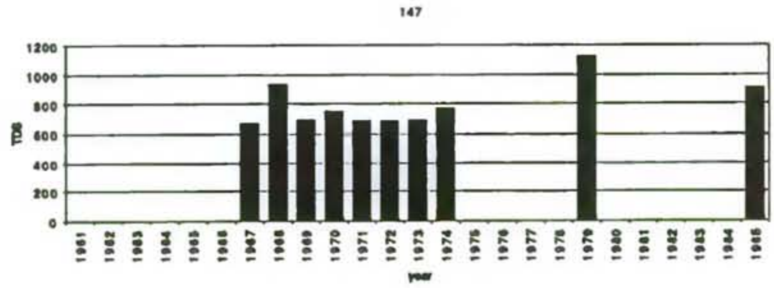
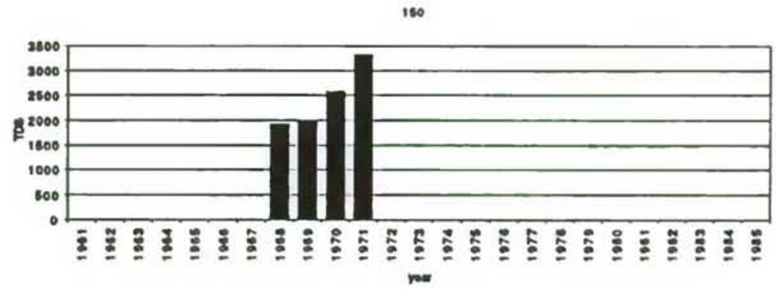


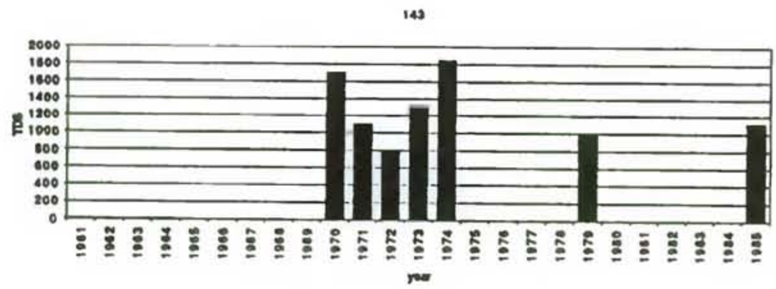
Fig. B-I. 3.8 (5) Variation of Salinity in Azapa Valley (Saucache Area)

< Variación de Salinidad en Valle de Azapa (Zona Saucache)>









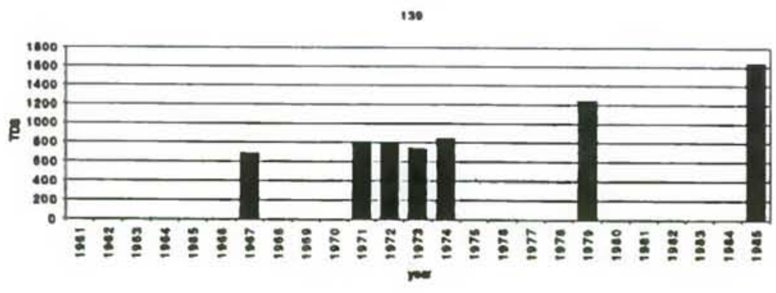


Fig. B-I. 3.8 (6) Variation of Salinity in Azapa Valley (City Area)

< Variación de Salinidad en Valle de Azapa (Zona Ciudad)>

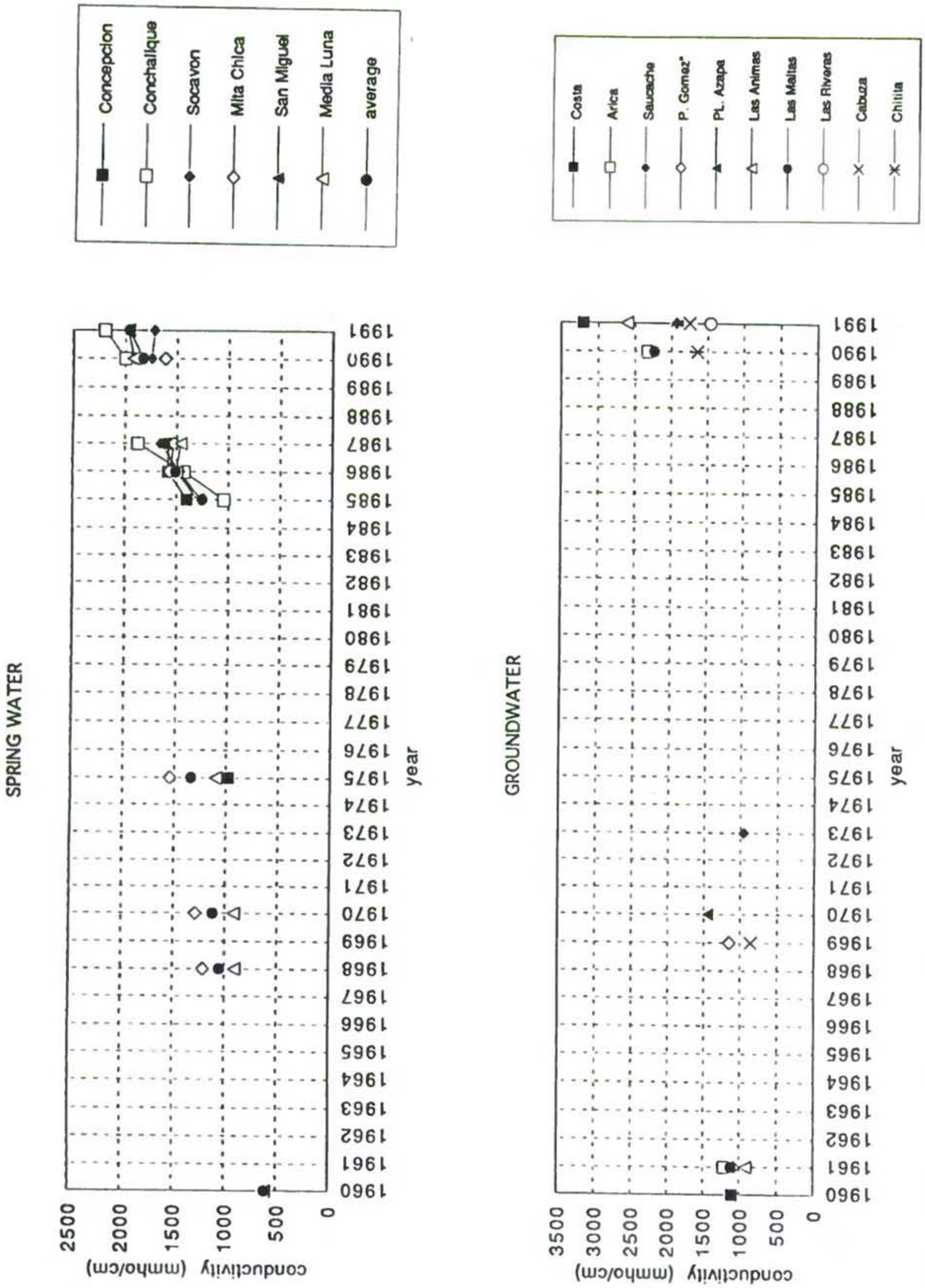


Fig. B-I. 3.9 Variation of Conductivity (Azapa Valley)

< Variación de Conductividad (Valle de Azapa)>

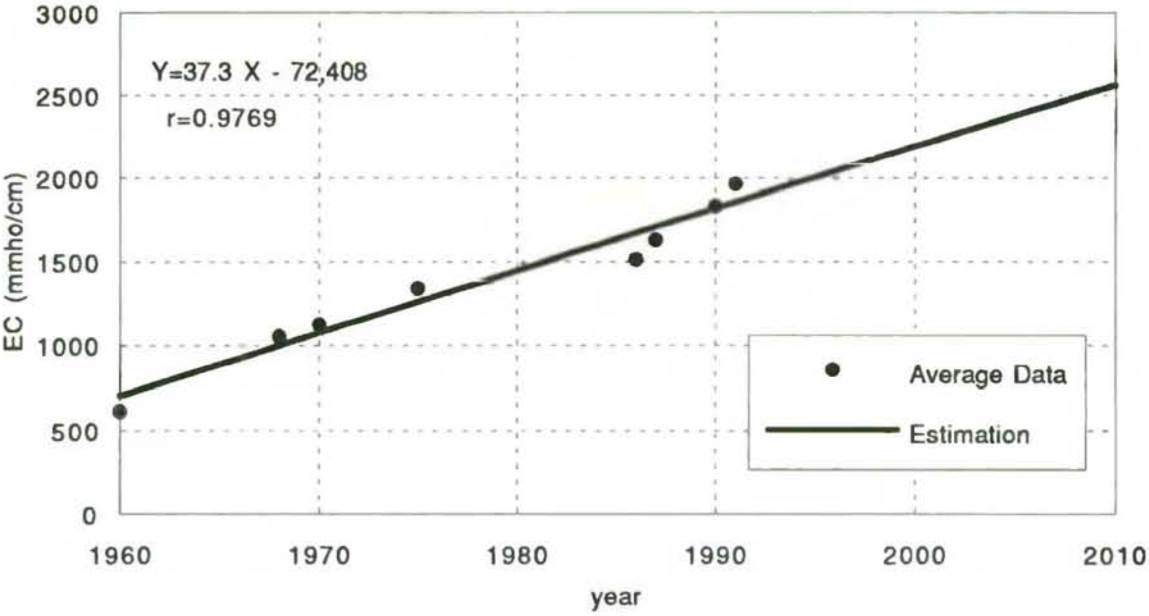


Fig. B-I. 3.10 Assumption of Salinity Increase (Azapa Valley)

< Hipótesis del Aumento de Salinidad (Valle de Azapa) >

Chapter IV GROUNDWATER MONITORING

Aquifers in the San José River Basin are distributed mainly in the Azapa Valley from Cabuza to Arica City area and are extensively used as water sources for potable water supply, irrigation water, industry water, etc. Amount of groundwater extraction reaches to 11,300,000 m^3/year. This amount is over the annual recharge. Static water level has been declined and salinity of groundwater is increased in the lower reaches and the city area. The life of aquifer is estimated about 30 years if present condition continues in future.

Under these circumstances, following groundwater monitoring plan is proposed for protection of water resources. Items of monitoring are water level and water quality. Proposed wells to be monitored are mentioned below. It is important to continue observation at the same wells and never to change monitoring wells.

Total number of 12 wells are selected for the observation as follows. For location, refer Fig. B-I, 2.1.

Well No.	Well Name	Interval of Observation	
		Water Level	Water Quality
-	any existing well in Cabuza	every 2 months	once a year
225 or 176	Facumoo Guiterrez or Chugal Santa Gena	every 2 months	once a year
115	Cerro Morbno	every 2 months	once a year
113	Las Riveras Madrid	every 2 months	once a year
114	Parcela 16	every 2 months	once a year
103	Las Maitas Violeta	every 2 months	once a year
196	Las Animas	every 2 months	once a year
199	Las Palomas	every 2 months	once a year
224	HDA. San Juan de Occurir	every 2 months	once a year
109	Algodnal	every 2 months	once a year
110	Saucache	every 2 months	once a year
142	AP Cancha Tucapel	every 2 months	once a year
133	AVDA. Tarapacá	every 2 months	once a year
126	AVDA. Azola	every 2 months	once a year
214	Hospital	every 2 months	once a year
147	Planta AP. San José	every 2 months	once a year

Wells to be observed are listed above. However, if it is impossible to observe at some wells, other wells should be selected in the adjacent areas.

Items of water quality to be analyzed are as follows;

Temperature, pH, TDS, Ca, Mg, K, Na, SO4, Cl, CO_3, HCO_3, NO_3, As, F, Cd, Cr, Pb, B, Fe, Mn, Zn, Cu, Al

B-II LLUTA RIVER BASIN

TABLE OF CONTENTS

B-II LLUTA RIVER BASIN

LIST OF TABLES

B-II LLUTA RIVER BASIN

LIST OF FIGURES

B-II LLUTA RIVER BASIN

Chapter I. TOPOGRAPHY AND GEOLOGY

1.1. Topography

The Lluta River Basin shows the same topographic features as the San José River Basin and consists of a part of Altiplano, Precordillera and Intermediate Depression, as shown in Fig. B-I, 1.1. Drainage patterns of the basin extracted from LANDSAT images are shown in Fig. B-I, 1.2. This figure clearly shows that the catchment of the upper stream is extremely large and widely spread in the Altiplano characterized by abundant volcanoes.

1.2. Geology

1.2.1. Methodology of Geological Analysis

About details of the methodology, refer to the part of San José River Basin (B-I).

1) Interpretation of LANDSAT Images

As for the Lluta River Basin, the same four (4) images used for the San José River Basin were interpreted.

2) Interpretation of Aerial Photographs

Thirty four sheets of black and white aerial photographs taken in 1976 and 1977 were used for the interpretation.

1.2.2 General Geological Features of Basin

The results of the interpretation on the basin were compiled in Fig. B-I, 1.3. Since the lithological sequence distributed in the Lluta River Basin is almost the same as that of the San José River Basin, the details can be referred to the part of the San José River Basin (B-I, Chapter 1).

1) General Geology of Basin

The geological units mentioned in the part of San José River Basin (Ref. B-I, Chapter I) were also discriminated over the Lluta River Basin on the LANDSAT images and aerial photographs.

The characteristic feature for the basin in comparison with the geology of San José River Basin is that Quaternary volcanic rocks show a wider distribution at the upper part of the basin situated in the Altiplano.

The Concordia Formation outcropping around the mouth of the Lluta River, reported in Sonia Vogel and Tomas Vila (1980) and so on, is identified as clastic sediments constituting a marine terrace and showing interfinger relationship with fluvial deposits. It could not be discriminated from recent sediments on this interpretation.

Stratigraphy in the Lluta River Basin is summarized in the following table;

Age		Formation			Units
Quaternary	Recent	Recent Beach Deposits	Recent Fluvial Deposits	Detrital Deposits	Rb Rf Rd
	Pleistocene	Concordia Formation	Fluvial Deposits		Qc Qf (Qfu,Qfl)
Tertiary	Pliocene	El Diablo Formation			
	Miocene	Oxaya Formation			Tox
		Azapa Formation			Taz
	Oligocene				
Pre-Tertiary		Basement Rocks			B

2) General Geological Structure of Basin

Many faults and lineaments are identified in the area where the Oxaya and El Diablo Formations are cropping out, which consist of two systems in the NW-SE and E-W directions. NW-SE system is found in the lower stream. And E-W system can be seen throughout the basin; however, it is predominantly developed in the area of Precordillera.

At the lower stream, two systems are intersected in most cases, where the strata show a very complicated structure.

In addition to the above features, extremely dense minor fractures are detected on the aerial photographs around the Puquios railway station, on the ignimbrite of the Oxaya Formation. These show NW-SE directions.

1.2.3 Hydrogeology of Lluta Valley

A detailed geological map (Fig. B-II. 1.1), a geological profile (Fig. B-II. 1.2) and geological cross sections (Fig. B-II, 1.3) of the Lluta River Basin were compiled by the Study Team based on the geological field survey and review of existing geological maps (<1, <2, <3 and <4).

Geology of the Lluta River Basin is generally classified into Basement Rocks and Quaternary formations. Aquifers in the Lower Lluta Valley are occurred in the Quaternary formations, especially in the Fluvial Deposits. Although the Concordia Formation also seems to be a aquifer, it distributes very close to the sea. Therefore, only the Fluvial Deposits are considered to be prospective aquifer in the Lower Lluta Valley. The Lower Lluta Valley is occupied by the Fluvial Deposits. They are in a interfinger relation. The aquifers seem to be extended up to around Tocontasi.

The aquifers are accumulated in the coastal plain and the valley which was formed by eroding the impermeable Basement Rocks. Thus, the hydrogeological condition is same as that of the San José River Basin. Groundwater flows in the aquifer from the upstream to the downstream with neither leaking to the outside of the valley nor receiving water from the outside of the valley.

Although the river system is developed in the Lluta River Basin, no surface water is recognized in the quebradas in the middle to lower reaches except the main stream of the Lluta River. Therefore, the groundwater is recharged mainly by the surface water of the Lluta River. In addition to this, fissures developed in the Basement Rocks may supply a certain measure of water to the aquifers. Explanation of each formation is given below;

1) Basement Rocks

The Basement Rocks are composed of the Azapa Formation, the Oxaya Formation, the El Diablo Formation and their slid blocks in ascending order.

Fissures and joints are well developed near the surface of the rocks but less developed in the deep part. Thus, it is considered to be impermeable.
Described below is characteristic features of different formations.

(1) Azapa Formation

The Azapa Formation is composed of fine to middle grained sandstone, siltstone, mudstone, conglomerates, calcareous evaporitic sediments and tuffs. Each bed is consolidated and matrix of the conglomerates is rich in fine materials. Therefore, the Azapa Formation is considered to be impermeable to less permeable.

(2) Oxya Formation

The Oxya Formation is divided into three (3) members; the lower, the middle and the upper. The lower member consists of grey andesite intercalated with ignimbrites and volcanic ash. The middle member consists of breccia intercalated with tuffaceous sandstone and tuffite. The upper member consists mainly of ignimbrites variable in welding. Lithofacies of the Oxaya Formation show impermeable to less permeable.

(3) El Diablo Formation

The El Diablo Formation consists of conglomerates and sandstone with thick coarse sandstone and thin evaporitic intercalation. Thus this formation is considered to be permeable. However, it is distributed on the plateau, therefore, this has less relation with hydrogeological condition of the study area.

2) Quaternary Formations

Quaternary Formations consist of six (6) units; Fluvial Deposits, Concordia Formation, Detrital Deposits, Pumice Tuff, Recent Beach Deposits and Recent Fluvial Deposits.

Details of each unit are described below.

(1) Fluvial Deposits

The Lower Lluta Valley is occupied by the Fluvial Deposits. Drilling results of JICA wells revealed that total thickness of the formation is approximately 200 m and there appear tuff layers. The tuff layers are 7 m in thickness in J-B well, not clear in J-2 well, 3 m in J-A well and 11 m thick tuffaceous sandy gravel in J-1 well.

The deposits are stratigraphically divided into three (3) units, the lower, the middle and the upper, considering the boring results; the upper and lower units are composed mainly of gravel beds and the middle unit is composed of impermeable tuff beds, however, it is not necessarily distributed in the whole area of the Lower Lluta Valley. Lithofacies of the upper and the lower units are same; the deposits are formed mainly of rounded gravels having a diameter of 5 to 30 cm. Gravels are derived mainly from diorite, ignimbrite, andesite, basalt and hard sedimentary rocks. Matrix of the deposits are composed mainly of silt and very fine sand originated from volcanic ashes.

Judging from the lithofacies, both the upper and lower units are permeable. The middle unit, tuff to tuffaceous layers, is impermeable.

The aquifer appeared in the Fluvial Deposits is divided into two (2); the upper aquifer and the lower aquifer. The upper aquifer is mainly utilized at Villa Frontera; a total number of 10 wells were constructed.

The lower aquifer has not been developed; no well is extracting groundwater from this aquifer.

(2) Concordia Formation

The Concordia Formation is marine deposits, distributed in the Villa Frontera and Concordia area, the lower reaches of the Lluta Valley. It has a interfinguring relationship with the Fluvial Deposits in the Lower Lluta Valley (See, Fig. B-II, 1.2). It changes to the Fluvial Deposits near the Panamerican Highway. It has three (3) members, the lower, the middle and the upper. The lower and the upper members are composed mainly of unconsolidated sand. The middle member consists mainly of volcanic ashes. The total thickness reaches to 200 m. It seems that the formation is in a interfingering relation with other Quaternary Formations (<1 and <2). As for the thickness of the middle member, it is approximated to be 40 m (<3) or 120 m (<4).

Judging from the lithofacies, the lower and the upper members are permeable, and the middle member is impermeable.

As the Concordia Formation is distributed very close to the sea, it is less worth as the prospective aquifer in the area.

(3) Detrital Deposits

The Detrital Deposits consist of talus deposits, slope deposits and fan deposits. Talus and slope deposits are composed of different sizes of clastics. The surface of them is cemented in various degree by salts. Large blocks of Oxaya Formation are sometimes slid and overlaid the talus deposits. The fan deposits are composed of mainly silt and sand. The Detrital Deposits seem to be impermeable.

(4) Pumice Tuff

The Pumice Tuff consisting of pumice and volcanic ash is distributed in Gallinazos and Apacheta, the lower reaches of the Lluta River. Permeability of this deposits are considered to be small.

(5) Recent Beach Deposits

Along the coast of the Pacific Ocean, the Recent Beach Deposits are distributed forming a beach. The deposits consist of sand and gravels. Fine materials are less in the matrix. Thus, the permeability of this unit is high.

(6) Recent Fluvial Deposits

The Recent Fluvial Deposits are distributed along the river channel of the Lluta River. The unit is composed of sand, gravel and silt. The unit is less permeable because the matrix of this unit is rich in fine materials.

References

<1: Cuadrangulos Arica y Poconchile, Región de Tarapacá, Carta Geologica de Chile (Escala 1:1,000,000), 1980 for Institute de Investigaciones Geologicas by Sania Vogel and Thomas Vila

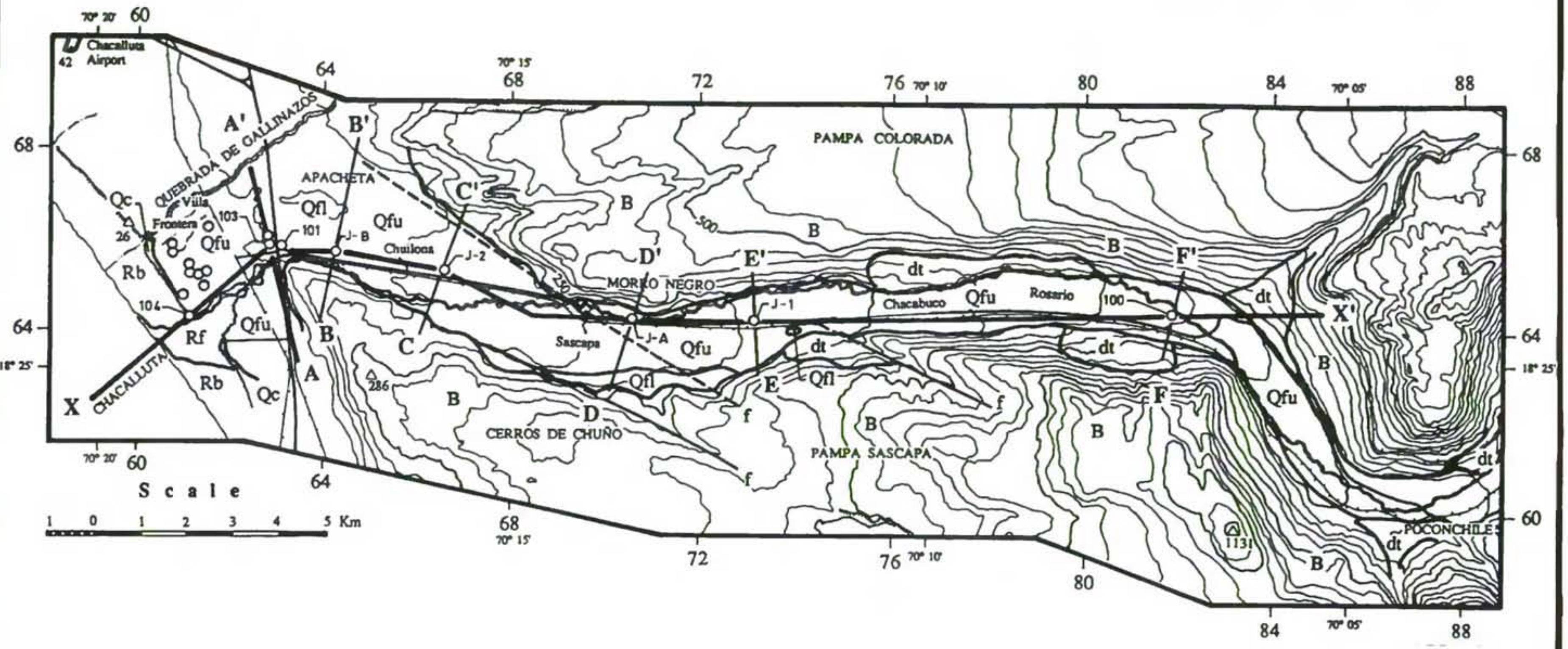
<2: Cuadrangulos Camaraca y Azapa, Provincia de Tarapacá, Carta Geologica de Chile (Escala 1:50,000), 1968 for Institute de Investigaciones Geologicas by Alvaro Tobar B, Ivan Salar Y y Rene F. Kast

<3: Geologia y recursos Minerales del Departmento de Arica, Provincia de Tarapacá, for Institute de Investigaciones Geologicas, 1966 by Raul Salas O., Rene F. Kast, Francisco Montecinos P. e Ivan Salas Y.

<4: Estudio Análisis de los Recursos de Agua de la Primera Región de Tarapacá, June 1991 for DGA by Ingenieria y Geotecnia Ltda.

Fig. B-II, 1.1 Geological Map (Lluta Valley)

< *Mapa Geológico (Valle de Lluta)* >



L e g e n d

Geological Division

- dt : Detrital Deposits
- Rf : Recent Fluvial Deposits
- Rb : Recent Beach Deposits
- Qfu : Fluvial Deposits (Upper)
- Qfl : Fluvial Deposits (Lower)
- Qc : Concordia Formation
- B : Basement Rocks (Oxaya Formation, Azapa Formation and Mesozoic)

- f : Fault
- X X' : Position of Geological Profile
- D D' : Position of Geological Cross Section
- J-A : Well

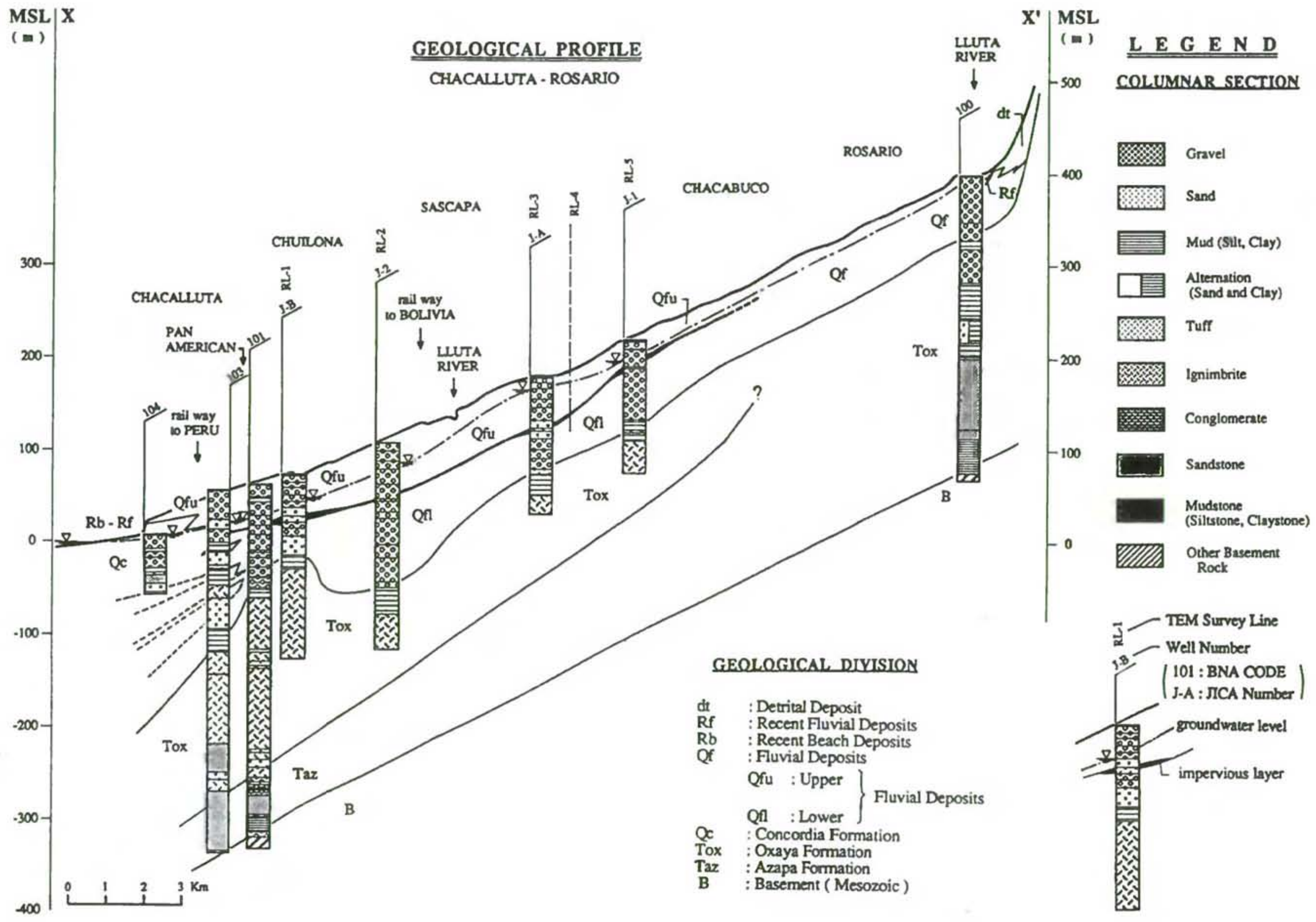


Fig. B-II, 1.2 Geological Profile (X-X')

<Perfil Geológico (X-X')>

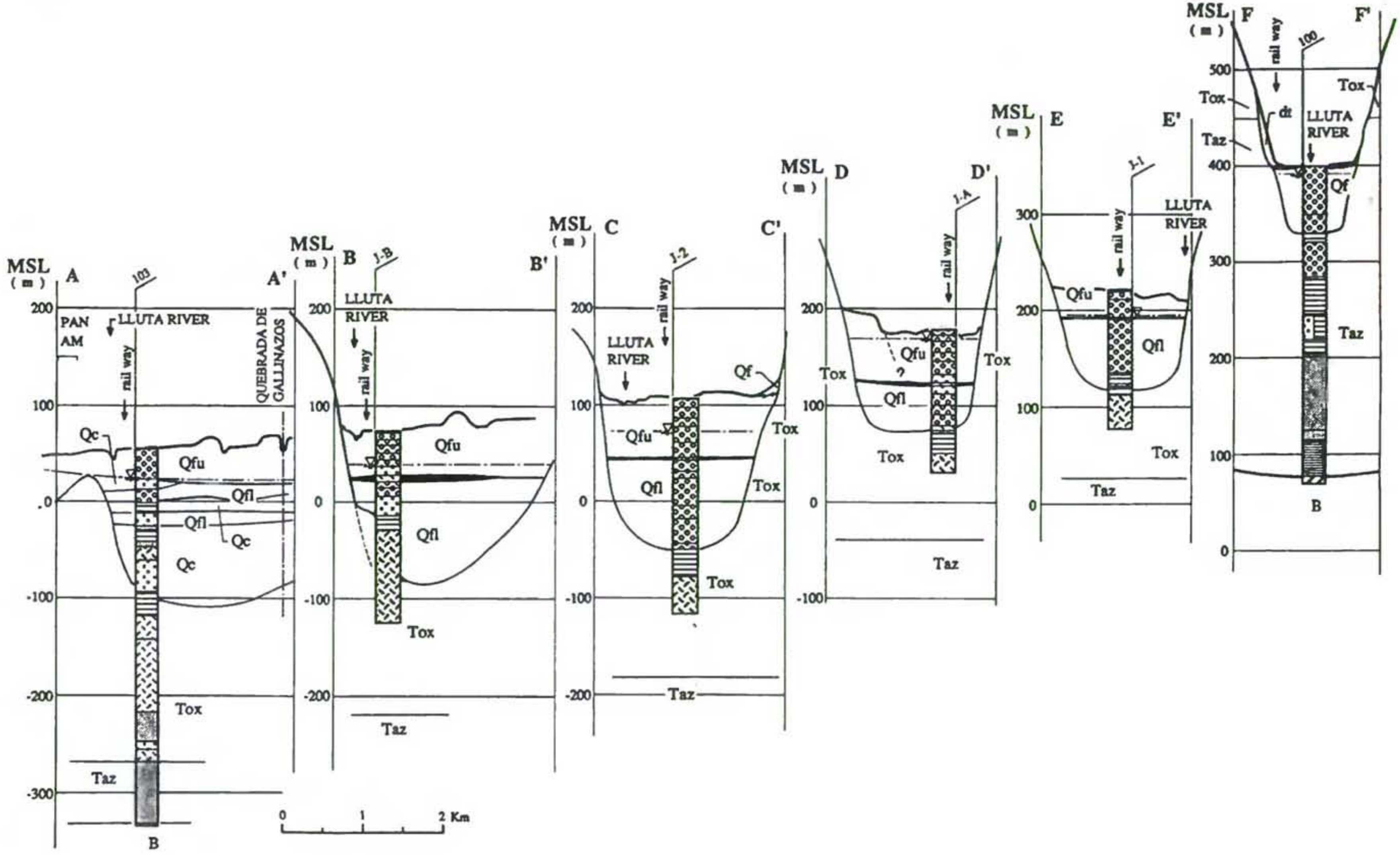


Fig. B-II, 1.3 Geological Cross Sections
<Seccion de es Cruce Geológico>

Chapter II. AQUIFER OF LLUTA VALLEY

2.1 Inventory of Existing Wells

The JICA Study Team established well inventory of existing wells, dug wells and springs by the same method as that of the Azapa Valley (refer to B-I, Chapter 2.1) based on the existing well inventories attached to following reports;

1) Análisis Crítico de la Red de Medición de Niveles de Agua Subterránea 1 Región, October 1987 for DGA by Alamos y Peralta Ingenieros Consultores Ltda.
2) Modelo de Simulación de las Aguas Subterráneas del Valle de Azapa, January 1989 for DGA by Ayala, Cabrera y Asociados Ltda. Ingenieros Consultores con la asesoris de IPLA Ltda.
3) Estudio Análisis de los Recursos de Agua de la Primera Región de Tarapacá, Informe Final de la Primera Etpa, June 1991, for DGA by Ingenieria y Geotecnica Ltda.

The CORFO code (1975) and the BNA code are applied to only deep wells (sondajes) in the area. Springs (vertientes) and dug wells (norias) had no number, therefore, the Study Team temporarily assigned the numbers to the wells: V-1 and 2 for springs and N-0 to 9 for dug wells. The DGA code has not been applied in the Lluta River Basin.

Total number of existing wells comes to 19, consisting seven (7) deep wells, 10 dug wells and two (2) springs in the valley. The Well List is shown in Table B-II, 2.1 including four (4) JICA wells. Well locations are shown in Fig. B-II, 2.1. The Well Inventory is attached as Data Book. Items included in the inventory are same as that of the Azapa Valley. None of the dug wells has any information, therefore, DGA and the JICA Study Team executed field survey on these dug wells. In the field survey, exact locations of dug wells were measured by GPS (Global Positioning System). The results of the measurement are also included in the Well List.

Most wells are located in the Villa Frontera. In this area there are five (5) deep wells and the rest are dug wells. Other two (2) deep wells are located in the middle stream of the Lluta River; one is at Bocanegra and the another is at Rosario. Among these, six (6) deep wells were constructed in 1960s. As for remaining one (1) deep well and all the dug wells, no data is available.

2.2 Existing Boring Data

2.2.1 Boring Logs

Available boring data are for following six (6) logs of deep wells;

100-7	Bocanegra
100-2	Rosario
101-0	Villa Frontera (near the Panamerican)
102-0	Villa Frontera (near the railway to Peru)
103-7	Villa Frontera (near the railway to Peru)
104-5	Playa Las Machas (near the coast)

Geostratigraphic columns of these wells are attached to the Well Inventory (see, Data Book).

2.2.2 Pumping Test

The Well List (Table B-II, 2.1) shows the results of the pumping test executed at the completion of well construction. Six (6) data are available in the basin. However, aquifer constants are not analyzed. Based on these data, specific yield (Sy) is calculated by the Study Team. Results are shown in Table B-II, 2.1.

2.3 Supplementary Geological Survey

The following geological surveys were executed by the JICA Study Team to supplement the existing geological data. The survey locations are shown in Fig. B-II, 2.2.

1) Electromagnetic Survey — 30 survey points (5 lines)

2) Boring Test
   - (1) Drilling
     - Test well drilling — 2 wells
     - Observation well drilling — 2 wells
   - (2) Pumping Test — 4 wells

3) Water Quality Analysis — 4 wells (JICA wells)

4) C-14 analysis — 1 well

2.3.1 Electromagnetic (TEM) Survey

1) Survey Area

The survey area is located along the Route 11 in the Lower Lluta Valley (Fig. B-II, 2.2). Five (5) TEM lines were set perpendicular to the main axis of the Lluta River. A total of 30 stations were set at an interval of 250m each as shown below ;

Quantity of TEM Survey

Profile	Stations	Station Interval
RL-1	6	250 m
RL-2	6	250 m
RL-3	6	250 m
RL-4	6	250 m
RL-5	6	250 m
Total	30	

2) Methodology of Survey

(1) Selected Method

The purpose of the electromagnetic exploration is to clarify the resistivity structure of layers and to select the promising boring locations.

The measurement of the electrical resistivity of layers has been a tool for groundwater exploration for many years. Traditionally, D.C. current methods (Wenner, Schlumberger, etc.) have been widely used for this purpose. However, often are problems encountered in typical areas such as desert and rocky surface where it is difficult to obtain sufficient current flow. Furthermore, a considerable effort is usually required to lay out the array, so that D.C. resistivity surveys tend to be expensive to perform. For these reasons, there is a growing interest in the use of non-contacting electromagnetic (EM) techniques to measure resistivity. The TEM method used here, is starting to be widely used for groundwater exploration with measuring depth from hundreds to thousands meters. For the above mentioned reasons, the TEM method was adopted for the project.

(2) Principal of TEM Method.

In the TEM method most commonly used, a square transmitter loop, of which side length is decided corresponding to the desired depth of exploration, is laid out on the ground and energized with an alternating current wave. This current wave form induces horizontal eddy current loops in the ground which expand in radius and diffuse to greater depths with passage of time. By measuring the decaying magnetic field from these eddy currents as a function of time, information is successively derived from greater depth. The value of magnitude of the decaying magnetic field is converted to an apparent resistivity as a function of time, from which a layered earth interpretation can be made using techniques analogous to those for conventional resistivity soundings.

3) Survey Results

Measured apparent resistivity curves in the area are shown in Fig. B-II, 2.3. Geoelectrical profiles are prepared from the apparent resistivity curve of each station. The geoelectrical profiles along Line RL-1 to RL-5 are shown in Fig. B-II, 2.4. According to the data from DGA, conductivities of groundwater in this area show high values of 2,600 (3.8 Ω-m) to 5,200 (1.9 Ω-m) mΩ/cm.

The resistivity structure in this area consists of 3 to 4 layers, with a stratiform structure, in general. Resistivities of the layers are relatively low, less than 200 Ω-m. The geophysical characteristics of each layer are summarized as follows.

(1) The first layer (5 m to 70 m thick) shows a resistivity range of 28 to 300 Ω-m. The resistivity of the layer other than profile RL-5, is relatively high (99 - 300 Ω-m). These layer is considered dry. On the other hand, in RL-5 it shows a relatively low resistivity (28 - 84 Ω-m) due to the wet land conditions by irrigation water.

(2) The second layer (50 m to 250 m thick) shows a resistivity range of 11 to 30 Ω-m. This layer is distributed in the whole area. It is considered as a expected aquifer because the resistivity value of prospective aquifer is usually in the order of ten (10) times of that of the groundwater in the area.

(3) The third layer (70 to 190 m thick) shows a resistivity range of 29 to 96 Ω-m. The layer exists only in stations 1 and 2 of RL-3, and in all stations of RL-4. The layer of RL-3 is considered as expected aquifer because of its low resistivity. On the other hand, the layer of RL-4 is considered dry or impermeable, judging from its high resistivity.

(4) The forth layer shows a resistivity value of less than 9.8 Ω-m. The layer is distributed in the whole area. The layer is presumed to have groundwater potential to some degree. However, its extremely low resistivity indicates that the layer is much contaminated by salty to brackish water.

Lateral discontinuities of resistivity exist between station No. 1 and No. 2 of profile RL-1 and between stations No. 2 and No. 3 of RL-3. These discontinuities may be coincident with geological boundaries, such as faults or fracture zones.

4) Interpretation with Boring Log

Geoelectric profiles, described in above section, are analyzed together with the boring logs (lithological description and geophysical logging data). Fig. B-II, 2.4 shows geoelectric profile and Figures B-II, 2.5 (1) to 2.5 (5) show analyzed resistivity profiles Results of interpretation are summarized as follows.

(1) Profile RL-1 (see, Fig. B-II, 2.5 (1))

The profile is analyzed as a three (3) layered model from resistivity curves. The results are shown in the table mentioned below.

The first layer is considered to be dry layer because of its relatively high resistivity range. It corresponds to surface deposits. Judging from the resistivity, the second layer is considered to be a aquifer. However, groundwater in the aquifer may contain a little quantity of salty contents because the resistivity of the aquifer is relatively low.

The third layer consists of Ignimbrite appearing at the depth of 40 m. Resistivity of the third layer is generally low, less than 9.8 Ω-m. This is probably due to the following geological characteristics.

- Joints are developed in the upper part of the rock by which the rock was broken into blocks. Then, groundwater saturated these joints and it made the resistivity of the rock low.

It is considered to be difficult to exploit the groundwater in this aquifer, because the groundwater is stored in the large spacing joints.

Layer	Depth (mBGL)	Resistivity Range(Ω-m)	Lithology	Interpretation
1 st	0 - 46	65 - 180	gravel, sandy to clayey	surface deposits
2 nd	46 - 150	13 - 26	gravel to sand in upper, clay to ignimbrite in lower	expected aquifer
3 rd	150 <	< 9.8	ignimbrite	ignimbrite with joints

(2) Profile RL-2 (see, Fig, B-II, 2.5 (2))

The profile was analyzed as a three (3) layered model and no discontinuity throughout the survey line. The results are summerized in the table mentioned below.

The first layer shows a resistivity range of 65-80 Ω-m and correspond to dry surface deposits. The second layer has a resistivity range of 17 to 30 Ω-m and considered as expected aquifer. The third layer is of low resistivity range, lower than 12 Ω-m, and is correlated to ignimbrite with joints as previously mentioned on the survey line RL-1.

The well No. J-2 is drilled on this survey line and lithology of each layer was confirmed as follows.

Layer	Depth (mBGL)	Resistivity Range(Ω-m)	Lithology	Interpretation
1 st	0 - 20	110 - 300	gravel	surface deposits
2 nd	20 - 158	17 - 30	gravel, sandy to clayey	expected aquifer
3 rd	158<	<12	clay and ignimbrite	ignimbrite with joints

(3) Profile RL-3 (see, Fig. B-II, 2.5 (3))

The profile was analyzed as a three (3) layered model. The results are summerized as the table mentioned below. The first layer has a relatively high and is correlated with the dry surface deposits. The second is considered as a expected aquiferjudging from the resistivity. The third layer shows a relatively low resistivity range, therefore, it is considered to be correspond to the jointed ignimbrite as described in (1).

A resistivity discontinuity was observed between the station No. 2 and No. 3; The profile was analyzed as four (4) layered model on the southern side (No. 1 and 2) and as three (3) layered model on the northern side (No. 3 to 5). However, the second layer and the third layer are basically same unit because there is not so large difference in the resistivity of the both layers. The second layer is a resistivity range of 13 to 14 Ω-m and the third layer is in a rang of 29 to 47 Ω-m. Then, the third layer was included in the second layer. This feature may be due to the difference of lithofacies of aquifer; The upper is more silty and the lower is more gravelly.

The well No. J-A was drilled on this survey line and the lithology of each layer is confirmed as following table.

Layer	Depth (mBGL)	Resistivity Range(Ω-m)	Lithology	Interpretation
1 st	0 - 30	120 - 160	gravel	surface deposits
2 nd	30 - 180	26 - 12	gravel, sandy to clayey	expected aquifer
3 rd	180<	<7.6	clay and ignimbrite	ignimbrite with joints

(4) Profile RL-4 (see, Fig. B-II, 2.5 (4))

A four (4) layered model was established and no discontinuity of resisitivity is observed. The results of interpretation is shown in the table mentioned below.

The first layer has a relatively high resistivity range, therfore, it is correlated with dry surface deposits. The secoend layer is considered as an expected aquifer from its resistivity. The second layer indicates a resistivity range of

13 to 26 Ω-m and considered as an expected aquifer. The third layer is of relatively low resistivity range. Then, it corresponds to the ignimbrite with joints as mentioned in (1).

No drilling was made on this survey line, therfore, lithology of each layer was confirmed.

Layer	Depth (mBGL)	Resistivity Range(Ω-m)	Lithology	Interpretation
1 st	0 - 40	100 - 140	not confirmed	surface deposits
2 nd	20 - 180	13 - 26	not confirmed	expected aquifer
3 rd	70-335	71 - 96	not confirmed	impermeable bed
4 rd	335<	4.2 - 6.8	not confirmed	ignimbrite with joints

(5) Profile RL-5 (see, Fig. B-II, 2.5 (5))

A three (3) layered model was established on the profile. The results are summerized as the table mentioned below.

The first layer is correlated with dry surface deposits since it shows relatively high resistivity. The second layer has a resistivity range of 11 to 23 Ω-m and is considered to be an expected aquifer. The third layer shows a low resistivity range, therfore, it corresponds to the ignimbrite with joints. The boundary of the 2nd and 3rd layers is unclear at station 4.

The well No. J-1 was located on this survey line.

Layer	Depth (mBGL)	Resistivity Range(Ω-m)	Lithology	Interpretation
1 st	0 - 12	28 - 84	clayey gravel	surface deposits
2nd	12 - 230?	11 - 23	gravel, sandy to clayey and ignimbrite (?)	expected aquifer
3rd	230<	<5.8	not confirmed	ignimbrite with joints

2.3.2 Boring Test

1) Location and Depth of Well

Two (2) test wells (J-A, J-B) and two (2) observation wells (J-1, J-2) are placed along the line of the TEM survey (see Fig. B-II, 2.2). Location, drilling depth and casing size of each well are summarized as follows.

Well No.	Location	Latitude	Longitude	Elevation (mMSL)	Casing (inch)	Depth (mBGL)
J-A	Lluta	18° 23' 08.95"	70° 13' 58.16"	178.510	8-5/8"	150.0
J-B	Panamericana	18° 24' 03.85"	70° 17' 19.04"	74.301	8-5/8"	200.4
J-1	Chacabuco	18° 25' 42.54"	70° 13' 03.31"	219.539	5-1/2"	145.0
J-2	Lluta	18° 23' 40.05"	70° 16' 06.17"	107.769	5-1/2"	225.0

2) Methodology of Well Construction

(1) Drilling Method and Procedure

Both test and observation wells were drilled by the rotary drilling method with a direct mud circulation system. The reason is why this drilling method is much suitable for taking cutting samples and well logging than other method such as percussion type drilling method. It is indispensable to take samples and well logging for the evaluation of hydrogeological evaluation. Furthermore, the construction period can be much reduced by rotary drilling method.

Typical well designs are shown in Fig. B-II, 2.10 for test well and Fig. B-II, 2.11 for observation well. The procedure of the drilling is described below. However, drilling depth, packing depth and test interval were altered by the Drilling Experts of the Study Team to meet the hydrogeological conditions of the site.

i) Test Well

The well was designed as a 8-5/8" cased well, therefore, following procedure and bit size (borehole size) are specified.

Step No.	Work Procedure	Specification
1	Drill a conductor borehole to a depth of 5.5m to 8.0m.	Hole size: 17-1/2" (444.5 mm)
2	Install a conductor pipe to the drilled depth.	Pipe size: 14" (355.6 mm)
3	Seal the annular space between the borehole and the conductor pipe by cementing.	Maximum 8m depth
4	Resume drilling of the borehole to the required depth.	Bit size: 13-1/4" (336.5 mm)
5	Perform well logging through the drilled borehole.	Resistivity, SP, Temperature, Gamma Ray,
6	Determine the position(s) of well screen.	Designed by Drilling Expert of JICA Study Team
7	Install casing and screen pipes as determined.	Casing size: 8-5/8" (219.1 mm) Screen size: 8-5/8" (219.1 mm)
8	Make gravel-packing for the annular space between the borehole and pipes.	Grain size: 3 - 5 mm
9	Make clay-packing for the annular space between the borehole and casing pipes.	At least 3m thickness.
10	Cementation for the annular space above the clay-packing.	Up to ground surface.
11	Perform the development of the well by air-lifting and/or surging.	At least 1 hour for each piece of screen
12	Carry out the pumping test by submersible pump.	Step draw down test, constant discharge test and recovery test.

ii) Observation well

The well was designed as a 5-1/2" cased well, therfore the following procedure and bit size (borehole size) are specified.

Step No.	Work Procedure	Specification
1	Drill a conductor borehole to a depth of 5m to 8m.	Hole size: 17-1/2" (444.5 mm)
2	Install a conductor pipe to the conductor borehole.	Pipe size: 12" (323.9 mm)
3	Seal the annular space between the borehole and the conductor pipe by cementing.	Maximum 8m depth.
4	Resume drilling of the borehole to the required depth.	Bit size: 10-5/8" (269.9 mm)
5	Perform Well logging through the drilled borehole.	Resistivity, SP, Temperature, Gamma Ray,
6	Determine the position(s) of well screen.	Designed by Drilling Expert of JICA Study Team.
7	Install casing and screen pipes as determined.	Casing size: 5-1/2" (141.3 mm) Screen size: 5-1/2" (138.8 mm)
8	Make gravel-packing for the annular space between the borehole and pipe.	Grain size: 3 - 5 mm
9	Make clay-packing for the annular space between the borehole and casing.	At least 3m thickness.
10	Cement the annular space above the clay-packing.	Up to the ground surface
11	Perform the development of a well by air-lifting and/or surging.	At least 1 hour for each piece of screen
12	Carry out the pumping test by submersible pump.	Step draw down test, constant discharge test and recovery test.

(2) Structural Design of Well

i) Test Well

The structure of borehole was determined considering the size of the permanent casing and screen pipes, and planned drilling depth. The standard design is shown in Fig. B-II, 2.6. The borehole size was designed as 13-1/4" in order to keep enough space for gravel packing in an annular space between 8-5/8" pipes and borehole wall. Maximum depth was planned as 250m.

For future pumping use and periodical water level measurement, the well head was constructed as shown in Fig. B-II 2.8. Internal and external well caps were installed on the well head as shown in Fig. B-II, 2.9. The fence was built up around the well head as shown in Fig. B-II, 2.10.

ii) Observation Well

Considering the same purpose of the test well, the borehole size was designed as 10-5/8". The standard design of the observation well is shown in Fig. B-II, 2.7. Maximum depth was planned as 300m.

A water level recorder donated by JICA was installed on the well head as shown in Fig. B-II, 2.11 for successive measurement by DGA. The same fence as the test well was built up around each well.

(3) Materials Used

Particular materials were selected for test and observation wells. The specifications of major materials are described hereunder.

i) Pipes

(i) Conductor Pipe

Standard : ASTM A-106 Grade B schedule 40

Outside Diameter	Wall Thickness	Type of Well
355.6 mm (14")	12 mm	Test Well
323.9 mm (12")	12 mm	Observation Well

(ii) Casing Pipe

Standard : ASTM A-106 Grade B schedule 40

Outside Diameter	Wall Thickness	Type of Well
a) 8-5/8" (219.10mm)	11.2 mm	Test Well
b) 5-1/2" (141.30mm)	13.1 mm	Observation Well

(iii) Screen Pipe

Johnson type was selected as the screen pipe. The detailed specifications are as follows:

a) For Test Well

Nominal size (inch)	:	ASTM 8-5/8"
Screen outside diameter (mm)	:	219.10
Effective unit length (mm)	:	5,924
Opening ratio (%)	:	More than 20%

b) For Observation Well

Nominal size	:	ASTM 5-1/2"
Screen outside diameter (mm)	:	138.8
Effective unit length (mm)	:	5,924
Overall unit length (mm)	:	6,000
Materials	:	Galvanized steel (SAE 1010/15)
Slot size (mm)	:	1.0
Opening ratio (%)	:	More than 20%

ii) Packing Materials

The following packing materials were used for both test and observation wells.

(i) Cement Grouting

Mixture of 50% Portland cement and 50% casting plaster.

(ii) Gravel Pack

Uniformly-graded, well-sorted and well rounded river gravel with 3 - 5mm grain size.

3) Results of Boring Test

The well data for each well, lithological column, casing design, well logging and drilling rate, are shown in Fig. B-II, 2.12 and Fig. B-II, 2.13 for test well and Fig. B-II, 2.14 and Fig. B-II, 2.15 for observation well.

(1) Well No. J-A (see Fig. B-II, 2.12)

i) Lithology

The well was drilled up to 150m depth. Two (2) formations, Fluvial Deposits and Oxaya Formation, were observed at the depth from surface to 106m and from 106m to 150m respectively. Based on the results of geophysical logging and lithology observed, the following four (4) major layers were classified.

(J-A)

Layer	Depth (m)	Classification	Lithology	Period	Formation
1 st	0 - 56	Shallow Aquifer	clayey to sandy gravel	Quaternary	Fluvial Dep.
2 nd	56 - 59	Impermeable layer	tuff		
3 rd	59 - 101	Deep Aquifer	sand, sandy to clayey gravel		
4 th	101 - 150	Impermeable Bed	clay, ignimbrite	Quaternary Tertiary	Fluvial Dep. Oxaya Form.

ii) Well Logging

Spontaneous potential (SP) indicates a range of 985 to 1040 mv. Considering the lithology, the relative basement line (relative 0 line) is established as 1025 mv. The line indicates the boundary of permeable formation (gravel, sand) and impermeable formation (mud). Resistivity indicates a high range of 20 to 100 Ω-m at surface, a short range of 10 to 30 Ω-m at below 60m depth. Temperature is 28 to 28.5 °C in general.

iii) Determination of Casing Design

The position of screen pipes was determined at the depth between 59.93 m and 101.98 m on the basis of interpretations of lithological and well logging data. The details of interpretation are mentioned below. For the casing design, see Fig. B-II, 2.12.

(i) 1 st layer (Shallow Aquifer)

The layer consists mainly of clayey, sandy gravel and is intercalated with sand at some minor parts. The layer is interpreted as an aquifer by the value of SP and resistivity, except the top surface (0 to 12m in depth). The temperature curve shows a surface water permeation to the groundwater at depth from 15 to 30m. Gamma ray value shows a range of 60 to 100 cps from surface to 76m depth. This value is relatively higher than others, therefore, the layer is considered to be rather rich in clay.

(ii) 2 nd layer (Impermeable Layer)

The layer is composed totally of tuff. Both SP and resistivity values indicate that the layer is impermeable. The layer acts as a boundary of the shallow and the deep aquifer.

(iii) 3 rd layer (Deep Aquifer)

Based on the values of SP and resistivity, the layer is classified as the most promising aquifer in the sequence. Especially, resistivity value shows a range of 15 to 30 Ω-m which is similar to the results of TEM survey (12 to 26 Ω-m). Compared to that of shallow aquifer, the value of gamma ray is more lower (50 - 70 cps) at the depth from 66 to 100 m. It is considered that the layer is much permeable than shallow aquifer. A slow increasing rate of water temperature also characterizes a promising aquifer. It is observed at a zone of 50 to 100 m depth.

The screen pipes were installed in this layer.

(iv) 4 th layer (Impermeable bed)

The layer consists of clay at upper part and ignimbrite at lower part. Judging from the lithology, the layer is clearly impermeable. This is supported by the following logging data; The value of SP exceeds basement line (1025 mv) and Gamma ray value shows relatively high cps ranging form 50 to 90 for clay and 60 to 100 for ignimbrite.

(2) Well No. J-B (see Fig. B-II, 2.13)

i) Lithology

The total drilling depth was 200.4m. Two (2) formations, Quaternary Fluvial Deposits and Tertiary Oxaya Formation, were observed at a depth of 89m from surface and from 89 to 200m respectively. Based on the results of the geophysical logging and lithological observation, following six (6) layers were classified.

(J-B)

Layer	Depth (m)	Classification	Lithology	Period	Formation
1 st	0 - 46	Shallow Aquifer	sandy to clayey gravel, sand	Quaternary	Fluvial Dep.
2 nd	46 - 53	Impermeable Layer	clayey tuff		
3 rd	53 - 89	Deep Aquifer	sandy to clayey gravel, sand		
4 th	89 - 104	Impermeable Layer	silty clay	Tertiary	Oxaya Form.
5 th	104 - 147	Fissured zone	ignimbrite		
6 th	147 - 200	Impermeable Bed	ignimbrite		

ii) Well Logging

Values of the spontaneous potential (SP) indicate minus (-) in all the sequences. Based on the lithology and cps curve of gamma ray, relative basement line of SP is estimated as - 8.4 mv. Layers are clearly classified into three (3) units by the cps curve of gamma ray; From surface to 63m depth as impermeable (muddy gravel or alternation of mud and gravel), from the depth of 64 to 140m as permeable , and from 140m to the bottom as impermeable (ignimbrite). The infiltration from surface water is identified by the temperature curve, at the depth of 15 to 70m .

iii) Determination of Casing Design

Casing design is determined as shown in Fig. B-II, 2.13, based on the following interpretation for each layer. The range of screen pipes are from 60.05 m to 90.1 m and from 102.1 m to 144.17 m.

(i) 1 st layer (Shallow Aquifer)

The layer is composed mainly of sandy and clayey gravel. Surface of this layer is considered as a boulder formation due to the slow drilling rate (less than 60 min./m). Because high resistivity (60 to 150 Ω-m) appears from the surface to 23m the surface is dry. From the depth of 17 to 46m, SP value is located on the permeable side of the basement line. The infiltration from the surface water is clearly observed on the temperature curve. The gamma ray shows high value (50 -100 cps) which means that the layer predominates in mud. Therefore, it is considered that the layer has a small scaled alternation of mud.

(ii) 2nd layer (Impermeable Layer)

The layer is composed of clayey tuff. The thickness of the layer is 7 m. The boundaries of the layer are very clear; The drilling rate varies at the boundaries with other layers. The layer is classified as impermeable.

(iii) 3 rd layer (Deep Aquifer)

All the geophysical logging data indicate that the layer is a promising aquifer, except the high value of gamma ray in the upper part (53m - 63m). Especially, the value of Gamma Ray shows a low value (25 to 50 cps). Thus, it is considered as a high permeable layer.

The screen pipes were installed in this layer.

(iv) 4 th layer (Impermeable Layer)

The layer is composed of silty clay having 15m in thickness. The layer is judged as impermeable by the value of SP and gamma ray.

(v) 5 th layer (Fissured Zone)

The layer consists of ignimbrite of Tertiary Oxaya Formation. The layer forms basement rock of the area. However, the resistivity range (15 - 30 Ω-m), a gentle increasing rate of temperature and gamma ray value indicates that the layer is permeable. Therefore, joints are well developed in this layer.

The screen pipes were also installed in this layer at the depth from 102.1 m to 144.17 m.

(vi) 6 th layer (Impermeable Bed)

The layer consists of ignimbrite of the same formation as in the 5 th layer. However, considering the high value of resistivity and gamma ray, the layer is considered as dry.

(3) Well No. J-1 (see Fig. B-II, 2.14)

i) Lithology

The well was drilled up to 145m. Based on the lithology and well logging data, the following four (4) major layers are classified. These are correlated with Quaternary Fluvial Deposit and the Tertiary Oxaya Formation.

(J-1)

Layer	Depth (m)	Classification	Lithology	Period	Formation
1 st	0 - 29	Shallow Aquifer	clayey to sandy gravel	Quaternary	Fluvial Dep.
2 nd	29 - 31	Impermeable Layer	clay		
3 rd	31 - 101	Deep Aquifer	sandy gravel, clay at bottom		
4 th	101 - 145	Impermeable Bed	clay, ignimbrite	Tertiary	Oxaya Form.

ii) Well Logging

Resistivity shows a rather low range of 10 to 30 Ω-m in general. Several reversal relation of long and short normal resistivity value are observed at the surface to 29m depth. Gamma ray shows a boundary of upper and lower strata at 83m depth. The cps value is high (50-110) at upper, low (20 -80) at lower strata. A relative basement line of the spontaneous potential is established at 935 mv, based on the resistivity value and lithology. A large scale of groundwater flow into the borehole is confirmed by the temperature curve from 30 to 90m depth.

iii) Determination of Casing Design

Casing design was determined as shown in Fig. B-II, 2.14, based on the following interpretation. The screen pipes were installed at the depth from 31m to 91m.

(i) 1 st layer (Shallow Aquifer)

The layer is mainly composed of clayey gravel and sandy gravel. The layer is considered as highly permeable judging from the SP value. Surface water infiltration is observed at depths from 5 to 10m and 26 to 29m by the temperature curve.

(ii) 2 nd layer (Impermeable Layer)

The layer is composed of a single thin (3m thick) stratum of Quaternary clay. The layer is the impermeable unit between the upper and the deep aquifers.

(iii) 3 rd layer (Deep Aquifer)

The layer consists mainly of gravel and sandy gravel. The resistivity range is 25 to 35 Ω-m. The surface water inflow to the groundwtaer is confirmed by the temperature curve. The range of SP value is also located in the permeable side from the relative basement line. The layer is considered as the most promising aquifer within the sequence.

The screen pipes were installed in this layer.

(iv) 4 th layer (Impermeable bed)

The layer is composed of ignimbrite of Tertiary Oxaya Formation. At the top of the bed, clay of 9m thickness is confirmed. According to the SP range, the layer is expected to be permeable by the developed fissure. However, a low resistivity value of less than 10 Ω-m indicates high contamination.

(4) Well No. J-2 (see Fig. B-II, 2.15)

i) Lithology

Within 225m of total depth, two (2) formations are confirmed ; one is Quaternary Fluvial Deposit at a depth of 158m from surface, and the other one is Tertiary Oxaya Formation at depth from 158m to the bottom. The following three (3) major layers are classified by the interpretation of lithology and geophysical logging.

(J-2)

Layer	Depth (m)	Classification	Lithology	Period	Formation
1 st	0 - 30	Surface Deposit	gravel to clayey gravel	Quaternary	Fluvial Dep.
2 nd	30 - 158	Aquifer	gravel, sandy to clayey	Quaternary	Fluvial Dep.
3 rd	158 - 225	Impermeable Bed	clay, Ignimbrite	Tertiary	Oxaya Form.

ii) Well Logging

An homogeneous curve is observed at each logging of SP, resistivity and gamma ray. The gamma ray range in this area shows an abnormal value. At gravel layer, a high range of 60 to 110 cps is observed. So it is considered that the permeability is not reflected by the cps value of the gamma ray in this case. Considering the lithology and resistivity curve, a line of 1100 mv is estimated as a relative basement line of spontaneous potential. A temperature curve displays gentle increment of the whole sequence. Thus, a groundwater flow at thick sequence is expected.

iii) Determination of Casing Design

In order to determine the position of screen pipes, following interpretations were made. For details of the casing design, see Fig. B-II, 2.15.

(i) 1 st layer (Surface Deposit)

The layer consists of gravel and clayey gravel. The layer is considered as permeable by the lithological observation and SP. However, a high resistivity value (30 to over 100 Ω-m) confirms the layer to be dry. Blank casing pipes are installed in this layer.

(ii) 2 nd layer (Aquifer)

Based on a permeable indication of SP and typical range (20 - 30 Ω-m) of resistivity, the layer is classified as most promising aquifer in the sequence. The resistivity range is almost the same as TEM result (17 - 30 Ω-m). Groundwater flow indication is also visible at 45 to 85m depth by the temperature curve.

Screen pipes were installed at depth from 64.02m to 154.01m of this layer.

(iii) 3 rd layer (Impermeable Bed)

The layer is composed of clay at upper part, and ignimbrite at lower part. Low SP value indicates that the layer is impermeable. Moreover, low resistivity range of less than 10 Ω-m indicates that the layer has no groundwater potential. Blank casing pipes were installed in this layer.

2.3.3 Pumping Test

1) Methodology of Pumping Test

Three (3) different kinds of pumping tests; step drawdown test, constant discharge test and recovery test were conducted for both test and observation wells, after completion of drilling work and air lifting development.

(1) Pumping

Based on the casing size installed, following submersible pumps were used for pumping.

for test wells	:	1,500 l/min. x 50m head
for observation wells	:	240 l/min. x 50m head

The pumps was installed in the casing pipes with a setting depth of 90 mBGL, through rising main and delivery pipes. A valve and flow meter were installed on the delivery pipe works.

(2) Method of Test

Each test was carried out following the standard method mentioned below.

Step drawdown test	:	At least seven (7) round steps (discharge increased and decreased) are carried out and duration of each step is 120 minutes.
Constant discharge test	:	24 hours measurement is conducted as soon as the water level has recovered its original static water level after the completion of the step drawdown test.
Recovery test	:	The test starts immediately after completion of the constant discharge test and continues until the water level recovers its static water level.

However, in order to meet the hydrogeological conditions at each well, discharge rate, test duration, number of steps and time interval were altered by the Hydrogeologist of the Study Team.

(3) Measurement

The static water level is measured just before the commencement of the any pumping test. Throughout the duration of each test, the water level was measured and recorded following observation time schedule listed below;

Time from start of pumping or increase of pumping rate (minutes)	Time interval between observations (minutes)
0 - 5	1/2
5 -10	1
10 - 20	2
20 - 30	3
30 - 60	5
60 - 120	10
120 - 240	20
240 - 360	40
360 and longer	60

The flow rate of all water pumped from the well during the pumping test is measured by both a flow meter in the delivering pipe works and a triangular weir. Discharge rate is recorded during the pumping test at intervals mentioned above.

(4) Method of Analysis

i) Aquifer Constants

Aquifer constants necessary for the hydrogeological evaluation are transmissibility, storage coefficient and permeability. These aquifer constants were analyzed by using the results of the constant discharge and recovery tests. For the above analyzation, Theis and Jacob methods were applied. The aquifer constants are given by the following formulas;

(i) Theis Equation

Transmissibility (T) = Q x W(u) / 4π x s

Where Q = pumping rate (m^3/day)
W(u) = well function of u
s = drawdown (m) at matching point

Permeability (K) = T/L

Where T = transmissibility (m^3/day/m)
L = thickness of aquifer (m : total length of screen pipes)

(ii) Jacob's Equation

Transmissibility (T) = 0.183 x Q / Δs

Where Q = pumping rate (m^3/day)
Δs = draw down on one log cycle (m)

Permeability (K) = T/L

Where T = transmissibility (m^3/day/m)
L = thickness of aquifer (m : total length of screen pipes)

ii) Well Efficiency and Area of Influence

In order to estimate critical discharge and safe yield, well efficiency and area of influence are calculated by the data of step drawdown test.

Critical discharge is determined by the slope of the Q (Discharge Rate) - Sw (drawdown) chart. Maximum pumping rate which does not cause a large drawdown is defined as critical discharge. On the other hand, safe yield is estimated by the ratio of well efficiency and area of influence as described below ;

$$\text{Well Efficiency (\%) } Ew = BQ/(BQ+CQ^2) \times \frac{BQ}{BQ+CQ^2}$$

Where B = aquifer loss
C = well loss
Q = discharge rate (l/s)

In this report, the following criterion is determined for well efficiency.

Well Efficiency : more than 85%

Radius of influence is discussed in Chapter III.

2) Results of Pumping Test

(1) Aquifer Constants

Aquifer constants are analyzed by the graphs as shown in Fig. B-II, 2.16 (1) to (4). The tables include the pumping data and the aquifer constants calculated by two (2) equations mentioned above. The aquifer constants for four (4) wells are summarized in Table B-II, 2.4.

The average of the transmissibility of four (4) wells is calculated as 212.73 m^3/day/m. The highest value of 368.06 m^3/day/m is found at J-1 which has the highest specific yield. J-1 is considered to have high groundwater potential. On the other hand, the lowest transmissibility is found at J-A (22.72 m^3/day/m). The well has also the lowest specific yield (0.24 l/s/m). The well is considered to have low groundwater potential.

Permeability of the four (4) wells are similar. The highest value is 1.93 x 10^{-3} cm/sec at J-2, and the lowest is 6.25 x 10^{-4} cm/sec at J-A. The average of permeability is calculated as 3.64 x 10^{-3} cm/sec. This value is lower than permeability usually expected in this lithology mainly consisting sand, gravel and clayey to sandy gravel.

Storage coefficients are in a range from 3.31 x 10^{-6} to 1.93 x 10^{-3}, averaging 7.26 x 10^{-4}.

There are three (3) existing deep wells near the entrance to Route 11 (Road to Bolivia) from Panamerican. Two (2) wells out of these, are operating. The distance of both wells is approximately 500m. No influence is recognized during operating of these wells. This shows that radius of influence of both wells is less than 250 m (=500÷2).

(2) Well Capacity

Well capacity is evaluated by the amount of critical discharge and safe yield. The Q-Sw chart for to examine the critical discharge and the Q-s/Q chart for to obtain the well efficiency and area of influence are shown in Fig. B-II, 2.17 (1) to 2.17 (4). The detailed results of the analysis for step drawdown tests are described in Table B-II. The capacities for four (4) wells are summarized as follows;

Well No.	Critical Discharge (l/s)	Safe Yield (l/s)
J-A	15.30	7.50
J-B	20.30	13.00
J-1	more than 4.40	2.25
J-2	3.85	2.25

The average critical discharge of test wells and observation wells are estimated as 17.80 l/s and 4.13 l/s respectively. On the other hand, the average safe yield of test wells and observation wells are 10.25 l/s and 2.25 l/s respectively. Safe yield is approximately the half of critical discharge for both types of well.

2.3.4 Carbon-14 Analysis

The purpose of the C-14 Analysis is to decide the age of groundwater for interpretation of groundwater recharge mechanism and for evaluation of the groundwater potential. Two (2) samples were taken from the well No. 101-0 and 102-9 located near the Panamerican Road (see, Fig. B-II, 2.1).

The radiocarbon technique is based on the general law of radioactive decay:

$$t = \gamma / \log 2 \times \log A_O/A_t$$

where γ is the half life in time units, equal to 5,730 ± 30 years in case of ^{14}C. A_O is referred as the ^{14}C content of the atmospheric CO_2 and A_t is the ^{14}C content of the sample. In dating organic remains, it is assumes that the ^{14}C activity of the living plant at time zero was equal to that of the atmospheric CO_2. Then, the age of the sample is determined by measuring A_t expressed as percent carbon modern (pmc) with respect to A_O, which is equal to 100% of modern carbon.

Several goechemical models have been developed to adjust ^{14}C data in groundwaters (e.g. Ingerson an Pearson, 1964; Mook, 1972; Tamers 1975; Fontes and Garnier, 1979; and Reardon and Fritz, 1978). Each model has some defects for groundwater age determination. Therefore, Modeified Pearson Model was adopted for the estimation of the groundwater age.

Results are shown in following table.

Well No. Sampled	Tritium (TU)	C - 14 (pmc)	Age (Y.BP)*
101-0 (A-4)	<0.8	118.9	modern (40<)
- (N-5)	1.1±0.6	122.7	modern (40<)

Note Y.BP* : years before present

Estimated groundwater ages are both modern. However, the tritium data are below or close to the detection limit, therefore, age of the groundwater is older than 40 years. The C-14 values show more than 100 pmc. These do not mean the ages are modern, but reflect the influence of the return flow of surface water from the irrigation area in the agricultural area.

The river water of the Lluta is lead to irrigation area at the lower reach of Tocontasi and returns to the river through drainage system. The surface water of the Lluta is influenced by agricultural activities. Accordingly, the groundwater in the Lower Lluta Valley is also influenced by the return flow of irrigation water.

2.4 Configuration of Aquifer

The aquifer of the Lower Lluta Valley is mainly in the Fluvial Deposits. The boring test by the Study Team revealed that the aquifers in the Fluvial Deposits are divided into two (2) units, the upper and the lower, separated by thin tuff beds (Ref. 2.3 of this Chapter). Profile and cross sections of the two units are shown in Fig. B-II, 1.2 and 1.3 respectively. The distribution of tuff layers is restricted up to Chacabuco. Towards the upper stream from here, the Fluvial Deposits form a single aquifer; there is no impermeable layer between the upper and the lower units.

Although the aquifer in the Lower Lluta Valley is divided into two aquifers, there is no significant difference of groundwater quality between the aquifers. Furthermore, continuity of the tuff bed sometimes become unclear. Therefore, groundwater of both aquifers can be leaked each other.

2.4.1 Shallow Aquifer

No water level data is available on the shallow aquifer except Villa Frontera area. Therefore, thickness of this aquifer is described in this report assuming the water level is same as that of the deep aquifer.

It is thin at Chacabuco, about 10 m and increases toward the downstream; it is 30 to 40 m between Sascapa and Chuilona, and less than 10 m at Villa Frontera. It is 800 to 1000 m in width at Bocanegra to Chacabuco area, and increases toward the downstream from Sascapa. Reaching to Chuilona and Villa Frontera, the Concordia Formation is widespread toward the north and no boundary is recognized with deposits from other rivers such as the Gallinazo and the Concordia Rivers. Therefore, the limit to the north is temporarily supposed up to the Gallinazo River; the width is estimated 3 to 4 km.

2.4.2 Deep Aquifer

The deep aquifer is distributed from Chacabuco to the downstream. Fig. B-II. 2.28 is an isopach map of the deep aquifer. Width of the valley is narrow in the area between Chacabuco and Poconchile, approximately 800 m. It increase its width toward the downstream. It is approximately 70 m in thickness and 800 to 1000 m in width at Chacabuco. Thickness decreases to 50 m at Sascapa, however, increases again up to 100 m at Chuilona and Villa Frontera. Width of the aquifer is 1500 m at Sascapa, 2800 to 3000 m near Chuilona and more than 3000 m at Villa Frontera.

Fig. B-II, 2.29 is a contour map which shows depth of the deep aquifer from the ground level. Depth of the deep aquifer is shallow at Chacabuco, 15 m and is deep between Sascapa and Chuilona, 30 m. Gradient of the top of aquifer changes to gentle at Chuilona.

Fig. B-II, 2.30 shows the elevation of the base of the deep aquifer. The base of the aquifer is above the sea level at Sascapa and Chacabuco, and below at Chuilona and Villa Frontera. Elevation of the base of the aquifer is 0 m MSL at about 5.5 km eastward from the Panamerican Road.

Details of the deep aquifer is summarized in the following table.

Area	Thickness (m)	Width (m)	Top of Aquifer (mBGL)	Base of Aquifer (mMSL)
Chacabuco	70	800 to 1000	15	110
Sascapa	50	1500	30	90
Chuilona	100	2800 to 3000	30	-25
Villa Frontera	100	3000	20 to 25	-80 to -90

note: Aquifer means the deep aquifer.

2.5 Hydrogeological Characteristics of Aquifer

2.5.1 Shallow Aquifer

All the wells penetrated into the shallow aquifer are dug wells at Villa Frontera and no pumping test was executed at the completion of construction. Thus, no data is available. However, the lithofacies of the shallow aquifer is almost same as that of the deep aquifer. Therefore, it seems that the hydrogeological characteristics of this aquifer is also same as that of the deep aquifer.

In the lower reaches of the Lluta River (mainly in Villa Frontera area), groundwater is extracted from the upper member of the Concordia Formation. It is composed mainly of gravel and sand, and its matrix is rich in volcanic ash and mud. Lithology is almost similar to that of the Fluvial Deposits. The permeability coefficient of the aquifer is estimated to be in the order of 10^{-3} cm/sec (about 1 m/day) considering the lithofacies. Judging from the pumping test result of JICA wells, permeability is seemed in a order of 10^{-3} cm/sec.

2.5.2 Deep Aquifer

The bed of deep aquifer is composed mainly of sand and gravel, and the matrix is abundant in mud. As mentioned in 2.4, it is sometimes separated from the shallow aquifer by impermeable tuff beds and the tuff beds end between Chacabuco and Rosario. Therefore, the deep aquifer is recharged from the surface water of the Lluta River mainly in the upstream of Sascapa. In the downstream of Sascapa, the surface water recharges the shallow aquifer. However, since the deep aquifer directly contacts with the shallow aquifer in places where no tuff bed exists, the groundwater of both aquifers can be leaked each other.

Reflacting these condition, there is a difference in the water quality; NO_3 content of the deep aquifer is low while the shallow aquifer shows high contents. This is also supported by the results of the C-14 analysis.

The deep aquifer has an interfinguring relation with the Concordia Formation at Chuilona. The Concordia Formation is also permeable but distributed below the sea level. If a large quantity of groundwater extraction is continued, the sea water intrusion to this aquifer will be happened. Therefore, the Concordia Formation is not considered to be a prospective aquifer.

Aquifer constants of JICA wells and existing wells are shown in following table.

Well No.	Specific Yield (l/sec/m)	Transmissibility (m^3/day/m)	Permeability (cm/sec)
J-1	1.44	368	7.01×10^{-3}
J-A	0.24	23	6.25×10^{-4}
J-2	0.73	150	1.93×10^{-3}
J-B	0.62	310	4.98×10^{-3}
100-2	0.36	-	-
101-0	2.60	-	-
102-9	0.99	-	-
103-7	2.70	-	-
104-5	4.26	-	-
average	1.72	213	3.63×10^{-3}

Permeability coefficients are in a order of 10^{-3} cm/sec. This order is common one as a aquifer. Considering the lithofacies of the aquifer, however, permeability coefficient is rather small as that of gravel bed.

Specific yield changes from place to place; it ranges from 0.24 (J-1) to 4.26 l/sec/m (104-5). This means that productivity of the deep aquifer is different in places.

1) At Rosario, specific yield is very small in the well 100-2 (Rosario), 0.24 l/sec/m. It shows low productivity of the aquifer. This well penetrated into the Fluvial Deposits. However, it is not clear in which horizon screens are installed.

2) JICA wells installed screens strictly in the deep aquifer. Therefore, specific yields of those represent that of the deep aquifer; 024 to 1.44 l/sec/m, averaging 0.76 l/sec/m

3) Remaining four (4) wells are mainly located in Villa Frontera. The Fluvial Deposits (the deep aquifer) changes to the Concordia Formation around the Panamerican Road. Therefore, there is a possibility that these wells penetrated to the Concordia Formation. Specific yields of those show ordinary values; they range from 0.99 to 4.26 l/sec/m, averaging 2.64 l/sec/m.

2.6 Estimation of Groundwater Storage

Groundwater storage of the Lower Lluta Valley is shown in Table B-I, 2.5 and Fig. B-I, 2.21. These figures present the estimated groundwater storage in the area from Chacabuco to the Panamerican Road near the river mouth of the Lluta River. Total volume of the groundwater storage is estimated as follow;

$$S_{\text{Total Storage}} = 107 \times 10^6 \, m^3.$$

The estimation was made based on the one (1) geological profile and six (6) geological sections dividing the area into five (5) zones as shown in the following table;

Zone	Geological Section	Area
1	sect. A-A to B-B'	Panamerican Road. to J-B (Chuilona)
2	sect. B-B' to C-C'	J-B to J-2 (Chuilona)
3	sect. C-C' to D-D'	J-2 to J-A (Sascapa)
4	sect. D-D' to E-E'	J-A to J-1
5	sect. E-E' to F-F	J-1 to Well No. 100 (Rosario)

Conditions applied in the estimation are as follows;

1) Climate condition will be constant during the estimated period.

2) The extent of the estimation is limited to the area from the Panamerican Road to Rosario, because no stratigraphic column of well is available toward the upper reaches from Rosario.

3) Groundwater stored below the sea level is included in the storage.

4) Estimation is made on the groundwater stored in permeable beds and well-fissured ignimbrite in the downstream. Although the groundwater is stored in impermeable beds, it is not considered as prospective one.

5) Effective porosity of aquifer is assumed to be 20 % as a whole, considering the materials which compose the aquifer.

References

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<4: Estudio Análisis de los Recursos de Agua de la Primera Región de Tarapacá, June 1991 for DGA by Ingenieria y Geotecnia Ltda.

Table B-II, 2.1 Well List (Lluta Valley)

<Lista de Sondaje (Valle de Lluta)>

BNA CODE		CORFO CODE (1975)		COORDINATE		COMMUNITY	LOCATION NAME	NAME OF OWNER	CONSTRUCTOR	ELEVATION (mASL)	DRILLING DEPTH (m)	SPECIFIC YIELD (m2/d)	DATE OF CONSTRUCTION	STAIC WATER LEVEL (1993)	
		LAT.-LONG.	NO.	LAT.	LONG.									(mBGL)	(mASL)
012 10	100-7	1820-6950	A-1			ARICA	BOCANEGRA	CORFO	CORFO-437		99		63/06		
		1820-6950	V-1			ARICA	BOCANEGRA				-		-		
		1820-7000	V-2			ARICA	STA. RAQUEL				-		-		
012 11	100-2	1820-7010	A-1			ARICA	COLONIA J FUENZALIDA	CORA	CORFO-373	350.00	332	30.9	62/11	5.83	344.17
		1820-7010	A-3			ARICA	GALLINAZOS	(MILITARY)							
012 11	101-0	1820-7010	A-4	18-23-45	70-17-47	ARICA	CARCEL DE ARICA	DIR. DE PROSIONES	CORFO-388	62.00	384	225.0	62/05	36.10	25.90
012 11	102-9	1820-7010	A-5	18-23-45	70-17-58	ARICA	VILLA FRONTERA	CORFO	CORFO-451	55.00	168	85.2	63/11	30.06	24.94
012 11	103-7	1820-7010	A-6	18-23-45	70-17-58	ARICA	VILLA FRONTERA	CORFO	CORFO-468	55.00	384	233.5	64/11	30.06	24.94
012 11	104-5	1820-7010	A-7			ARICA	HACIENDA VIPA	DUILIO TONINI	CORFO-631		65	367.7	67/06		
		1820-7010	N-0	18-24-10	70-18-43	ARICA	VILLA FRONTERA			32.00	38			27.22	4.78
		1820-7010	N-1	18-23-51	70-19-12	ARICA	VILLA FRONTERA			22.00	19			15.66	6.34
		1820-7010	N-2			ARICA	VILLA FRONTERA			22.00	-			-	
		1820-7010	N-3	18-24-58	70-18-33	ARICA	PLAYA LAS MACHAS			11.00	6			5.00	6.00
		1820-7010	N-4	18-24-20	70-19-01	ARICA	VILLA FRONTERA			22.00	20			19.98	2.02
		1820-7010	N-5	18-24-13	70-18-46	ARICA	VILLA FRONTERA			30.00	38			24.60	5.40
		1820-7010	N-6	18-24-05	70-18-51	ARICA	VILLA FRONTERA			32.00	28			24.53	7.47
		1820-7010	N-7	18-24-00	70-18-57	ARICA	VILLA FRONTERA			32.00	25			DRY	
		1820-7010	N-8	18-24-00	70-18-57	ARICA	VILLA FRONTERA			32.00	-			-	
		1820-7010	N-9	18-23-35	70-18-45	ARICA	VILLA FRONTERA			36.00	41			23.76	12.24
				18-25-43	70-13-03	ARICA	CHACABUCO	DGA-JICA	JICA J-1	219.52	145	124.2	93/12	21.69	197.83
				18-23-09	70-13-58	ARICA	PANAMERICANA	DGA-JICA	JICA J-A	178.03	150	20.4	93/12	9.82	168.21
				18-23-40	70-16-07	ARICA	LLUTA	DGA-JICA	JICA J-2	107.37	225	62.8	93/11	35.02	72.35
				18-24-04	70-17-19	ARICA	PANAMERICANA	DGA-JICA	JICA J-B	73.77	200	53.3	93/11	34.56	39.21

NOTE: (PUNPING TEST)
D/W: DYNAMIC WATER LEVEL
S/W: STATIC WATER LEVEL

(STAIC WATER LEVEL)
mBGL: m BELOW THE GROUND LEVEL
mMSL: m ABOVE THE MEAN SEA LEVEL

Table B-II 2.2 Result of Boring Test (Lower Lluta Valley)

< Resultado de Prueba de Sondaje en el Valle de Lluta Bajo>

Well No.	Bore hole Depth (m)	Casing Pipe		Screen Pipe		Geological Conditions of Aquifer			Geophysical Characteristics of Aquifer			
									Well Logging			TEM
		Size (inches)	Total Length (m)	Position (m)	Total Length (m)	Lithology	Formation	Period	Spontaneous Potential (mv)	Resistivity (ohm-m)	Gamma Ray (cps)	Resistivity (ohm-m)
J-A	150	8-5/8"	108.01	59.93 to 101.98	42.05	Sand, Sandy to clayey gravel	Fluvial Deposit	Quaternary	985-1025	15-30	50-70	12-26
J-B	200.4	8-5/8"	126.00	60.05 to 90.10	72.12	Clayey gravel, Sand	Fluvial Deposit	Quaternary	-8.2 to -8.4	15-30	25-50	17-26
				102.10 to 144.17		Fissured Ignimbrite	Oxaya Formation	Tertiary	-8.3 to -8.4	15-30	35-75	17-26
J-1	145	5-1/2"	85.00	31.00 to 91.00	60.00	Gravel, Sandy gravel	Fluvial Deposit	Quaternary	925-935	22-32	50-110	11-23
J-2	225	5-1/2"	136.00	64.02 to 154.01	89.99	Silty to sandy gravel	Fluvial Deposit	Quaternary	1060-1100	20-30	50-100	17-30

Table B-II, 2.3 Result of Pumping Test (Lower Lluta Valley)

< Resultado de Prueba de Bombeo en el Valle de Lluta Bajo>

Well No.	Pumping Data (from Constant Test)					Aquifer Constants			Well Capacity	
	Static Water Level (m)	Pumping Rate (l/s)	Dynamic Water Level (m)	Drawdown (m)	Specific Yield (l/s/m)	Transmissibility (m3/d/m)	Storage Coefficient	Permeability (cm/sec)	Critical Discharge (l/s)	Safe Yield (l/s)
J-A	9.82	15.30	74.51	64.69	0.24	22.72	8.54E-04	6.25E-04	15.30	7.50
J-B	34.56	18.90	65.19	30.63	0.62	310.44	4.72E-04	4.98E-03	20.30	13.00
J-1	21.69	4.40	24.75	3.06	1.44	368.06	6.62E-06	7.01E-03	4.40<	2.25
J-2	35.02	4.92	41.78	6.76	0.73	149.69	6.60E-06	1.93E-03	3.85	2.25

Table B-II, 2.4 Aquifer Constants (Lluta River Area)
<Coeficientos de Acúiferos (Area del Rio Lluta)>

Well No.	Aquifer Constant		Test Method				Average
			Theis		Jacob		
			Constant	Recovery	Constant	Recovery	
J-A	Transmissibility	(m3/s/m)	3.41E-04	1.96E-04	3.31E-04	1.84E-04	2.63E-04
	Storage Coefficient		1.36E-03		3.47E-04		8.54E-04
	Permeability	(cm/sec)	8.11E-04	4.66E-04	7.87E-04	4.38E-04	6.26E-04
J-B	Transmissibility	(m3/s/m)	6.02E-04	2.55E-03	9.02E-03	2.20E-03	3.59E-03
	Storage Coefficient		2.41E-04		7.03E-04		4.72E-04
	Permeability	(cm/sec)	8.35E-04	3.54E-03	1.25E-02	3.05E-03	4.98E-03
J-1	Transmissibility	(m3/s/m)	4.03E-03	4.56E-03	4.16E-03	4.29E-03	4.26E-03
	Storage Coefficient		6.62E-06		6.86E-12		3.31E-06
	Permeability	(cm/sec)	6.72E-03	7.60E-03	6.93E-03	7.15E-03	7.10E-03
J-2	Transmissibility	(m3/s/m)	1.33E-03	2.24E-03	1.12E-03	2.24E-03	1.73E-03
	Storage Coefficient		1.59E-06		1.16E-05		6.60E-06
	Permeability	(cm/sec)	1.48E-03	2.49E-03	1.24E-03	2.49E-03	1.93E-03

Table B-II, 2.5 Estimation of Groundwater Storage

<Estimación de Reservas de Agua Subterránea>

DEPTH (m BSWL)	ZONE 1 (SECT.A-B) (x million m3)		ZONE2 (SECT. B-C) (x million m3)		ZONE3 (SECT. C-D) (x million m3)		ZONE4 (SECT. D-E) (x million m3)		ZONE5 (SECT. E-F) (x million m3)		TOTAL (SECT. A-F) (x million m3)	
		SUM		SUM		SUM		SUM		SUM		SUM
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	1.52	1.52	2.60	2.60	2.75	2.75	2.01	2.01	5.68	5.68	14.56	14.56
20	1.56	3.08	2.45	5.04	2.46	5.21	1.78	3.79	4.94	10.62	13.19	27.75
30	1.03	4.12	2.42	7.46	2.59	7.81	1.76	5.55	4.62	15.24	12.43	40.17
40	1.03	5.15	2.30	9.76	2.48	10.28	1.69	7.23	4.49	19.73	11.98	52.16
50	1.44	6.59	2.24	12.00	2.35	12.63	1.63	8.86	4.16	23.89	11.81	63.97
80	1.10	7.69	2.15	14.15	2.28	14.91	1.51	10.37	3.84	27.73	10.88	74.84
70	0.78	8.47	2.10	16.25	2.27	17.19	1.42	11.78	2.52	30.24	9.08	83.93
80	1.29	9.76	1.84	18.08	1.98	19.17	1.09	12.87	1.09	31.33	7.29	91.21
90	1.16	10.92	1.60	19.68	1.79	20.97	0.71	13.58	0.00	31.33	5.26	96.48
100	1.11	12.03	1.48	21.16	1.08	22.05	0.18	13.78	0.00	31.33	3.85	100.32
110	0.98	13.01	1.23	22.39	0.76	22.81	0.00	13.76	0.00	31.33	2.97	103.29
120	0.83	13.83	0.96	23.35	0.70	23.51	0.00	13.76	0.00	31.33	2.48	105.78
130	0.45	14.28	0.22	23.57	0.20	23.71	0.00	13.76	0.00	31.33	0.87	106.65
140	0.22	14.51	0.00	23.57	0.00	23.71	0.00	13.76	0.00	31.33	0.22	106.87
TOTAL	14.51		23.57		23.71		13.76		31.33		106.87	

NOTE: "BSWL" means below the static water level in 1993.

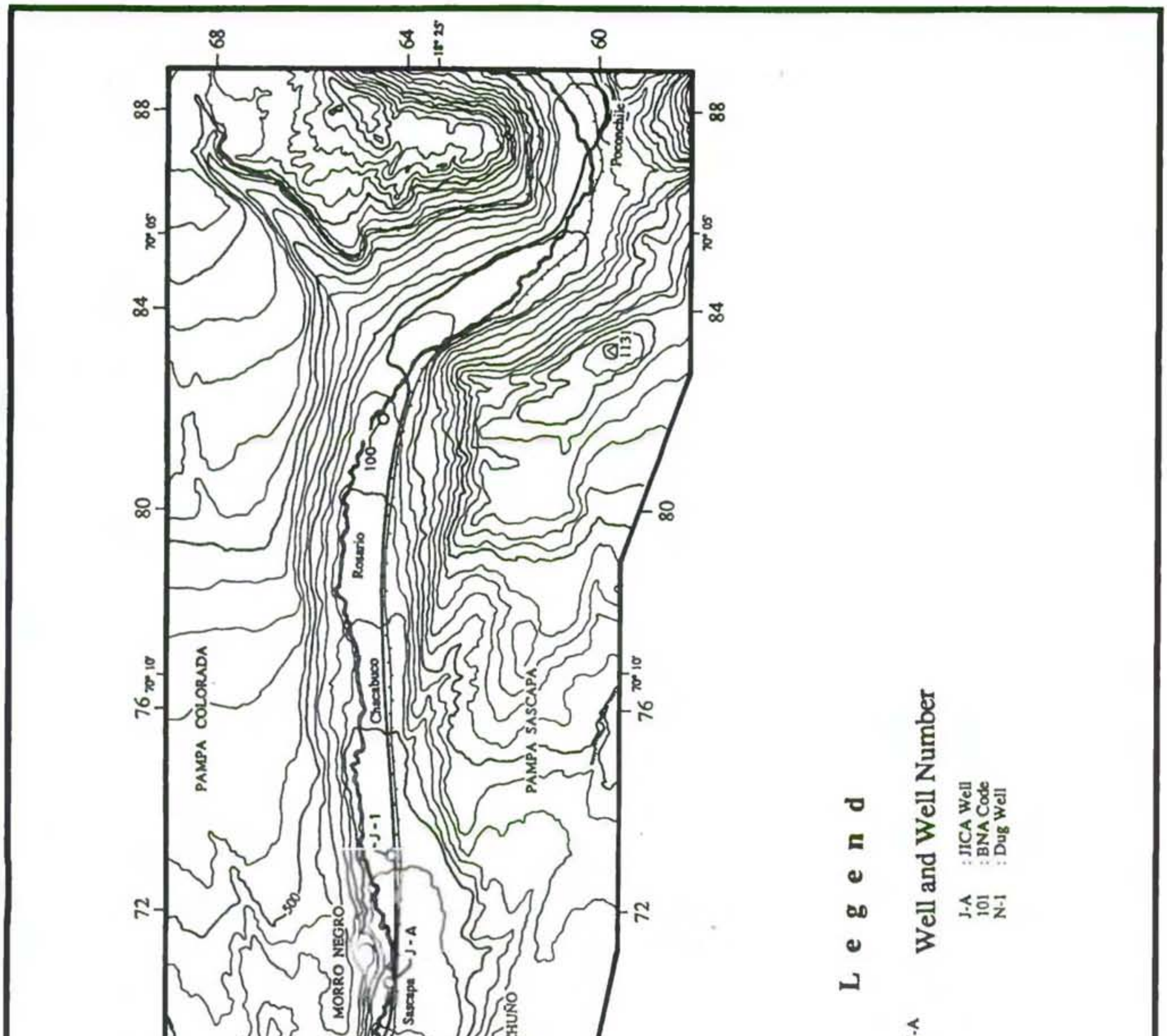

Fig. B-II, 2.1 Well Location (Lluta Valley)

< Ubicación de Pozos (LlutaValley)>

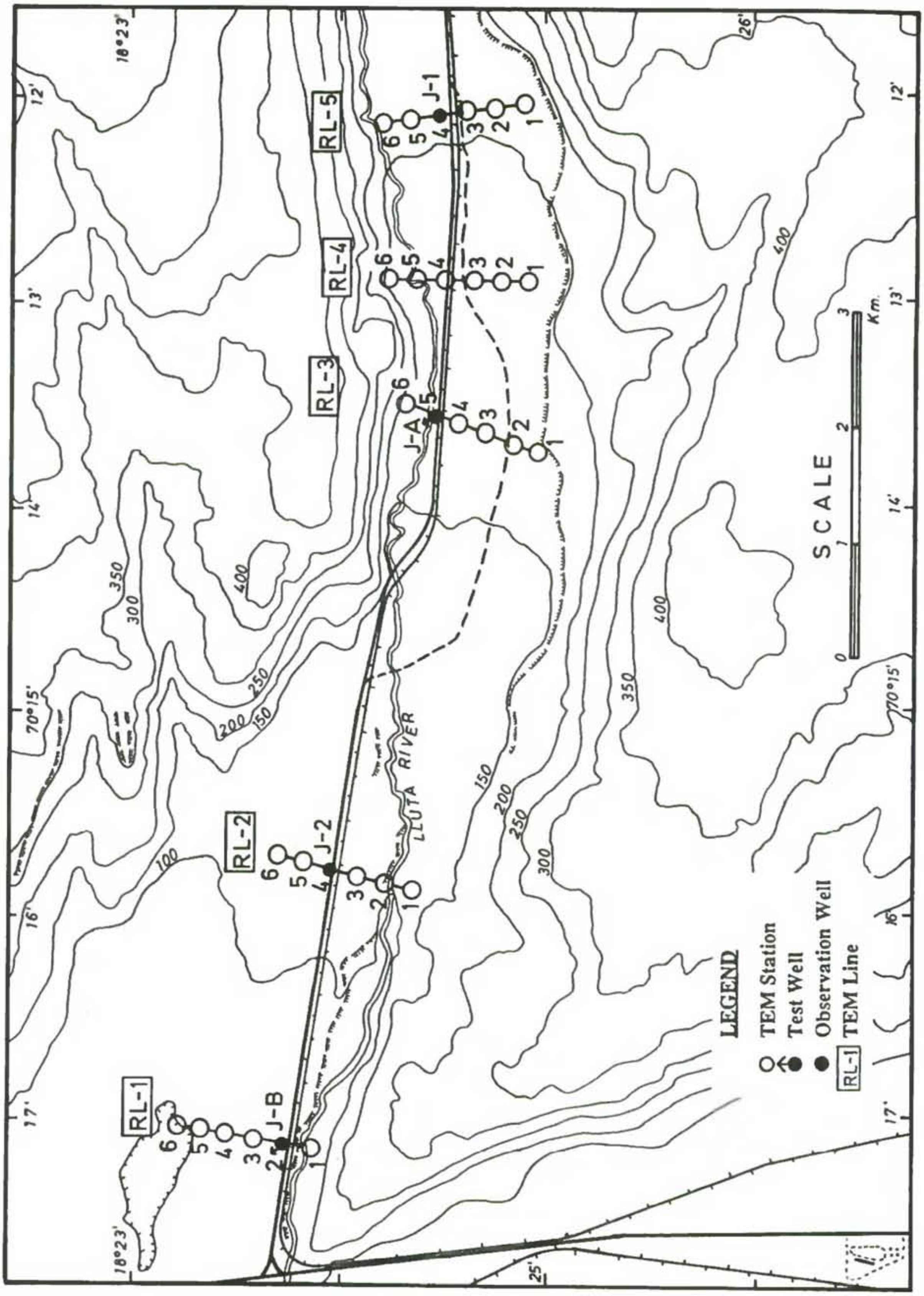

Fig. B-II, 2.2 Location of TEM Station and Test/Observation Well in LLuta River Area

<Ubicación de las Estaciones TEM y Pozos de Prueba y Observación en el Area del Río Lluta>

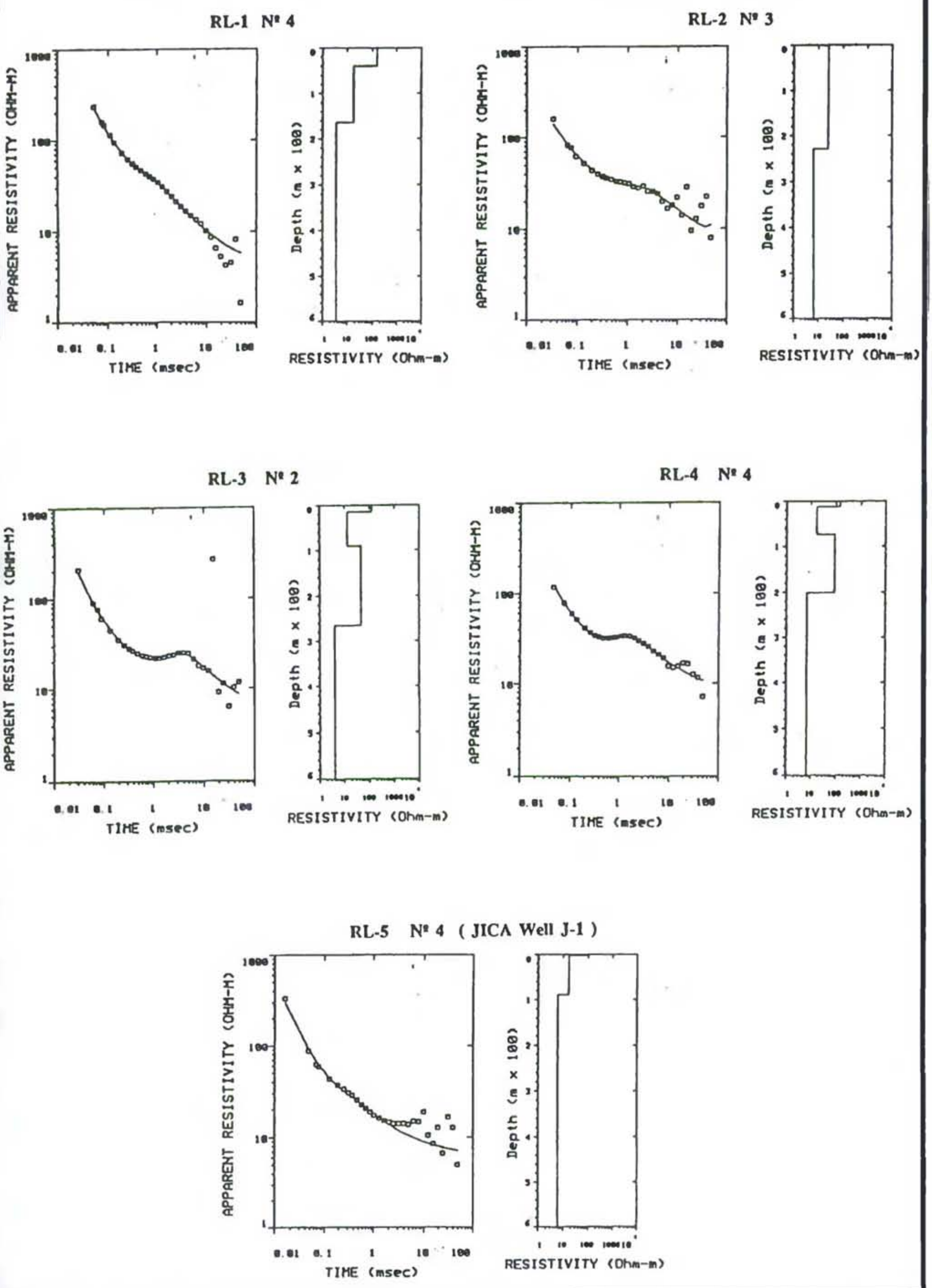

Fig. B-II, 2.3 Measured Apparent Resistivity Curves and Inverted Geoelectrical Section in Lluta River Area

<Curvas de resistividad Aparente y Secciones Geoeléctricas Invertidas en el Area del Río Lluta>

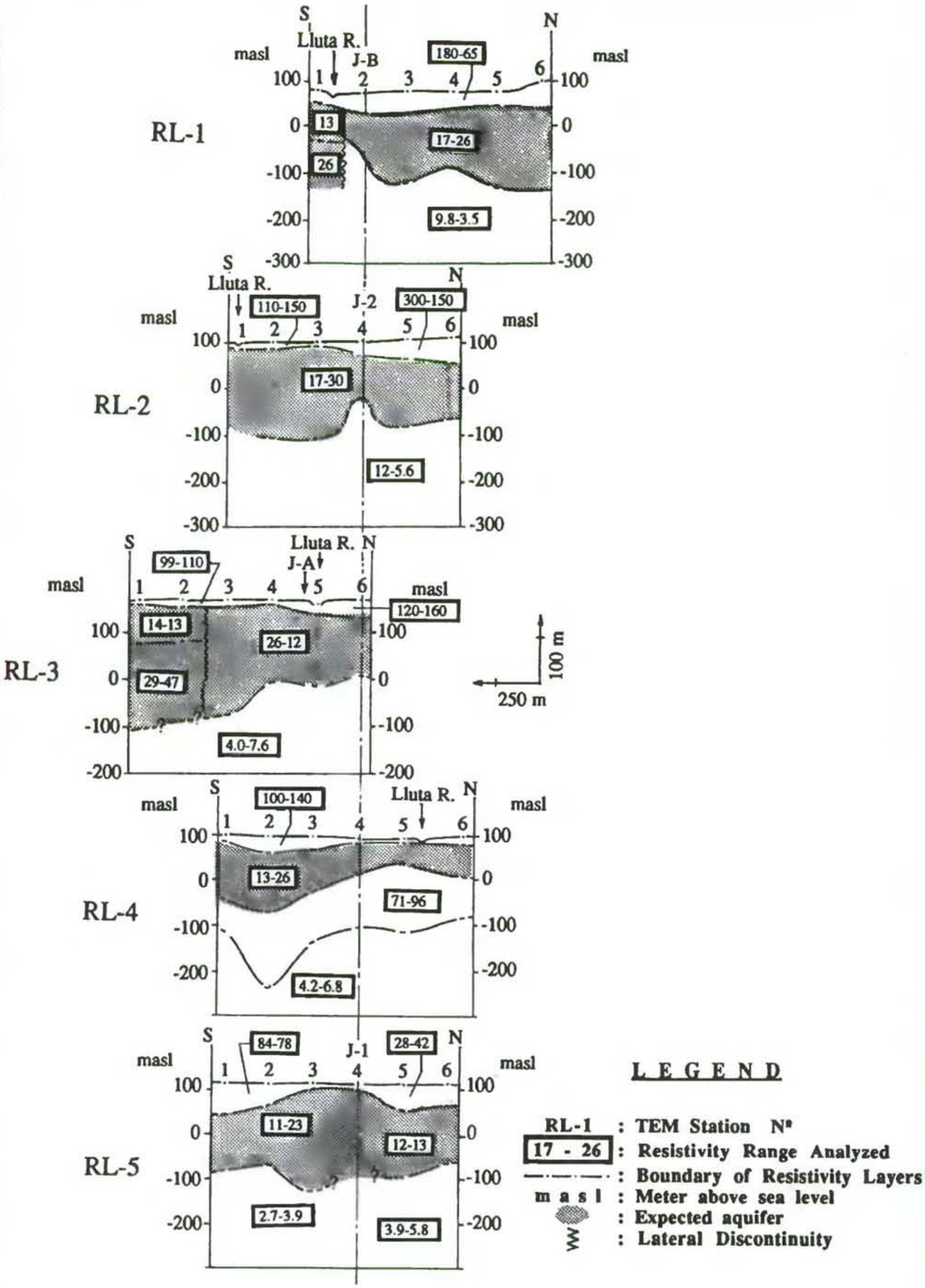

Fig. B-II, 2.4 Geoelectric Profiles Constructed from all TEM Soundings in Lluta River Area
<Perfiles Geoeléctricos Construídos de todos los sondeos TEM en el Area del Río Lluta>

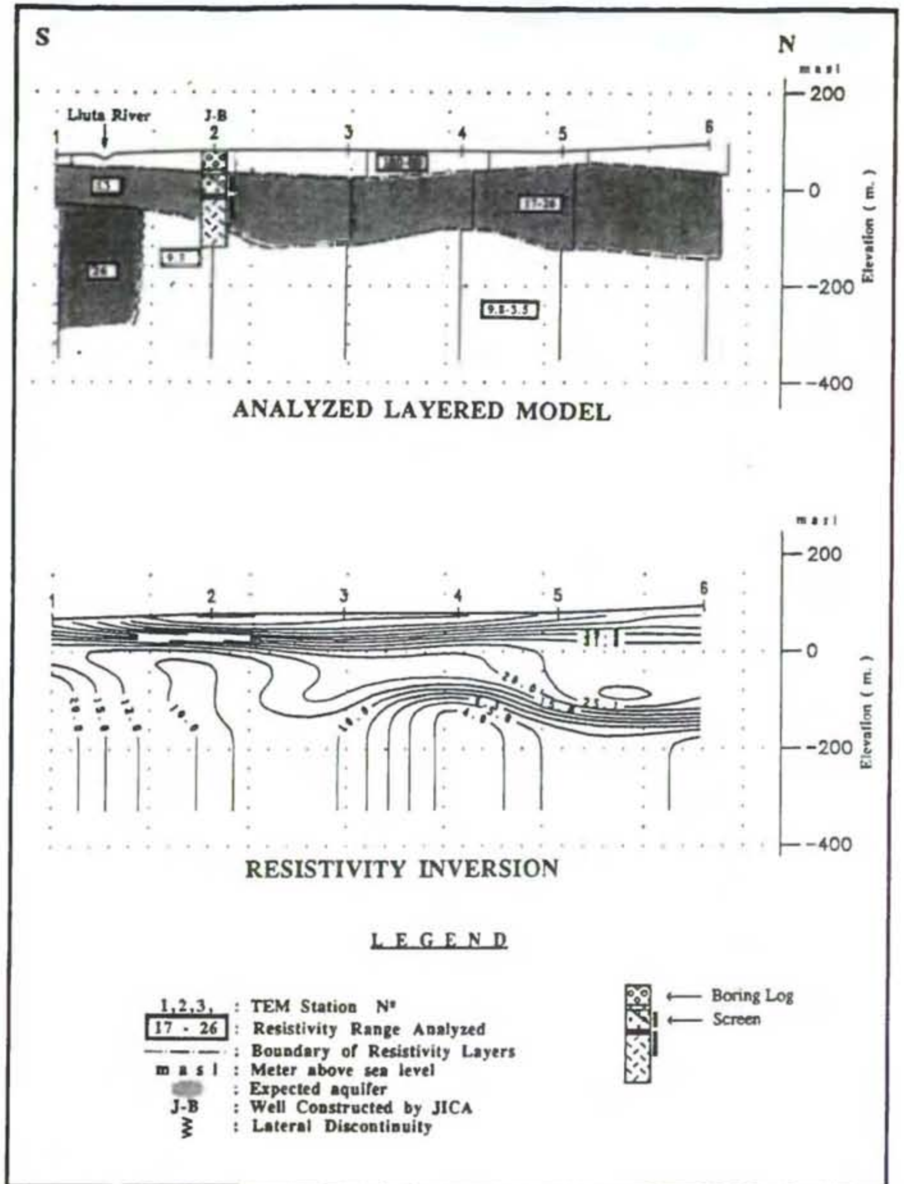

Fig. B-II, 2.5 Analized Resistivity Profile of RL-1 in Lluta River Area

< Perfil de Resistividad Analizado del RL-1 en el Area del Río Lluta>

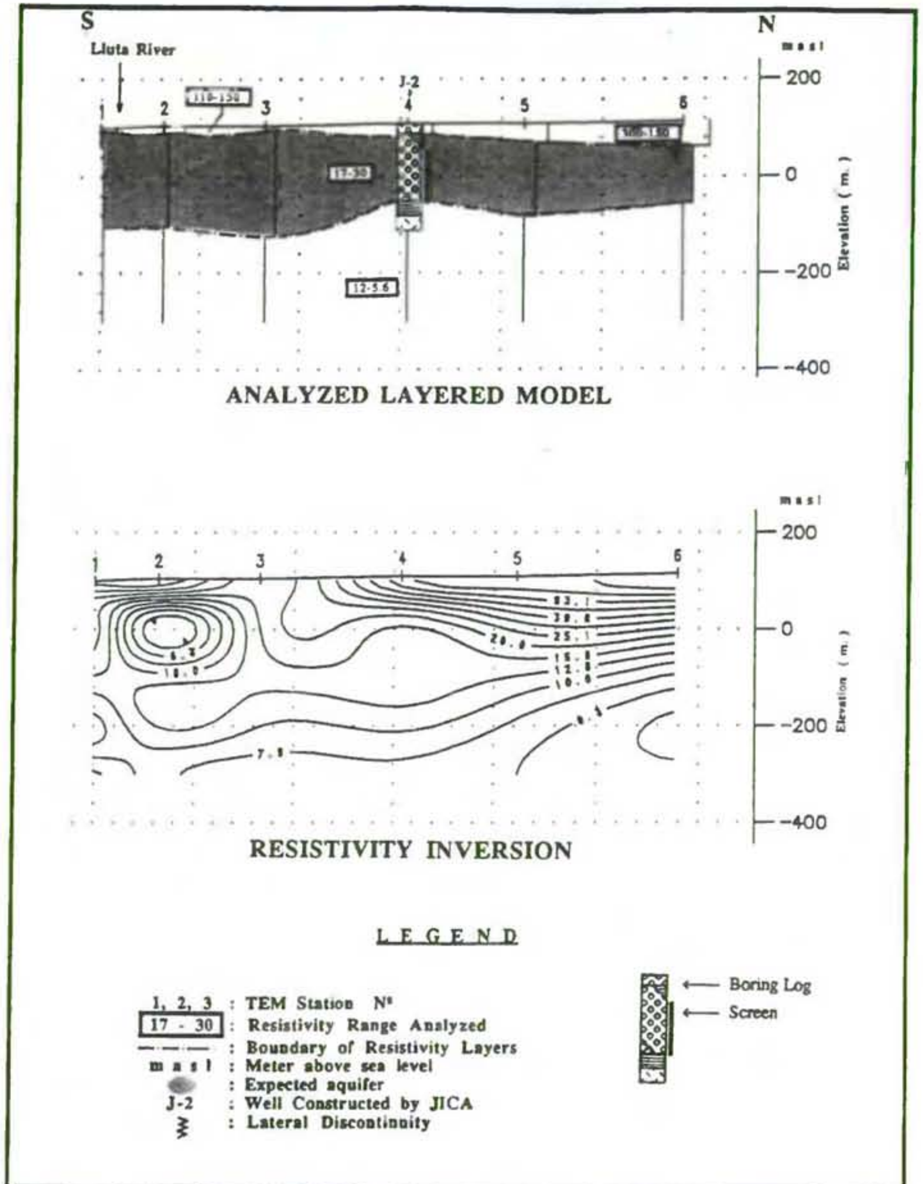

Fig. B-II, 2.6 Analized Resistivity Profile of RL-2 in Lluta River Area

< Perfil de Resistividad Analizado del RL-2 en el Area del Río Lluta>

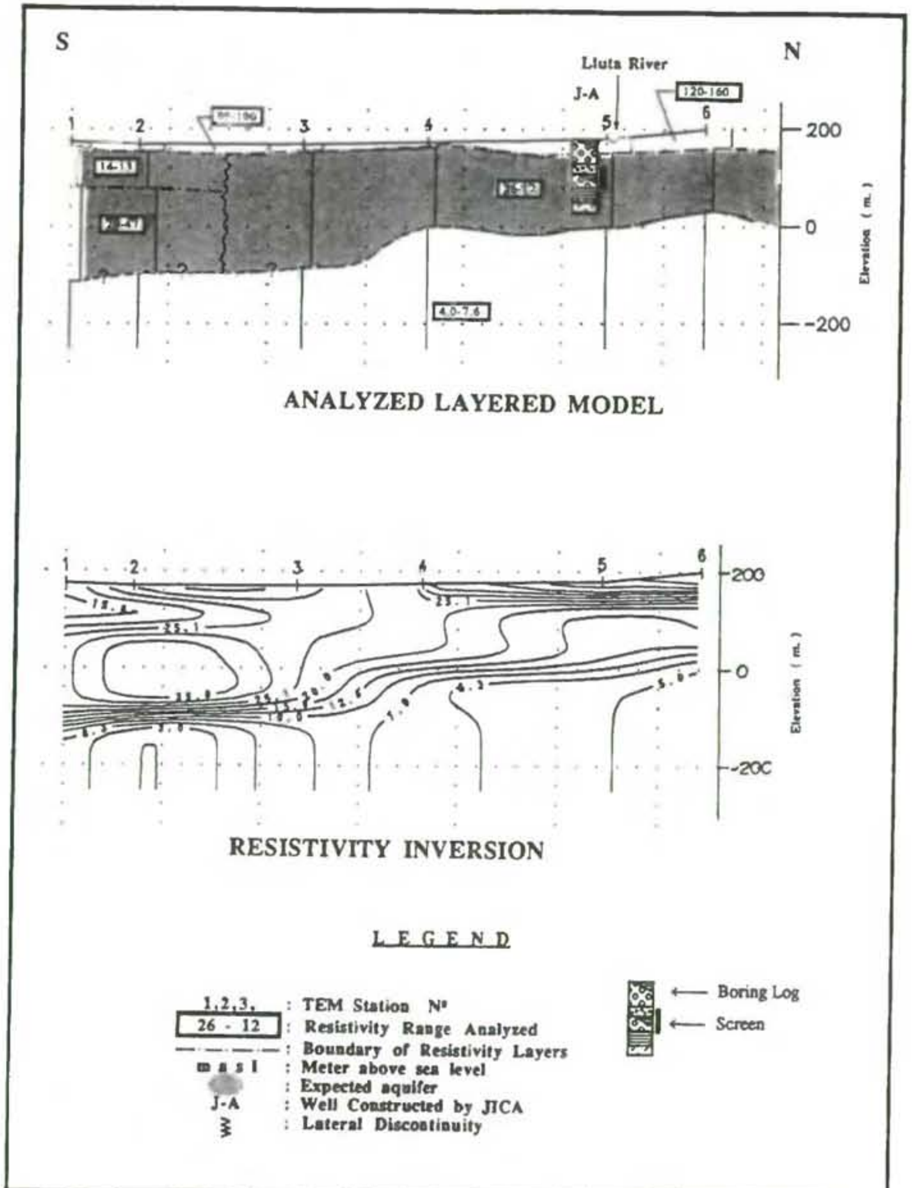

Fig. B-II, 2.7 Analized Resistivity Profile of RL-3 in Lluta River Area

< Perfil de Resistividad Analizado del RL-3 en el Area del Río Lluta>

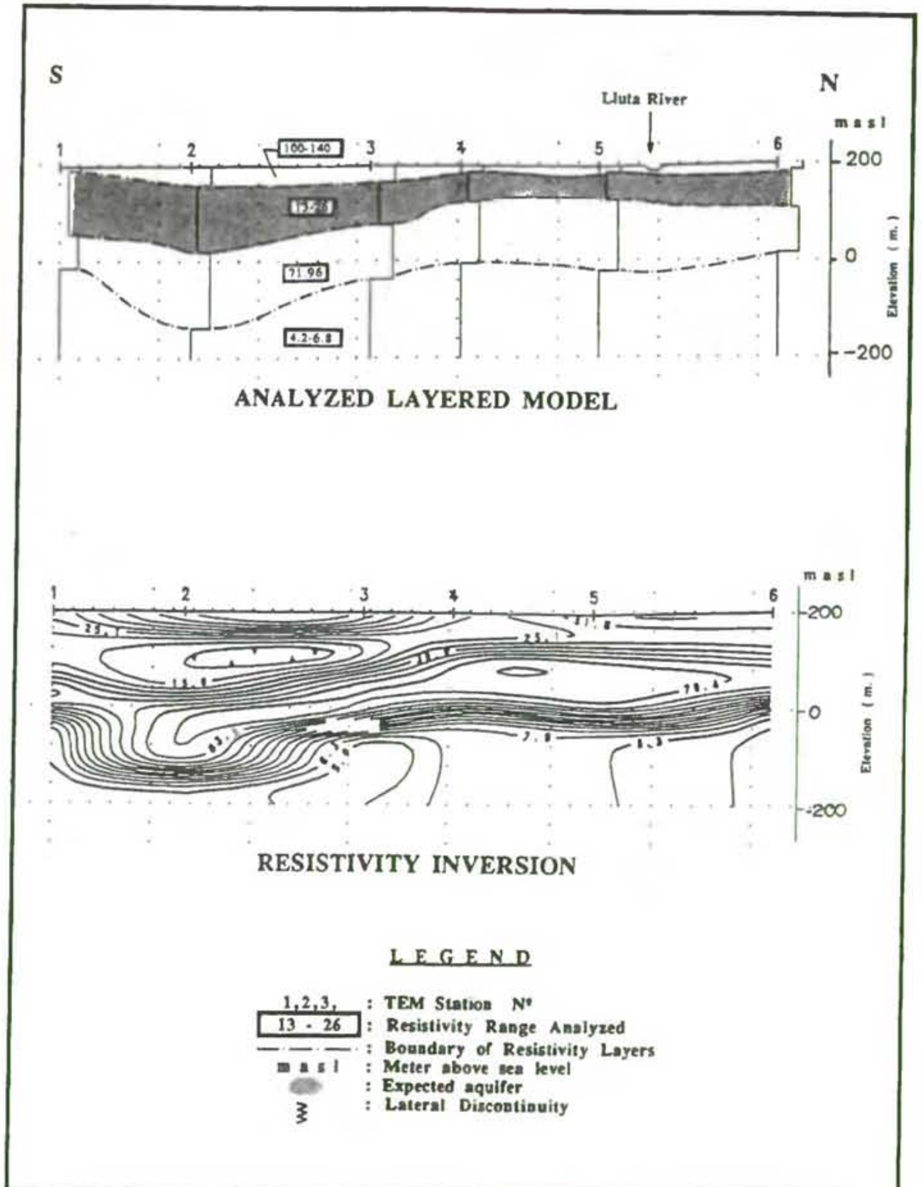

Fig. B-II, 2.8 Analized Resistivity Profile of RL-4 in Lluta River Area

< Perfil de Resistividad Analizado del RL-4 en el Area del Río Lluta>

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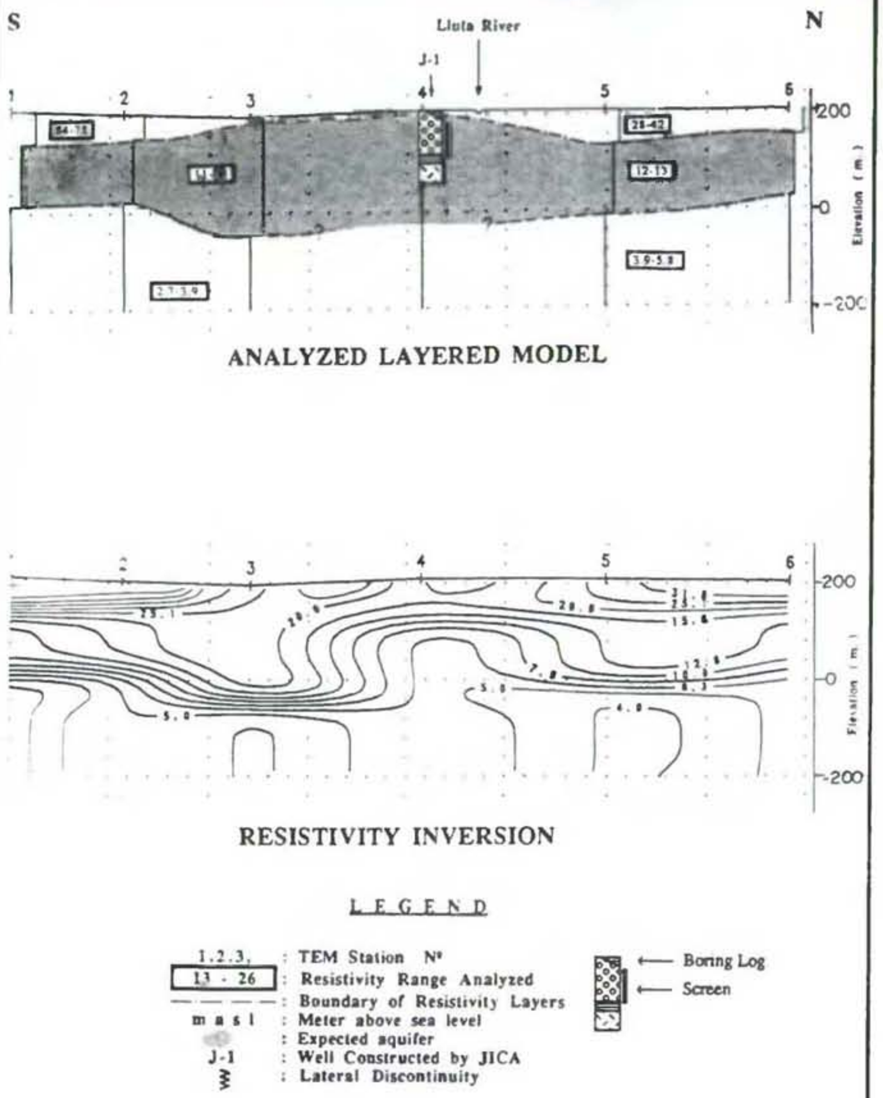

Fig. B-II, 2.9 Analized Resistivity Profile of RL-5 in Lluta River Area

< Perfil de Resistividad Analizado del RL-5 en el Area del Río Lluta>

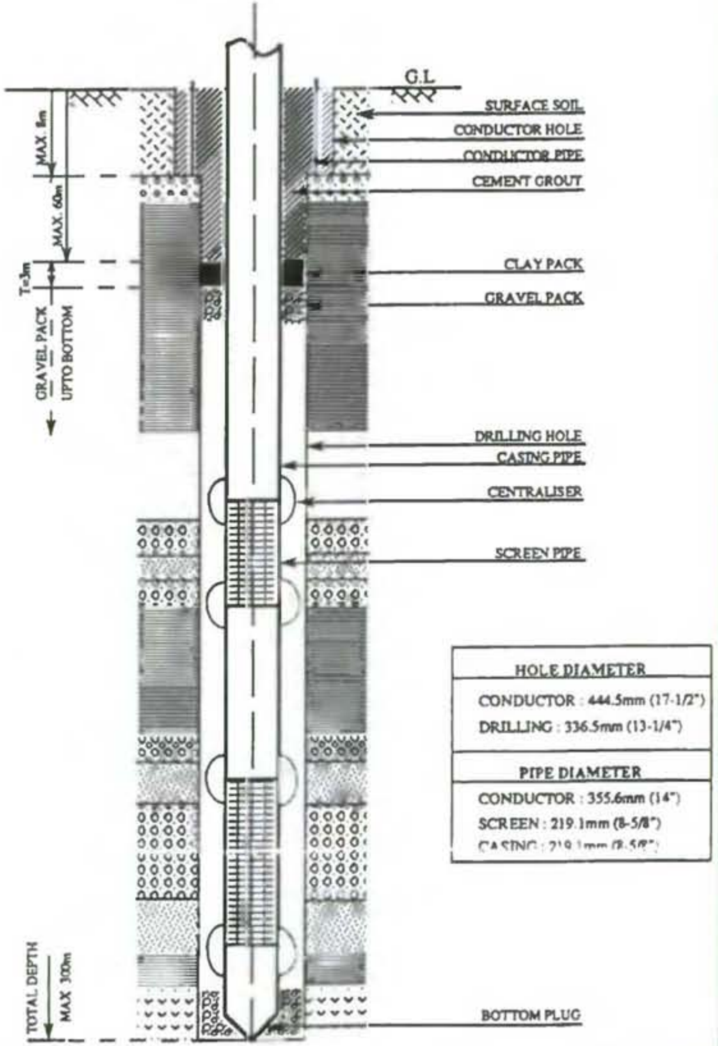

Fig. B-II, 2.10 Standard Design of Test Well
<Diseño Estándar de Pozo de Prueba>

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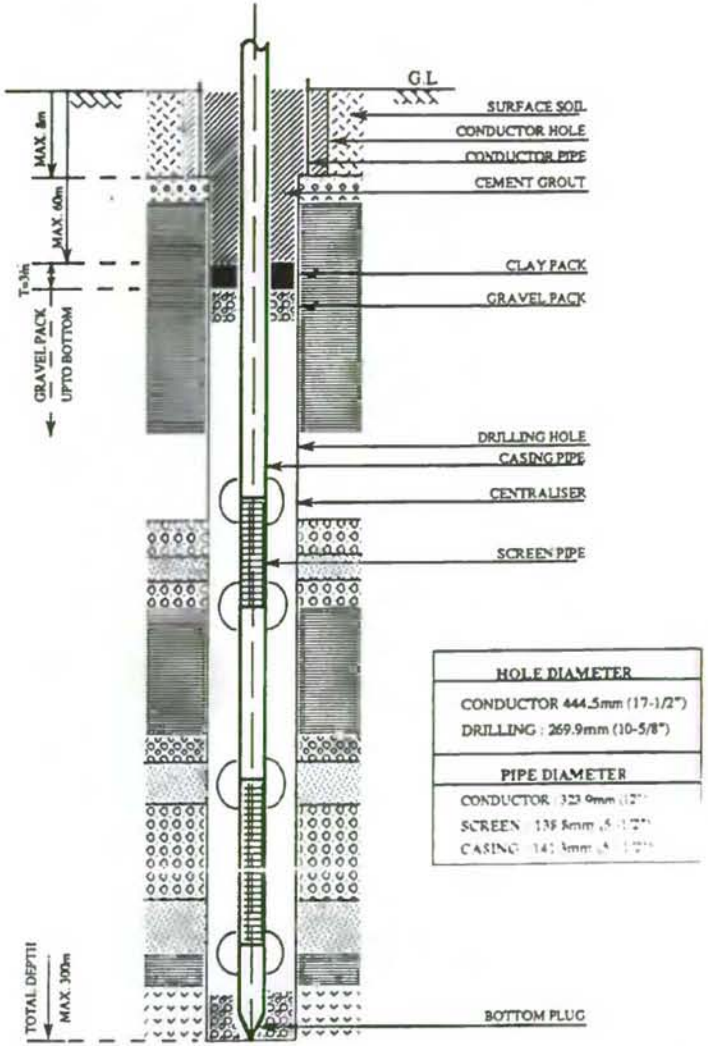

Fig. B-II, 2.11 Standrd Design of Observation Well
<Diseño Estándar de Pozo de Observación>

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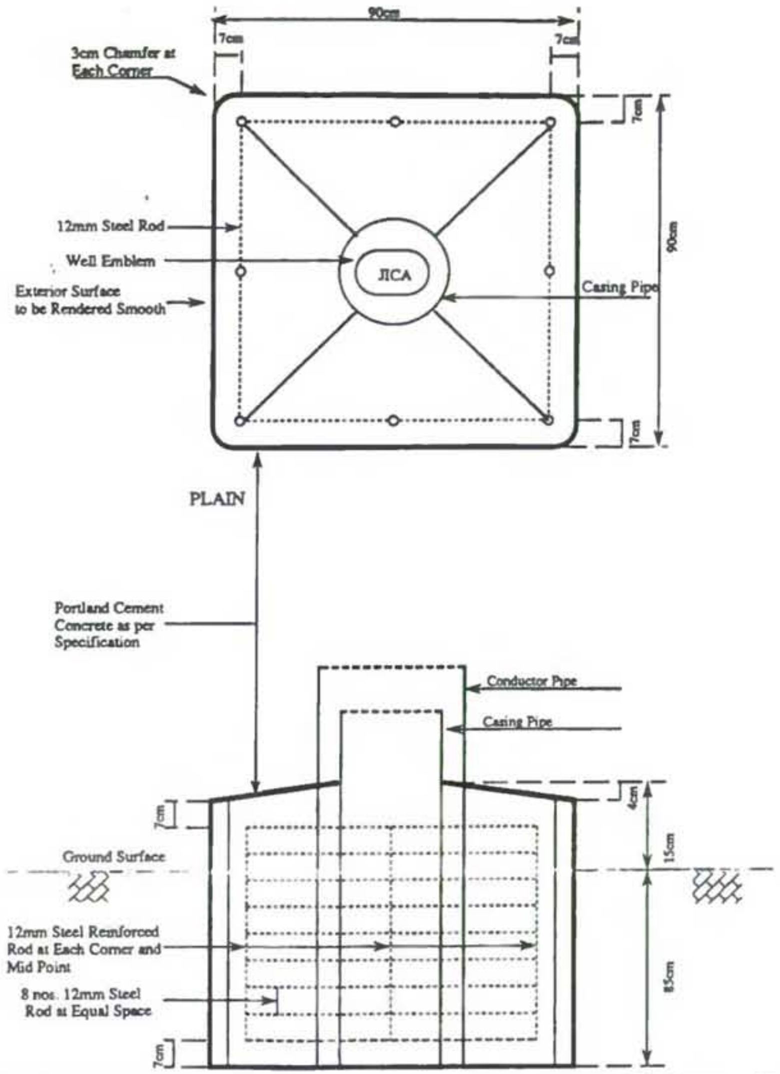

Fig. B-II, 2.12 Concrete Well Head Block for Test Well
<Bloque de Concreto de la Cabeza de Pozo para Pozos de Prueba>

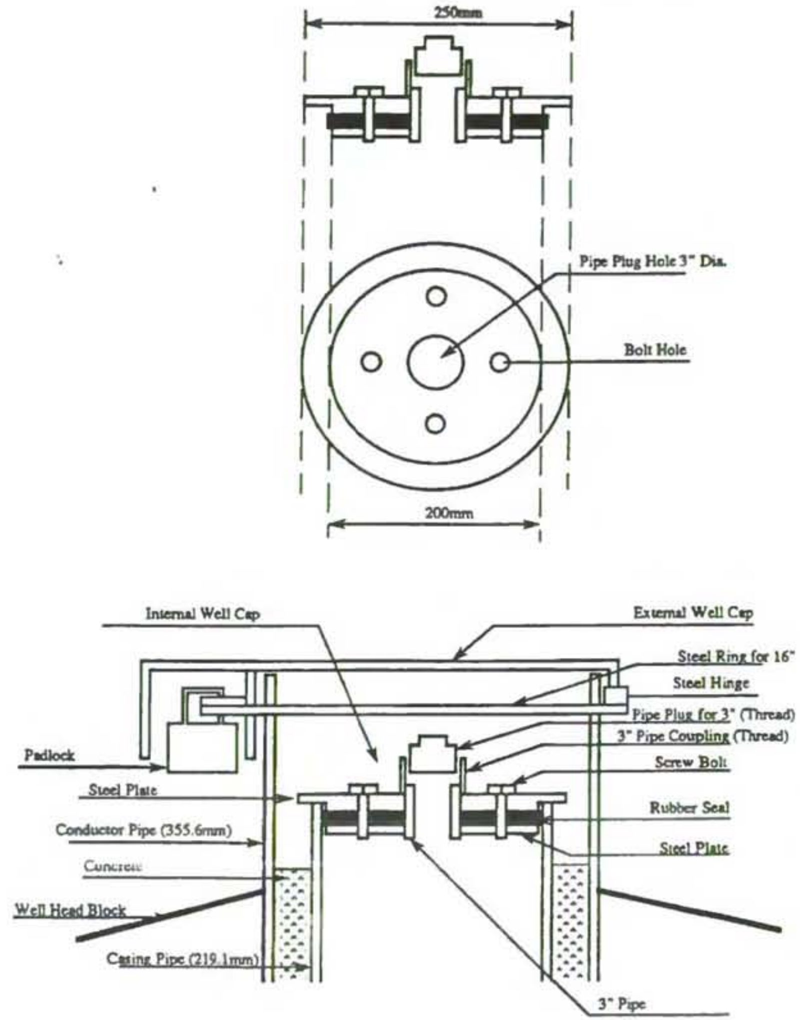

Fig. B-II, 2.13 Well Cap for Test Well
<Tapa para Pozo de Prueba>

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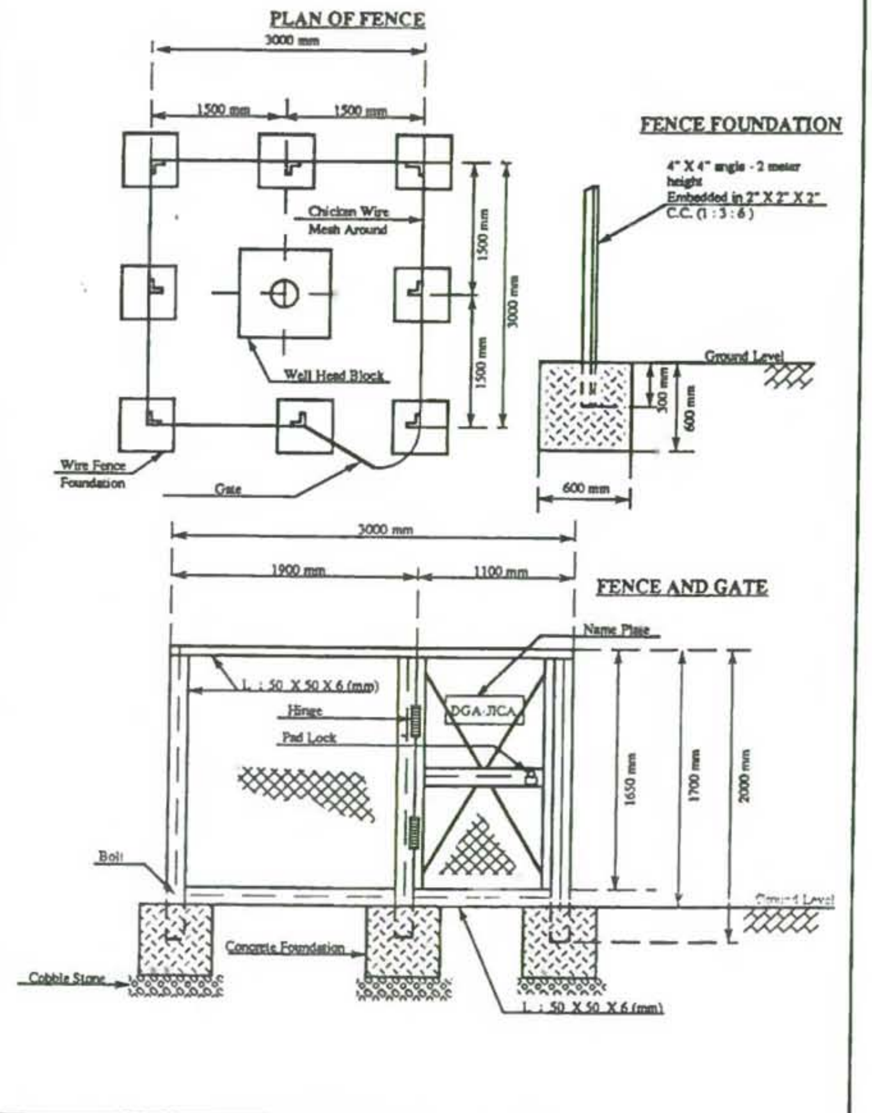

Fig. B-II, 2.14 Fence for Test and Observation Wells
<Cerco para Pozos de Prueba y Observación>

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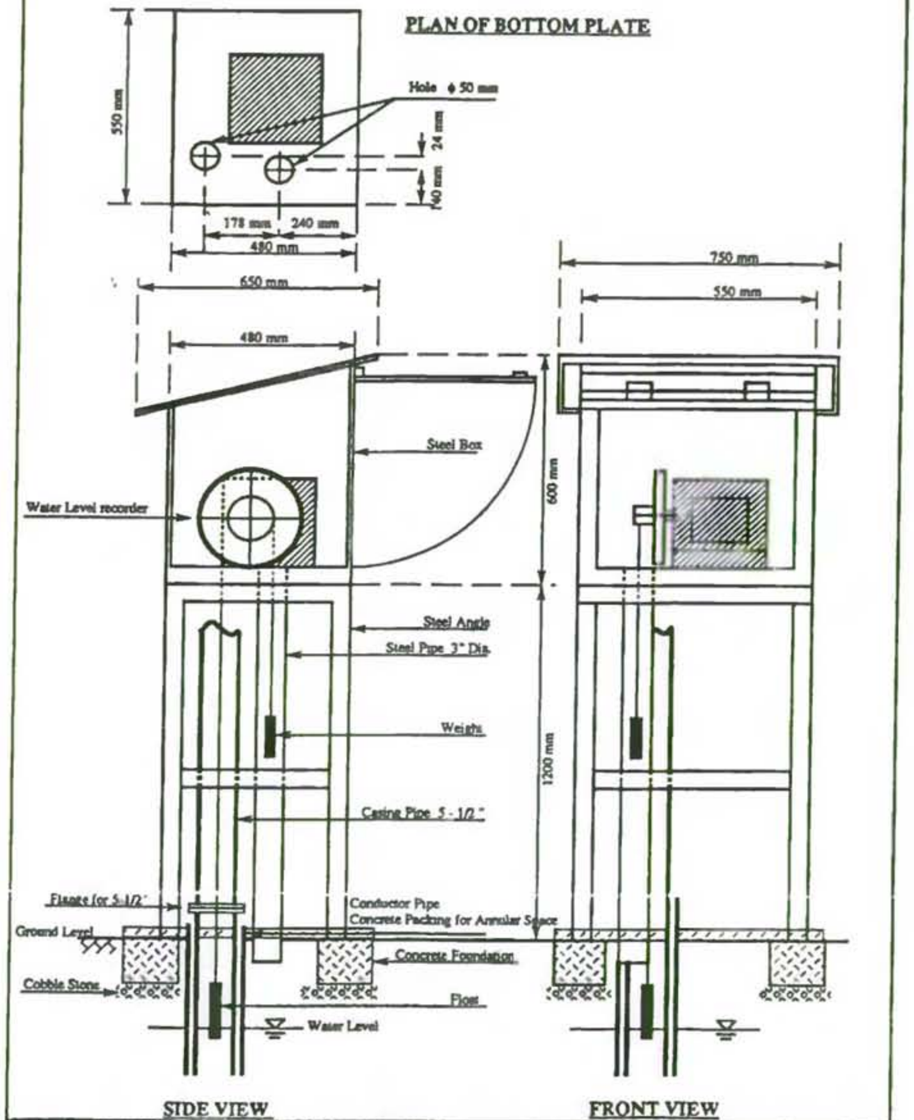

Fig. B-II, 2.15 **Water Level Recorder for Observation Well**
<Registrador de Nivel de Agua para Pozo de Observación>

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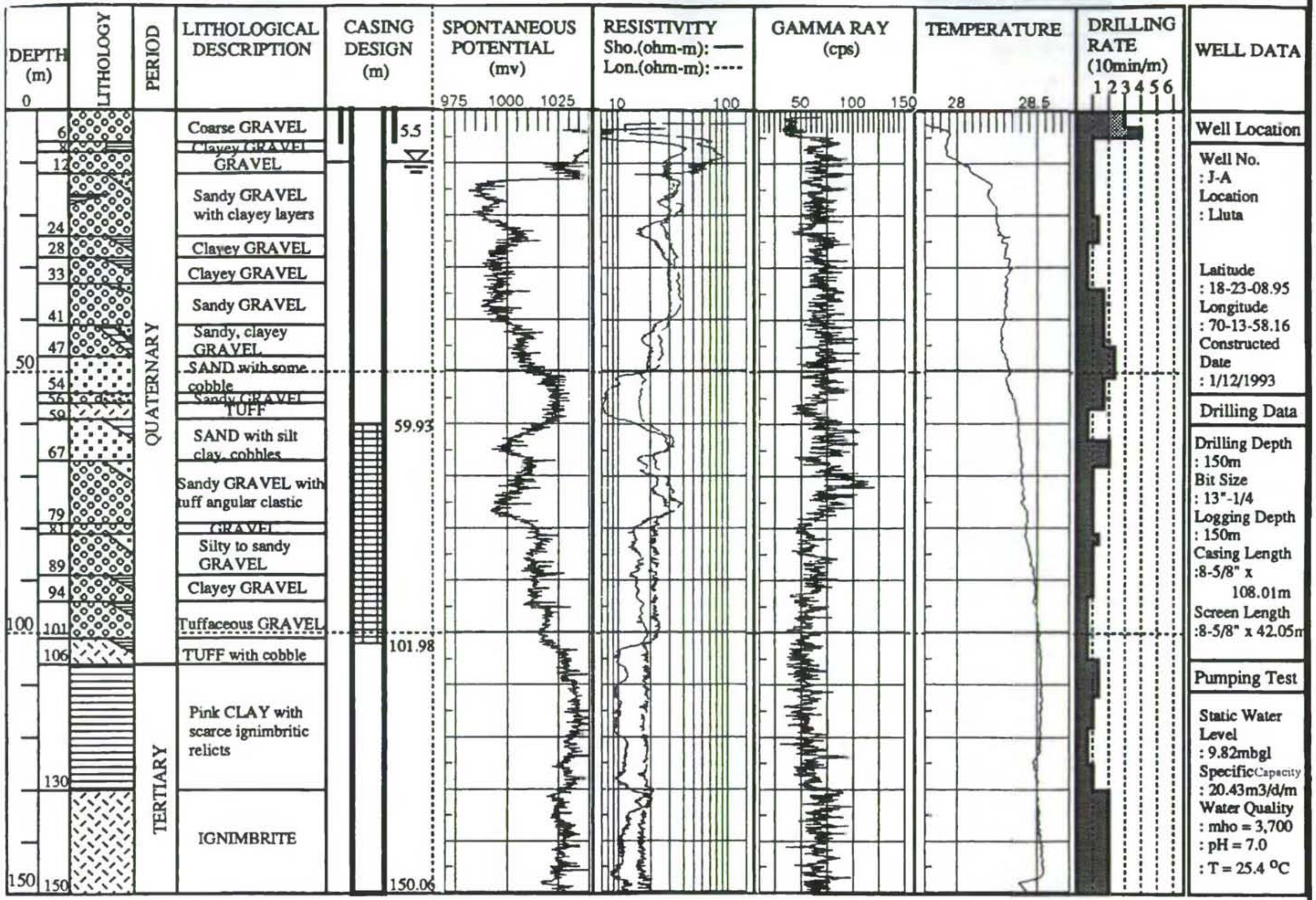
Fig. B-II, 2.16 Well Data for J-A

< Información del Pozo J-A >



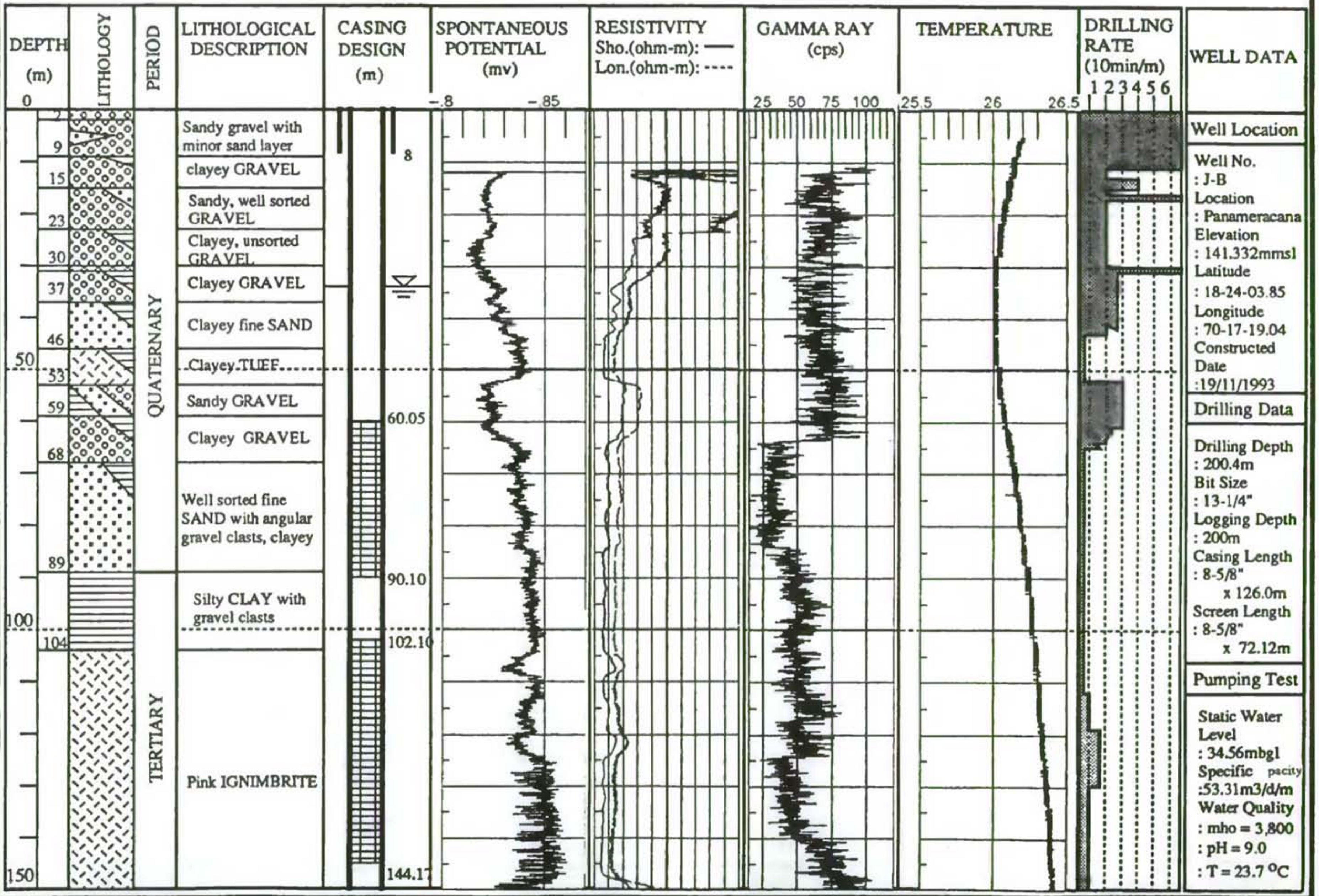
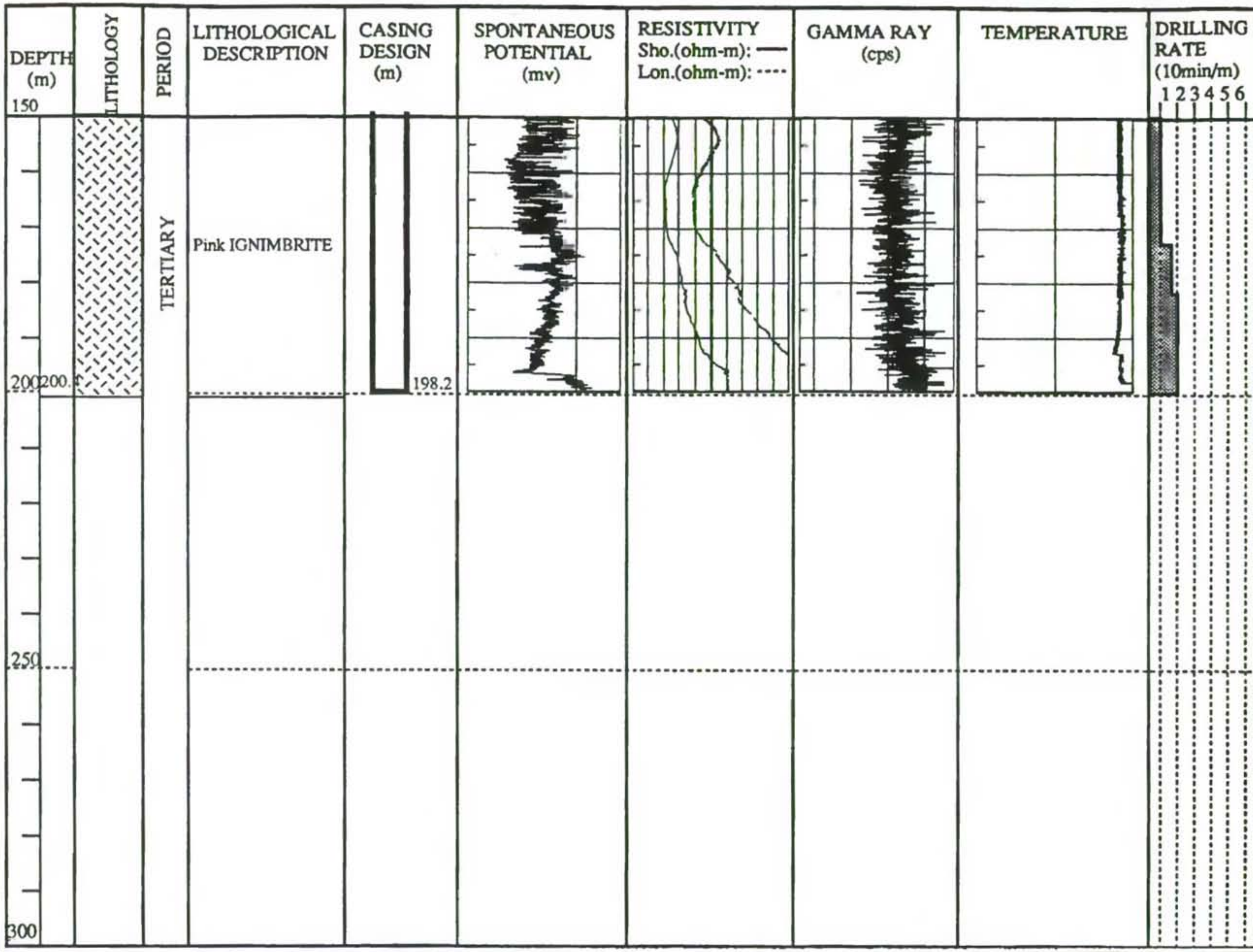


Fig. B-II, 2.17 Well Data for J-B (Sheet No.1)
< *Información del Pozo J-B (Hoja № 1)* >

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

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



WELL DATA

Well Location

Well No.
: J-B
Location
: Panameracana
Elevation
: 141.332mmsl
Latitude
: 18-24-03.85
Longitude
: 70-17-19.04
Constructed Date
:19/11/1993

Drilling Data

Drilling Depth
: 200.4m
Bit Size
: 13-1/4"
Logging Depth
: 200m
Casing Length
: 8-5/8" x 126.0m
Screen Length
: 8-5/8" x 72.12m

Pumping Test

Static Water Level
: 34.56mbgl
Specific Capacity
:53.31m3/d/m
Water Quality
: mho = 3,800
: pH = 9.0
: T = 23.7 °C

Fig. B-II, 2.18 Well Data for J-1

<Información del Pozo J-1>

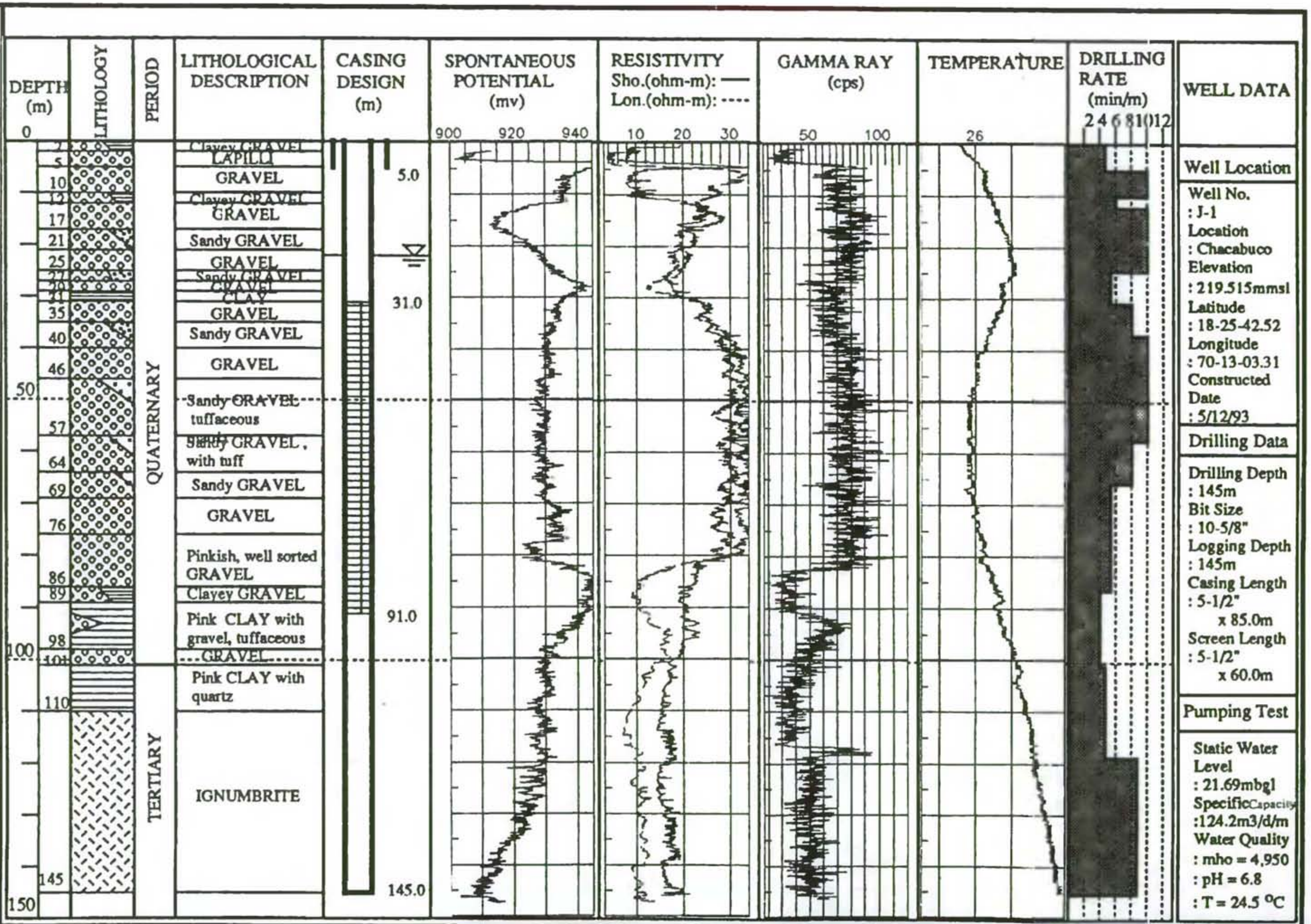
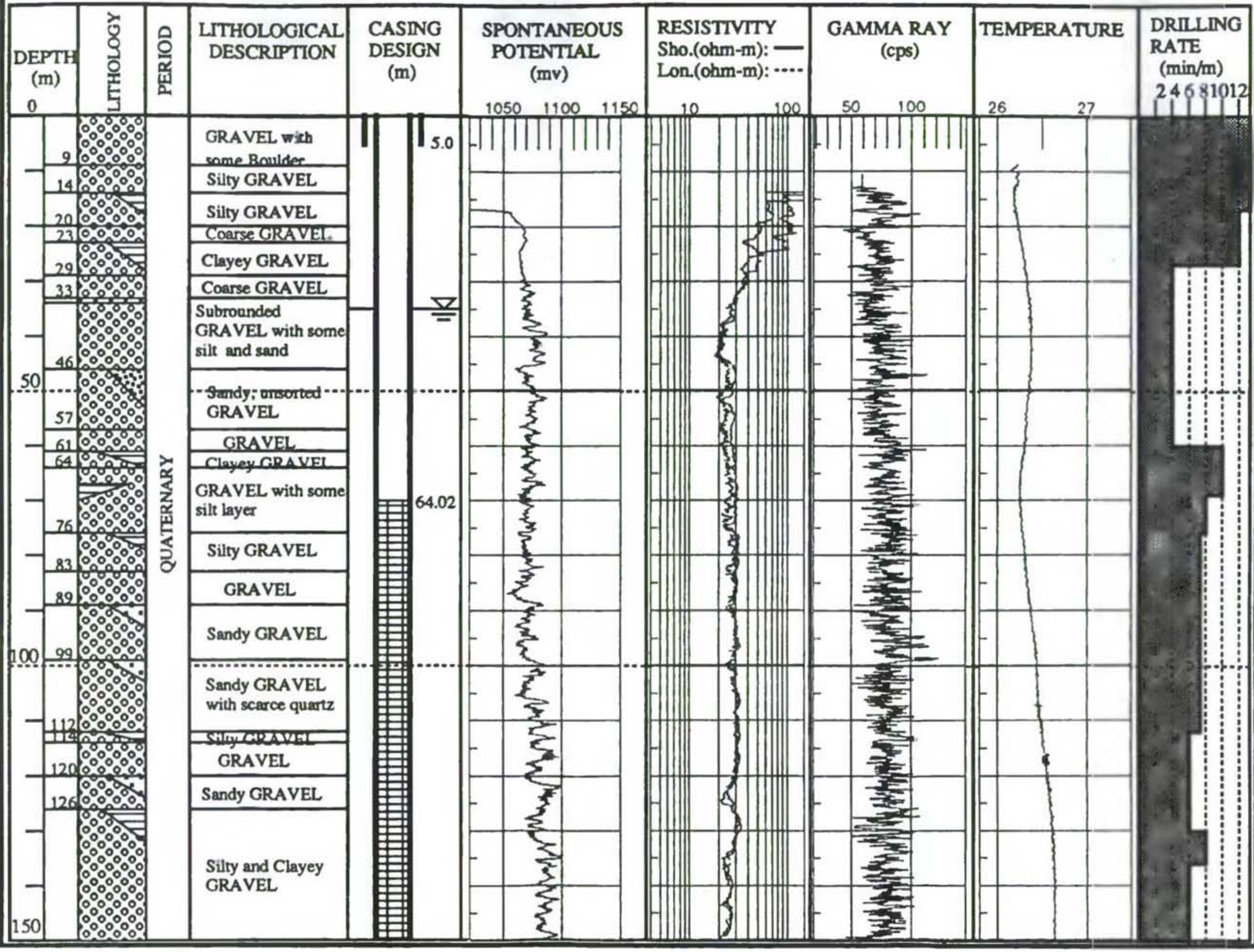


Fig. B-II, 2.19 Well Data for J-2 (Sheet No. 1)

< Información del Pozo J-2 (Hoja Nº 1) >



WELL DATA

Well Location

Well No.
: J-2
Location
: Lluta
Elevation
: 73.907mmsl
Latitude
: 18-23-40.05
Longitude
: 70-16-06.17
Constructed Date
: 27/11/93

Drilling Data

Drilling Depth
: 225m
Bit Size
: 10-5/8"
Logging Depth
: 225m
Casing Length
: 5-1/2" x 136.00m
Screen Length
: 5-1/2" x 89.99m

Pumping Test

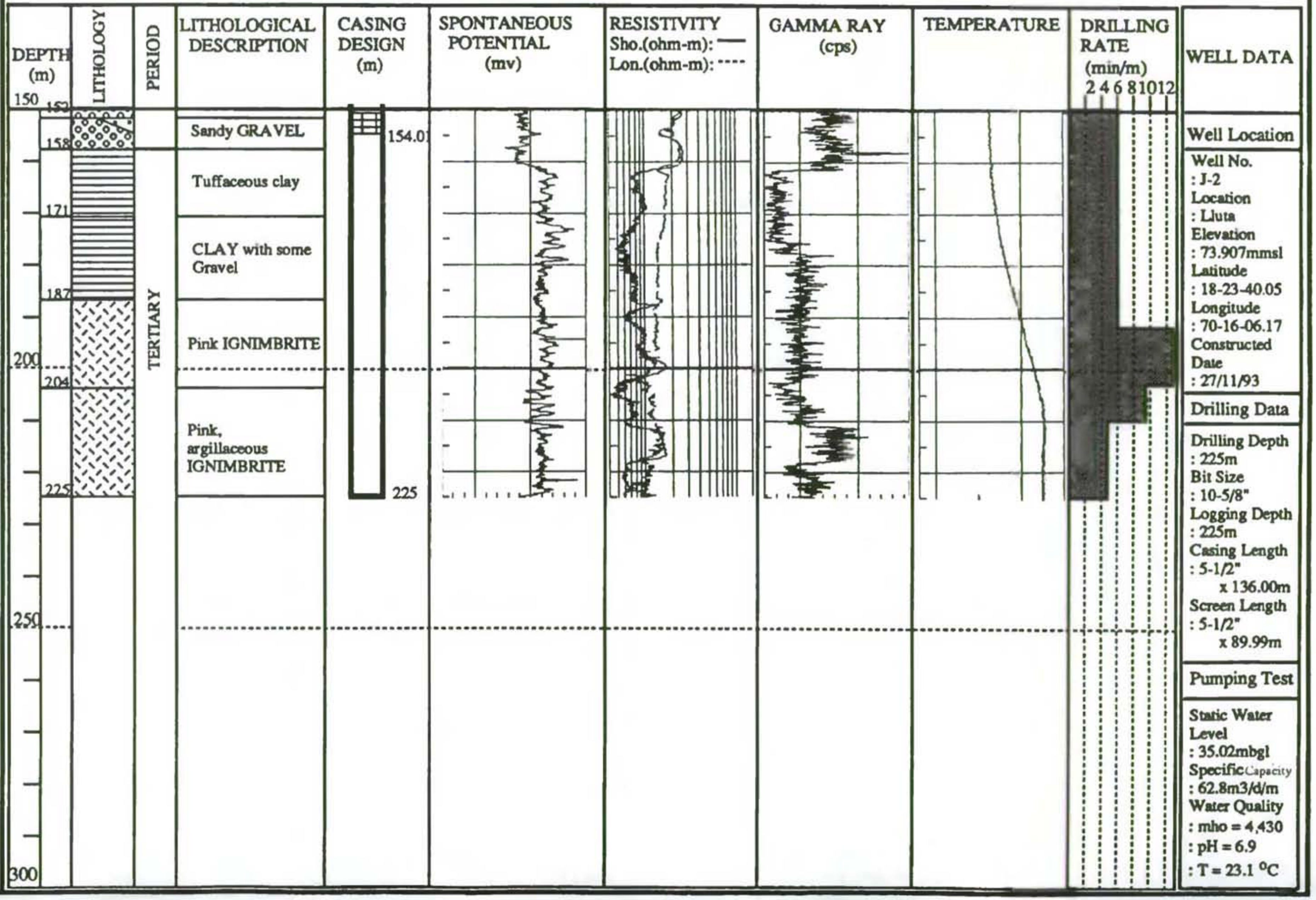
Static Water Level
: 35.02mbgl
Specific Capacity
: 62.8m3/d/m
Water Quality
: mho = 4,430
: pH = 6.9
: T = 23.1 °C

THE STUDY ON THE DEVELOPMENT OF WATER RESOURCES IN NORTHERN CHILE

JICA

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

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



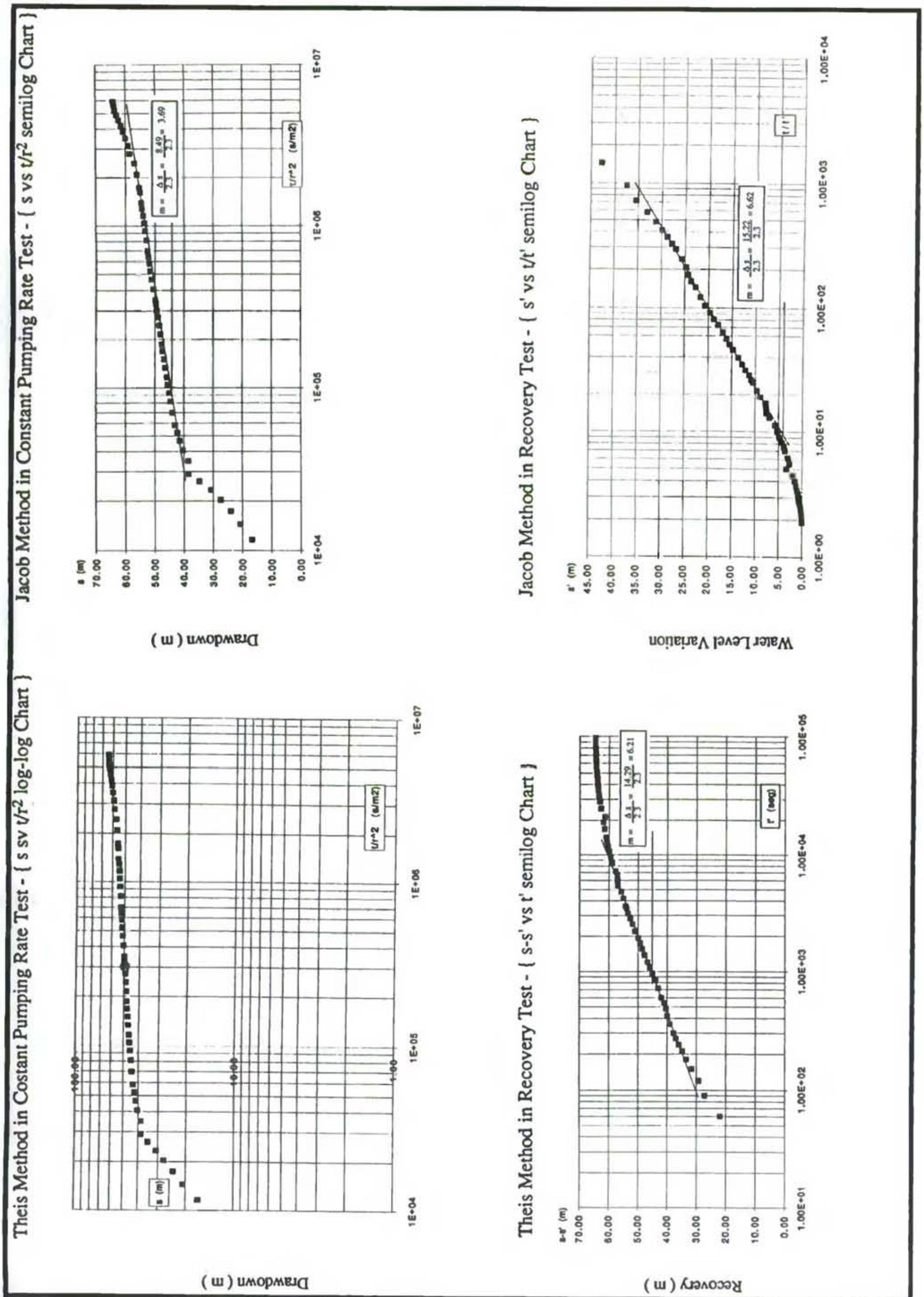


Fig. B-II, 2.20 Graphs for Theis and Jacob Method Analysis (Well No.J-A)

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

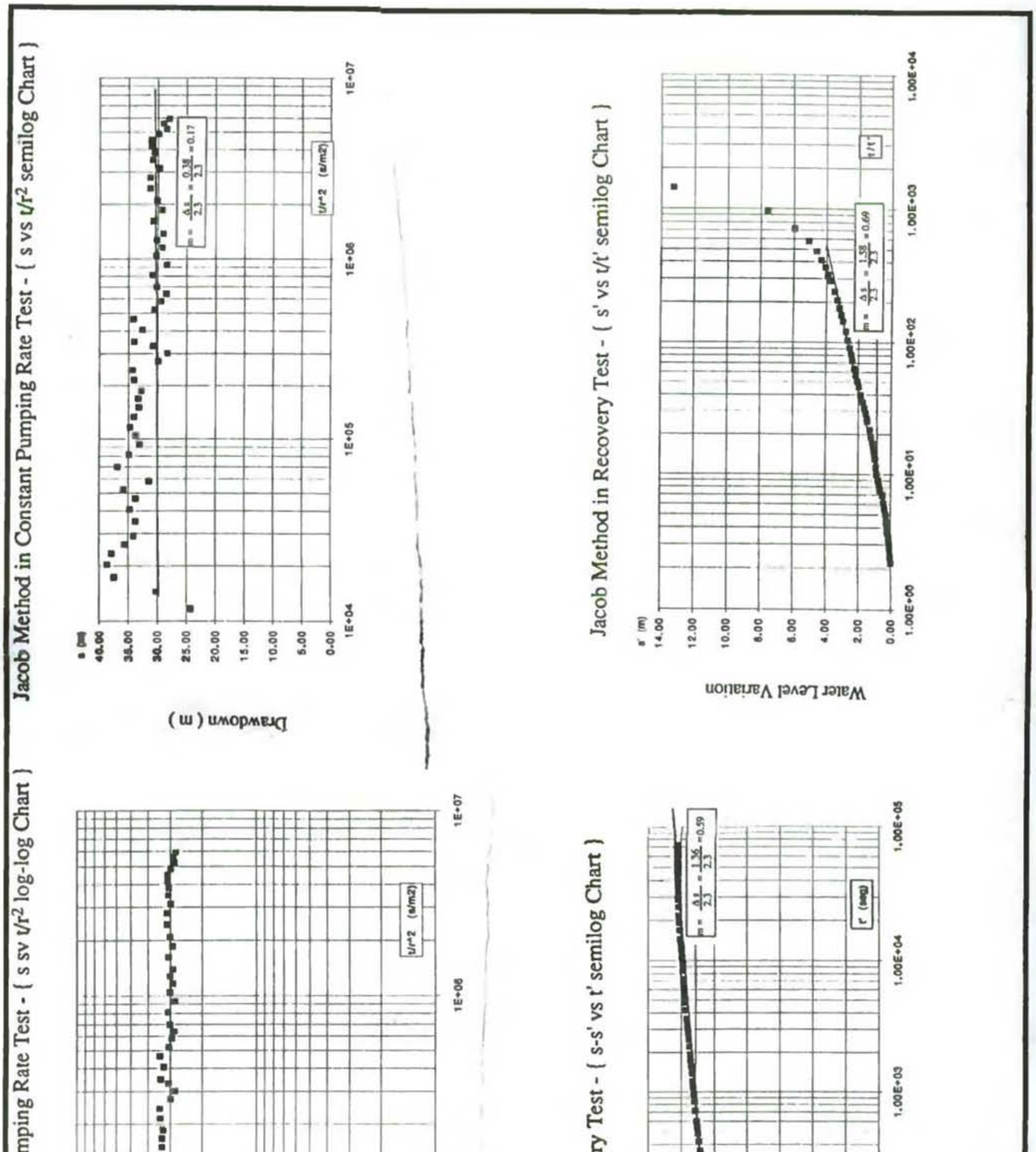


Fig. B-II, 2.21 Graphs for Theis and Jacob Method Analysis (Well No.J-B)

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

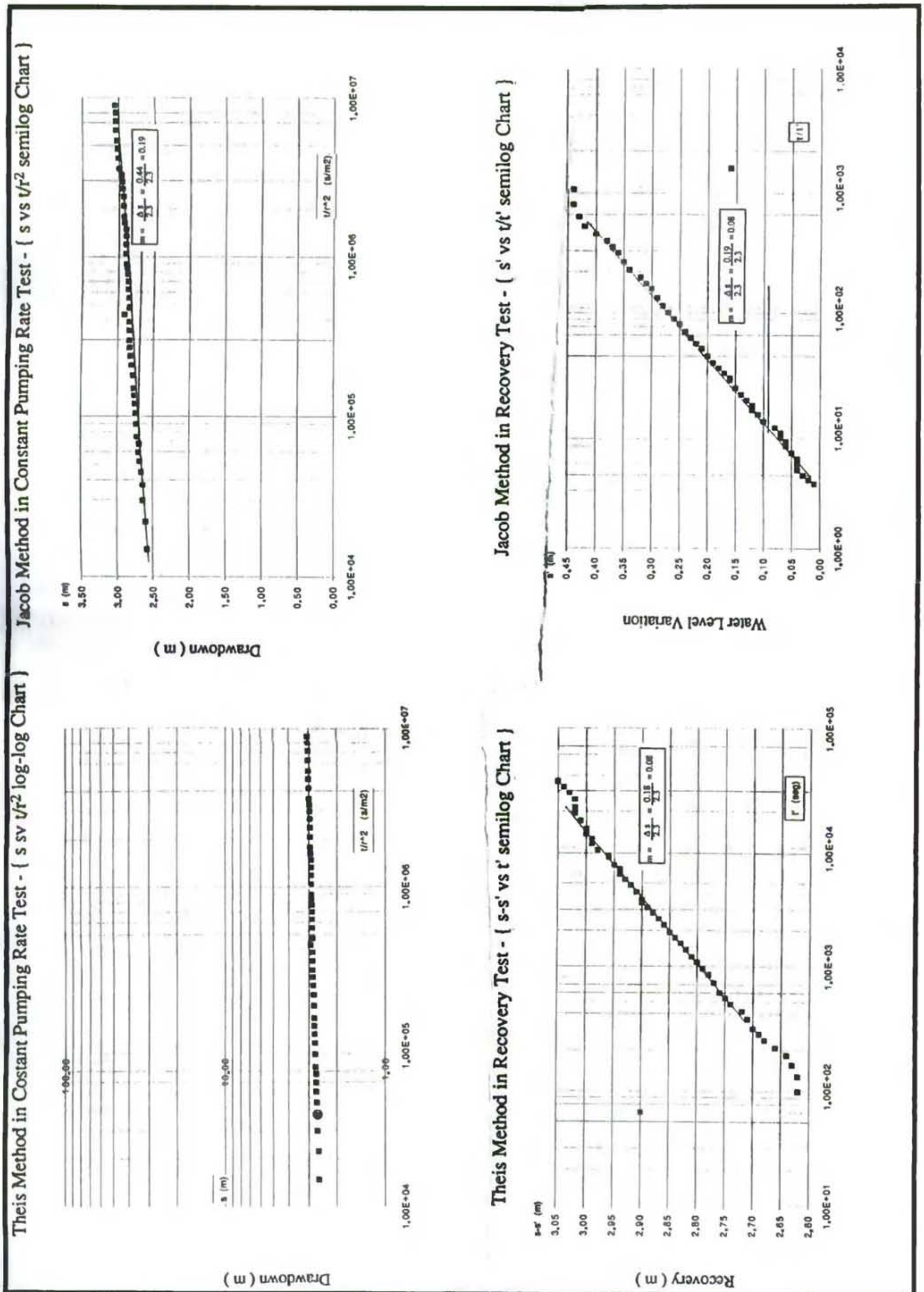


Fig. B-II, 2.22 Graphs for Theis and Jacob Method Analysis (Well No.J-1)

< Gráficos para los Métodos de Análisis Theis y Jacob (Pozo Nº J-1) >

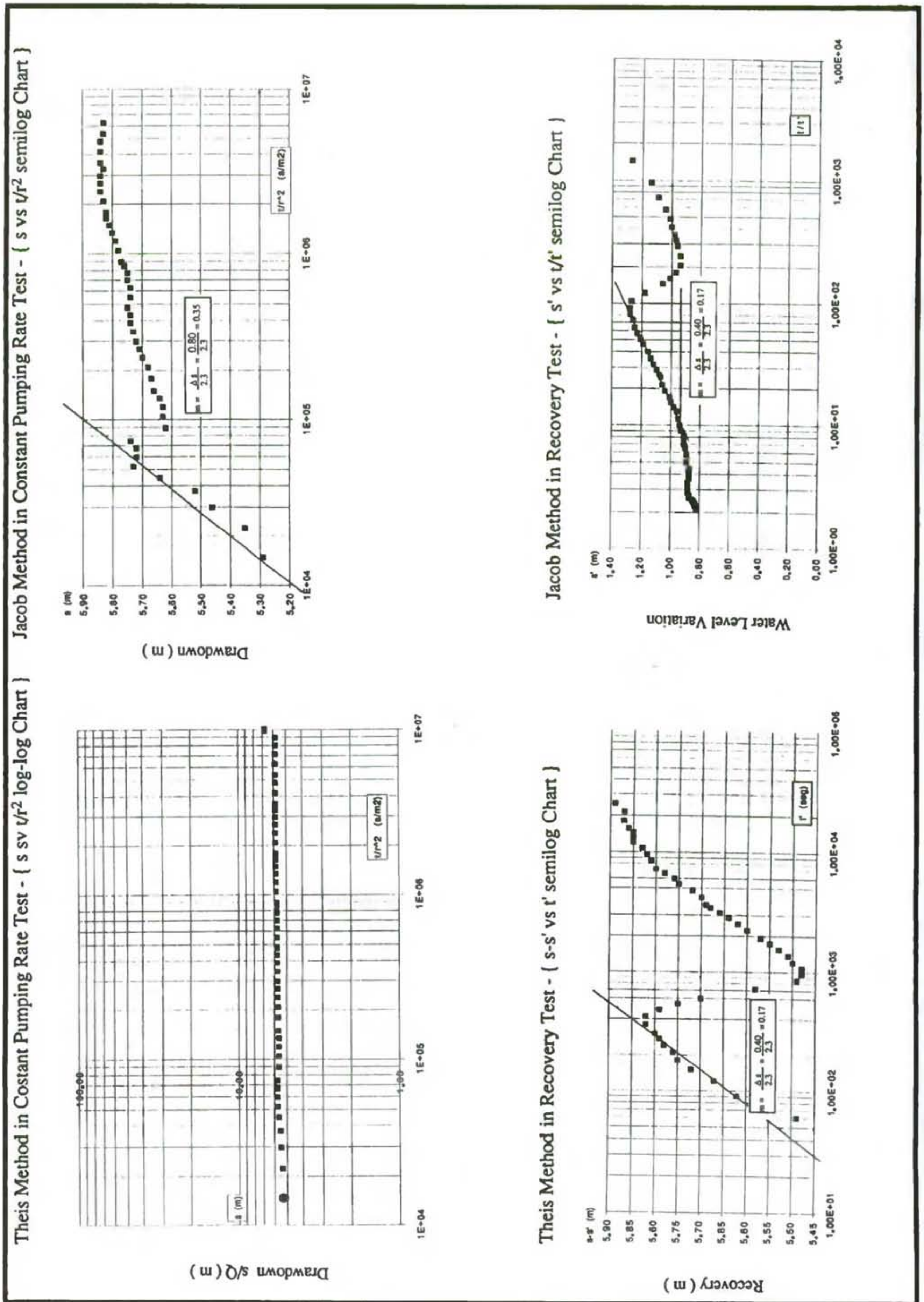
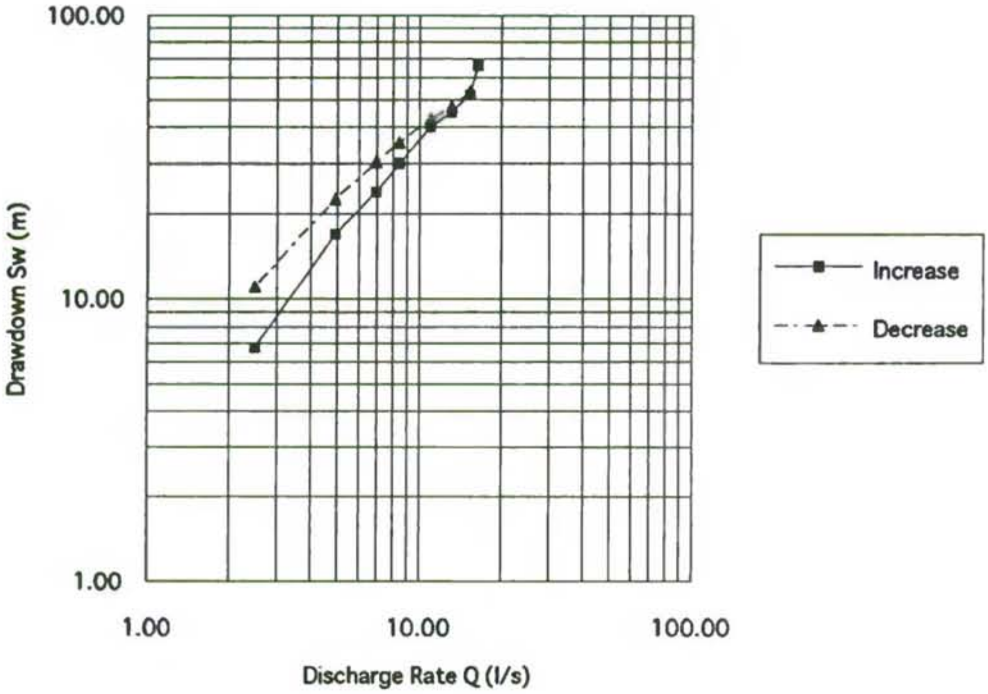


Fig. B-II, 2.23 Graphs for Theis and Jacob Method Analysis (Well No.J-2)

< Gráficos para los Métodos de Análisis Theis y Jacob (Pozo Nº J-2) >

Q - Sw Chart



Q - s/Q Chart

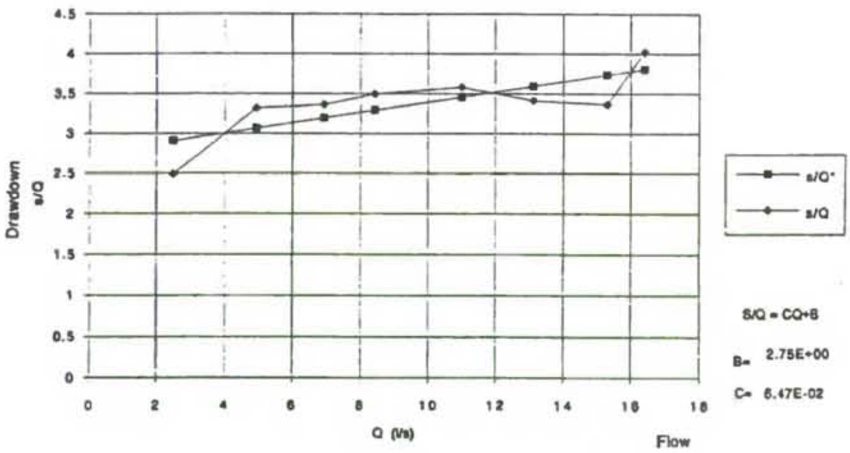
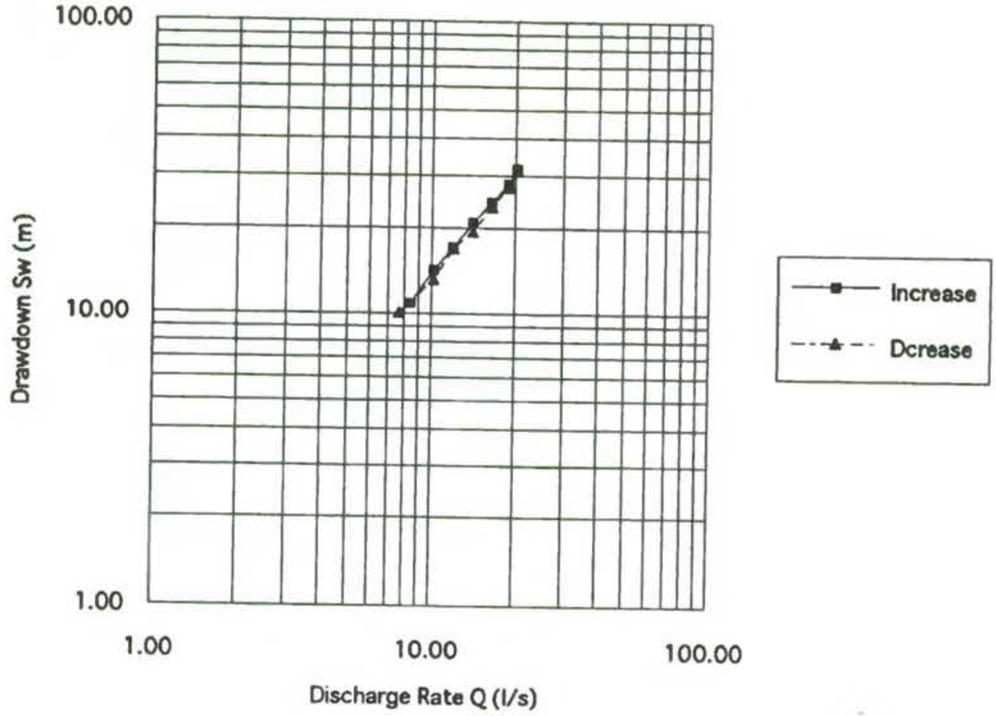


Fig. B-II, 2.24 Graphs for Step Drawdown Test (Well No.J-A)
<Gráficos para Prueba de Gasto Variable (Pozo No.-A)>

Q - Sw Chart



Q - s/Q Chart

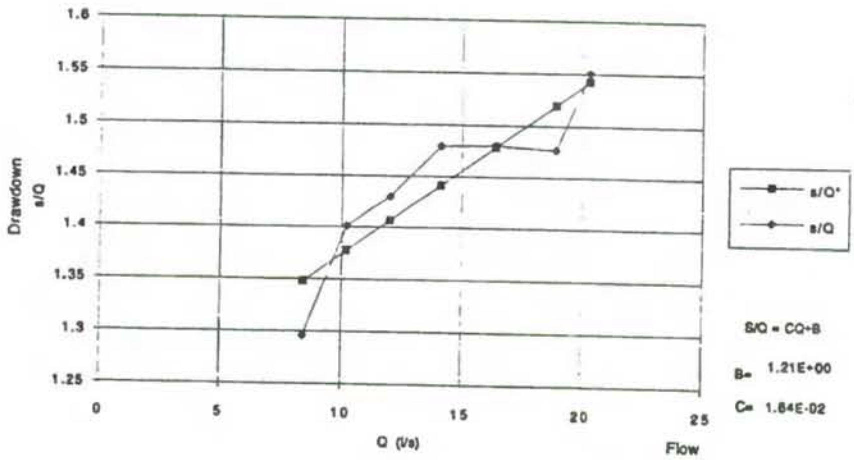
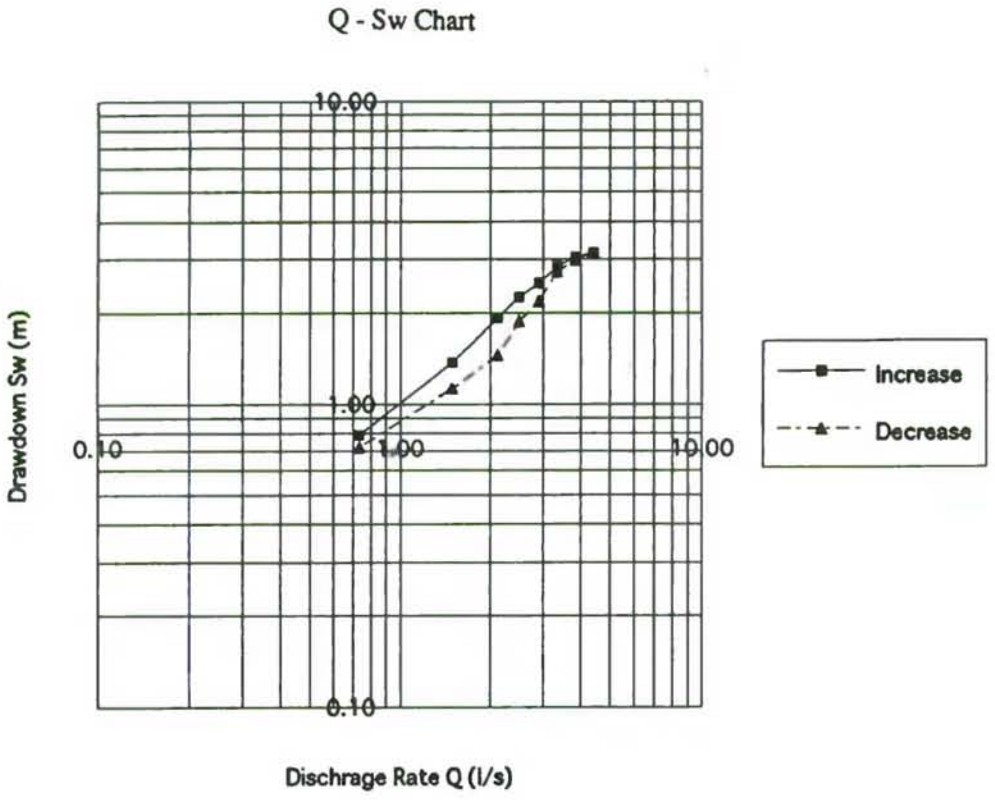


Fig. B-II, 2.25 Graphs for Step Drawdown Test (Well No.J-B)

<Gráficos para Prueba de Gasto Variable (Pozo No.-B>



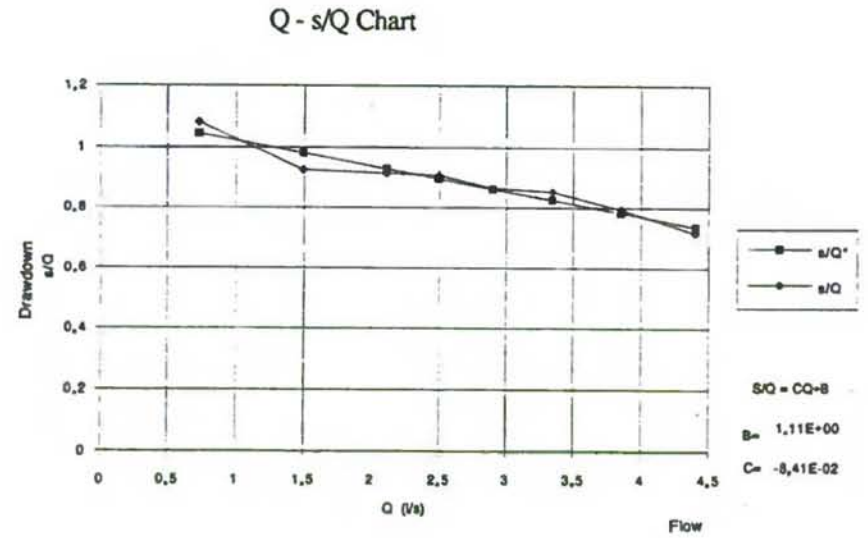
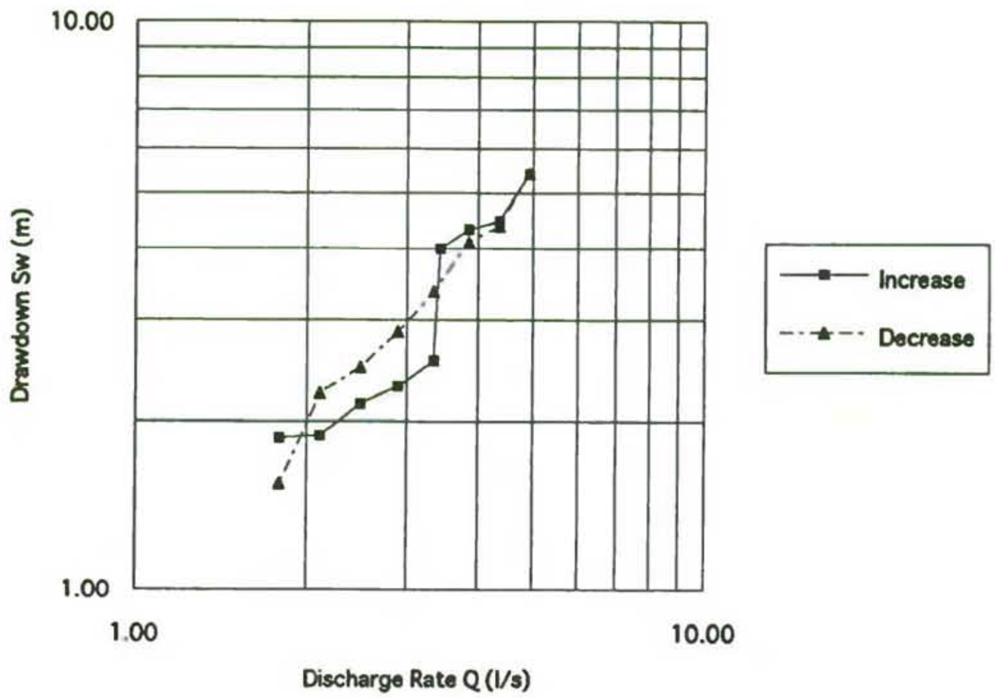


Fig. B-II, 2.26 Graphs for Step Drawdown Test (Well No.J-1)

<Gráficos para Prueba de Gasto Variable (Pozo No.J-1)>

Q - Sw Chart



Q - s/Q Chart

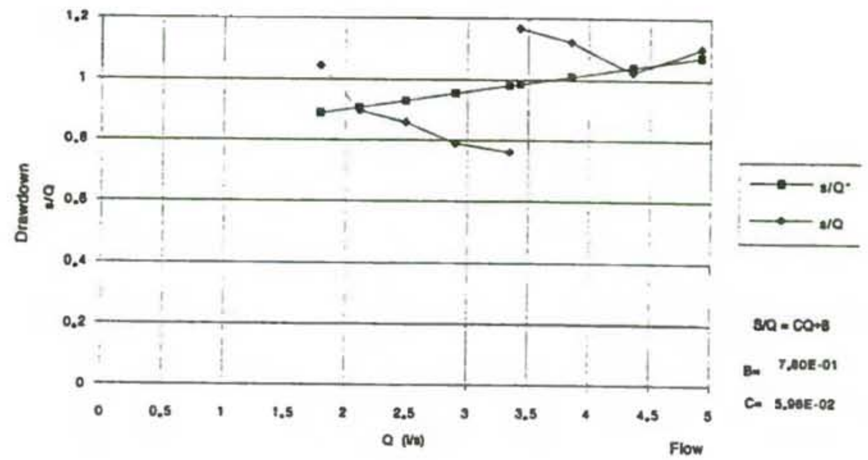


Fig. B-II, 2.27 Graphs for Step Drawdown Test (Well No.J-2)

<Gráficos para Prueba de Gasto Variable (Pozo No.J-2)>

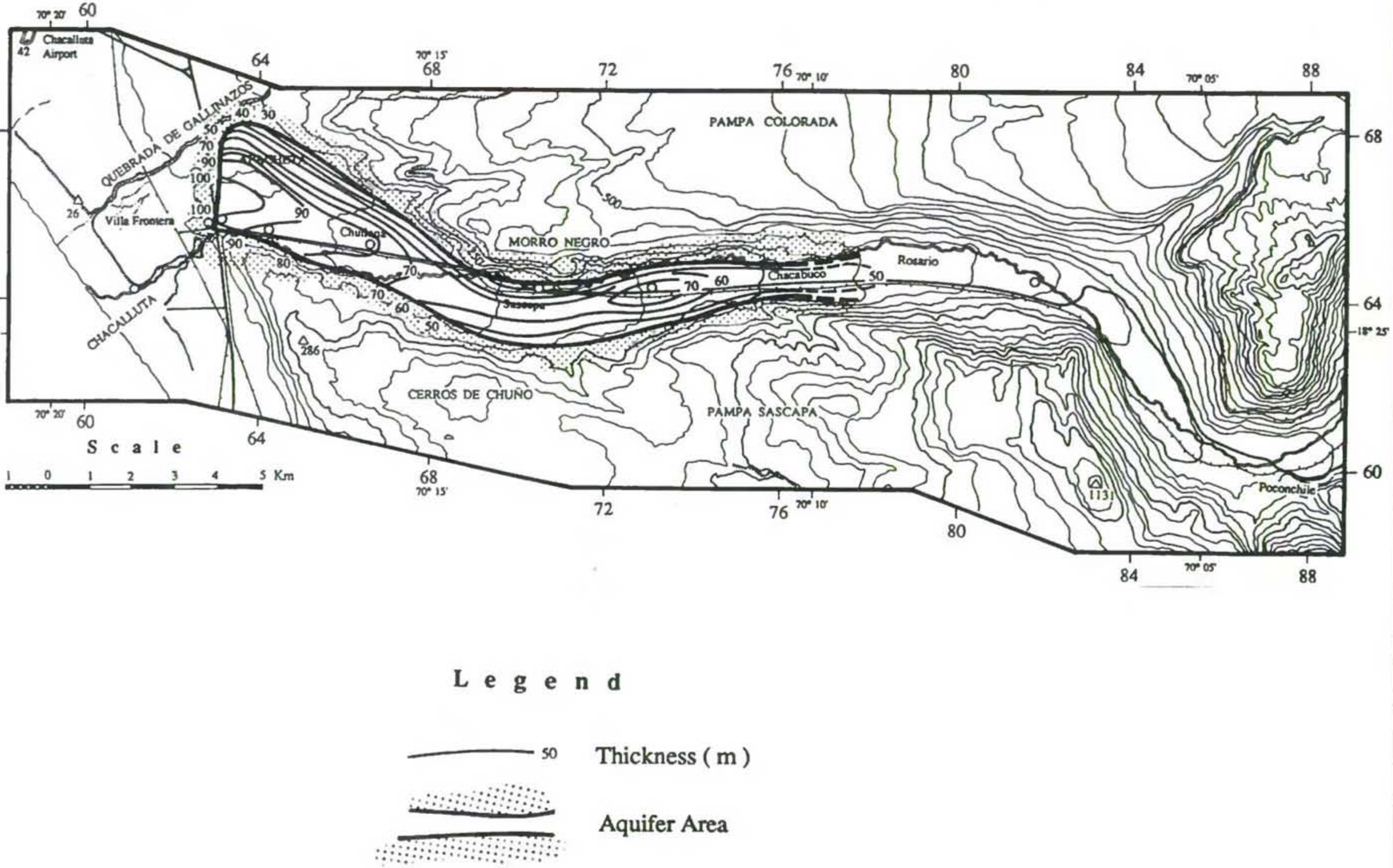
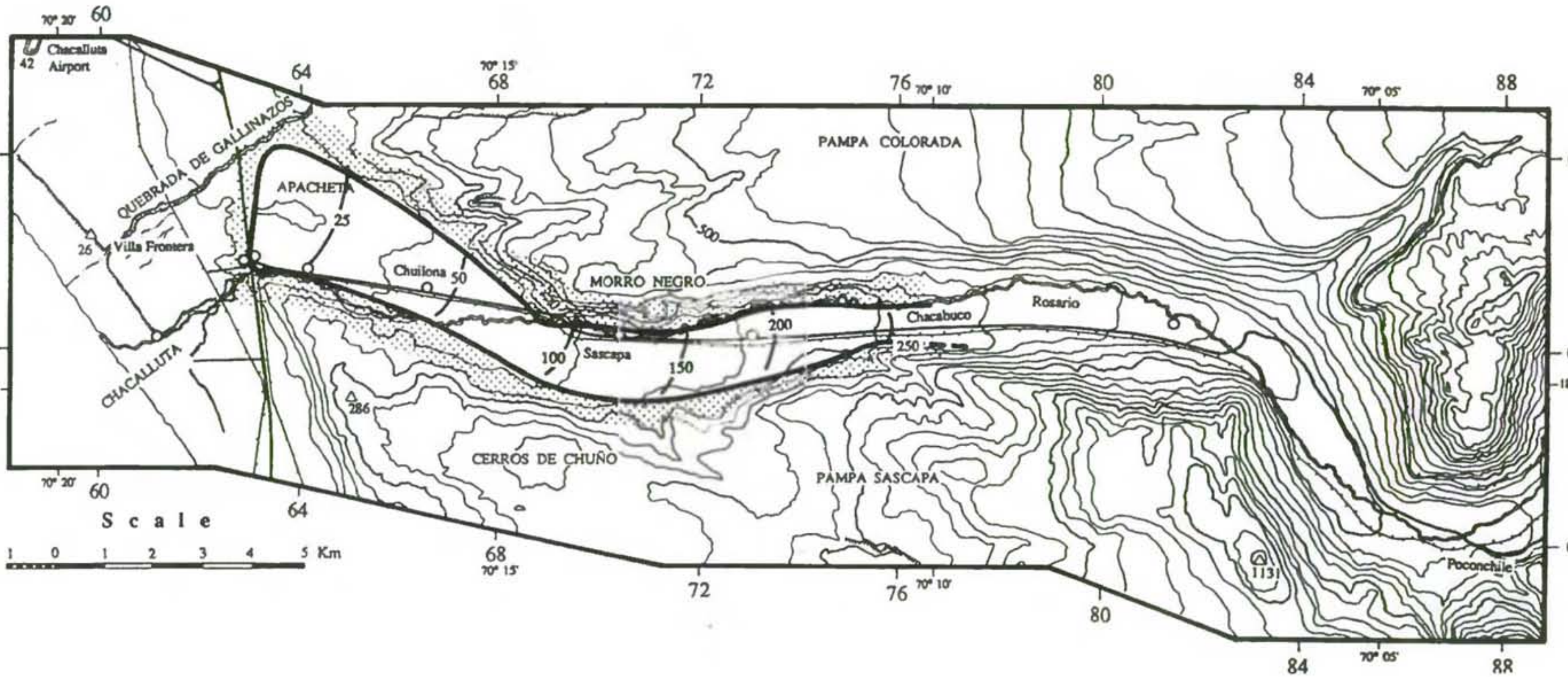


Fig. B-II, 2.28 Isopach Map of Deep Aquifer

< Mapa Isopaca de Acuífero Profundo >



Legend

Top Level of Deep Aquifer (m MSL) (line labelled 100)

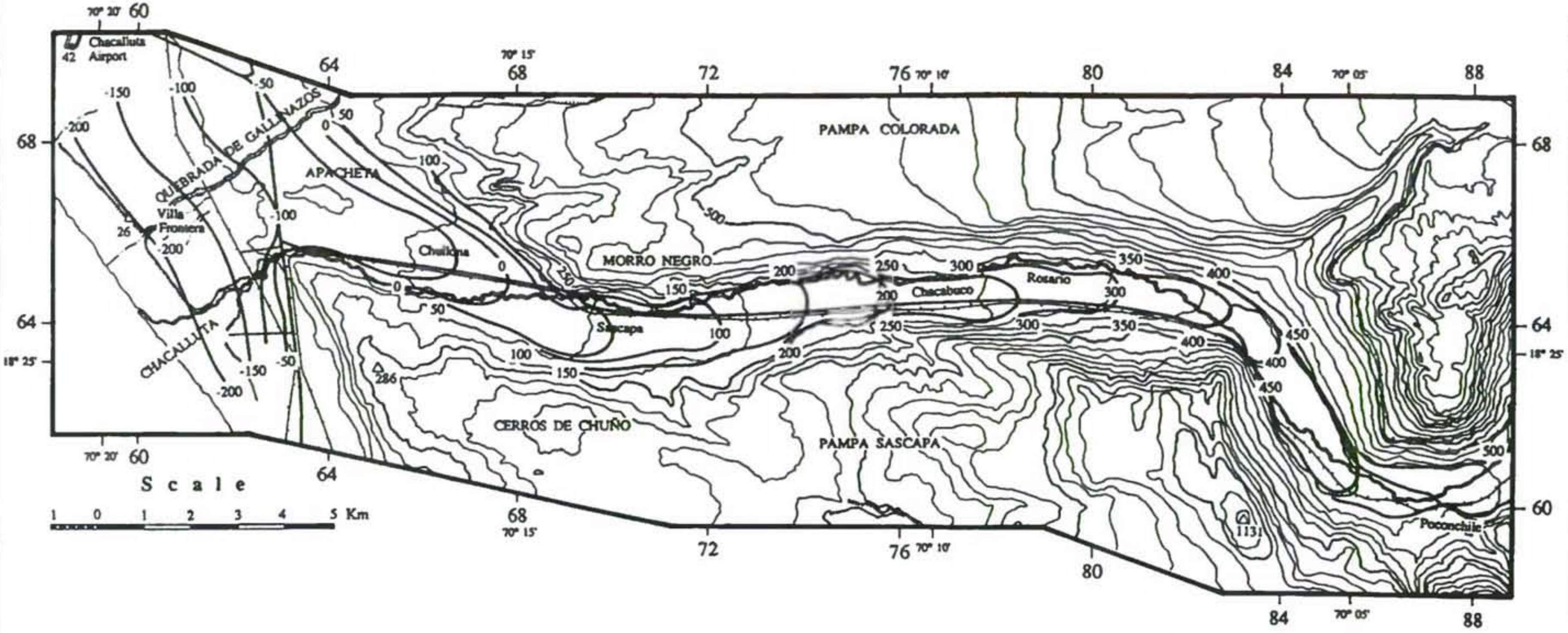
Aquifer Area

Fig. B-II, 2.29 Top of Deep Aquifer

< Superficie del Acuifero Bajo >

Fig. B-II, 2.30 Base of Deep Aquifer

< Fondo del Acuifero Bajo >



Legend

100 Base Level of Deep Aquifer (m MSL)

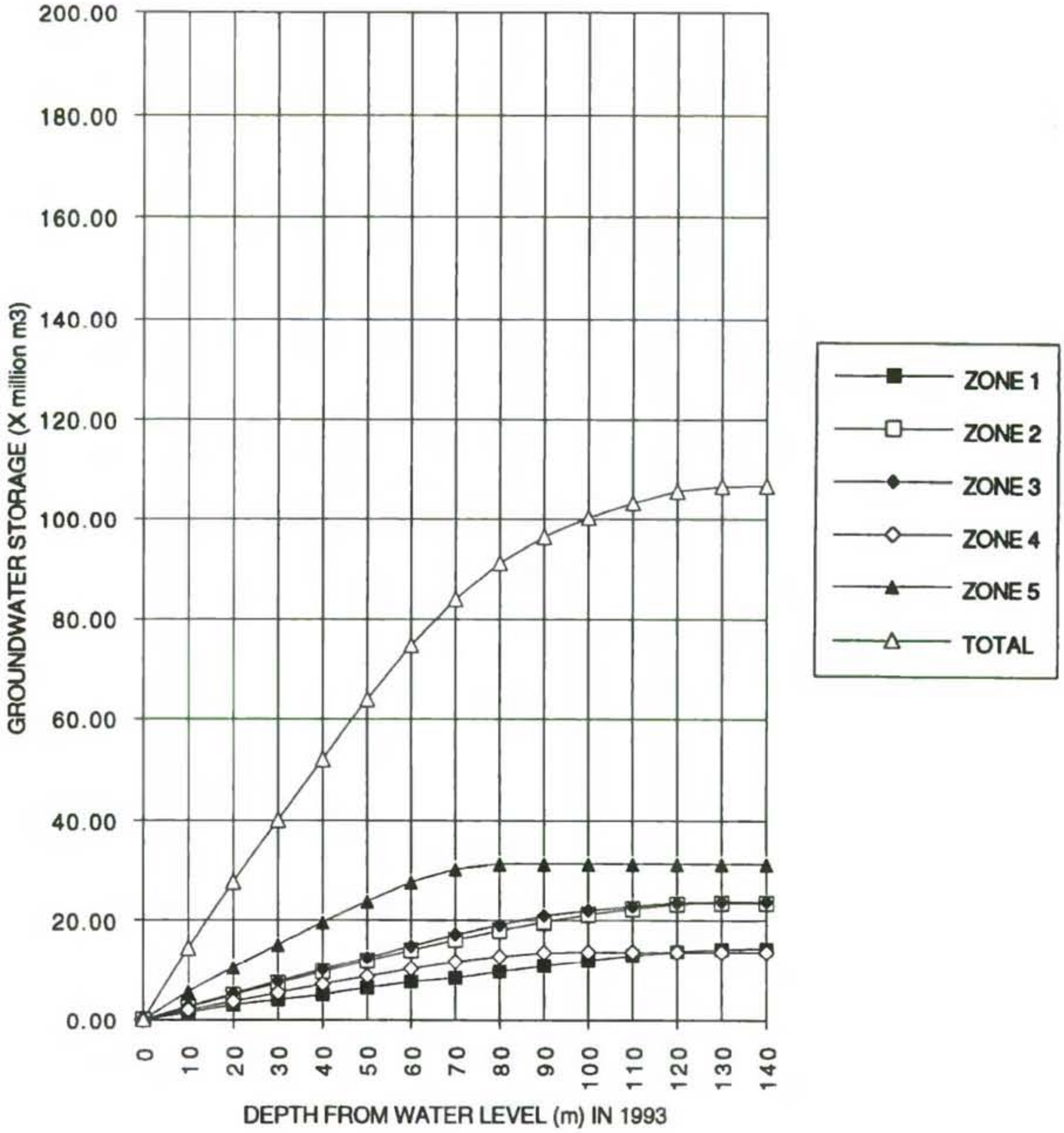


Fig. B-II, 2.31 Estimation of Groundwater Storage

<Estimación de Reservas de Agua Subterránea>

Chapter III. GROUNDWATER EXTRACTION

3.1 Existing Groundwater Extraction

Groundwater has been extracted from springs at Bocanegra and Poconchile, and from two (2) deep wells and dug wells at Villa Frontera area. The groundwater is used for the drinking water at Poconchile town, and for industries and irrigation at Villa Frontera, the lower reaches of the valley.

3.1.1 Deep Aquifer

The deep aquifer originally appears under the shallow aquifer and is mostly separated from it by the tuff layer. However, there is no tuff layer, boundary between two (2) aquifers, in the upstream of Chacabuco. For this reason, the aquifer distributed from Poconchile to Bocanegra (about 10 km northeast from Poconchile) is included in the deep aquifer for convenience.

1) Chuilona and Villa Frontera

Only two (2) wells, well No. 101 and 103 are extracting the groundwater from the deep aquifer near the Panamerican Road and the railway to Peru. The well, No.101 is operating for irrigation use at the Villa Frontera area. The well, No.103 is for private use. Extraction rate is not clear for both wells.

2) Poconchile

One (1) spring is located about 4 km east of Poconchile town. Water of the spring (No. V-2: refer to Table B-II, 2.1) is led to Poconchile town for potable water supply. The yield of the spring is seemed to be not small.

3) Bocanegra

There are one (1) well and one (1) spring at Bocanegra. The well was drilled for the groundwater study and is now abandoned. The spring supplies water to the Borax factory for the industrial use. However, extraction rate is unclear.

3.1.2 Shallow Aquifer

10 dug wells are extracting the groundwater from the shallow aquifer at the Villa Frontera area. Out of these, eight (8) dug wells are used for irrigation and industry.

Only one (1) data is available on the yield. According to the data, the dug well (No. V-2) is estimated to supply about 105,500 m^3/year of groundwater for industrial use. Extraction rate of other wells are unclear.

3.2 Groundwater Level

There are two (2) aquifers in the Lluta Valley as mentioned in Chapter 2; the shallow aquifer and the deep aquifer. DGA and the Study Team executed the groundwater level observation on 17th June 1993, since few data were available in the Lluta River Basin. In addition, the Study Team constructed two (2) test wells and two (2) observation wells during phase 2 study.

3.2.1 Water Level in Shallow Aquifer

The wells in the shallow aquifer are located only in the Villa Frontera area. However, no data is available on these wells. DGA and the Study Team observed water levels on 10 dug wells constructed in the shallow aquifer in Villa Frontera area. The result of the observation are shown below;

Well No.	Location	Elevation (m)	Static Water Level (m BGL)	Static Water Level (m MSL)
N-0	Villa Frontera	32	27.22	4.78
N-1	Villa Frontera	22	15.66	6.34
N-2	Villa Frontera	22	-	-
N-3	Villa Frontera	11	5.00	6.00
N-4	Villa Frontera	22	19.98	2.02
N-5	Villa Frontera	30	24.60	5.40
N-6	Villa Frontera	32	24.53	5.47
N-7	Villa Frontera	32	dried	
N-8	Villa Frontera	32	-	-
N-9	Villa Frontera	36	23.76	12.24

The depth to the water level ranges from 5 m to 27 m, averaging 20.1m. Static Water Level is generally low; 2 to 12 mMSL.

A contour map of water level (Fig. B-II, 3.1) is prepared based on the results of water level observation. The map presents the distribution of water level (MSL) in the Villa Frontera area. The water level ranges from 12.24 m (well No. N-9: refer Table B-II, 2.1) at Panamericana to 2.0 m (well No. N-4) at the southeast side of the Villa Frontera area (Fig. B-II, 3.1). Isopotential lines of the water level suggest groundwater flow from east and northeast. This means that groundwater of the shallow aquifer is recharged from these directions i.e. the Lluta River. This is supported by the water quality analysis data (see 3.3 of Chapter 3).

Other contour maps were prepared by Alamos y Perelta and Ingendesa. These results are in well agreement with this Study.

3.2.2 Water Level in Deep Aquifer

There are four (4) existing wells and four JICA wells penetrated to the deep aquifer. Water levels of these wells are as follows;

Well No.	Location	Elevation (m)	Static Water Level (m BGL)	(m MSL)
100	Rosario	350	5.83	344.17
J-1	Chacabuco	220	21.69	197.83
J-A	Lluta	178	9.82	168.21
J-2	Lluta	107	34.56	72.81
J-B	Panamericana	74	73.77	38.75
101	Panamericana	60	36.10	23.90 *)
102	Panamericana	55	30.06	24.94
103	Panamericana	55	30.06	24.94

note: the mark *) means the water level not completely recovered after pumping.

Static water level in the deep aquifer is shown in Fig. B-II. 3.2. Static water level is about 450 mMSL near Poconchile, 300 to 350 mMSL at Rosario, 250 mMSL at Chacabuco, 50 mMSL at Chuilona and 25 mMSL at the entrance to Villa Frontera. Gradient of water level is 20/1000 which is larger than that of the Lluta River.

3.3 Groundwater Quality

No existing water quality data was available in the area. Therefore, DGA and the Study Team executed groundwater sampling and water quality analysis on the existing wells and JICA wells. The results of water quality analysis are shown in Table B-II, 3.1.

3.3.1 Water Quality of Shallow Aquifer

Results of the water quality analysis are as follows;

1) Temperature ranges from 21.8 to 25.2 °C. TDS values are in a range between 2,948 mg/l and 4,390 mg/l. All the TDS values exceed the standard of drinking water (WHO).

2) The health significance parameters other than NO_3 are generally within the standard (WHO). NO_3 is in a range between 5.66 mg/l and 18.73 mg/l, averaging 9.56 mg/l; i.e. all the wells exceed the standard. Contamination by NO_3 is possibly caused by agricultural chemicals.

3) Arsenic (As) contents are generally lower than the standard value; only the groundwater of well No. N-3 exceeds the standard.

4) Contents of boron (B) range from 13.92 to 29.00 mg/l. These values exceed the tentative standard of the Study, 5 mg/l.

5) Among the major ions, Na, Cl and SO_4 contents show the values much higher than the standard.

3.3.2 Groundwater Quality of Deep Aquifer

Groundwater Quality of the Deep aquifer is summarized in the following table.

Item	Standard (mg/l)	Range (mg/l)	Average (mg/l)	Number of well*
Temperature	-	21.4-26.8	23.7	-
pH	6.0-8.5	6.6-7.3	6.9	none
TDS	1000	2845-3945	3,289	all the wells
Mg	125	74-105	92	none
Na	200	437-613	529	all the wells
SO_4	250	625-1023	852	all the wells
Cl	250	791-1089	949	all the wells
NO_3	10.00	0.41-15.75	5.6	100-2
As	0.05	0.005-0.045	0.029	none
F	1.50	0.72-1.14	1.00	none
Cd	0.005	0.005-0.015	0.010	J-1, 2:J-A, B
Cr	0.05	0.01-0.03	0.021	none
Pb	0.05	0.015-0.08	0.04	J-1, J-2
B	5.00	11.87-27.30	21.87	all the wells
Fe	0.30	0.05-6.60	1.53	100-2, J-1, J-A
Mn	0.10	0.01-3.85	0.72	J-1,J-A
Zn	5.00	0.041-3.220	1.124	none
Cu	1.00	0.013-0.039	0.024	none
Al	0.20	0.10-0.30	0.20	none

note: * means number of wells which exceed the standard.

Fe contents of JICA wells No. J-1&J-A may be influenced by the riser pipes.

Characteristics of water quality are shown below;

1) TDS value is much higher than the standard.

2) B content is very high compared with the surface water.

3) As content is fairly low in comparison with the surface water.

4) NO_3 content is less than standard, although that of the shallow aquifer almost exceeds the standard. This fact suggests that groundwater in the deep aquifer is not influenced by the surface water in the Lower Lluta Valley.

5) All the JICA wells show higher contents of Cd and Fe. However, there is high possibility that Fe contents of J-1 and J-A are influenced by riser pipes used during the pumping tests, because the brand new pipes are used at the tests.

6) Other ion contents are generally lower than that of standards.

3.3.3 Major Ion Composition

Fig. B-II, 3.3 is a tri-linear diagram which shows the ion composition of the groundwater. All the wells are plotted in a small area concentrating near the boundary between the Non carbonate hardness type and the Non carbonate alkali type. This fact leads to following suggestions;

1) The groundwater originated from the same source i.e. the surface water of the Lluta River.

2) The groundwater are influenced by the waste water from mines or water originated from volcanoes. As a matter of fact, contamination sources are found in the upper reaches of the Lluta River (see, Supporting Report A).

3.3.4 Evaluation of Groundwater Quality

Groundwater quality in the aquifers is mentioned in 3.3.1 and 3.3.2 of this chapter. High content of NO_3 in the shallow aquifer shows the contamination by agricultural chemicals as mentioned above. Furthermore, if it is true, the shallow aquifer is possibly contaminated by other organic chemicals.

So far as concerned with the deep aquifer, the groundwater quality is not suitable for domestic water as it is, especially due to high TDS value and B contents. Some wells exceed the standard of Cd, Pb, Fe and Mn. Therefore, the groundwater in the deep aquifer is also not suitable for the drinking water as it is. At treatment system should be considered if this water will be used for the drinking water source.

3.3.5 Future Change of Water Quality

Among the items of water quality, there are large differences in As and B contents of the surface water and the groundwater. B content is low in the surface water and increases its contents in the groundwater. In contrary to this, As contents is high in the surface water and low in the groundwater. These phenomena are caused by the infiltration of the surface water into the groundwater. Therefore, this phenomena will continue after the development of groundwater in the Lower Lluta Valley.

As for the other items, there is not so much difference between the surface water and the groundwater.

Considering these conditions, water quality of the groundwater will not change in the future even if the groundwater development will be made in the valley.

3.4 Evaluation of Groundwater Development Potential

Prospective aquifer area in the Lower Lluta Valley is shown in Fig. B-II, 3.5.

The aquifers in the Lower Lluta Valley are recharged by the surface water of the Lluta River. In the Lluta River Basin, the aquifers are saturated with groundwater because only a small quantity of groundwater is extracted through wells from the aquifers. The future groundwater extraction will cause a certain degree of water level depression. It will accerelate groundwater infiltration to the aquifers.

On the other hand, surface water is extracted for irrigation use based on the water rights. The groundwater development may cause obstacles to the existing extraction of the surface water for irrigation use; water rights (legally authorized water rights and customary rights (accións)). Accordingly, the groundwater development potential is studied on the following items.

- the potentail groundwater recharge rate from the Lluta River
- groundwater development potential considering water use
- limitation of number of well development

3.4.1 Calculation of Possible Groundwater Recharge

The surface water recharges the groundwater in the Lower Lluta Valley. However, data of infiltration rate from the surface water to the groundwater is not available in the area. Then, an assumption was made by using the data of the Azapa Valley. Average surface flow rate at Antes Bocatoma/Ausipar, Azapa Valley, is 1,101 l/sec and the average out flow rate to the sea is 149 l/sec. Azapa canal is taking the surface water at Bocatoma a total volume of 487 l/sec. Accordingly, the recharge rate to the groundwater from the surplus surface water at Bocatoma is calculated by the following equation;

$$R = (Q_A - Q_C - Q_O) \div (Q_A - Q_C)$$

where, R : Recharge rate in the Azapa Valley (l/sec)
Q_A: Average flow rate at Antes Bocatoma/Ausipar (l/sec)
Q_C : Extraction rate to Azapa Canal (l/sec)
Q_O: Average out flow rate to the sea (l/sec)

$$R = (1{,}101 - 487 - 149) \div (1{,}101 - 487) = 0.757$$

This result suggests that 75.7 % of surface water recharges the groundwater from the river bed in the Azapa Valley. The recharge is made through both the river bed and the farmlands in the valley. However, recharge by the flood water is made mainly through the river bed of the San José River.

The aquifers in the Lower Lluta Valley are seems to be recharged by the surface water through the river bed because the farmlands are drained the irrigation water. It shows that the soil of the farmland is of low permeability because of its clayey lithofacies.
The concept that the aquifers of both the Azapa valley and the Lower Lluta Valley are recharged by the surface water through the river beds in the flood period is supposed by the following facts.

Floods were occurred several times in both the San José and the Lluta Rivers in 1994. One of the flood was observed on 24th January, 1994 and continued several days. The conditions of flood are shown in Fig. B-II, 3.4 (1) as photographs. The flood water mainly flows only in the river bed through the river, from the upper reaches to the river mouth of the Azapa Valley. At the same time, a flood was also occurred in the Lluta River which is shown in Fig. B-II, 3.4 (2). The conditions of the flood is same as that of the San José River.

The features mentioned above suggest that the groundwater is recharged by the flood water in the Lower Lluta Valley. Therefore, recharge rate in the Lower Lluta Valley is estimated following method comparing the lithofacies of both valleys.

Lithology of aquifers of the Azapa Valley and the Lluta Valley are both composed of sand and gravel. However, aquifers in the Lluta Valley are more muddy and tuffaceous than that of Azapa Valley. Effective porosity of aquifers in the Lluta Valley is estimated about 70 % of that in the Azapa Valley. Then, recharge rate to the groundwater in the Lluta Valley is estimated to be 53 % (=0.757 x 0.7) of the surface water at Kesler Headworks. Groundwater recharge in the Azapa Valley is made between Cabuza to the river mouth. Its distance is about 22 km. In case of the Lower Lluta Valley, recharge is made between Poconchile and Sascapa (near the JICA well No. J-1). The distance is 17 km. Considering this condition, groundwater recharge from the river bed of the Lluta River is estimated as follows;

$$
\begin{aligned}
R_L &= (Q_T - C_R) \times 0.53 \times 17 \div 22 \\
&= (2{,}216 - 819) \times 0.53 \times 17 \div 22 \\
&= 572 \text{ (l/sec)}
\end{aligned}
$$

where,

= Recharge rate to the groundwater from the river bed (l/sec)

= Flow rate at Tocontasi (l/sec)

= Real consumption in the valley (l/sec)

The results show that the potential of groundwater recharge is 572 l/sec. However, this volume of the groundwater development may unable the exraction of surface water for irrigation use because infiltration of surface water to the groundwater will be accerelate. It is difficult to develop the 572 l/sec of groundwater without any facilities for compensation works.

3.4.2 Consideration to Existing Agricultural Water Use

The surface water of the Lluta River recharges the aquifers of the Lluta Valley mainly in the reaches between Poconchile and Sascapa. The proposed groundwater development will lower the existing groundwater table, resulting in accerelation of river water infiltration into underground. It may infringe the existing river wter extraction for the irrigation use. Therefore, existing irrigation intakes located in the downstream of Poconchile (irrigation sector III, IV and V) shall be integrated to one (1) headworks proposed at Kesler. All the irrigation water for the sector III, IV and V will be extracted from this headworks. For recycling use of extracted water, collection channels are also constructed along the river banks. The required irrigation intake volume, potential surplus river water and expected groundwater recharge are estimated for two (2) cases. Case 1 will satisfy the existing water rights including legally authorized ones and customary ones (acción) throughout the year. Case 2 will satisfy the actual water demand verying by month. These calculation were made by month. The results are shown in Table B-II, 3.2 to 3.5.

1) Case 1: Water Right and Acción

The surface water of the Lluta River is extracted for the irrigation use on the basis of the legally authorized water rights and customary rights, accións. In the development of groundwater in the Lower Lluta Valley, the development plan should be in harmony with these extraction. For this purpose, a irrigation canal was planned as well as the groundwater development plan. Proposed new irrigation system is shown in Fig. B-II, 3.6, 3.7 and 3.8.

An intake is located at the irrigation sector Kesler. The canal water is led to the Sector III, IV and V. Because the intake is located after Tocontasi, available surface water at the headworks is obtained by reducing the consumption in the irrigation sector I and II, and Comunidad Vilca Loredo. Groundwater is recharged mainly in the area between Poconchile and Sascapa, after the headworks. Therefore, groundwater development does not affect the extraction of the irrigation water.

Recycle use of extracted water was calculated by assuming that the real consumption is 50 % of water rights quantity for case 1.

The surface water consumption between Tocontasi and the proposed headwarks is estimated to be 551 l/sec; The legally authorized water right volume at Comunidad Vilca Loredo is 35.5 l/sec and the total number of acción is 687.2 which is equal to the 514.4 l/sec of water volume. For details of water rights, see, Supporting Report C. The surface flow rate at the headworks is calculated deducting this volume (551 l/sec) from the surface flow rate at Tocontasi by month.

Calculations of distribution to irrigation canal are made on the average surface flow rate and 80 % drought flow rate. The results are shown in following tables. For detailed calculations, refer Table B-II, 3.2.

(average flow)

	Tocontasi	Consum. (Upstr.)	Intake Point	Required Extraction	Actual Extraction	Remaining in River	Recharge
Jan.	2,887	275	2,612	819	819	1,793	753
Feb.	4,741	275	4,466	819	819	3,647	1,532
Mar.	4,222	275	3,947	819	819	3,128	1,314
Apr.	1,759	275	1,484	819	819	665	279
May.	1,809	275	1,534	819	819	715	300
Jun.	1,802	275	1,527	819	819	708	297
Jul.	1,937	275	1,662	819	819	843	354
Aug.	1,746	275	1,471	819	819	652	274
Sep.	1,542	275	1,267	819	819	448	188
Oct.	1,332	275	1,057	819	819	238	100
Nov.	1,307	275	1,032	819	819	213	89
Dec.	1,508	275	1,233	819	819	414	174
Ave.	2,216	275	1,941	819	819	1,122	471

In the year of average flow rate, the surface flow rate is larger than the required extraction rate for the satisfaction of the water rights through the year. The surplus surface flow rate (overflow rate at headworks) is in a range from 3,647 l/sec to 213 l/sec, averaging 1,122 l/sec. Grounwater is recharged from this surplus water flow a volume of 471 l/sec (1,122 l/sec x 0.42 = 471 l/sec).

(80 % drought flow)

	Tocontasi	Consum. (Upstr.)	Intake Point	Required Extraction	Actual Extraction	Remaining in River	Recharge
Jan.	1,614	275	1,339	819	819	520	218
Feb.	1,813	275	1,538	819	819	719	302
Mar.	1,830	275	1,555	819	819	736	309
Apr.	1,400	275	1,125	819	819	306	129
May.	1,444	275	1,169	819	819	350	147
Jun.	1,521	275	1,246	819	819	427	179
Jul.	1,589	275	1,314	819	819	495	208
Aug.	1,470	275	1,195	819	819	376	158
Sep.	1,302	275	1,027	819	819	208	87
Oct.	1,168	275	893	819	819	74	31
Nov.	1,089	275	814	819	814	0	0
Dec.	1,091	275	816	819	816	0	0
Ave.	1,444	275	1,169	819	819	351	147

In case of 80 % drought flow, the required extraction volume is within the remaining flow rate at the headworks except November and December. In these two (2) months, all the surface flow is extracted to irrigation canal so that the groundwater cannot receive the recharge from the surface water. In other months, the groundwater receives a recharge from the surface water in a range between 31 l/sec and 309 l/sec, averaging 147 l/sec.

Storage of the groundwater will be consumed in November and December. However, this deficit causes no affect to the irrigation water use because irrigation water is extracted from the intake before the recharge area from Poconchile to Sagasca. Consumption of groundwater in the drought year is compensated during the years other than drought year.

<Case 2: Existing Water Demand>

Existing real consumption of irrigation in sector I, II, and Comunidad Vilca Loredo is estimated to be from 114 l/sec to 4,741 l/sec, averaging 250 l/sec, by month, considering the cropping area and patterns. Water demand and real consumption in the sector III, IV and V are also estimated by same method. Irrigation water other than the volume of real consumption is drained to the canal again and is used for the next irrigation sector; the canal water is used repeatedly as the surface water of the Lluta River used for irrigation at present. Following water disribution is analyzed on the basis of these conditions. Detailed calculation is shown in Table B-II, 3.3 and 3.4.

(Average Flow)

Month	Tocontasi	Consum. (Upstr.)	Intake Point	Required Extraction	Actual Extraction	Remaining in River	Recharge
Jan.	2,887	448	2,439	433	433	2,006	843
Feb.	4,741	446	4,295	431	431	3,864	1,623
Mar.	4,222	393	3,829	1,212	1,212	2,617	1,099
Apr.	1,759	193	1,566	878	878	688	289
May.	1,809	150	1,660	709	709	951	399
Jun.	1,802	118	1,684	583	583	1,101	463
Jul.	1,937	114	1,823	156	156	1,667	700
Aug.	1,746	128	1,618	189	189	1,429	600
Sep.	1,542	164	1,378	859	859	519	218
Oct.	1,332	201	1,132	927	927	205	86
Nov.	1,307	236	1,071	1,056	1,056	15	6
Dec.	1,508	407	1,101	1,209	1,101	0	0
Ave.	2,216	250	1,966	720	711	1,255	527

In case of average flow, the surface flow rates are larger than the water demand except in December. Extraction rate to canal satisfies the required water demand from January to November. The surface flow rate at the headworks in December is 407 l/sec which is originally smaller than the actual water demand. Therefore, the extraction rate in December is limited to 1,101 l/sec which is the total flow rate at the headworks.

Average of surplus surface flow rate is 1,255 l/sec which recharges the groundwater a total volume of 527 l/sec .

(80% Drought flow)

Month	Tocontasi	Consum. (Upstr.)	Intake Point	Required Extraction	Actual Extraction	Remaining	Recharge
Jan.	1,614	448	1,166	433	433	733	308
Feb.	1,813	446	1,367	431	431	936	393
Mar.	1,830	393	1,437	1,212	1,212	225	95
Apr.	1,400	193	1,207	878	878	329	138
May.	1,444	150	1,295	709	709	586	246
Jun.	1,521	118	1,403	583	583	820	344
Jul.	1,589	114	1,475	156	156	1,319	554
Aug.	1,470	128	1,342	189	189	1,153	484
Sep.	1,302	164	1,138	859	859	279	117
Oct.	1,168	201	968	927	927	41	17
Nov.	1,089	236	853	1,056	853	0	0
Dec.	1,091	407	684	1,209	684	0	0
Ave.	1,444	250	1,194	720	659	535	225

In case of 80 % drought flow, flow rates are less than required flow rate, except in November and December. In these two (2) months, extraction rate to the irrigation canal is limited to the surplus water rate at the headworks. Averagd surplus flow rate is 535 l/sec which recharges the groundwater a total volume of 225 l/sec.

3.4.3 Restriction by Distribution of Aquifer

Groundwater development potential area is considered from Chuilona to Rosario. Distance between both sites is approximately 14 km. In this clause, the possible number of well construction is analyzed. Conditions of well construction are planned as follows;

Diameter of well	: 17-1/2" (444.5 mm)
Diameter of casing	: 12" (318.5 mm)
Production rate	: 25 l/sec

Allowable draw down : 40 m

Drilling depth : 120 - 150 m

Radius of Influence

The radius of influence is defined as "the radius of area where the draw down is 10 cm when pumping." Radius of influence is given by the following formula after Theis Equation;

$$0.001=\frac{Q}{4\pi T}\,W(u)\,, \qquad u=\frac{R^2 S}{4tT}$$

Then, $R=\sqrt{\frac{4tTu}{S}}$

where,

Q	: Production rate (m^3/sec)
R	: Radius of influence area by pumping (m)
t	: Time of pumping operation (sec)
T	: Transmissibility (m^3/sec/m)
W(u)	: Well function of Theis
S	: Confined aquifer---Storage coefficient
	: Unconfined aquifer---Effective porosity (assumed to be 0.2)

In the lower reaches of Chacabuco, the aquifer is considered to be a confined one. Radius of influence is rather large in this area. On the one hand, it is unconfined one in the upper reaches of Chacabuco. Accordingly, radiuses of influence are estimated by using storage coefficient for the confined aquifer and effective porosity for the unconfined aquifer. The deep aquifer will become unconfined after the water level withdraws up to the top of the aquifer bed. Therefore, the estimation of the radius of influence was made on the both cases. Estimated radiuses of influence are as follows;

Case 1 <confined aquifer: S= 10cm>

	R (m)	Q (m^3/s)	T (m^2/s)	t (s)	S
J-A	411	0.025	2.63E-04	86400	1.60E-03
J-B	2689	0.025	3.59E-03	86400	4.72E-04
J-1	2556	0.025	4.26E-03	86400	1.60E-03
J-2	12114	0.025	1.73E-03	86400	6.60E-06

Case 2-1 <unconfined aquifer: s= 1mm>

	R (m)	Q (m^3/s)	T (m^2/s)	t (s)	S
J-A	56	0.025	2.63E-04	86400	2.00E-01
J-B	169	0.025	3.59E-03	86400	2.00E-01
J-1	181	0.025	4.26E-03	86400	2.00E-01
J-2	125	0.025	1.73E-03	86400	2.00E-01

Case 2-2 <unconfined aquifer: s= 10cm>

	R (m)	Q (m^3/s)	T (m^2/s)	t (s)	S
J-A	37	0.025	2.63E-04	86400	2.00E-01
J-B	84	0.025	3.59E-03	86400	2.00E-01
J-1	78	0.025	2.63E-03	86400	2.00E-01
J-2	70	0.025	1.73E-03	86400	2.00E-01

Radius of influences are generally large in the confined aquifer, from 411 m to 12,114 m, averaging 4,443 m. They are generally small in the unconfined aquifer. The aquifer will become unconfined one as mentioned above. After becoming unconfined aquifer, the influence radius of the deep aquifer also become small, between 37 m and 84 m for 10cm of draw down, and between 56 m and 181 m for 1 mm of draw down. If pumping will be continued more than 24 hours without any rest, the radius of influence will become more wide. The spacing of production wells is, therefore, proposed to be 500 m considering the safety side.

Extent of potential groundwater development area is approximately 14 km as mentioned above. Then, the possible number of well construction is given below;

n=14,000 (m)÷500 (m)= 28 (wells)

The number of wells should be decided considering the peak demand and the spare wells. The number of emergency well (for peak demand) is 1.3 times of production wells for average demand and the ratio of spare well is 20 % of total well number (production well and emergency well). Thus, the numbers of well are calculated as follows, considering allowance;

- Production well : 17 wells
- Emergency well : 5 wells
- Spare well : 4 wells

Total : 26 wells

A total production rate for 17 wells comes to 425 l/sec (= 25 l/sec x 17).

3.4.4 Conclusion

The groundwater development potential in the Lower Lluta Valley is decided to be 425 l/sec considering the results of 3.4.1 to 3.4.3. For this volume of development, new irrigation system is necessary to construct as discussed in 3.4.2.

Table B-II, 3.1 Groundwater Quality

<Calidad de Agua Subterránea>

TYPE	WELL NO.		NAME		TEMP.	pH	TDS	Ca	Mg	Na	K	SO4	Cl	CO3	HCO3	NO3	As	F	Cd	Cr	Pb	B	Fe	Mn	Zn	Cu	Al
																HEALTH SIGNIFICANCE											
					(C)			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
(STANDARD)						6.0-8.5	1000		125	200		250	250			10.00	0.050	1.50	0.005	0.050	0.050		0.30	0.10	5.000	1.000	0.20
SPRING		V-1	BOCANEGRA	Jul-93	20.7	6.1	1527	166	48	271	32.0	462	499	0	41	7.76	<0.005	0.47	0.002	0.040	0.020	182.54	0.01	0.03	0.018	0.024	0.30
				Oct-93	20.7	6.3	1585	159	50	276	34.0	489	529	0	42	6.27	0.044	0.57	0.004	0.010	0.010	32.10	0.04	0.01	0.030	0.033	0.50
				(Average)	20.7	6.2	1556	163	49	274	33.0	476	514	0	42	7.02	0.022	0.52	0.003	0.025	0.015	107.32	0.03	0.02	0.024	0.029	0.40
		V-2	POCONCHILE	Jul-93	22.1	7.5	1983	238	52	329	33.5	576	595	0	149	10.78	0.046	0.68	0.002	0.040	0.020	16.92	0.01	0.03	0.007	0.027	0.10
				Oct-93	21.5	7.6	1954	227	53	331	37.0	528	616	0	153	9.24	0.052	0.69	0.005	0.030	0.020	19.55	0.02	0.01	0.023	0.025	0.10
				(Average)	21.8	7.6	1968	232	52.5	330	35.3	552	605	0	151	10.01	0.049	0.69	0.004	0.035	0.020	18.24	0.02	0.02	0.015	0.026	0.10
	Average				21.3	6.9	1762	197	50.8	302	34.1	514	560	0	96	8.51	0.036	0.60	0.003	0.030	0.018	62.78	0.02	0.02	0.02	0.027	0.25
SHALLOW AQUIFER		N-0	Villa Frontera	Jul-93	23.4	7.4	3407	334	124	628	71.2	913	1241	0	87	9.68	0.006	0.57	0.003	0.050	0.020	18.05		0.51	0.186	0.051	0.30
				Oct-93	23.8	7.8	3510	389	137	580	68.0	941	1308	0	85	1.64	0.005	1.10	0.001	0.020	0.010	10.34	5.42	0.02	0.063	0.044	0.30
				(Average)	23.6	7.6	3458	361	131	604	69.6	927	1274	0	86	5.66	0.006	0.84	0.002	0.035	0.015	14.20	2.71	0.27	0.125	0.048	0.30
		N-1	Villa Frontera	Jul-93	24.1	7.0	2785	335	113	416	53.0	889	888	0	79	12.36	0.014	0.39	0.004	0.040	0.020	16.92	0.10	0.04	12.920	0.032	0.10
				Oct-93	23.2	7.2	2920	331	112	428	56.0	975	936	0	75	7.30	0.011	0.43	0.003	0.030	0.010	23.13	0.30	0.04	4.220	0.027	0.40
				(Average)	23.7	7.1	2852	333	112	422	54.5	932	912	0	77	9.83	0.013	0.41	0.004	0.035	0.015	20.03	0.20	0.04	8.570	0.030	0.25
		N-2	Villa Frontera	Jul-93	24.9	6.5	2628	329	107	378	51.2	845	841	0	69	8.08	0.016	0.42	0.003	0.400	0.010	17.95	0.04	0.03	0.010	0.031	0.10
				Oct-93	25.5	6.9	2715	321	105	386	53.0	884	898	0	61	6.80	0.019	0.45	0.004	0.020	0.020	19.03	0.02	0.01	0.026	0.027	0.40
				(Average)	25.2	6.7	2672	325	106	382	52.1	865	869	0	65	7.44	0.018	0.44	0.004	0.210	0.015	18.49	0.03	0.02	0.018	0.029	0.25
		N-3	Villa Frontera	Jul-93	21.5	6.5	3126	304	96	580	71.2	975	975	0	120	4.87	0.076	0.94	0.003	0.030	0.010	21.12	0.34	0.07	0.132	0.037	0.10
				Oct-93	22.1	6.8	2988	273	88	552	57.0	975	928	0	104	11.65	0.128	1.05	0.005	0.010	0.030	36.88	0.22	0.03	0.070	0.033	0.40
				(Average)	21.8	6.6	3057	289	92	566	64.1	975	952	0	112	8.26	0.102	1.00	0.004	0.020	0.020	29.00	0.28	0.05	0.101	0.035	0.25
		N-5	Villa Frontera	Jul-93	23.8	6.9	2657	201	93	476	58.0	821	902	0	92	15.04	0.037	0.83	0.003	0.030	0.010	17.03	0.04	0.05	0.024	0.031	0.10
				Oct-93	23.6	7.2	2800	287	92	469	58.0	865	928	0	93	7.90	0.041	0.76	0.002	0.010	0.010	20.31	0.11	0.02	0.409	0.032	0.20
				(Average)	23.7	7.0	2729	244	92	473	58.0	843	915	0	93	11.47	0.039	0.80	0.003	0.020	0.010	18.67	0.08	0.04	0.217	0.032	0.15
		N-6	Villa Frontera	Jul-93	23.5	6.9	2982	336	106	506	53.8	884	1022	0	68	7.01	0.028	0.66	0.002	0.030	0.020	18.05	0.21	0.10	0.036	0.036	0.10
				Oct-93	24.1	7.0	3075	338	106	511	56.0	922	1069	0	68	5.43	0.036	0.56	0.002	0.010	0.020	21.74	0.09	0.01	0.046	0.036	0.20
				(Average)	23.8	6.9	3028	337	106	508	54.9	903	1045	0	68	6.22	0.032	0.61	0.002	0.020	0.020	19.90	0.15	0.06	0.041	0.036	0.15
		N-8	Villa Frontera	Oct-93	24.1	7.0	3931	465	144	616	63.0	1013	1544	0	77	8.86	0.033	0.34	0.002	0.020	0.010	13.92	0.13	0.02	0.128	0.046	0.20
		N-9	Villa Frontera	Jul-93	24.5	6.7	3397	479	154	437	55.0	884	1316	0	49	23.06	0.023	0.34	0.003	0.040	0.020	16.31	0.82	0.25	0.736	0.037	0.70
				Oct-93	23.1	7.4	3553	490	154	469	59.0	903	1415	0	48	14.39	0.020	0.44	0.004	0.020	0.010	18.27	0.16	0.02	0.200	0.027	0.40
				(Average)	23.8	7.0	3475	485	154	453	57.0	893	1366	0	49	18.73	0.022	0.39	0.004	0.030	0.015	17.29	0.49	0.14	0.468	0.032	0.55
	Average				23.7	7.0	3150	355	117	503	59.2	919	1110	0	78	9.56	0.033	0.60	0.003	0.049	0.015	18.94	0.51	0.08	1.208	0.036	0.26
DEEP AQUIFER	012 11 100-2		ROSARIO	Jul-93	21.6	6.8	3211	314	97	610	73.5	961	1071	0	64	21.99	0.039	1.15	0.004	0.040	0.020	24.50	1.38	0.10	0.351	0.039	0.20
				Oct-93	21.1	6.8	3401	324	103	616	75.0	1085	1107	0	81	9.51	0.050	1.12	0.005	0.020	0.010	30.10	0.13	0.03	0.085	0.039	0.40
				(Average)	21.4	6.8	3306	319	100	613	74.3	1023	1089	0	73	15.75	0.045	1.14	0.005	0.030	0.015	27.30	0.76	0.07	0.218	0.039	0.30
	012 11 101-0		CARCEL DE ARICA	Oct-93	26.8	7.3	2982	258	85	437	49.0	845	791	0	79	4.58	0.035	0.72	0.005	0.010	0.020	11.87	0.03	0.01	0.041	0.028	0.30
	DGA-JICA	J-1	CHACABUCO	Feb-94	24.5	6.9	3075	338	105	612	65.5	875	1063	0	148	0.41	0.046		0.015	0.020	0.080	24.50	2.26	3.85	3.220	0.022	0.10
	DGA-JICA	J-A	LLUTA	Feb-94	25.4	7.1	3028	239	85	451	52.0	625	839	0	104	0.54	0.009		0.012	0.020	0.050	19.24	6.60	0.94	0.680	0.014	0.20
	DGA-JICA	J-2	LLUTA	Feb-94	23.1	6.6	3931	299	74	515	60.0	825	908	0	104	1.43	0.019		0.012	0.020	0.060	23.45	0.05	0.05	1.420	0.014	0.10
	DGA-JICA	J-B	PANAMERICANA	Feb-94	23.7	6.9	3397	296	93	460	51.0	750	868	0	78	0.74	0.005		0.014	0.020	0.040	19.45	0.28	0.03	2.070	0.013	0.10
	Average				23.7	6.9	3289	295	92	529	60.9	852	949	0.0	94	5.60	0.029	1.00	0.010	0.021	0.040	21.87	1.53	0.72	1.124	0.024	0.20

(Note) V: SPRING, N: DUG WELL (No. of spring and dug well are temporary.).
SAMPLED AND ANALYZED BY DGA AND JICA STUDY TEAM IN NOVEMBER 1993.
SAMPLES OF JICA WELLS WERE TAKEN AFTER PUMPING TEST. OTHERS WERE SAMPLED WITHOUT PUMPING (WELLS WERE NOT IN USE.).

Table B-II, 3.2 Water Distribution to Irrigation Canal (by Water Right)
<Distribución de Agua al Canal de Irrigación>

Acción between Tocontasi and Sector III =	687.2 Acc.	
x 0.75 =	515.4 l/sec	(a)
Water Right (Vilca-Loredo) =	35.5 l/sec	(b)
Total Demand (Tocontasi-Sector III) =	550.9 l/sec	(a)+(b)

		Acción	Acc. x 0.75 (l/sec)	Water Demand (l/sec)	Real Coms. (l/sec)	(1) Intake/Canal (l/sec)	(2) Distribution (l/sec)	(3) Remaining (l/sec)	(4) Return (l/sec)	(3)+(4) Canal(2) (l/sec)
Sector III	Kesler	4.70	3.53							
Right Bank	Pro-Chile	65.90	49.43							
	García	5.00	3.75							
	La Palma Uno	23.00	17.25							
	La Palma Dos	36.00	27.00	101.0	50.5	140.3	101.0	39.4	50.5	89.8
	Visconti	119.50	89.63	89.6	44.8	89.8	89.6	0.2	44.8	45.0
	Kesler Gil	60.00	45.00	45.0	22.5	45.0	45.0	0.0	22.5	22.5
	Sub-Total	314.10	235.58	235.6	117.8					
Left Bank	La Isla	22.40	16.80							
	Huanca	7.08	5.31							
	Linderos	23.90	17.93							
	Poconchile	83.80	62.85							
	Barranco Sta. Rosa	19.00	14.25							
	Mayorca	20.30	15.23							
	Huancarane	31.63	23.72							
Sector IV	Arellano Beyzan	18.70	14.03							
	Cora Beyzan	93.60	70.20	240.3	120.2	678.5	240.3	438.2	120.2	558.3
	El Muro	158.45	118.84							
	Alanoca	10.50	7.88	126.7	63.4	558.3	126.7	431.6	63.4	495.0
	Chacabuco (1)	155.00	116.25	116.3	58.1	495.0	116.3	378.7	58.1	436.9
	Chacabuco (2)	155.00	116.25							
	Dominguez	10.00	7.50	123.8	61.9	436.9	123.8	313.1	61.9	375.0
	Sascapa (1)	123.00	92.25	92.3	46.1	375.0	92.3	282.7	46.1	328.9
	Sascapa (2)	123.00	92.25	92.3	46.1	328.9	92.3	236.6	46.1	282.7
	Bravo Uno	18.75	14.06							
	Bravo Dos	11.26	8.45	22.5	11.3	282.7	22.5	260.2	11.3	271.5
	Sub-Total	1085.37	814.03	814.0	407.0					
Sector V	Valle Hermoso	249.00	249.00							
	Aica González	30.00	22.50	271.5	135.8	271.5	271.5	0.0	135.8	135.7
	M. Beovic	8.00	6.00							
	B'ba Pte.Chacall.	5.00	3.75							
	Ambrosio Flores	2.00	1.50	11.3	5.6	135.7	11.3	124.5	5.6	130.1
	Bellet	32.00	24.00							
	Beneficiencia	39.19	29.39							
	Santa Rosa	46.83	35.12	88.5	44.3	130.1	88.5	41.6	44.3	85.9
	Sub-Total	412.02	371.27							
	Total	1399.47	1049.60	1049.6	524.8					
			1049.60		524.8					

Table B-II, 3.3 (1) Actual Water Demand and Real Consumption
<Demanda Actual de Agua y Consumo Real>

Jan.

		Existing Irrigation Area (ha)					Water Demand (l/sec)				Real Consumption			Consum
		Maize	Vegetable	Pasture	Fallow	Total	Maize	Vegetable	Pasture	Total	Maize	Vegetable	Pasture	Total
Sector III Right Bank	Kesler	0.0	1.3	0.0	5.0	6.3	0.0	1.5	0.0	1.5	0.0	0.7	0.0	0.7
	Pro-Chile	18.0	6.0	38.0	25.9	87.9	0.0	6.8	47.0	53.8	0.0	3.0	28.2	31.2
	García	3.2	0.7	1.4	1.3	6.7	0.0	0.8	1.8	2.5	0.0	0.3	1.1	1.4
	La Palma Uno	16.0	2.0	3.0	9.7	30.7	0.0	2.3	3.7	6.0	0.0	1.0	2.2	3.2
	La Palma Dos	35.5	4.0	0.5	8.0	48.0	0.0	4.5	0.6	5.1	0.0	2.0	0.4	2.4
	Visconti	100.8	8.7	10.5	39.3	159.3	0.0	9.8	13.0	22.8	0.0	4.4	7.8	12.2
	Kesler Gil	38.8	8.1	17.0	16.1	80.0	0.0	9.2	21.0	30.2	0.0	4.1	12.6	16.7
	Sub-Total	212.4	30.8	70.4	105.3	418.9	0.0	34.7	87.1	121.8	0.0	15.6	52.3	67.9
Left Bank Sector III	La Isla	18.0	8.0	0.0	4.0	30.0	27.4	9.0	0.0	36.4	11.0	4.1	0.0	15.0
	Huanca	4.6	1.0	2.0	1.9	9.4	6.9	1.1	2.5	10.5	2.8	0.5	1.5	4.7
	Linderos	16.0	7.9	8.0	0.0	31.9	24.4	8.9	9.9	43.2	9.7	4.0	5.9	19.7
	Poconchile	45.0	15.0	46.0	5.7	111.7	0.0	16.9	56.9	73.8	0.0	7.6	34.1	41.7
	Barranco Sta. Rosa	8.3	1.0	7.0	9.0	25.3	0.0	1.1	8.7	9.8	0.0	0.5	5.2	5.7
	Mayorca	13.1	2.7	5.8	5.4	27.1	0.0	3.1	7.1	10.2	0.0	1.4	4.3	5.7
	Huancarane	31.6	6.6	13.9	13.1	65.2	0.0	7.5	17.2	24.6	0.0	3.4	10.3	13.6
	Sub-Total	136.6	42.2	82.6	39.1	300.6	58.7	47.6	102.2	208.5	23.5	21.4	61.3	106.2
Sector IV	Arellano Beyzan	18.7	0.0	2.0	6.0	26.7	0.0	0.0	2.5	2.5	0.0	0.0	1.5	1.5
	Cora Beyzan	93.6	1.0	5.0	30.0	129.6	0.0	1.1	6.2	7.3	0.0	0.5	3.7	4.2
	El Muro	158.5	32.7	12.6	77.7	281.4	0.0	36.8	15.6	52.4	0.0	16.6	9.3	25.9
	Alanoca	10.5	1.0	1.0	23.0	35.5	0.0	1.1	1.2	2.4	0.0	0.5	0.7	1.2
	Chacabuco	310.0	30.0	10.0	106.8	456.8	0.0	33.8	12.4	46.2	0.0	15.2	7.4	22.6
	Dominguez	10.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sascapa	246.0	110.0	36.7	172.0	564.7	0.0	124.0	45.4	169.4	0.0	55.8	27.2	83.0
	Bravo Uno	18.8	3.9	1.5	9.2	33.3	0.0	4.4	1.8	6.2	0.0	2.0	1.1	3.1
	Bravo Dos	11.3	2.3	0.9	5.5	20.0	0.0	2.6	1.1	3.7	0.0	1.2	0.7	1.8
	Sub-Total	877.3	180.9	69.6	430.2	1,558.0	0.0	203.9	86.1	290.1	0.0	91.8	51.7	143.5
										620.4				
Sector V	Valle Hermoso	60.0	35.0	12.0	225.0	332.0	83.6	36.1	13.4	133.1	33.4	16.3	8.1	57.7
	Aica González	24.0	8.0	1.0	7.0	40.0	33.4	8.3	1.1	42.8	13.4	3.7	0.7	17.8
	M. Beovic	0.0	0.0	8.0	2.7	10.7	0.0	0.0	9.0	9.0	0.0	0.0	5.4	5.4
	B'ba Pta.Chacall.	0.0	0.0	6.7	0.0	6.7	0.0	0.0	7.5	7.5	0.0	0.0	4.5	4.5
	Ambrosio Flores	0.0	0.0	2.0	0.7	2.7	0.0	0.0	2.2	2.2	0.0	0.0	1.3	1.3
	Bellet	0.0	2.7	0.0	40.0	42.7	0.0	2.8	0.0	2.8	0.0	1.3	0.0	1.3
	Beneficiencia	4.8	11.5	16.5	19.5	52.3	6.7	11.9	18.5	37.0	2.7	5.3	11.1	19.1
	Santa Rosa	12.0	10.0	8.0	32.4	62.4	16.7	10.3	9.0	36.0	6.7	4.6	5.4	16.7
	Total	100.8	67.2	54.2	327.3	549.5	140.4	69.4	60.6	270.4	56.2	31.2	36.4	123.8

Feb.

		Existing Irrigation Area (ha)					Water Demand (l/sec)				Real Consumption			
		Maize	Vegetable	Pasture	Fallow	Total	Maize	Vegetable	Pasture	Total	Maize	Vegetable	Pasture	Total
Right Bank Sector III	Kesler	0.0	1.3	0.0	5.0	6.3	0.0	1.5	0.0	1.5	0.0	0.7	0.0	0.7
	Pro-Chile	18.0	6.0	38.0	25.9	87.9	0.0	6.8	46.9	53.6	0.0	3.0	28.1	31.2
	García	3.2	0.7	1.4	1.3	6.7	0.0	0.8	1.8	2.5	0.0	0.3	1.1	1.4
	La Palma Uno	16.0	2.0	3.0	9.7	30.7	0.0	2.3	3.7	5.9	0.0	1.0	2.2	3.2
	La Palma Dos	35.5	4.0	0.5	8.0	48.0	0.0	4.5	0.6	5.1	0.0	2.0	0.4	2.4
	Visconti	100.8	8.7	10.5	39.3	159.3	0.0	9.8	12.9	22.7	0.0	4.4	7.8	12.2
	Kesler Gil	38.8	8.1	17.0	16.1	80.0	0.0	9.1	21.0	30.1	0.0	4.1	12.6	16.7
	Sub-Total	212.4	30.8	70.4	105.3	418.9	0.0	34.7	86.9	121.5	0.0	15.6	52.1	67.7
Left Bank Sector III	La Isla	18.0	8.0	0.0	4.0	30.0	27.3	9.0	0.0	36.3	10.9	4.1	0.0	15.0
	Huanca	4.6	1.0	2.0	1.9	9.4	6.9	1.1	2.5	10.5	2.8	0.5	1.5	4.7
	Linderos	16.0	7.9	8.0	0.0	31.9	24.3	8.9	9.9	43.1	9.7	4.0	5.9	19.6
	Poconchile	45.0	15.0	46.0	5.7	111.7	0.0	16.9	56.7	73.6	0.0	7.6	34.0	41.6
	Barranco Sta. Rosa	8.3	1.0	7.0	9.0	25.3	0.0	1.1	8.6	9.8	0.0	0.5	5.2	5.7
	Mayorca	13.1	2.7	5.8	5.4	27.1	0.0	3.1	7.1	10.2	0.0	1.4	4.3	5.7
	Huancarane	31.6	6.6	13.9	13.1	65.2	0.0	7.4	17.1	24.6	0.0	3.3	10.3	13.6
	Sub-Total	136.6	42.2	82.6	39.1	300.6	58.6	47.5	101.9	208.0	23.4	21.4	61.1	105.9
Sector IV	Arellano Beyzan	18.7	0.0	2.0	6.0	26.7	0.0	0.0	2.5	2.5	0.0	0.0	1.5	1.5
	Cora Beyzan	93.6	1.0	5.0	30.0	129.6	0.0	1.1	6.2	7.3	0.0	0.5	3.7	4.2
	El Muro	158.5	32.7	12.6	77.7	281.4	0.0	36.8	15.5	52.3	0.0	16.5	9.3	25.9
	Alanoca	10.5	1.0	1.0	23.0	35.5	0.0	1.1	1.2	2.4	0.0	0.5	0.7	1.2
	Chacabuco	310.0	30.0	10.0	106.8	456.8	0.0	33.8	12.3	46.1	0.0	15.2	7.4	22.6
	Dominguez	10.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sascapa	246.0	110.0	36.7	172.0	564.7	0.0	123.8	45.3	169.0	0.0	55.7	27.2	82.8
	Bravo Uno	18.8	3.9	1.5	9.2	33.3	0.0	4.4	1.8	6.2	0.0	2.0	1.1	3.1
	Bravo Dos	11.3	2.3	0.9	5.5	20.0	0.0	2.6	1.1	3.7	0.0	1.2	0.7	1.8
	Sub-Total	877.3	180.9	69.6	430.2	1558.0	0.0	203.5	85.9	289.4	0.0	91.6	51.5	143.1
										618.9				

Table B-II, 3.3 (2) Actual Water Demand and Real Consumption
<Demanda Actual de Agua y Consumo Real>

Mar.

		Existing Irrigation Area (ha)					Water Demand (l/sec)				Real Consumption			
		Maize	Vegetable	Pasture	Fallow	Total	Maize	Vegetable	Pasture	Total	Maize	Vegetable	Pasture	Total
Sector III	Kesler	0.0	1.3	0.0	5.0	6.3	0.0	1.3	0.0	1.3	0.0	0.6	0.0	0.6
Right Bank	Pro-Chile	18.0	6.0	38.0	25.9	87.9	24.2	6.0	41.1	71.3	9.7	2.7	24.6	37.0
	García	3.2	0.7	1.4	1.3	6.7	4.4	0.7	1.5	6.6	1.7	0.3	0.9	3.0
	La Palma Uno	16.0	2.0	3.0	9.7	30.7	21.5	2.0	3.2	26.8	8.6	0.9	1.9	11.5
	La Palma Dos	35.5	4.0	0.5	8.0	48.0	47.8	4.0	0.5	52.3	19.1	1.8	0.3	21.2
	Visconti	100.8	8.7	10.5	39.3	159.3	135.6	8.7	11.3	155.6	54.2	3.9	6.8	64.9
	Kesler Gil	38.8	8.1	17.0	16.1	80.0	52.2	8.1	18.4	78.7	20.9	3.6	11.0	35.6
	Sub-Total	212.4	30.8	70.4	105.3	418.9	285.7	30.7	76.1	392.5	114.3	13.8	45.7	173.8
Left Bank														
Sector III	La Isla	18.0	8.0	0.0	4.0	30.0	24.2	8.0	0.0	32.2	9.7	3.6	0.0	13.3
	Huanca	4.6	1.0	2.0	1.9	9.4	6.1	1.0	2.2	9.2	2.5	0.4	1.3	4.2
	Linderos	16.0	7.9	8.0	0.0	31.9	21.5	7.9	8.6	38.0	8.6	3.5	5.2	17.3
	Poconchile	45.0	15.0	46.0	5.7	111.7	60.5	14.9	49.7	125.2	24.2	6.7	29.8	60.8
	Barranco Sta. Rosa	8.3	1.0	7.0	9.0	25.3	11.2	1.0	7.6	19.7	4.5	0.4	4.5	9.5
	Mayorca	13.1	2.7	5.8	5.4	27.1	17.7	2.7	6.2	26.7	7.1	1.2	3.7	12.0
	Huancarane	31.6	6.6	13.9	13.1	65.2	42.5	6.6	15.0	64.1	17.0	3.0	9.0	29.0
	Sub-Total	136.6	42.2	82.6	39.1	300.6	183.8	42.1	89.3	315.2	73.5	18.9	53.6	146.0
Sector IV	Arellano Beyzan	18.7	0.0	2.0	6.0	26.7	25.2	0.0	2.2	27.3	10.1	0.0	1.3	11.4
	Cora Beyzan	93.6	1.0	5.0	30.0	129.6	125.9	1.0	5.4	132.3	50.4	0.4	3.2	54.1
	El Muro	158.5	32.7	12.6	77.7	281.4	213.2	32.6	13.6	259.3	85.3	14.7	8.2	108.1
	Alanoca	10.5	1.0	1.0	23.0	35.5	14.1	1.0	1.1	16.2	5.6	0.4	0.6	6.7
	Chacabuco	310.0	30.0	10.0	106.8	456.8	417.0	29.9	10.8	457.7	166.8	13.5	6.5	186.7
	Dominguez	10.0	0.0	0.0	0.0	10.0	13.5	0.0	0.0	13.5	5.4	0.0	0.0	5.4
	Sascapa	246.0	110.0	36.7	172.0	564.7	330.9	109.6	39.7	480.2	132.4	49.3	23.8	205.5
	Bravo Uno	18.8	3.9	1.5	9.2	33.3	25.2	3.9	1.6	30.7	10.1	1.7	1.0	12.8
	Bravo Dos	11.3	2.3	0.9	5.5	20.0	15.1	2.3	1.0	18.4	6.1	1.0	0.6	7.7
	Sub-Total	877.3	180.9	69.6	430.2	1,558.0	1,180.1	180.2	75.3	1,435.6	472.0	81.1	45.2	598.3
										2143.3				

Apr.

		Existing Irrigation Area (ha)					Water Demand (l/sec)				Real Consumption			
		Maize	Vegetable	Pasture	Fallow	Total	Maize	Vegetable	Pasture	Total	Maize	Vegetable	Pasture	Total
Right Bank	Kesler	0.0	1.3	0.0	5.0	6.3	0.0	1.0	0.0	1.0	0.0	0.5	0.0	0.5
Sector III	Pro-Chile	18.0	6.0	38.0	25.9	87.9	19.1	4.7	30.9	54.7	7.6	2.1	18.6	28.3
	García	3.2	0.7	1.4	1.3	6.7	3.4	0.5	1.2	5.1	1.4	0.2	0.7	2.3
	La Palma Uno	16.0	2.0	3.0	9.7	30.7	16.9	1.6	2.4	21.0	6.8	0.7	1.5	8.9
	La Palma Dos	35.5	4.0	0.5	8.0	48.0	37.6	3.1	0.4	41.1	15.0	1.4	0.2	16.7
	Visconti	100.8	8.7	10.5	39.3	159.3	106.8	6.8	8.5	122.1	42.7	3.1	5.1	50.9
	Kesler Gil	38.8	8.1	17.0	16.1	80.0	41.1	6.4	13.9	61.3	16.4	2.9	8.3	27.6
	Sub-Total	212.4	30.8	70.4	105.3	418.9	224.9	24.2	57.3	306.4	90.0	10.9	34.4	135.2
Left Bank														
Sector III	La Isla	18.0	8.0	0.0	4.0	30.0	0.0	6.3	0.0	6.3	0.0	2.8	0.0	2.8
	Huanca	4.6	1.0	2.0	1.9	9.4	0.0	0.7	1.6	2.4	0.0	0.3	1.0	1.3
	Linderos	16.0	7.9	8.0	0.0	31.9	0.0	6.2	6.5	12.7	0.0	2.8	3.9	6.7
	Poconchile	45.0	15.0	46.0	5.7	111.7	47.7	11.8	37.4	96.9	19.1	5.3	22.5	46.8
	Barranco Sta. Rosa	8.3	1.0	7.0	9.0	25.3	8.8	0.8	5.7	15.3	3.5	0.4	3.4	7.3
	Mayorca	13.1	2.7	5.8	5.4	27.1	13.9	2.2	4.7	20.8	5.6	1.0	2.8	9.4
	Huancarane	31.6	6.6	13.9	13.1	65.2	33.5	5.2	11.3	50.0	13.4	2.3	6.8	22.5
	Sub-Total	136.6	42.2	82.6	39.1	300.6	103.9	33.1	67.3	204.2	41.5	14.9	40.4	96.8
Sector IV	Arellano Beyzan	18.7	0.0	2.0	6.0	26.7	19.8	0.0	1.6	21.4	7.9	0.0	1.0	8.9
	Cora Beyzan	93.6	1.0	5.0	30.0	129.6	99.1	0.8	4.1	104.0	39.7	0.4	2.4	42.4
	El Muro	158.5	32.7	12.6	77.7	281.4	167.8	25.6	10.2	203.7	67.1	11.5	6.1	84.8
	Alanoca	10.5	1.0	1.0	23.0	35.5	11.1	0.8	0.8	12.7	4.4	0.4	0.5	5.3
	Chacabuco	310.0	30.0	10.0	106.8	456.8	328.3	23.5	8.1	360.0	131.3	10.6	4.9	146.8
	Dominguez	10.0	0.0	0.0	0.0	10.0	10.6	0.0	0.0	10.6	4.2	0.0	0.0	4.2
	Sascapa	246.0	110.0	36.7	172.0	564.7	260.5	86.3	29.9	376.7	104.2	38.8	17.9	161.0
	Bravo Uno	18.8	3.9	1.5	9.2	33.3	19.9	3.0	1.2	24.1	7.9	1.4	0.7	10.0
	Bravo Dos	11.3	2.3	0.9	5.5	20.0	11.9	1.8	0.7	14.5	4.8	0.8	0.4	6.0
	Sub-Total	877.3	180.9	69.6	430.2	1,558.0	929.1	141.9	56.7	1,127.6	371.6	63.8	34.0	469.5
										1638.3				

Table B-II, 3.3 (3) Actual Water Demand and Real Consumption
<Demanda Actual de Agua y Consumo Real>

May

		Existing Irrigation Area (ha)					Water Demand (l/sec)				Real Consumption			
		Maize	Vegetable	Pasture	Fallow	Total	Maize	Vegetable	Pasture	Total	Maize	Vegetable	Pasture	Total
Sector III Right Bank	Kesler	0.0	1.3	0.0	5.0	6.3	0.0	0.8	0.0	0.8	0.0	0.4	0.0	0.4
	Pro-Chile	18.0	6.0	38.0	25.9	87.9	15.5	3.8	23.8	43.1	6.2	1.7	14.3	22.2
	García	3.2	0.7	1.4	1.3	6.7	2.8	0.4	0.9	4.1	1.1	0.2	0.5	1.8
	La Palma Uno	16.0	2.0	3.0	9.7	30.7	13.8	1.3	1.9	16.9	5.5	0.6	1.1	7.2
	La Palma Dos	35.5	4.0	0.5	8.0	48.0	30.5	2.5	0.3	33.4	12.2	1.1	0.2	13.5
	Visconti	100.8	8.7	10.5	39.3	159.3	86.7	5.5	6.6	98.8	34.7	2.5	3.9	41.1
	Kesler Gil	38.8	8.1	17.0	16.1	80.0	33.4	5.2	10.6	49.2	13.4	2.3	6.4	22.1
	Sub-Total	212.4	30.8	70.4	105.3	418.9	182.7	19.6	44.1	246.4	73.1	8.8	26.4	108.3
Left Bank Sector III	La Isla	18.0	8.0	0.0	4.0	30.0	0.0	5.1	0.0	5.1	0.0	2.3	0.0	2.3
	Huanca	4.6	1.0	2.0	1.9	9.4	0.0	0.6	1.3	1.9	0.0	0.3	0.8	1.0
	Linderos	16.0	7.9	8.0	0.0	31.9	0.0	5.0	5.0	10.0	0.0	2.3	3.0	5.3
	Poconchile	45.0	15.0	46.0	5.7	111.7	38.7	9.6	28.8	77.0	15.5	4.3	17.3	37.0
	Barranco Sta. Rosa	8.3	1.0	7.0	9.0	25.3	7.1	0.6	4.4	12.2	2.9	0.3	2.6	5.8
	Mayorca	13.1	2.7	5.8	5.4	27.1	11.3	1.8	3.6	16.7	4.5	0.8	2.2	7.5
	Huancarane	31.6	6.6	13.9	13.1	65.2	27.2	4.2	8.7	40.1	10.9	1.9	5.2	18.0
	Sub-Total	136.6	42.2	82.6	39.1	300.6	84.4	26.9	51.7	162.9	33.7	12.1	31.0	76.9
Sector IV	Arellano Beyzan	18.7	0.0	2.0	6.0	26.7	16.1	0.0	1.3	17.3	6.4	0.0	0.8	7.2
	Cora Beyzan	93.6	1.0	5.0	30.0	129.6	80.5	0.6	3.1	84.3	32.2	0.3	1.9	34.4
	El Muro	158.5	32.7	12.6	77.7	281.4	136.3	20.8	7.9	165.0	54.5	9.4	4.7	68.6
	Alanoca	10.5	1.0	1.0	23.0	35.5	9.0	0.6	0.6	10.3	3.6	0.3	0.4	4.3
	Chacabuco	310.0	30.0	10.0	106.8	456.8	266.7	19.1	6.3	292.0	106.7	8.6	3.8	119.0
	Dominguez	10.0	0.0	0.0	0.0	10.0	8.6	0.0	0.0	8.6	3.4	0.0	0.0	3.4
	Sascapa	246.0	110.0	36.7	172.0	564.7	211.6	70.1	23.0	304.7	84.6	31.5	13.8	130.0
	Bravo Uno	18.8	3.9	1.5	9.2	33.3	16.1	2.5	0.9	19.5	6.5	1.1	0.6	8.1
	Bravo Dos	11.3	2.3	0.9	5.5	20.0	9.7	1.5	0.6	11.7	3.9	0.7	0.3	4.9
	Sub-Total	877.3	180.9	69.6	430.2	1,558.0	754.6	115.3	43.6	913.5	301.9	51.9	26.1	379.9
										1322.8				

Jun.

		Existing Irrigation Area (ha)					Water Demand (l/sec)				Real Consumption			
		Maize	Vegetable	Pasture	Fallow	Total	Maize	Vegetable	Pasture	Total	Maize	Vegetable	Pasture	Total
Right Bank Sector III	Kesler	0.0	1.3	0.0	5.0	6.3	0.0	0.7	0.0	0.7	0.0	0.3	0.0	0.3
	Pro-Chile	18.0	6.0	38.0	25.9	87.9	12.8	3.2	18.5	34.5	5.1	1.4	11.1	17.7
	García	3.2	0.7	1.4	1.3	6.7	2.3	0.4	0.7	3.4	0.9	0.2	0.4	1.5
	La Palma Uno	16.0	2.0	3.0	9.7	30.7	11.4	1.1	1.5	13.9	4.6	0.5	0.9	5.9
	La Palma Dos	35.5	4.0	0.5	8.0	48.0	25.3	2.1	0.2	27.7	10.1	1.0	0.1	11.2
	Visconti	100.8	8.7	10.5	39.3	159.3	71.9	4.6	5.1	81.6	28.7	2.1	3.1	33.9
	Kesler Gil	38.8	8.1	17.0	16.1	80.0	27.7	4.3	8.3	40.2	11.1	1.9	5.0	18.0
	Sub-Total	212.4	30.8	70.4	105.3	418.9	151.4	16.3	34.3	202.0	60.6	7.3	20.6	88.5
Left Bank Sector III	La Isla	18.0	8.0	0.0	4.0	30.0	0.0	4.2	0.0	4.2	0.0	1.9	0.0	1.9
	Huanca	4.6	1.0	2.0	1.9	9.4	0.0	0.5	1.0	1.5	0.0	0.2	0.6	0.8
	Linderos	16.0	7.9	8.0	0.0	31.9	0.0	4.2	3.9	8.1	0.0	1.9	2.3	4.2
	Poconchile	45.0	15.0	46.0	5.7	111.7	32.1	7.9	22.4	62.4	12.8	3.6	13.4	29.8
	Barranco Sta. Rosa	8.3	1.0	7.0	9.0	25.3	5.9	0.5	3.4	9.9	2.4	0.2	2.0	4.7
	Mayorca	13.1	2.7	5.8	5.4	27.1	9.4	1.5	2.8	13.6	3.7	0.7	1.7	6.1
	Huancarane	31.6	6.6	13.9	13.1	65.2	22.5	3.5	6.8	32.8	9.0	1.6	4.1	14.6
	Sub-Total	136.6	42.2	82.6	39.1	300.6	69.9	22.3	40.3	132.5	28.0	10.0	24.2	62.2
Sector IV	Arellano Beyzan	18.7	0.0	2.0	6.0	26.7	13.3	0.0	1.0	14.3	5.3	0.0	0.6	5.9
	Cora Beyzan	93.6	1.0	5.0	30.0	129.6	66.7	0.5	2.4	69.7	26.7	0.2	1.5	28.4
	El Muro	158.5	32.7	12.6	77.7	281.4	113.0	17.3	6.1	136.4	45.2	7.8	3.7	56.6
	Alanoca	10.5	1.0	1.0	23.0	35.5	7.5	0.5	0.5	8.5	3.0	0.2	0.3	3.5
	Chacabuco	310.0	30.0	10.0	106.8	456.8	221.0	15.8	4.9	241.7	88.4	7.1	2.9	98.5
	Dominguez	10.0	0.0	0.0	0.0	10.0	7.1	0.0	0.0	7.1	2.9	0.0	0.0	2.9
	Sascapa	246.0	110.0	36.7	172.0	564.7	175.4	58.1	17.9	251.4	70.2	26.1	10.7	107.0
	Bravo Uno	18.8	3.9	1.5	9.2	33.3	13.4	2.0	0.7	16.1	5.3	0.9	0.4	6.7
	Bravo Dos	11.3	2.3	0.9	5.5	20.0	8.0	1.2	0.4	9.7	3.2	0.6	0.3	4.0
	Sub-Total	877.3	180.9	69.6	430.2	1,558.0	625.5	95.5	33.9	754.9	250.2	43.0	20.4	313.5
										1089.4				

Table B-II, 3.3 (4) Actual Water Demand and Real Consumption
<Demanda Actual de Agua y Consumo Real>

Jul.

		Existing Irrigation Area (ha)					Water Demand (l/sec)				Real Consumption			
		Maize	Vegetable	Pasture	Fallow	Total	Maize	Vegetable	Pasture	Total	Maize	Vegetable	Pasture	Total
Sector III Right Bank	Kesler	0.0	1.3	0.0	5.0	6.3	0.0	0.7	0.0	0.7	0.0	0.3	0.0	0.3
	Pro-Chile	18.0	6.0	38.0	25.9	87.9	0.0	3.1	17.9	21.0	0.0	1.4	10.8	12.2
	García	3.2	0.7	1.4	1.3	6.7	0.0	0.3	0.7	1.0	0.0	0.2	0.4	0.6
	La Palma Uno	16.0	2.0	3.0	9.7	30.7	0.0	1.0	1.4	2.4	0.0	0.5	0.9	1.3
	La Palma Dos	35.5	4.0	0.5	8.0	48.0	0.0	2.0	0.2	2.3	0.0	0.9	0.1	1.1
	Visconti	100.8	8.7	10.5	39.3	159.3	0.0	4.5	5.0	9.4	0.0	2.0	3.0	5.0
	Kesler Gil	38.8	8.1	17.0	16.1	80.0	0.0	4.2	8.0	12.2	0.0	1.9	4.8	6.7
	Sub-Total	212.4	30.8	70.4	105.3	418.9	0.0	15.8	33.3	49.0	0.0	7.1	20.0	27.1
Left Bank														
Sector III	La Isla	18.0	8.0	0.0	4.0	30.0	0.0	4.1	0.0	4.1	0.0	1.8	0.0	1.8
	Huanca	4.6	1.0	2.0	1.9	9.4	0.0	0.5	0.9	1.4	0.0	0.2	0.6	0.8
	Linderos	16.0	7.9	8.0	0.0	31.9	0.0	4.0	3.8	7.8	0.0	1.8	2.3	4.1
	Poconchile	45.0	15.0	46.0	5.7	111.7	0.0	7.7	21.7	29.4	0.0	3.5	13.0	16.5
	Barranco Sta. Rosa	8.3	1.0	7.0	9.0	25.3	0.0	0.5	3.3	3.8	0.0	0.2	2.0	2.2
	Mayorca	13.1	2.7	5.8	5.4	27.1	0.0	1.4	2.7	4.1	0.0	0.6	1.6	2.3
	Huancarane	31.6	6.6	13.9	13.1	65.2	0.0	3.4	6.6	9.9	0.0	1.5	3.9	5.5
	Sub-Total	136.6	42.2	82.6	39.1	300.6	0.0	21.6	39.0	60.6	0.0	9.7	23.4	33.1
Sector IV	Arellano Beyzan	18.7	0.0	2.0	6.0	26.7	0.0	0.0	0.9	0.9	0.0	0.0	0.6	0.6
	Cora Beyzan	93.6	1.0	5.0	30.0	129.6	0.0	0.5	2.4	2.9	0.0	0.2	1.4	1.6
	El Muro	158.5	32.7	12.6	77.7	281.4	0.0	16.7	5.9	22.7	0.0	7.5	3.6	11.1
	Alanoca	10.5	1.0	1.0	23.0	35.5	0.0	0.5	0.5	1.0	0.0	0.2	0.3	0.5
	Chacabuco	310.0	30.0	10.0	106.8	456.8	0.0	15.4	4.7	20.1	0.0	6.9	2.8	9.7
	Dominguez	10.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sascapa	246.0	110.0	36.7	172.0	564.7	0.0	56.3	17.3	73.6	0.0	25.3	10.4	35.7
	Bravo Uno	18.8	3.9	1.5	9.2	33.3	0.0	2.0	0.7	2.7	0.0	0.9	0.4	1.3
	Bravo Dos	11.3	2.3	0.9	5.5	20.0	0.0	1.2	0.4	1.6	0.0	0.5	0.3	0.8
	Sub-Total	877.3	180.9	69.6	430.2	1,558.0	0.0	92.6	32.9	125.5	0.0	41.7	19.7	61.4
										235.2				

Aug.

		Existing Irrigation Area (ha)					Water Demand (l/sec)				Real Consumption			
		Maize	Vegetable	Pasture	Fallow	Total	Maize	Vegetable	Pasture	Total	Maize	Vegetable	Pasture	Total
Right Bank Sector III	Kesler	0.0	1.3	0.0	5.0	6.3	0.0	0.7	0.0	0.7	0.0	0.3	0.0	0.3
	Pro-Chile	18.0	6.0	38.0	25.9	87.9	0.0	3.4	20.3	23.6	0.0	1.5	12.2	13.7
	García	3.2	0.7	1.4	1.3	6.7	0.0	0.4	0.8	1.1	0.0	0.2	0.5	0.6
	La Palma Uno	16.0	2.0	3.0	9.7	30.7	0.0	1.1	1.6	2.7	0.0	0.5	1.0	1.5
	La Palma Dos	35.5	4.0	0.5	8.0	48.0	0.0	2.3	0.3	2.5	0.0	1.0	0.2	1.2
	Visconti	100.8	8.7	10.5	39.3	159.3	0.0	4.9	5.6	10.5	0.0	2.2	3.4	5.6
	Kesler Gil	38.8	8.1	17.0	16.1	80.0	0.0	4.6	9.1	13.6	0.0	2.1	5.4	7.5
	Sub-Total	212.4	30.8	70.4	105.3	418.9	0.0	17.4	37.6	54.9	0.0	7.8	22.5	30.3
Left Bank														
Sector III	La Isla	18.0	8.0	0.0	4.0	30.0	0.0	4.5	0.0	4.5	0.0	2.0	0.0	2.0
	Huanca	4.6	1.0	2.0	1.9	9.4	0.0	0.5	1.1	1.6	0.0	0.2	0.6	0.9
	Linderos	16.0	7.9	8.0	0.0	31.9	0.0	4.5	4.3	8.7	0.0	2.0	2.6	4.6
	Poconchile	45.0	15.0	46.0	5.7	111.7	0.0	8.5	24.5	33.0	0.0	3.8	14.7	18.5
	Barranco Sta. Rosa	8.3	1.0	7.0	9.0	25.3	0.0	0.6	3.7	4.3	0.0	0.3	2.2	2.5
	Mayorca	13.1	2.7	5.8	5.4	27.1	0.0	1.5	3.1	4.6	0.0	0.7	1.8	2.5
	Huancarane	31.6	6.6	13.9	13.1	65.2	0.0	3.7	7.4	11.1	0.0	1.7	4.4	6.1
	Sub-Total	136.6	42.2	82.6	39.1	300.6	0.0	23.8	44.1	67.8	0.0	10.7	26.4	37.1
Sector IV	Arellano Beyzan	18.7	0.0	2.0	6.0	26.7	0.0	0.0	1.1	1.1	0.0	0.0	0.6	0.6
	Cora Beyzan	93.6	1.0	5.0	30.0	129.6	0.0	0.6	2.7	3.2	0.0	0.3	1.6	1.9
	El Muro	158.5	32.7	12.6	77.7	281.4	0.0	18.4	6.7	25.1	0.0	8.3	4.0	12.3
	Alanoca	10.5	1.0	1.0	23.0	35.5	0.0	0.6	0.5	1.1	0.0	0.3	0.3	0.6
	Chacabuco	310.0	30.0	10.0	106.8	456.8	0.0	16.9	5.3	22.2	0.0	7.6	3.2	10.8
	Dominguez	10.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sascapa	246.0	110.0	36.7	172.0	564.7	0.0	62.0	19.6	81.5	0.0	27.9	11.7	39.6
	Bravo Uno	18.8	3.9	1.5	9.2	33.3	0.0	2.2	0.8	3.0	0.0	1.0	0.5	1.5
	Bravo Dos	11.3	2.3	0.9	5.5	20.0	0.0	1.3	0.5	1.8	0.0	0.6	0.3	0.9
	Sub-Total	877.3	180.9	69.6	430.2	1,558.0	0.0	101.9	37.1	139.0	0.0	45.9	22.3	68.1
										261.8				

Table B-II, 3.3 (5) Actual Water Demand and Real Consumption
<Demanda Actual de Agua y Consumo Real>

Sep.

		Existing Irrigation Area (ha)					Water Demand (l/sec)				Real Comsumption			
		Maize	Vegetable	Pasture	Fallow	Total	Maize	Vegetable	Pasture	Total	Maize	Vegetable	Pasture	Total
Right Bank Sector III	Kesler	0.0	1.3	0.0	5.0	6.3	0.0	0.9	0.0	0.9	0.0	0.4	0.0	0.4
	Pro-Chile	18.0	6.0	38.0	25.9	87.9	17.2	4.3	26.1	47.5	6.9	1.9	15.6	24.4
	García	3.2	0.7	1.4	1.3	6.7	3.1	0.5	1.0	4.6	1.2	0.2	0.6	2.0
	La Palma Uno	16.0	2.0	3.0	9.7	30.7	15.3	1.4	2.1	18.8	6.1	0.6	1.2	8.0
	La Palma Dos	35.5	4.0	0.5	8.0	48.0	33.9	2.8	0.3	37.1	13.6	1.3	0.2	15.1
	Visconti	100.8	8.7	10.5	39.3	159.3	96.4	6.2	7.2	109.7	38.5	2.8	4.3	45.6
	Kesler Gil	38.8	8.1	17.0	16.1	80.0	37.1	5.7	11.7	54.5	14.8	2.6	7.0	24.4
	Sub-Total	212.4	30.8	70.4	105.3	418.9	203.0	21.8	48.3	273.2	81.2	9.8	29.0	120.0
Left Bank														
Sector III	La Isla	18.0	8.0	0.0	4.0	30.0	0.0	5.7	0.0	5.7	0.0	2.6	0.0	2.6
	Huanca	4.6	1.0	2.0	1.9	9.4	0.0	0.7	1.4	2.0	0.0	0.3	0.8	1.1
	Linderos	16.0	7.9	8.0	0.0	31.9	0.0	5.6	5.5	11.1	0.0	2.5	3.3	5.8
	Poconchile	45.0	15.0	46.0	5.7	111.7	43.0	10.6	31.6	85.2	17.2	4.8	18.9	40.9
	Barranco Sta Rosa	8.3	1.0	7.0	9.0	25.3	7.9	0.7	4.8	13.4	3.2	0.3	2.9	6.4
	Mayorca	13.1	2.7	5.8	5.4	27.1	12.6	1.9	4.0	18.5	5.0	0.9	2.4	8.3
	Huancarane	31.6	6.6	13.9	13.1	65.2	30.2	4.7	9.5	44.4	12.1	2.1	5.7	19.9
	Sub-Total	136.6	42.2	82.6	39.1	300.6	93.8	29.9	56.7	180.4	37.5	13.5	34.0	85.0
Sector IV	Arellano Beyzan	18.7	0.0	2.0	6.0	26.7	17.9	0.0	1.4	19.2	7.2	0.0	0.8	8.0
	Cora Beyzan	93.6	1.0	5.0	30.0	129.6	89.5	0.7	3.4	93.6	35.8	0.3	2.1	38.2
	El Muro	158.5	32.7	12.6	77.7	281.4	151.5	23.1	8.6	183.3	60.6	10.4	5.2	76.2
	Alanoca	10.5	1.0	1.0	23.0	35.5	10.0	0.7	0.7	11.4	4.0	0.3	0.4	4.7
	Chacabuco	310.0	30.0	10.0	106.8	456.8	296.4	21.3	6.9	324.5	118.5	9.6	4.1	132.2
	Dominguez	10.0	0.0	0.0	0.0	10.0	9.6	0.0	0.0	9.6	3.8	0.0	0.0	3.8
	Sascapa	246.0	110.0	36.7	172.0	564.7	235.2	77.9	25.2	338.3	94.1	35.1	15.1	144.2
	Bravo Uno	18.8	3.9	1.5	9.2	33.3	17.9	2.7	1.0	21.7	7.2	1.2	0.6	9.0
	Bravo Dos	11.3	2.3	0.9	5.5	20.0	10.8	1.6	0.6	13.0	4.3	0.7	0.4	5.4
	Sub-Total	877.3	180.9	69.6	430.2	1,558.0	838.7	128.1	47.8	1,014.6	335.5	57.6	28.7	421.8
										1468.1				

Oct.

		Existing Irrigation Area (ha)					Water Demand (l/sec)				Real Comsumption			
		Maize	Vegetable	Pasture	Fallow	Total	Maize	Vegetable	Pasture	Total	Maize	Vegetable	Pasture	Total
Sector III	Kesler	0.0	1.3	0.0	5.0	6.3	0.0	1.1	0.0	1.1	0.0	0.5	0.0	0.5
Right Bank	Pro-Chile	18.0	6.0	38.0	25.9	87.9	20.2	5.0	32.0	57.1	8.1	2.2	19.2	29.5
	García	3.2	0.7	1.4	1.3	6.7	3.6	0.6	1.2	5.4	1.5	0.3	0.7	2.4
	La Palma Uno	16.0	2.0	3.0	9.7	30.7	17.9	1.7	2.5	22.1	7.2	0.7	1.5	9.4
	La Palma Dos	35.5	4.0	0.5	8.0	48.0	39.8	3.3	0.4	43.5	15.9	1.5	0.3	17.7
	Visconti	100.8	8.7	10.5	39.3	159.3	112.9	7.2	8.8	129.0	45.2	3.2	5.3	53.7
	Kesler Gil	38.8	8.1	17.0	16.1	80.0	43.5	6.7	14.3	64.5	17.4	3.0	8.6	29.0
	Sub-Total	212.4	30.8	70.4	105.3	418.9	237.9	25.5	59.3	322.7	95.1	11.5	35.6	142.2
Left Bank														
Sector III	La Isla	18.0	8.0	0.0	4.0	30.0	0.0	6.6	0.0	6.6	0.0	3.0	0.0	3.0
	Huanca	4.6	1.0	2.0	1.9	9.4	0.0	0.8	1.7	2.5	0.0	0.4	1.0	1.4
	Linderos	16.0	7.9	8.0	0.0	31.9	0.0	6.6	6.7	13.3	0.0	2.9	4.0	7.0
	Poconchile	45.0	15.0	46.0	5.7	111.7	50.4	12.4	38.7	101.6	20.2	5.6	23.2	49.0
	Barranco Sta. Rosa	8.3	1.0	7.0	9.0	25.3	9.3	0.8	5.9	16.0	3.7	0.4	3.5	7.6
	Mayorca	13.1	2.7	5.8	5.4	27.1	14.7	2.3	4.9	21.9	5.9	1.0	2.9	9.8
	Huancarane	31.6	6.6	13.9	13.1	65.2	35.4	5.5	11.7	52.6	14.2	2.5	7.0	23.6
	Sub-Total	136.6	42.2	82.6	39.1	300.6	109.8	35.0	69.6	214.4	43.9	15.8	41.7	101.4
Sector IV	Arellano Beyzan	18.7	0.0	2.0	6.0	26.7	20.9	0.0	1.7	22.6	8.4	0.0	1.0	9.4
	Cora Beyzan	93.6	1.0	5.0	30.0	129.6	104.8	0.8	4.2	109.9	41.9	0.4	2.5	44.8
	El Muro	158.5	32.7	12.6	77.7	281.4	177.5	27.1	10.6	215.2	71.0	12.2	6.4	89.5
	Alanoca	10.5	1.0	1.0	23.0	35.5	11.8	0.8	0.8	13.4	4.7	0.4	0.5	5.6
	Chacabuco	310.0	30.0	10.0	106.8	456.8	347.2	24.9	8.4	380.5	138.9	11.2	5.1	155.1
	Dominguez	10.0	0.0	0.0	0.0	10.0	11.2	0.0	0.0	11.2	4.5	0.0	0.0	4.5
	Sascapa	246.0	110.0	36.7	172.0	564.7	275.5	91.3	30.9	397.7	110.2	41.1	18.5	169.8
	Bravo Uno	18.8	3.9	1.5	9.2	33.3	21.0	3.2	1.3	25.5	8.4	1.4	0.8	10.6
	Bravo Dos	11.3	2.3	0.9	5.5	20.0	12.6	1.9	0.8	15.3	5.0	0.9	0.5	6.4
	Sub-Total	877.3	180.9	69.6	430.2	1,558.0	982.6	150.0	58.7	1,191.3	393.0	67.5	35.2	495.8
										1728.5				

Table B-II, 3.3 (6) Actual Water Demand and Real Consumption

<Demanda Actual de Agua y Consumo Real>

Nov.

		Existing Irrigation Area (ha)					Water Demand (l/sec)				Real Consumption			
		Maize	Vegetable	Pasture	Fallow	Total	Maize	Vegetable	Pasture	Total	Maize	Vegetable	Pasture	Total
Right Bank Sector III	Kesler	0.0	1.3	0.0	5.0	6.3	0.0	1.2	0.0	1.2	0.0	0.6	0.0	0.6
	Pro-Chile	18.0	6.0	38.0	25.9	87.9	22.9	5.6	37.9	66.4	9.1	2.5	22.8	34.4
	García	3.2	0.7	1.4	1.3	6.7	4.1	0.6	1.4	6.2	1.7	0.3	0.9	2.8
	La Palma Uno	16.0	2.0	3.0	9.7	30.7	20.3	1.9	3.0	25.2	8.1	0.8	1.8	10.8
	La Palma Dos	35.5	4.0	0.5	8.0	48.0	45.1	3.8	0.5	49.3	18.0	1.7	0.3	20.0
	Visconti	100.8	8.7	10.5	39.3	159.3	128.0	8.2	10.5	146.7	51.2	3.7	6.3	61.2
	Kesler Gil	38.8	8.1	17.0	16.1	80.0	49.3	7.6	17.0	73.9	19.7	3.4	10.2	33.3
	Sub-Total	212.4	30.8	70.4	105.3	418.9	269.6	29.0	70.3	368.9	107.8	13.0	42.2	163.1
Left Bank Sector III														
	La Isla	18.0	8.0	0.0	4.0	30.0	0.0	7.5	0.0	7.5	0.0	3.4	0.0	3.4
	Huanca	4.6	1.0	2.0	1.9	9.4	0.0	0.9	2.0	2.9	0.0	0.4	1.2	1.6
	Linderos	16.0	7.9	8.0	0.0	31.9	0.0	7.4	8.0	15.4	0.0	3.3	4.8	8.1
	Poconchile	45.0	15.0	46.0	5.7	111.7	57.1	14.1	45.9	117.2	22.9	6.3	27.6	56.8
	Barranco Sta. Rosa	8.3	1.0	7.0	9.0	25.3	10.5	0.9	7.0	18.5	4.2	0.4	4.2	8.8
	Mayorca	13.1	2.7	5.8	5.4	27.1	16.7	2.6	5.8	25.0	6.7	1.2	3.5	11.3
	Huancarane	31.6	6.6	13.9	13.1	65.2	40.2	6.2	13.9	60.2	16.1	2.8	8.3	27.2
	Sub-Total	136.6	42.2	82.6	39.1	300.6	124.5	39.7	82.5	246.7	49.8	17.9	49.5	117.2
Sector IV	Arellano Beyzan	18.7	0.0	2.0	6.0	26.7	23.7	0.0	2.0	25.7	9.5	0.0	1.2	10.7
	Cora Beyzan	93.6	1.0	5.0	30.0	129.6	118.8	0.9	5.0	124.8	47.5	0.4	3.0	51.0
	El Muro	158.5	32.7	12.6	77.7	281.4	201.2	30.7	12.6	244.5	80.5	13.8	7.5	101.8
	Alanoca	10.5	1.0	1.0	23.0	35.5	13.3	0.9	1.0	15.3	5.3	0.4	0.6	6.4
	Chacabuco	310.0	30.0	10.0	106.8	456.8	393.6	28.2	10.0	431.8	157.4	12.7	6.0	176.1
	Dominguez	10.0	0.0	0.0	0.0	10.0	12.7	0.0	0.0	12.7	5.1	0.0	0.0	5.1
	Sascapa	246.0	110.0	36.7	172.0	564.7	312.3	103.5	36.6	452.4	124.9	46.6	22.0	193.5
	Bravo Uno	18.8	3.9	1.5	9.2	33.3	23.8	3.6	1.5	28.9	9.5	1.6	0.9	12.1
	Bravo Dos	11.3	2.3	0.9	5.5	20.0	14.3	2.2	0.9	17.4	5.7	1.0	0.5	7.2
	Sub-Total	877.3	180.9	69.6	430.2	1,558.0	1,113.8	170.1	69.6	1,353.5	445.5	76.6	41.7	563.8
										1,969.2				

Dec.

		Existing Irrigation Area (ha)					Water Demand (l/sec)				Real Consumption			
		Maize	Vegetable	Pasture	Fallow	Total	Maize	Vegetable	Pasture	Total	Maize	Vegetable	Pasture	Total
	Kesler	0.0	1.3	0.0	5.0	6.3	0.0	1.3	0.0	1.3	0.0	0.6	0.0	0.6
	Pro-Chile	18.0	6.0	38.0	25.9	87.9	25.1	6.2	42.5	73.8	10.0	2.8	25.5	38.3
Sector III	García	3.2	0.7	1.4	1.3	6.7	4.5	0.7	1.6	6.8	1.8	0.3	1.0	3.1
Right Bank	La Palma Uno	16.0	2.0	3.0	9.7	30.7	22.3	2.1	3.4	27.7	8.9	0.9	2.0	11.9
	La Palma Dos	35.5	4.0	0.5	8.0	48.0	49.5	4.1	0.6	54.1	19.8	1.9	0.3	22.0
	Visconti	100.8	8.7	10.5	39.3	159.3	140.4	9.0	11.7	161.1	56.2	4.0	7.0	67.3
	Kesler Gil	38.8	8.1	17.0	16.1	80.0	54.1	8.4	19.0	81.5	21.6	3.8	11.4	36.8
	Sub-Total	212.4	30.8	70.4	105.3	418.9	295.8	31.8	78.8	406.4	118.3	14.3	47.3	179.9
Left Bank	La Isla	18.0	8.0	0.0	4.0	30.0	25.1	8.3	0.0	33.3	10.0	3.7	0.0	13.7
	Huanca	4.6	1.0	2.0	1.9	9.4	6.4	1.0	2.8	10.1	2.5	0.4	1.7	4.7
	Linderos	16.0	7.9	8.0	0.0	31.9	22.3	8.2	11.1	41.6	8.9	3.7	6.7	19.3
	Poconchile	45.0	15.0	46.0	5.7	111.7	62.7	15.5	64.1	142.2	25.1	7.0	38.4	70.5
	Barranco Sta. Rosa	8.3	1.0	7.0	9.0	25.3	11.6	1.0	9.8	22.3	4.6	0.5	5.9	10.9
	Mayorca	13.1	2.7	5.8	5.4	27.1	18.3	2.8	8.0	29.2	7.3	1.3	4.8	13.4
	Huancarane	31.6	6.6	13.9	13.1	65.2	44.1	6.8	19.3	70.2	17.6	3.1	11.6	32.3
	Sub-Total	136.6	42.2	82.6	39.1	300.6	190.3	43.6	115.1	349.0	76.1	19.6	69.1	164.8
Sector IV	Arellano Beyzan	18.7	0.0	2.0	6.0	26.7	26.0	0.0	2.8	28.8	10.4	0.0	1.7	12.1
	Cora Beyzan	93.6	1.0	5.0	30.0	129.6	130.4	1.0	7.0	138.4	52.2	0.5	4.2	56.8
	El Muro	158.5	32.7	12.6	77.7	281.4	220.7	33.7	17.5	272.0	88.3	15.2	10.5	114.0
	Alanoca	10.5	1.0	1.0	23.0	35.5	14.6	1.0	1.4	17.1	5.9	0.5	0.8	7.2
	Chacabuco	310.0	30.0	10.0	106.8	456.8	431.8	31.0	13.9	476.7	172.7	13.9	8.4	195.0
	Dominguez	10.0	0.0	0.0	0.0	10.0	13.9	0.0	0.0	13.9	5.6	0.0	0.0	5.6
	Sascapa	246.0	110.0	36.7	172.0	564.7	342.7	113.5	51.1	507.3	137.1	51.1	30.7	218.8
	Bravo Uno	18.8	3.9	1.5	9.2	33.3	26.1	4.0	2.1	32.2	10.4	1.8	1.2	13.5
	Bravo Dos	11.3	2.3	0.9	5.5	20.0	15.7	2.4	1.2	19.3	6.3	1.1	0.7	8.1
	Sub-Total	877.3	180.9	69.7	430.2	1,558.0	1,222.0	186.6	97.0	1,505.7	488.8	84.0	58.2	631.0

Table B-II, 3.4 (1) Water Distribution to Irrigation Channel (by Demand)

<Distribución de Agua al Canal de Irrigación (por Demanda)>

Jan.

		Water Demand (l/sec)	Real Cons. (l/sec)	Consum.	Demand	(1) Intake/Canal (l/sec)	(2) Distribution (l/sec)	(3) Remaining (l/sec)	(4) Return (l/sec)	(5) (3)+(4) (l/sec)
Sector III Right Bank	Kesler	1.5	0.7							
	Pro-Chile	53.8	31.2							
	García	2.5	1.4							
	La Palma Uno	6.0	3.2							
	La Palma Dos	5.1	2.4	38.9	68.8	81	69	12	30	42
	Visconti	22.8	12.2	12.2	22.8	42	23	20	11	30
	Kesler Gil	30.2	16.7	16.7	30.2	30	30	0	13	13
	Sub-Total	121.8	67.9	67.9	121.8					
Left Bank	La Isla	36.4	15.0							
	Huanca	10.5	4.7							
	Linderos	43.2	19.7							
	Poconchile	73.8	41.7							
	Barranco Sta. Rosa	9.8	5.7							
	Mayorca	10.2	5.7							
	Huancarane	24.6	13.6							
Sector IV	Arellano Beyzan	2.5	1.5							
	Cora Beyzan	7.3	4.2	111.9	218.3	351	218	133	106	239
	El Muro	52.4	25.9							
	Alanoca	2.4	1.2	27.1	54.8	239	55	184	28	212
	Chacabuco (1)	23.1	11.3	11.3	23.1	212	23	189	12	201
	Chacabuco (2)	23.1	11.3							
	Dominguez	0.0	0.0	11.3	23.1	201	23	178	12	189
	Sascapa (1)	84.7	41.5	41.5	84.7	189	85	105	43	148
	Sascapa (2)	84.7	41.5	41.5	84.7	148	85	63	43	106
	Bravo Uno	6.2	3.1							
	Bravo Dos	3.7	1.8	4.9	9.9	106	10	96	5	101
Sector V	Valle Hermoso	54.3	26.7							
	Aica González	10.3	4.8	31.5	64.6	101	65	37	33	70
	M. Beovic	9.9	5.9							
	B'ba Pte.Chacall.	8.3	5.0							
	Ambrosio Flores	2.5	1.5	12.4	20.7	70	21	49	8	58
	Bellet	3.0	1.4							
	Beneficiencia	33.4	18.1							
	Santa Rosa	21.2	11.0	30.5	57.6	58	58	0	27	27
	Sub-Total	641	324	324	641					
	Total	763	392	392	763					

Feb.

		Water Demand (l/sec)	Real Cons. (l/sec)	Consum.	Demand	(1) Intake/Canal (l/sec)	(2) Distribution (l/sec)	(3) Remaining (l/sec)	(4) Return (l/sec)	(5) (3)+(4) (l/sec)
Sector III Right Bank	Kesler	1.5	0.7							
	Pro-Chile	53.6	31.2							
	García	2.5	1.4							
	La Palma Uno	5.9	3.2							
	La Palma Dos	5.1	2.4	38.8	68.6	81	69	13	30	42
	Visconti	22.7	12.2	12.2	22.7	42	23	20	11	30
	Kesler Gil	30.1	16.7	16.7	30.1	30	30	0	13	13
	Sub-Total	121.4	67.7	67.7	121.4					
Left Bank	La Isla	36.3	15.0							
	Huanca	10.5	4.7							
	Linderos	43.1	19.6							
	Poconchile	73.6	41.6							
	Barranco Sta. Rosa	9.8	5.7							
	Mayorca	10.2	5.7							
	Huancarane	24.6	13.6							
Sector IV	Arellano Beyzan	2.5	1.5							
	Cora Beyzan	7.3	4.2	111.6	217.9	350	218	132	106	238
	El Muro	52.3	25.9							
	Alanoca	2.4	1.2	27.1	54.7	238	55	184	28	211
	Chacabuco (1)	23.1	11.3	11.3	23.1	211	23	188	12	200
	Chacabuco (2)	23.1	11.3							
	Dominguez	0.0	0.0	11.3	23.1	200	23	177	12	189
	Sascapa (1)	84.5	41.4	41.4	84.5	189	85	104	43	147
	Sascapa (2)	84.5	41.4	41.4	84.5	147	85	63	43	106
	Bravo Uno	6.2	3.1							
	Bravo Dos	3.7	1.8	4.9	9.9	106	10	96	5	101
Sector V	Valle Hermoso	54.2	26.6							
	Aica González	10.2	4.8	31.4	64.4	101	64	37	33	70
	M. Beovic	9.9	5.9							
	B'ba Pte.Chacall.	8.3	5.0							
	Ambrosio Flores	2.5	1.5	12.4	20.6	70	21	49	8	57
	Bellet	3.0	1.4							
	Beneficiencia	33.3	18.0							
	Santa Rosa	21.1	11.0	30.4	57.4	57	57	0	27	27
	Sub-Total	640.1	323.1	323.1	640.1					
	Total	761.5	390.9	390.9	761.5		Total Extraction		431	

Table B-II, 3.4 (2) Water Distribution to Irrigation Channel (by Demand)
<Distribución de Agua al Canal de Irrigación (por Demanda)>

Mar.

		Water Demand (l/sec)	Real Coms. (l/sec)	Consum.	Demand	(1) Intake/Canal (l/sec)	(2) Distribution (l/sec)	(3) Remaining (l/sec)	(4) Return (l/sec)	(5) (3)+(4) (l/sec)
Sector III	Kesler	1.3	0.6							
Right Bank	Pro-Chile	71.3	37.0							
	García	6.6	3.0							
	La Palma Uno	26.8	11.5							
	La Palma Dos	52.3	21.2	73.3	158.2	229	158	71	85	156
	Visconti	155.6	64.9	64.9	155.6	156	156	0	91	91
	Kesler Gil	78.7	35.6	35.6	78.7	91	79	12	43	55
	Sub-Total	392.5	173.8	173.8	392.5					
Left Bank	La Isla	32.2	13.3							
	Huanca	9.2	4.2							
	Linderos	38.0	17.3							
	Poconchile	125.2	60.8							
	Barranco Sta. Rosa	19.7	9.5							
	Mayorca	26.7	12.0							
	Huancarane	64.1	29.0							
Sector IV	Arellano Beyzan	27.3	11.4							
	Cora Beyzan	132.3	54.1	211.5	474.7	983	475	508	263	772
	El Muro	259.3	108.1							
	Alanoca	16.2	6.7	114.8	275.5	772	276	496	161	657
	Chacabuco (1)	228.9	93.4	93.4	228.9	657	229	428	136	563
	Chacabuco (2)	228.9	93.4							
	Dominguez	13.5	5.4	98.7	242.4	563	242	321	144	465
	Sascapa (1)	240.1	102.8	102.8	240.1	465	240	225	137	362
	Sascapa (2)	240.1	102.8	102.8	240.1	362	240	122	137	259
	Bravo Uno	30.7	12.8							
	Bravo Dos	18.4	7.7	20.5	49.1	259	49	210	29	239
Sector V	Valle Hermoso	173.8	75.9							
	Aica González	64.8	27.5	103.4	238.7	239	239	0	135	135
	M. Beovic	9.9	5.9							
	B'ba Pte.Chacall.	8.3	5.0							
	Ambrosio Flores	2.5	1.5	12.4	20.7	135	21	115	8	123
	Bellet	0.0	0.0							
	Beneficiencia	33.1	17.6							
	Santa Rosa	41.7	19.3	36.9	74.8	123	75	48	38	86
	Sub-Total	2,084.9	897.1	897.1	2,084.9					
	Total	2,477.4	1,070.9	1,070.9	2,477.4		Total Extraction		1,212	

Apr.

		Water Demand (l/sec)	Real Coms. (l/sec)	Consum.	Demand	(1) Intake/Canal (l/sec)	(2) Distribution (l/sec)	(3) Remaining (l/sec)	(4) Return (l/sec)	(5) (3)+(4) (l/sec)
Sector III	Kesler	1.0	0.5							
Right Bank	Pro-Chile	54.7	28.3							
	García	5.1	2.3							
	La Palma Uno	21.0	8.9							
	La Palma Dos	41.1	16.7	56.7	123.0	179	123	56	66	122
	Visconti	122.1	50.9	50.9	122.1	122	122	0	71	71
	Kesler Gil	61.3	27.6	27.6	61.3	71	61	10	34	44
	Sub-Total	306.4	135.2	135.2	306.4					
Left Bank	La Isla	6.3	2.8							
	Huanca	2.4	1.3							
	Linderos	12.7	6.7							
	Poconchile	96.9	46.8							
	Barranco Sta. Rosa	15.3	7.3							
	Mayorca	20.8	9.4							
	Huancarane	50.0	22.5							
Sector IV	Arellano Beyzan	21.4	8.9							
	Cora Beyzan	104.0	42.4	148.1	329.7	700	330	370	182	552
	El Muro	203.7	84.8							
	Alanoca	12.7	5.3	90.1	216.4	552	216	335	126	462
	Chacabuco (1)	180.0	73.4	73.4	180.0	462	180	282	107	388
	Chacabuco (2)	180.0	73.4							
	Dominguez	10.6	4.2	77.6	190.6	388	191	198	113	311
	Sascapa (1)	188.4	80.5	80.5	188.4	311	188	122	108	230
	Sascapa (2)	188.4	80.5	80.5	188.4	230	188	42	108	150
	Bravo Uno	24.1	10.0							
	Bravo Dos	14.5	6.0	16.1	38.6	150	39	111	23	134
Sector V	Valle Hermoso	100.7	43.6							
	Aica González	32.5	13.5	57.1	133.3	134	133	0	76	77
	M. Beovic	6.5	3.9							
	B'ba Pte.Chacall.	5.5	3.3							
	Ambrosio Flores	1.6	1.0	8.2	13.6	77	14	63	5	68
	Bellet	2.1	1.0							
	Beneficiencia	27.5	14.1							
	Santa Rosa	27.1	12.5	27.6	56.7	68	57	12	29	41
	Sub-Total	1,535.5	659.2	659.2	1,535.5					
	Total	1,841.9	794.4	794.4	1,841.9		Total Extraction		879	

Table B-II, 3.4 (3) Water Distribution to Irrigation Channel(by Demand)

<Distribución de Agua al Canal de Irrigación (por Demanda)>

May

		Water Demand (l/sec)	Real Coms. (l/sec)	Consum.	Demand	(1) Intake/Canal (l/sec)	(2) Distribution (l/sec)	(3) Remaining (l/sec)	(4) Return (l/sec)	(5) (3)+(4) (l/sec)
Sector III Right Bank	Kesler	0.8	0.4							
	Pro-Chile	43.1	22.2							
	García	4.1	1.8							
	La Palma Uno	16.9	7.2							
	La Palma Dos	33.4	13.5	45.1	98.3	144	98	46	53	99
	Visconti	98.8	41.1	41.1	98.8	99	99	0	58	58
	Kesler Gil	49.2	22.1	22.1	49.2	58	49	9	27	36
	Sub-Total	246.4	108.3	108.3	246.4					
Left Bank	La Isla	5.1	2.3							
	Huanca	1.9	1.0							
	Linderos	10.0	5.3							
	Poconchile	77.0	37.0							
	Barranco Sta. Rosa	12.2	5.8							
	Mayorca	16.7	7.5							
	Huancarane	40.1	18.0							
Sector IV	Arellano Beyzan	17.3	7.2							
	Cora Beyzan	84.3	34.4	118.4	264.6	565	265	300	146	447
	El Muro	165.0	68.6							
	Alanoca	10.3	4.3	72.9	175.3	447	175	271	102	374
	Chacabuco (1)	146.0	59.5	59.5	146.0	374	146	228	87	314
	Chacabuco (2)	146.0	59.5							
	Dominguez	8.6	3.4	62.9	154.6	314	155	160	92	251
	Sascapa (1)	152.4	65.0	65.0	152.4	251	152	99	87	186
	Sascapa (2)	152.4	65.0	65.0	152.4	186	152	34	87	121
	Bravo Uno	19.5	8.1							
	Bravo Dos	11.7	4.9	13.0	31.2	121	31	90	18	108
Sector V	Valle Hermoso	81.4	35.2							
	Aica González	26.4	10.9	46.1	107.8	108	108	0	62	62
	M. Beovic	5.0	3.0							
	B'ba Pte.Chacall.	4.2	2.5							
	Ambrosio Flores	1.3	0.8	6.3	10.4	62	10	52	4	56
	Bellet	1.7	0.8							
	Beneficiencia	21.8	11.1							
	Santa Rosa	21.7	10.0	21.9	45.2	56	45	11	23	34
	Sub-Total	1,239.7	531.0	531.0	1,239.7					
	Total	1,486.1	639.3	639.3	1,486.1		Total Extraction		709	

Jun.

		Water Demand (l/sec)	Real Coms. (l/sec)	Consum.	Demand	(1) Intake/Canal (l/sec)	(2) Distribution (l/sec)	(3) Remaining (l/sec)	(4) Return (l/sec)	(5) (3)+(4) (l/sec)
Sector III Right Bank	Kesler	0.7	0.3							
	Pro-Chile	34.5	17.7							
	García	3.4	1.5							
	La Palma Uno	13.9	5.9							
	La Palma Dos	27.7	11.2	36.6	80.2	118	80	38	44	82
	Visconti	81.6	33.9	33.9	81.6	82	82	0	48	48
	Kesler Gil	40.2	18.0	18.0	40.2	48	40	7	22	30
	Sub-Total	202.0	88.5	88.5	202.0					
Left Bank	La Isla	4.2	1.9							
	Huanca	1.5	0.8							
	Linderos	8.1	4.2							
	Poconchile	62.4	29.8							
	Barranco Sta. Rosa	9.9	4.7							
	Mayorca	13.6	6.1							
	Huancarane	32.8	14.6							
Sector IV	Arellano Beyzan	14.3	5.9							
	Cora Beyzan	69.7	28.4	96.4	216.5	465	217	248	120	369
	El Muro	136.4	56.6							
	Alanoca	8.5	3.5	60.2	144.9	369	145	224	85	308
	Chacabuco (1)	120.9	49.3	49.3	120.9	308	121	188	72	259
	Chacabuco (2)	120.9	49.3							
	Dominguez	7.1	2.9	52.1	128.0	259	128	131	76	207
	Sascapa (1)	125.7	53.5	53.5	125.7	207	126	81	72	154
	Sascapa (2)	125.7	53.5	53.5	125.7	154	126	28	72	100
	Bravo Uno	16.1	6.7							
	Bravo Dos	9.7	4.0	10.7	25.8	100	26	74	15	89
Sector V	Valle Hermoso	67.1	28.9							
	Aica González	21.8	9.0	38.0	88.9	89	89	0	51	51
	M. Beovic	3.9	2.3							
	B'ba Pte.Chacall.	3.3	2.0							
	Ambrosio Flores	1.0	0.6	4.9	8.1	51	8	43	3	46
	Bellet	1.4	0.6							
	Beneficiencia	17.5	8.9							
	Santa Rosa	17.7	8.1	17.7	36.7	46	37	10	19	29
	Sub-Total	1,021.1	436.2	436.2	1,021.1					
	Total	1,223.1	524.7	524.7	1,223.1		Total Extraction		583	

Table B-II, 3.4 (4) Water Distribution to Irrigation Channel(by Demand)
<Distribución de Agua al Canal de Irrigación (por Demanda)>

Jul.

		Water Demand (l/sec)	Real Coms. (l/sec)	Consum.	Demand	(1) Intake/Canal (l/sec)	(2) Distribution (l/sec)	(3) Remaining (l/sec)	(4) Return (l/sec)	(5) (3)+(4) (l/sec)
Sector III	Kesler	0.7	0.3							
Right Bank	Pro-Chile	21.9	12.2							
	García	1.0	0.6							
	La Palma Uno	2.4	1.3							
	La Palma Dos	2.3	1.1	15.4	27.4	33	27	5	12	17
	Visconti	9.4	5.0	5.0	9.4	17	9	8	4	12
	Kesler Gil	12.2	6.7	6.7	12.2	12	12	0	6	6
	Sub-Total	49.0	27.1	27.1	49.0					
Left Bank	La Isla	4.1	1.8							
	Huanca	1.4	0.8							
	Linderos	7.8	4.1							
	Poconchile	29.4	16.5							
	Barranco Sta. Rosa	3.8	2.2							
	Mayorca	4.1	2.3							
	Huancarane	9.9	5.5							
Sector IV	Arellano Beyzan	0.9	0.6							
	Cora Beyzan	2.9	1.6	35.3	64.4	124	64	60	29	89
	El Muro	0.0	0.0							
	Alanoca	1.0	0.5	0.5	1.0	89	1	88	0	88
	Chacabuco (1)	10.1	4.9	4.9	10.1	88	10	78	5	83
	Chacabuco (2)	10.1	4.9							
	Dominguez	0.0	0.0	4.9	10.1	83	10	73	5	78
	Sascapa (1)	36.8	17.9	17.9	36.8	78	37	42	19	61
	Sascapa (2)	36.8	17.9	17.9	36.8	61	37	24	19	43
	Bravo Uno	0.0	0.0							
	Bravo Dos	0.0	0.0	0.0	0.0	43	0	43	0	43
Sector V	Valle Hermoso	23.6	11.5							
	Aica González	4.6	2.1	13.6	28.2	43	28	15	15	29
	M. Beovic	3.8	2.3							
	B'ba Pte.Chacall.	3.2	1.9							
	Ambrosio Flores	0.9	0.6	4.7	7.9	29	8	21	3	24
	Bellet	1.4	0.6							
	Beneficiencia	13.7	7.3							
	Santa Rosa	8.9	4.6	12.5	24.0	24	24	0	11	12
	Sub-Total	219.1	112.1	112.1	219.1					
	Total	268.1	139.1	139.1	268.1		Total Extraction		157	

Aug.

		Water Demand (l/sec)	Real Coms. (l/sec)	Consum.	Demand	(1) Intake/Canal (l/sec)	(2) Distribution (l/sec)	(3) Remaining (l/sec)	(4) Return (l/sec)	(5) (3)+(4) (l/sec)
Sector III	Kesler	0.7	0.3							
Right Bank	Pro-Chile	23.6	13.7							
	García	1.1	0.6							
	La Palma Uno	2.7	1.5							
	La Palma Dos	2.5	1.2	17.3	30.8	37	31	6	13	19
	Visconti	10.5	5.6	5.6	10.5	19	10	9	5	14
	Kesler Gil	13.6	7.5	7.5	13.6	14	14	0	6	6
	Sub-Total	54.9	30.3	30.3	54.9					
Left Bank	La Isla	4.5	2.0							
	Huanca	1.6	0.9							
	Linderos	8.7	4.6							
	Poconchile	33.0	18.5							
	Barranco Sta. Rosa	4.3	2.5							
	Mayorca	4.6	2.5							
	Huancarane	11.1	6.1							
Sector IV	Arellano Beyzan	1.1	0.6							
	Cora Beyzan	3.2	1.9	39.7	72.1	152	72	80	32	112
	El Muro	25.1	12.3							
	Alanoca	1.1	0.6	12.9	26.2	112	26	86	13	99
	Chacabuco (1)	11.1	5.4	5.4	11.1	99	11	88	6	94
	Chacabuco (2)	11.1	5.4							
	Dominguez	0.0	0.0	5.4	11.1	94	11	83	6	89
	Sascapa (1)	40.8	19.8	19.8	40.8	89	41	48	21	69
	Sascapa (2)	40.8	19.8	19.8	40.8	69	41	28	21	49
	Bravo Uno	3.0	1.5							
	Bravo Dos	1.8	0.9	2.4	4.8	49	5	44	2	47
Sector V	Valle Hermoso	26.1	12.7							
	Aica González	5.0	2.3	15.1	31.1	47	31	16	16	32
	M. Beovic	4.3	2.6							
	B'ba Pte.Chacall.	3.6	2.1							
	Ambrosio Flores	1.1	0.6	5.3	8.9	32	9	23	4	26
	Bellet	1.5	0.7							
	Beneficiencia	15.3	8.2							
	Santa Rosa	9.9	5.1	14.0	26.7	26	27	0	13	12
	Sub-Total	273.6	139.7	139.7	273.6					
	Total	328.5	170.0	170.0	328.5		Total Extraction		189	

Table B-II, 3.4 (5) Water Distribution to Irrigation Channel (by Demand)

<Distribución de Agua al Canal de Irrigación (por Demanda)>

Sep.

		Water Demand (l/sec)	Real Coms. (l/sec)	Consum.	Demand	(1) Intake/Canal (l/sec)	(2) Distribution (l/sec)	(3) Remaining (l/sec)	(4) Return (l/sec)	(5) (3)+(4) (l/sec)
Sector III	Kesler	0.9	0.4							
Right Bank	Pro-Chile	47.5	24.4							
	García	4.6	2.0							
	La Palma Uno	18.8	8.0							
	La Palma Dos	37.1	15.1	49.9	108.9	160	109	51	59	110
	Visconti	109.7	45.6	45.6	109.7	110	110	0	64	64
	Kesler Gil	54.5	24.4	24.4	54.5	64	55	10	30	40
	Sub-Total	273.2	120.0	120.0	273.2					
Left Bank	La Isla	5.7	2.6							
	Huanca	2.0	1.1							
	Linderos	11.1	5.8							
	Poconchile	85.2	40.9							
	Barranco Sta. Rosa	13.4	6.4							
	Mayorca	18.5	8.3							
	Huancarane	44.4	19.9							
Sector IV	Arellano Beyzan	19.2	8.0							
	Cora Beyzan	93.6	38.2	131.1	293.2	699	293	406	162	568
	El Muro	183.3	76.2							
	Alanoca	11.4	4.7	80.9	194.7	568	195	373	114	487
	Chacabuco (1)	162.2	66.1	66.1	162.2	487	162	325	96	421
	Chacabuco (2)	162.2	66.1							
	Dominguez	9.6	3.8	70.0	171.8	421	172	249	102	351
	Sascapa (1)	169.2	72.1	72.1	169.2	351	169	182	97	279
	Sascapa (2)	169.2	72.1	72.1	169.2	279	169	110	97	207
	Bravo Uno	21.7	9.0							
	Bravo Dos	13.0	5.4	14.4	34.7	207	35	172	20	192
Sector V	Valle Hermoso	145.6	63.2							
	Aica González	46.8	19.4	82.6	192.4	192	192	0	110	110
	M. Beovic	9.9	5.9							
	B'ba Pte.Chacall.	8.3	5.0							
	Ambrosio Flores	2.5	1.5	12.4	20.7	110	21	89	8	97
	Bellet	3.0	1.4							
	Beneficiencia	40.7	21.0							
	Santa Rosa	39.4	18.3	40.7	83.2	97	83	14	42	57
	Sub-Total	1,491.2	642.5	642.5	1,491.2					
	Total	1,764.4	762.5	762.5	1,764.4		Total Extraction		859	

Oct.

		Water Demand (l/sec)	Real Coms. (l/sec)	Consum.	Demand	(1) Intake/Canal (l/sec)	(2) Distribution (l/sec)	(3) Remaining (l/sec)	(4) Return (l/sec)	(5) (3)+(4) (l/sec)
Sector III	Kesler	1.1	0.5							
Right Bank	Pro-Chile	57.1	29.5							
	García	5.4	2.4							
	La Palma Uno	22.1	9.4							
	La Palma Dos	43.5	17.7	59.5	129.2	189	129	59	70	129
	Visconti	129.0	53.7	53.7	129.0	129	129	0	75	75
	Kesler Gil	64.5	29.0	29.0	64.5	75	65	11	36	46
	Sub-Total	322.7	142.2	142.2	322.7					
Left Bank	La Isla	6.6	3.0							
	Huanca	2.5	1.4							
	Linderos	13.3	7.0							
	Poconchile	101.6	49.0							
	Barranco Sta. Rosa	16.0	7.6							
	Mayorca	21.9	9.8							
	Huancarane	52.6	23.6							
Sector IV	Arellano Beyzan	22.6	9.4							
	Cora Beyzan	109.9	44.8	155.7	347.0	738	347	391	191	582
	El Muro	215.2	89.5							
	Alanoca	13.4	5.6	95.1	228.6	582	229	354	133	487
	Chacabuco (1)	190.3	77.6	77.6	190.3	487	190	297	113	410
	Chacabuco (2)	190.3	77.6							
	Dominguez	11.2	4.5	82.0	201.5	410	201	208	119	328
	Sascapa (1)	198.9	84.9	84.9	198.9	328	199	129	114	243
	Sascapa (2)	198.9	84.9	84.9	198.9	243	199	44	114	158
	Bravo Uno	25.5	10.6							
	Bravo Dos	15.3	6.4	17.0	40.8	158	41	117	24	141
Sector V	Valle Hermoso	106.4	46.0							
	Aica González	34.4	14.2	60.3	140.7	141	141	0	80	81
	M. Beovic	6.7	4.0							
	B'ba Pte.Chacall.	5.6	3.4							
	Ambrosio Flores	1.7	1.0	8.4	14.1	81	14	66	6	72
	Bellet	2.2	1.0							
	Beneficiencia	28.8	14.8							
	Santa Rosa	28.5	13.2	28.9	59.5	72	60	13	31	43
	Sub-Total	1,620.1	694.8	694.8	1,620.1					
	Total	1,942.8	837.1	837.1	1,942.8		Total Extraction		927	

Table B-II, 3.4 (6) Water Distribution to Irrigation Channel(by Demand)
<Distribución de Agua al Canal de Irrigación (por Demanda)>

Nov.

		Water Demand (l/sec)	Real Coms. (l/sec)	Consum.	Demand	(1) Intake/Canal (l/sec)	(2) Distribution (l/sec)	(3) Remaining (l/sec)	(4) Return (l/sec)	(5) (3)+(4) (l/sec)
Sector III	Kesler	1.2	0.6							
Right Bank	Pro-Chile	66.4	34.4							
	García	6.2	2.8							
	La Palma Uno	25.2	10.8							
	La Palma Dos	49.3	20.0	68.6	148.4	215	148	67	80	147
	Visconti	146.7	61.2	61.2	146.7	147	147	0	85	85
	Kesler Gil	73.9	33.3	33.3	73.9	85	74	12	41	52
	Sub-Total	368.9	163.1	163.1	368.9					
Left Bank	La Isla	7.5	3.4							
	Huanca	2.9	1.6							
	Linderos	15.4	8.1							
	Poconchile	117.2	56.8							
	Barranco Sta. Rosa	18.5	8.8							
	Mayorca	25.0	11.3							
	Huancarane	60.2	27.2							
Sector IV	Arellano Beyzan	25.7	10.7							
	Cora Beyzan	124.8	51.0	178.8	397.2	841	397	444	218	662
	El Muro	244.5	101.8							
	Alanoca	15.3	6.4	108.2	259.7	662	260	402	152	554
	Chacabuco (1)	215.9	88.1	88.1	215.9	554	216	338	128	466
	Chacabuco (2)	215.9	88.1							
	Dominguez	12.7	5.1	93.1	228.6	466	229	237	135	373
	Sascapa (1)	226.2	96.8	96.8	226.2	373	226	147	129	276
	Sascapa (2)	226.2	96.8	96.8	226.2	276	226	50	129	179
	Bravo Uno	28.9	12.1							
	Bravo Dos	17.4	7.2	19.3	46.3	179	46	133	27	160
Sector V	Valle Hermoso	121.1	52.5							
	Aica González	39.0	16.2	68.7	160.1	160	160	0	91	91
	M. Beovic	8.0	4.8							
	B'ba Pte.Chacall.	6.7	4.0							
	Ambrosio Flores	2.0	1.2	10.0	16.7	91	17	75	7	81
	Bellet	2.5	1.1							
	Beneficiencia	33.4	17.2							
	Santa Rosa	32.6	15.1	33.5	68.6	81	69	13	35	48
	Sub-Total	1,845.5	793.1	793.1	1,845.5					
	Total	2,214.4	956.2	956.2	2,214.4		Total Extraction		1,056	

Dec.

		Water Demand (l/sec)	Real Coms. (l/sec)	Consum.	Demand	(1) Intake/Canal (l/sec)	(2) Distribution (l/sec)	(3) Remaining (l/sec)	(4) Return (l/sec)	(5) (3)+(4) (l/sec)
Sector III	Kesler	1.3	0.6							
Right Bank	Pro-Chile	73.8	38.3							
	García	6.8	3.1							
	La Palma Uno	27.7	11.9							
	La Palma Dos	54.1	22.0	75.8	163.8	237	164	73	88	161
	Visconti	161.1	67.3	67.3	161.1	161	161	0	94	94
	Kesler Gil	81.5	36.8	36.8	81.5	94	81	12	45	57
	Sub-Total	406.4	179.9	179.9	406.4					
Left Bank	La Isla	33.3	13.7							
	Huanca	10.1	4.7							
	Linderos	41.6	19.3							
	Poconchile	142.2	70.5							
	Barranco Sta. Rosa	22.3	10.9							
	Mayorca	29.2	13.4							
	Huancarane	70.2	32.3							
Sector IV	Arellano Beyzan	28.8	12.1							
	Cora Beyzan	138.4	56.8	233.7	516.2	972	516	455	283	738
	El Muro	272.0	114.0							
	Alanoca	17.1	7.2	121.1	289.0	738	289	449	168	617
	Chacabuco (1)	238.4	97.5	97.5	238.4	617	238	378	141	519
	Chacabuco (2)	238.4	97.5							
	Dominguez	13.9	5.6	103.1	252.3	519	252	267	149	416
	Sascapa (1)	253.7	109.4	109.4	253.7	416	254	162	144	307
	Sascapa (2)	253.7	109.4	109.4	253.7	307	254	53	144	197
	Bravo Uno	32.2	13.5							
	Bravo Dos	19.3	8.1	21.6	51.5	197	52	146	30	176
Sector V	Valle Hermoso	133.1	57.7							
	Aica González	42.8	17.8	75.5	175.9	176	176	0	100	100
	M. Beovic	9.0	5.4							
	B'ba Pte.Chacall.	7.5	4.5							
	Ambrosio Flores	2.2	1.3	11.2	18.7	100	19	82	7	89
	Bellet	2.8	1.3							
	Beneficiencia	37.0	19.1							
	Santa Rosa	36.0	16.7	37.0	75.8	89	76	13	39	52
	Sub-Total	2,125.1	919.5	919.5	2,125.1					
	Total	2,531.5	1,099.5	1,099.5	2,531.5		Total Extraction		1,209	

Table B-II, 3.5 Monthly Average Groundwater Recharge Potential
<Potencialidad Medio Mensual de Recarga de Agua Subterránea>

(Case 1) : Water Right

(Unit: l/s)

	Tocontasi	Consum. (Upstr.)	Intake Point	Required Extraction	Actual Extraction	Remaining in River	Recharge
Jan	2,887	275	2,612	819	819	1,793	735
Feb	4,741	275	4,466	819	819	3,647	1,495
Mar	4,222	275	3,947	819	819	3,128	1,282
Apr	1,759	275	1,484	819	819	665	273
May	1,809	275	1,534	819	819	715	293
Jun	1,802	275	1,527	819	819	708	290
Jul	1,937	275	1,662	819	819	843	346
Aug	1,746	275	1,471	819	819	652	267
Sep	1,542	275	1,267	819	819	448	184
Oct	1,332	275	1,057	819	819	238	98
Nov	1,307	275	1,032	819	819	213	87
Dec	1,508	275	1,233	819	819	414	170
Ave.	2,216	275	1,941	819	819	1,122	460

(Case 2) : Water Demand

(Unit: l/s)

	Tocontasi	Consum. (Upstr.)	Intake Point	Required Extraction	Actual Extraction	Remaining in River	Recharge
Jan	2,887	448	2,439	433	433	2,006	822
Feb	4,741	446	4,295	431	431	3,864	1,584
Mar	4,222	393	3,829	1,212	1,212	2,617	1,073
Apr	1,759	193	1,566	878	878	688	282
May	1,809	150	1,660	709	709	951	390
Jun	1,802	118	1,684	583	583	1,101	451
Jul	1,937	114	1,823	156	156	1,667	683
Aug	1,746	128	1,618	189	189	1,429	586
Sep	1,542	164	1,378	859	859	519	213
Oct	1,332	201	1,132	927	927	205	84
Nov	1,307	236	1,071	1,056	1,056	15	6
Dec	1,508	407	1,101	1,209	1,101	0	0
Ave.	2,216	250	1,966	720	711	1,255	515

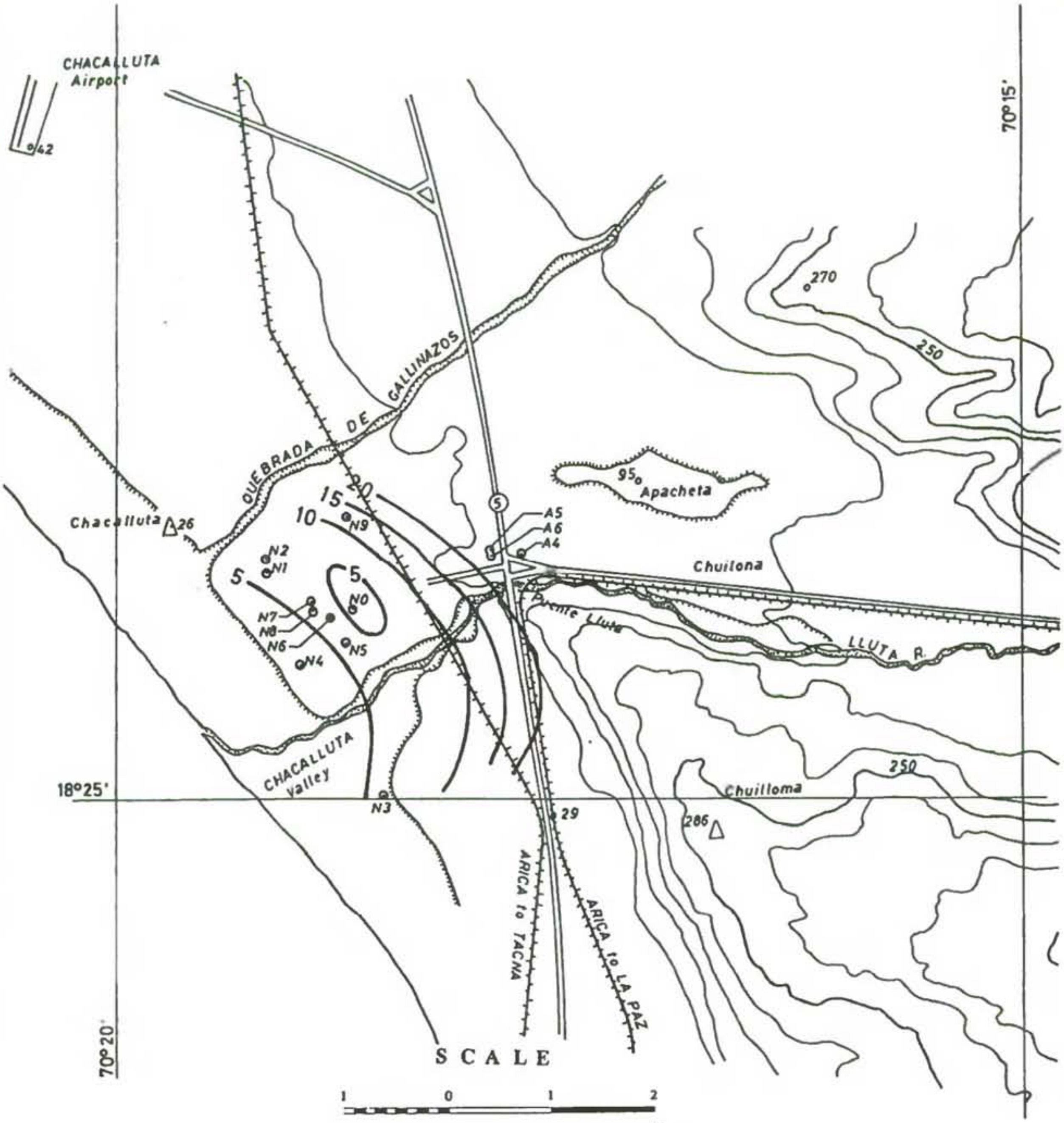


Fig. B-II, 3.1 Static Water Level of Shallow Aquifer

<Nivel Estático de Acuífero Poco Profundo>

Fig. B-II, 3.2 Static Water Level of Deep Aquifer

<Nivel Estático de Acuífero Profundo>

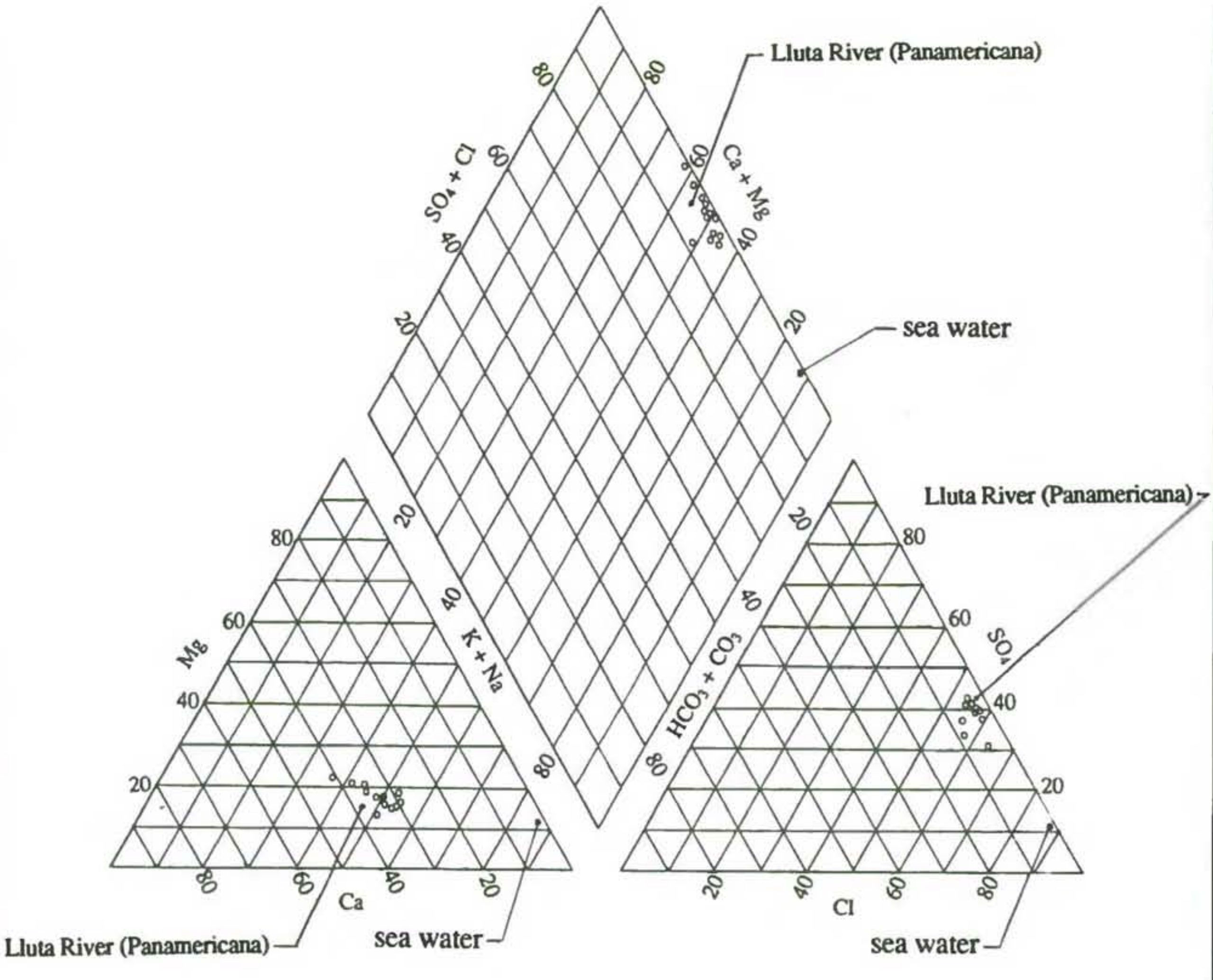


Fig. B-II, 3.3 Tri-linear Diagram of Major Ions

< Diagrama Tri-Lineal de Iones Mayores

Near Casa Grande

At the Azapa Intake

River Mouth of the San José River

Fig. B-II, 3.4 (1) Flood in San José River (24 Nov., 1994)

<Avenidas en RíoSan José(24 Nov., 1994)>

Near the Santa Rosa Bridge

At the Chacalluta Bridge

At the Chacalluta Bridge

Fig. B-II, 3.4 (2) Flood in Lluta River (24 Nov., 1994)

<Avenidas en Río Lluta (24 Nov., 1994)>

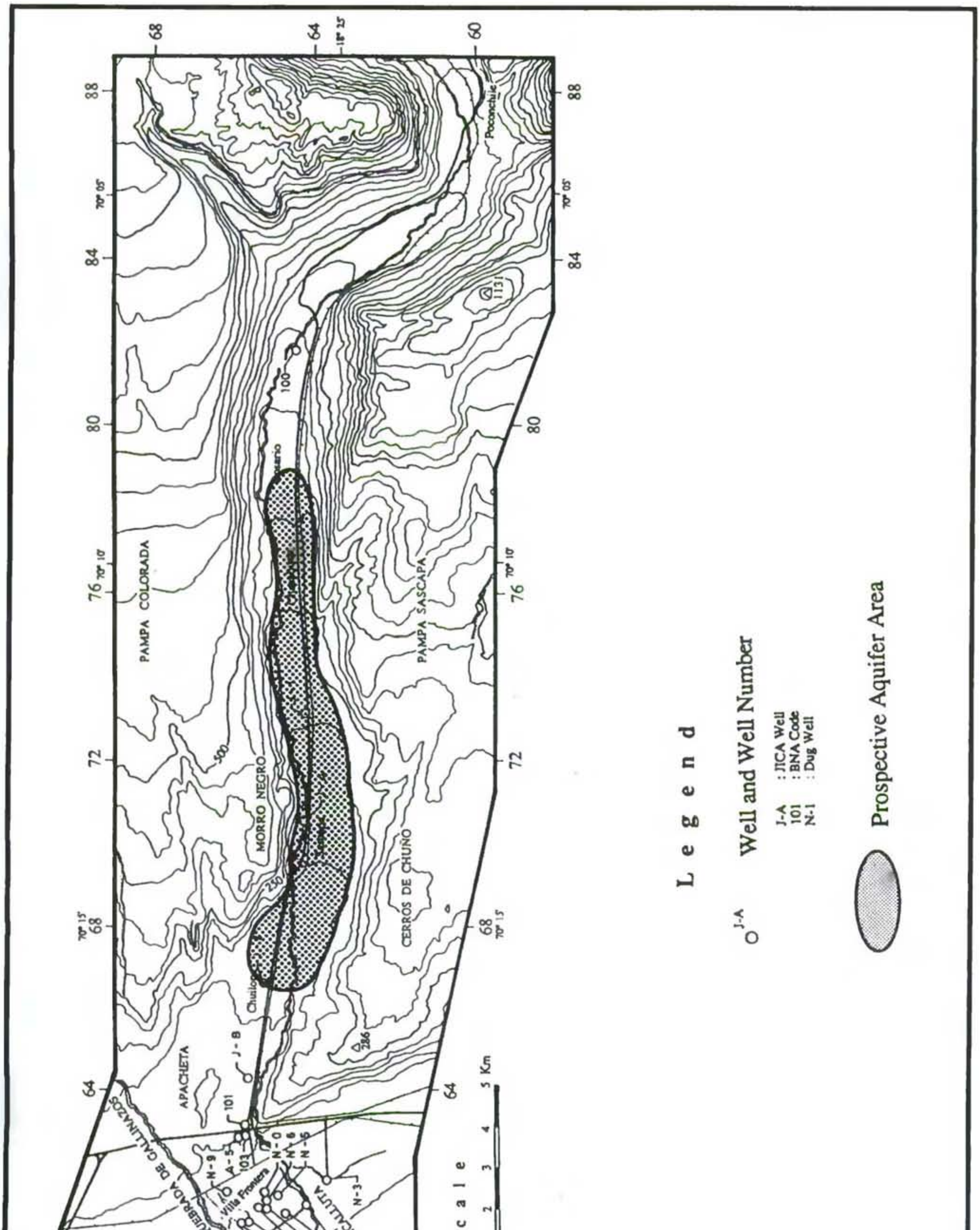


Fig. B-II, 3.5 Prospective Aquifer Area

< Area de Acuíferos Probable >

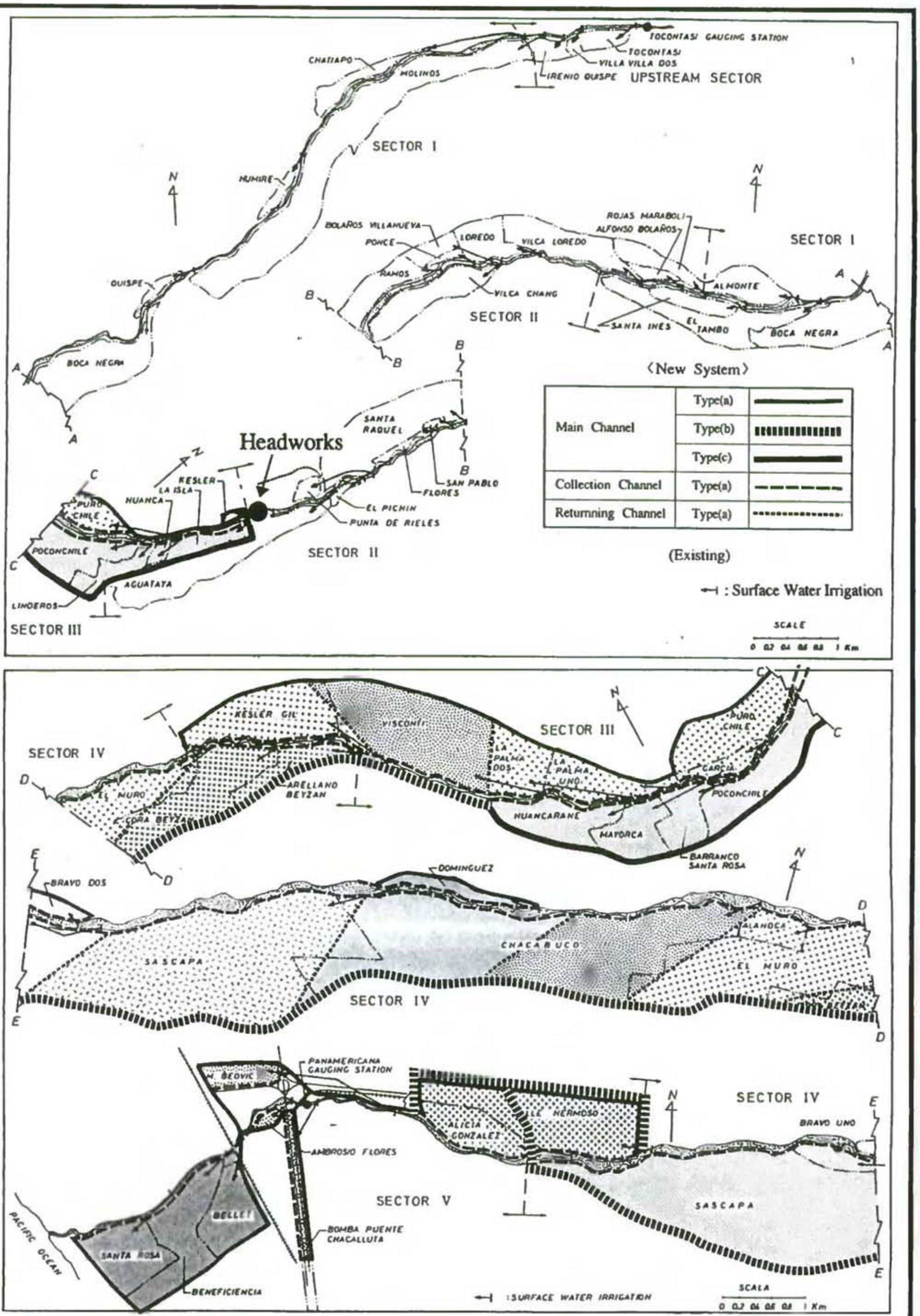


Fig. B-II, 3.6 **Proposed New Irrigation System**

<Nuevo Sistema de Irrigación Prospuesto>

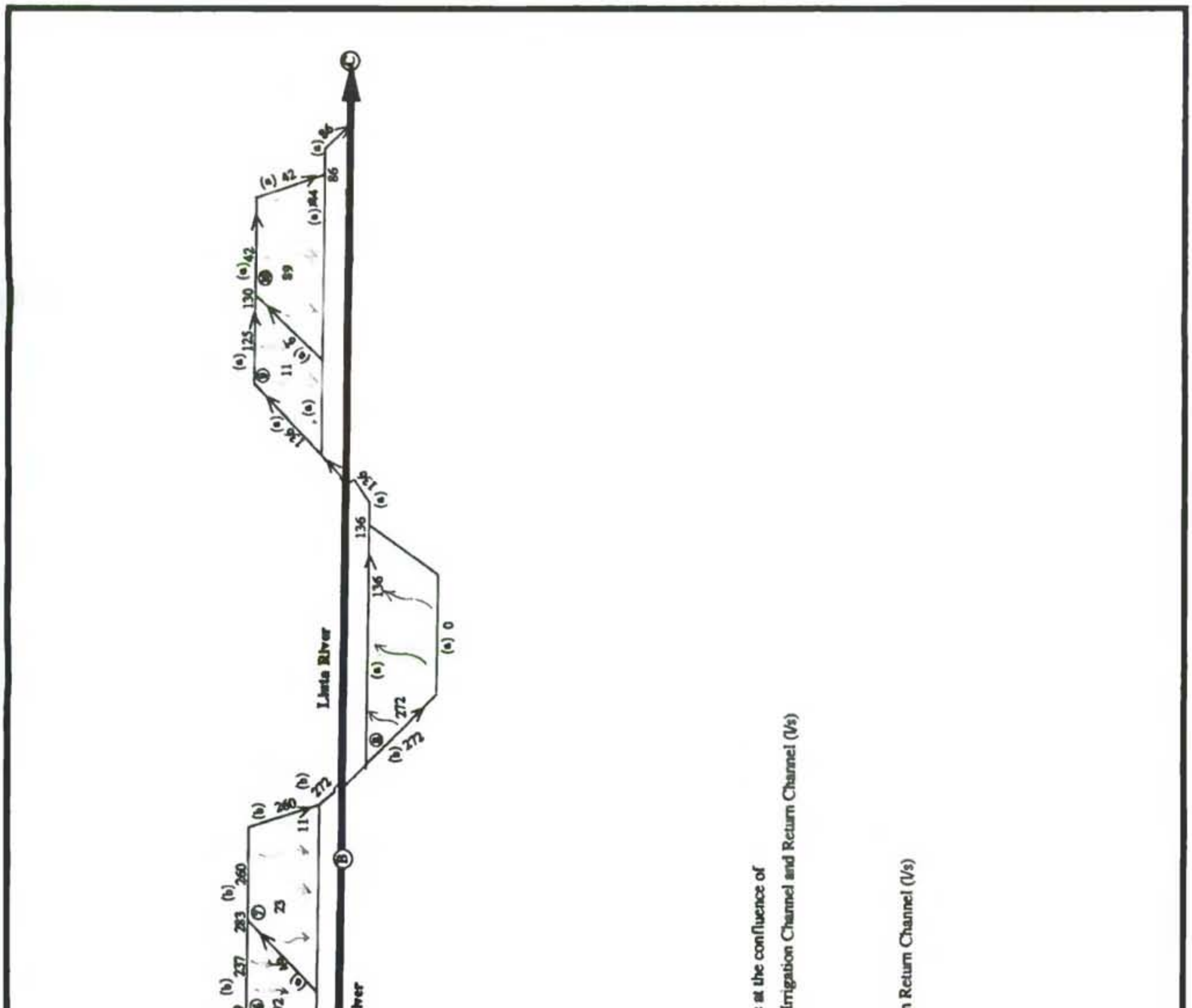
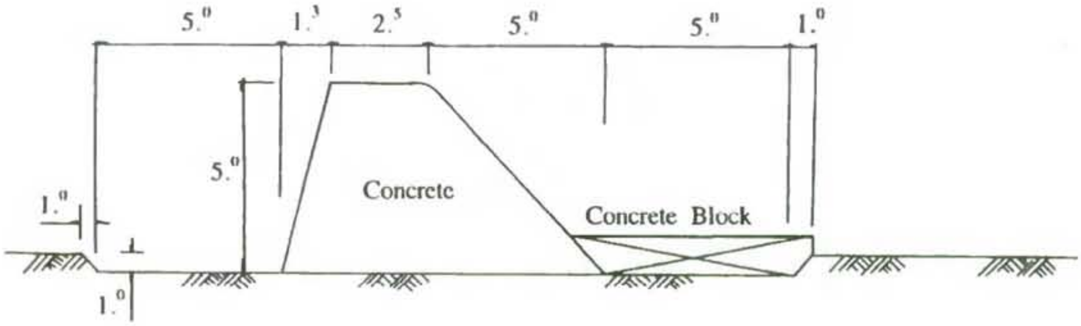
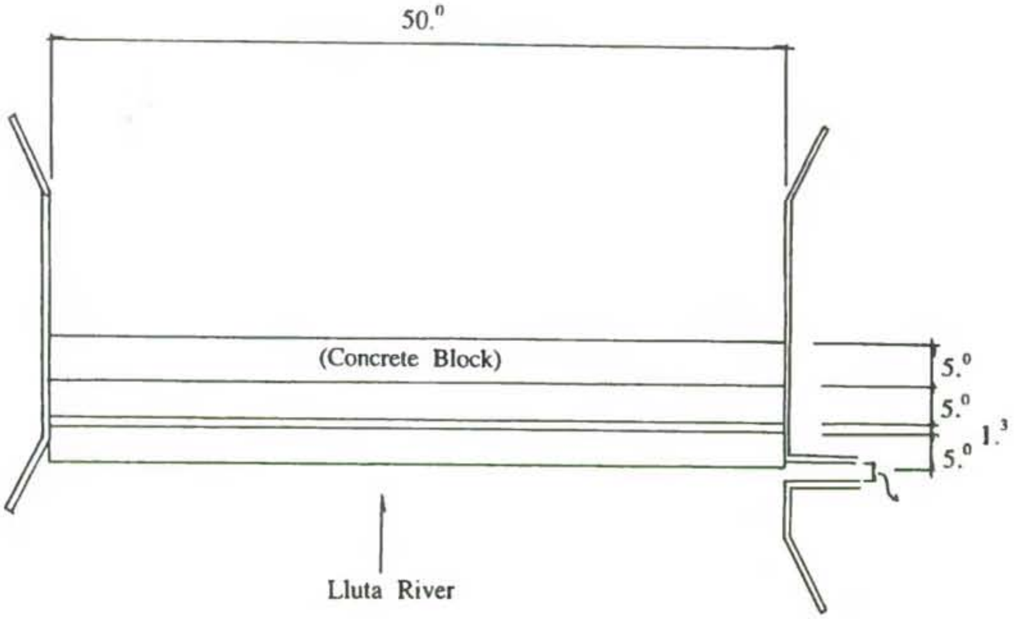


Fig. B-II, 3.7 Conception of Proposed New Irrigation System

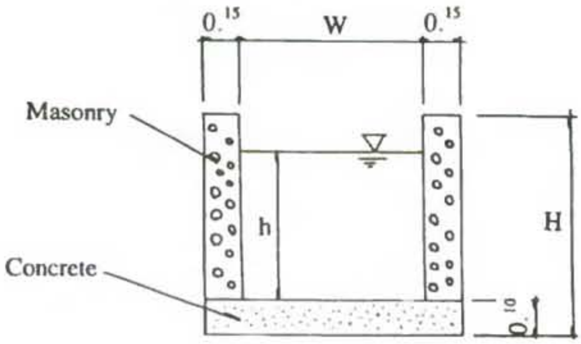
<Concepción del Nuevo Sistema de Irrigación Prospuesto>



Section of Headworks



Plan of Headworks



Type	h(cm)	W(cm)	H(cm)	Q(l/s)	V(m/s)
(a)	30	40	50	190	1.6
(b)	35	65	55	460	2.0
(c)	50	70	70	810	2.3

Section of Irrigation Channel

Fig. B-II, 3.8 **Irrigation Facilities**

<Facilidadses de Irrigación >

Chapter IV GROUNDWATER MONITORING PLAN

Aquifers in the Lower Lluta River Basin are distributed mainly from Rosario to Villa Frontera. Amount of groundwater extraction is negriliblly small because only two (2) deep wells and some dug wells are used for production.

Although present groundwater extraction is small, total extraction rate will reach to 425 l/sec after the Lower Lluta Groundwater Development will be cmpleted in 1999. Therefore, it is important to observe the water level and water quality of the Lower Lluta Valley.

The JICA Study Team drilled four (4) wells, two (2) test wells and two (2) observation wells. Automatic water level recorders are installed to the observation wells and the recording was already commenced in March, 1994. In addition to these, it is proposed to observe other wells as the periodical observation in the Azapa Valley and Pampa del Tamarugal by DGA.

Items of monitoring are water level and water quality. Proposed wells to be monitored are mentioned below. It is important to continue observation at the same wells and never to change monitoring wells. Items of water quality analysis are same as that of the Azapa Valley.

Total number of 12 wells are selected for the observation as follows. For location, refer Fig. B-II, 2.1.

Well No.	Well Name	Item to be observed	
		Water Level	Water Quality
100-2	Colonia J Fuenzalida	every month	once a year
J-1	JICA Well No. J-1	every month	once a year
J-A	JICA Well No. J-A	every month	once a year
J-2	JICA Well No. J-2	every month	once a year
J-B	JICA Well No. J-B	every month	once a year
101	Carcel de Arica	every month	once a year
103	Villa Frontera	every month	once a year
N-6	Villa Frontera	every month	once a year
N-4	Villa Frontera	every month	once a year
N-0	Villa Frontera	every month	once a year
N-9	Villa Frontera	every month	once a year
N-3	Playa las Machas	every month	once a year

B-III PAMPA DEL TAMARUGAL-BASIN

TABLE OF CONTENTS

B-III PAMPA DEL TAMARUGAL BASIN

LIST OF TABLES

B-III PAMPA DEL TAMARUGAL BASIN

LIST OF FIGURES

B-III PAMPA DEL TAMARUGAL BASIN

Chapter I TOPOGRAPHY AND GEOLOGY

1.1. Topography

The Pampa del Tamarugal Basin consists of the parts of Altiplano, Precordillera and Intermediate Depression, as shown in Fig. B-I, 1.1. The Pampa del Tamarugal is lying over the Intermediate Depression and is bounded by the Coastal Range to the west and the Precordillera to the east. It is located at an altitude between 1,000 and 1,600 m.

Drainage patterns of the basin extracted from LANDSAT images are shown in Fig. B-III, 1.1, and these form two different types; a dendritic pattern at the Altiplano and a subparallel pattern at the Precordillera and Intermediate Depression. Main rivers in the basin are Aroma, Tarapacá, Quipisca, Tambillo, Quisma, Chacarilla and Guatacondo rivers. All the streams of Aroma, Tarapaca, Quipisca and Tambillo flow into the Salar de Pintados.

1.2. Geology

1.2.1. Methodology of Geological Analysis

On the details of the methodology, refer to the part of San José River basin.

1) Interpretation of LANDSAT images

As for the Pampa del Tamarugal Basin, six (6) scenes of images were used, whose path and row are: 001-073; 001-074; 001-075; 002-073; 001-074 and 002-075. Details of the used data are shown in Table B-I, 1.1.

2) Interpretation of Aerial Photographs

One hundred ninety seven sheets of black and white aerial photographs taken in 1977 and 1981 were used for the interpretation.

1.2.2. General Geological Features of Basin

Several geological maps published by SERNAGEOMIN (Servicio Nacional de Geologia y Mineria) are available for Pampa del Tamarugal as mentioned below.

Geological Maps

"Pisagua y Zapiga" (1:100,000) (<1)

"Mamiña" (1:50,000) (<2)

"Juan de Morales" (50,000) (<3)

"Pica, Alca, Matilla y Chacarilla" (<4)

Magnetic Map

"Arica, Pisagua-Huara" (1:250,000) (<5)

The results of the interpretation on the basin were compiled in Fig. B-III, 1.2 reviewing these existing data. Stratigraphic classification is given in the following table;

Geologic Age	Formation	Lithology	Units
Quaternary	Recent Sediments	alluvial, eolian, fan deposits	Qal, Qe, Qf.
Quaternary Tertiary	Altos de Pica Formation	continental sedimentary rocks and pyroclastic rocks, divided into 5 members: - Member 5 : dark to greenish grey and middle to fine sandstone. - Member 4 : pinkish orange-grey to white rhyolitic tuff. - Member 3 : yellowish middle to coarse sandstone. - Member 2 : pinkish orange and dark grey rhyolitic welded tuff. - Member 1 : yellowish brown conglomerate and middle to coarse sandstone.	TQau TQal
Mesozoic	Longacho Formation	fissible shale, mudstone, fine sandstone, limestone, generally grey in color.	J

1) General Geology of the Basin

Geology of Pampa del Tamarugal Basin is composed of Mesozoic and Cenozoic rocks, as shown in the table above. The interpretation resulted in the classification of six (6) geological units as shown in Fig. B-III, 1.2. Lithology of each discriminated units were discussed with published references which are mainly from Carlos Gali Oliver and Robert J. Dingman (1962). Lithological characteristics of each unit are as follows:

(1) Mesozoic Unit (J)

It is distributed on the low isolated mountains forming an anticlinal structure at the eastern side of Pampa del Tamarugal. Mesozoic rocks outcropping around

Pica are called the Longacho Formation which consists of fissible shale, mudstone, fine sandstone and limestone, generally grey in color. In many parts, the rocks of this formation are intensely silicified.

The Mesozoic Formation is intruded by andesite, dacite, diorite, granite porphyry, syenitic porphyry and gabbro.

(2) Altos de Pica Formation (Upper Tertiary to Lower Quaternary) (TQau)

The Formation is divided into three (3) continental sedimentary members, distinguished by the numbers 1, 3 and 5, and two (2) members mainly composed of pyroclastic rocks, 2 and 4. The sequence of each members of Altos de Pica Formation in the type -locality is as follows:

Member 5 : Dark to greenish grey and middle to fine sandstone, containing ventifact, showing cross-bedding (200 m in thickness).
Member 4 : Pinkish orange-grey to white rhyolitic tuff (23 m in thickness).
Member 3 : Yellowish middle to coarse sandstone, containing ventifact, showing cross-bedding (173 m in thickness).
Member 2 : Pinkish orange and dark grey rhyolitic welded tuff (17 m in thickness).
Member 1 : Yellowish brown conglomerate and middle to coarse sandstone, showing cross-bedding (322 m in thickness).

The Member 5 is easily differentiated from other members on the LANDSAT images and aerial photographs. The Member 5, TQau on the interpretation map, shows pinkish grey or dark grey color on LANDSAT images. The welded tuff of extensive distribution between Pica and Salar del Huasco corresponds to the Member 4.

(3) Recent (Upper Quaternary) Unit (Qf, Qe, Qal)

It consists of three (3) units, which are fan deposits, eolian deposits and alluvial deposits. Among these, fan deposits have a wide extent in Pampa del Tamarugal.

2) General Geological Structure of the Basin

The results of interpretations revealed the two (2) characteristics on the structure, which are the successional anticlinal structure with N-S trend and dense fractures developed in the welded tuff of Altos de Pica Formation.

Anticlinal structures can be observed at the low isolated mountains between the area from Tarapacá in the north to Challacollo in the south, where the Mesozoic rocks are exposed in parts (see Fig. B-III, 1.2). These structures are supposed to be successional from north to south with culminations and form a trap for the groundwater.

Fractures in the welded tuff show two (2) systems in NE-SW and N-S directions, as shown in Fig. B-III, 1.3. NE-SW system fractures are extended from Collacagua to Altos de Pica and N-S systems are located in the Altos de Pica. These fractures are thought to control the groundwater system and to be a pathway to lead water to Pica.

1.2.3 Hydrogeological Characteristics of Pampa del Tamarugal

Geology of Pampa del Tamarugal is classified into three (3) units from the hydrogeological point of view;

Recent Sediments
Altos de Pica Formation
Basement Rocks

Pampa del Tamarugal is a closed structural basin and is filled by the basin fill deposits and the Altos de Pica Formation which is formed by salty crust, sand, gravel, silt, clay, etc. Basement Rocks are mainly composed of the Mesozoic Formation, therefore, they are impermeable in general. The Altos de Pica Formation is seemed to be permeable considering its lithology. Principal aquifers are occurred in this formation which widely cover the basin. Lithology of the aquifers are mainly sand and gravel. The thickness of the deposits is generally less than 100 m in the north and increases toward the south reaching 700 m in Salar de Pintados.

The aquifers are recharged groundwater mainly from the quebradas flowing into the basin from the east. Channels of the quebradas are concentrated in the following areas as shown in Fig. B-III, 1.1;

(1) Huara area
(2) Pozo Almonte area
(3) The lower reaches of the Qda. de Chacarilla

Furthermore, the Altos de Pica formation supplies the groundwater through fissures and faults of ENE-WSW direction in Pica and Matilla area as mentioned in 1.2.2.

The groundwater flows gently from north to south (from Huara to Salar de Bellavista) after entering in the basin.

Since the extension of the aquifers is so wide (about 4,000 km^2), the influence of extraction of groundwater is quite small (Ref. Chapter 3, 3.2).

Fig. B-III, 1.7 shows geological structure and a schematic geological profile of Pica and Salar del Huasco area. In Pica area, the Altos de Pica Formation is thickly deposited in the eastern side of the rise of the Basement Rocks. As the Basement Rocks are impermeable, the groundwater flowing in the Altos de Pica Formation is dammed up and occurs as the springs in Pica area. The similar hydrogeological condition is recognized along the eastern side of the basin such as Mamiña and Camiña areas.

References

<1: Cuadrangulos "Pisagua y Zapiga", Carta Geologica de Chile (Escala 1: 100,000), 1962 for Instituto de Investigaciones Geologicas Chile by Carlos Galli Olivier y Robert J. Dingman.

<2: Cuadrangulos "Mamiña", Carta Geologica de Chile (Escala 1: 50,000), 1967 for Instituto de Investigaciones Geologicas Chile by Arturo Thomas N.

<3: Cuadrangulos "Juan de Morales", Carta Geologica de Chile (Escala 1: 50,000), 1968 for Instituto de Investigaciones Geologicas Chile by Carlos Galli Olivier.

<4 Cuadrangulos Pica, Alca, Matilla y Chacarilla, Carta Geologica de Chile (Escala 1: 50,000), 1962 for Instituto de Investigaciones Geologicas Chile by Carlos Galli Olivier y Robert J. Dingman.

<5: Hojas "Arica, Pisagua-Huara", Carta Magnetica de Chile (Escala 1: 250,000), 1983 by Servicio Nacional de Geologia y Mineria,

<6: Analisis Programa de Desarrollo de Empresa de Servicios Sanitarios de Tarapaca, February 1991 for ESSAT by Bustamante y Schudeck Ingenieros Consultores Ltda.

Table B-III, 1.1 Correlation of Strata(Pampa del Tamarugal)

<Correlación de Estaatos (Pampa del Tamarugal)>

AGE		Area	ARICA PROVINCE	CAMARACA and AZAPA	PISAGUA and ZAPIGA	MAMIÑA	JUAN de MORALES	PICA, ALCA, MATILLA, CHACARILLA	QUILLAGUA	PAMPA DEL TAMARUGAL	PAMPA DEL TAMARUGAL
		Author (Year)	Salas et al. (1966)	Tobar et al. (1968)	Ignacio Silva (1977)	Thomas (1967)	Galli (1968)	Galli and Dingman (1962)	Skarmeta and Marinovic (1981)	ENAP (1987)	JICA (1994)
CENOZOIC	QUATERNARY	Holocene	Volcanics	Recent Deposits	Recent Deposits	Recent Deposits	Recent Deposits	Recent Deposits	Recent Deposits	Recent Deposits	Recent Deposits
		Pleistocene	Concordia F. Huaylas F.	El Diablo F.	Gravel, Andesitic Clastics (Altos de Pica F.)	Upper (Altos de Pica F.)	Imagua M. (Altos de Pica F.)	TQa 5 TQa4 TQa3 (Altos de Pica F.)	Soledad F.	A B El Loa Limestone (Fill Deposit of Pampa)	Q4 Q3 Q2 Q1 Upper (TQau) (Altos de Pica F.)
	TERTIARY	Neogene P.	Oxaya F.	Oxaya F.	Ignimbrite, Riolites Gravel	Ignimbrite, Riolite Lower	Tambillo M. Sagasca M.	TQa2 TQa1	El Loa F. Ichuno F.	C D E Altos de Pica	Lower (TQal)
		Neogene M.		Azapa F.							
		Paleogene O.	Azapa F. Putani F.						Sichal F. Tambillo F.		
MESO-ZOIC			Lupica F. Sausin F. Arica F.	Atajaña F. Los Tarros F. Camaraca F.	(Intrusive) Huantajaya F. Caleta Ligate F. Of. Viz F.	Cerro Empexa F. Chacarilla F.	Cerro Empexa F. Chacarilla F. Duplija F.	Cerro Empexa F. Chacarilla F. Longacho F.	Arca F. Quinchamall F.	Pintados F.	Basement

(Note) : constructed by the JICA Study Team (1994).

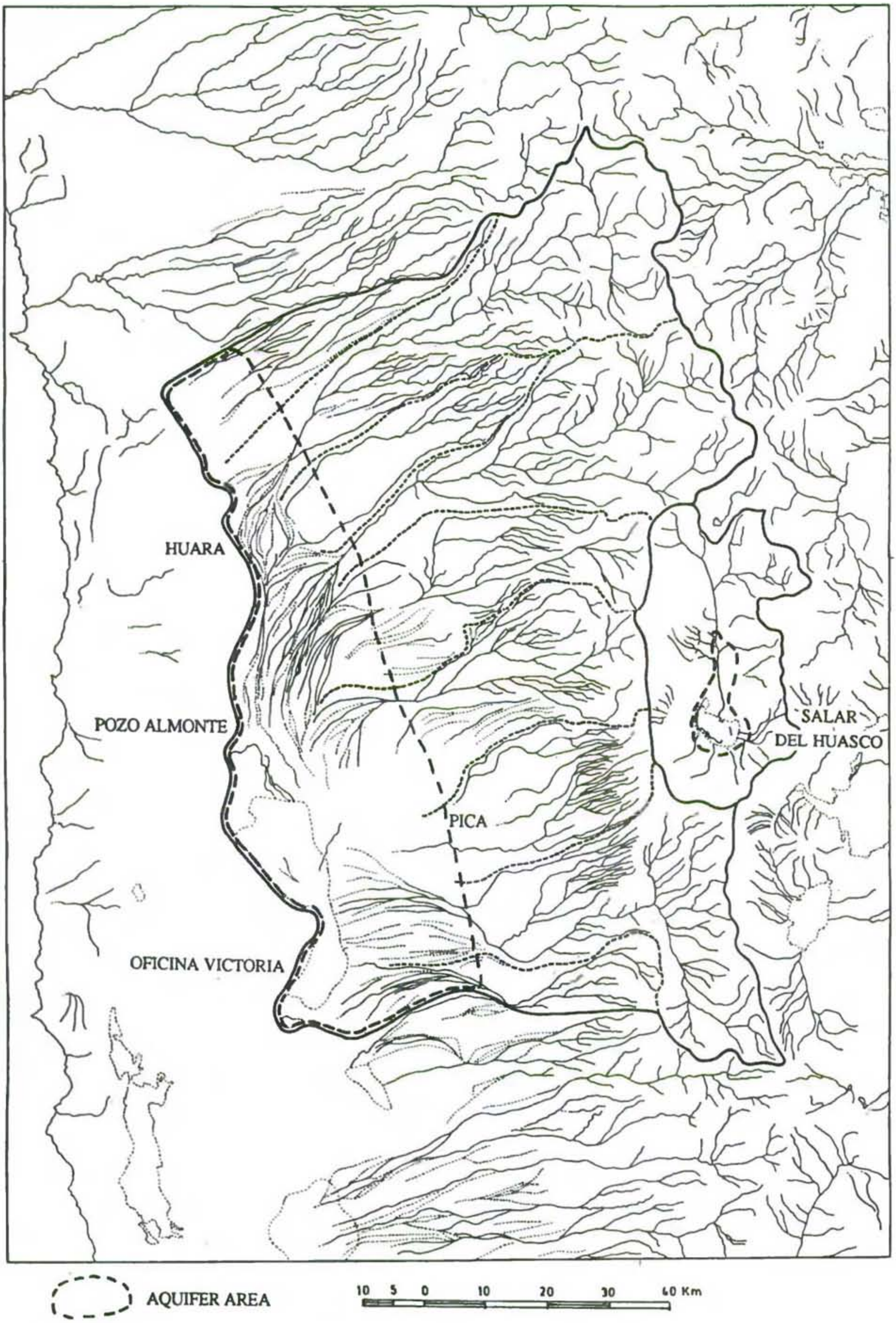


Fig. B-III, 1.1. River Network (Pampa del Tamarugal)

< Red Hidrológica (Pampa del Tamarugal) >

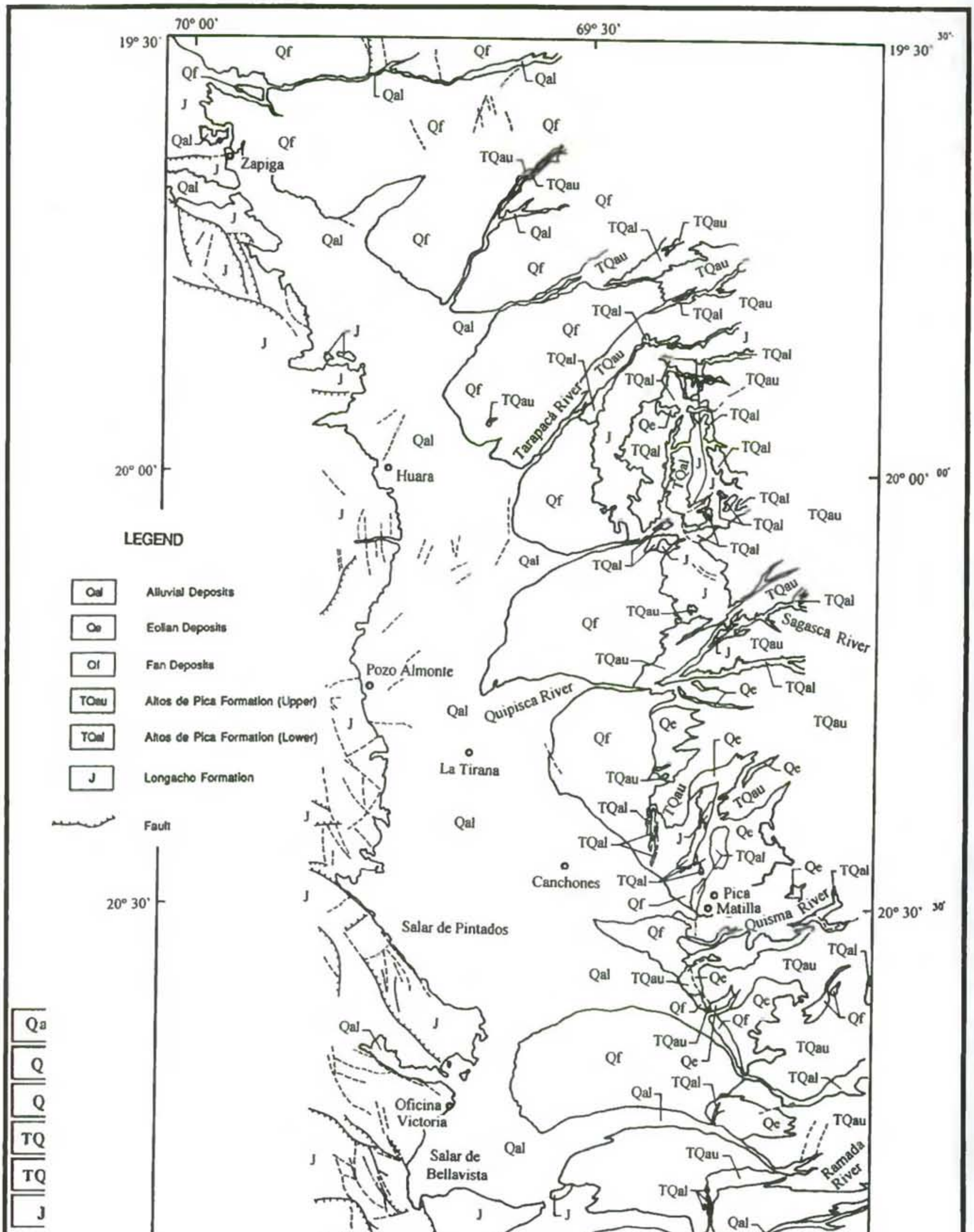


Fig. B-III. 1.2. **Geological Map (Pampa del Tamarugal)**

< Mapa Geológico (Pampa del Tamarugal)>

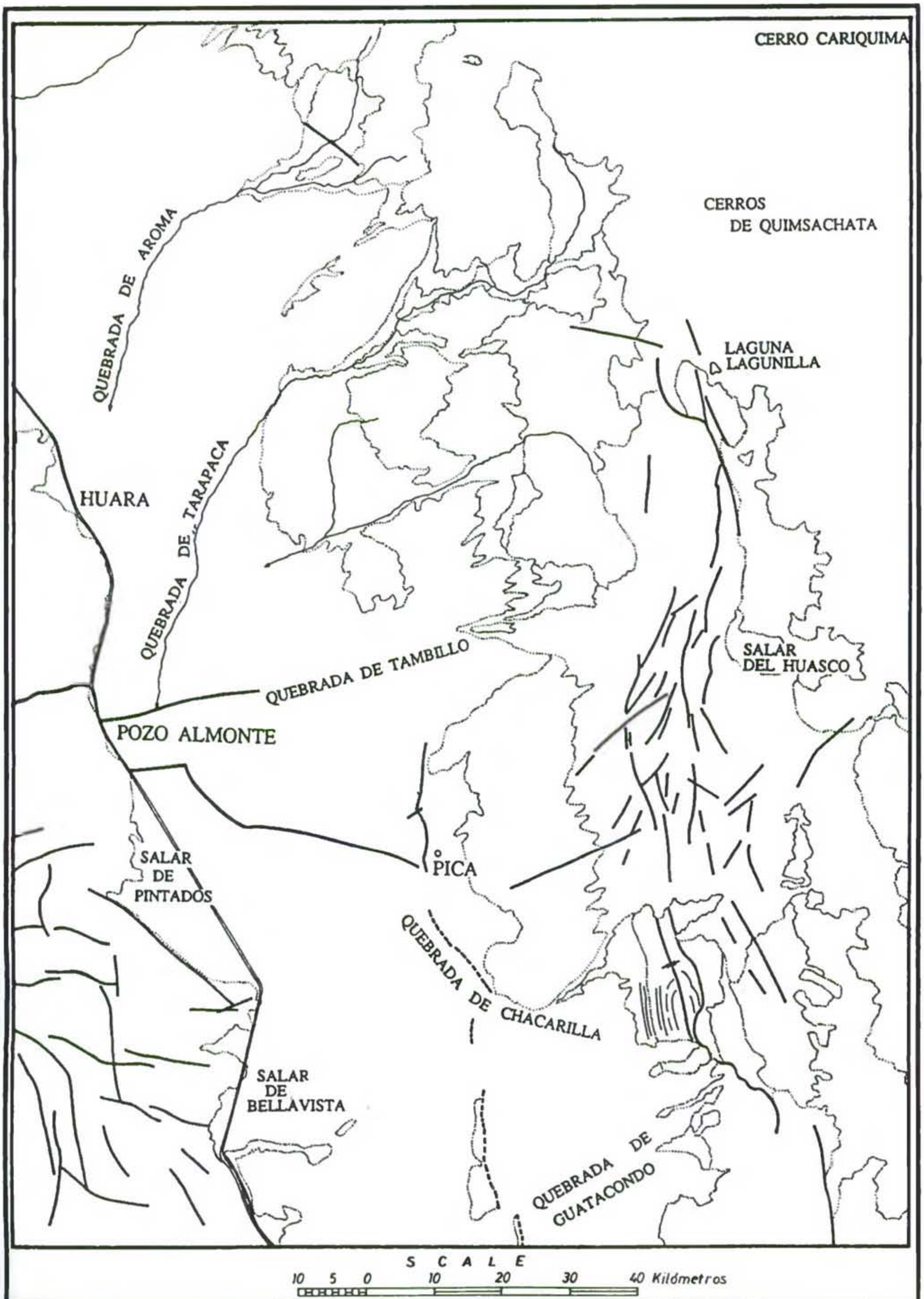


Fig. B-III, 1.3 Geological Structure (Pampa del Tamarugal)

< Estructura Geológica (Pampa del Tamarugal) >

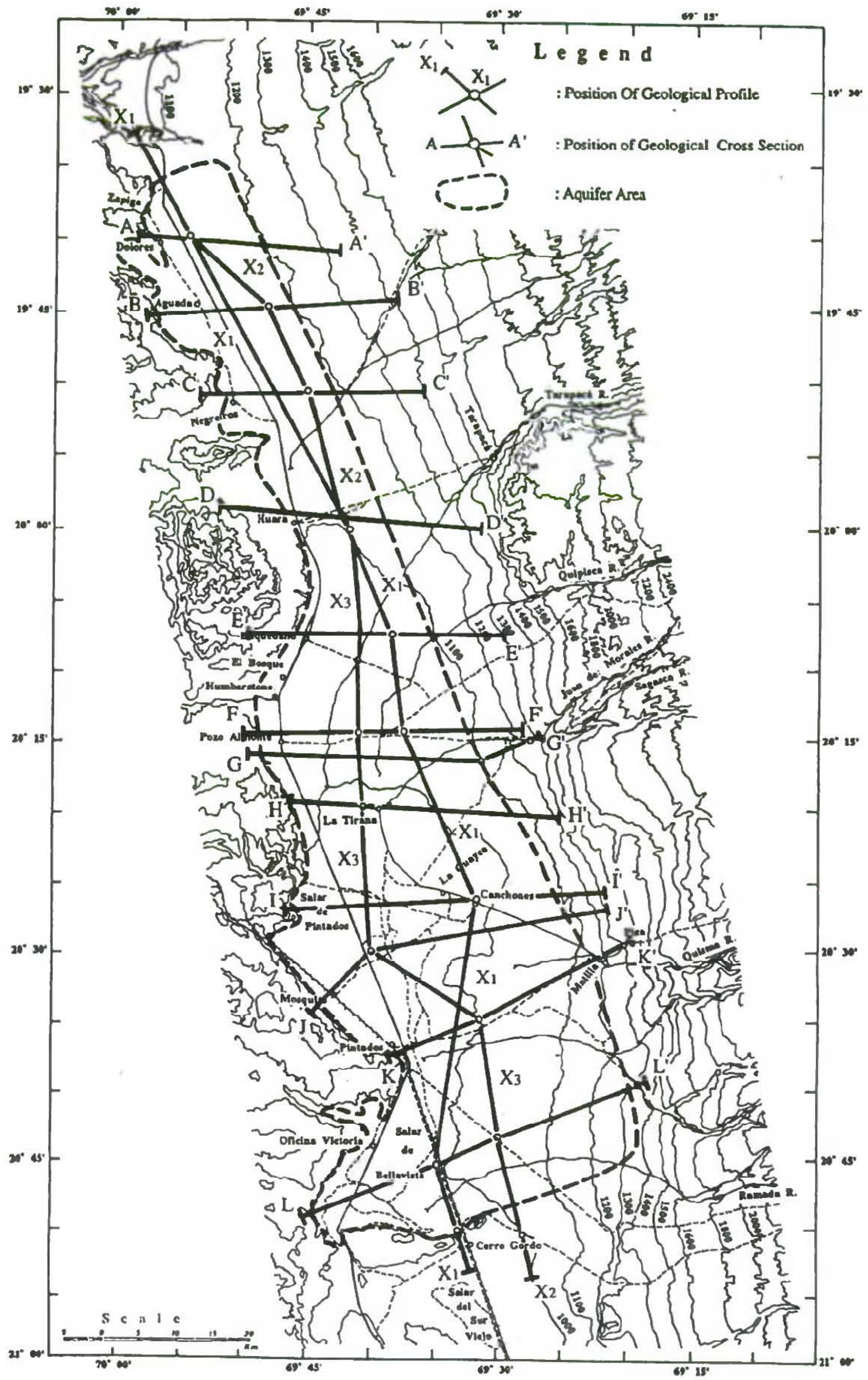
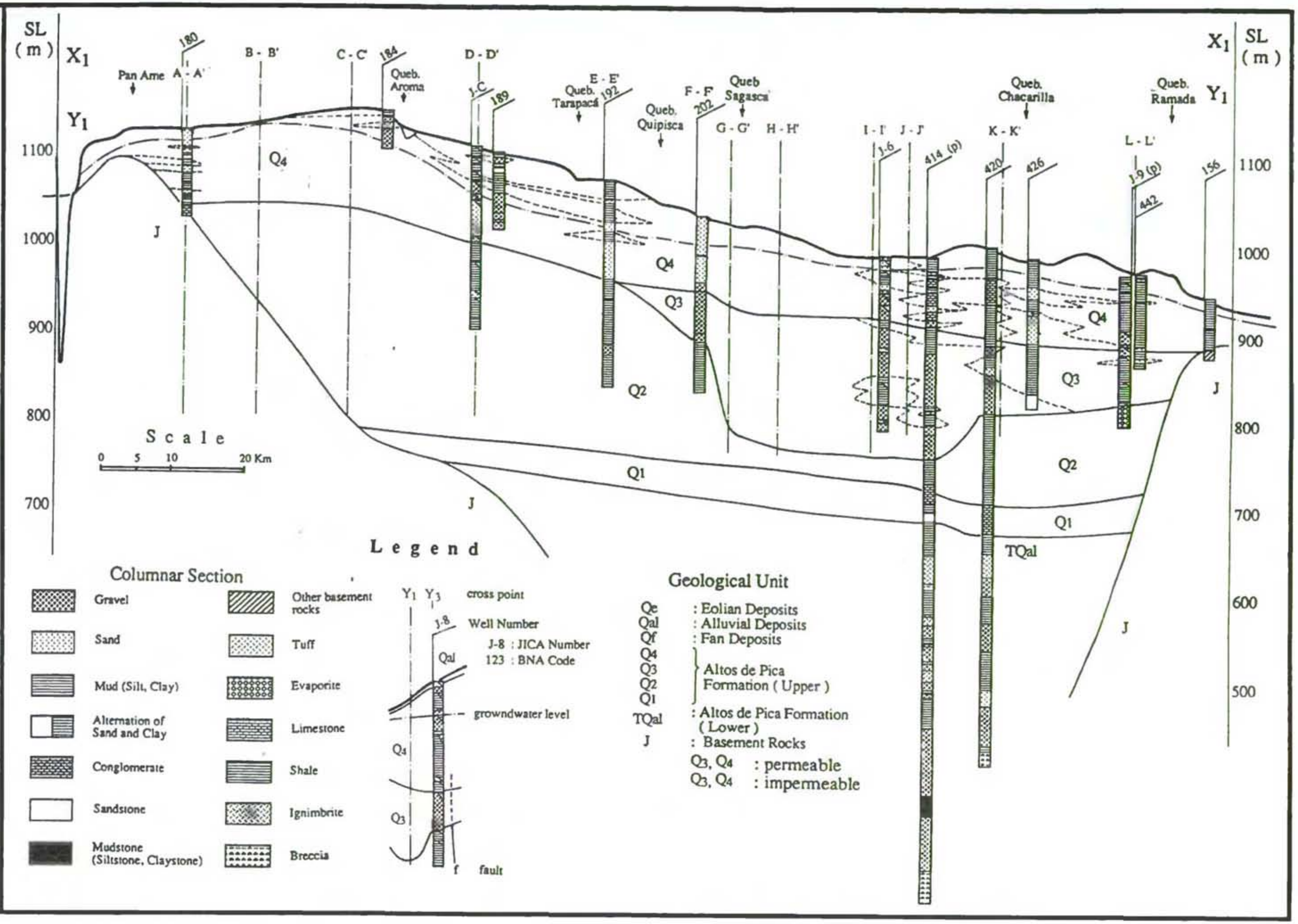


Fig. B-III, 1.4 Location of Geological Profile and Cross Section (Pampa del Tamarugal)

<*Ubicación de* Perfil Geológico y Sección Geológica Transversal (Pampa del Tamarugal) >

Fig. B-III, 1.5 (1) Geological Profile (Pampa del Tamarugal)

< Perfil Geológico (Pampa del Tamarugal)>



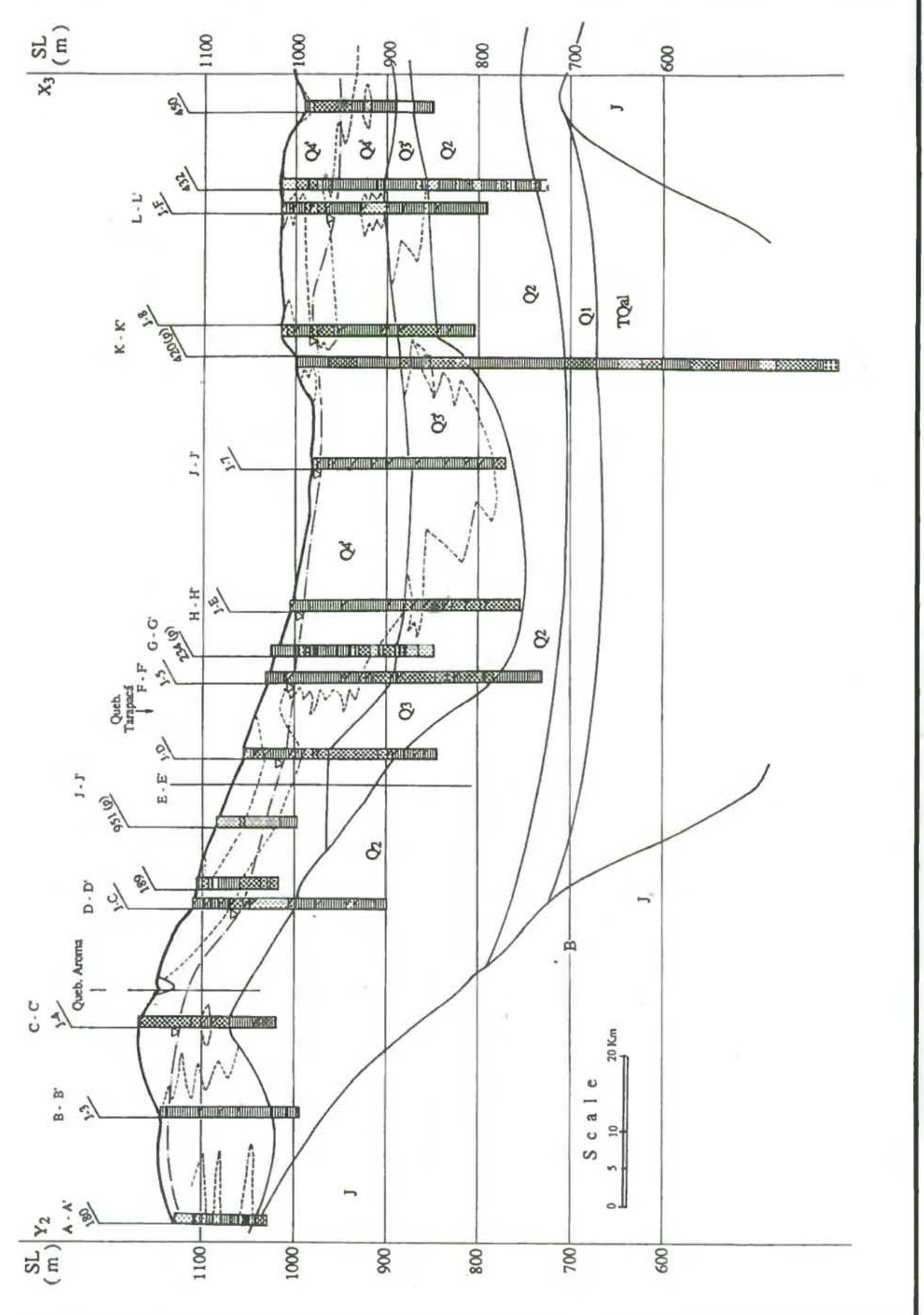


Fig. B-III, 1.5 (2) Geological Profile (Pampa del Tamarugal)

< Perfil Geológico (Pampa del Tamarugal)>

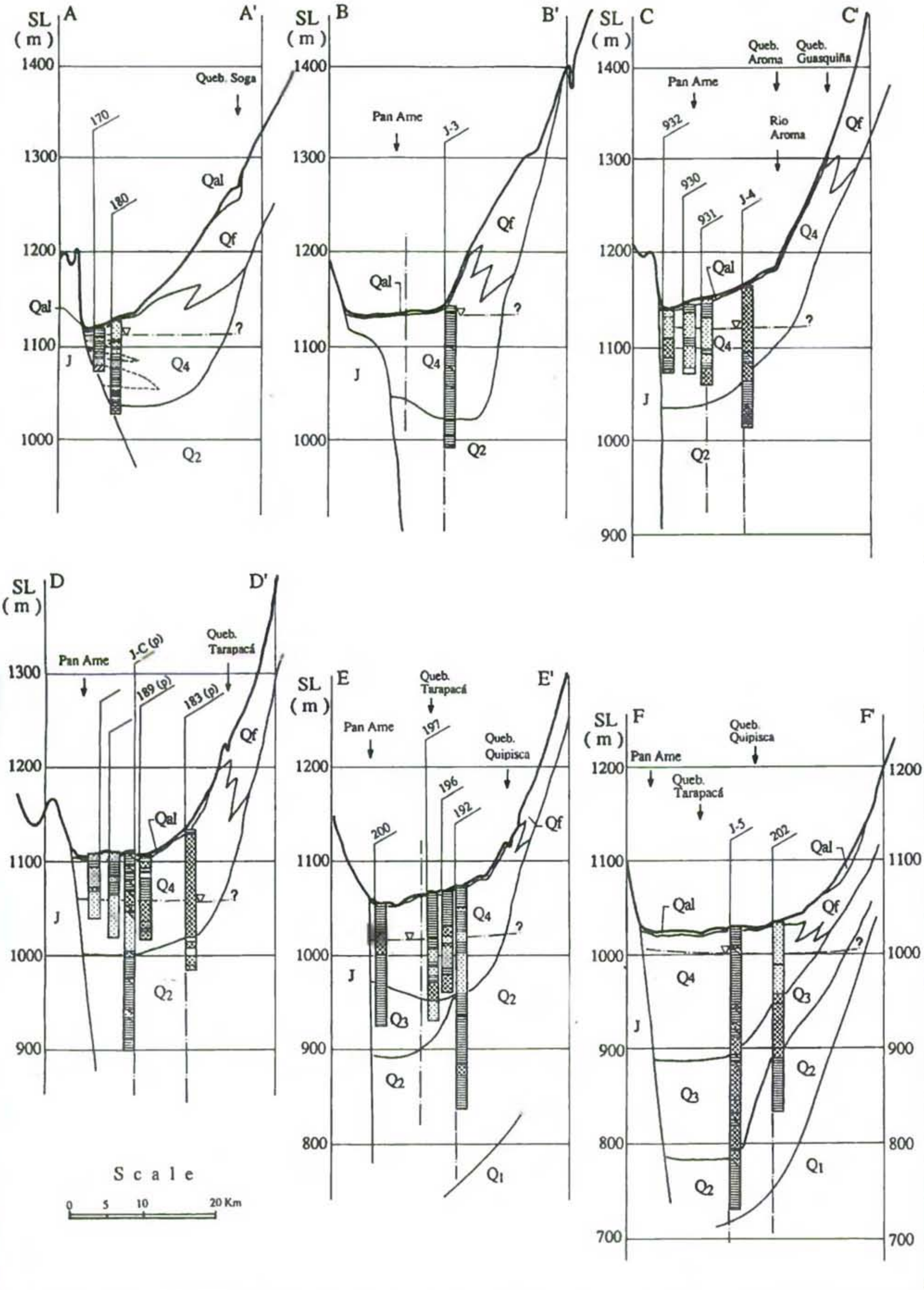


Fig. B-III, 1.6 (1) Geological Cross Section (Pampa del Tamarugal)

< Sección Geológica Transversal (Pampa del Tamarugal)>

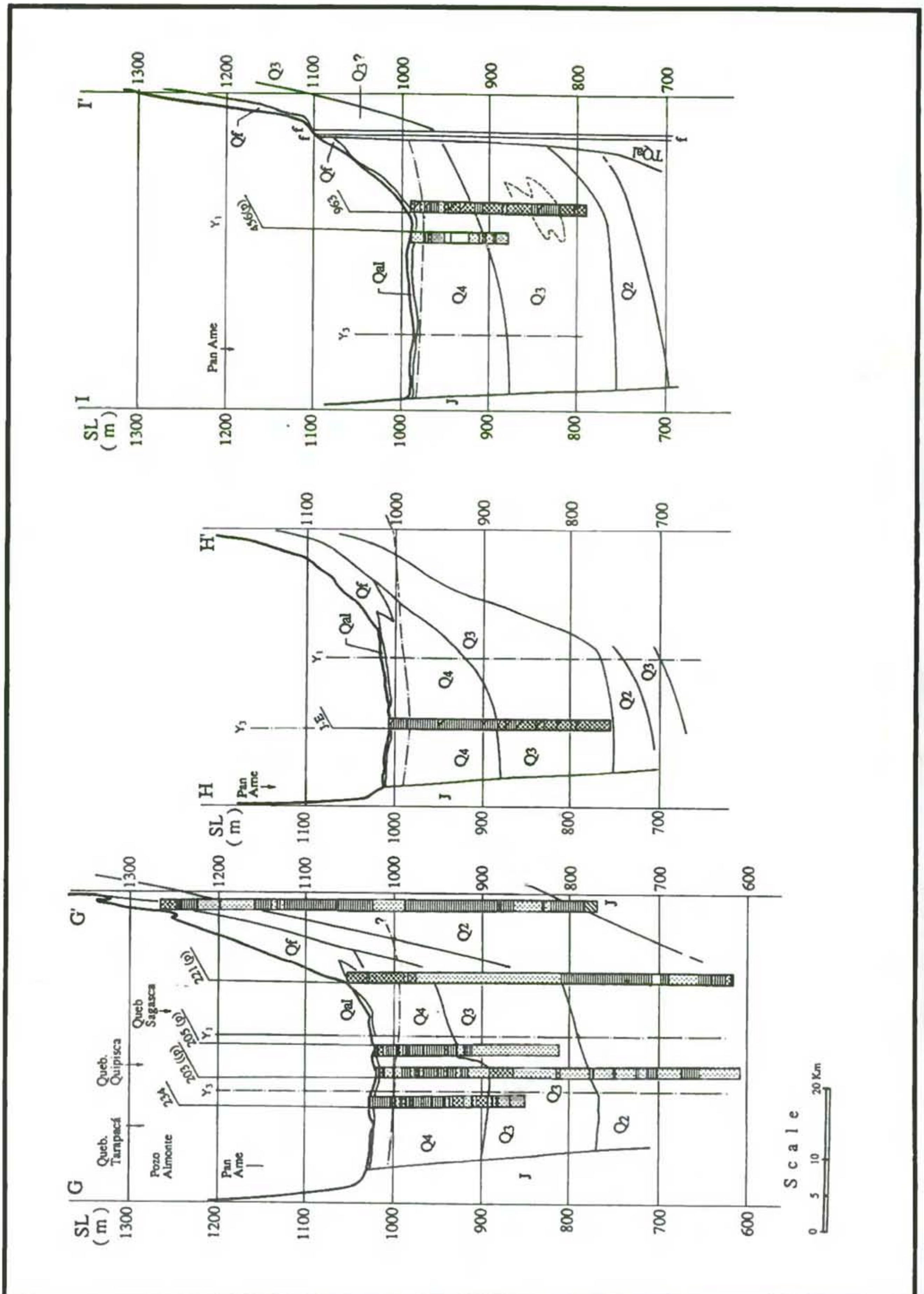


Fig. B-III, 1.6 (2) Geological Cross Section (Pampa del Tamarugal)

< Sección Geológica Transversal (Pampa del Tamarugal)>

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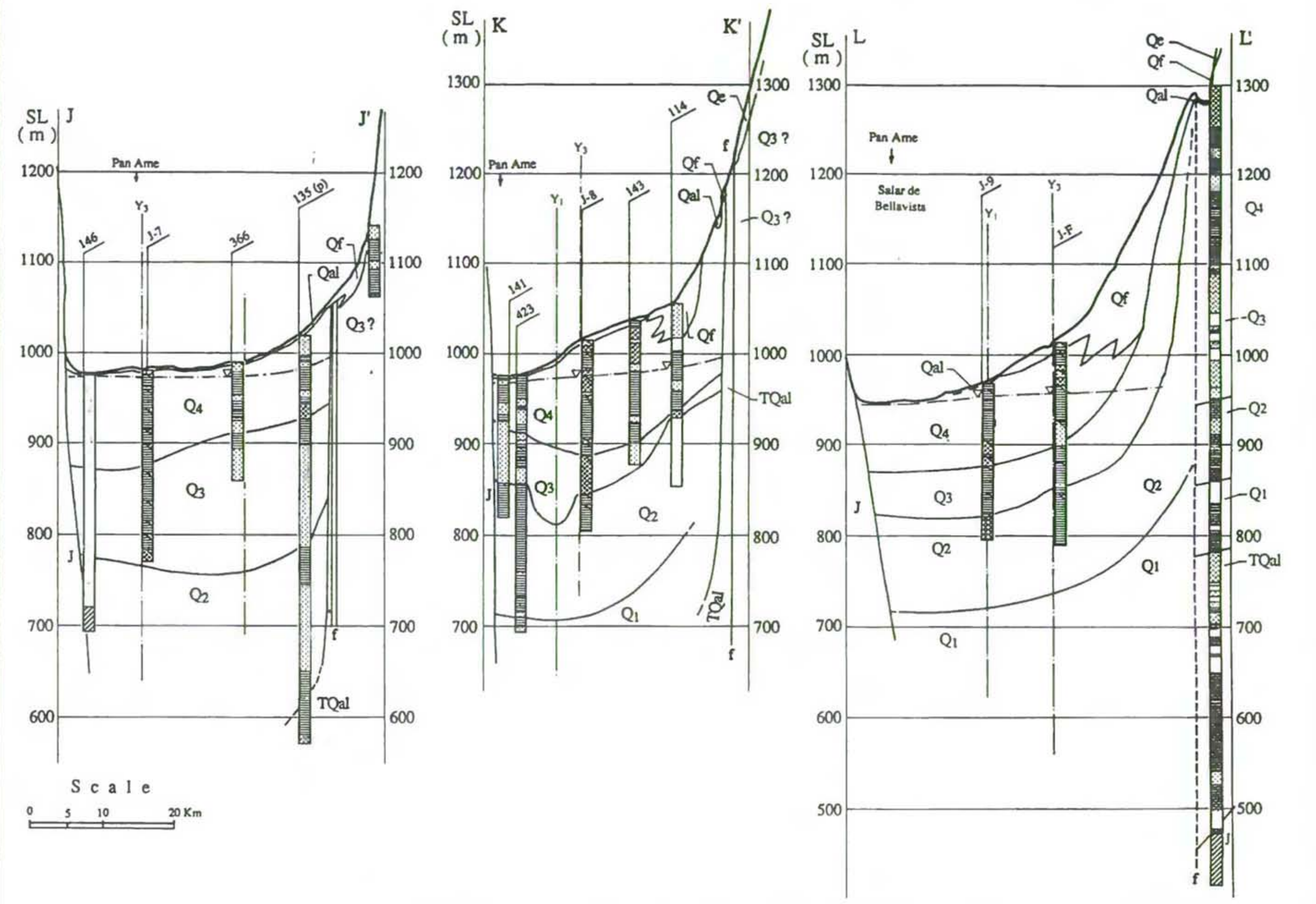
Fig. B-III, 1.6 (3) Geological Cross Section (Pampa del Tamarugal)

< Sección Geológica Transversal (Pampa del Tamarugal)>



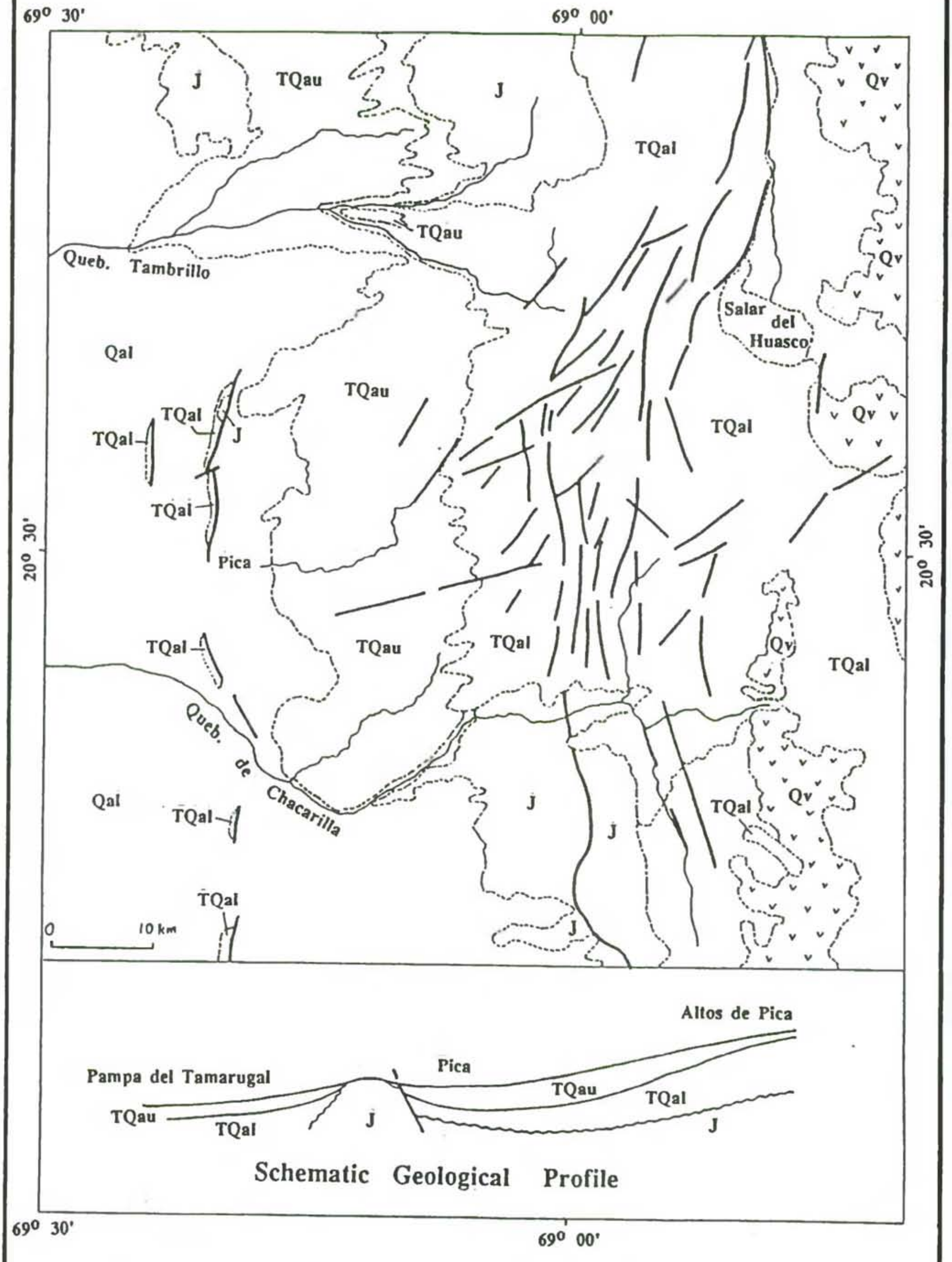


Fig. B-III, 1.7 Geological Structure (Pica and Huasco)

<Estructura Geológico (Pica y Huasco)>

Chapter II. AQUIFER OF PAMPA DEL TAMARUGAL BASIN

2.1 Inventory of Existing Wells

The inventory of existing wells was established by the JICA Study Team based on the same method mentioned in Clause 2.1 of Chapter II in B-I reviewing the following reports:

(1) Análisis Crítico de la Red de Medición de Niveles de Agua Subterránea I Región, October 1987 for DGA by Alamos y Peralta Ingenieros Consultores Ltda.

(2) Modelo de Simulación Hidrogeológica de la Pampa del Tamarugal, 1988 for DGA by Universidad de Chile.

The wells in Pampa del Tamarugal are given the numbers based on both the BNA code and the CORFO code (1975). Once the DGA code and the CORFO code (1969) were used. The CORFO code (1963) was improved to the CORFO code (1975) and the DGA code was not applied afterward.

In this report, the wells are expressed by the three (3) digits of consecutive numbers on the basis of the BNA code like "188".

The number of wells (sondajes) comes to 458 in the basin, consisting of 256 wells for research including observatory wells, five (5) wells for the industrial use, 77 wells for the potable water supply, 35 wells for the irrigation, 49 wells for the mining and 36 wells have no data. Out of 458 wells, total number of 68 wells are already abandoned. In addition to this, there are many dug wells in the basin, however, no data is available.

381 wells are already registered to BNA/CORFO(1975) codes (Table B-III, 2.1 (1)). 63 wells were drilled in Pampa del Tamarugal to apply the water right for mainly mining and irrigation use in the second half of 1980s. Those 63 wells' data are collected by DGA. Most of these wells has not yet registered to neither BNA nor CORFO (1975). Therefore, temporary numbers (BNA/CORFO codes) were given to the wells for the convenience (Table B-III, 2.1 (2)). Accordingly, a total number of 458 wells were listed in the Well Lists in Pampa del Tamarugal; 395 wells in Table B-III, 2.1 (1) and 63 wells in 2.1 (2). For those locations, see Fig. B-III, 2.1 (1) and 2.1 (2).

As for the date of well construction, 285 data are available. The number of well construction and the increase of wells are shown in Fig. B-III, 2.2. The wells have been constructed every year since 1950. Significant increase suddenly occurred during three (3) years; 1965, 1966 and 1967. Totally 175 wells were constructed in this period; most wells are for water level observation. The number of wells exceeded 200 during 1950 and 1967. A few wells were constructed in 1970s. In 1980s, number of well construction increased for the application of water right as mentioned above. Even in 1990s, well construction have been continued.

Depth of well is shown in Fig. B-III, 2.3. 235 wells are less than 100 m in depth. 56 wells are in a depth between 100 and 200 m and rest 49 wells are penetrated more than 200 m. This means that most wells are tapping groundwater from the shallower aquifers.

2.2 Existing Boring Data

2.2.1 Boring Logs

More than 400 boring logs are collected from the existing wells (both registered wells and new wells for application of water right). These logs were interpreted from the hydrogeological point of view and geostratigraphic columns are constructed which are attached to the Well Inventory (see, Data Book).

2.2.2 Pumping Test

The results of pumping test are shown in Well List (Table B-III, 2.1 (1) and 2.1 (2). Aquifer constants are estimated only for 36 wells and 40 data show only draw down and pumping rate. Specific yield (Sy) was calculated based on the 40 pumping data.

2.3 Supplementary Geological Survey

The following geological surveys were executed by the JICA Study Team to supplement the existing geological data. The survey locations are shown in Fig. B-III, 2.4.

a) Electromagnetic Survey — 100 survey points (8 lines)

b) Boring Survey

  (a) Drilling

    Test well drilling — 4 wells

Observation well drilling	7 wells
(b) Pumping Test	11 wells
c) Water Quality Analysis	11 wells (JICA wells)
d) C-14 Analysis	5 wells

2.3.1 Electromagnetic (TEM) Survey

1) Survey Area

Transient Electro Magnetic (TEM) survey was conducted in Pampa del Tamarugal area as shown in Fig. B-III, 2.4. Eight (8) TEM lines were set perpendicular to the main axis of the Precordillera range. A total of 100 stations were set at an interval of 2,000 m each as shown below.

Outline of TEM Survey

	Profile	Stations	Station Interval
	PT-1	14	2,000 m
	PT-2	9	2,000 m
	PT-3	28	2,000 m
	PT-4	14	2,000 m
	PT-5	8	2,000 m
	PT-6	15	2,000 m
	PT-7	4	2,000 m
	PT-8	8	2,000 m
Total		100	

2) Methodology of Survey

For the details of the methodology, see B-II, Section 2.3.1 of Chapter II.

3) Survey Results

Typical apparent resistivity curves in the area are shown in Fig. B-III, 2.5. Geoelectrical profiles are made by analyzing the apparent resistivity curve of each station. The geoelectrical profiles along the line PT-1 to PT-8 are shown in Fig. B-III, 2.6. According to the well logging (long normal) data of three (3) existing wells (Pintados No. 1, No. 2 and Dolores No. 1), the resistivity value of aquifer with no contamination is in the range of 10 to 40 Ω-m. Among these wells, Pintados No. 1 is located near station No. 5 of PT-8. Resistivity calibration was made by using the logging data of Pintados No. 1 as shown in Fig. B-III, 2.7.

The resistivity structure of the surveyed area is classified as 3 to 4 layers with stratiform structure. The geophysical characteristics of each layer are summarized as follows;

(1) The first layer (10 m to 120 m thick) shows a resistivity range of 28 to 1,400 Ω-m. The layer is distributed in the whole area. In the area, at stations No. 1 to 3 and 6 to 8 of PT-5, station No.13 to 16, 21 to 23 and 25 to 28 of PT-3, the layer shows a relatively low resistivity (28 to 100 Ω-m). This is probably due to the wet land conditions by irrigation water.

Resistivity of the layer at stations 11 to 13 of PT-1 and all stations of PT-7 is extremely high (more than 1,000 Ω-m). This is probably due to the hard and dry land conditions. In general, in the eastern part of the area, the layer shows higher resistivity than the western part. This resistivity range in the eastern part is between 200 and 1,200 Ω-m. The layer thickness gradually increases towards southeast.

The depth of the boundary between the first and second layer is almost coincident with the water level of wells in the area.

(2) The second layer (between 20 and 400 m thick) shows a resistivity range of approximately 10 to 50 Ω-m. The layer is distributed over almost all the stations of profiles. According to the resistivity logging data of the existing well of Pintados No. 1 (located near the station No. 5 on profile PT-8), this layer is considered as a expected aquifer. The layer thickness gradually increases from 100 m (PT-1) to 400 m (PT-7). However, it rapidly decrease from 200 m (PT-8) to less than 100 m (PT-4).

(3) The third layer (more than 50m thick) shows a resistivity value lower than 10 Ω-m. The layer is distributed over the whole area. The layer is presumed to have a groundwater potential of the same degree throughout the area. However, its low resistivity indicates that the layer is contaminated by salty water. The depth of the layer gradually increases to southwards.

(4) The fourth layer shows a resistivity value approximately higher than 100 Ω-m. The layer is distributed in the northern and western part of the area. According to the existing data such as the well logging of Dolores No. 1 and a gravity map of the area, the layer is considered as a geological basement composed of high density rocks. Thus, the layer is classified as the impermeable basement.

Lateral discontinuities of resistivity exist between station No. 4 and No. 5 of PT-2, station No. 4 and No. 5 of PT-6, station No. 2 and No. 3 of PT-3, and station No. 1 and No. 2 of PT-7. These discontinuities may be coincident with geological boundaries such as faults of fracture zones.

4) Interpretation with Boring Log

Geoelectric profiles, described in the above section, are analyzed comparing with the boring logs. Fig B-III, 2.3.8 to 2.3.15 show analyzed resistivity profiles. Results of interpretation for each resistivity profile are summarized as follows.

(1) Profile PT-1 (see, Fig. B-III, 2.8)

The profile is analyzed as a four (4) layered model except the area between stations No. 11 to 13. In this area, the first layer is divided into two (2) parts; the upper shows high resistivity (1,100 - 1,300 Ω-m) because of dry land, and the lower shows a resistivity range of 96 - 300 Ω-m. The second layer shows a resistivity range of 8.1 to 27 Ω-m and is considered as a aquifer. The well No. J-C is located at the station No. 4. Third layer is distributed at stations No. 5 to 14. Resistivity range shows less than 8.7 Ω-m. The boundary with the fourth layer is unclear. The summary of the interpretation are shown in the following table.

(PT-1)

Layer	Depth (m.bgl)	Resistivity Range(Ω-m)	Lithology	Interpretation
1 st	0 - 90	1100 - 1300	not confirmed	dry surface
	0 -40	96 -300	sandy clay	surface deposits
2 nd	40 - 130	8.1 -27	clayey gravel at upper, clayey sand at middle, clay at lower	expected aquifer
3 nd	-	<8.7	not confirmed	contaminated aquifer
4 th	>130	>100	sandy clay	impermeable bed

(2) Profile PT-2 (see, Fig. B-III, 2.9)

A four (4) layered model is applied to this profile. The first layer shows a high resistivity range between 94 and 440 Ω-m due to dry condition. The second layer and shows a resistivity range of 7.9 to 14 Ω-m is considered as a aquifer. Lateral discontinuity of resistivity was observed between stations No. 4 and 5; Crossing this lateral discontinuity, two (2) different ranges resistivity were observed. The eastern side of the discontinuity shows a low range of less than 6.5 Ω-m and the western side indicates a high range of more than 100 Ω-m. The well No. J-D was drilled on this profile. Results of the interpretation are summarized in the following table.

(PT-2)

Layer	Depth (m.bgl)	Resistivity Range(Ω-m)	Lithology	Interpretation
1 st	0 -30	94 -440	mainly clayey gravel (sandy silt at top surface)	surface deposits
2 nd	30 - 160	7.9 -14	clayey gravel to clean gravel	expected aquifer
3 rd	-	<6.5	not confirmed	contaminated aquifer
4 th	>160	>100	clayey gravel	impermeable bed

(3) Profile PT-3 (see, Fig. B-III, 2.10)

The profile is analyzed as a three (3) layered model. The first layer shows a high resistivity range due to the dry surface condition and is correlated with the surface deposits. The second layer shows a resistivity range of 9.1 to 19 Ω-m and is considered to be an expected aquifer. The third layer shows a low resistivity range, therefore, it is corresponds to a contaminated aquifer.

The well No. J-E and J-6 are located at stations No. 5 and 6 respectively.

(PT-3)

Layer	Depth (m.bgl)	Resistivity Range(Ω-m)	Lithology	Interpretation
1 st	0 - 50	77 - 360	sandy to gravelly clay	surface deposits
2 nd	50 - 240	9.1 - 19	gravelly clay at upper, clayey gravel at lower	expected aquifer
3 rd	>240	<6.7	not confirmed	contaminated aquifer

(4) Profile PT-4 (see, Fig. B-III, 2.11)

A three (3) layered model was applied on this profile. However, the third layer is intercalated with a higher resistivity layer.

The first layer shows high resistivity range due to the dry condition and is correlated with the surface deposits. The second layer is considered as a prospective aquifer from its resistivity. The third layer is also considered as an aquifer as well as the second layer. In the eastern side of the station No. 5, the third layer contains a thick layer of higher resistivity range which is the fourth layer.

Well No. J-F is located at station No. 8.

(PT-4)

Layer	Depth (m.bgl)	Resistivity Range(Ω-m)	Lithology	Interpretation
1 st	0 - 80	690 - 1000	gravelly clay at upper sandy clay at lower	surface deposits
2 nd	80 - 150	7.3 - 16	clayey sand at upper sandy clay at lower	expected aquifer
4 th	150 - 300	9.2 - 13	not confirmed	expected aquifer
3 rd	>150	<6.6	sandy clay	contaminated aquifer

(5) Profile PT-5 (see Fig. B-III, 2.12)

The profile is analyzed as a four (4) layered model. The first layer is of high resistivity range. The first layer is distributed in a restricted area between stations No. 3 and 6 which are at the central part of the profile. The second layer shows a resistivity range of 52 to 70 Ω-m and is considered as a aquifer. The third layer shows a low resistivity range, therefore, is considered to be a impermeable layer.

The well No. J-4 is located on the station No. 4.

(PT-5)

Layer	Depth (m.bgl)	Resistivity Range(Ω-m)	Lithology	Interpretation
1 st	0 - 30	110 -120	gravel	surface deposits
2 nd	30 - 100	52 - 70	gravel at upper part clayey gravel at lower	expected aquifer
3 rd	100 - 160	6.3 -9.7	clayey gravel at upper conglomerate at lower	contaminated aquifer
4 th	>160	>100	not confirmed	impermeable bed

(6) Profile PT-6 (see, Fig. B-III, 2.13)

The profile is analyzed as a three (3) layered model. The first layer shows a high resistivity range and is correlated with the dry surface deposits. The second layer is considered as a aquifer. However, the layer ends at the west of station No. 5. The third layer is also ends at the same place as the second layer. The layer shows a low resistivity range. The fourth layer is distributed in the western side of the profile,showing a high resistivity range, therfore, it is considered as the impermeable bed.

Well No. J-5 is located at station No. 6.

(PT-6)

Layer	Depth (m.bgl)	Resistivity Range(Ω-m)	Lithology	Interpretation
1 st	0 -80	690 -1,200	sandy clay	surface deposits
2 nd	80 - 210	10 - 17	clayey gravel to gravel	expected aquifer
3 rd	>210	<7.5	gravel at upper sandy clay at lower	contaminated aquifer
4 th	-	>100	not confirmed	impermeable bed

(7) Profile PT-7 (see, Fig. B-III, 2.14)

A three (3) layered model is established except the station No.1. The first layer shows a high resistivity range and corresponds to the dry surface deposits. The second layer shows a resistivity range of 7.4 to 9.5 Ω-m and is considered as a aquifer. The third aquifer is of low resistivity range and is considered to be a contaminated by the salty water. The third layer is not distributed at the station No. 1; The fourth layer appears at the station instead of the first layer. The fourth layer shows a high resistivity range. It is probably due to the distribution of the basement rocks.

Well No. J-7 is located at the survey point No.4.

(PT-7)

Layer	Depth (m.bgl)	Resistivity Range(Ω-m)	Lithology	Interpretation
1 st	0 -10	1,000 -1,400	sandy clay	surface deposits
2 nd	10 - 380	7.4 - 9.5	sandy clay to gravelly clay, gravel in some parts	expected aquifer
3 rd	>380	2.0 - 2.6	not confirmed	contaminated aquifer
4 th	-	1250	not confirmed	impermeable bed

(8) Profile PT-8 (see, Fig. B-III, 2.15)

In this profile, a five (5) layered model is applied. The first layer shows a high resistivity range which is corresponds to the surface deposits. The second layer is considered as a aquifer, however, it becomes a layer of low resistivity range. Therefore, the second aquifer is considered to be contaminated by the salty water in the western part of the profile. The third layer and fourth layer are considered as a aquifers as well as the second layer.

The well No. J-8 is drilled on this profile.

(PT-8)

Layer	Depth (m.bgl)	Resistivity Range(Ω-m)	Lithology	Interpretation
1 st	0 -30	920 - 950	sand and gravel at surface clay at lower	surface deposits
2 nd		25 - 47	alternation of clay and gravel	expected aquifer contaminated in the west
3 rd	30 - 320	8.9 - 9.3		expected aquifer
4 th		14 -30		expected aquifer
5 th	>320	<6.6	not confirmed	contaminated aquifer

2.3.2 Boring Test

1) Location and Depth of Each Well

Four (4) test wells (J-C, J-D, J-E and J-F) and seven (7) observation wells (J-3, J-4, J-5, J-6, J-7, J-8 and J-9) were placed along the TEM survey line (see, Fig. B-III, 2.3.1). Location, drilling depth and casing size of each well are summarized as follows.

Well No.	Location	Latitude	Longitude	Elevation (m.msl)	Casing (inch)	Depth (m.bgl)
J-C	Huara	19° 59' 05.7"	69° 42' 09.8"	1,109.711	8-5/8"	209
J-D	Baquedano	20° 09' 54.2"	69° 41' 10.4"	1,058,019	8-5/8"	210
J-E	La Tirana	20° 19' 53.2"	69° 41' 18.6"	1,009.990	8-5/8"	250
J-F	Ramada	20° 43' 53.2"	69° 30' 17.3"	1,016.128	8-5/8"	200
J-3	Aguada	19° 45' 09.1"	69° 49' 15.3"	1,135.588	5-1/2"	150
J-4	Negreiros	19° 51' 37.2"	69° 44' 51.8"	1,169.267	5-1/2"	150
J-5	Pozo Almonte	20° 15' 10.7"	69° 41' 26.1"	1,029.330	5-1/2"	300
J-6	Canchones	20° 26' 40.9"	69° 31' 15.7"	993.763	5-1/2"	200
J-7	Conaf	20° 30' 44.4"	69° 39' 56.9"	982.752	5-1/2"	210
J-8	Pintados	20° 35' 37.7"	69° 31' 08.2"	1,016.012	5-1/2"	210
J-9	Oficina Victoria	20° 45' 12.6"	69° 35' 26.3"	971.103	5-1/2"	172

2) Methodology of Well Construction

For the details of the methodology, see B-II, section 2.3.2 of Chapter II

3) Results of Boring Test

The well data for each well, lithological column, casing design, well logging and drilling rate, are shown in Fig. B-III, 2.16 to 2.19 for the test well and Fig. B-III, 2.20 to 2.26 for the observation well with scale of 1:1000.

(1) Well No. J-C (see, Fig. B-III, 2.16)

i) Lithology

The well was drilled up to 209m depth. The units, Q4 and Q2 of the Quaternary Upper Altos de Pica Formation is observed. Based on the results of geophysical logging and lithology observed, the following five (5) layers are classified.

(J-C)

Layer	Depth (m)	Classification	Lithology	Unit	Formation
1 st	0 - 40	Shallow Aquifer	sandy to silty clay	Q4	Altos de Pica
2 nd	40 - 100	Deep Aquifer	clayey gravel, clayey sand		
3 rd	100 - 160	Impermeable Intercalation	clay, sandy clay	Q2	
4 th	160 -197	Deep Aquifer	clayey sand		
5 th	197 - 209	Impermeable Bed	clay,		

ii) Well Logging

Spontaneous Potential (SP) indicates a range of 800 to 920 mv. A relative basement line (relative 0 line) was decided as 900 mv. The resistivity indicates a high range of 10 - 100 Ω-m at surface. The reversal relation of long and short normal resistivity is appeared at the surface. On the other hand, short resistivity range of 10 to 30 Ω-m is indicated at depth below 40m.

iii) Determination of Casing Design

In order to determine the position of screen pipes, following interpretations are made by using the lithological and well logging data. For the details of casing design, see, Fig. B-III, 2.16.

a) 1 st layer (Shallow Aquifer)

The layer is composed mainly of sandy clay, which is considered as less permeable in normal case. In contrary to this, the value of SP indicates that the layer is permeable. Moreover, temperature curve shows a groundwater flow at the depth from 20 to 30m. Resistivity values show a contamination by the salty water. Therefore, the layer is classified as a shallow aquifer, however, fresh water yielding can not be expected.

b) 2 nd layer (Deep Aquifer)

All the geophysical logging data that indicate a range which can be considered as aquifer, except depth from 73 to 80m. This sequence (73 to

80m) shows a relatively high gamma ray range of 50 - 110 cps. Therefore, it is interpreted as a small scale impermeable intercalation.

The screen pipes were installed in this layer except the impermeable parts. The positions of the screen are at depths from 43.01 to 73.01m and 79.01 to 97.02m.

c) 3 rd layer (Impermeable Bed)

The layer is composed mainly of clay and sandy clay. The value of the SP exceeds relative basement line of 900 mv and gamma ray shows a rather high range of 40 to 80 cps. Blank casing pipes were installed in this layer.

d) 4 th layer (Deep Aquifer)

The layer consists mainly of clayey sand. The value of SP indicates approximately 900 mv. However, other logging data show the layer is permeable; The resistivity value is a range of 10 - 25 Ω-m, the gamma ray is less than 40 cps and temperature gently increases toward the bottom. Based on these characteristics, the layer is classified as a aquifer. Screen pipes were installed in this layer at the depth from 163.02 to 192.99m.

e) 5 th layer (Impermeable Bed)

The layer is composed of clay. Sp value and the gamma ray value also show the layer is impermeable, therefore, blank casing pipes were installed in this layer.

(2) Well No. J-D (see, Fig. B-III, 2.17)

i) Lithology

The total drilling depth is 210m. Based on the results of geophysical logging and lithological observation, following four (4) layers are classified. They are correlated with Q4, Q3 and Q2 of the Quaternary Upper Altos de Pica Formation.

(J-D)

Layer	Depth (m)	Classification	Lithology	Unit	Formation
1 st	0 - 49	Surface Deposits	sandy silt, gravelly clay	Q4	Altos de Pica
2 nd	49 - 98	Shallow Aquifer	alternation of clayey gravel and gravelly clay		
3 rd	98 - 161	Deep Aquifer	clayey gravel, gravel	Q3	
4 th	161 - 210	Deep Aquifer	gravelly clay, clayey gravel	Q2	

ii) Well Logging

Spontaneous potential shows a range of 850 to 1000 mv. Considering the lithological, the relative basement line is estimated as 950 mv. Resistivity indicates a range of 40 to 80 Ω-m up to the depth of 30m from the surface. The resistivity of short range is 10 to 30 Ω-m from the depth of 50m to the bottom. Temperature increases from the surface to the 50m of depth and is in a range 23 to 28°C below the depth of 50m.

iii) Determination of Casing Design.

Casing design is decided as shown in Fig. B-III, 2.17, based on the following interpretation.

a) 1 st layer (Surface Deposits)

The layer consists mainly of gravelly clay except the surface which is formed of sandy silt. The layer is considered as dry because of the high value of resistivity and gamma ray.

b) 2 nd layer (Shallow Aquifer)

The ranges of all the geophysical logging indicate that the layer is aquifer, except the depth from 90 to 95m where the value of gamma ray is high.

The screen pipes were installed in this layer in two (2) parts, one is at the depth from 53.89 to 59.91m and the other is from 71.91 to 89.93m.

c) 3 rd layer (Deep Aquifer)

Geophysical characteristics of the layer are similar to the 2nd layer (Shallow Aquifer). Geological unit of the layer was classified as Q3 of the Altos de Pica Formation.

The screen pipes were installed in this layer at depths from 101.94 to 150m and from 156 to 162m.

d) 4 th layer (Deep Aquifer)

According to the lithological column, more clayey materials are observed compared with the other layers. However, the layer is classified as the lower part of the deep aquifer considering the following reasons.

- The resistivity is in a range of 7 to 20 Ω-m.
- The gamma ray shows a low range of cps value.

The screen pipes were installed at depths from 174 to 180.01m and 186.01 to 198.02m.

(3) Well No. J-E (see, Fig. B-III, 2.18)

i) Lithology

The well was drilled to a depth of 250m. On the basis of the lithology observed and well logging data, following two (2) layers are classified. They are Q4 and Q3 of the Quaternary Upper Altos de Pica Formation.

(J-E)

Layer	Depth (m)	Classification	Lithology	Unit	Formation
1 st	0 - 70	Surface Deposits	sandy to gravelly clay	Q4	Altos de Pica
2 nd	70 - 250	Aquifer	gravelly clay at upper, clayey gravel at lower	Q4 Q3	

ii) Well Logging

The range of the resistivity is rather low (10 - 30 Ω-m) except at the surface. The relative basement line of the spontaneous potential is established as 950 mv based on the value of resistivity and lithology observed. Generally, lithology of the whole sequence is composed of gravelly clay to clayey gravel, however, ratio of gravel content gradually increases toward the bottom.

According to the interpretation of SP, permeability is higher at the bottom and lower at the surface. It is in well coincident with the lithological observation. Groundwater flow is observed on the temperature curve at the surface.

iii) Determination of Casing Design

Casing design was decided as shown in Fig. B-III, 2.18, based on the following interpretation.

a) 1 st layer (Surface Deposits)

The layer consists of sandy clay up to the depth of 20m from the surface, and gravelly clay in the deeper part. The SP value exceeding 950 mv indicates that the layer is impermeable. Water flow is observed on the temperature curve. However, the resistivity values of long and short normal indicate that the layer is contaminated. Considering these situation, the layer is correlated with the surface deposits with low groundwater potential. Yield of fresh water is not expected. Hence, blank casing pipes were installed.

b) 2 nd Layer (Aquifer)

The layer is composed mainly of clayey gravel throughout the whole sequence. The ratio of gravel amount is gradually increases toward the bottom. The curve of SP and resistivity is in well coincidence with this change. The resistivity range, 10 to 20 Ω-m shows that the layer is a expected aquifer.

The screen pipes were installed in this layer at eight (8) separated positions, where much gravel is confirmed. For the details of casing design, see Fig. B-III, 2.18.

(4) Well No. J-F (see, Fig. B-III, 2.19)

i) Lithology

The well was drilled up to 224m depth. Three (3) lithological units of Q4, Q3 and Q2 of the Quaternary Altos de Pica formation are confirmed. Following three (3) layers are classified by the interpretation of lithology observed and geophysical logging.

(J-F)

Layer	Depth (m)	Classification	Lithology	Unit	Formation
1 st	0 - 47	Surface Deposits	clay, clayey gravel and clayey sand	Q4	Altos de Pica
2 nd	47 - 160	Shallow Aquifer	sandy, gravelly clay, clayey sand	Q4 Q3	
3 rd	160 - 224	Deep Aquifer	sandy clay	Q3	

ii) Well Logging

Gamma ray indicates homogeneous unchanged range of 50 - 70 cps at all sequence, however, clay layer is well identified by the particular value which exceeds 100 cps. Considering lithology and resistivity curve, a line of 900 mv is estimated as a relative basement line of spontaneous potential. Temperature curve indicates gentle and gradual increase in general. Groundwater flow is expected by the temperature curve.

iii) Determination of Casing Design

In order to determine the position of screen pipes, following interpretation was made. For the details of casing design, see, Fig. B-III, 2.19.

a) 1st layer (Surface Deposits)

The layer consists of clay, clayey gravel and clayey sand. The layer is expected to be dry because of the high resistivity value (more than 100 Ω-m). Blank casing pipes were installed in this layer.

b) 2 nd Layer (Shallow Aquifer)

Based on the SP value and the resistivity range of 10 - 30 Ω-m, the layer is considered as the most promising aquifer. Groundwater flow is confirmed by the temperature curve.

Four (4) separated positions were selected for the screen pipes as shown in Fig. B-III, 2.19.

c) 3 rd layer (Deep Aquifer)

The layer consists of sandy gravelly clay and clayey sand. Characteristics of all thelogging data are same as that of the second layer. Therefore, the layer is also considered as a aquifer.

The screen pipes were installed at three (3) different positions in this layer as shown in Fig. B-III, 2.19.

(5) Well No. J-3 (see, Fig. B-III, 2.20)

The well was drilled up to 150m depth. In the whole sequence, two (2) units, Q4 and Q2 of the Quaternary Upper Altos de Pica Formation were confirmed. Based on the results of the geophysical logging and lithology observed, following four (4) layers are classified.

(J-3)

Layer	Depth (m)	Classification	Lithology	Unit	Formation
1 st	0 - 42	Surface Deposits	clay, sandy clay	Q4	Altos de Pica
2 nd	42 - 100	Shallow Aquifer	sandy clay	Q4	
3 rd	100 - 131	Impermeable Bed	sandy clay clay	Q4 Q2	
4 th	131 -150	Deep Aquifer	sandy clay	Q2	

ii) Well Logging

Spontaneous potential indicates a homogeneous range of 970 to 1,030 mv. A relative basement line is estimated as 1,015 mv. However, due to clay predominance material in all the layers, identification of the permeable zone by SP is difficult. The range of gamma ray is mostly within 40 to 60 cps at all layers. Groundwater flow at depths from 40 to 90m and from 120 to 145m is confirmed by temperature curve. No TEM survey was conducted in this area.

iii) Determination of Casing Design

The position of screen pipes was determined considering both the lithological and well logging data. For the details of casing design, see, Fig. B-III, 2.20.

a) 1 st layer (Surface Deposits)

The layer consists of clay at 7m from surface and sandy clay at lower part. It is estimated as impermeable by the SP range which exceeds more than 1015 mv (relative base line). A small potential of groundwater is expected by the temperature curve. Blank casing pipes were installed in this layer.

b) 2 nd layer (Shallow Aquifer)

The layer is composed of thick bed of sandy clay. Considering the lithology and well logging result, high permeability is not expected in this layer. However, the range of resistivity shows a value of 20 to 40 Ω- m similar to the aquifer in other wells. The temperature curve indicates the groundwater flow in this layer.

The layer was considered as a aquifer, and screen pipes were installed at two (2) different positions as shown in Fig. B-III, 2.20.

c) 3 rd layer (Impermeable Intercalation)

The layer consists of sandy clay at the upper part and clay at the lower part. The layer is impermeable intercalated bed, therefore, blank casing pipes were installed.

d) 4 th layer (Deep Aquifer)

The layer is situated at the upper part of Q4 unit of Altos de Pica Formation. It consists of clay and sandy clay. The value of resistivity also indicates a similar range with the 2nd layer. Therefore, the layer is classified as the deep aquifer.

The screen pipes were installed at the depth from 132.83 to 144.83m.

(6) Well No. J-4 (see, Fig. B-III, 2.21)

i) Lithology

The total drilling depth is 150m. Two (2) units of Q4 and Q2 of Quaternary Upper Altos de Pica Formation are confirmed. Based on the results of geophysical logging and lithological observation, following three (3) layers were classified.

(J-4)

Layer	Depth (m)	Classification	Lithology	Unit	Formation
1 st	0 - 45	Surface Deposits	sand, gravel	Q4	Altos de Pica
2 nd	45 - 95	Shallow Aquifer	gravel, clayey gravel and gravelly clay		
3 rd	98 - 161	Deep Aquifer	clayey gravel, conglomerate	Q2	

ii) Well Logging

The results of all measurements is in well coincident with high permeability of the lithology. The relative basement line of the SP is estimated as 95m mv, based on the lithology and the value of gamma ray. Resistivity shows a high and unstable range at 40m from surface, short and stable range at below 45m. A small scale of groundwater flow was confirmed by the temperature curve at 10m from surface.

iii) Determination of Casing Design

The position of screen pipes was determined, based on the following interpretations. For the details of casing design, see, Fig. B-III, 2.21.

a) 1 st layer (Surface Deposits)

The layer is estimated to have high permeability by the lithological observation and SP range. However, it is expected that the layer has a less potential of groundwater since the layer is surface deposits. Water quality is critical, because of the unstable and reversal range of resistivity. Blank casing pipes were installed in this layer.

b) 2 nd layer (Shallow Aquifer)

The layer is classified as a expected aquifer by the TEM results. Resistivity shows a range of 10 to 45 Ω-m. Compared with the resistivity range of other layers, this value is within the range of the aquifer. Except middle part of the layer (75m depth) showing high gamma ray value, the layer is expected to be permeable.

Based on the above, screen pipes were installed at two (2) different positions . For the details of casing design, see, Fig. B-III, 2.21.

c) 3 rd layer (Deep Aquifer)

The same interpretation with 2 nd layer was made because of similar result of loggings.

Screen pipes were installed at depths from 97.67 to 115.72m and 138.92 to 144.94m of this layer.

(7) Well No. J-5 (see, Fig. B-III, 2.22)

i) Lithology

The well was drilled up to 300m depth. Three (3) units of Q4, Q3 and Q2 of Quaternary Upper Altos de Pica Formation were confirmed. According to lithology observed and well logging data, following three (3) layers were classified.

(J-5)

Layer	Depth (m)	Classification	Lithology	Unit	Formation
1 st	0 - 20	Surface Deposits	silty clay, sandy clay		
2 nd	20 - 100	Shallow Aquifer	sandy clay	Q4	Altos de Pica
3 rd	100 - 300	Deep Aquifer	clayey gravel sandy clay	Q3 Q2	

ii) Well Logging

Based on the lithology and resistivity, the relative basement line of the SP value is estimated as 920 mv. The range of SP is stable, because most of the layer consists of clayey materials. Resistivity shows a range of 10 to 20 Ω-m up to 100m depth and 10 to 30 Ω-m below 100m. It is also stable at all the sequences except top surface.

iii) Determination of Casing Design

Casing design was decided as shown in Fig. B-III, 2.22, based on the following interpretation.

a) 1 st layer (Surface Deposits)

Large amount of clay matrix is observed in the layer. The layer is estimated as impermeable deposit. It is also estimated to be dry due to a high value of the resistivity. Blank casing pipes were installed.

b) 2 nd layer (Shallow Aquifer)

The layer is expected as aquifer due to the value of the resistivity and SP. However, higher potential is expected at 3 rd layer. The screen pipes were not installed in this layer.

c) 3 rd layer (Deep Aquifer)

The layer consists of clayey gravel and sandy clay. The range of the resistivity shows a similar value with that of TEM measurement (10 - 17 Ω-m), therefore the layer is expected as a aquifer.

The screen pipes were installed at six (6) different positions as shown in Fig. B-III, 2.22.

(8) Well No. J-6 (see, Fig. B-III, 2.23)

i) Lithology

The well was drilled up to 200m depth. In the whole sequence, three (3) units of Q4, Q3 and Q2 of Quaternary Upper Altos de Pica Formation are observed. Based on the results of geophysical logging and lithology observed, following three (3) major layers were classified.

(J-6)

Layer	Depth (m)	Classification	Lithology	Unit	Formation
1 st	0 - 35	Surface Deposits	sand, sandy clay, clay	Q4	Altos de Pica
2 nd	35 - 138	Shallow Aquifer	clayey to sandy gravel, gravel	Q4 Q3	
3 rd	138 - 200	Deep Aquifer	clay, gravelly clay, clayey gravel	Q2	

ii) Well Logging

Gamma ray shows a stable range of 40 to 70 cps for whole sequence. Clay layers were clearly distinguished by a high value (more than 100 cps) of the gamma ray at depths of 20, 85 and 150m. Based on the gamma ray and lithology, a relative basement line of the SP is estimated to be 870 mv. Compared with TEM result, rather higher resistivity range was measured by logging. A flow of the groundwater was observed by the temperature curve at the depth of 35 to 100m.

iii) Determination of Casing Design

Casing design was decided as shown in Fig. B-III, 2.23, based on the following interpretations.

a) 1 st layer (Surface Deposits)

The layer consists of sand and sandy clay at upper 16m and clay at lower 19m. The thickness and the resistivity range of the layer is similar to the first layer classified by TEM survey. It is considered as the dry surface deposits. Blank casing pipes were installed.

b) 2 nd layer (Shallow Aquifer)

The layer was classified as an expected aquifer by the TEM results. Compared with TEM range of 10 to 17 Ω-m, the logging resistivity range of 20 to 40 Ω-m is rather high. However, high permeability can be expected by the lithological observation except clayey part at a depth from 73 to 81m. Groundwater flow at a depth from 35 to 100m was observed by the temperature curve.

The screen pipes were installed at three (3) positions as shown in Fig. B-III, 2.23.

c) 3 rd layer (Deep aquifer)

Resistivity and gamma ray value is similar to 2nd layer. The range of SP indicates permeable. The layer is classified as a deep aquifer at Q2 unit.

Two (2) positions of screen pipes were selected as shown in Fig. B-III, 2.23.

(9) Well No. J-7 (see, Fig. B-III, 2.24)

i) Lithology

Within a 210m total depth, two (2) units of Q4 and Q3 of Quaternary Upper Altos de Pica Formation were confirmed. According to the lithology observed and well logging data, following three (3) major layers were classified.

(J-7)

Layer	Depth (m)	Classification	Lithology	Unit	Formation
1 st	0 - 35	Surface Deposits	sandy clay	Q4	Altos de Pica
2 nd	35 - 106	Shallow Aquifer	sandy to gravelly clay		
3 rd	100 - 131	Deep Aquifer	sandy to gravelly clay	Q3	

ii) Well Logging

All the layers are rich in clayey matrix. Due to this, the range of the gamma ray is almost the same for whole layer. Based on the lithology and gamma ray range, a relative basement line of SP is estimated as 970 mv. Resistivity indicates a homogeneous range of 10 to 20 Ω-m except 35m from surface. According to the TEM results, this values lie within the range of the aquifer. Therefore, the position of screen pipes was mainly determined by the SP and gamma ray values.

iii) Determination of Casing Design

Casing design was decided as shown in Fig. B-III, 2.24, based on the following interpretations.

a) 1 st layer (Surface Deposits)

The layer consists of mainly sandy clay except the sand which appears from surface to 4m depth. It is estimated as dry because of a high resistivity value. Blank casing pipes were installed in this layer.

b) 2 nd layer (Shallow Aquifer)

The layer is expected as a aquifer. However, it is not highly permeable. Permeable zone was determined by SP and gamma ray for the installation of screen pipes.

The screen pipes were installed at two (2) different positions of 55.79 to 61.76m and 67.79 to 79.8m depth.

c) 3 rd layer (Deep aquifer)

Same interpretation as the 2nd layer was made due to same lithology and logging measurement. However, the layer is estimated as rather more permeable than the 2 nd layer, based on the lower value of SP.

Five (5) different positions were selected for screen pipes as shown in Fig. B-III, 2.24.

(10) Well No. J-8 (see, Fig. B-III, 2.25)

i) Lithology

The well was drilled up to 210m depth. In the whole sequence, three (3) units of Q4, Q3 and Q2 of Quaternary Upper Altos de Pica Formation were observed. Based on the results of geophysical logging and lithology observed, following three (3) layers were classified.

(J-8)

Layer	Depth (m)	Classification	Lithology	Unit	Formation
1 st	0 - 50	Surface Deposits	sand, gravel, clay	Q4	Altos de Pica
2 nd	50 - 169	Shallow Aquifer	gravel clayey, clayey gravel	Q4 Q3	
3 rd	169 - 210	Deep aquifer	gravelly clay, sandy clay	Q2	

ii) Well Logging

Spontaneous potential value indicates a range from 820 to over 1000 mv. Considering the lithology observed and the resistivity, a relative basement line is estimated as 990 mv. Resistivity value indicates a high value at 40m from the surface and a stable range of 10 to 30 Ω-m at below 50m. This range is in coincidence with the resistivity of the aquifer in the area. Intercalation of clay was identified by the gamma ray. This intercalation of clay exceeds 100 cps. A permeable layer is also identified by the gamma ray which is less than 50 cps.

iii) Determination of Casing Design

Casing design was decided as shown in Fig. B-III, 2.25, based on the following interpretations.

a) 1 st layer (Surface Deposits)

The layer consists of sand to gravel at 14m from the surface and gravelly clay at the lower part. However, most of the layer were estimated as dry because of high resistivity value. Blank casing pipes were installed in this layer.

b) 2 nd layer (Shallow Aquifer)

The layer is classified as a shallow aquifer based on the resistivity range of 10 to 30 Ω-m. However, high permeability can not be expected. Because, large amount clayey matrix is observed at all sequence, except fine gravel at bottom 11m. Therefore, the position of the screen pipes were selected by the gamma ray.

Eight (8) short interval positions were selected for the screen pipes as shown in Fig. B-III, 2.25.

c) 3 rd layer (Deep Aquifer)

Same interpretation was made based on the same value of the resistivity and SP. Two (2) different positions were selected for screen pipes as shown in Fig. B-III, 2.25.

(11) Well No. J-9 (see, Fig. B-III, 2.26)

i) Lithology

Three (3) units of Q4, Q3 and Q2 of Quaternary Upper Altos de Pica Formation were confirmed. The total drilling depth is 172m. Based on the results of geophysical logging and lithological observation, following three (3) major layers are classified.

(J-9)

Layer	Depth (m)	Classification	Lithology	Unit	Formation
1 st	0 - 55	Surface Deposits	sandy clay, clay	Q4	Altos de Pica
2 nd	55 - 146	Shallow Aquifer	clayey gravel gravelly clay, clay	Q4 Q3	
3 rd	146 - 172	Deep Aquifer	gypsum clay	Q2	

ii) Well Logging

At 50m from the surface, the SP curve is not coincident with lithology and gamma ray. Considering the lithology and gamma ray, a relative basement line of the SP is estimated as 1000 mv from below 50m depth. Resistivity range indicates a typical value of 10 to 20Ω-m which is a similar range with the aquifer in the area. Clay intercalation can be found by the gamma ray. This intercalation shows more than 100 cps.

iii) Determination of Casing Design

Casing design was decided as shown in Fig. B-III, 2.26, based on the following interpretations.

a) 1 st layer (Surface Deposits)

The layer consists of mainly clay to sandy clay. It is estimated as a impermeable deposits. The value of the gamma ray indicates a rather high range of 50 to 100 cps. The layer is interpreted as dry, therefore, blank casing pipes were installed.

b) 2 nd Layer (Shallow Aquifer)

The resistivity range of 10 to 20 Ω-m was observed at all the sequence. The gamma ray shows a rather lower value of 20 to 70 cps except the clay intercalation. Therefore, the layer is considered as a promising aquifer. The position of screen pipes were examined by the permeability indication of the gamma ray.

The screen pipes were installed at three (3) different positions as shown in Fig, B-III, 2.26.

c) 3 rd layer (Deep Aquifer)

The layer consists of clay with gypsum of Q2 unit. It is estimated as a impermeable layer. On the one hand, a low value of SP and gamma ray indicate that the layer is permeable. Moreover, resistivity value indicates within the range of the aquifer. Therefore, the layer is considered as a aquifer.

The screen pipes were installed as shown in Fig. B-III, 2.26.

2.3.3 Pumping Test

1) Methodology of Pumping Test

For the details of the methodology, see, B-II, section 2.3.3 of Chapter II.

2) Results of Pumping Test

(1) Aquifer Constants

Results of pumping tests are shown in Table B-III, 2.2. Aquifer constants are analyzed by the graphs shown in Fig. B-III, 2.27 to 2.37. The results of this analysis are summarized in Table B-III, 2.3. The aquifer constants for eleven (11) wells are as follows;

Well No.	Transmissibility ($m^3/d/m$)	Permeability (cm/sec)
J-C	8.29	1.23×10^{-4}
J-D	1506.17	1.81×10^{-2}
J-E	644.33	7.31×10^{-3}
J-F	86.81	9.57×10^{-4}
J-3	113.81	2.20×10^{-3}
J-4	271.08	5.22×10^{-3}
J-5	769.61	8.23×10^{-3}
J-6	21.63	3.20×10^{-4}
J-7	383.83	5.30×10^{-3}
J-8	376.27	5.18×10^{-3}
J-9	266.06	3.54×10^{-3}

A wide range of the transmissibility was obtained from eleven (11) wells; It is the highest at J-D (1506.17 $m^3/d/m$) and the lowest at J-E (633.33 $m^3/d/m$). The average of the transmissibility is calculated to be 404.35 $m^3/d/m$. The area of the high transmissibility is concentrated in the area from Baquedano to La Tirana. The wells in this area have also a high value of the specific yield. This area is considered to have the high groundwater potential. On the other hand, the area of the low transmissibility (less than 150 $m^3/d/m$) is distributed in the northern and the southern part of the area (J-C, J-F, J-3, and J-6). The lowest transmissibility is estimated at J-C (8.29 $m^3/d/m$). The wells are of the low specific yield.

The permeability coefficients of the eleven (11) wells are similar. The highest value is 1.18×10^{-2} cm/sec at J-D, and the lowest one is 1.23×10^{-4} cm/sec at J-

4. The average of permeability is calculated as 5.13×10^{-3} cm/sec. This value is in well agreement with the permeability usually expected in this lithology mainly consisting clayey gravel, gravelly clay and sandy clay.

(2) Well Capacity

The well capacity is evaluated by the amount of the critical discharge and the safe yield. The Q-Sw chart for the examination of the critical discharge and the Q-s/Q chart for the obtaining the well efficiency and the area of influence are shown in Fig. B-III, 2. 38 to 2. 48. The detailed results of the analysis for the step drawdown tests are described in Table B-III, 2.3. The well capacity for eleven (11) wells are summarized as the following table;

Well No.	Critical Discharge (l/s)	Safe Yield (l/s)
J-C	2.50	0.80
J-D	more than 25.00	10.00
J-E	more than 27.00	20.00
J-F	8.33	1.80
J-3	more than 5.00	3.75
J-4	4.00	0.30
J-5	more than 5.00	2.00
J-6	more than 4.04	5.00
J-7	more than 5.00	10.00
J-8	more than 3.34	29.00
J-9	more than 5.00	3.50

At the most of wells, the critical discharge is confirmed as larger than the maximum capacity of the submersible pump used. The highest rate, more than 27 l/s, was obtained at J-E among the test wells. The safe yield of the well is 20 l/s. Among the observation wells, high values, more than 5 l/s, were found at J-3, J-5, J-7 and J-9. According to the rate of the safe yield of the wells, high critical discharge rates are expected in all the area except J-C, J-F and J-4.

2.3.4 Carbon-14 Analysis

The Purpose of Carbon- 14 Analysis is to decide the age of groundwater for the interpretation of the groundwater recharge mechanism and for the evaluation of the groundwater potential. Ten (10) samples were taken in Pampa del Tamarugal; one (1) sample from the JICA Well (J-F) and nine (9) samples from the existing wells (see, Fig. B-III, 2.1).

Methodology of the Carbon-14 Analysis is reffered to Chapter 2 of B-II in this Report.

Results are shown in Fig. B-III, 2.49 and the following table;

Well No.	Tritium (TU)	C-14 (pmc)	Age (Y.BP)*	Average Age**
172 (Dolores)	<0.8	7.8	3,400-4,530	3,965
473 (Remolino)	<0.8	51.9	modern	modern
193 (Mapocho)	<0.8	33.6	570-1,630	1,100
- (Dupliza)	<0.8	62.7	modern-840	440
222 (Sagasca)	<0.8	67.1	modern-1,000	520
354 (Canchones)	1.1±0.6	18.7	10,780-11,840	11,310
- (Esmeralda)	<0.8	91.3	***	***
470 (Pica)	<0.8	94.1	***	***
J-F (Oficina Victoria)	<0.8	9.7	10,370-11,500	10,935
- (Cerro Gordo)	<0.8	17.8	6,320-7,450	6,885

Y.BP: years before present

* : Estimated age by the Modified Pearson Model

** : Ages are calculated considering modern as 40 years.

*** : Influenced by the irrigation water.

All the Tritium data are below or close to the detection limit, therefore, it is considered that the groundwater in the area is older than 40 years. C-14 age of the groundwater is young in the western side of Pampa, Sagasca and Dupliza, and old in the southern side, Canchones and Salar de Pintados area. Ages in Esmeralda and Pica also show modern ages, however, it does not mean the recent ages, because C-14 contents show that the groundwater of both area is influenced by the return flow of irrigation water; C-14 contents of Pica and Esmerald are 94.1 and 91.3 pmc, respectively, which are close to 100 pmc.

Considering the recharging system and the groundwater flow in Pampa, C-14 age of Dupliza seems to be too young. The wells in Dupliza are located in the lower reach of the Quipisca River. This area is covered with the surface water during floods of the Aroma, Tarapacá and Quipisca Rivers in the wet season (so called "Bolivian Winter"). This means the groundwater of Dupliza is recharged by these flood water; C-14 age is also influenced by this recharges.

2.4 Configuration of Aquifer

The Study Area, the Pampa del Tamarugal Basin is defined as follows;

(north): The divide of the basin between the Qda de Aroma and the Qda. de Tiliviche.

(south): Cerro Gordo

(east) : The western foot of the mountains.
(this border was formed by faults that pass west of Pica and Tarapaca)

(west) : The eastern edge of the Cordillera de la Costa (the coastal mountains)
(this border was formed by faults).

The Pampa del Tamarugal Basin is filled by the Tertiary to Quaternary formation (Altos de Pica Formation). The aquifers area appeared in this formation. Detailed geological and hydrogeological information are given by the 11 wells drilled by the Study Team and three (3) wells by ENAP. Results of JICA Wells are mentioned in 2.3 of this Chapter. ENAP drilled three (3) wells in the study area, "Dolores 1" in the northern part of the area and, "Pintados 1" and "Pintados 2" in the southern part of the area. These wells give information on the stratigraphy and geological structure of the basin, because ENAP wells penetrated into the Basement Rocks through the Tertiary to Quaternary formation and JICA Wells reached the base of the aquifer.

Geological profiles and cross sections of Pampa del Tamarugal are shown in Fig. B-III, 1.5 and 1.6 respectively. These are constructed based on the results of the drilling by the Study Team and the reviewing the existing profiles (<2).

The shape of the basin was controlled by the depression caused by the faults of north-south direction. The aquifers in the basin appear in the basin fill deposits which elongates in a north-south direction. Thickness of the deposits increases to the east. Although the deposits store the groundwater, the depth to the water (depth from ground surface to the water level) also increase to the east reaching more than 100m. Therefore, the eastern part of the basin is not economically suitable to develop the groundwater.

As shown in Fig. B-III, 1.5 and 1.6, aquifers occur in units Q3 and Q4 of the Altos de Pica Formation. The expected aquifer area is shown in Fig. B-III, 2.50 by the dotted lines. The Altos de Pica Formation is covered by the Recent Deposits which increase in thickness toward the east. It means that depth to the aquifer is generally high in the eastern area; The pumping head is large. Therefore, the expected aquifer area is limited within this dotted line. Width of the aquifers ranges from 13 km to 46 km, averaging 30 km.

Aquifers occur in units Q3 and Q4 of the Altos de Pica Formation (Ref. Table B-III, 1.1). The unit Q3 is composed of sand and gravel and is underlain by Q2. Q4 consists of sand and gravel with mud, and/or intercalated with mud layers. The unit

Q4 is deposited overlying the unit Q3. Thus, the distribution of Q4 is wider than that of Q3. The unit Q3 is distributed in the area from Huara to Salar de Bellavista. The unit Q4 is widespread in the aquifer area (Ref. Fig. B-III, 2.50). No impermeable layer appears between unit Q3 and Q4. Those aquifers are underlain by thick impermeable clayey beds which are the hydrogeological base of aquifers in the basin (Ref. Fig. B-III, 1.5 and 1.6).

The aquifers are occurred in some horizons, mainly in sand and gravel.

The thickness of this formation varies from place to place. It is generally thin in the northern area and thick in the southern area;

Thickness of aquifers (Fig. B-III, 2.51) is about 25 m near Dolores and increases toward the south reaching about 150 m in the center area of Pampa. The deposits are accumulated almost horizontally and sometimes interbedded with each other.

Depth to the top and the bottom of the aquifer is shown in Fig. B-III, 2.52 and 2.53 respectively. Figure of aquifers in Pampa del Tamarugal is summarized as follows;

Area	Maximum Thickness (m)	Width (km)	Top of Aquifer (mBGL)	Base of Aquifer (mBGL)
Zapiga/Dolores	80	13-17	<10	90
Negreiros	70	15	20	90
Huara	60	15-19	50	110
Humberstone	150	27	30-40	180-200
Pozo Almonte	220	26	20-30	240-260
Pintados	220	30-37	10-30	230
Bellavista	160	30-46	10-70	120-170

2.5 Hydrogeological Characteristics of Aquifer

Pampa del Tamarugal is basically a closed basin from the hydrogeological point of view, although a small river flows out from the southern end of the basin. The pampa area does not receive any precipitation throughout the year. The groundwater in Pampa is recharged from the surface water of several rivers and some fissure waters. Main rivers which flow into the pampa are Qdas. Aroma, Tarapacá, Quipisca, Juan de Morales, Quisma, Chacarilla and Ramada. Surface water of these rivers infiltrates to the underground before entering to Pampa. Pampa is sometimes covered by the flood water in so called "Bolivian Winter" season. Fissure water reaches to Pampa from the east through faults, joints and fissures developed in the volcanic rocks. One of the possible resources is the water from Salar del Huasco Basin.

The western and the southern margins of the pampa are surrounded by impermeable basement rocks. The aquifers Q3 and Q4 are underlain by the thick clay (Q2) and/or basement rocks which are \both generally impermeable. Q2 is composed mainly of clay, but sometimes contains sandy materials. Thus, Q2 also shows a certain degree of permeability. This is supposed by logging data of JICA Wells; a part of screens was also installed in Q4 in some wells (J-3, 4, C, D, 5, 6, 8, 9). The groundwater recharged into the units Q3 and Q4 are stored in these units and gently flows toward the south reaching Salar de Bellavista through Salar de Pintados.

Quantitative character of the aquifers are given by aquifer constants. Aquifer constants are available on 11 JICA Wells and 36 existing wells. Specific yield is estimated on 51 wells including JICA Wells. Data of JICA Wells are given in the following table. Details are shown in Table B-III, 2.3. Data of existing wells are in Table B-III, 2.4.

(JICA Wells)

Area	Well No.	Specific Yield		Transmissibility	Permeability
		(l/sec/m)	(m^3/day/m)	(m^3/day/m)	(cm/sec)
Dolores	J-3	0.73	63.1	113.81	2.20×10^{-3}
Negreilos	J-4	2.22	191.8	271.08	5.22×10^{-3}
Huara	J-C	0.09	7.8	8.29	1.23×10^{-4}
	J-D	3.47	299.8	1506.17	1.81×10^{-2}
Pozo Almonte	J-5	8.33	719.7	769.61	8.23×10^{-3}
l	J-E	6.77	584.9	644.33	7.31×10^{-3}
Canchones	J-6	0.26	22.5	21.63	3.20×10^{-4}
l	J-7	2.72	235.0	383.83	5.30×10^{-3}
Pintados	J-8	2.18	188.4	376.27	5.18×10^{-3}
Bellavista	J-9	1.92	165.9	266.06	3.54×10^{-3}
	J-F	1.65	142.6	86.81	9.57×10^{-4}
Average		2.76	238.5	404.35	5.13×10^{-3}

Specific yield (Sy) of aquifers is 2.13 l/sec/m in average, ranging from 0.03 l/sec/m (well No. 936 at Negreilos) to 10.67 l/sec/m (well No. 202 at Porvenir, east from Pozo Almonte). Sy is relatively high in Huara area and Pozo Almonte to Pintados area and low in Zapiga to Negreilos area and Bellavista area.

Transmissibility and permeability are generally high. Average of transmissibility by area is in a range from 154 m^3/day/m to 1102 m^3/day/m. Permeability of aquifers is in same order in the whole area of Pampa; its average is in a order of 10^{-2} cm/sec. This order is high as aquifers.

A contour map of static water level is constructed as shown in Fig. B-III, 3.2.1. This shows that there is a difference of water level gradient between the north of Huara and Baquedano; The gradient is less than 1/1000 in the area from Zapiga to the north of Huara and 4/1000 in the area from the north of Huara to Baquedano. It suggests that there is a low permeable zone in the area from the north of Huara and flow of groundwater from the north, such as the water from Qda. Aroma, is retarded to south.

Characteristics of aquifer constants by area are as follows;

a) Zapiga-Dolores-Negreilos area

Main aquifer of this area is the unit Q4. Productivity of Q4 is low, because Sy is between 0.03 l/sec/m and 2.20 l/sec/m, having average of 0.73 l/sec/m. Relatively high Sy appear in the wells located along the Panamerican Road; this area lies in main stream of the groundwater flow. Low Sy appear mainly in the small valleys in the western side of the area. Although permeability is relatively high (10^{-2} cm/sec. order), transmissibility is rather small (154 m^3/day/m).

Two (2) JICA Wells are drilled in the area (J-3, J-4). Both of wells show relatively low Sy and transmissibility.

b) Huara area

The unit Q4 is the main aquifer in this area. The highest average of Sy appears in this area, 3.7 l/sec/m. Transmissibility is also high, 675 m^3/day/m in average. Permeability is lower than average.

Two (2) JICA Wells are drilled in the area (J-C, J-D). J-D shows relatively high Sy (3.47 l/sec/m) and high transmissibility (1506 m^3/day/m) which is the largest in the Pampa area. In contrary to this, J-C shows low Sy and low transmissibility. Lithology of aquifer is much clayey in J-C, and extremely poor in sand and gravel beds. Therefore, lithology of aquifers in this area changes from place to place.

c) Pozo Almonte-Canchones-Pintados area

Main aquifers are Q3 and Q4 in this area. Sy is high, 3.26 l/sec/m in average which succeeds Huara area. 19 wells, out of 26 wells including JICA Wells, have Sy higher than 2 l/sec/m. Both transmissibility and permeability are of the highest value in Pampa; 1102 m^3/day/m and 4.4 x 10^{-2} respectively.

d) Oficina Victoria-Bellavista area

Main aquifers are Q3 and Q4. Sy is the lowest, 1.30 l/sec/m in average, compared with other area in Pampa. Transmissibility is also low, 219.5 1102 m^3/day/m, while permeability is relatively high, 1.4 x 10^{-2}.

Two (2) JICA Wells are drilled in the area (J-9, J-F). Both wells show higher Sy than average. However, transmissibility is lower than average.

2.6 Estimation of Groundwater Storage

Groundwater storage of Pampa del Tamarugal is shown in Table B-III, 2.5 and Fig. B-III, 2.54. These present the estimated groundwater storage in the total area of Pampa del Tamarugal shown in Fig. B-III, 2.50. Total volume of groundwater storage is estimated as follow;

$$S_{\text{Total Storage}} = \mathbf{26.9 \times 10^9\ m^3}.$$

The estimation was made based on the two (2) geological profile and 12 geological sections dividing the area into 12 zones. Each profile represent following zones;

Zone	Geological section	Major communities in the zone
1	sect. A-A' to B-B'	Dolores, Negreiros
2	sect. B-B' to C-C'	
3	sect. C-C' to D-D'	
4	sect. D-D' to E-E'	Huara
5	sect. E-E' to F-F'	Baquedano, Humberstone
6	sect. F-F' to G-G'	Pozo Almonte
7	sect. G-G' to H-H'	
8	sect. H-H' to I-I'	La Tirana, Huayca
9	sect. I-I' to J-J'	Canchones
10	sect. J-J' to K-K'	Pintados
11	sect. K-K' to L-L'	Oficina Victoria
12	sect. L-L' to southern end	Cerro Gordo

Conditions applied in the estimation are as follows;

(1) Climate condition will remain constant during the estimated period.

(2) The extent of the estimation is limited to the area shown in Fig. B-III, 2.50.

(3) Estimated volume is the groundwater stored in aquifers, Q_3 and Q_4.

(4) Estimation is made on the groundwater stored in permeable and semi-permeable beds. Although groundwater is stored in impermeable beds, it is not considered as prospective one.

(5) Effective porosity of aquifer is assumed to be 30 % as a whole, considering the materials which compose the aquifer.

References

<1: Cuadrangulos Pica, Alca, Matilla y Chacarilla, Carta Geologica de Chile (Escala 1: 50,000), 1962 for Instituto de Investigaciones Geologicas Chile by Carlos Galli Olivier y Robert J. Dingman.

<2: Analisis Programa de Desarrollo de Empresa de Servicios Sanitarios de Tarapaca, February 1991 for ESSAT by Bustamante y Schudeck Ingenieros Consultores Ltda.

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<4: Informe Geologico, Pozo : Pintados 1, March 1987 by ENAP

<5: Informe Geologico, Pozo : Pintados 2, March 1987 by ENAP

<6: Algunos Antecedentes Tecnicos Hidrogeologicos de los Sondajes en Busca de Agua Ejectadis por en Tarapaca, November 1962 for ENAP by Jorge Alvarez R.

Table B-III, 2.1 (1) Well List (Pampa del Tamarugal)

<Lista de Sondajes (Pampa del Tamarugal)>

DGA CODE	BNA CODE	CORFO CODE(1975)			CORFO CODE(1969)			COMMUNITY	LOCATION NAME	NAME OF OWNER	CONSTRUCTOR	ELEVATION	DRILLING DEPTH	SPECIFIC YIELD	DATE OF CONSTRUCTION	STAIC WATER LEVEL (93/ 10-11)	
		LAT	LONG.	NO.	LAT	LONG.	NO					(mMSL)	(m)	(m3/d/m)		(mBGL)	(mMSL)
5	017 00 161-2	1930	6950	C-1	1930	6930	A-14	HUARA	SALAR ZAPIGA	CORFO-B2	CORFO-658	1128.69	22		67/05		
6	017 00 162-0	1930	6950	C-2	1930	6930	A-15	HUARA	SALAR ZAPIGA	CORFO-B3	CORFO-658	1126.45	14		67/05		
21	017 00 164-7	1940	6940	A-1	1930	6930	A-21	HUARA	SALAR ZAPIGA	CORFO-D7	CORFO-658	1144.30	20		67/07		
23	017 00 165-5	1940	6940	A-2	1930	6930	A-22	HUARA	SALAR ZAPIGA	CORFO-D8	CORFO-658	1145.26	23		67/07	16.98	1128.30
	017 00 473-5	1940	6940	AN-3				HUARA	REMOLINO								
26	017 00 166-3	1940	6940	C-1	1930	6930	C-5	HUARA	SALAR ZAPIGA	CORFO-C8	CORFO-658	1145.70	14		67/05		
29	017 00 167-1	1940	6940	C-2	1930	6930	C-8	HUARA	SALAR ZAPIGA	CORFO-C9	CORFO-658	1132.05	24		67/07		
30	017 00 104-3	1940	6940	C-3	1930	6930	C-9	HUARA	SALAR ZAPIGA	CORFO-B9	CORFO-658	1145.57	20		67/04	14.97	1130.60
16	017 00 168-k	1940	6950	A-1	1930	6930	A-2	HUARA	PTA. AP DOLORES 1	DOS	DOS	1119.18	32	53.3			
15	017 00 169-8	1940	6950	A-2	1930	6930	A-3	HUARA	PTA. AP DOLORES 2	DOS	DOS	1120.97			63/05		
10	017 00 170-1	1940	6950	A-3	1930	6930	A-4	HUARA	PTA. AP DOLORES 3	DOS	DOS	1119.86	45	26.6			
11	017 00 171-k	1940	6950	A-4	1930	6930	A-5	HUARA	PTA. AP DOLORES 4	DOS	DOS	1120.11	49	71.2			
12	017 00 172-8	1940	6950	A-5	1930	6930	A-6	HUARA	PTA. AP DOLORES 5	DOS	DOS	1119.88	40	40.4	64/04		
13	017 00 173-6	1940	6950	A-6	1930	6930	A-7	HUARA	PTA. AP DOLORES 6	DOS	DOS	1120.90	49	79.6		8.92	1111.98
14	017 00 174-4	1940	6950	A-7	1930	6930	A-8	HUARA	PTA. AP DOLORES 7	DOS	DOS	1120.36	46	65.6			
8	017 00 175-2	1940	6950	A-8				HUARA	SALAR EL OBISPO	CORFO	CORFO-656	1121.79	16		67/05		
9	017 00 17[illegible]	1940	6950	B-1	1930	6930	A-9	HUARA	DOLORES	ENAP B-4	ENAP	1127.00	88		67/05	9.99	1117.01
17	017 00 177-9	1940	6950	B-2	1930	6930	A17	HUARA	SALAR DE ZAPIGA	CORFO-C6	CORFO-658	1127.40	20		67/07	14.39	1113.01
18	017 00 101-9	1940	6950	B-3	1930	6930	A18	HUARA	SALAR DE ZAPIGA	CORFO-B6	CORFO-658	1127.99	12		67/05		
19	017 00 178-7	1940	6950	B-4	1930	6930	A-19	HUARA	SALAR DE ZAPIGA	CORFO-C8	CORFO-658	1145.67	17		67/05	12.50	1133.17
20	017 00 179-5	1940	6950	B-5	1930	6930	A-20	HUARA	SALAR DE ZAPIGA	CORFO-B8	CORFO-658	1133.48	12		67/05		
22	017 00 100-0	1940	6950	B-6	1930	6930	A-23	HUARA	SALAR DE ZAPIGA	CORFO-C7	CORFO-658	1142.66	14		67/05		
7	017 00 180-9	1940	6950	B-7				HUARA	DOLORES E1	ENAP	ENAP	1127.00					
24	017 00 181-7	1940	6950	C-1	1930	6930	C-4	HUARA	SALAR EL OBISPO	CORFO-AA5	CORFO-658	1134.15	8		67/05		
25	017 00 102-7	1940	6950	D-1	1930	6930	C-3	HUARA	SALAR DE ZAPIGA	CORFO-B7	CORFO-658	1135.01	9		67/04		
28	017 00 103-5	1940	6950	D-2	1930	6930	C-6	HUARA	SALAR DE ZAPIGA	CORFO-B8	CORFO-659	1140.05	12		67/04		
27	017 00 182-5	1940	6950	D-3	1930	6900	C-7	HUARA	SALAR EL OBISPO	CORFO-AA6	CORFO-658	1133.69	8		67/05		
39	017 30 100-4	1950	6920	A-1	1930	6900	C-1	HUARA	PACHICA 1	CORFO	CORFO-483	1517.50	54	617.1	64/08		
40	017 30 101-2	1950	6920	A-2	1930	6900	C-2	HUARA	PACHICA 2	CORFO	CORFO-494	1537.69	36	351.0	64/11		
41	017 30 102-0	1950	6920	A-3	1930	6930	C-3	HUARA	PACHICA 3	CORFO	CORFO-509	1534.94	51	868.3	65/03		
38	017 00 183-3	1950	6930	C-1	1930	6930	D-3	HUARA	HUARA 2	CORFO	CORFO-729	1135.24	150		69/10		
34	017 00 184-1	1950	6940	A-1	1930	6930	C-2	HUARA	QBDA. AROMA 1	CORFO	CORFO-733	1150.46	43		68/04		
31	017 00 105-1	1950	6940	A-2	1930	6930	C-10	HUARA	SALAR DE ZAPIGA	CORFO-B10	CORFO-658	1150.54	24		67/05		
32	017 00 106-k	1950	6940	A-3	1930	6930	C-11	HUARA	SALAR DE ZAPIGA	CORFO-B11	CORFO-658	1150.83	29		67/05		
33	017 00 185-k	1950	6940	B-1	1930	6930	D-4	HUARA	QBDA. AROMA 2	CORFO	CORFO-737	1120.14	12		68/05		
33A	017 00 186-8	1950	6940	B-2	1930	6930	D-5	HUARA	QBDA. AROMA 3	CORFO	CORFO-740		12		68/05		
36	017 00 187-6	1950	6940	C-1	2000	6930	C-1	HUARA	HUARA 1	DOS	DOS	1106.71	25			53.56	1053.15
35	017 00 188-4	1950	6940	D-1	2000	6930	D-1	HUARA	HUARA-PACHICA 2	DOS	DOS	1106.04	176				
37	017 00 189-2	1950	6940	D-2	2000	6930	D-2	HUARA	HUARA 1	CORFO	CORFO-727	1104.31	161		68/03		
49A	017 00 190-6	2000	6930	A-1				HUARA	BAQUEDANO 2	EJERCITO CHILE	CORFO-1320		175		74/09		
45	017 00 191-4	2000	6930	C-1	2000	6930	B-5	POZO ALMONTE	BAQUEDANO 4	CORFO	RIEGO	1071.00	360				
45A	017 00 192-2	2000	6930	C-2	2000	6930	B-6	POZO ALMONTE	BAQUEDANO 5	CORFO	RIEGO	1074.00	242		51/06		
42	017 00 193-0	2000	6940	B-1	2000	6930	B-1	POZO ALMONTE	MAPOCHO	RIEGO	RIEGO	1078.60	60		57/04		
48	017 00 194-9	2000	6940	D-1	2000	6930	B-2	POZO ALMONTE	BAQUEDANO 1	CORFO	RIEGO	1055.81					
49	017 00 195-7	2000	6940	D-2	2000	6930	B-3	POZO ALMONTE	BAQUEDANO 2	CORFO	RIEGO	1057.00					
46	017 00 196-5	2000	6940	D-3	2000	6930	B-4	POZO ALMONTE	BAQUEDANO 3	CORFO	RIEGO	1068.92	105		50/06		
43	017 00 197-3	2000	6940	D-4	2000	6930	B-7	POZO ALMONTE	BAQUEDANO 6	RIEGO	RIEGO	1071.06	134		51/10		
44	017 00 198-1	2000	6940	D-5	2000	6930	B-8	POZO ALMONTE	BAQUEDANO 7	RIEGO	RIEGO	1070.00	92		51/12		
47	017 00 199-k	2000	6940	D-6	2000	6930	B-9	POZO ALMONTE	BAQUEDANO 8	RIEGO	RIEGO	1065.00	81		52/06		
46A	017 00 200-7	2000	6940	D-7				POZO ALMONTE	BAQUEDANO 1	EJERCITO CHILE	CORFO-1262		130	10.0	74/04		
169	017 00 201-5	2010	6920	A-1	2000	6930	A-1	POZO ALMONTE	QBDA. J. MORALES	RIEGO	RIEGO	1275.90	462				
53	017 00 202-3	2010	6930	A-1	2000	6930	p13	POZO ALMONTE	PORVENIR	RIEGO	RIEGO	[illegible]	202	921.[illegible]	63/04	35.43	1001.09
45B	017 00	2010	6930	A-2				POZO ALMONTE	DUPLIZA-1	MILITARY			114	172.8	75/	52.00	
45C	017 00	2010	6930	A-3				POZO ALMONTE	DUPLIZA-2	MILITARY			90	172.8	75/	52.00	
45D	017 00	2010	6930	A-4				POZO ALMONTE	DUPLIZA-3	MILITARY			114	172.8	75/	52.00	
57	017 00 131-0	2010	6930	C-1	2000	6930	D34	POZO ALMONTE	LA TIRANA 1	CORFO	CORFO-544	1019.89	199	331.0	67/06	21.65	998.24
56	017 00 203-1	2010	6930	C-2	2000	6930	D-35	POZO ALMONTE	LA TIRANA 2	CORFO	CORFO-645		412		67/04		
59	017 00 204-k	2010	6930	C-3	2000	6930	D-36	POZO ALMONTE	EL CARMELO 1	CORFO	CORFO-572	1022.79	62		66/07		
60	017 00 132-9	2010	6930	C-4	2000	6930	D-37	POZO ALMONTE	EL CARMELO 2	CORFO	CORFO-[illegible]	1022.60	183	225.8	67/07	25.09	997.51
61	017 00 205-8	2010	6930	C-5	2000	6930	D-38	POZO ALMONTE	EL CARMELO 3	CORFO	CORFO-626	1022.79	211		69/01		
62	017 00 206-6	2010	6930	C-6	2000	6930	D-39	POZO ALMONTE	EL CARMELO 4	CORFO	CORFO-754		176	180.0	69/04		
66	017 00 207-4	2010	6930	C-7	2000	6930	D-52	POZO ALMONTE	LA TIRANA	CORFO	CORFO-654	1006.28	30	70.2	67/10	CAPPED	
67	017 00 208-2	2010	6930	C-8	2000	6930	D-53	POZO ALMONTE	LA TIRANA RADIOI	CORFO-1A	CORFO-654	1006.77	21		67/12		
68	017 00 209-0	2010	6930	C-9	2000	6930	D54	POZO ALMONTE	LA TIRANA RADIOI	CORFO-1B	CORFO-654	1006.72	20		67/10		
89	017 00 210-4	2010	6930	C-10	2000	6930	D-55	POZO ALMONTE	LA TIRANA RADIOI	CORFO-1C	CORFO-654	1006.75	20		67/04		
90	017 00 211-[illegible]	2010	6930	C-11	2000	6930	D-56	POZO ALMONTE	LA TIRANA RADIOI	CORFO-1D	CORFO-654	1006.85	20		67/04		
91	017 00 212-0	2010	6930	C-12	2000	6930	D-57	POZO ALMONTE	LA TIRANA RADIOI	CORFO-1E	CORFO-654	1006.94	20		67/04		
92	017 00 213-9	2010	6930	C-13	2000	6930	D-58	POZO ALMONTE	LA TIRANA RADIOI	CORFO-1F	CORFO-654	1006.69	20		67/04		
93	017 00 214-7	2010	6930	C-14	2000	6930	D-59	POZO ALMONTE	LA TIRANA RADIOI	CORFO-1G	CORFO-654	1006.54	21		67/06		
69	017 00 215-5	2010	6930	C-15	2000	6930	D-71	POZO ALMONTE	SALAR PINTADOS	CORFO-E1	CORFO-551	1014.64	19		65/07		
70	017 00 216-3	2010	6930	C-16	2000	6930	D-72	POZO ALMONTE	SALAR PINTADOS	CORFO-F1	CORFO-551	1017.41	25		65/07		
71	017 00 217-1	2010	6930	C-17	2000	6930	D-73	POZO ALMONTE	SALAR PINTADOS	CORFO-G1	CORFO-551	1023.24	28		65/07		
94	017 00 218-k	2010	6930	C-18	2000	6930	D-78	POZO ALMONTE	SALAR PINTADOS	CORFO-F2	CORFO-551	1009.36	21		65/07		
95	017 00 219-6	2010	6930	C-19	2000	6930	D-79	POZO ALMONTE	SALAR PINTADOS	CORFO-G2	CORFO-551	1013.10	21		65/07		
85	017 00 220-1	2010	6930	C-20	2000	6930	D-77	POZO ALMONTE	SALAR PINTADOS	CORFO-E2	CORFO-551	1008.54	15		65/07		
63	017 00 221-k	2010	6930	D-1	2000	6930	D42	POZO ALMONTE	Q. J. MORALES 1	RIEGO	RIEGO	1063.56	438	589.8	65/01	75.00	988.56
64	017 00 222-8	2010	6930	D-2	2000	6930	D-43	POZO ALMONTE	Q. J. MORALES	MIN SAGASCA	CORFO-775	1079.28	274	382.6	69/11	65.00	994.28
96	017 00 223-6	2010	6930	D-3	2000	6930	D-66	POZO ALMONTE	SALAR PINTADOS	CORFO-H2	CORFO-551	1016.52	14		65/07		
51	017 00 224-4	2010	6940	B-1	2000	6930	B-10	POZO ALMONTE	HUMBERSTONE 3	DOS	DOS-337	1038.20	51		54/10	34.85	1003.35
52	017 00 225-[illegible]	2010	6940	B-2	2000	6930	B-11	POZO ALMONTE	HUMBERSTONE 1	RIEGO	RIEGO	1035.92	107		56/07		
50	017 00 226-0	2010	6940	B-3	2000	6930	B12	POZO ALMONTE	HUMBERSTONE 2	RIEGO	RIEGO	1039.22	105	234.7	52/06	35.49	1003.73
54	017 00 227-9	2010	6940	C-1	2000	6930	C-1	POZO ALMONTE	POZO ALMONTE	DOS		1026.50					
65	017 00 107-8	2010	6940	C-2	2000	6930	C-2	POZO ALMONTE	SALARPINTADOS	CORFO-A1	CORFO-551	1020.57	26		65/08		
75	017 00 228-7	2010	6940	D-1	2000	6930	D-1	POZO ALMONTE	PTA. SARA 1	DOS	DOS-338		176		50/03		
73	017 00 108-6	2010	6940	D-2	2000	6930	D-2	POZO ALMONTE	PTA. SARA 1A	DOS	DOS-339	1018.20	181		52/12		
74	017 00 111-6	2010	6940	D-3	2000	6930	D-3	POZO ALMONTE	PTA. SARA 2	DOS	DOS-340		146				
76	017 00 229-5	2010	6940	D-4	2000	6930	D-4	POZO ALMONTE	PTA. SARA 3	DOS	DOS-341	1016.40	53	18.2	52/07		
72	017 00 129-9	2010	6940	D-5	2000	6930	D-5	POZO ALMONTE	PTA. SARA 3A	DOS	DOS-342	1019.43	54	446.3	53/11	21.42	998.01
77	017 00 230-9	2010	6940	D-6	2000	6930	D-6	POZO ALMONTE	PTA. SARA 4	DOS	DOS-343		102		52/11		
78	017 00 231-7	2010	6940	D-7	2000	6930	D-7	POZO ALMONTE	PTA. SARA 5	DOS	DOS-344		73		53/09		
79	017 00 232-5	2010	6940	D-8	2000	6930	D-8	POZO ALMONTE	PTA. SARA 5A	DOS	DOS-345		54	172.8	54/04		
80	017 00 233-3	2010	6940	D-9	2000	6930	D-9	POZO ALMONTE	PTA. SARA 6	DOS	DOS-349		79		53/06		
81	017 00 133-7	2010	6940	D-10	2000	6930	D-10	POZO ALMONTE	SARA TIRANA 6	DOS	DOS-346		84		54/06		
55	017 00 130-2	2010	6940	D-11	2000	6930	D-40	POZO ALMONTE	POZO ALMONTE 1	CORFO	CORFO-612	1026.03	190	143.8	67/07	26.92	999.11
58	017 00 234-1	2010	6940	D-12	2000	6930	D-41	POZO ALMONTE	POZO ALMONTE 2	CORFO	CORFO-632		176.1		67/03		
66	017 00 235-k	2010	6940	D-13	2000	6930	D-68	POZO ALMONTE	SALAR PINTADOS	CORFO-B1	CORFO-551	1019.52	25		65/08	21.50	998.02
67	017 00 236-8	2010	6940	D-14	2000	6930	D-69	POZO ALMONTE	SALAR PINTADOS	CORFO-C1	CORFO-551	1016.79	23		65/06		
68	017 00 237-6	2010	6940	D-15	2000	6930	D-70	POZO ALMONTE	SALAR PINTADOS	CORFO-D1	CORFO-551	1015.10	20		65/07		
82	017 00 109-4	2010	6940	D-16	2000	6930	D-74	POZO ALMONTE	SALAR PINTADOS	CORFO-B2	CORFO-551	1013.49	20		65/06		
83	017 00 238-4	2010	6940	D-17	2000	6930	D-75	POZO ALMONTE	SALAR PINTADOS	CORFO-C2	CORFO-551	1011.37	18		65/08		
84	017 00 239-2	2010	6940	D-18	2000	6930	D-76	POZO ALMONTE	SALAR PINTADOS	CORFO-D2	CORFO-551	1007.69	16		65/06		
81A	017 00 240-6	2010	6940	D-19	2000	6900	D-112	POZO ALMONTE	SARA TIRANA	DOS	DOS-350	1010.55	80	288.0	56/02	15.72	994.83
175	017 00 241-4	2020	6910	A-1	2000	6900	C-6	PICA	PAMPA BRUGGEN 1	RIEGO	RIEGO		325		57/02		
176	017 00 242-2	2020	6910	A-2	2000	6900	C-7	PICA	PMPA.BRUGGEN 1A	RIEGO	RIEGO		250		61/02		
177	017 00 243-0	2020	6910	A-3	2000	6900	C-8	PICA	PAMPA BRUGGEN 2	RIEGO	RIEGO		200		61/06		
178	017 00 244-9	2020	6910	A-4	2000	6900	C-9	PICA	PAMPA BRUGGEN 3	RIEGO	RIEGO		151		61/09		
179	017 00 245-7	2020	6910	A-6	2000	6900	C-10	PICA	PAMPA BRUGGEN 4	G DE CHILE	RIEGO		175		61/12		

Table B-III, 2.1 (1) Well List (Pampa del Tamarugal)

<Lista de Sondajes (Pampa del Tamarugal)>

DGA CODE	BNA CODE	CORFO CODE(1975)			CORFO CODE(1969)			COMMUNITY	LOCATION NAME	NAME OF OWNER	CONSTRUCTOR	ELEVATION (mMSL)	DRILLING DEPTH (m)	SPECIFIC YIELD (m3/d/m)	DATE OF CONSTRUCTION	STAIC WATER LEVEL (93/ 10-11)	
		LAT.	LONG.	NO.	LAT.	LONG.	NO.									(mBGL)	(mMSL)
161	017 00 246-5	2020	6910	A-6	2000	6900	C-52	PICA	PAMPA PICA 1	G. DE CHILE					58/		
160	017 00 247-3	2020	6910	A-7	2000	6900	C-53	PICA	PAMPA PICA 2	RIEGO					56/		
215	017 00 248-1	2020	6910	C-1	2000	6900	C-54	PICA	PUQUIO LORETO D	RIEGO	RIEGO	1420.00	110		19/		
218	017 00 249-k	2020	6910	C-2	2000	6900	C55	PICA	PUQUIO MIRAF. N	RIEGO	RIEGO		131		31/		
221	017 00 250-3	2020	6910	C-3	2000	6900	C-56	PICA	PUQUIO CONCOV S	RIEGO	RIEGO	1459.00	54				
228	017 00 251-1	2020	6910	C-4	2000	6900	C-57	PICA	PUQUIO CARMEN E	RIEGO	RIEGO	1350.00			22/		
223	017 00 252-k	2020	6910	C-5	2000	6900	C-58	PICA	CONCOVA 1 P.TT'	CORFO	CORFO-679A	1476.05	216	32.4	68/02		
222	017 00 253-8	2020	6910	C-6	2000	6900	C-59	PICA	CONCOVA 2 C.+3	CORFO	CORFO-698	1476.23	100	12.1	67/12		
216	017 00 254-6	2020	6910	C-7	2000	6900	C-60	PICA	LORETO 1	CORFO	CORFO-720		90		68/02		
217	017 00 255-4	2020	6910	C-8	2000	6900	C-61	PICA	LORETO 2	CORFO	CORFO-724	1446.75	46		66/04		
219	017 00 256-2	2020	6910	C-9	2000	6900	C-62	PICA	LORETO 3	CORFO	CORFO-736	1450.76	208		68/08	39.06	1411.70
218A	017 00 257-0	2020	6910	C-10				PICA	PAMPA MIRAFLO.1	RIEGO	RIEGO		48				
218B	017 00 258-9	2020	6910	C-11				PICA	PAMPA MIRAFLO M	RIEGO	RIEGO		50				
218C	017 00 259-7	2020	6910	C-12				PICA	PAMPA MIRAFLO.0	RIEGO	RIEGO		60				
219A	017 00 260-0	2020	6910	C-13				PICA	PMPA.CONCOVA R	RIEGO	RIEGO		77				
219B	017 00 261-9	2020	6910	C-14				PICA	PMPA. CONCOVA T	RIEGO	RIEGO		81				
172	017 00 262-7	2020	6920	A-1	2000	6900	C-1	PICA	LA CALERA 1	RIEGO	RIEGO	1057.19	195				
170	017 00 263-5	2020	6920	A-2	2000	6900	C-5	PICA	LA CALERA 3	RIEGO	RIEGO	1300.00	263		61/06	66.13	1233.87
171	017 00 264-3	2020	6920	A-3	2000	6900	C-2	PICA	LA CALERA 2	RIEGO	RIEGO	1046.60	75		61/10	19.34	1027.26
174	017 00 265-1	2020	6920	A-4	2000	6900	C-4	PICA	ESMERALDA 6	RIEGO	RIEGO	1007.00	232	163.5	54/08	17.80	989.20
173	017 00 266-k	2020	6920	A-5	2000	6900	C66	PICA	SALAR PINTADOS	CORFO-J5	CORFO-551	1006.23	20		65/09		
212	017 00 135-3	2020	6920	C-1	2000	6900	C11	PICA	ESMERALDA 1	CORFO	RIEGO	1018.00	446		53/06		
224	017 00 267-8	2020	6920	C-2	2000	6900	C12	PICA	ESMERALDA 2	CORFO	RIEGO	1027.00	176		53/06	BURIED	
227	017 00 268-6	2020	6920	D-1	2000	6900	C-5	PICA	SAUQUECITO	RIEGO	RIEGO	1300.00	263		58/20		
220	017 00 269-4	2020	6920	D-2	2000	6900	C13	PICA	ESMERALDA 4	CORFO	RIEGO	1161.44	349		54/11		
213	017 00 270-8	2020	6920	D-3	2000	6900	C-15	PICA	ESMERALDA 7	CORFO	RIEGO	1087.00	360		55/01	42.54	1044.46
214	017 00 271-6	2020	6920	D-4	2000	6900	C-16	PICA	ESMERALDA 8	CORFO	RIEGO	1094.70	450				
225	017 00 272-4	2020	6920	D-5	2000	6900	C-17	PICA	ESMERALDA 9	CORFO	RIEGO	1117.57	312	3.1	56/06		
226	017 00 149-3	2020	6920	D-6	2000	6900	C-20	PICA	ESMERLDA 12	CORFO	RIEGO	1153.91	150		57/12		
210	017 00 273-2	2020	6920	D-7	2000	6900	C-63	PICA	QBDA. SECA 1	CORFO	CORFO-722		18		68/02		
211	017 00 274-0	2020	6920	D-8	2000	6900	C-64	PICA	QBDA. SECA 2	CORFO	CORFO-781	1332.17	163		69/03		
162	017 00 275-9	[illegible]	6920	D-9	2000	6900	C-14	PICA	ESMERLDA 5	CORFO	RIEGO	1113.30	380		55/11		
209A	017 00 276-7	2020	6920	D-10	2000	6900	C-18	PICA	ESMERALDA 10	CORFO	RIEGO						
163	017 00 277-5	2020	6920	D-11	2000	6900	C-19	PICA	ESMERALDA 11	CORFO	RIEGO	1096.60	315		57/05	24.84	1071.76
184	017 00 278-3	2020	6920	D-12	2000	6900	C-21	PICA	ESMERALDA 13	CORFO	RIEGO	1113.30	94				
185	017 00 279-1	2020	6920	D-13	2000	6900	C-22	PICA	ESMERALDA 14	CORFO	RIEGO	1113.34	90				
209B	017 00 280-5	2020	6920	D-14	2000	6900	C-23	PICA	ESMERALDA 15	CORFO	RIEGO	1115.77	100				
186	017 00 281-3	2020	6920	D-15	2000	6900	C-24	PICA	ESMERALDA 16	CORFO	RIEGO	1126.25	120				
187	017 00 282-1	2020	6920	D-16	2000	6900	C-26	PICA	ESMERALDA 18	CORFO	RIEGO	1101.11	150				
188	017 00 283-k	2020	6920	D-17	2000	6900	C-27	PICA	ESMERALDA 19	CORFO	RIEGO	1141.00	130				
189	017 00 284-8	2020	6920	D-18	2000	6900	C-28	PICA	ESMERALDA 20	CORFO	RIEGO	1104.57	150				
190	017 00 285-6	2020	6920	D-19	2000	6900	C-29	PICA	ESMERALDA 21	CORFO	RIEGO	1143.45	150				
191	017 00 286-4	2020	6920	D-20	2000	6900	C-30	PICA	ESMERALDA 22	CORFO	RIEGO	1109.90	150		62/04		
192	017 00 287-2	2020	6920	D-21	2000	6900	C-31	PICA	ESMERALDA 23	CORFO	RIEGO	1132.40	101				
193	017 00 288-0	2020	6920	D-22	2000	6900	C-32	PICA	ESMERALDA 24	CORFO	RIEGO	1130.32	63				
194	017 00 289-9	2020	6920	D-23	2000	6900	C-33	PICA	ESMERALDA 25	CORFO	RIEGO	1123.46	64		62/05		
195	017 00 290-2	2020	6920	D-24	2000	6900	C-34	PICA	ESMERALDA 25A	CORFO		1123.66	61		62/10		
196	017 00 291-0	2020	6920	D-25	2000	6900	C-35	PICA	ESMERALDA 26	CORFO	RIEGO	1110.70	126		62/05		
209D	017 00 292-9	2020	6920	D-26	2000	6900	C-36	PICA	ESMERALDA 27	CORFO	RIEGO		76		62/07		
197	017 00 293-7	2020	6920	D-27	2000	6900	C-37	PICA	ESMERALDA 28	CORFO	RIEGO	1130.92	63		62/07	40.30	1090.62
198	017 00 294-5	2020	6920	D-28	2000	6900	C-38	PICA	ESMERALDA 29	CORFO	RIEGO	1112.03	102		62/06		
199	017 00 295-3	2020	6920	D-29	2000	6900	C-39	PICA	ESMERALDA 30	CORFO	[illegible]	1116.99	70		62/07		
200	017 00 296-1	2020	6920	D-30	2000	6900	C-40	PICA	ESMERALDA 31	CORFO	RIEGO	1111.77	65		62/07	49.50	1062.27
201	017 00 297-k	2020	6920	D-31	2000	6900	C-41	PICA	ESMERALDA 32	CORFO	RIEGO	1115.46	92		62/06		
202	017 00 298-8	2020	6920	D-32	2000	6900	C-42	PICA	ESMERALDA 33	CORFO	RIEGO	1113.45	90		62/06		
203	017 00 299-6	2020	6920	D-33	2000	6900	C-43	PICA	ESMERALDA 34	CORFO	RIEGO	1118.72	85		62/09	45.75	1072.97
204	017 00 300-3	2020	6920	D-34	2000	6900	C-44	PICA	ESMERALDA 35	CORFO	RIEGO	1121.31	63		62/10		
205	017 00 301-1	2020	6920	D-35	2000	6900	C-45	PICA	ESMERALDA 36	CORFO	RIEGO	1120.60	62		62/10		
206	017 00 302-k	2020	6920	D-36	2000	6900	C-46	PICA	ESMERALDA 37	CORFO	RIEGO	1119.98	62		62/09		
207	017 00 303-8	2020	6920	D-37	2000	6900	C-47	PICA	ESMERALDA 38	CORFO	RIEGO	1119.24	62		62/10		
208	017 00 304-6	2020	6920	D-38	2000	6900	C-48	PICA	ESMERALDA 39	CORFO	RIEGO	1122.57	52		62/11		
209	017 00 305-4	2020	6920	D-39	2000	6900	C-49	PICA	ESMERALDA 40	CORFO	RIEGO	1124.97	55		62/11		
209E	017 00 306-2	2020	6920	D-40	2000	6900	C-50	PICA	ESMERALDA 41	CORFO	RIEGO	1122.44	62		62/11		
209F	017 00 307-0	2020	6920	D-41	2000	6900	C-51	PICA	ESMERALDA 42	CORFO	RIEGO	1120.72	50		62/11		
209C	017 00 308-9	2020	6920	D-42	2000	6930	C-25	PICA	ESMERALDA 17	CORFO	RIEGO	1120.16	100		66/07		
110	017 00 309-7	2020	6930	A-1	2000	6930	D-108	PICA	BOSQUE JUNOY 16	CORFO	CORFO-551		12		66/07		
77A	017 00 310-0	2020	6930	A-2	2000	6930	D-11	POZO ALMONTE	LA TIRANA 8A	DOS-347	DOS-347	1008.00	61				
77B	017 00 311-9	2020	6930	A-3	2000	6930	D-12	POZO ALMONTE	LA TIRANA 104A	DOS-439	DOS-439	1007.24	42		56/11		
100	017 00 312-7	2020	6930	A-4	2000	6930	D-63	POZO ALMONTE	SALAR PINTADOS	CORFO-E3	CORFO-551	1000.76	13		65/07	13.06	987.72
101	017 00 313-5	2020	6930	A-5	2000	6930	D-64	POZO ALMONTE	SALAR PINTADOS	CORFO-F3	CORFO-551	1001.58	12		65/07		
102	017 00 314-3	2020	6930	A-6	2000	6930	D-65	POZO ALMONTE	SALAR PINTADOS	CORFO-G3	CORFO-551	1002.49	15		65/07		
108	017 00 315-1	2020	6930	A-7	2000	6930	D-106	POZO ALMONTE	BOSQUE JUNOY 4	CORFO	CORFO-551	1001.16	12		66/07		
107	017 00 316-k	2020	6930	A-8	2000	6930	D-107	POZO ALMONTE	BOSQUE JUNOY 15	CORFO	CORFO-551		12		66/07	9.59	
	017 00 463-8	2020	6930	A-9				POZO ALMONTE									
	017 00 148-5	2020	6930	A-10				POZO ALMONTE									
	017 00 464-6	2020	6930	A-11				POZO ALMONTE									
	017 00 465-4	2020	6930	A-12				POZO ALMONTE									
	017 00 466-2	2020	6930	A-13				POZO ALMONTE	LA TIRANA	DOS			100	135.4	69/04		
	017 00 901-	2020	6930	A-14													
103	017 00 317-8	2020	6930	B-1	2000	6930	D-86	POZO ALMONTE	SALAR PINTADOS	CORFO-H3	CORFO-551	1007.01	14		65/07		
104	017 00 318-6	2020	6930	B-2	2000	6930	D-87	POZO ALMONTE	SALAR PINTADOS	CORFO-I3	CORFO-551		11		65/09		
105	017 00 319-4	2020	6930	B-3	2000	6930	D-88	POZO ALMONTE	SALAR PINTADOS	CORFO-H4	CORFO-551	996.96	10		65/07		
106	017 00 320-8	2020	6930	B-4	2000	6930	D-89	POZO ALMONTE	SALAR PINTADOS	CORFO-14	CORFO-551	996.23	11		65/09		
111	017 00 134-5	2020	6930	B-5	2000	6930	D-94	POZO ALMONTE	SALAR PINTADOS	CORFO-H5	CORFO-551	988.03	6		65/07		
112	017 00 321-6	2020	6930	B-6	2000	6930	D-96	POZO ALMONTE	SALAR PINTADOS	CORFO-15	CORFO-551	991.14	13		65/09		
	017 00 461-1	2020	6930	B-7				POZO ALMONTE									
	017 00 462-K	2020	6930	B-8				POZO ALMONTE									
139	017 00 322-4	2020	6930	C-1	2000	6930	D-13	POZO ALMONTE	PTA. AP HISPANIA	DOS-246	SONDA		100			8.54	
140	017 00 323-2	2020	6930	C-2	2000	6930	D-14	POZO ALMONTE	PTA. AP HISPANIA	DOS-247	SONDA	989.69	106		69/12	9.43	980.26
141	017 00 324-0	2020	6930	C-3	2000	6930	D-15	POZO ALMONTE	PTA. AP HISPANIA	DOS-248	SONDA	989.49	103		60/02		
142	017 00 325-9	2020	6930	C-4	2000	6930	D-16	POZO ALMONTE	PTA. AP HISPANIA	DOS-249	SONDA	989.14	101		60/03		
143	017 00 326-7	2020	6930	C-5	2000	6930	D-17	POZO ALMONTE	PTA. AP HISPANIA	DOS-250	SONDA	969.07	100		59/11		
144	017 00 158-2	2020	6930	C-6	2000	6930	D-18	POZO ALMONTE	PTA. AP HISPANIA	DOS-290	SONDA	986.70	106				
145	017 00 327-5	2020	6930	C-7	2000	6930	D-19	POZO ALMONTE	PTA. AP HISPANIA	DOS-291	SONDA	989.05					
146	017 00 328-3	2020	6930	C-8	2000	6930	D-93	POZO ALMONTE	SALAR PINTADOS	CORFO-Q1	CORFO-551	985.42	9		65/10		
151	017 00 329-1	2020	6930	C-9	2000	6930	D-103	POZO ALMONTE	BOSQUE JUNOY 12	CORFO	CORFO-551	988.68	13		66/08		
148	017 00 330-5	2020	6930	C-10	2000	6930	D-104	POZO ALMONTE	BOSQUE JUNOY 6	CORFO	CORFO-551		12		66/07		
166	017 00 331-3	2020	6930	C-11	2000	6930	D109	POZO ALMONTE	BOSQUE JUNOY 14	CORFO	CORFO-551	981.00	9		66/06		
165	017 00 332-1	2020	6930	C-12	2000	6930	D-110	POZO ALMONTE	BOSQUE JUNOY 1	CORFO	CORFO-551		10		66/06		
164	017 00 333-K	2020	6930	C-13	2000	6930	D-111	POZO ALMONTE	BOSQUE JUNOY 10	CORFO	CORFO-551	983.67	13		66/06		
161	017 00 [illegible]4-8	[illegible]	6930	C-14	2000	6930	D112	POZO ALMONTE	BOSQUE JUNOY 9	CORFO	CORFO-551	966.76	15		66/07		
153	017 00 335-6	2020	6930	C-15	2000	6930	D-119	POZO ALMONTE	BOSQUE JUNOY 7	CORFO	CORFO-551		13		65/12		
152	017 00 336-4	2020	6930	C-16	2000	6930	D-120	POZO ALMONTE	SALAR PINTADOS	CORFO	CORFO-551	986.74	13		66/06		
109	017 00 337-2	2020	6930	C-17	2000	6930	D-105	POZO ALMONTE	BOSQUE JUNOY 2	CORFO	CORFO-551		10				
	017 00 902-	2020	6930	C-18					LA HUAICA								
	017 00 903-	2020	6930	C-28													
111A	017 00 338-0	2020	6930	D-1	2000	6930	D-44	POZO ALMONTE	LA HUAICA	CORFO-1	CORFO-659	988.98	30		67/11		

Table B-III, 2.1 (1) Well List (Pampa del Tamarugal)

<Lista de Sondajes (Pampa del Tamarugal)>

DGA CODE	BNA CODE	CORFO CODE(1975)			CORFO CODE(1969)			COMMUNITY	LOCATION NAME	NAME OF OWNER	CONSTRUCTOR	ELEVA-TION	DRILLING DEPTH	SPECIFIC YIELD	DATE OF CONST-RUCTION	STAIC WATER LEVEL (93/ 10-11)	
		LAT.	LONG.	NO.	LAT.	LONG.	NO.					(mMSL)	(m)	(m3/d/m)		(mBGL)	(mMSL)
111B	017 00 339-9	2020	6930	D-2	2000	6930	D-45	POZO ALMONTE	LA HUAICA	CORFO-1A	CORFO-659	989.20	11		67/12		
111C	017 00 340-2	2020	6930	D-3	2000	6930	D-46	POZO ALMONTE	LA HUAICA	CORFO-1B	CORFO-659	989.06	11		67/11		
111D	017 00 341-0	2020	6930	D-4	2000	6930	D-47	POZO ALMONTE	LA HUAICA	CORFO-1C	CORFO-659	988.99	23		67/11		
111E	017 00 342-9	2020	6930	D-5	2000	6930	D-48	POZO ALMONTE	LA HUAICA	CORFO-1D	CORFO-659	989.21	11		67/12		
111F	017 00 343-7	2020	6930	D-6	2000	6930	D-49	POZO ALMONTE	LA HUAICA	CORFO-1E	CORFO-659	989.21	11		67/12		
111G	017 00 344-5	2020	6930	D-7	2000	6930	D-50	POZO ALMONTE	LA HUAICA	CORFO-1F	CORFO-659	989.33	23		67/11		
111H	017 00 345-3	2020	6930	D-8	2000	6930	D-51	POZO ALMONTE	LA HUAICA	CORFO-1G	CORFO-659	988.81	15		67/12		
125	017 00 346-1	2020	6930	D-9	2000	6930	D-33	POZO ALMONTE	ESMER. CALERA 3	CORFO	RIEGO	996.00	226				
127	017 00 347-K	2020	6930	D-10	2000	6930	D-25	POZO ALMONTE	P. CANCHONES A	DOS 658	DOS -658	993.90	110				
128	017 00 348-8	2020	6930	D-11	2000	6930	D-26	POZO ALMONTE	P. CANCHONES B	DOS 657	DOS -657	996.21	108				
131	017 00 349-6	2020	6930	D-12	2000	6930	D-29	POZO ALMONTE	P. CANCHONES E	DOS 660	DOS - 660	995.10	54				
126	017 00 350-K	2020	6930	D-13	2000	6930	D-24	POZO ALMONTE	P. CANCHONES G	DOS	RIEGO	989.00	96				
129	017 00 351-8	2020	6930	D-14	2000	6930	D-27	POZO ALMONTE	P. CANCHONES C	DOS- 656	DOS-656	997.33	101				
132	017 00 352-6	2020	6930	D-15	2000	6930	D-30	POZO ALMONTE	P. CANCHONES F	DOS	DOS	998.00	102				
130	017 00 353-4	2020	6930	D-16	2000	6930	D-28	POZO ALMONTE	P. CANCHONES D	DOS-659	DOS-659	997.24	54				
134	017 00 354-2	2020	6930	D-17	2000	6930	D-32	POZO ALMONTE	P. CANCHONES H	DOS	DOS	994.27	100			32.74	961.53
147	017 00 355-0	2020	6930	D-18	2000	6930	D-95	POZO ALMONTE	SALAR PINTADOS	CORFO-H6	CORFO-551	994.71	10		65/07		
126A	017 00 356-9	2020	6930	D-19	2000	6930	D118	POZO ALMONTE	SALAR PINTADOS	CORFO-I6	CORFO-551	993.97	18		65/09		
158	017 00 357-7	2020	6930	D-20	2000	6930	D23	POZO ALMONTE	PTA. CUMINALLA	DOS-496	DOS-496	988.11	108	462.9			
157	017 00 358-5	2020	6930	D-21	2000	6930	D22	POZO ALMONTE	PTA. CUMINALLA	DOS-495	DOS-495	986.06	110				
156	017 00 359-3	2020	6930	D-22	2000	6930	D-21	POZO ALMONTE	PTA. CUMINALLA	DOS-494	DOS-494	986.01	100		61/11		
155	017 00 360-7	2020	6930	D-23	2000	6930	D-20	POZO ALMONTE	PTA. CUMINALLA	DOS-493	DOS-493	986.36	112		61/11		
154	017 00 361-5	2020	6930	D-24	2000	6930	D-114	POZO ALMONTE	SALAR PINTADOS	CORFO-H7	CORFO-551	982.26	6		65/07		
159	017 00 362-3	2020	6930	D-25	2000	6930	D-117	POZO ALMONTE	SALAR PINTADOS	CORFO-I7	CORFO-551	994.37	12		65/09		
167	017 00 363-1	2020	6930	D-26	2000	6930	D-115	POZO ALMONTE	SALAR PINTADOS	CORFO-H8	CORFO-551	985.24	10		65/06	10.50	974.74
166	017 00 364-K	2020	6930	D-27	2000	6930	D-116	POZO ALMONTE	SALAR PINTADOS	CORFO- I8	CORFO-551	997.41	18		65/09		
133	017 00 365-8	2020	6930	D-28	2000	6930	D-31	POZO ALMONTE	PTA. AP CANCHON	DOS	DOS		12		66/07		
126B	017 00 366-6	2020	6930	D-29				POZO ALMONTE	CANCHONES 1	CORFO	CORFO-672		183	408.2	70/04		
	017 00 454-9	2020	6930	D-30				POZO ALMONTE	CANCHONES 1	DOS			110	141.7	61/05		
	017 00 455-7	2020	6930	D-31				POZO ALMONTE	CANCHONES 2	DOS							
	017 00 456-5	2020	6930	D-32				POZO ALMONTE	CANCHONES 3	DOS			110				
	017 00 457-	2020	6930	D-33				POZO ALMONTE	CANCHONES 4	DOS							
	017 00 458-	2020	6930	D-34				POZO ALMONTE	CANCHONES 5	DOS							
	017 00 459-	2020	6930	D-35				POZO ALMONTE	CANCHONES 6	DOS			120		65/09		
	017 00 460-	2020	6930	D-36				POZO ALMONTE	CANCHONES 7	DOS			120				
97	017 00 367-4	2020	6940	A-1	2000	6930	C-3	POZO ALMONTE	SALAR PINTADOS	CORFO T-1	CORFO-551	1007.16	16		65/12		
98	017 00 147-7	2020	6940	B-1	2000	6930	D-81	POZO ALMONTE	S. PINTADOS	CPRFO P-1	CORFP-551	1004.59	15		65/09		
99	017 00 366-2	2020	6940	B-2	2000	6930	D-82	POZO ALMONTE	SALAR PINTADOS	CORFO D-3	CORFO-551	1033.93	13		65/08		
121	017 00 110-8	2020	6940	C-1	2000	6930	C-4	POZO ALMONTE	SALAR PINTADOS	CORFO T-2	CORFO-551	997.75	15		65/11		
162	017 00 112-4	2020	6940	C-2	1930	6930	A-2	POZO ALMONTE	SALAR PINTADOS	CORFO T-3	CORFO-551	990.74	13		65/11	9.28	981.46
113	017 00 136-1	2020	6940	D-1	2030	6930	D-60	POZO ALMONTE	REFRESCO RADIO	CORFO-1	CORFO-655	994.58	32	34.6	67/10		
114	017 00 369-0	2020	6940	D-2	2030	6930	D-61	POZO ALMONTE	REFRESCO RADIO	CORFO-1A	CORFO-655	994.97	16		67/04		
115	017 00 370-4	2020	6940	D-3	2030	6930	D-62	POZO ALMONTE	REFRESCO RADIO	CORFO-1B	CORFO-655	994.98	12		67/10		
116	017 00 371-2	2020	6940	D-4	2030	6930	D-63	POZO ALMONTE	REFRESCO RADIO	CORFO-1C	CORFO-655	995.01	12		67/10		
117	017 00 272-0	2020	6940	D-5	2030	6930	D-64	POZO ALMONTE	REFRESCO	CORFO-1D	CORFO-655	995.01	12		67/04		
118	017 00 373-9	2020	6940	D-6	2030	6930	D-65	POZO ALMONTE	REFRESCO	CORFO-1E	CORFO-655	995.02	13		67/04		
119	017 00 374-7	2020	6940	D-7	2030	6930	D-66	POZO ALMONTE	REFRESCO	CORFO-1F	CORFO-655	994.93	12		67/10		
120	017 00 375-5	2020	6940	D-8	2030	6930	D-67	POZO ALMONTE	REFRESCO	CORFO-1G	CORFO-655	996.06	12		67/10		
122	017 00 138-8	2020	6940	D-9	2030	6930	D-90	POZO ALMONTE	SALAR PINTADOS	CORFO-P2	CORFO-551	996.20	15		65/09		
123	017 00 139-6	2020	6940	D-10	2030	6930	D-91	POZO ALMONTE	SALAR PINTADOS	CORFO-2	CORFO-551	993.84	15		65/11		
124	017 00 376-3	2020	6940	D-11	2030	6900	D-92	POZO ALMONTE	SALAR PINTADOS	CORFO-G2	CORFO-551	991.72	12		65/10		
135	017 00 377-1	2020	6940	D-12	2030	6900	D-97	POZO ALMONTE	BOSQUE JUNOY	CORFO-W	CORFO-551	993.41	13		66/09		
133	017 00 378-K	2020	6940	D-13	2030	6900	D-102	POZO ALMONTE	BOSQUE JUNOY	CORFO-I1	CORFO-551	991.63	16		66/08		
136	017 00 379-8	2020	6940	D-14	2030	6900	D-98	POZO ALMONTE	SALAR PINTADOS	CORFO-D1	CORFO-551	989.84	15		65/12		
137	017 00 140-K	2020	6940	D-15	2030	6900	D-101	POZO ALMONTE	BOSQUE JUNOY	CORFO-8	CORFO-551		16		66/07	13.51	
150	017 00 380-1	2020	6940	D-16	2030	6900	D-100	POZO ALMONTE	SALAR PINTADOS	CORFO-P3	CORFO-551	989.29	18		65/09		
149	017 00 381-K	2020	6940	D-17	2030	6900	D-99	POZO ALMONTE	BOSQUE JUNOY	CORFO-X	CORFO-551	999.61	12		66/09	13.17	986.44
160	017 00 382-8	2020	6940	D-18	2030	6900	D-113	POZO ALMONTE	SALAR PINTADOS	CORFO-P3	CORFO-551	985.45	15		65/11		
163	017 00 383-6	2020	6940	D-19	2030	6900	D-121	POZO ALMONTE	SALAR PINTADOS	CORFO-T3	CORFO-551	987.48	6		66/07		
	017 00 137-K	2020	6940	D-20				POZO ALMONTE									
308	017 00 384-4	2030	6910	A-1	2030	6900	A-2	PICA	P.CHIANTAGUAY C	DOS	DOS	1420.00	265				
307	017 00 385-2	2030	6910	A-2	2030	6900	A-3	PICA	P.CHIANTAGUAY G	DOS	DOS	1312.00	67				
306	017 00 386-0	2030	6910	A-3	2030	6900	A-4	PICA	P.CHIANTAGUAY H	DOS	DOS	1305.00	182				
305	017 00 387-9	2030	6910	A-4	2030	6900	A-5	PICA	P.CHIANTAGUAY I	DOS	DOS	1303.00	66				
304	017 00 388-7	2030	6910	A-5	2030	6900	A-6	PICA	P.CHIANTAGUAY J	DOS	DOS	1269.00	35				
312	017 00 389-5	2030	6910	A-6	2030	6900	A15	PICA	MATILLA 2	CORFO	CORFO-676	1307.70	185	13.8	67/09		
313	017 00 390-9	2030	6910	A-7	2030	6900	A-16	PICA	MATILLA 3	CORFO	CORFO-697	1316.54	141	3.3	67/12		
317	017 00 391-7	2030	6910	A-8	2030	6900	A-14	PICA	MATILLA 1	CORFO	CORFO-547	1283.48	159		66/04		
318	017 00 392-5	2030	6910	A-9	2030	6900	A-26	PICA	PUQUIO NUNEZ A	RIEGO	RIEGO	1352.00	52				
319	017 00 393-3	2030	6910	A-10	2030	6900	A-10	PICA	PUQUIO NUNEZ 1	RIEGO	RIEGO	1526.50	378		57/02		
321	017 00 394-1	2030	6910	A-11	2030	6900	A-25	PICA	PUQUIO NUNEZ 2	CORFO	CORFO-734	1266.10	206	5.2	68/08		
322	017 00 395-K	2030	6910	C-1	2030	6900	A-24	PICA	PUQUIO NUNEZ 1	CORFO	CORFO-716	1[illegible]53.70	230		[illegible]/04		
320	017 00 143-4	2030	6920	A-1	2030	6900	A-22	PICA	PINTADOS PICA 2	CORFO	CORFO-671	1039.38	159		67/07		
315	017 00 114-0	2030	6920	A-2	2030	6900	A-23	PICA	PINTADOS PICA 3	CORFO	CORFO-674	1057.89	201		67/07	71.56	986.33
301	017 00 142-6	2030	6920	B-1	2030	6900	A-17	PICA	MATILLA 4	CORFO	CORFO-711	1136.60	59				
302	017 00 117-5	2030	6920	B-2	2030	6930	A-18	PICA	MATILLA 5	CORFO	CORFO-764	1136.60	164	6.6	68/11	3.76	1132.84
309	017 00 396-6	2030	6920	B-3	2030	6930	A9	PICA	MATILLA 1A	RIEGO	RIEGO	1113.24	372		61/02		
311	017 00 397-6	2030	6920	B-4	2030	6930	A8	PICA	P.CHIANTAGUAY P	DOS		1206.00					
303	017 00 398-4	2030	6920	B-5	2030	6930	A7	PICA	P. CHIANTAGUAY O	DOS		1213.00					
310	017 00 399-2	2030	6920	B-6	2030	6930	B-13	PICA	POQUIO NUNEZ 4	RIEGO	RIEGO	1165.00	112		61/12		
314	017 00 400-K	2030	6920	B-7	2030	6930	A-12	PICA	PUQUIO NUNEZ 3	RIEGO	RIEGO	1169.40			61/12		
316	017 00 401-8	2030	6920	B-8	2030	6930	A-11	PICA	PUQUIO NUNEZ 2	RIEGO	RIEGO	1120.10	187		62/01		
	017 00 469-7	2030	6920	BN-9				PICA	GRANJA MA.JOSE								
	017 00 470-0	2030	6920	BN-10	2030	6930	B-28	PICA	E. ARROYO								
	017 00 471-9	2030	6920	BN-11	2030	6930	B-25	PICA	A. NAPOLI P-1								
324	017 00 402-6	2030	6920	C-1	2030	6930	A-20	PICA	CHACA[illegible]LA 1	CORFO	CORFO-659	1083.9[illegible]	287		67/05	62.79	1021.13
325	017 00 403-4	2030	6920	C-2	2030	6930	A21	PICA	CHACARILLA 2	CORFO	CORFO-665	1083.49	194	37.6	66/03	62.25	1021.24
323	017 00 404-2	2030	6920	D-1	2030	6930	A-1	PICA	PUQUIO NUNEZ B	RIEGO	RIEGO	1205.00	52			20.63	1164.37
	017 00 909-	2030	6920	D-2					P NUNEZ								
	017 00 910-	2030	6920	D-3					P NUNEZ								
238	017 00 113-2	2030	6930	A-1	2030	6930	B-11	POZO ALMONTE	PINTADOS RADIO	CORFO-1	CORFO-656	975.64	30		67/10	6.56	969.08
239	017 00 405-0	2030	6930	A-2	2030	6930	B-12	POZO ALMONTE	PINTADOS RADIO	CORFO-1A	CORFO-656	975.91	7		67/12		
240	017 00 406-9	2030	6930	A-3	2030	6930	B-13	POZO ALMONTE	PINTADOS RADIO	CORFO-1B	CORFO-656	975.81	7		67/12		
241	017 00 407-7	2030	6930	A-4	2030	6930	B-14	POZO ALMONTE	PINTADOS RADIO	CORFO-1D	CORFO-656	975.83	16		67/12		
242	017 00 123-K	2030	6930	A-5	2030	6930	B-15	POZO ALMONTE	PINTADOS RADIO	CORFO-1D	CORFO-656	975.97	7		67/12		
243	017 00 408-5	2030	6930	A-6	2030	6930	B-16	POZO ALMONTE	PINTADOS RADIO	CORFO-1E	CORFO-656	975.94	7		67/12		
244	017 00 409-3	2030	6930	A-7	2030	6930	B-17	POZO ALMONTE	PINTADOS RADIO	CORFO-1F	CORFO-656	975.99	16		67/12		
245	017 00 410-7	2030	6930	A-8	2030	6930	B-18	POZO ALMONTE	PINTADOS RADIO	CORFO-1G	CORFO-656	975.22	7		67/12		
237	017 00 411-5	2030	6930	A-9	2030	6930	B-26	POZO ALMONTE	SALAR PINTADOS	CORFO-P5	CORFO-656	975.34	6		65/10	6.21	969.13
230	017 00 412-3	2030	6930	A-10	2030	6930	B-25	POZO ALMONTE	BOSQUE JUNOY	CORFO-13	CORFO-551	981.16	8		[illegible]/08	11.[illegible]	969.77
248	017 00 413-1	2030	6930	A-11	2030	6930	B-46	POZO ALMONTE	SALAR PINTADOS	CORFO-P1	CORFO-551	980.25	8		66/01		
232	017 00 414-K	2030	6930	B-1	2030	6930	B-10	POZO ALMONTE	SALAR PINTAD E2	ENAP	ENAP	968.80	1255				
231	017 00 415-8	2030	6930	B-2	2030	6930	B-9	POZO ALMONTE	SALAR PINTAD 2	ENAP	ENAP	988.80	132	267.8		13.61	975.19
233	017 00 416-6	2030	6930	B-3	2030	6930	B-26	POZO ALMONTE	SALAR PINTADOS	CORFO-H9	CORFO-551	980.58	13		65/06		
234	017 00 417-4	2030	6930	B-4	2030	6930	B-27	POZO ALMONTE	SALAR PINTADOS	CORFO-I9	CORFO-551	1005.18	31		65/09		
246	017 00 418-2	2030	6930	B-5	2030	6930	B-29	POZO ALMONTE	SALAR PINTADOS	CORFO-H10	CORFO-551	990.56	19		65/08		
250	017 00 419-0	2030	6930	B-6	2030	6930	B-35	POZO ALMONTE	SALAR PINTADOS	CORFO-H11	CORFO-551	991.45	21				

Table B-III, 2.1 (1) Well List (Pampa del Tamarugal)

<Lista de Sondajes (Pampa del Tamarugal)>

DGA CODE	BNA CODE	CORFO CODE(1978)			CORFO CODE(1969)			COMMUNITY	LOCATION NAME	NAME OF OWNER	CONSTRUCTOR	ELEVA-TION	DRILLING DEPTH	SPECIFIC YIELD	DATE OF CONST-RUCTION	STAIC WATER LEVEL (93/ 10-11)	
		LAT.	LONG.	NO.	LAT.	LONG.	NO.					(mMSL)	(m)	(m3/d/m)		(mBGL)	(mMSL)
252	017 00 420-4	2030	6930	B-7	2030	6930	B-8	POZO ALMONTE	SALAR PINTA. E1	ENAP	ENAP	1001.70	2475			24.04	977.66
251	017 00 421-2	2030	6930	B-8	2030	6930	B-7	POZO ALMONTE	SALAR PINTADOS 1	ENAP	ENAP	1001.70	120	237.8			
254	017 00 118-3	2030	6930	C-1	2030	6930	B-33	POZO ALMONTE	SALAR PINTADOS	CORFO-S1	CORFO-551	976.43	12		65/11	5.34	970.09
255	017 00 422-0	2030	6930	C-2	2030	6930	B-34	POZO ALMONTE	SALAR PINTADOS	CORFO-P7	CORFO-551	978.03	12		65/10		
256	017 00 141-8	2030	6930	C-3	2030	6930	B-19	POZO ALMONTE	SALAR PINTADOS 2	CORFO	CORFO-661	978.29	156		67/06	8.79	969.50
257	017 00 144-2	2030	6930	C-4	2030	6930	B-22	POZO ALMONTE	SALAR PINTADOS 3	CORFO	CORFO-686		64		67/08	6.87	
258	017 00 423-9	2030	6930	C-5	2030	6900	B-21	POZO ALMONTE	SALAR PINTADOS 4	CORFO	CORFO-688		285	118.6	68/06		
265	017 00 161-5	2030	6930	C-6	2030	6900	B-37	POZO ALMONTE	SALAR PINTADOS	CORFO-P6	CORFO-551	976.73	15		65/11		
249	017 00 120-5	2030	6930	C-7	2030	6900	B-30	POZO ALMONTE	SALAR PINTADOS	CORFO-P6	CORFO-551	975.86	7		65/10		
259	017 00 119-1	2030	6930	D-1	2030	6930	B-36	POZO ALMONTE	SALAR PINTADOS	CORFO-H12	CORFO-551	990.05	21		65/12		
253	017 00 121-3	2030	6930	D-2	2030	6930	B-22	POZO ALMONTE	PINTADOS PICA 1	CORFO	CORFO-666	1006.26	110		67/06		
261	017 00 424-7	2030	6930	D-3	2030	6930	B-4	POZO ALMONTE	ESTACION PINTA 3	CO.AG.JEHOVA	RIEGO	987.99	315		66/04		
262	017 00 425-5	2030	6930	D-4	2030	6930	B-6	POZO ALMONTE	ESTACION PINTA.5	CO.AG.JEHOVA	RIEGO	987.99	326				
260	017 00 426-3	2030	6930	D-5	2030	6930	B-5	POZO ALMONTE	ESTACION PINTA.4	CO.AG.JEHOVA	RIEGO	987.43	395			11.97	975.46
263	017 00 150-7	2030	6930	D-6	2030	6930	B-2	POZO ALMONTE	ESTACION PINTA.1	CO.AG.JEHOVA	RIEGO	987.61	172			16.22	969.39
264	017 00 427-1	2030	5930	D-7	2030	6930	B-3	POZO ALMONTE	ESTACION PINTA.2	CO.AG.JEHOVA	RIEGO	983.48					
266	017 00 428-K	2030	6930	D-8	2030	6930	B-40	POZO ALMONTE	SALAR B. VISTA	CORFO-SB3	CORFO-621	984.26	24		66/04		
	017 00 116-7	2030	6930	D-9				POZO ALMONTE									
229	017 00 429-B	2030	6940	B-1	2030	6930	B-24	POZO ALMONTE	SALAR PINTADOS	CORFO-P4	CORFO-551	983.48	10		65/10		
235	017 00 430-1	2030	6940	B-2	2030	6930	B-31	POZO ALMONTE	SALAR PINTADOS	CORFO-S3	CORFO-561	983.07	8		65/11	6.35	976.72
247	017 00 145-0	2030	6940	B-3	2030	6930	B-32	POZO ALMONTE	SALAR PINTADOS	CORFO-S2	CORFO-551	977.04	9		65/11		
236	017 00 146-9	2030	6940	B-4	2030	6930	B-1	POZO ALMONTE	MOSQUITOS 1		RIEGO	978.71	285		57/05	4.20	974.51
326	017 00 122-1	2040	6910	A-1	2030	6930	A-19	PICA	CHACARILLA 1	RIEGO			338			86.00	
327	017 00 431-k	2040	6920	C-1	2030	6930	C-1	POZO ALMONTE	RAMADA 1	CORFO	CORFO-704	1019.26	202		68/07		
328	017 00 432-8	2040	6920	C-2	2030	6930	C-2	POZO ALMONTE	RAMADA 2	CORFO	CORFO-731	1019.55	290	130.1	68/07		
267	017 00 125-6	2040	6930	A-1	2030	6930	B-38	POZO ALMONTE	SALAR BELAVISTA	CORFO-SB1	CORFO-621	970.71	15		66/03	11.15	959.56
268	017 00 433-6	2040	6930	A-2	2030	6930	B-41	POZO ALMONTE	SALAR BELAVISTA	CORFO-SB4	CORFO-621	955.56	10		66/03		
269	017 00 126-4	2040	6930	A-3	2030	6930	B39	POZO ALMONTE	SALAR BELAVISTA	CORFO-SB2	CORFO-621	974.13	16		66/03		
271	017 00 434-4	2040	6930	A-4	2030	6930	B-42	POZO ALMONTE	SALAR BELAVISTA	CORFO-SB5	CORFO-621	970.36	16		66/04	11.56	956.82
273	017 00 435-2	2040	6930	A-5	2030	6930	B-45	POZO ALMONTE	SALAR BELAVISTA	CORFO-SB6	CORFO-621	960.63	10		66/03		
275	017 00 436-0	2040	6930	A-6	2030	6930	B-46	POZO ALMONTE	SALAR BELAVISTA	CORFO-SB9	CORFO-621	968.08	15		66/04	11.30	956.78
276	017 00 157-4	2040	6930	A-7	2030	6930	B-47	POZO ALMONTE	SALAR BELAVISTA	CORFO-SB10	CORFO-621	974.35	20		66/04	16.39	957.96
274	017 00 437-9	2040	6930	A-8	2030	6900	B-23	POZO ALMONTE	OF. VICTORIA 4	SOQUIMICH	RIEGO	954.55	85				
270	017 00 438-7	2040	6930	B-1	2030	6930	B43	POZO ALMONTE	SALAR BELLAVISTA	CORFO-SB6	CORFO-621	995.09	25		66/06		
280	017 00 128-0	2040	6930	C-1	2030	6930	D-7	POZO ALMONTE	SALAR BELLAVISTA	CORFO-SB12	CORFO-621	958.86	12		66/04	8.73	950.15
283	017 00 152-3	2040	6930	C-2	2030	6930	D-10	POZO ALMONTE	SALAR BELLAVISTA	CORFO-SB15	CORFO-621	949.40	8		66/04	2.96	946.44
285	017 00 439-5	2040	6930	C-3	2030	6930	D-11	POZO ALMONTE	SALAR BELLAVISTA	CORFO-SB18	CORFO-621	953.50	10		66/04		
287	017 00 440-9	2040	6930	C-4	2030	6930	D-14	POZO ALMONTE	SALAR BELLAVISTA	CORFO-SB19	CORFO-621	947.50	7		66/06	3.10	944.40
288	017 00 441-7	2040	6930	C-5	2030	6930	D-15	POZO ALMONTE	SALAR BELLAVISTA	CORFO-SB20	CORFO-621	947.15	7		66/06		
278	017 00 442-5	2040	6930	D-1	2030	6930	D-2	POZO ALMONTE	OF. VICTORIA 2	SOQUIMICH	RIEGO	973.05	106		55/02	15.87	957.18
277	017 00 443-3	2040	6930	D-2	2030	6930	D-3	POZO ALMONTE	OF. VICTORIA 3	SOQUIMICH	RIEGO	972.04	335		69/09		
281	017 00 444-1	2040	6930	D-3	2030	6930	D-8	POZO ALMONTE	SALAR BELLAVISTA	CORFO-SB13	CORFO-621	974.30	23		66/04	18.82	955.48
282	017 00 445- K	2040	6930	D-4	2030	6930	D-1	POZO ALMONTE	OF. VICTORIA Q	SOQUIMICH	RIEGO-	973.09	156		54/06		
286	017 00 127-2	2040	6930	D-5	2030	6930	D-12	POZO ALMONTE	SALAR BELLAVISTA	CORFO-SB17	CORFO-621	972.54	24		66/04	19.85	952.69
289	017 00 446-8	2040	6930	D-6	2030	6930	D-16	POZO ALMONTE	SALAR BELLAVISTA	CORFO-SB21	CORFO-621	966.91	12		66/05		
272	017 00 447-6	2040	6940	B-1	2030	6930	B-44	POZO ALMONTE	SALAR BELLAVISTA	CORFO-SB7	CORFO-621	962.60	12		66/03	5.80	956.80
279	017 00 448-4	2040	6940	D-1	2030	6930	D-6	POZO ALMONTE	SALAR BELLAVISTA	CORFO-SB11	CORFO-621	953.09	15		66/03		
284	017 00 449-2	2040	6940	D-2	2030	6930	D-9	POZO ALMONTE	SALAR BELLAVISTA	CORFO-SB14	CORFO-621	946.28	9		66/03		
329	017 00 450-6	2050	6920	A-1	2030	6900	C-3	POZO ALMONTE	CERRO GORDO 1	CORFO	CORFO-703	992.70	140		67/11		
	017 00 467-0	2050	6920	C-1				POZO ALMONTE									
	017 00 472-7	2050	6920	D-2				POZO ALMONTE									
296	017 00 153-1	2050	6930	A-1	2030	6930	D-20	POZO ALMONTE	SALAR SUR VIEJO	CORFO-SV3	CORFO-621	923.82	16		66/10		
298	017 00 451-4	2050	6930	A-2	2030	6930	D-22	POZO ALMONTE	SALAR SUR VIEJO	CORFO-SV6	CORFO-621	923.30	16		66/10		
291	017 00 45[illegible]	2050	6930	B-1	2030	6930	D-17	POZO ALMONTE	SALAR BELLAVISTA	CORFO-SB22	CORFO-621	948.28	10		66/06		
293	017 00 156-5	2050	6930	B-2	2030	6930	D-4	POZO ALMONTE	CHALLACOLLO 1	CORFO	CORFO-675	945.35	88		67/07		
292	017 00 453-0	2050	6930	B-3	2030	6930	D-5	POZO ALMONTE	CHALLACOLLO 2	CORFO	CORFO-677	945.80	21			36.85	908.95
294	017 00 155-8	2050	6930	B-4	2030	6930	D-18	POZO ALMONTE	SALAR BELLAVISTA	CORFO-SB23	CORFO-621	945.73	31		66/06	27.17	918.56
295	017 00 154-K	2050	6930	B-5	2030	6930	D-19	POZO ALMONTE	SALAR SUR VIEJO	CORFO-SV2	CORFO-621	930.87	22		66/10		
297	017 00 159-0	2050	6930	B-6	2030	6930	D-21	POZO ALMONTE	SALAR SUR VIEJO	CORFO-SV5	CORFO-621	931.40	24		66/10		
299	017 00 160-4	2050	6930	D-1	2030	6930	D-23	POZO ALMONTE	SALAR SUR VIEJO	CORFO-SV7	CORFO-621	923.21	19		66/10		
300	017 00 163-9	2050	6930	D-2	2030	6930	D-24	POZO ALMONTE	SALAR SUR VIEJO	CORFO-SV11	CORFO-621	927.11	24		66/10		
	017 00 917-6	2050	6930	D-3													
290	017 00 124-6	2050	6940	B-1	2030	6930	D-13	POZO ALMONTE	SALAR BELLAVISTA	CORFO-SB18	CORFO-621	947.56	7		66/06	3.18	944.38
								ZAPIGA		DGA-JICA	JICA J-3	1143.90	150	62.79	93/11	9.17	1134.73
								ZAPIGA	CAMINA	DGA-JICA	JICA J-4	1168.04	150	169.40	93/12	46.16	1121.88
								ZAPIGA	HUARA	DGA-JICA	JICA J-C	1110.86	209	8.20	93/11	52.03	1058.83
								POZO ALMONTE	BAQUEDANO	DGA-JICA	JICA J-D	1056.69	210	300.00	93/12	46.05	1010.64
								POZO ALMONTE	POZO ALMONTE	DGA-JICA	JICA J-5	1030.80	300	720.00	93/12	29.08	1001.72
								POZO ALMONTE	LA TIRANA	DGA-JICA	JICA J-E	1006.03	250	584.60	93/12	13.73	992.30
								POZO ALMONTE	CANCHONES	DGA-JICA	JICA J-6	991.90	200	22.30	93/12	14.04	977.86
								POZO ALMONTE	CONAF	DGA-JICA	JICA J-7	981.64	210	234.60	93/12	7.94	973.70
								POZO ALMONTE	PINTADOS	DGA-JICA	JICA J-8	1016.12	210	188.61	93/12	37.99	978.13
								POZO ALMONTE	OFICINA VICTORIA	DGA-JICA	JICA J-F	1016.16	224	142.20	93/01	57.00	959.16
								POZO ALMONTE	OFICINA VICTORIA	DGA-JICA	JICA J-9	969.80	172	166.10	93/01	13.97	955.83

NOTE

(PUNPING TEST)
D/W: DYNAMIC WATER LECEL
S/W: STATIC WATER LEVEL

Table B-III, 2.1 (2) Well List (Pampa del Tamarugal)
<Lista de Sondajes (Pampa del Tamarugal)>

BNA CODE	MAP	CORFO CODE(1975)			UTM		COMMUNITY	LOCATION NAME	NAME OF OWNER	CONSTRUCTOR	ELEVA-TION (mASL)	DRILLING DEPTH (m)	WELL DEPTH (m)	SPECIFIC YIELD (m2/d)	DATE OF CONST-RUCTION	STAIC WATER LEVEL	
		LAT.	LONG.	NO.	North (m)	East (m)										(mBGL)	(mMSL)
017 00 919	ZP-1	1940	6950	B-8	7.819.853	405.341	HUARA	STA. CATALINA	LUIS PAPIC	–		7.20	7.20	414.7		4.72	
017 00 920	ZP-2	1940	6950	D-4	7.815.343	407.751	HUARA	AGUADA	LUIS PAPIC	–		15.00	15.00	267.9		12.35	
017 00 928	ZP-3	1950	6950	B-1	7.805.763	411.189	HUARA	NEGREROS	SAL. RENACER	CRUZAT		30.25	30.25	154.7	07.89	12.43	
017 00 926	ZP-4	1940	6950	D-10	7.807.004	411.249	HUARA	NEGREROS	SAL. RENACER	CRUZAT		18.50	18.50		07.89	11.10	
017 00 925	ZP-5	1940	6950	D-9	7.807.322	412.083	HUARA	NEGREROS	SAL. RENACER	CRUZAT		26.70	26.70	104.9	07.89	13.73	
017 00 923	ZP-6	1940	6950	D-7	7.808.191	410.724	HUARA	NEGREROS	SAL. RENACER	CRUZAT		20.20	20.20	60.3	07.89	11.24	
017 00 922	ZP-7	1940	6950	D-6	7.808.640	411.377	HUARA	NEGREROS	SAL. RENACER	CRUZAT		45.00	45.00	76.5	06.89	12.98	
017 00 924	ZP-8	1940	6950	D-8	7.807.767	410.395	HUARA	NEGREROS	SAL. RENACER	CRUZAT		12.90	12.90			12.63	
017 00 921	ZP-9	1940	6950	D-5	7.809.917	410.789	HUARA	NEGREROS	SAL. RENACER	CRUZAT		25.40	25.40	95.3	06.89	10.45	
017 00 934	ZP-10	1950	6950	B-4	7.804.136	411.169	HUARA	NEGREROS	MERCK QCA.	SAACOL		24.00	24.00	7.3	02.88	13.19	
017 00 936	ZP-11	1950	6950	B-6	7.803.875	411.520	HUARA	NEGREROS	MERCK QCA.	SAACOL		44.00	44.00	2.4	03.88	14.77	
017 00 935	ZP-12	1950	6950	B-5	7.804.000	412.001	HUARA	NEGREROS	MERCK QCA.	SAACOL		32.00	32.00	5.5	02.88	15.60	
017 00 932	ZP-13	1950	6950	B-3	7.804.613	411.223	HUARA	NEGREROS	MERCK QCA	SAACOL		66.00	35.00	94.1	12.87	13.50	
017 00 938	ZP-14	1950	6950	B-8	7.803.243	411.275	HUARA	NEGREROS	MERCK QCA.	SAACOL		40.00	40.00	7.4	12.87	14.20	
017 00 939	ZP-15	1950	6950	B-7	7.803.374	411.526	HUARA	NEGREROS	MERCK QCA.	SAACOL		20.40			12.87	17.60	
017 00 941	ZP-16	1950	6950	B-11	7.802.270	409.971	HUARA	NEGREROS	MERCK QCA.	SAACOL		40.00	40.00	21.0	02.88	14.52	
017 00 929	ZP-17	1950	6950	B-2	7.804.584	410.455	HUARA	OF. MERCEDES	MERCK QCA.	SAACOL		22.20		16.4	11.89	14.35	
017 00 937	ZP-18	1950	6950	B-9	7.803.164	410.275	HUARA	NEGREROS	MERCK QCA.	SAACOL		17.00		43.2	11.89	15.00	
017 00 940	ZP-19	1950	6950	B-10	7.802.664	410.126	HUARA	NEGREROS	MERCK QCA.	SAACOL		19.00		933.1	11.89	14.75	
017 00 943	ZP-20	1950	6950	B-13	7.801.776	409.888	HUARA	OF. AGUA SANTA	MERCK QCA.	SAACOL		17.80		95.4	11.89	15.82	
017 00 942	ZP-21	1950	6950	B-12	7.802.217	411.482	HUARA	OF. PROGRESO	MERCK QCA.	SAACOL		17.75		259.2	11.89	15.44	
017 00 947	ZP-22	1950	6940	D-5	7.789.697	421.676	HUARA	STA. ROSA HUARA	MERCK QCA.	SAACOL	1106.25	68.00	68.00	10.3	12.87	48.70	1057.55
017 00 948	ZP-23	1950	6940	D-4	7.789.856	423.320	HUARA	STA. ROSA HUARA	MERCK QCA.	SAACOL	1106.37	93.00	90.00	187.5	04.89	50.97	1055.40
017 00 946	ZP-24	1950	6940	D-3	7.790.940	422.861	HUARA	STA. ROSA HUARA	MERCK QCA.	SAACOL	1110.74	90.00	90.00	352.9	05.89	51.44	1059.30
017 00	ZP-25	1940	6950	A-8	7.824.465	396.974	HUARA	OF. LOS POZOS	INV. JUNIN	CORFO							
017 00	ZP-26	1950	6940	A-9	7.801.445	419.049	HUARA										
017 00 930	ZP-27	1950	6940	A-5	7.804.565	413.382	HUARA	JOSERNA	MERCK QCA.	SAACOL	1146.28	73.00	68.00	52.1	07.88	18.19	1128.09
017 00 931	ZP-28	1950	6940	A-4	7.804.797	415.920	HUARA	JOSERNA	MERCK QCA.	SAACOL	1151.35	90.00	70.00	121.2	09.88	25.23	1126.12
017 00 944	ZP-29	1950	6940	A-7	7.600.973	416.060	HUARA	BARCELONA	MERCK QCA.	SAACOL	1148.21	27.00	27.00	28.8		22.00	1124.21
017 00 927	ZP-30	1940	6940	D-1	7.808.558	428.151	HUARA	CURANA	LUIS PAPIC	CRUZAT		45.00	45.00	13.3	07.89	7.50	
017 00 933	ZP-31	1950	6940	A-6	7.804.561	418.317	HUARA	NEGREROS	MERCK QCA.	SAACOL		62.50	61.50	190.5	06.89	25.38	
017 00 955	PA-1				7.758.701	419.112	P. ALMONTE	CARMEN BAJO	W. GONZALEZ	–		28.80	28.80	385.0	05.90	24.99	
017 00 954	PA-2				7.758.732	418.926	P. ALMONTE	CARMEN BAJO	PETROMIN.	–		29.30	29.30	514.9	05.90	25.63	
017 00 950	PA-3				7.787.146	423.456	P. ALMONTE	HORNILLOS	S. RENACER	CRUZAT		84.00	84.00	91.5	05.89	50.00	
017 00 949	PA-4				7.787.242	424.929	P. ALMONTE	HORNILLOS	S. RENACER	CRUZAT		87.00	87.00	347.6	05.89	53.75	
017 00 951	PA-5				7.780.049	425.690	P. ALMONTE	MAPOCHO	M. MAPOCHO	SAACOL		79.00	79.00	250.8	05.91	55.00	
017 00 960	PA-6				7.741.050	442.800	P. ALMONTE	LA GUAYCA	TITO BARRERA	L. CARVAJAL		60.00	60.00	153.5	08.86	11.80	
017 00 963	PA-10				7.739.918	446.226	P. ALMONTE	CANCHONES	SENDOS	SENDOS		54.00	54.00	122.8		18.90	
017 00 962	PA-11				7.740.763	446.244	P. ALMONTE	CANCHONES	SENDOS	SAACOL		110.00	110.00	360.2	05.81	20.35	
017 00 961	PA-12				7.741.082	446.082	P. ALMONTE	CANCHONES	SENDOS	SAACOL		110.00	110.00	498.3	05.81	19.00	
017 00 959	PA-13				7.741.360	446.312	P. ALMONTE	CANCHONES	SENDOS	SAACOL		110.00	110.00	339.9	05.81	17.35	
017 00 953	PA-15				7.765.700	417.250	P. ALMONTE	EL BOSQUE	REGO	REGO	1050.00	87.00			11.86	27.00	1023.00
017 00 952	PA-16				7.766.500	419.200	P. ALMONTE	EL BOSQUE	REGO	REGO	1050.00	100.50			10.86		
017 00 968	GT-6				7.716.100	466.900	P. ALMONTE	CHACARILLA	CORFO	CORFO	1300.00	862.00	862.00		02.80	130.00	1170.00
017 00	MM-1				7.708.425	478.260											
017 00 982	VC-1				7.702.276	437.721	P. ALMONTE	SALAR BELLAVISTA	SOQUIMICH	CAPTAGUA		23.80	23.80	46.6	05.88	12.47	
017 00 975	VC-3				7.706.670	431.740	P. ALMONTE	OF. VICTORIA	SOQUIMICH	--						3.30	
017 00 976	VC-4				7.706.641	431.862	P. ALMONTE	OF. VICTORIA	SOQUIMICH	--		109.30	109.30	57.5	10.87	3.75	
017 00 980	VC-5				7.703.192	437.030	P. ALMONTE	OF. VICTORIA	SOQUIMICH	--		17.05	17.05	218.1	10.87	10.33	
017 00 983	VC-6				7.702.321	440.093	P. ALMONTE	OF. VICTORIA	SOQUIMICH	--		20.70	20.70	105.4	05.88	15.11	
017 00 978	VC-7				7.705.820	439.700	P. ALMONTE	OF. VICTORIA	SOQUIMICH	--		24.00	24.00	227.4	08.87	16.30	
017 00 972	VC-8				7.711.636	425.158	P. ALMONTE	OF. VICTORIA	SOQUIMICH	--	959.30	6.50	6.50	51.1	04.88	4.54	954.76
017 00 973	VC-9				7.711.375	428.925	P. ALMONTE	OF. VICTORIA	SOQUIMICH	--	959.22	20.00	20.00	255.4	04.88	4.54	954.58
017 00 977	VC-10				7.706.547	431.728	P. ALMONTE	OF. VICTORIA	SOQUIMICH	--	973.87	6.40	6.40	79.5	05.88	1.64	972.23
017 00 984	VC-12																
017 00 974	VC-14				7.711.363	438.022	P. ALMONTE	OF. VICTORIA	SOQUIMICH	--		34.50	34.50	83.4	05.88	13.80	
017 00 981	VC-15				7.702.448	427.250	P. ALMONTE	OF. VICTORIA	JULIAN NINA	--		8.00	8.00		07.88	2.00	
017 00 986	VC-16				7.698.050	443.960	P. ALMONTE	OF. GRANJA	URRUTICOEC.	CRUZAT		25.30	25.30	262.5	10.91	22.82	
017 00 987	VC-17	107			7.696.890	443.925	P. ALMONTE	OF. GRANJA	URRUTICOEC.	CRUZAT		26.00	26.00	27.8	10.91	19.25	
017 00 985	VC-18				7.699.080	444.500	P. ALMONTE	OF. GRANJA	URRUTICOEC.	CRUZAT		24.45	24.45	162.0	10.91	23.30	
017 00 988	VC-19				7.689.900	439.100	P. ALMONTE	OF. LA GRANJA	URRUTICOEC.	CRUZAT		37.70	37.70	79.2	10.91	17.23	
017 00 989	VC-20				7.688.843	435.598	P. ALMONTE	OF. LA GRANJA	URRUTICOEC.	CRUZAT		28.30	28.30	9.1	10.91	16.65	
017 00 990	VC-21				7.687.799	434.339	P. ALMONTE	CAMPAM. IRIS	URRUTICOEC.	CRUZAT		27.40	27.40	9.4	10.91	13.48	

Note: BNA Code and CORFO Code mentioned in this list are all temporary ones.

(STAIC WATER LEVEL)
mBGL: m BELOW THE GROUND LEVEL
mMSL: m ABOVE THE SEA LEVEL

Table B-III, 2.2 Result of Pumping Test (Pampa del Tamarugal)
< Resultado de Prueba de Bombeo (Pampa del Tamarugal) >

Well No.	Pumping Data (by Constant Test)				
	Static Water Level (m)	Pumping Rate (l/s)	Dynamic Water Level (m)	Drawdown (m)	Specific Yield (l/s/m)
J-C	52.03	2.25	75.75	23.72	0.09
J-D	46.05	22.5	52.53	6.48	3.47
J-E	13.73	27.00	17.72	3.99	6.77
J-F	57.00	20.00	69.15	12.15	1.65
J-3	9.17	5.00	16.05	6.88	0.73
J-4	46.22	4.40	48.20	1.98	2.22
J-5	29.08	5.00	29.68	0.60	8.33
J-6	14.04	4.04	29.70	15.66	0.26
J-7	7.94	5.00	9.78	1.84	2.72
J-8	37.99	3.34	39.52	1.53	2.18
J-9	13.97	5.00	16.57	2.60	1.92

Table B-III, 2.3 Aquifer Constans (JICA Wells)
<Coeficientes de Acuíferos (Pozos JICA)>

Well No.	Aquifer Constant		Test Method				Average
			Theis		Jacob		
			Constant	Recovery	Constant	Recovery	
J-C	Transmissibility	(m3/s/m)	5.47E-05	1.22E-04	9.00E-05	1.17E-04	9.59E-05
	Storage Coefficient		1.46E-01		8.25E-03		7.71E-02
	Permeability	(cm/sec)	7.02E-05	1.56E-04	1.15E-04	1.50E-04	1.23E-04
J-D	Transmissibility	(m3/s/m)	6.49E-03	2.85E-02	7.64E-03	2.71E-02	1.74E-02
	Storage Coefficient		6.49E-06		7.86E-08		3.28E-06
	Permeability	(cm/sec)	6.75E-03	2.97E-02	7.95E-03	2.82E-02	1.82E-02
J-E	Transmissibility	(m3/s/m)	1.26E-02	3.67E-03	9.77E-03	3.79E-03	7.46E-03
	Storage Coefficient		8.40E-03		1.43E-04		4.27E-03
	Permeability	(cm/sec)	1.23E-02	3.60E-03	9.57E-03	3.71E-03	7.30E-03
J-F	Transmissibility	(m3/s/m)	4.99E-04	3.10E-04	2.93E-03	2.80E-04	1.00E-03
	Storage Coefficient		4.99E-07		2.63E-44		2.50E-07
	Permeability	(cm/sec)	4.75E-04	2.95E-04	2.79E-03	2.67E-04	9.57E-04
J-3	Transmissibility	(m3/s/m)	1.13E-03	1.65E-03	8.79E-04	1.61E-03	1.32E-03
	Storage Coefficient		3.16E-04		5.01E-03		2.66E-03
	Permeability	(cm/sec)	1.89E-03	2.76E-03	1.47E-03	2.69E-03	2.20E-03
J-4	Transmissibility	(m3/s/m)	3.32E-03	3.90E-03	1.44E-03	3.89E-03	3.14E-03
	Storage Coefficient		7.96E-06		3.12E-02		1.56E-02
	Permeability	(cm/sec)	5.53E-03	6.49E-03	2.40E-03	6.47E-03	5.22E-03
J-5	Transmissibility	(m3/s/m)	1.17E-02	3.92E-03	1.61E-02	3.91E-03	8.91E-03
	Storage Coefficient		1.88E-05		9.78E-09		9.40E-06
	Permeability	(cm/sec)	1.08E-02	3.62E-03	1.49E-02	3.61E-03	8.23E-03
J-6	Transmissibility	(m3/s/m)	3.44E-04	2.10E-04	2.45E-04	2.02E-04	2.50E-04
	Storage Coefficient		1.38E-04		6.44E-03		3.29E-03
	Permeability	(cm/sec)	4.40E-04	2.69E-04	3.14E-04	2.59E-04	3.21E-04
J-7	Transmissibility	(m3/s/m)	4.10E-03	3.28E-03	7.17E-03	3.22E-03	4.44E-03
	Storage Coefficient		1.07E-04		2.24E-10		5.35E-05
	Permeability	(cm/sec)	4.89E-03	3.91E-03	8.56E-03	3.84E-03	5.30E-03
J-8	Transmissibility	(m3/s/m)	2.66E-03	5.43E-03	3.99E-03	5.34E-03	4.36E-03
	Storage Coefficient		2.13E-03		7.98E-06		1.07E-03
	Permeability	(cm/sec)	3.17E-03	6.46E-03	4.75E-03	6.35E-03	5.18E-03
J-9	Transmissibility	(m3/s/m)	4.21E-03	2.91E-03	2.53E-03	2.66E-03	3.08E-03
	Storage Coefficient		2.36E-03		1.76E-03		2.06E-03
	Permeability	(cm/sec)	4.84E-03	3.34E-03	2.91E-03	3.06E-03	3.54E-03

Table B-III, 2.4 Aquifer Constants of Existing Wells

<Coeficientos de Acuíferos de Pozos Existentes>

(Zapiga-Dolores-Negreilos Area)

BNA NO.	Discharge Rate (l/s)	Specific Yield (l/sec/m)	Transmissibility (m3/d/m)	Permeability (cm/sec)	Storativity	Remarks
100-4	7.0	7.14	96	8.89E-03	3.32	J
102-0	15.0	10.00	1031	1.17E-01	1.11	J
101-5	2.5	2.50				J
170	4.0	0.31				J
172	5.0	0.47				J
168	9.0	0.62				J
171	7.0	0.82				J
173	7.0	0.92				J
174	7.5	0.99				J
101-2	6.5	4.06				J
928	6.0	1.79	520	4.15E-02		C
925		1.21	164	1.89E-02		C
923	3.0	0.70	398	5.12E-02		C
922	3.0	0.89	135	1.30E-02		C
921	3.0	1.10	258	2.99E-02		C
936	0.5	0.03	1	2.85E-05	2.42	J
935	0.5	0.06	9	8.16E-04	4.94E-02	J
938	1.0	0.09	3	1.59E-04	1.92	J
941	1.0	0.24	53	3.06E-03	9.99E-10	J
930	8.0	0.60	110	4.55E-03	2.84E-04	J
927		0.15	23	1.75E-03		C
933	5.5	2.20	173	9.02E-03		J
Average		1.68	212	0.0214	1.26	

(Huara Area)

BNA NO.	Discharge Rate (l/s)	Specific Yield (l/sec/m)	Transmissibility (m3/d/m)	Permeability (cm/sec)	Storativity	Remarks
190-6			1440			C
946	2.2	4.1	39	1.56E-04	5.26E-07	J
949		4.0	935	3.37E-02	6.00E-04	C
951	18.0	2.9	284	2.35E-02		J
Average		3.7	675	0.0191	0.0003	

(Pica-Matilla Area)

BNA NO.	Discharge Rate (l/s)	Specific Yield (l/sec/m)	Transmissibility (m3/d/m)	Permeability (cm/sec)	Storativity	Remarks
117-5	6.0	0.08				J
252-k	7.5	0.38				J
253-6	1.1	0.14				J
265-1	42.0	1.89				J
272-4	2.0	0.04				J
389-5	8.0	0.16	6	8.43E-05	2.81E-01	J
390-9	1.0	0.04	312	1.39E-02	4307	J
391 or 392			155			C
394-1	1.5	0.06				J
401-8			49			C
403-4	5.0	0.43				J
Average		0.36	130	6.99E-03	2.15E+03	0

(Pozo Almonte-Canchones-Pintados Area)

BNA NO.	Discharge Rate (l/s)	Specific Yield (l/sec/m)	Transmissibility (m3/d/m)	Permeability (cm/sec)	Storativity	Remarks Rate (l/
129-9	36.0	5.14				J
130-2		1.66	47		4.29E-02	C
131-0	60.0	3.82				J
132-9	30.0	2.61				J
136-1	3.8	0.40	9	8.51E-04	4.14E-01	J
200-7	6.0	0.12				J
202-3	64.0	10.67				J
206-6	25.0	2.08				J
207-4	3.5	0.81	1094	1.06E-01	2.62E-03	J
221-k	40.0	6.78				J
222-8	70.0	4.43	450			C
226-0	47.0	2.72				J
229-5	4.0	0.21				J
232-5	24.0	2.00				J
234-1			4280			C
240-6	20.0	3.33				J
357-7	120.0	5.36				J
366-6	120.0	4.72				J
415-8	9.3	3.10				J
421-2	5.5	2.75				J
423-9	70.0	1.37	920			C
955		4.46	915	2.52E-02	5.00E-04	C
Average		3.26	1102	0.044	0.115	Average

(Oficina Victoria-Bellavista Area)

BNA NO.	Discharge Rate (l/s)	Specific Yield (l/sec/m)	Transmissibility (m3/d/m)	Permeability (cm/sec)	Storativity	Remarks
432-b	25.0	1.51				432-b
445-k	26.0		420	1.39E-02	3.30E-01	J
985		3.04	220		3.00E-03	C
986		0.32	81		5.00E-02	C
987		0.32	157		1.00E-01	C
Average		1.30	219.5	0.014	0.121	Average

(TOTAL PAMPA AREA: except Pica-Matilla Area)

BNA NO.	Discharge Rate (l/s)	Specific Yield (l/sec/m)	Transmissibility (m3/d/m)	Permeability (cm/sec)	Storativity	Remarks
Average		2.43	492	0.024	0.574	

(Note) C: Existing Data.
J: Estimated by the Study Team on the basis of existing test data.

Table B-III. 2.5 Estimation of Groundwater Storage

<Estimacion de Reservas de Agua Subterraneas>

DEPTH	ZONE 1		ZONE2		ZONE 3		ZONE4		ZONE 5		ZONE 6	
(mBSL)	(Sect. A-B)		(SECT. B-C)		(Sect. C-D)		(Sect.D-E)		(Sect. E-F)		(Sect. F-G)	
	(x million m3)		(x million m3)		(x million m3)		(x million m3)		(x million m3)		(x million m3)	
		SUM		SUM		SUM		SUM		SUM		SUM
10	537	537	128	128	163	163	161	161	175	175	68	68
20	502	1,039	120	248	154	317	154	315	169	344	67	135
30	460	1,499	109	357	144	461	147	462	163	507	65	200
40	425	1,924	99	456	130	591	135	597	156	663	64	264
50	404	2,328	92	548	110	701	115	712	147	810	62	326
60	365	2,693	86	634	78	779	83	795	136	946	60	386
70	330	3,023	80	714	43	822	49	844	126	1,072	58	444
80	249	3,272	71	785	33	855	47	891	119	1,191	56	500
90	163	3,435	50	835	12	867	44	935	111	1,302	54	554
100	123	3,558	31	866	0	867	41	976	104	1,406	53	607
110	80	3,638	20	886	0	867	37	1,013	96	1,502	51	658
120	0	3,638	0	886	0	867	31	1,044	88	1,590	49	707
130	0		0	886	0	867	13	1,057	69	1,659	48	755
140	0	0	0	886	0	867	0	1,057	56	1,715	47	802
150	0	0	0	886	0	867	0	1,057	54	1,769	46	848
160	0	0	0	886	0	867	0	1,057	52	1,821	45	893
170	0	0	0	886	0	867	0	1,057	50	1,871	43	936
180	0	0	0	886	0	867	0	1,057	48	1,919	42	978
190	0	0	0	886	0	867	0	1,057	46	1,965	41	1,019
200	0	0	0	886	0	867	0	1,057	43	2,008	37	1,056
210	0	0	0	886	0	867	0	1,057	40	2,048	30	1,086
220	0	0	0	886	0	867	0	1,057	29	2,077	22	1,108
230	0	0	0	886	0	867	0	1,057	0	2,077	8	1,116
240	0	0	0	886	0	867	0	1,057	0	2,077	0	1,116
	3,638		886		867		1,057		2,077		1,116	

DEPTH	ZONE 7		ZONE 8		ZONE 9		ZONE 10		ZONE 11		ZONE 12		TOTAL	
(mBSL)	(Sect. G-H)		(Sect. H-I)		(Sect. I-J)		(Sect. J-K)		(Sect. K-L)		(Sect L-C Gordo)		(Whole Area)	
	(x million m3)		(x million m3)		(x million m3)		(x million m3)		(x million m3)		(x million m3)		(x million m3)	
		SUM		SUM		SUM		SUM		SUM		SUM		SUM
10	113	113	229	229	74	74	153	153	351	351	161	161	2,316	2,316
20	110	223	224	453	116	190	218	371	321	672	160	321	2,317	4,633
30	107	330	221	674	116	306	209	580	305	977	156	477	2,204	6,837
40	105	435	218	892	116	422	205	785	294	1,271	152	629	2,102	8,939
50	103	538	215	1,107	116	538	198	983	281	1,552	148	777	1,991	10,930
60	101	639	213	1,320	115	653	193	1,176	271	1,823	145	922	1,848	12,778
70	99	738	211	1,531	115	768	191	1,367	262	2,085	140	1,062	1,704	14,482
80	98	836	207	1,738	115	883	188	1,555	251	2,336	132	1,194	1,567	16,049
90	96	932	205	1,943	114	997	185	1,740	235	2,571	122	1,316	1,393	17,442
100	94	1,026	203	2,146	114	1,111	181	1,921	214	2,785	108	1,424	1,268	18,710
110	93	1,119	202	2,348	114	1,225	177	2,098	193	2,978	94	1,518	1,157	19,867
120	92	1,211	200	2,548	113	1,338	171	2,269	173	3,151	50	1,568	967	20,834
130	90	1,301	198	2,746	113	1,451	154	2,423	133	3,284	41	1,609	859	21,693
140	88	1,389	195	2,941	112	1,563	137	2,560	62	3,346	15	1,624	714	22,407
150	86	1,475	193	3,134	111	1,674	131	2,691	26	3,372	0	1,624	647	23,054
160	84	1,559	189	3,323	109	1,783	123	2,814	19	3,391	0	1,624	621	23,675
170	82	1,641	183	3,506	106	1,889	112	2,926	7	3,398	0	1,624	586	24,261
180	80	1,721	178	3,684	103	1,992	104	3,030	0	3,398	0	1,624	556	24,817
190	78	1,799	171	3,855	100	2,092	101	3,131	0	3,398	0	1,624	537	25,354
200	71	1,870	163	4,018	95	2,187	98	3,229	0	3,398	0	1,624	508	25,862
210	61	1,931	153	4,171	88	2,275	91	3,320	0	3,398	0	1,624	464	26,326
220	52	1,983	134	4,305	70	2,345	67	3,387	0	3,398	0	1,624	374	26,700
230	38	2,021	80	4,385	28	2,373	24	3,411	0	3,398	0	1,624	178	26,878
240	10	2,031	20	4,405	0	2,373	0	3,411	0	3,398	0	1,624	30	26,908
	2,031		4,405		2,373		3,411		3,398		1,624		26,908	

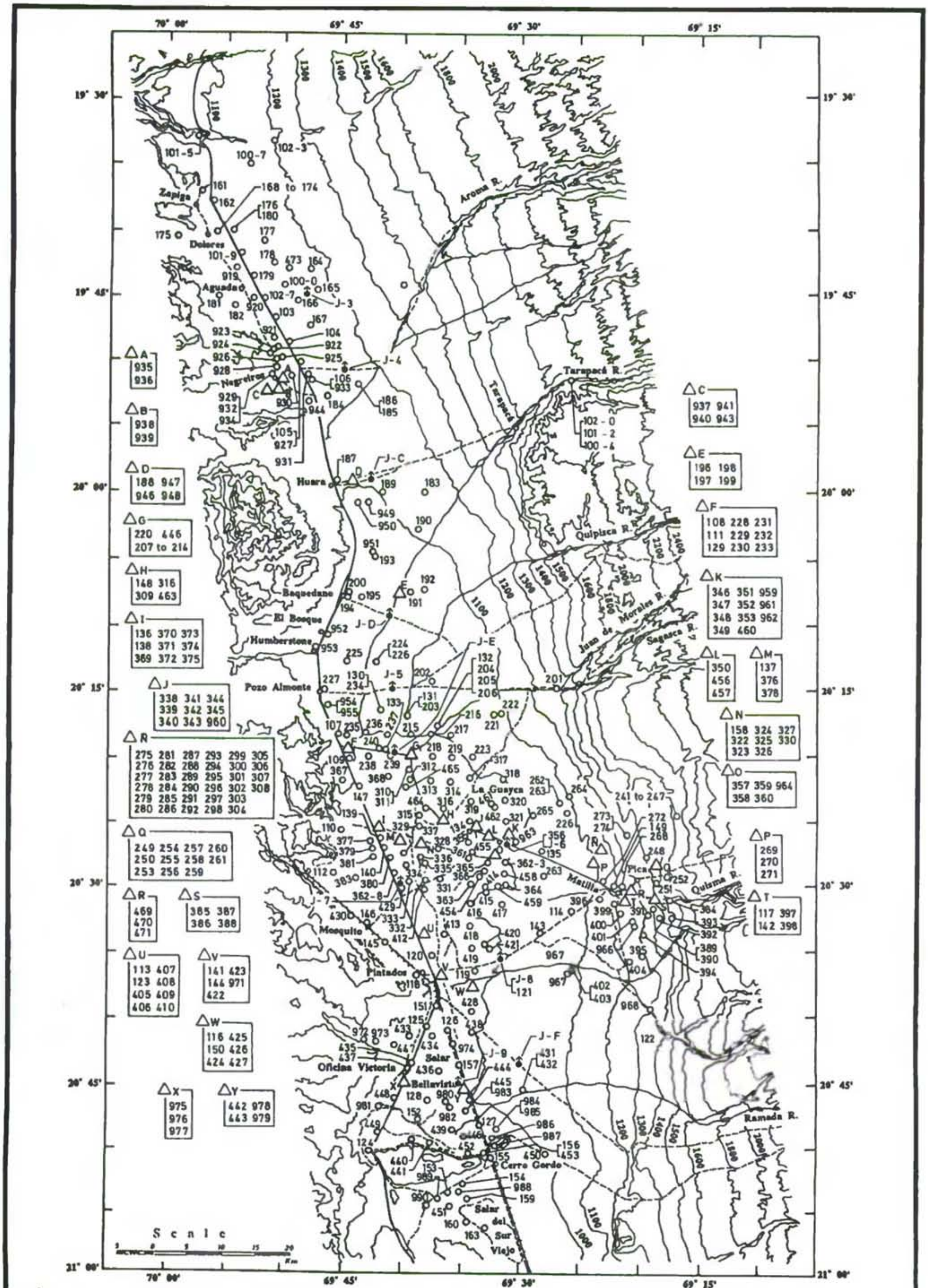

Fig. B-III. 2.1 (1) Well Location (Pampa del Tamarugal)

< Ubicación de Sondajes (Pampa del Tamarugal)>

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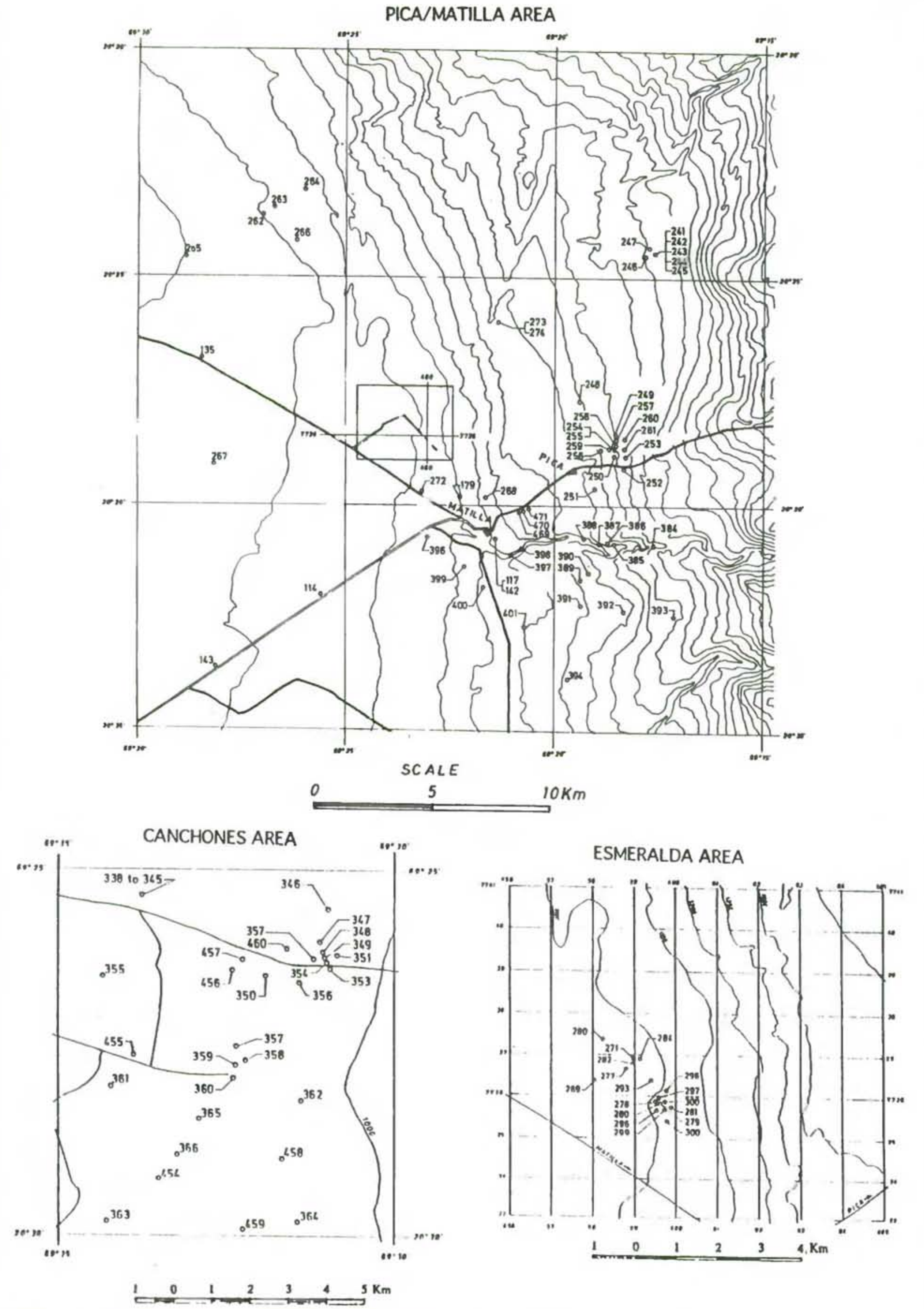
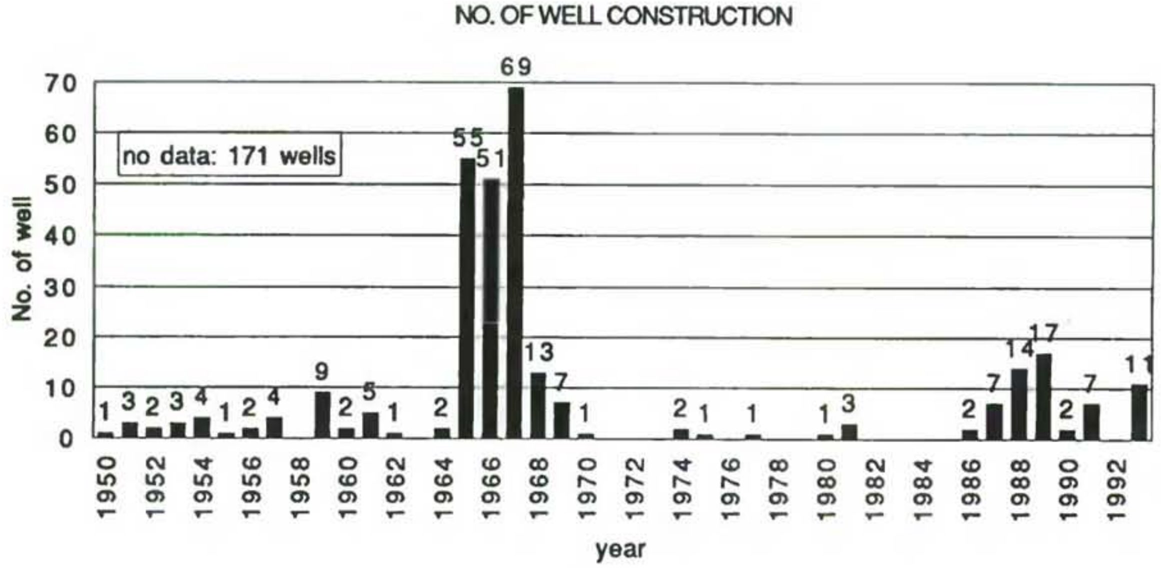


Fig. B-III. 2.1 (2) **Well Location (Canchones and Pica Area)**

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



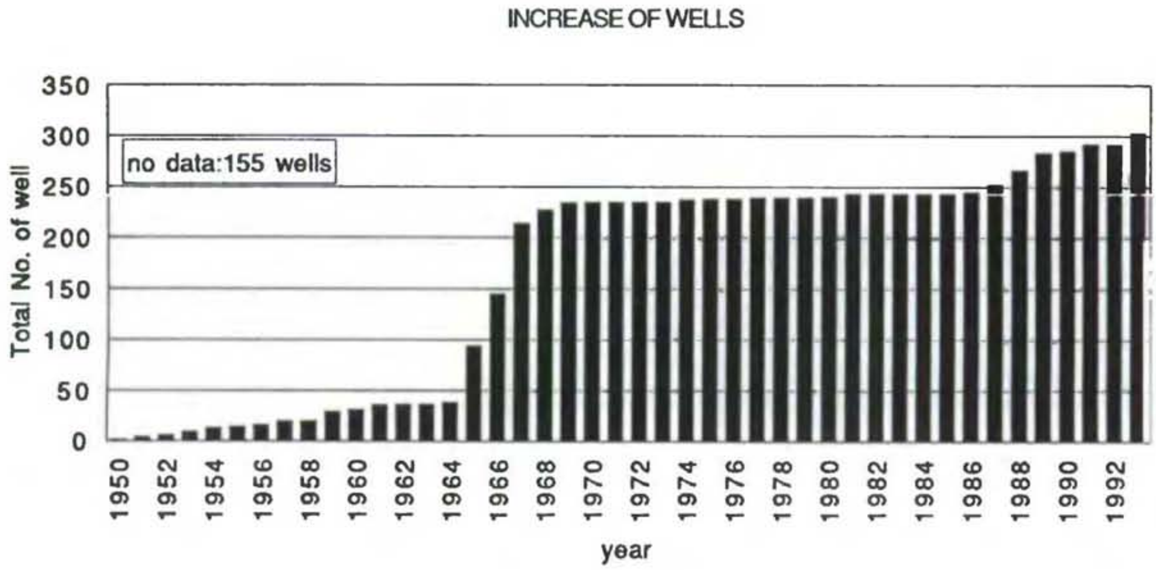


Fig. B-III. 2.2 Well Construction (Pampa del Tamarugal)

< Construcción de Sondajes (Pampa del Tamarugal)>

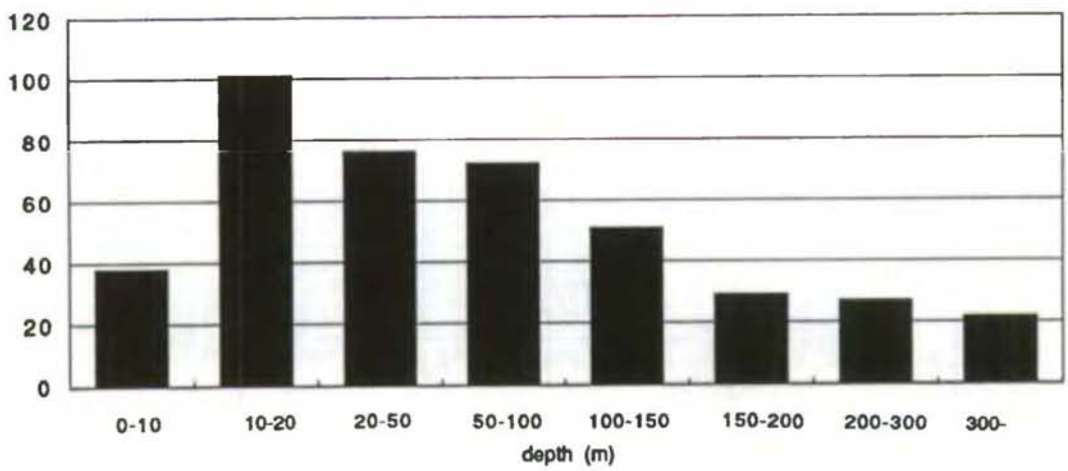


Fig. B-III, 2.3 Depth of Well (Pampa del Tamarugal)

<Profundidad de Pozos (Pampa del Tamarugal)>

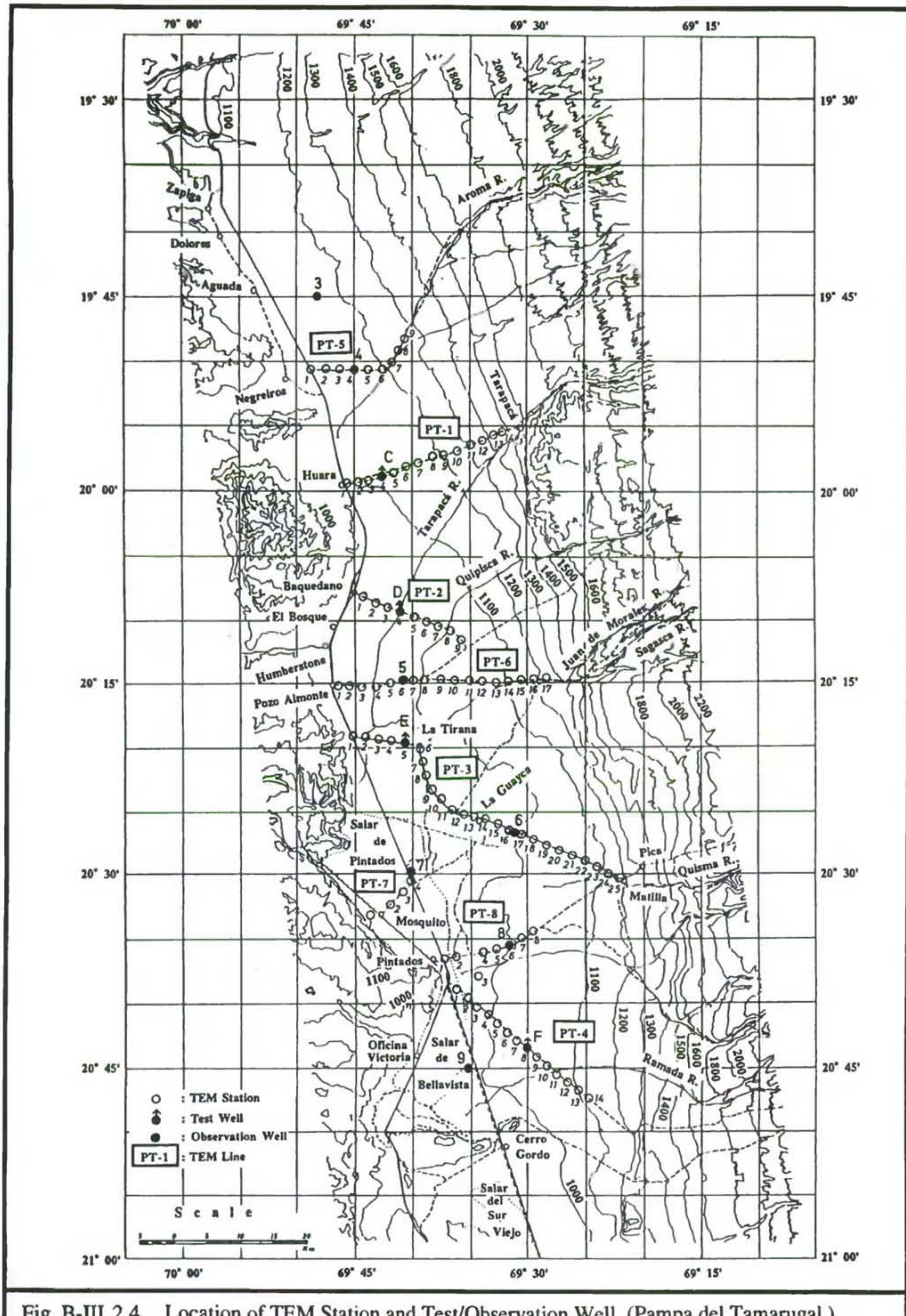


Fig. B-III, 2.4 Location of TEM Station and Test/Observation Well (Pampa del Tamarugal)

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

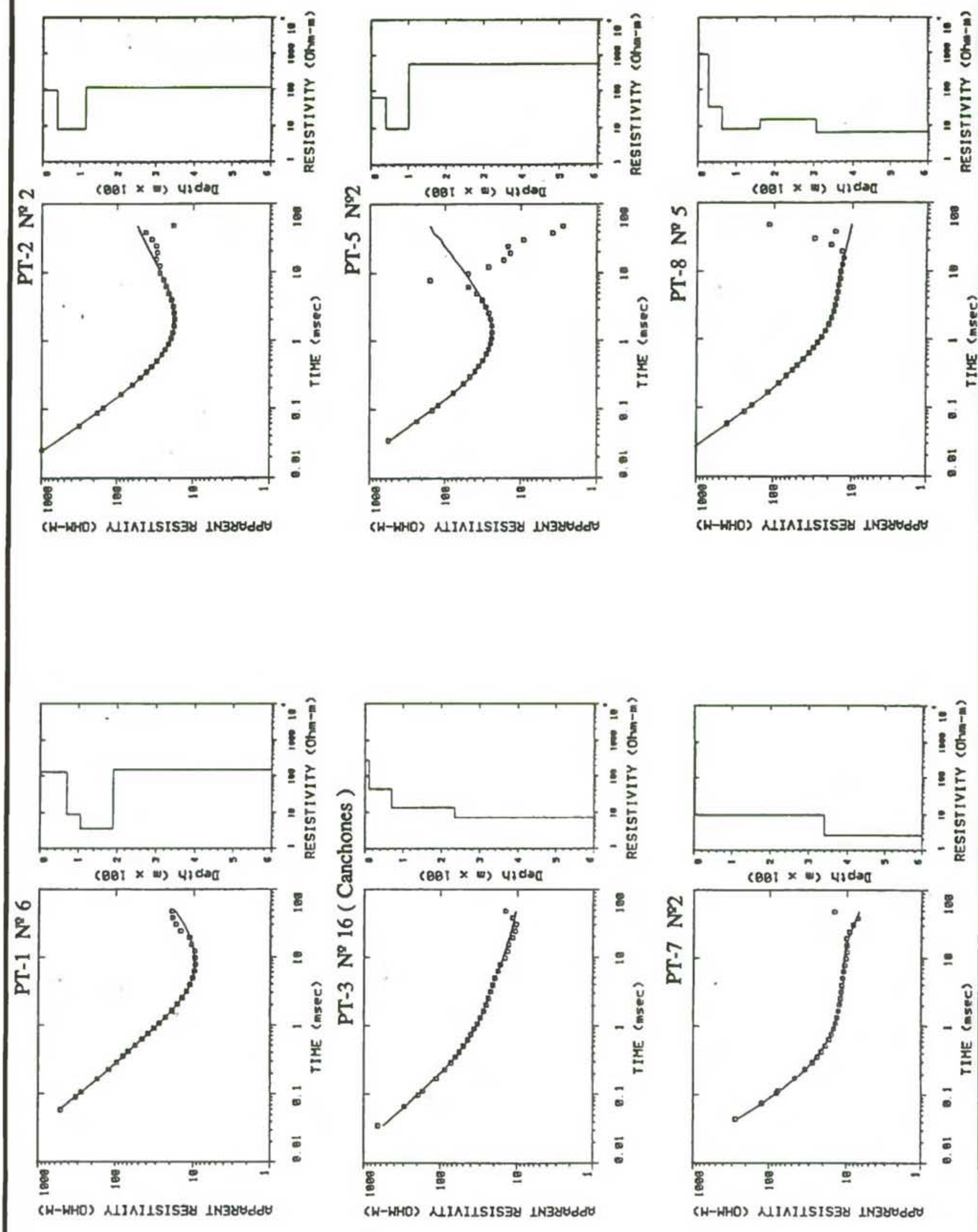


Fig. B-III, 2.5 Measured Apparent Resistivity Curves and Inverted Geoelectrical Section in Pampa del Tamarugal Area

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

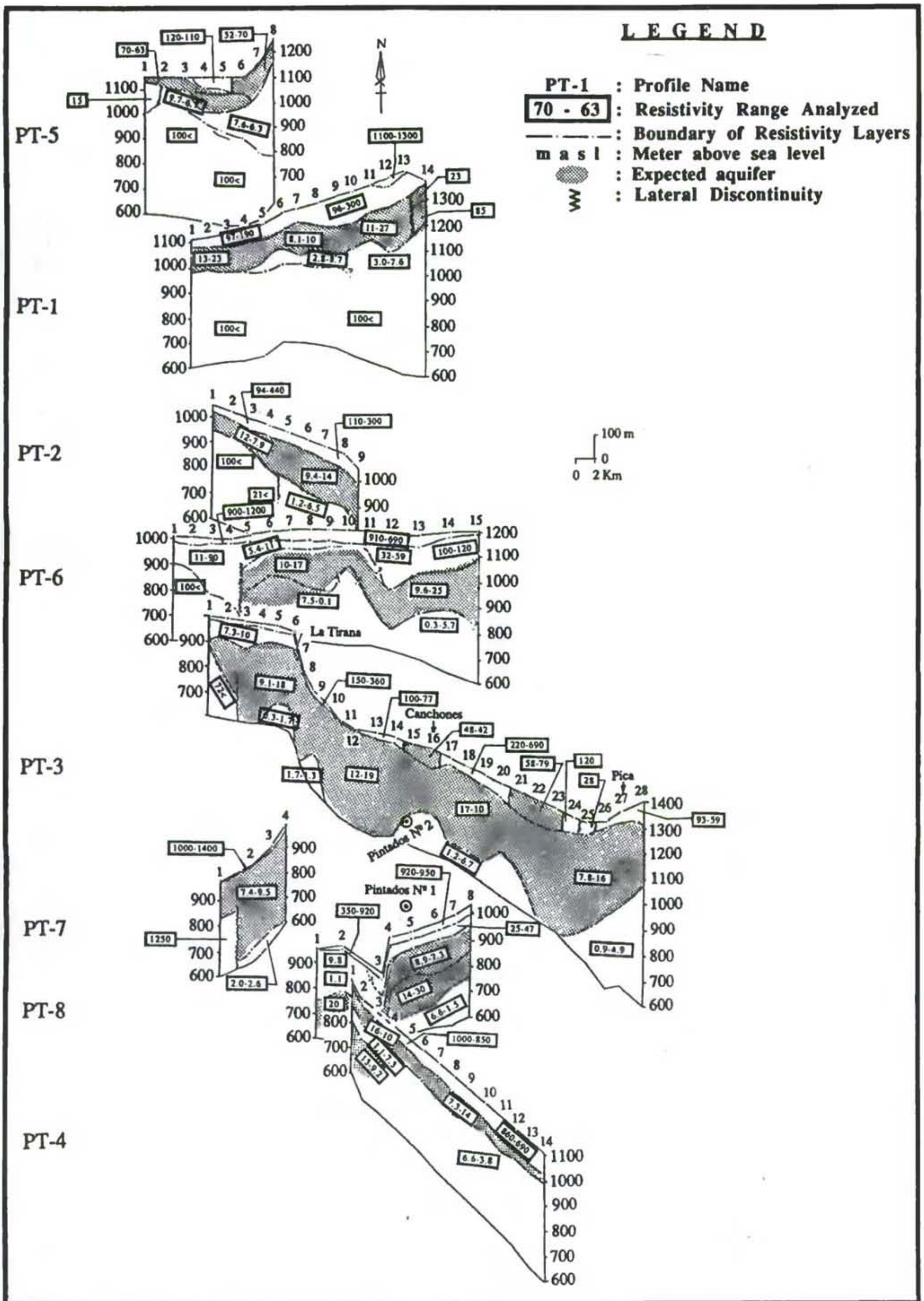


Fig. B-III, 2.6 Geoelectric Profiles Contructed from all TEM Soundings in Pampa del Tamarugal Area

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

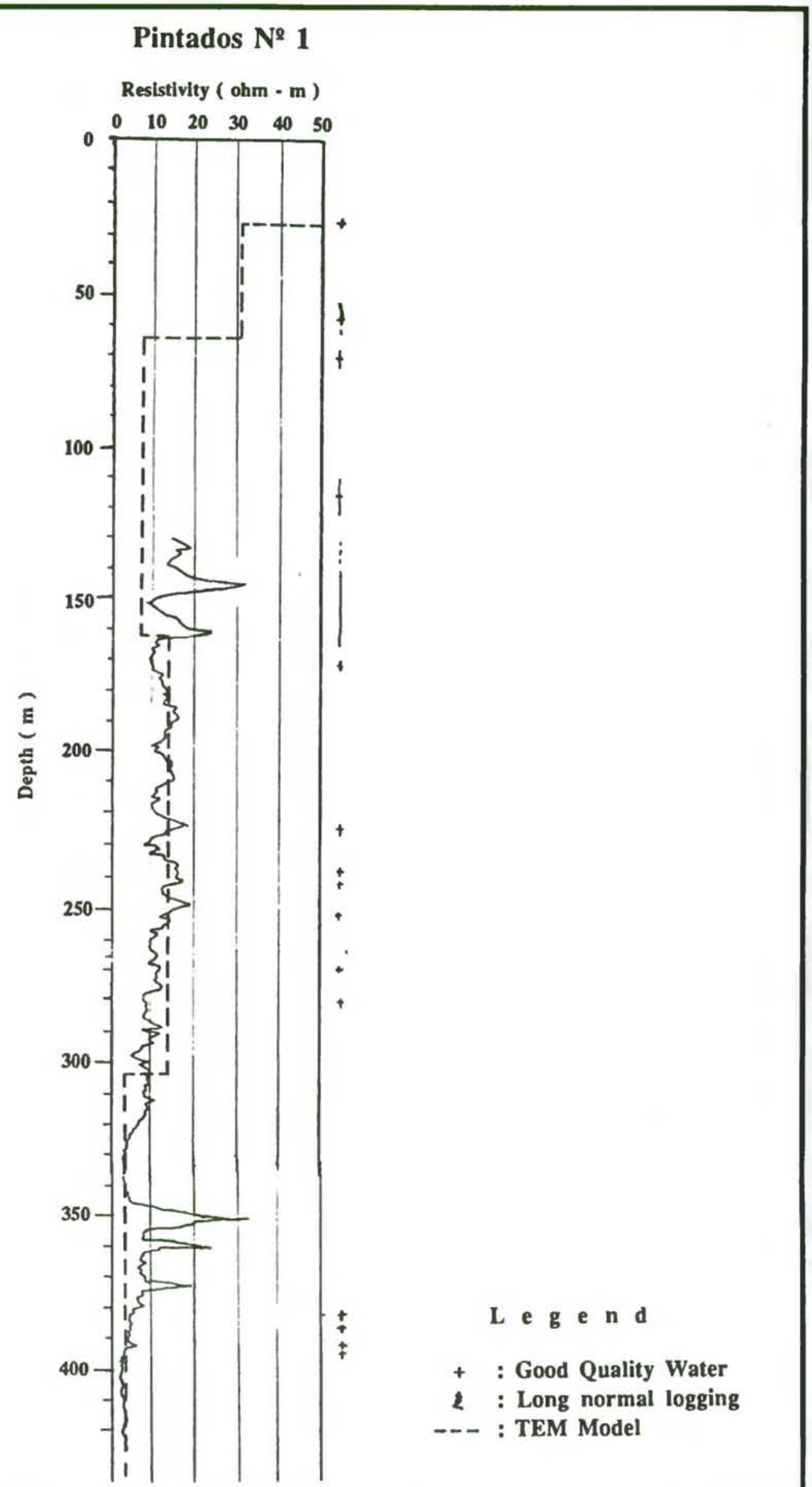
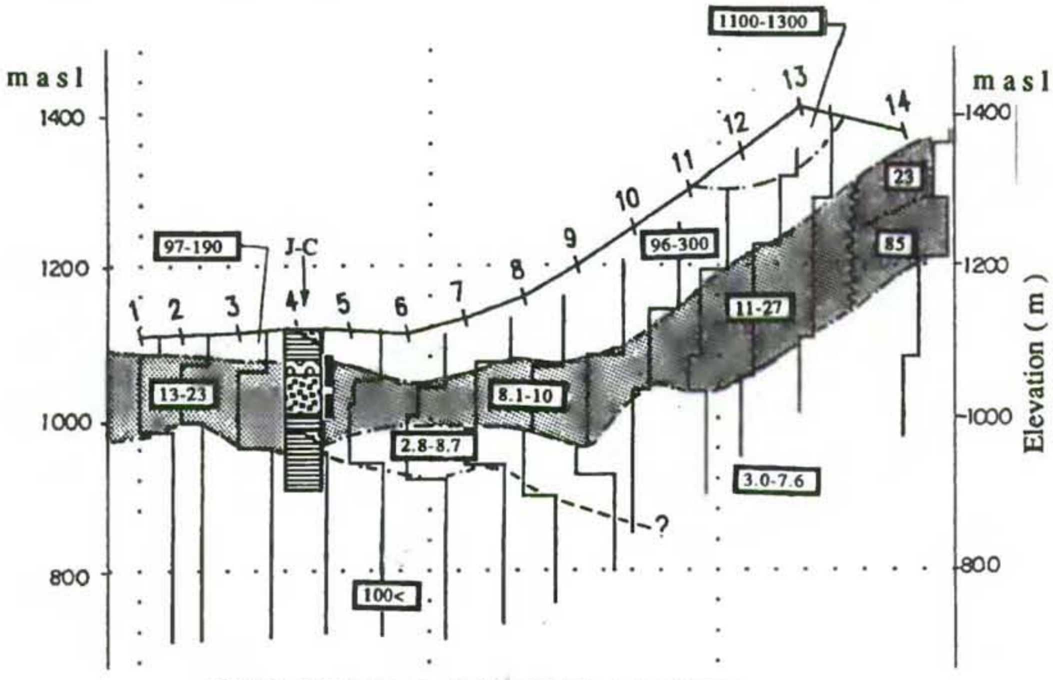
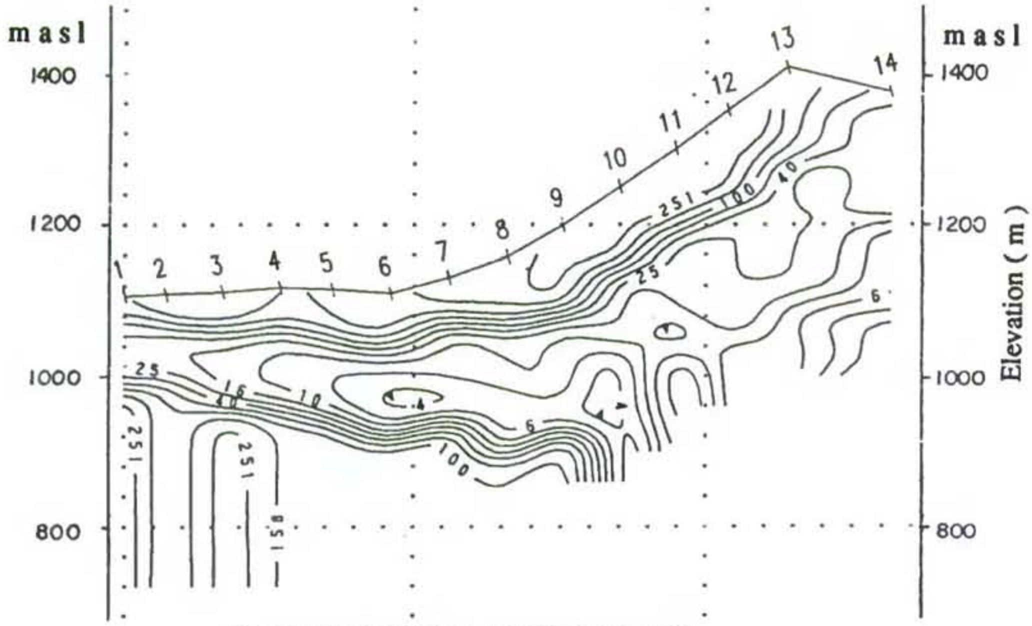


Fig. B-III, 2.7 Comparison of Geoelectric Section Derived from Well and TEM Sounding

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



ANALYZED LAYERED MODEL



RESISTIVITY INVERSION

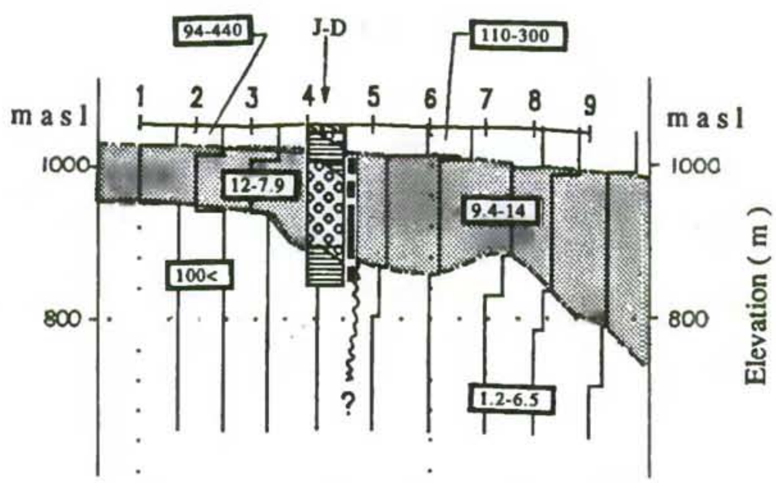
LEGEND

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

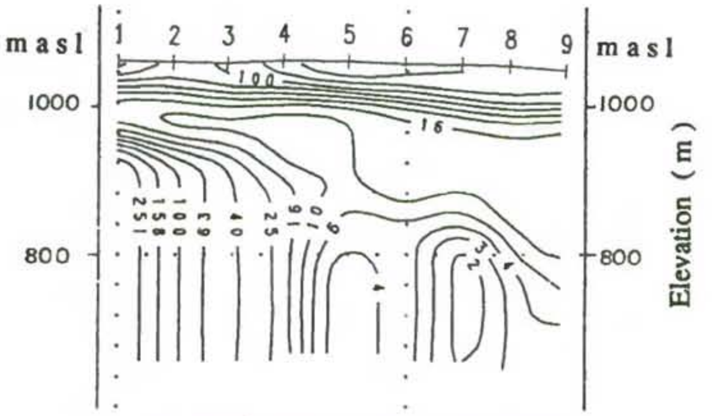
Boring Log
Screen

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**

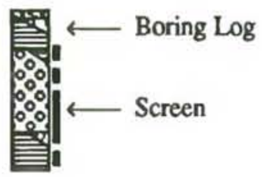


Fig. B-III, 2.9 Analyzed Resistivity Profile of PT-2 in Pampa del Tamarugal Area

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

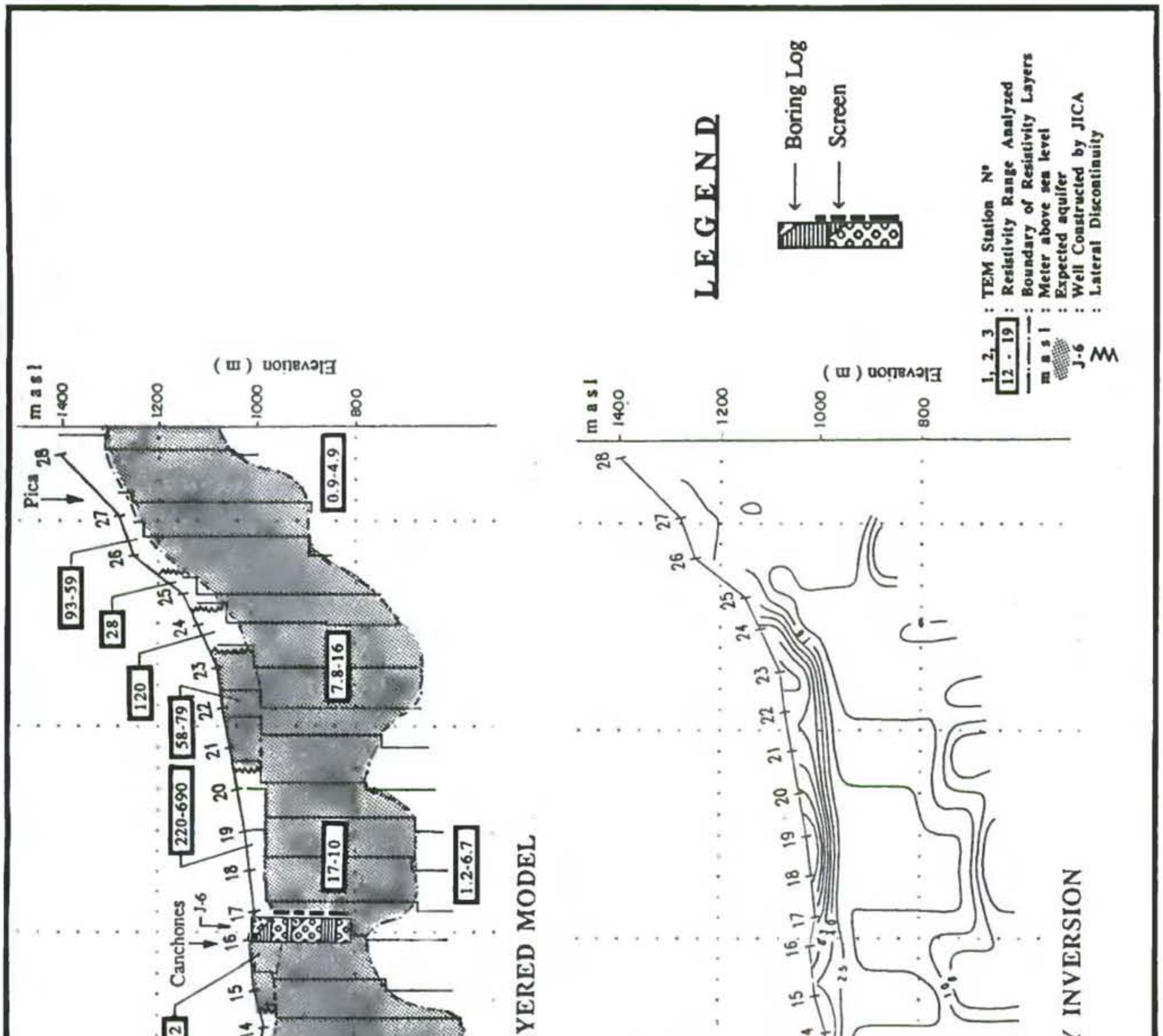


Fig. B-III, 2.10 Analyzed Resistivity Profile of PT-3 in Pampa del Tamarugal Area

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

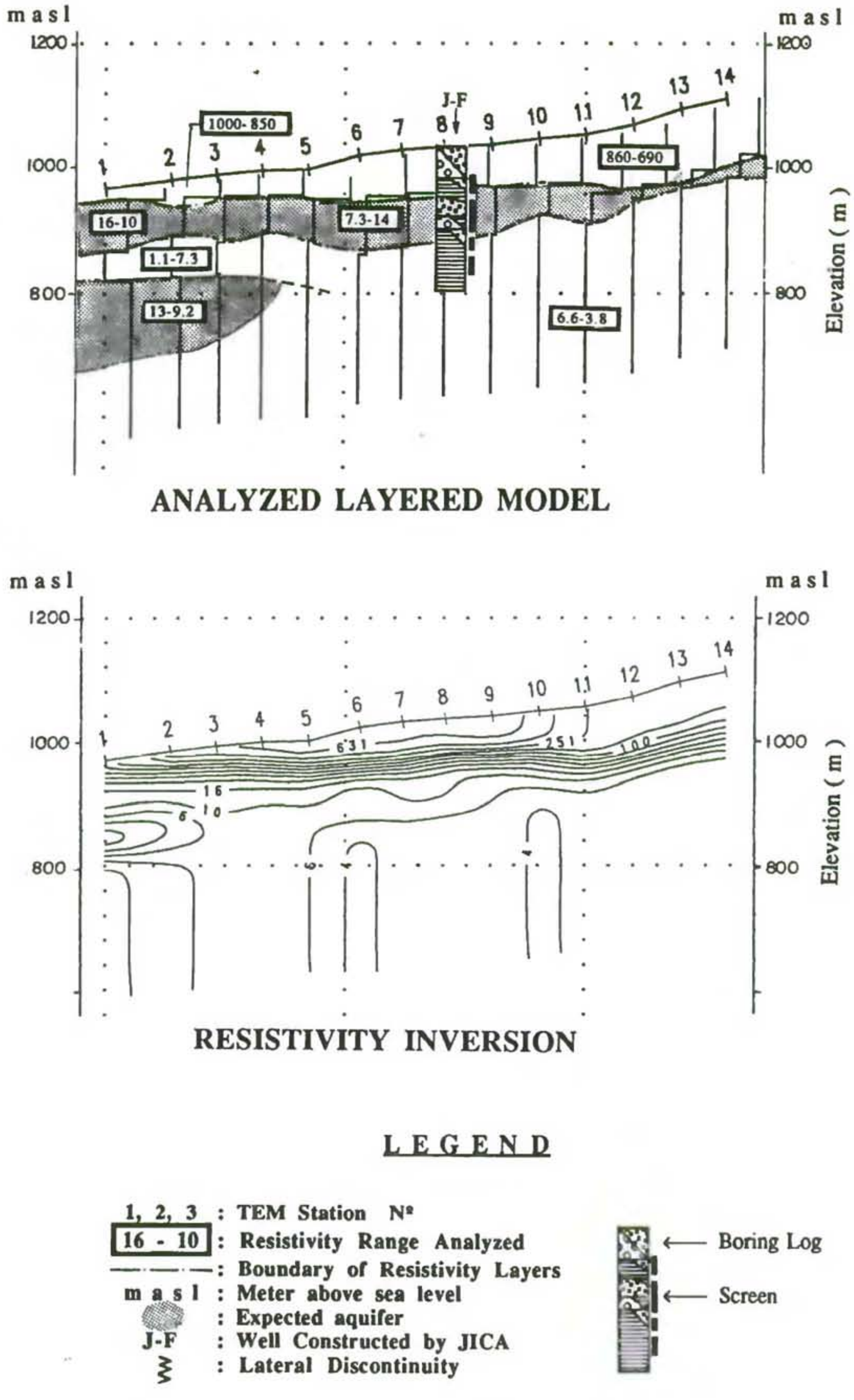
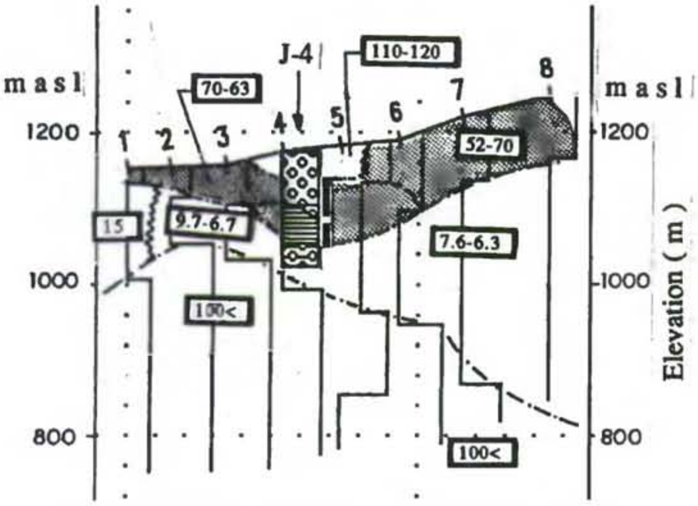
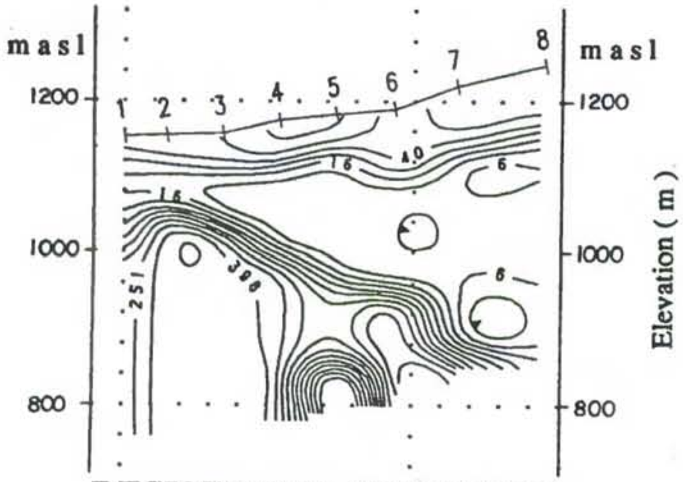


Fig. B-III, 2.11 Analyzed Resistivity Profile of PT-4 in Pampa del Tamarugal Area

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



ANALYZED LAYERED MODEL



RESISTIVITY INVERSION

LEGEND

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

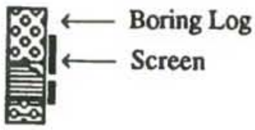
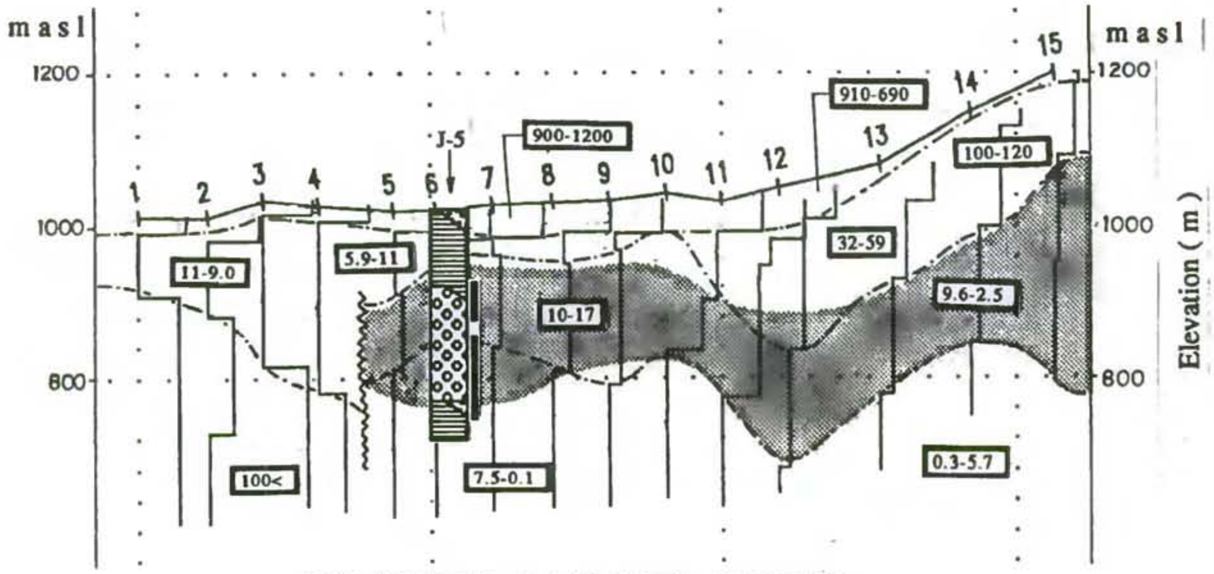
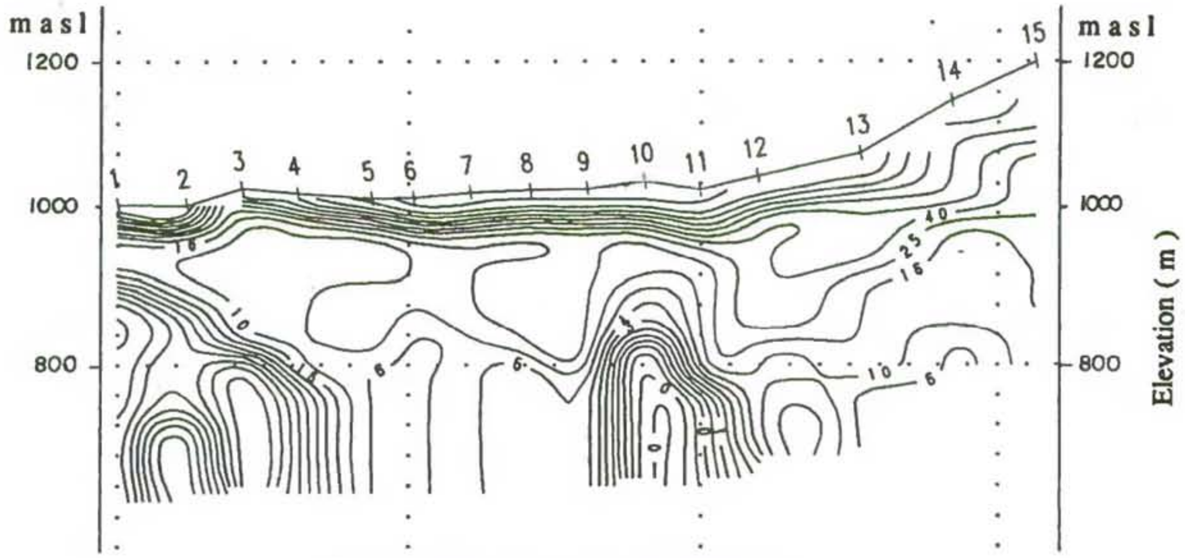


Fig. B-III, 2.12 Analyzed Resistivity Profile of PT-5 in Pampa del Tamarugal Area

< 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
m a s l : Meter above sea level
: Expected aquifer
J-5 : Well Constructed by JICA
: Lateral Discontinuity

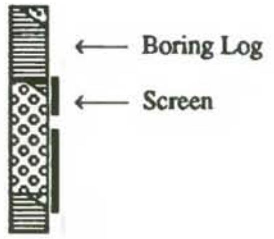
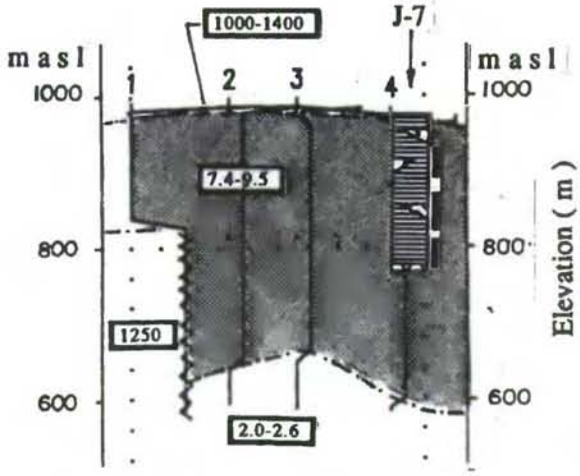
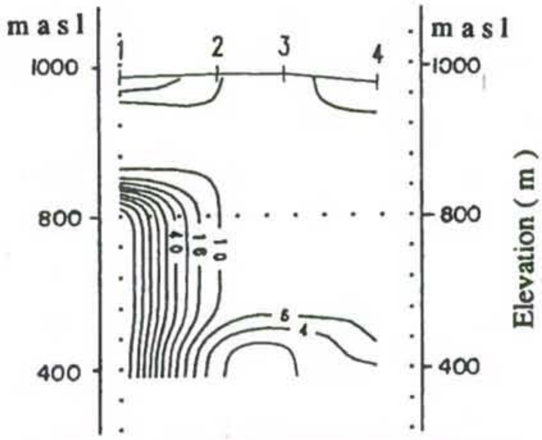


Fig. B-III, 2.13 Analyzed Resistivity Profile of PT-6 in Pampa del Tamarugal Area

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



ANALYZED LAYERED MODEL



RESISTIVITY INVERSION

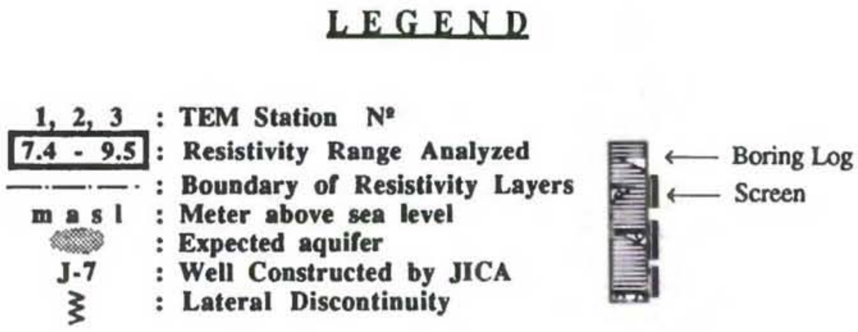
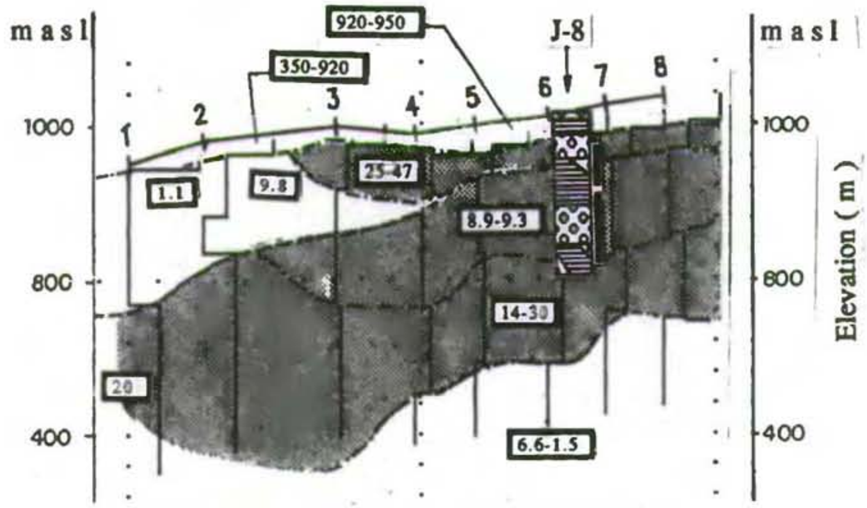
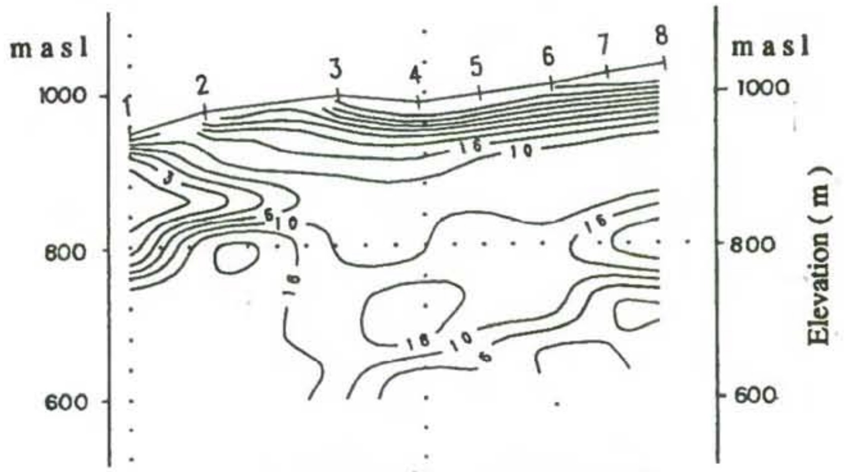


Fig. B-III, 2.14 Analyzed Resistivity Profile of PT-7 in Pampa del Tamarugal Area

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



ANALYZED LAYERED MODEL



RESISTIVITY INVERSION

LEGEND

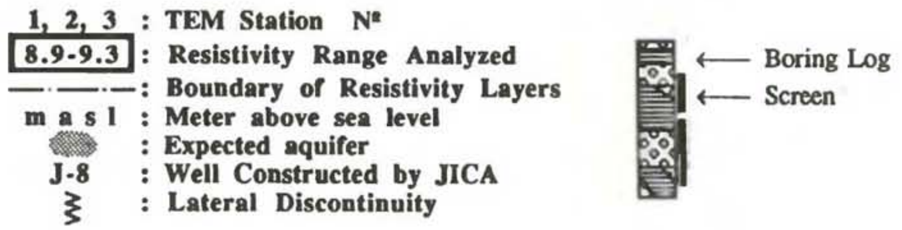


Fig. B-III, 2.15 Analyzed Resistivity Profile of PT-8 in Pampa del Tamarugal Area

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

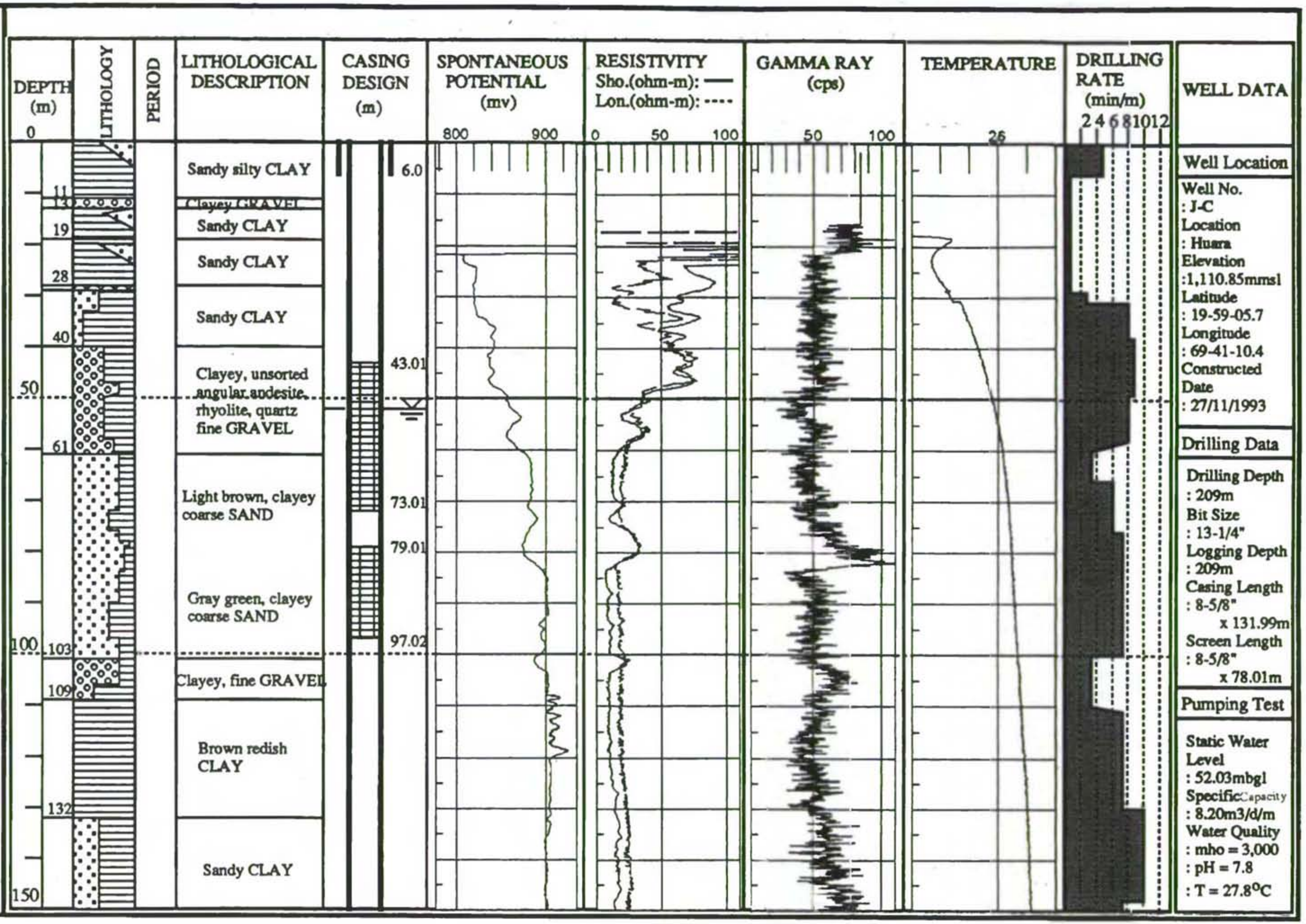


Fig. B-III, 2.16 Well Data for J-C (Sheet No. 1)

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

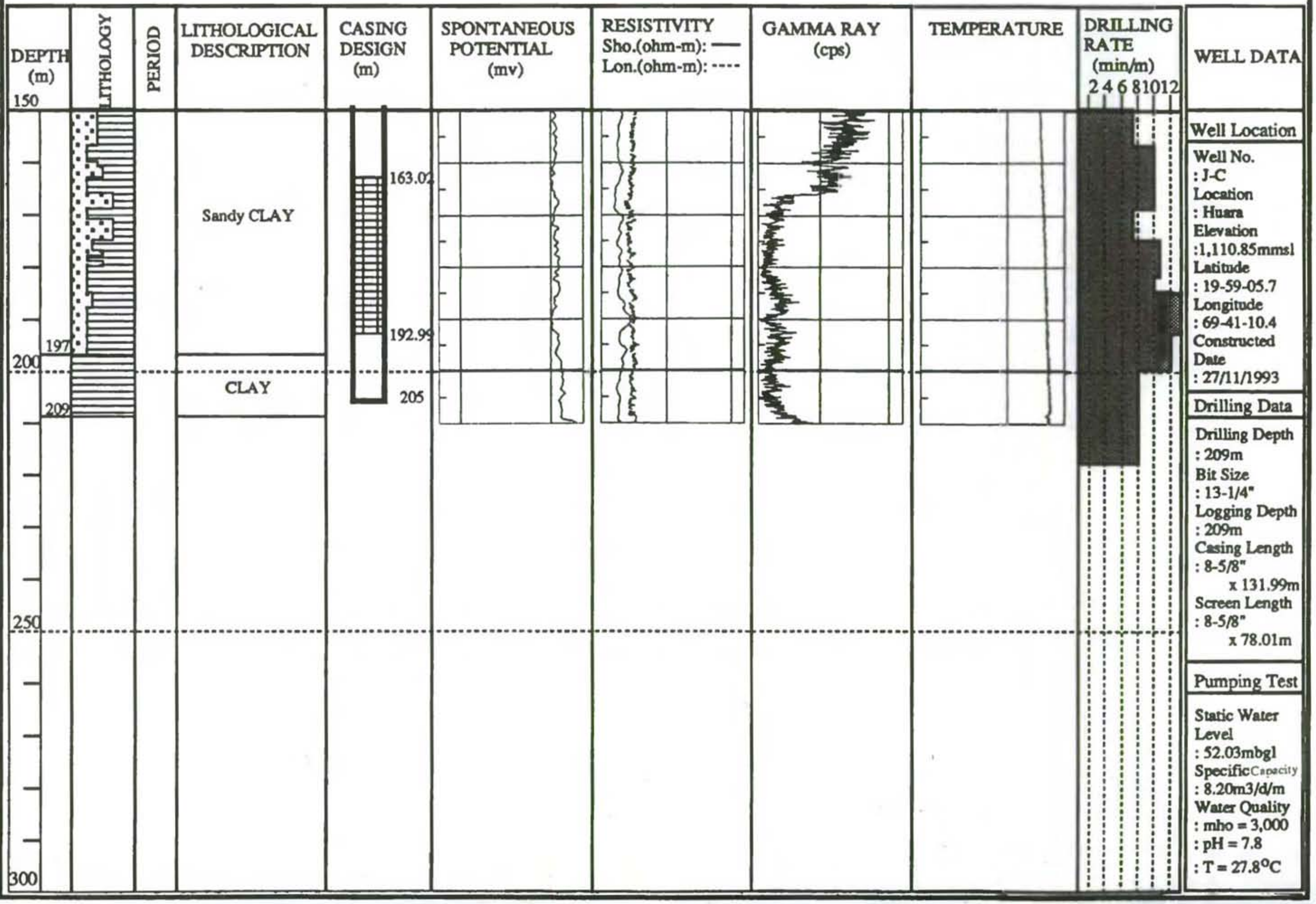
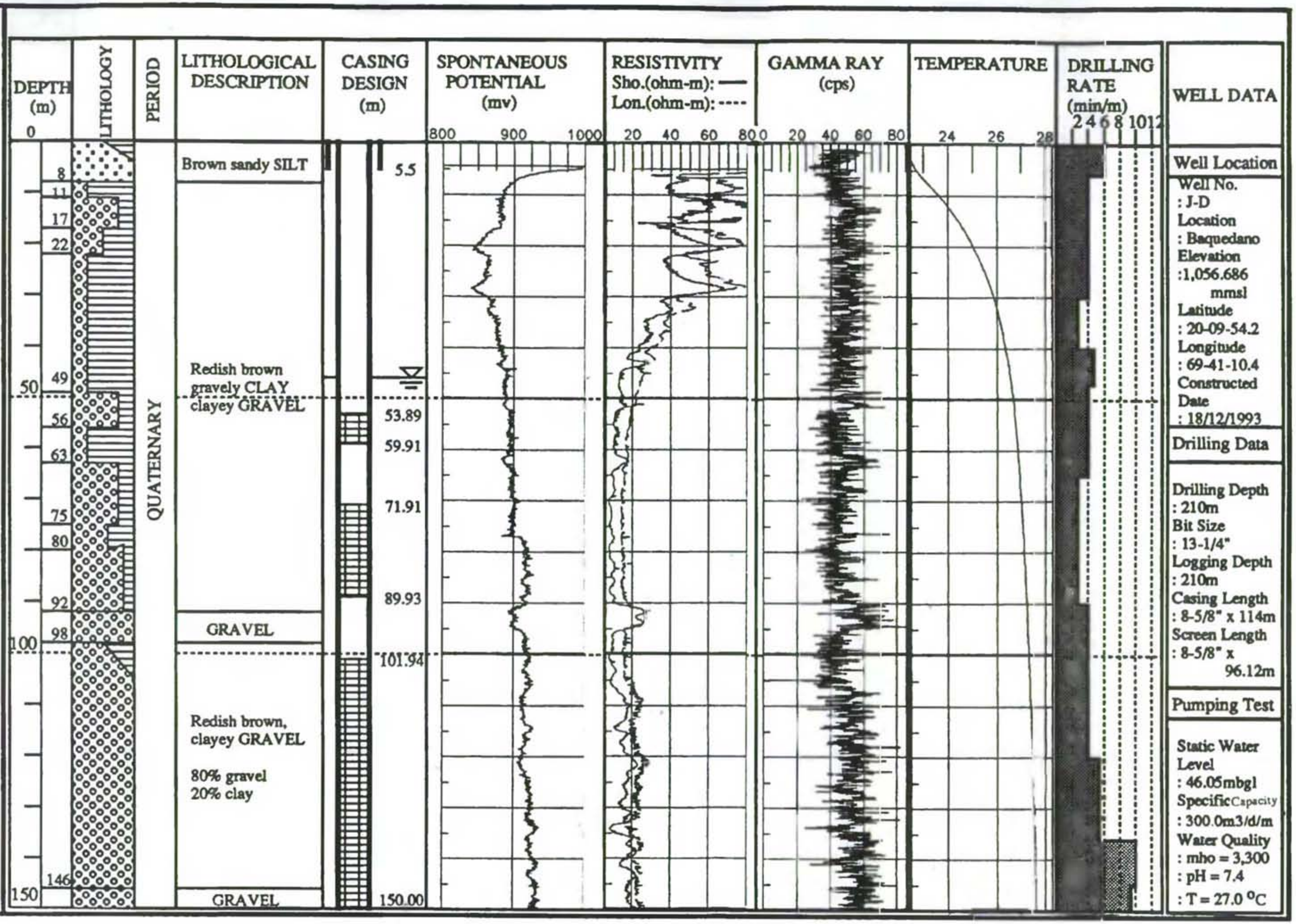


Fig. B-III, 2.16 Well Data for J-C (Sheet No. 2)

< 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) >



THE STUDY ON THE DEVELOPMENT OF WATER RESOURCES IN NORTHERN CHILE

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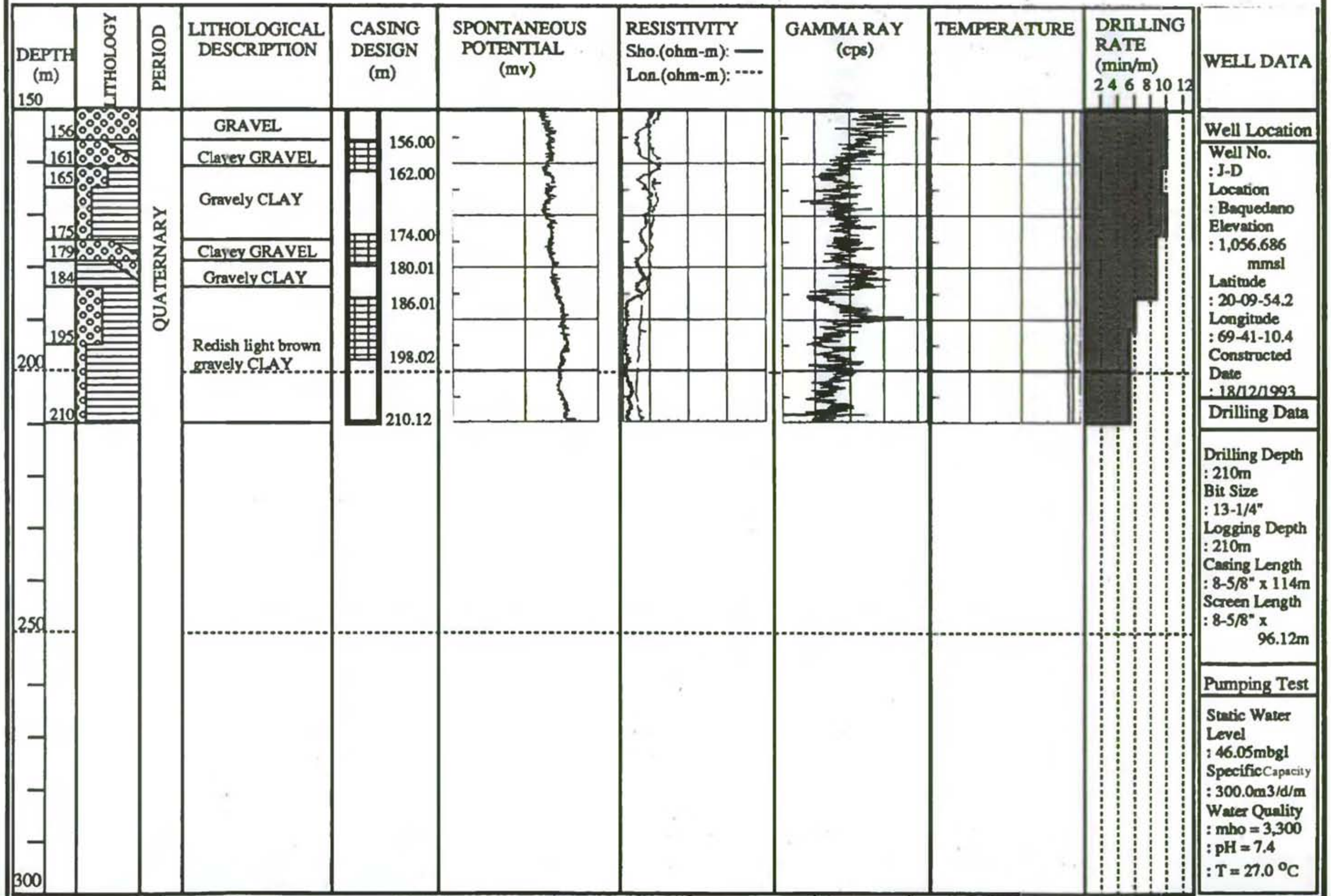
Fig. B-III, 2.17 Well Data for J-D (Sheet No. 2)

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



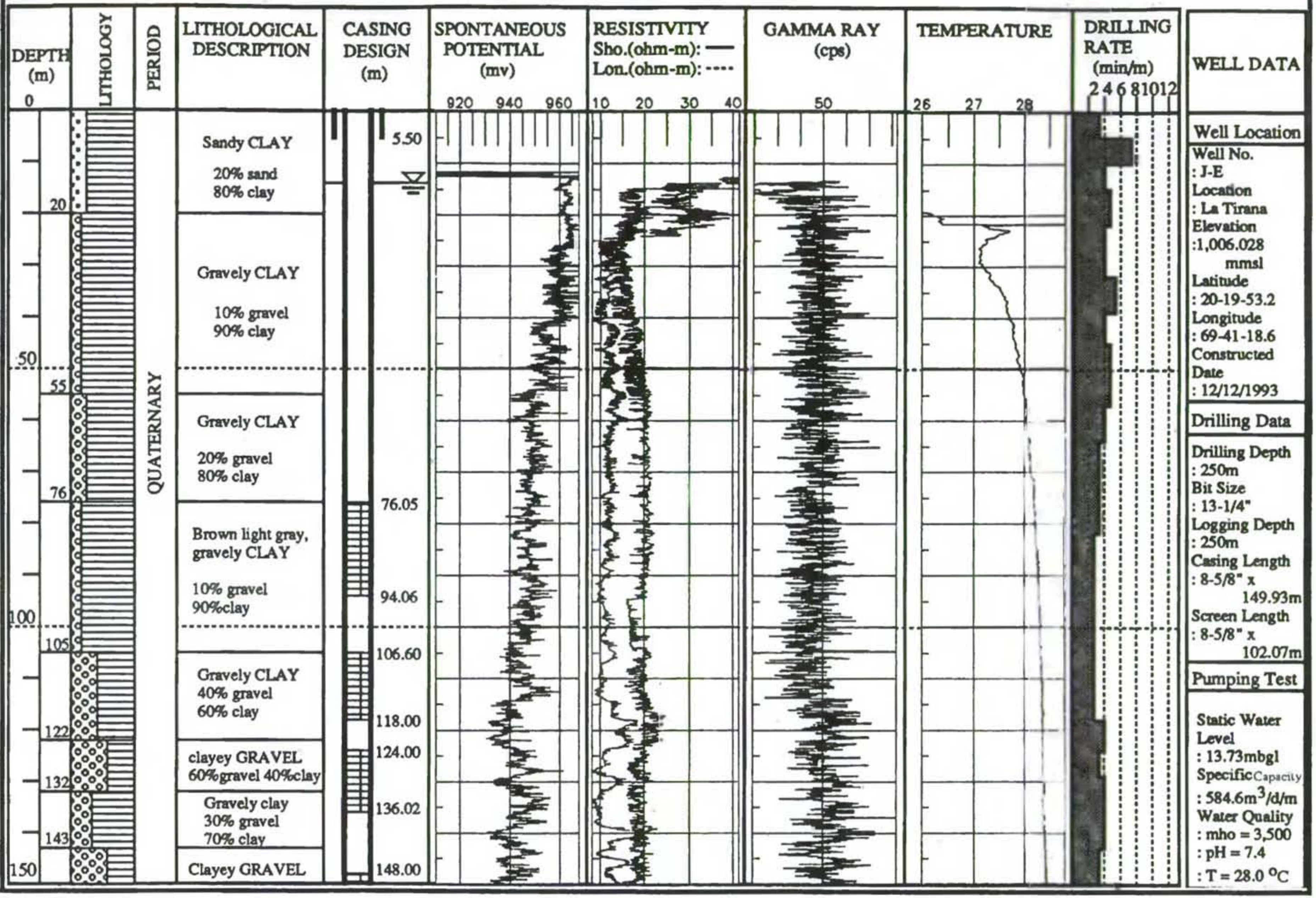


Fig. B-III, 2.18 Well Data for J-E (Sheet No. 1)

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

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

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

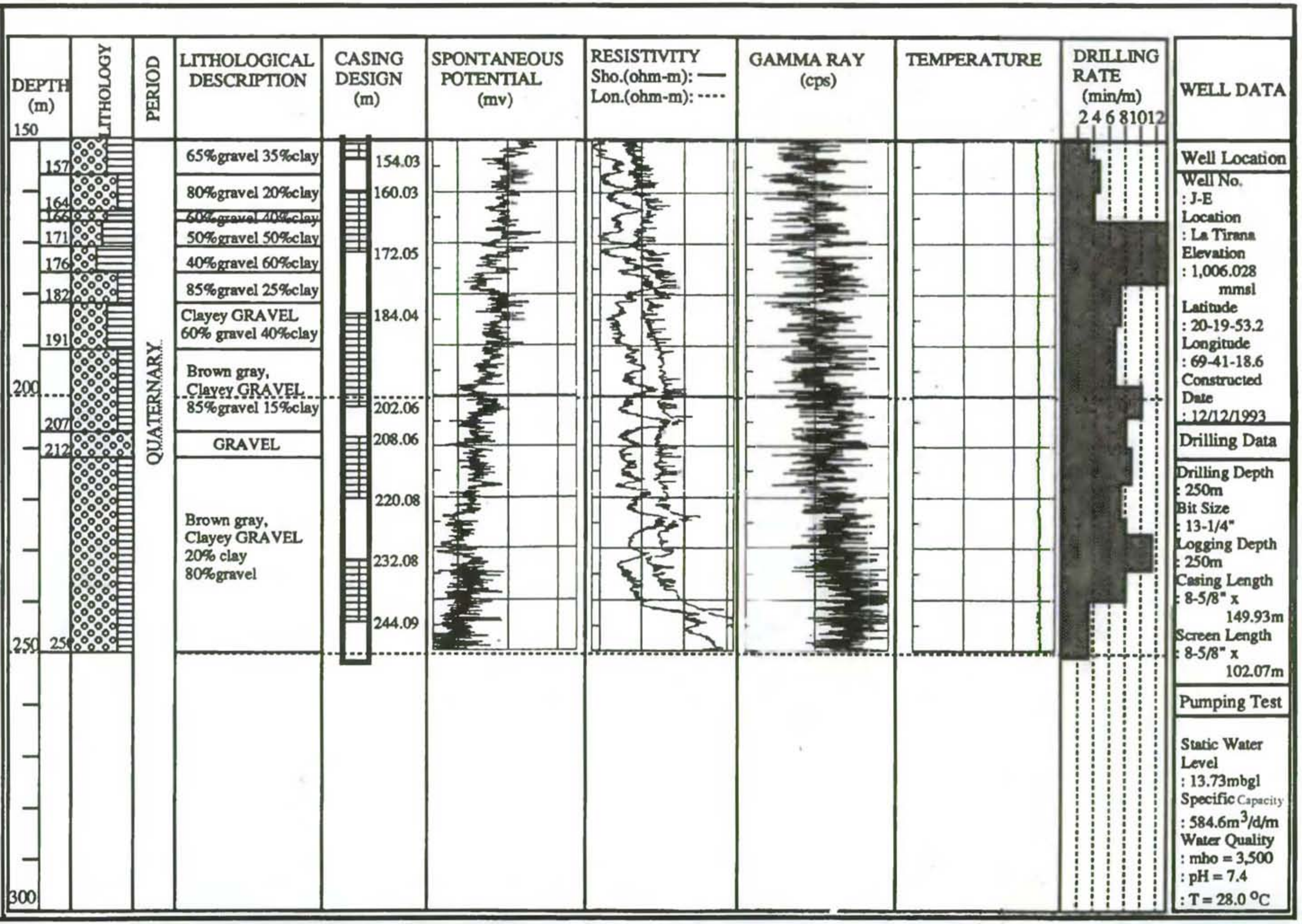
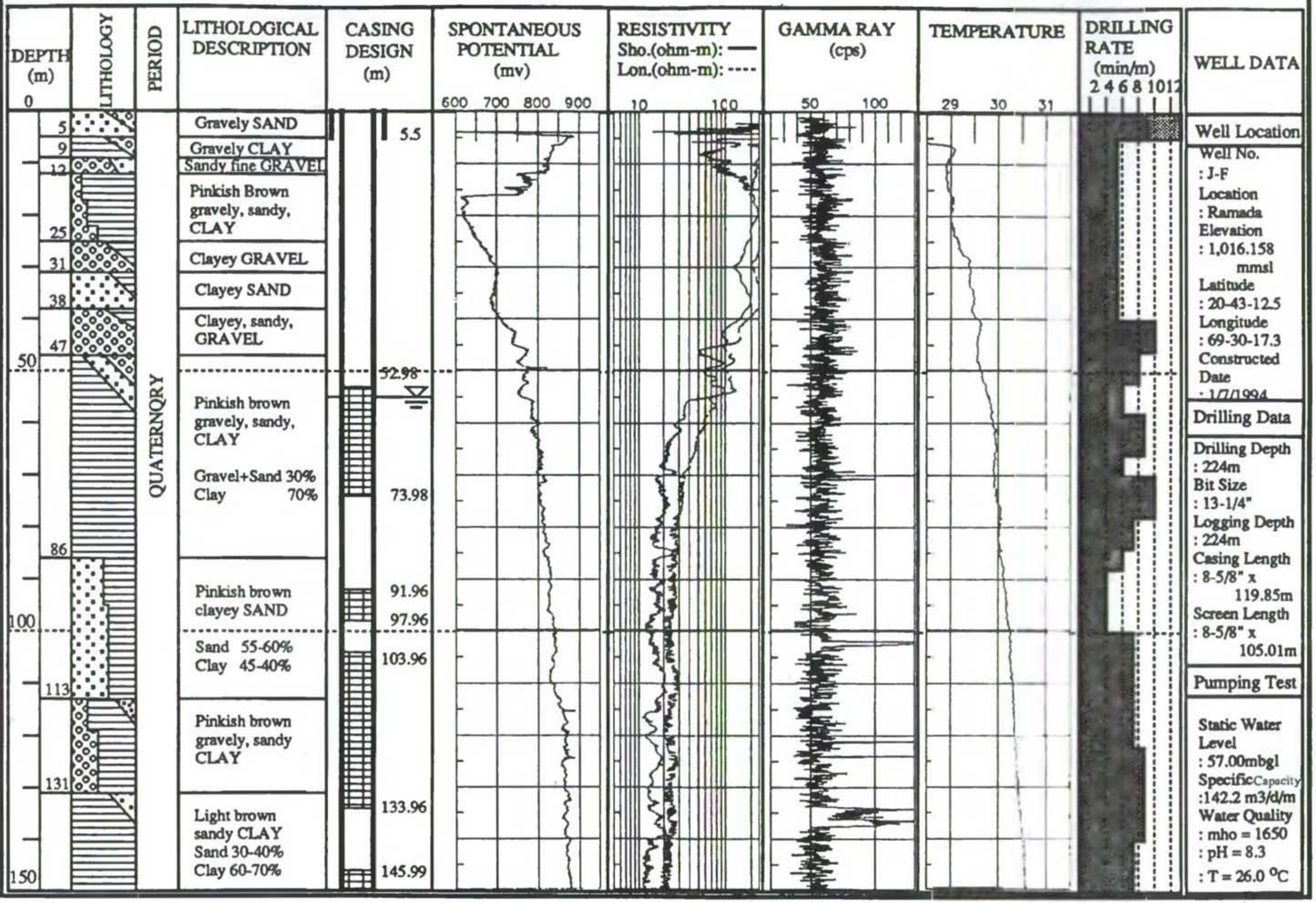


Fig. B-III, 2.19 Well Data for J-F (Sheet No. 1)

< *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) >

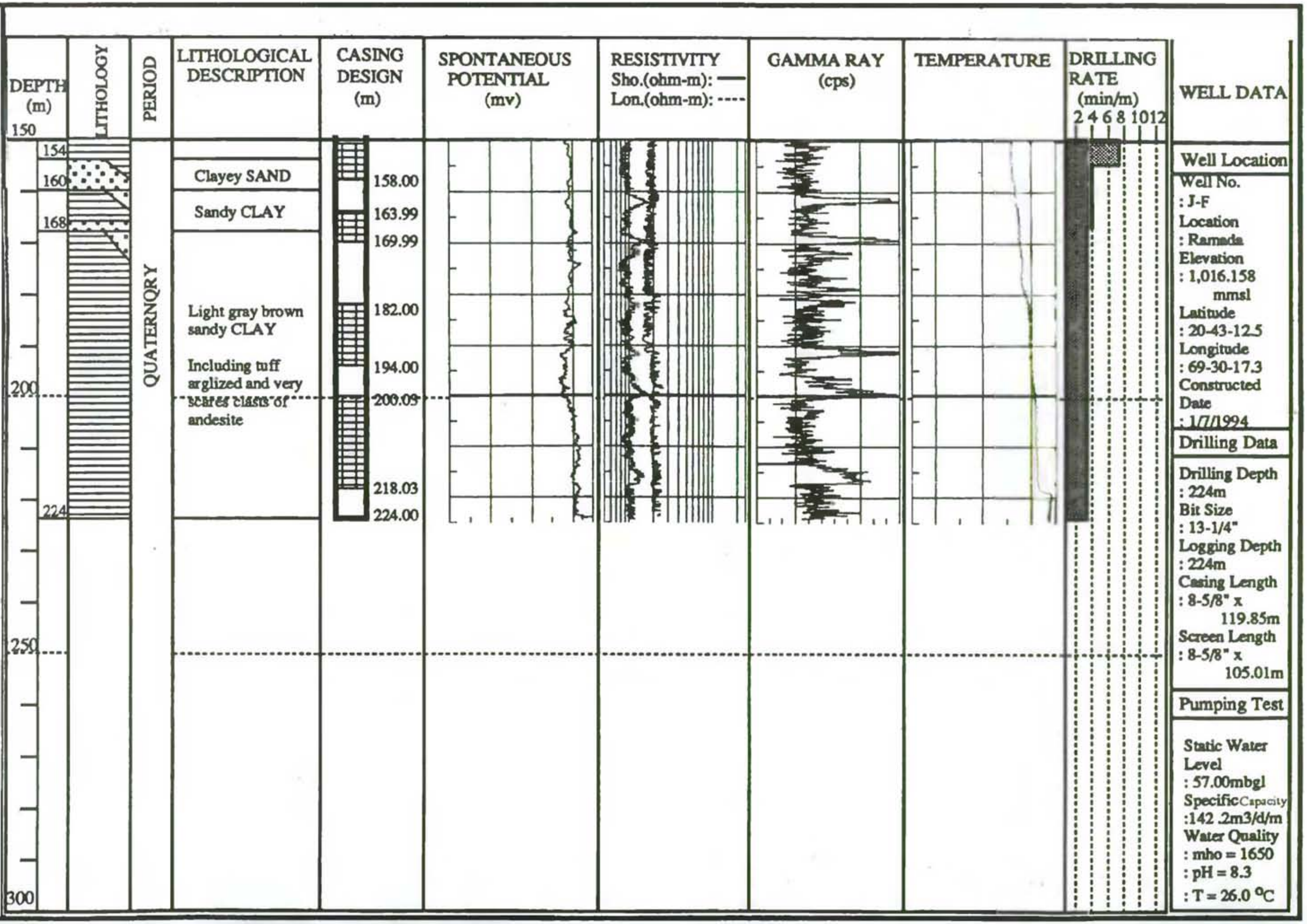


Fig. B-III, 2.20 Well Data for J-3

< Información del Pozo J-3 >

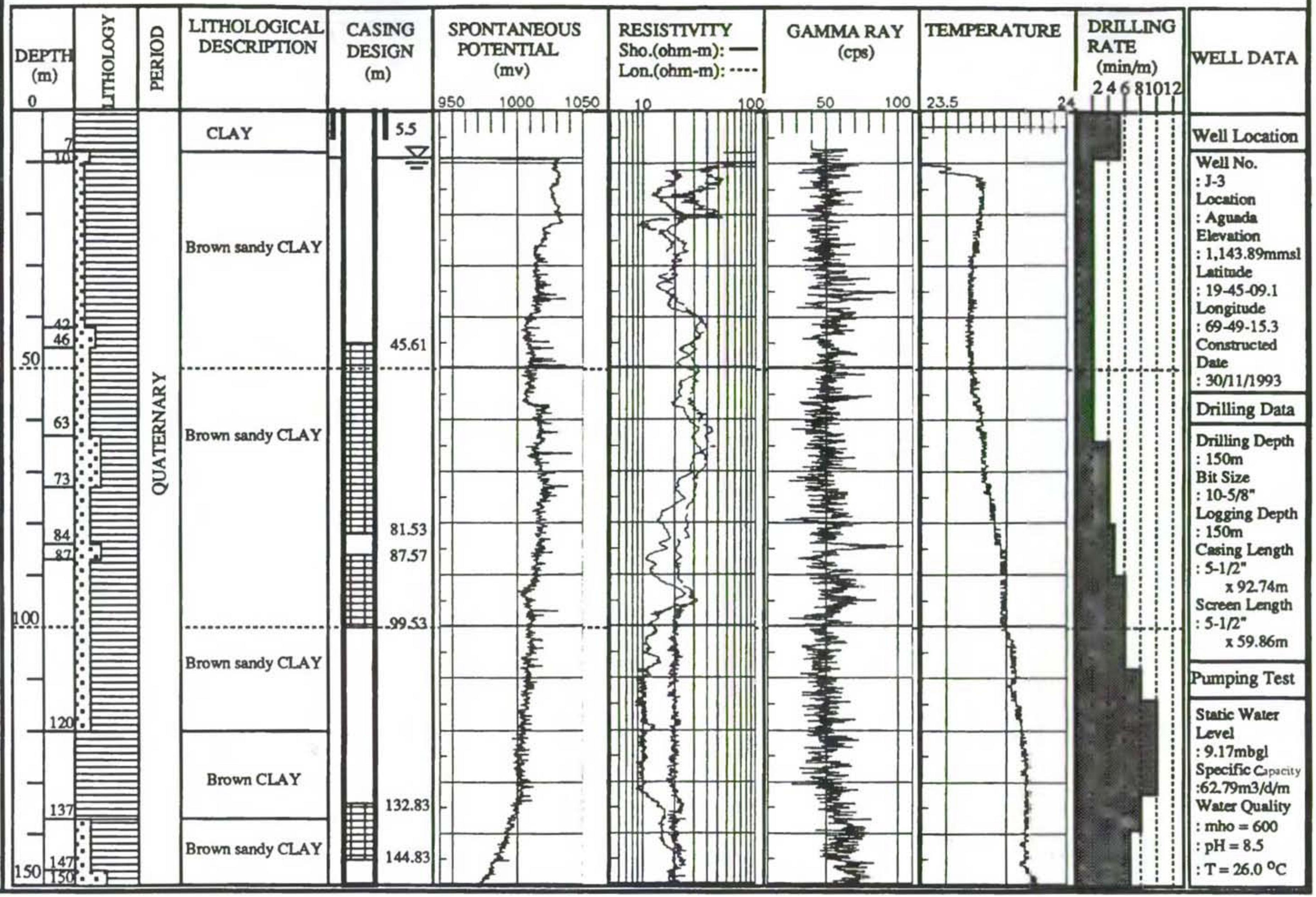


Fig. B-III, 2.21 Well Data for J-4

< *Información del Pozo J-4* >

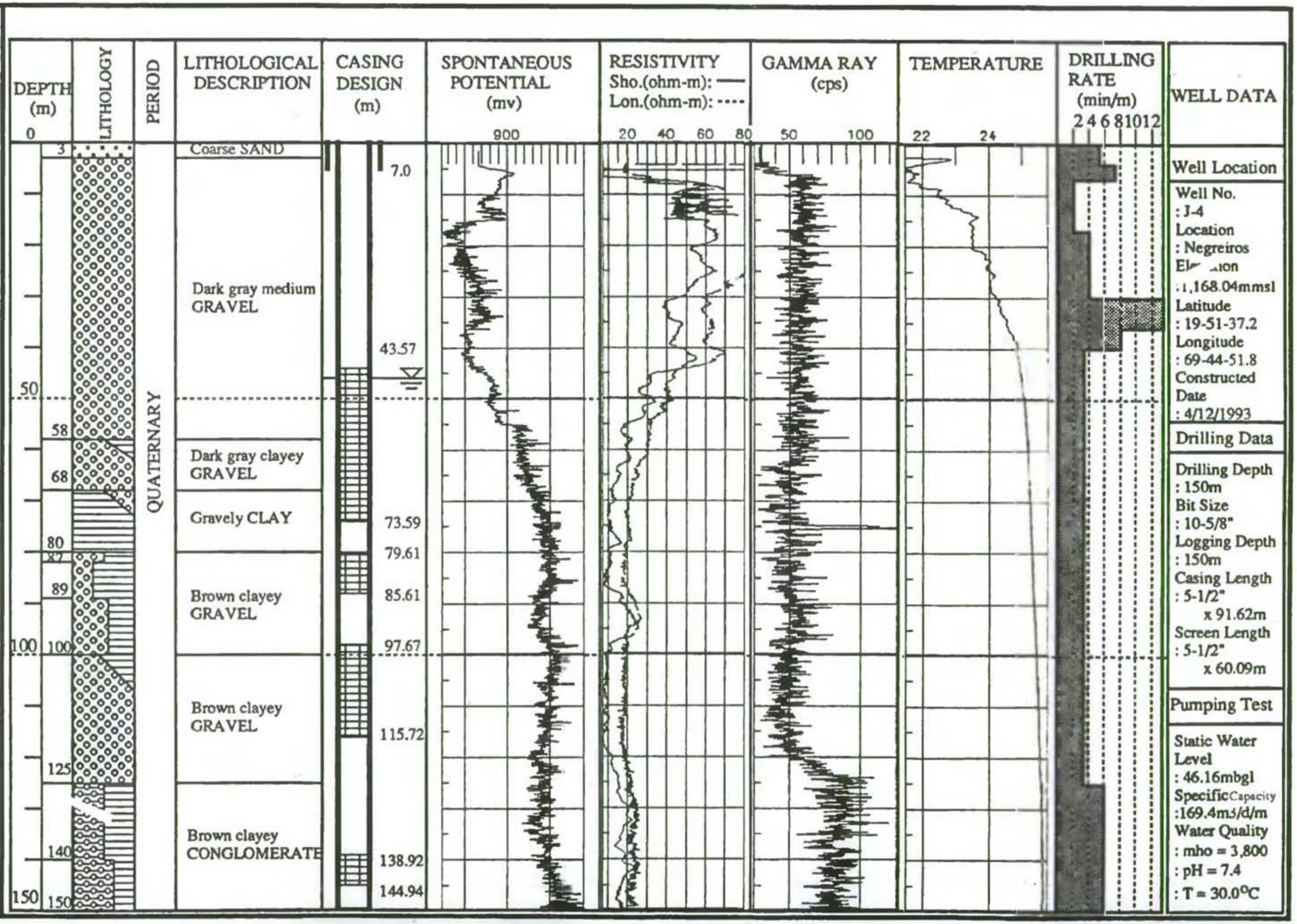


Fig. B-III, 2.22 Well Data for J-5 (Sheet No. 1)

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

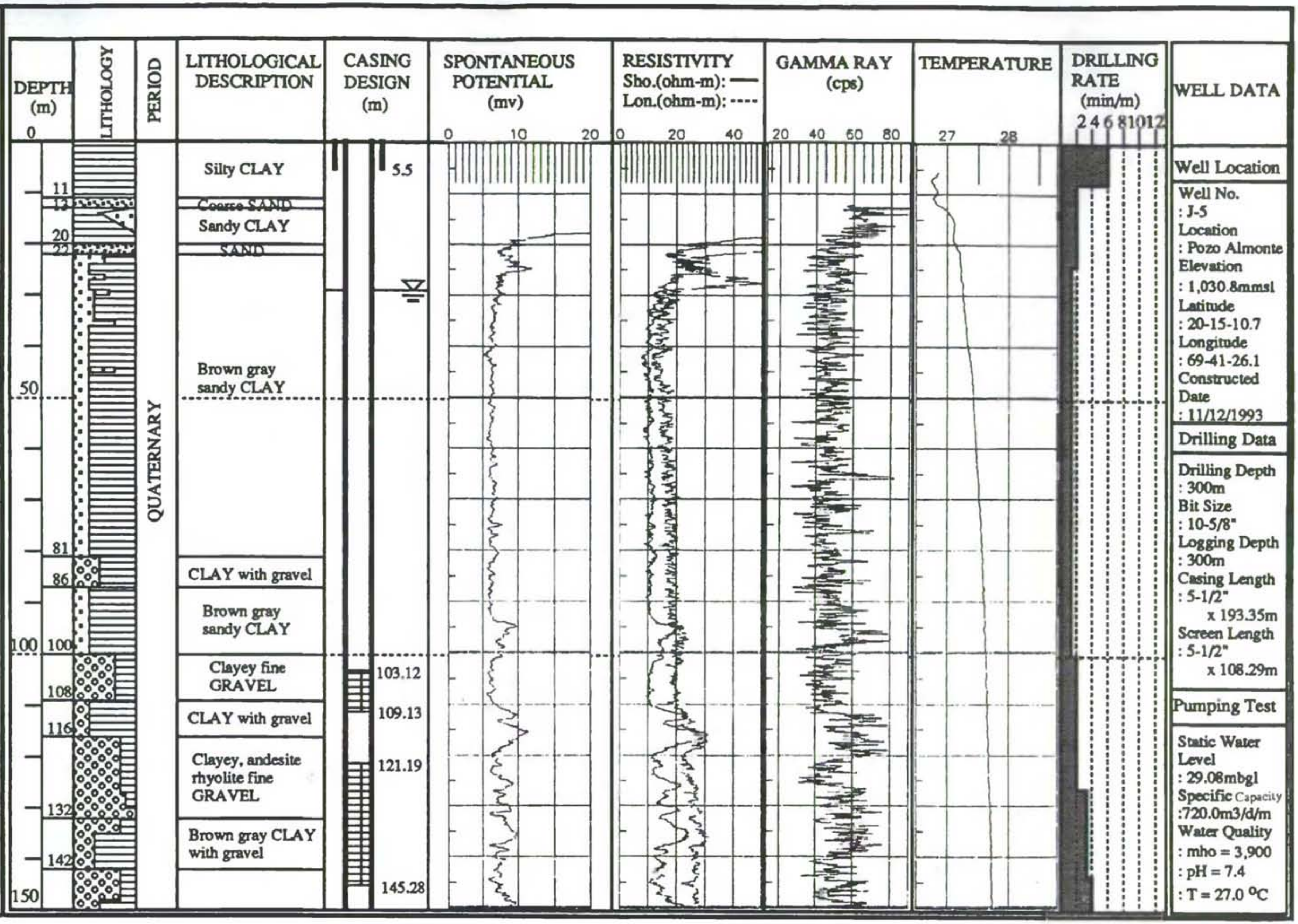


Fig. B-III, 2.22 Well Data for J-5 (Sheet No. 2)

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

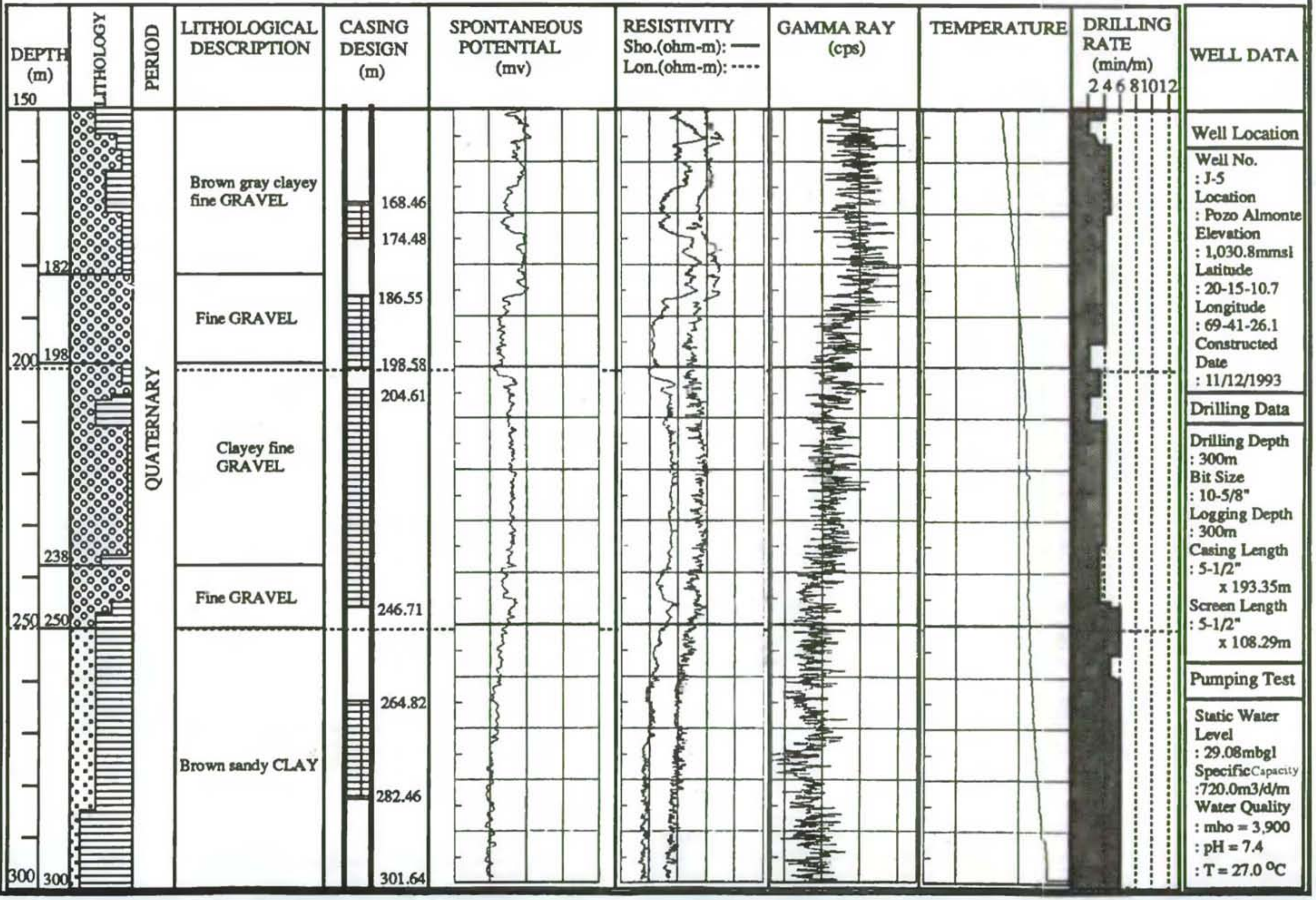


Fig. B-III, 2.23 Well Data for J-6 (Sheet No. 1)

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

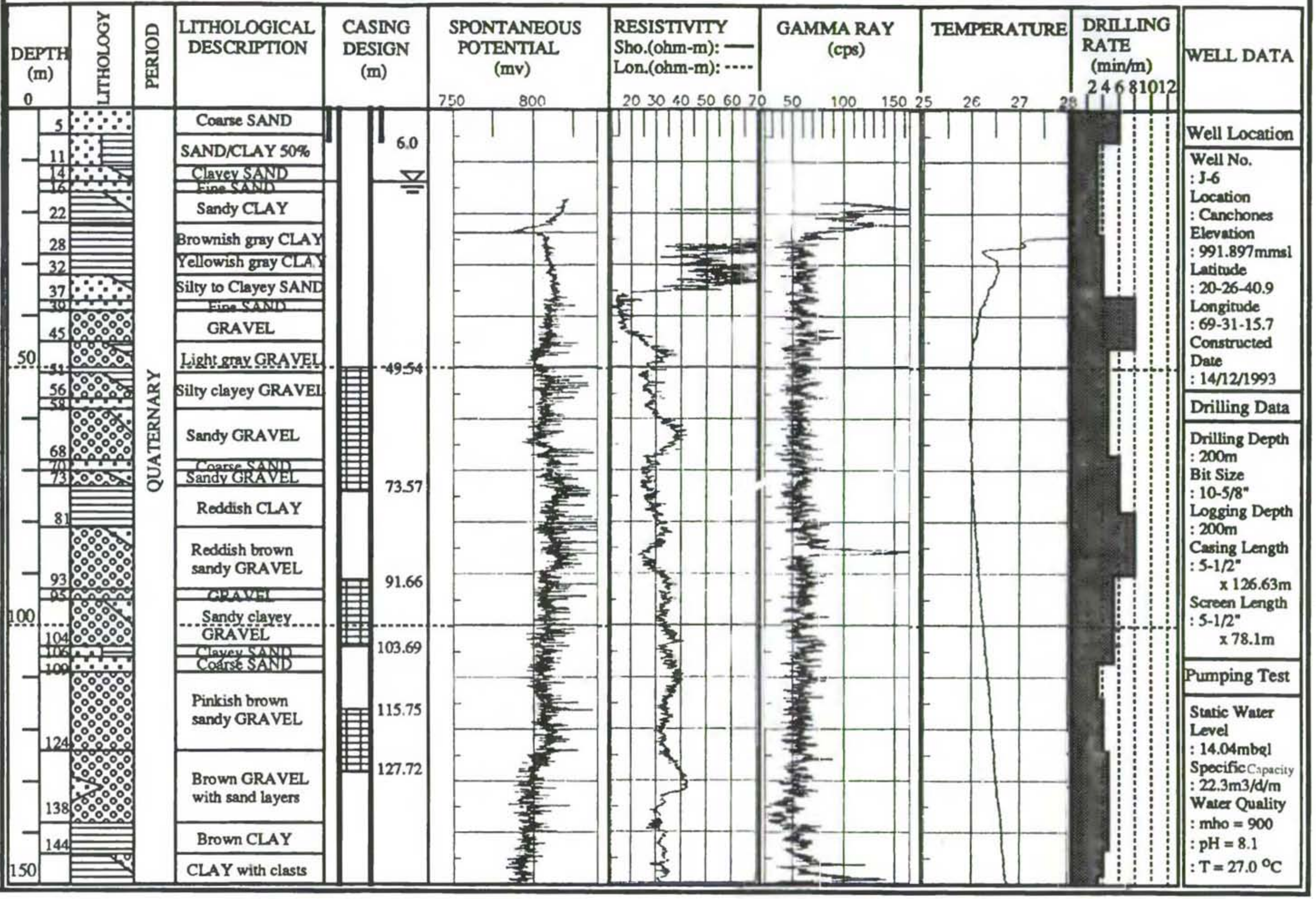
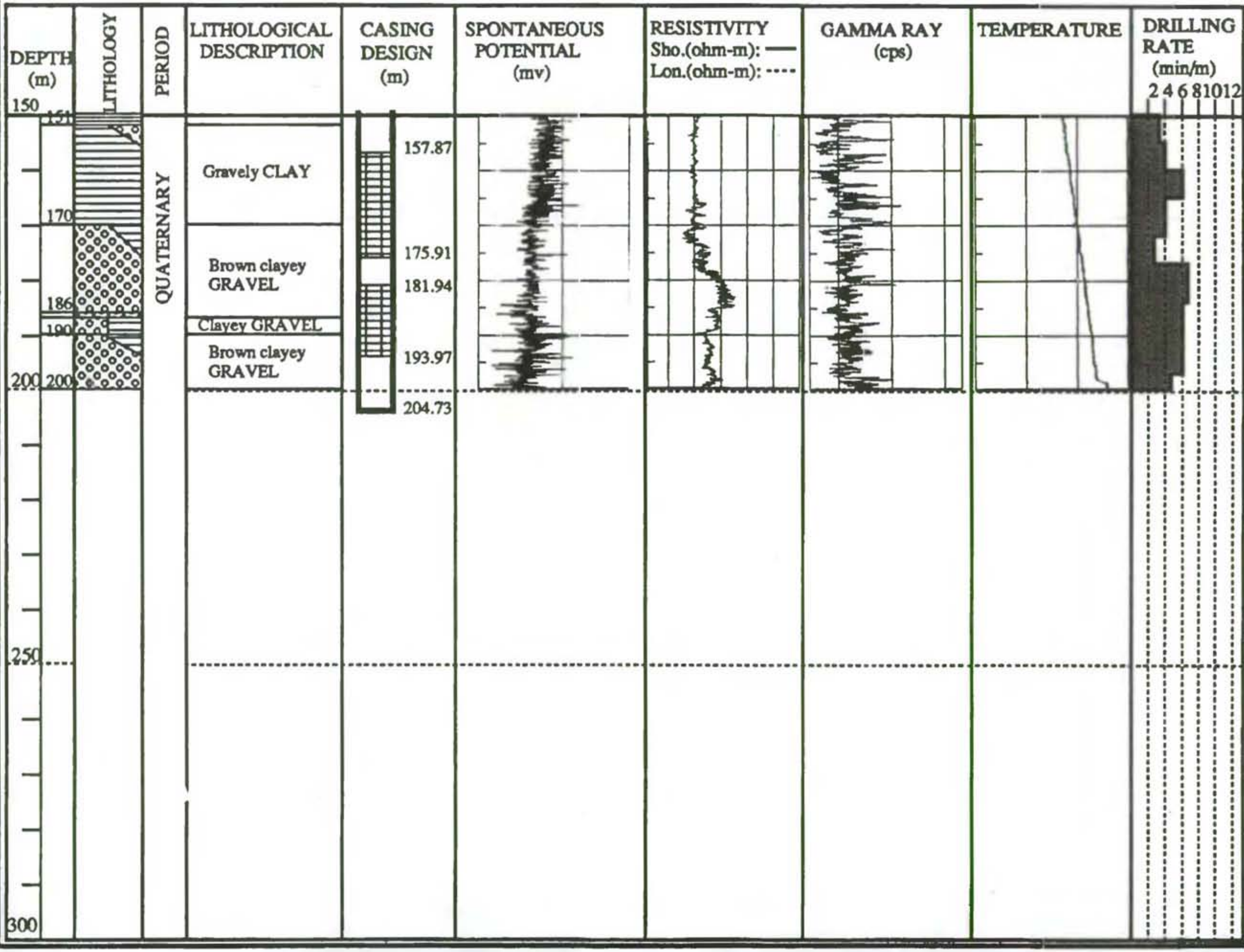


Fig. B-III, 2.23 Well Data for J-6 (Sheet No. 2)

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



WELL DATA

Well Location

Well No.
: J-6
Location
: Canchones
Elevation
: 991.897mmsl
Latitude
: 20-26-40.9
Longitude
: 69-31-15.7
Constructed Date
: 14/12/1993

Drilling Data

Drilling Depth
: 200m
Bit Size
: 10-5/8"
Logging Depth
: 200m
Casing Length
: 5-1/2" x 126.63m
Screen Length
: 5-1/2" x 78.1m

Pumping Test

Static Water Level
: 14.04mbgl
Specific Capacity
: 22.3m3/d/m
Water Quality
: mho = 900
: pH = 8.1
: T = 27.0 °C

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

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

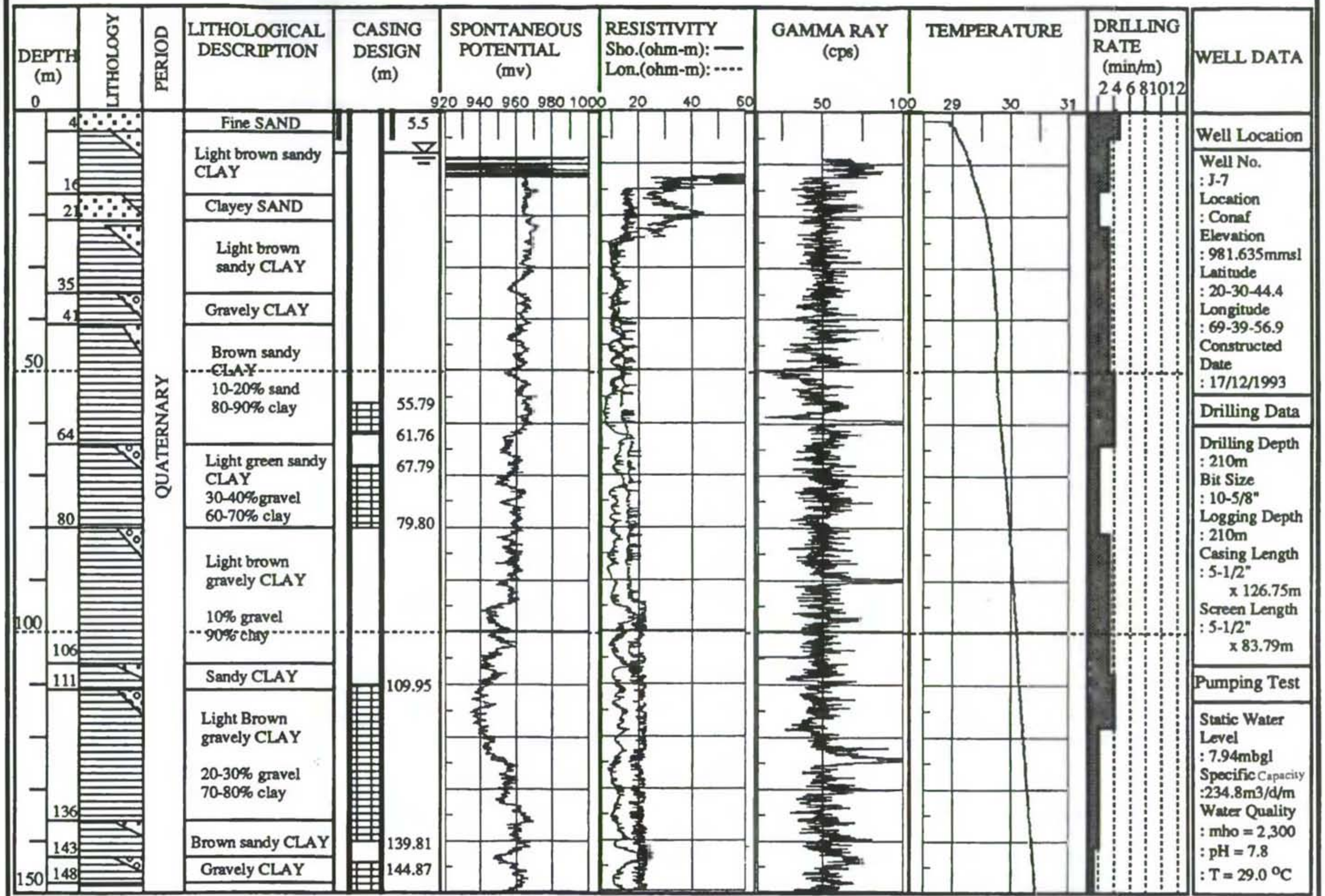
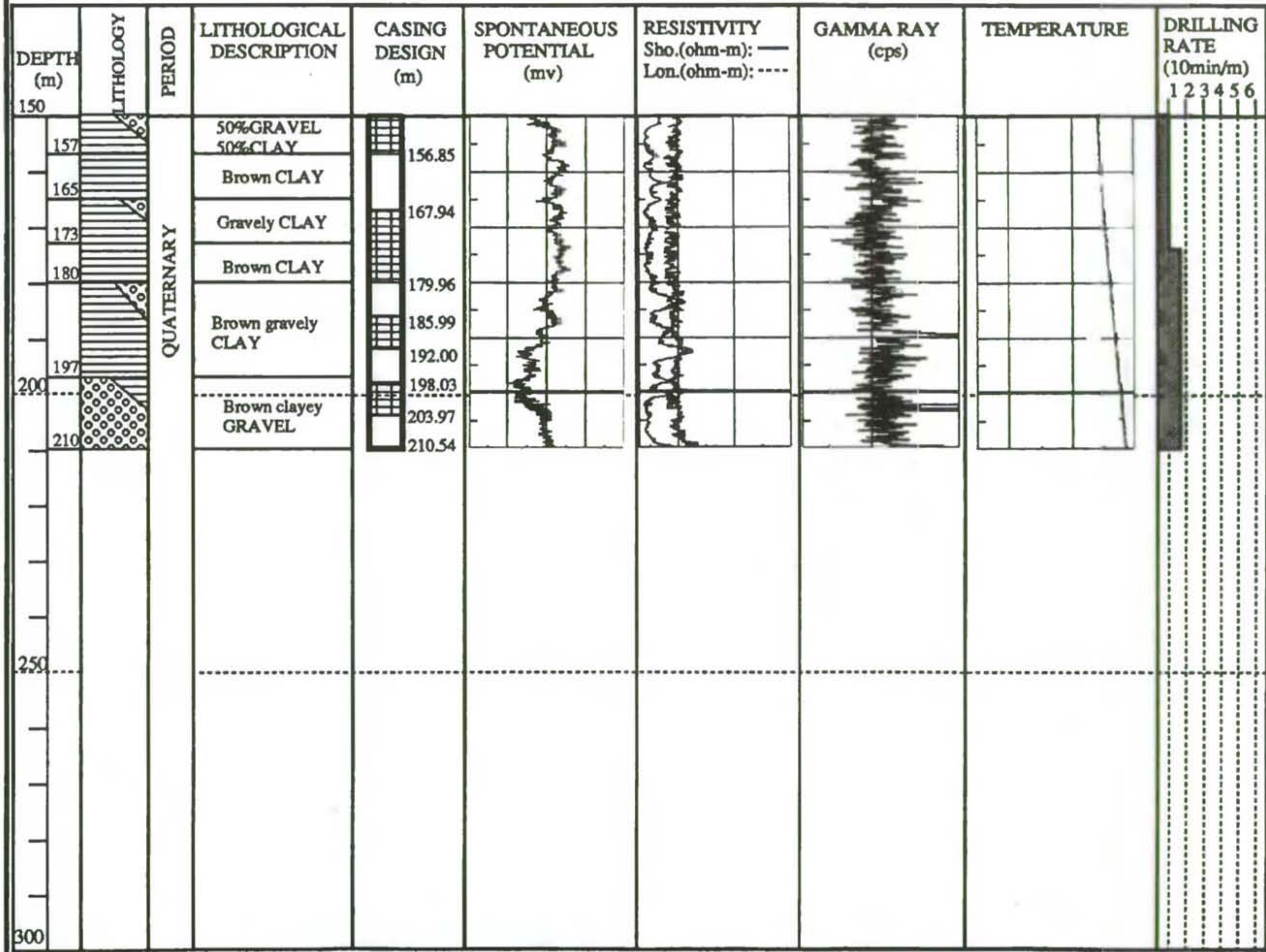


Fig. B-III, 2.24 Well Data for J-7 (Sheet No. 2)

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



WELL DATA

Well Location

Well No.
: J-7
Location
: Conaf
Elevation
: 981.635mmsl
Latitude
: 20-30-44.4
Longitude
: 69-39-56.9
Constructed Date
: 17/12/1993

Drilling Data

Drilling Depth
: 210m
Bit Size
: 10-5/8"
Logging Depth
: 210m
Casing Length
: 5-1/2" x 126.75m
Screen Length
: 5-1/2" x 83.79m

Pumping Test

Static Water Level
: 7.94mbgl
Specific Capacity
:234.8m3/d/m
Water Quality
: mho = 2,300
: pH = 7.8
: T = 29.0 °C

Fig. B-III, 2.25 Well Data for J-8 (Sheet No. 1)
< Información del Pozo J-8 (Hoja Nº 1) >

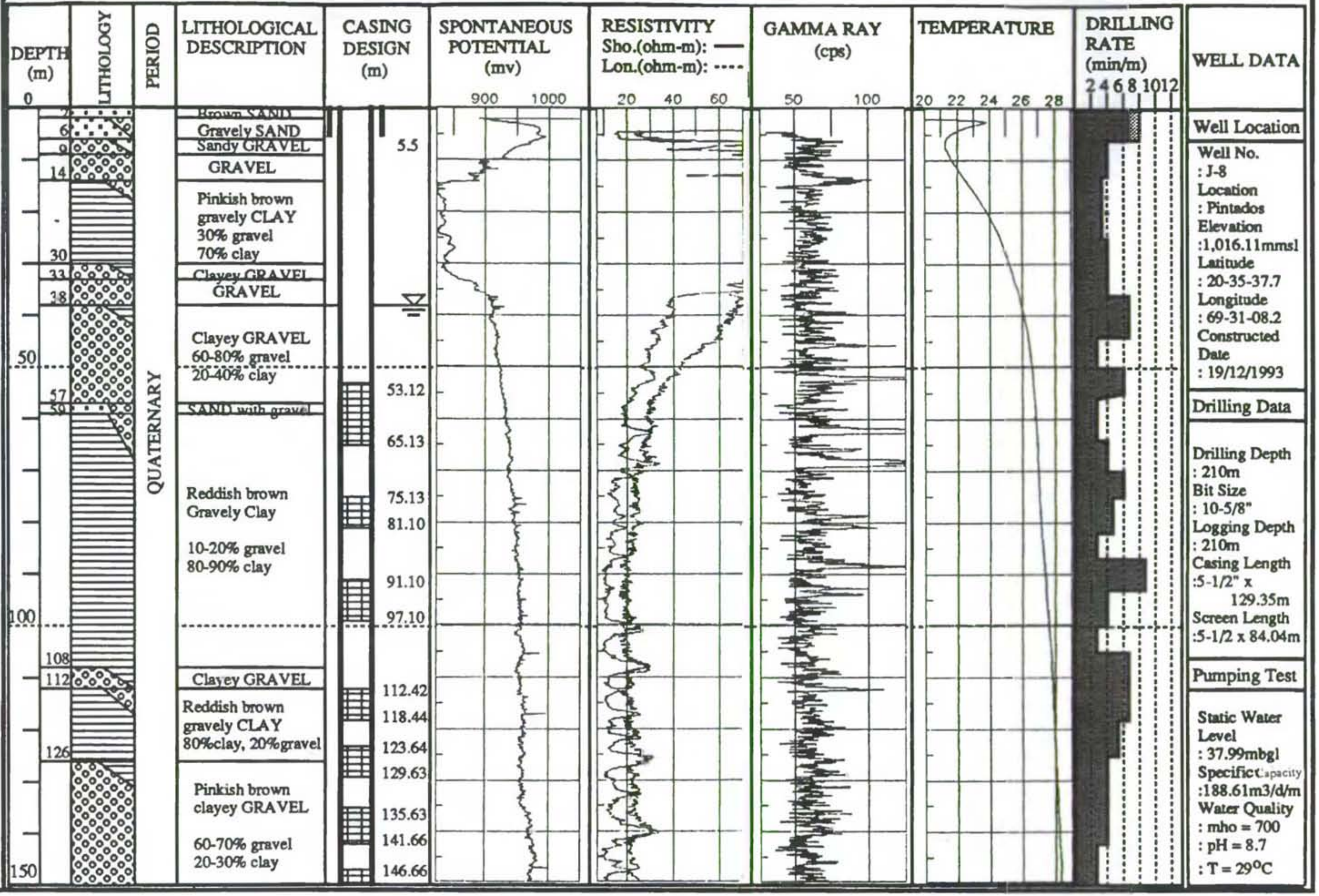
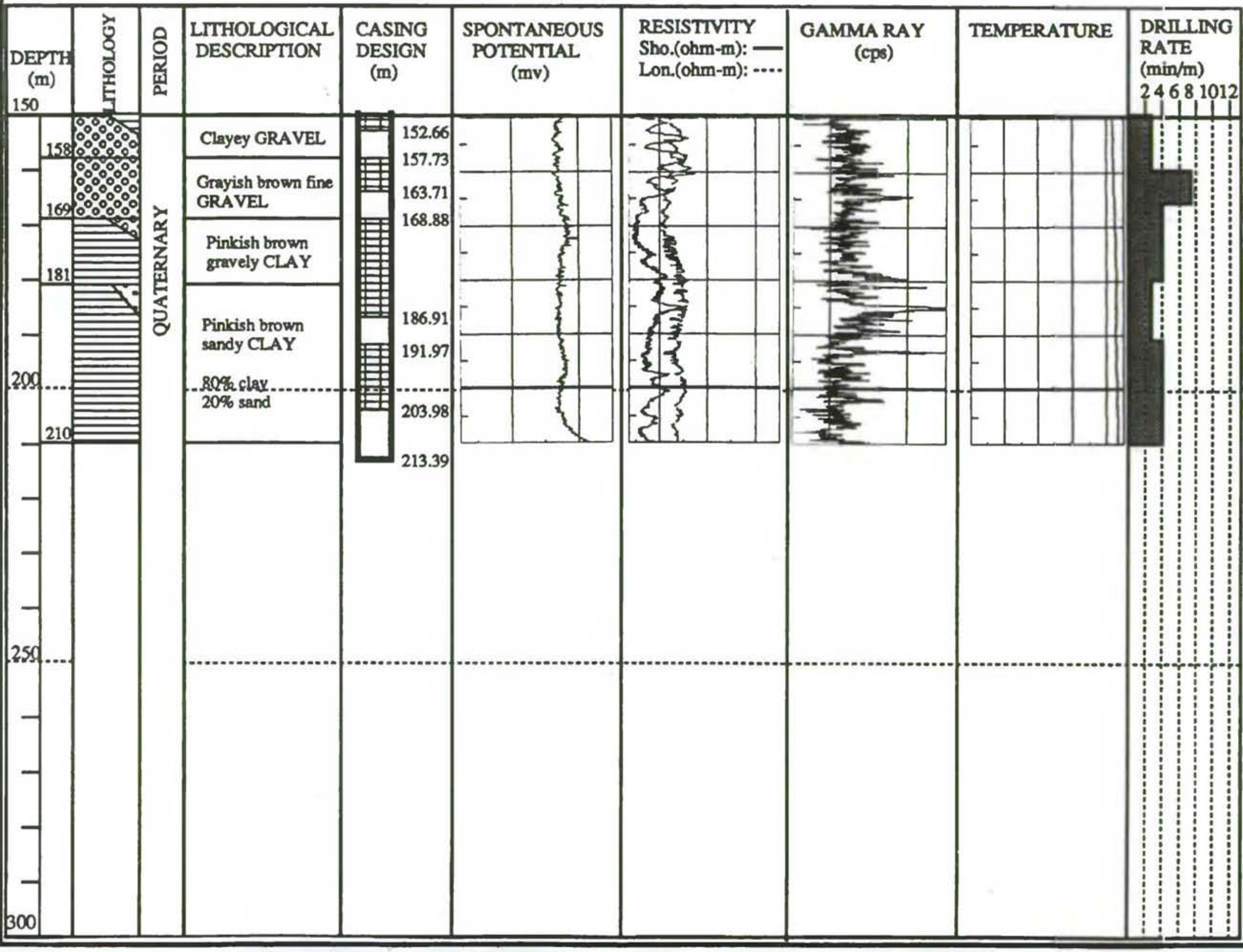


Fig. B-III, 2.25 Well Data for J-8 (Sheet No. 2)
< Información del Pozo J-8 (Hoja Nº 2) >



WELL DATA

Well Location

Well No.
: J-8
Location
: Pintados
Elevation
:1,016.11mmsl
Latitude
: 20-35-37.7
Longitude
: 69-31-08.2
Constructed Date
: 19/12/1993

Drilling Data

Drilling Depth
: 210m
Bit Size
: 10-5/8"
Logging Depth
: 210m
Casing Length
:5-1/2" x 129.35m
Screen Length
:5-1/2 x 84.04m

Pumping Test

Static Water Level
: 37.99mbgl
Specific Capacity
:188.61m3/d/m
Water Quality
: mho = 700
: pH = 8.7
: T = 29°C

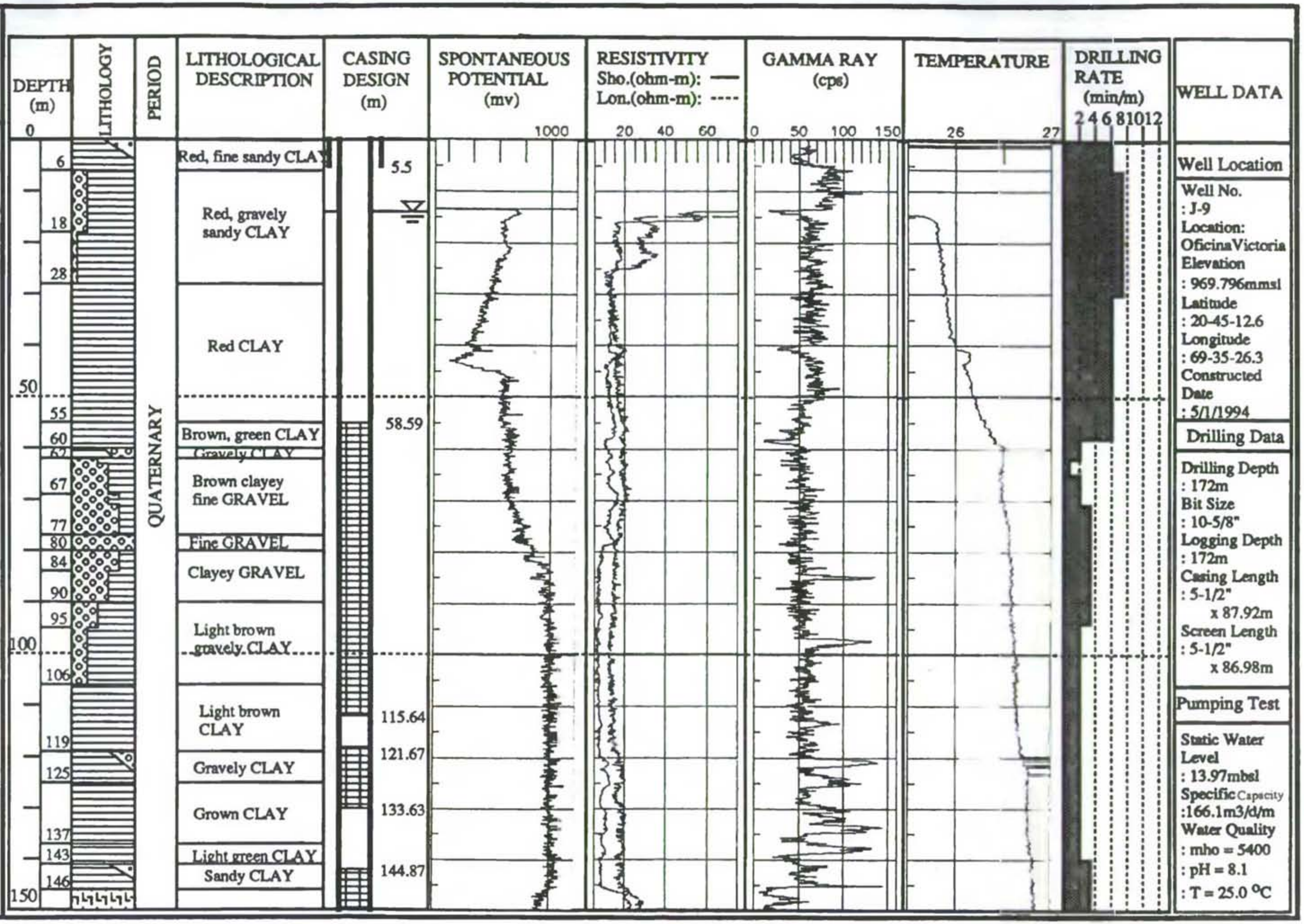
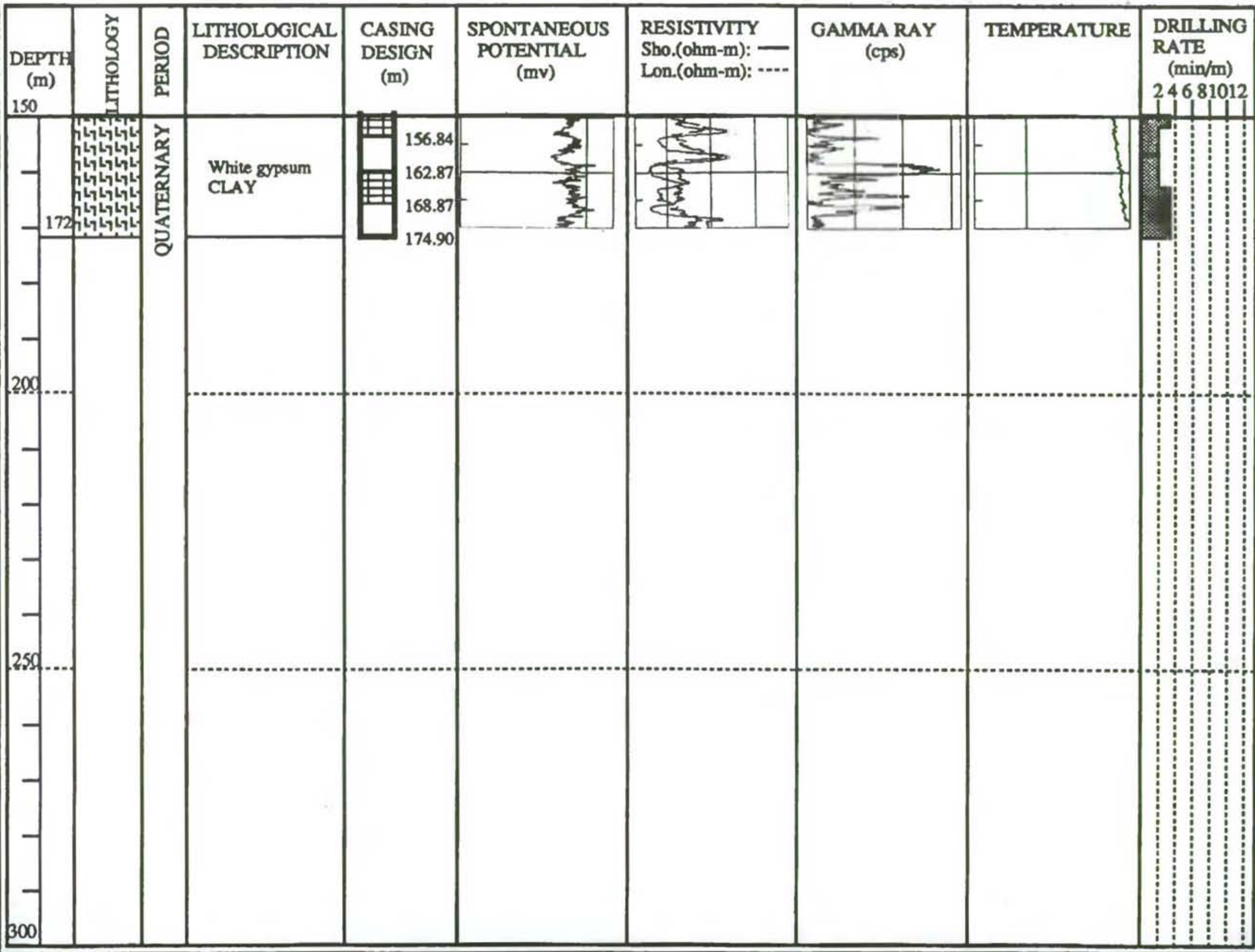


Fig. B-III, 2.26 Well Data for J-9 (Sheet No. 1)

< 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) >



WELL DATA

Well Location

Well No.
: J-9
Location:
Oficina Victoria
Elevation
: 969.796mmsl
Latitude
: 20-45-12.6
Longitude
: 69-35-26.3
Constructed Date
: 5/1/1994

Drilling Data

Drilling Depth
: 172m
Bit Size
: 10-5/8"
Logging Depth
: 172m
Casing Length
: 5-1/2" x 87.92m
Screen Length
: 5-1/2" x 86.98m

Pumping Test

Static Water Level
: 13.97mbgl
Specific Capacity
:166.1m3/d/m
Water Quality
: mho = 5400
: pH = 8.1
: T = 25.0 °C

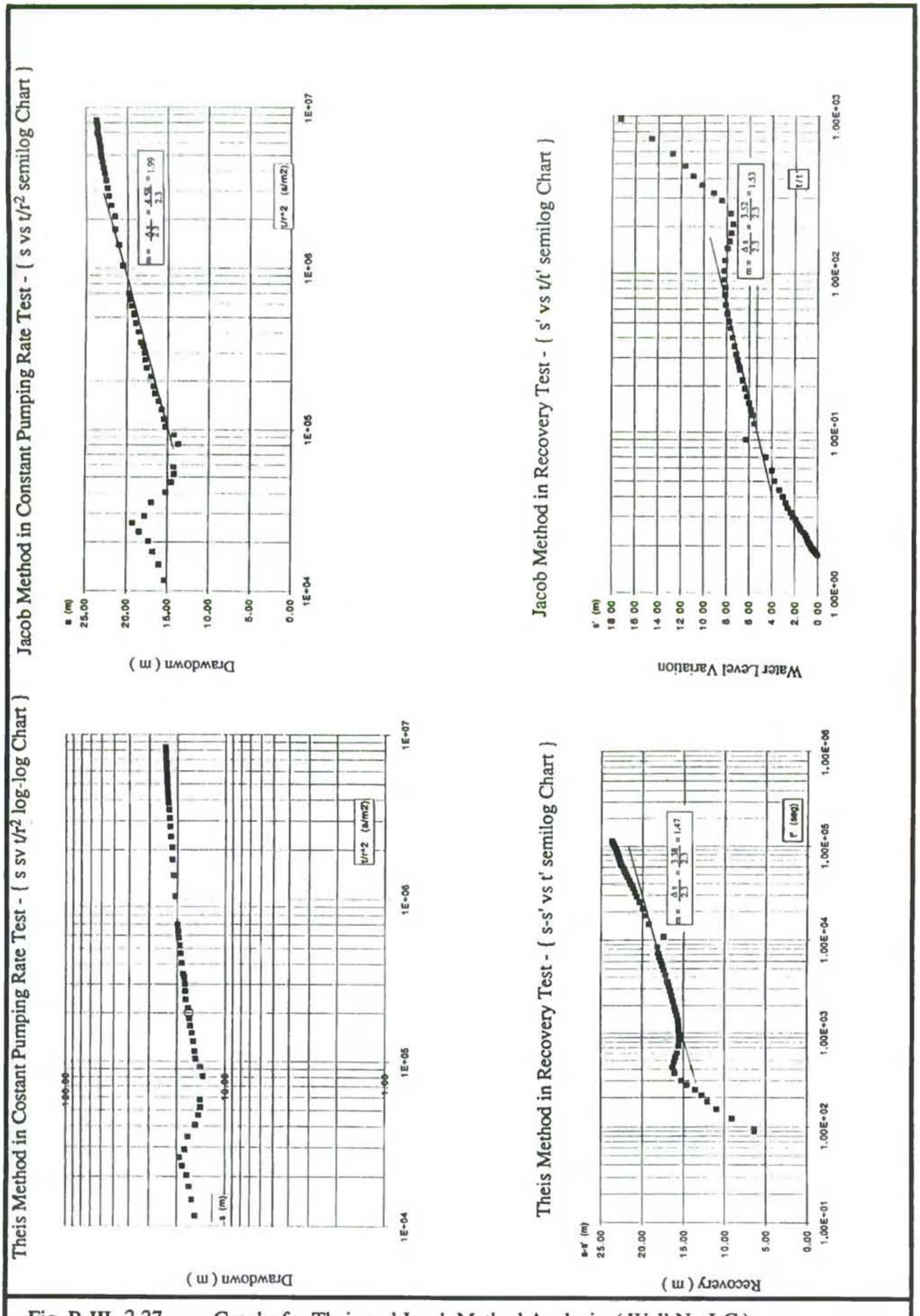


Fig. B-III, 2.27 Graphs for Theis and Jacob Method Analysis (Well No.J-C)

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

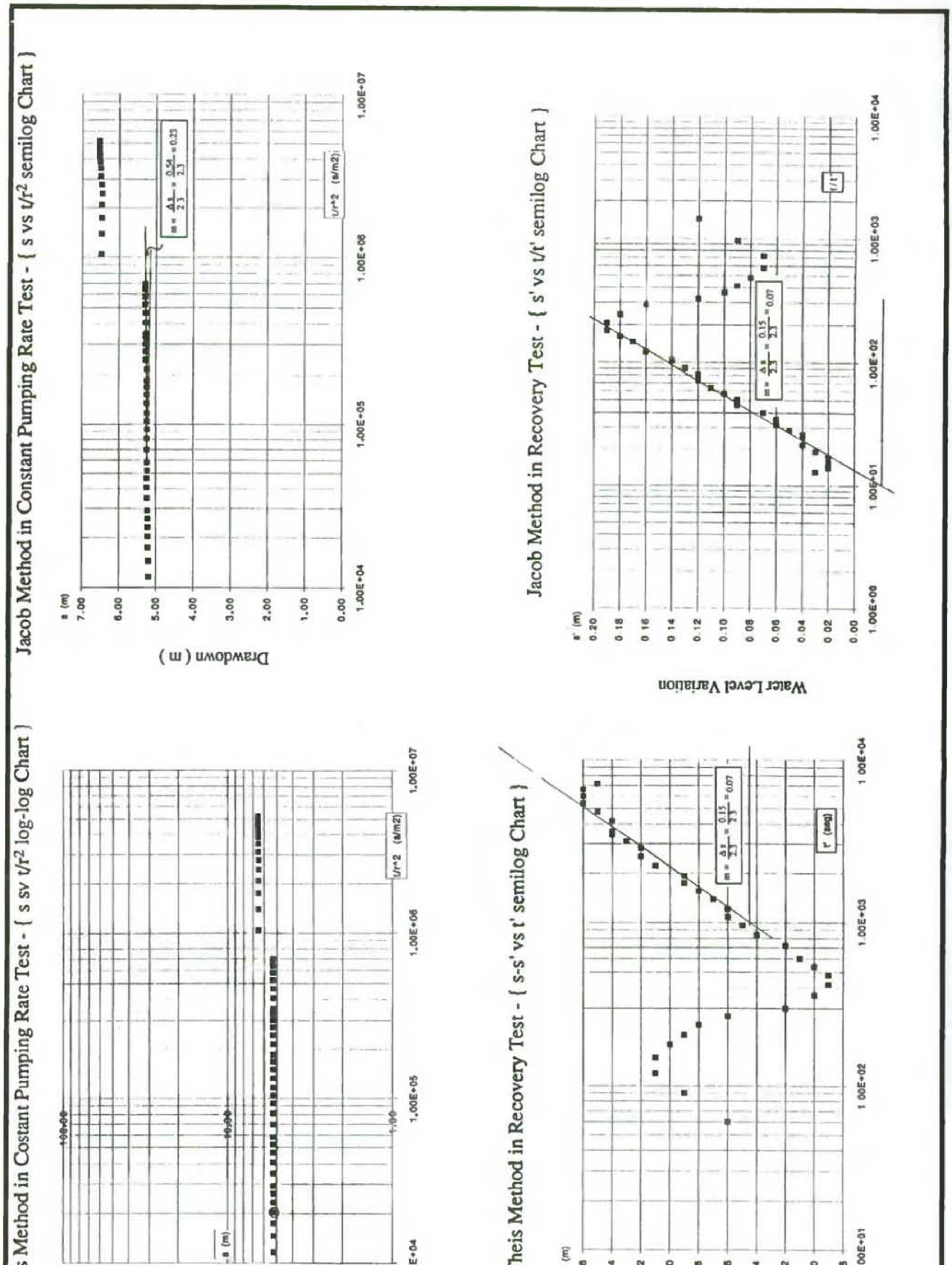


Fig. B-III, 2.28 Graphs for Theis and Jacob Method Analysis (Well No.J-D)

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

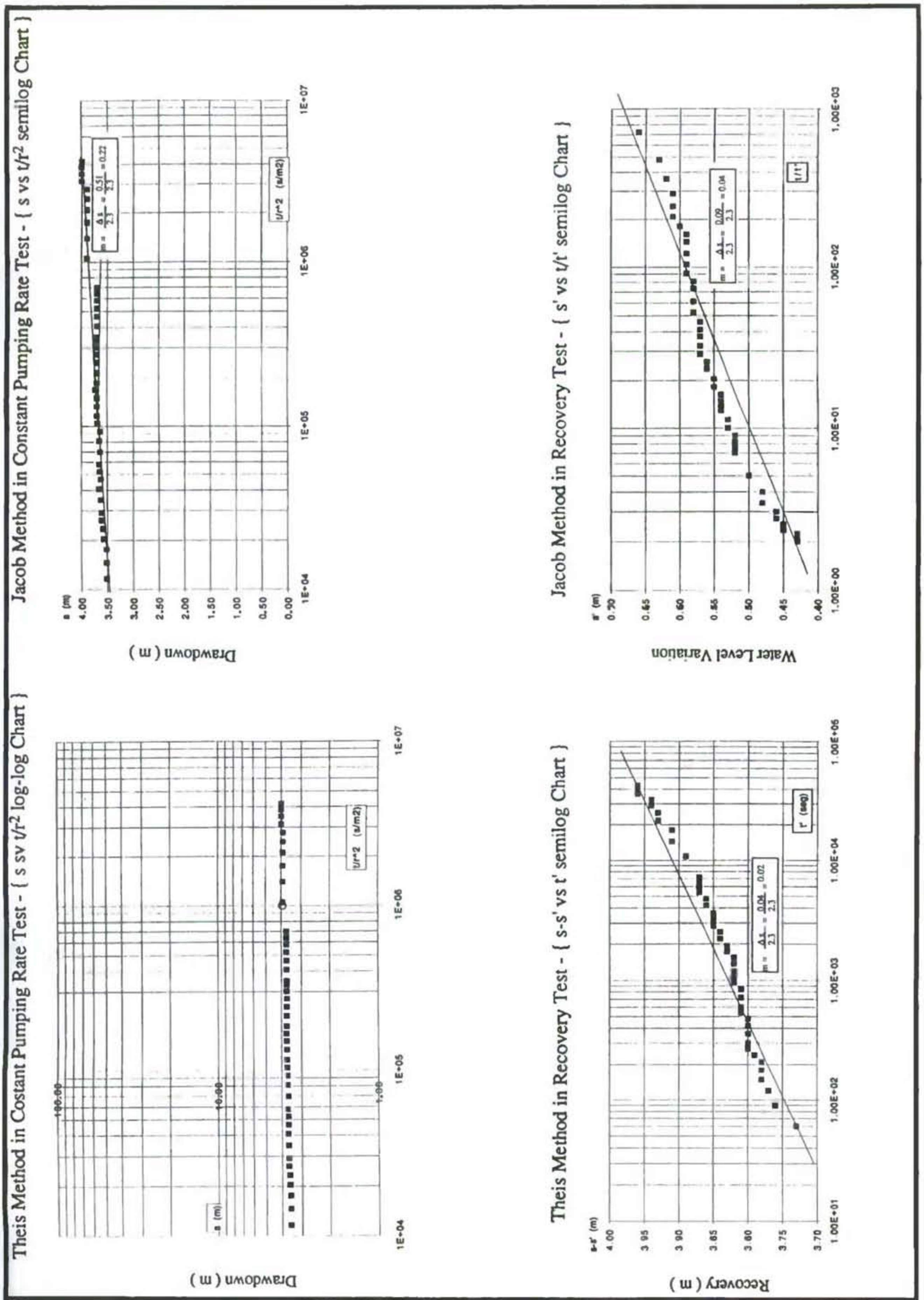


Fig. B-III, 2.29 Graphs for Theis and Jacob Method Analysis (Well No.J-E)

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

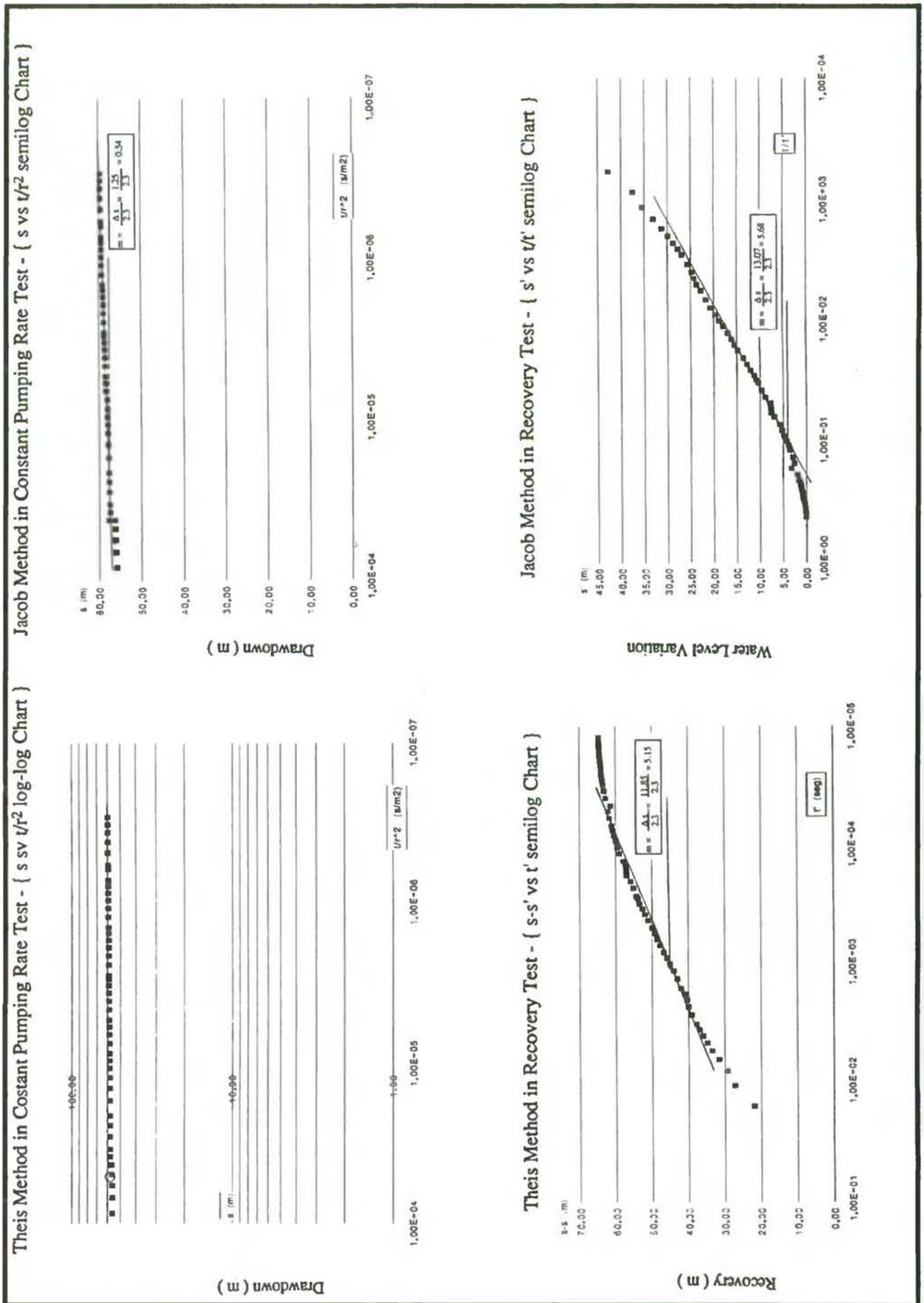


Fig. B-III, 2.30 Graphs for Theis and Jacob Method Analysis (Well No.J-F)

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

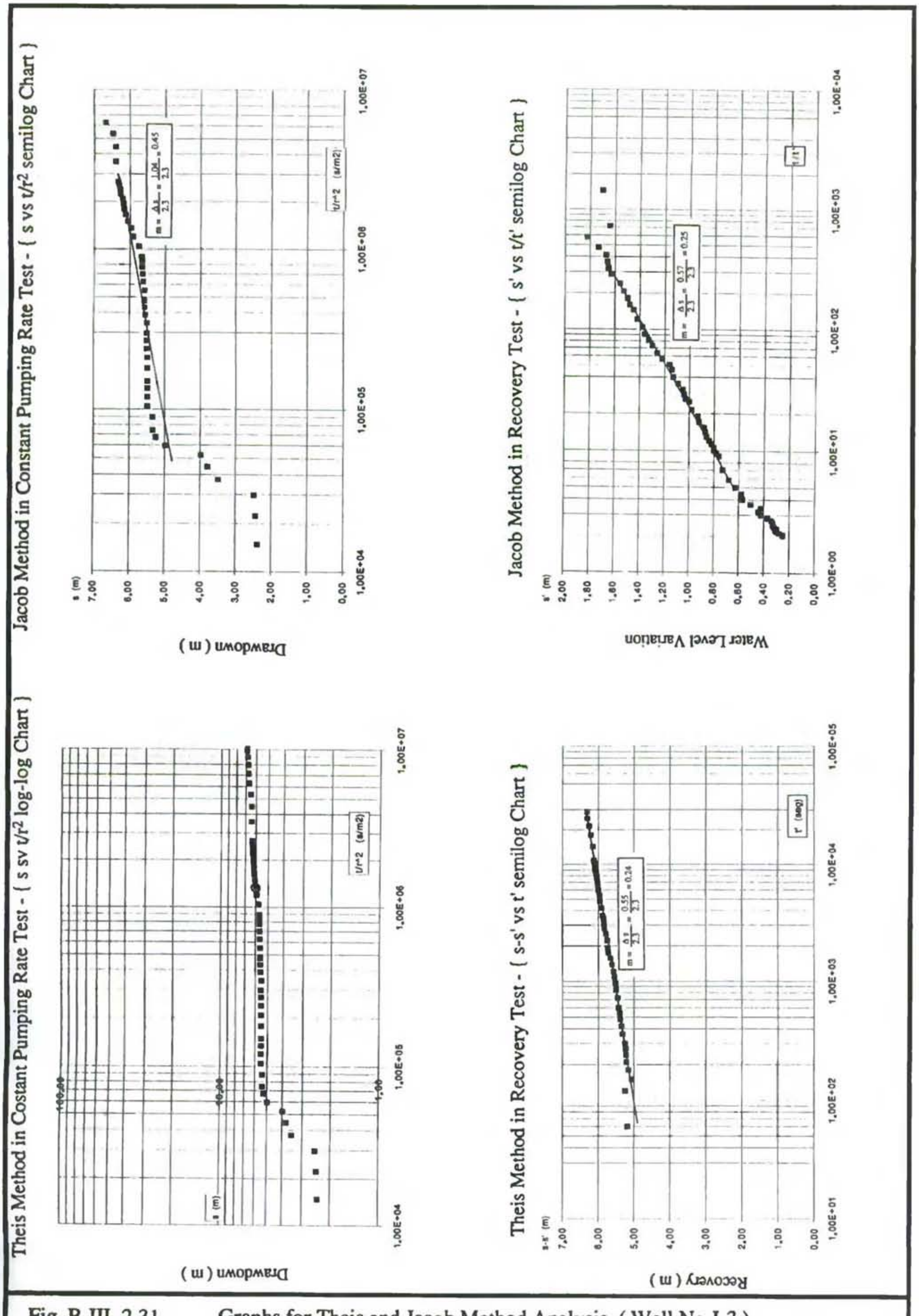


Fig. B-III, 2.31 Graphs for Theis and Jacob Method Analysis (Well No.J-3)

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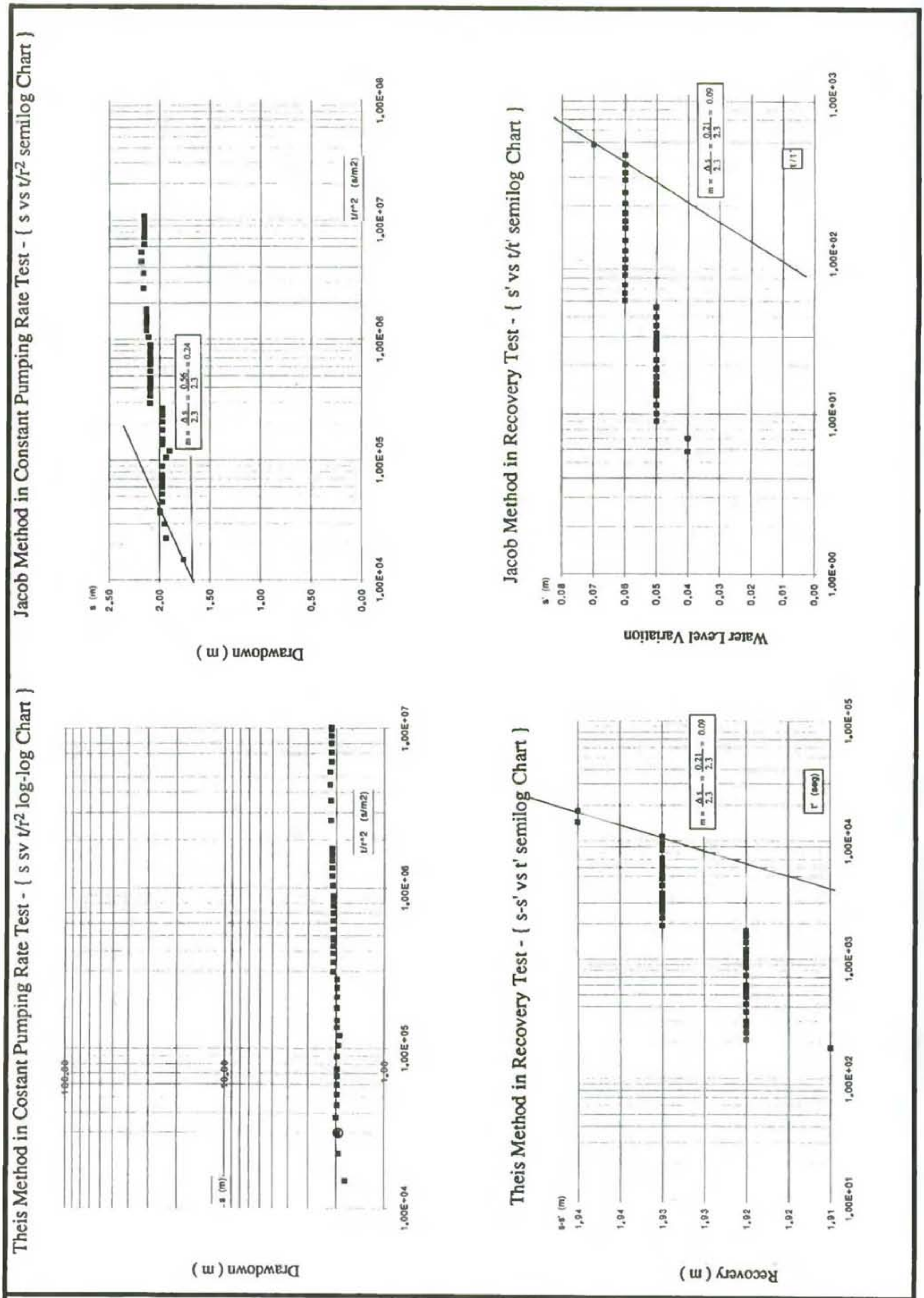

Fig. B-III, 2.32 Graphs for Theis and Jacob Method Analysis (Well No.J-4)

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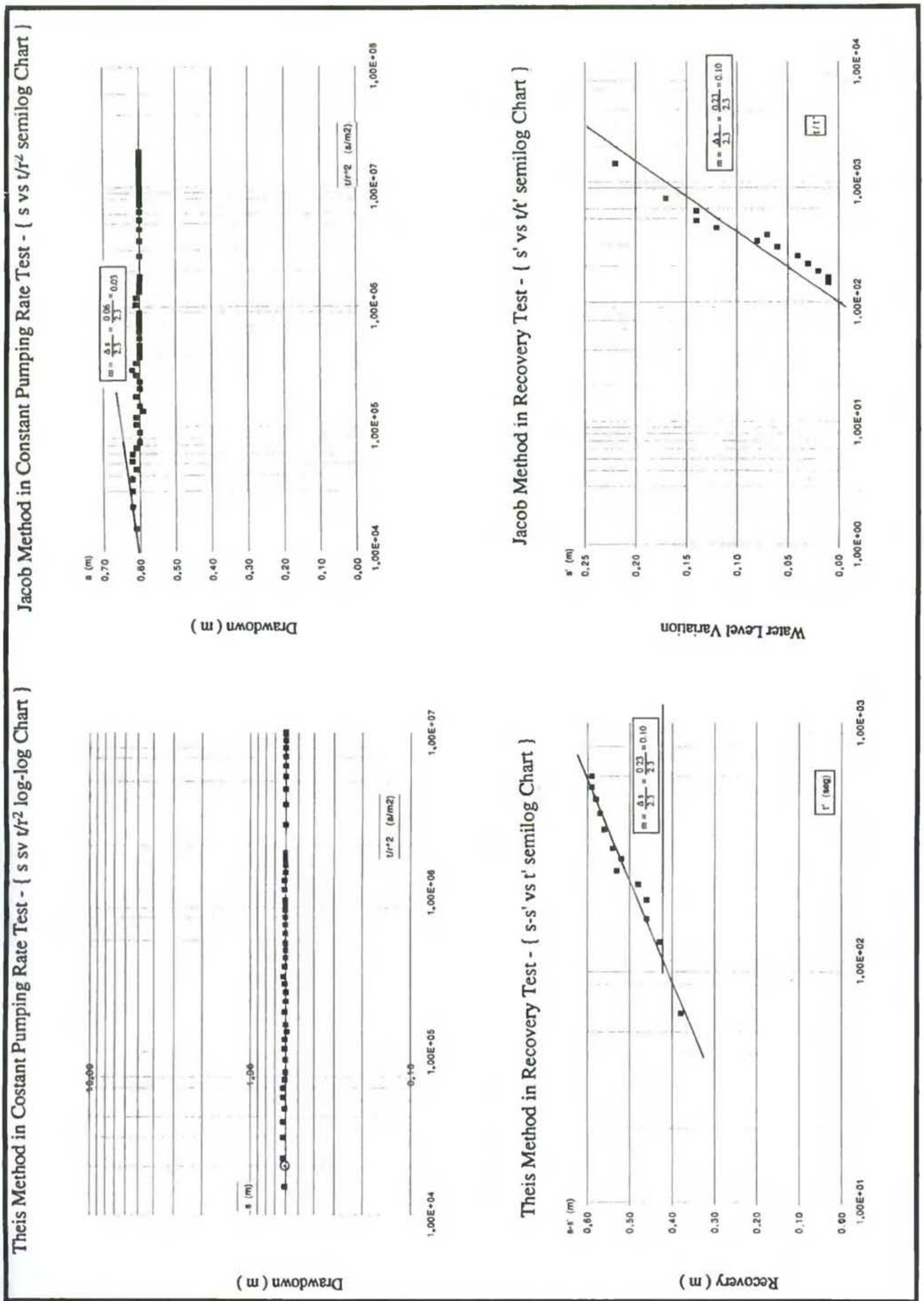

Fig. B-III, 2.33 Graphs for Theis and Jacob Method Analysis (Well No.J-5)

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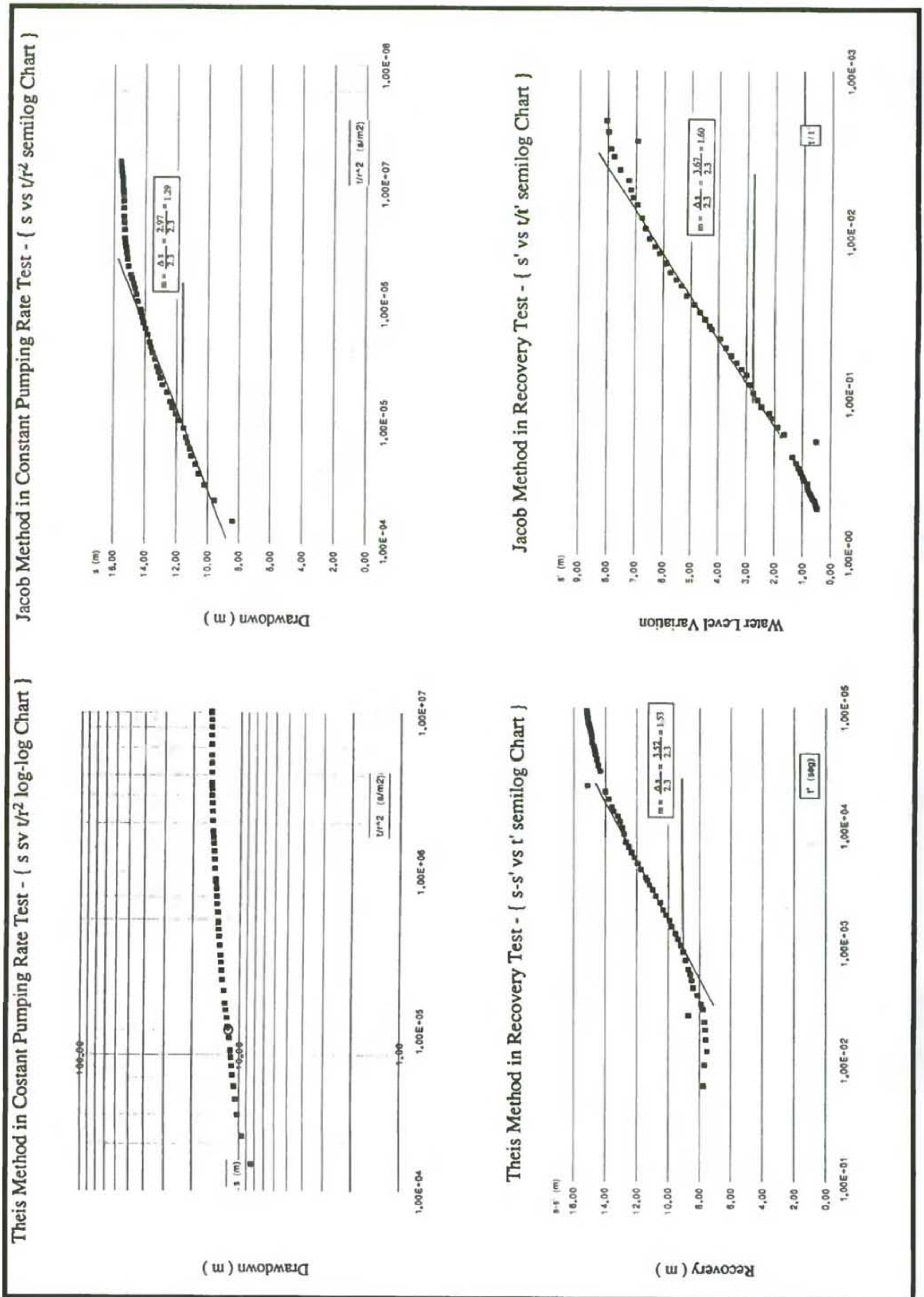

Fig. B-III, 2.34 Graphs for Theis and Jacob Method Analysis (Well No.J-6)

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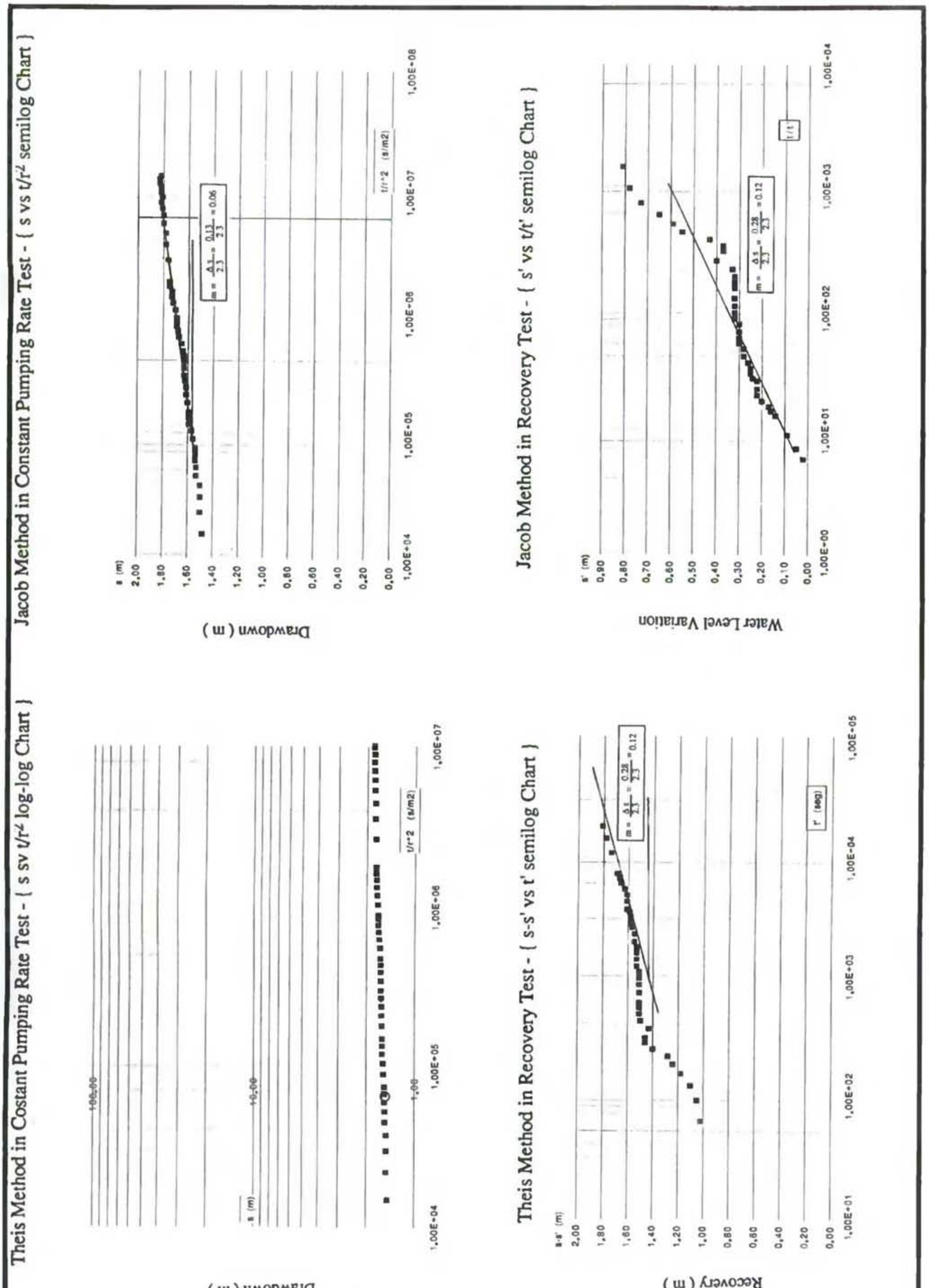

Fig. B-III, 2.35 Graphs for Theis and Jacob Method Analysis (Well No.J-7)

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

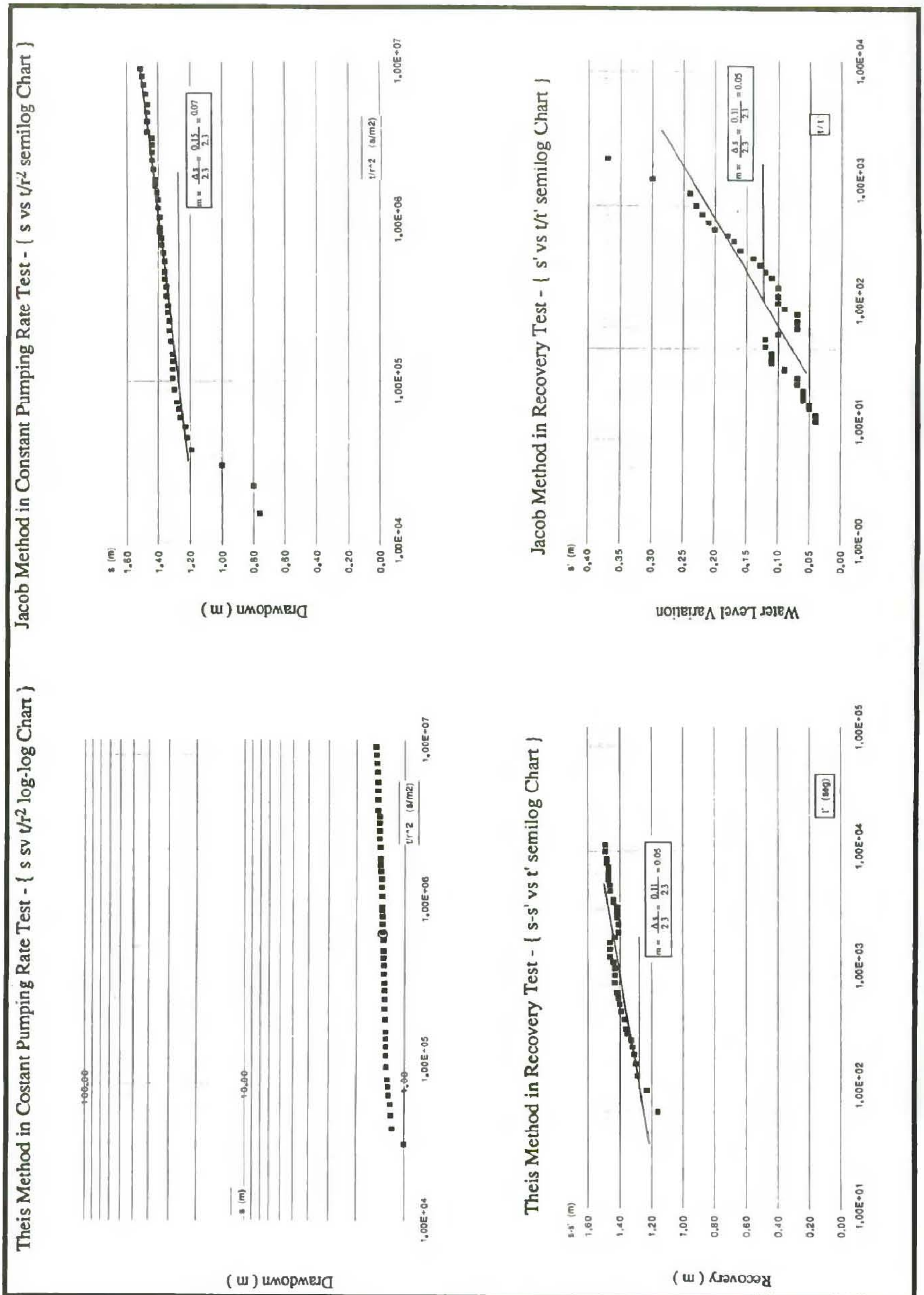

Fig. B-III, 2.36 Graphs for Theis and Jacob Method Analysis (Well No.J-8)

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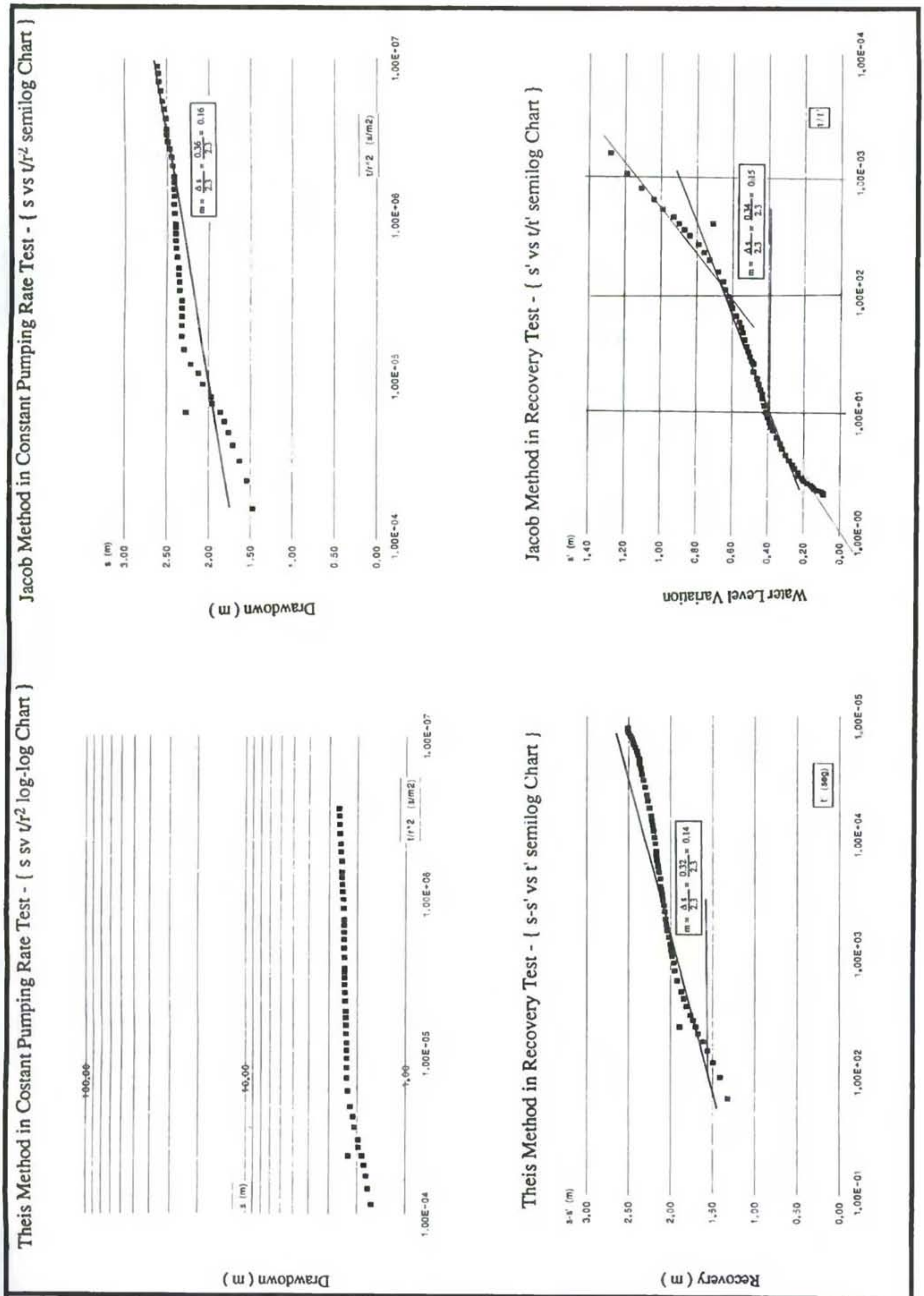

Fig. B-III, 2.37 Graphs for Theis and Jacob Method Analysis (Well No.J-9)

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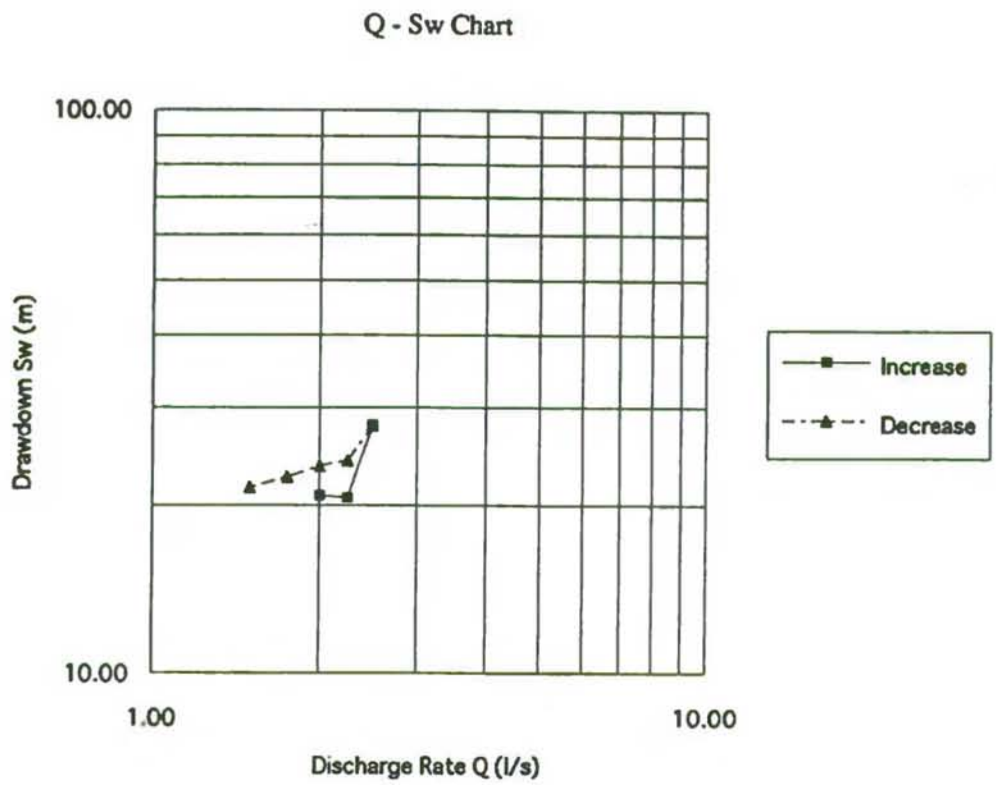


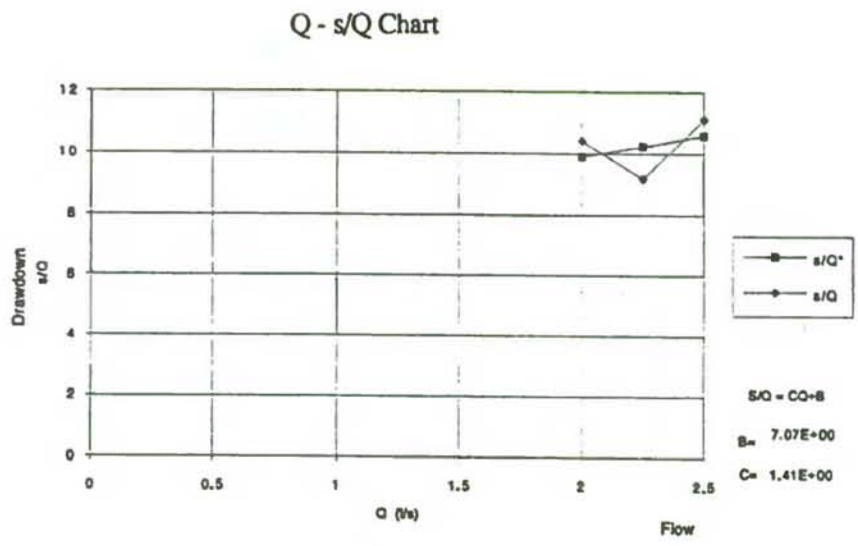
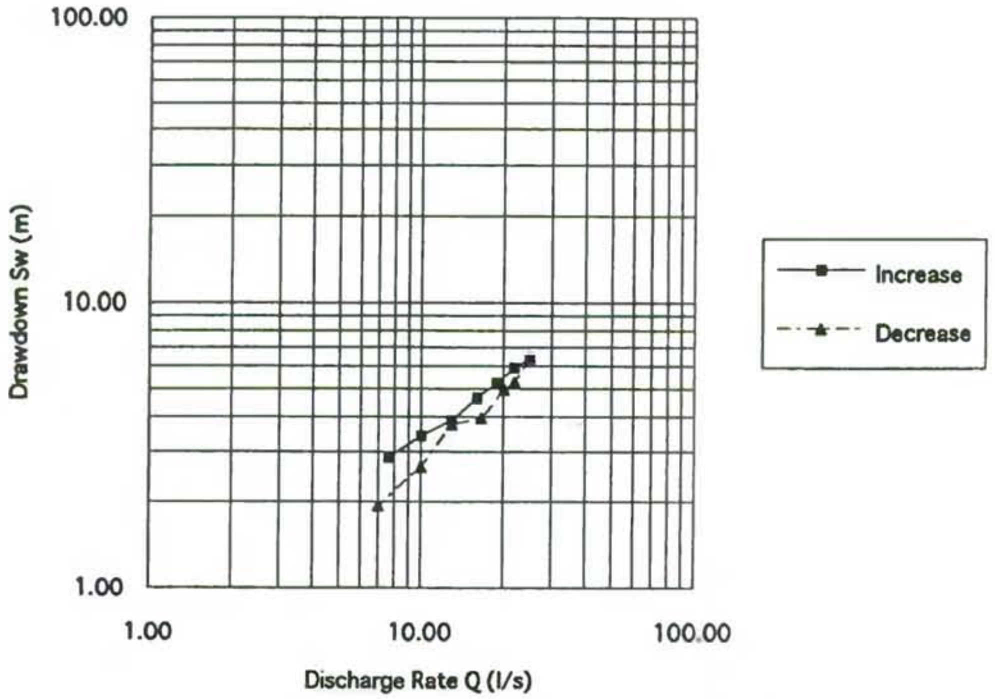


Fig. B-III, 2.38 Graphs for Step Drawdown Test (Well No.J-C)

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

Q - Sw Chart



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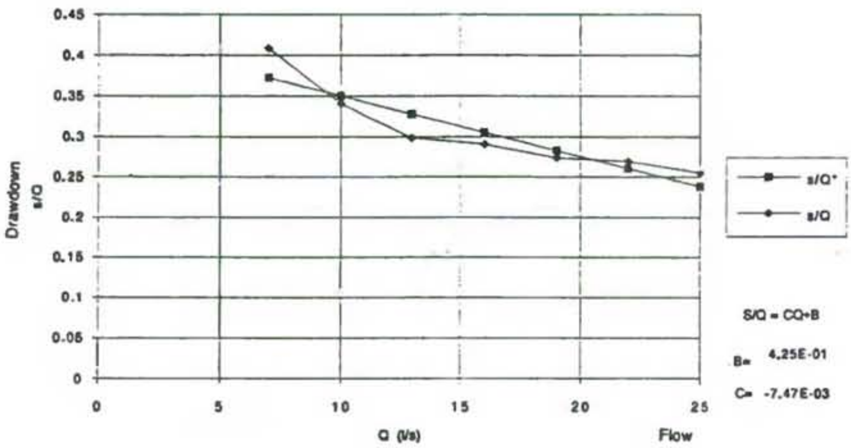

Fig. B-III, 2.39 Graphs for Step Drawdown Test (Well No.J-D)

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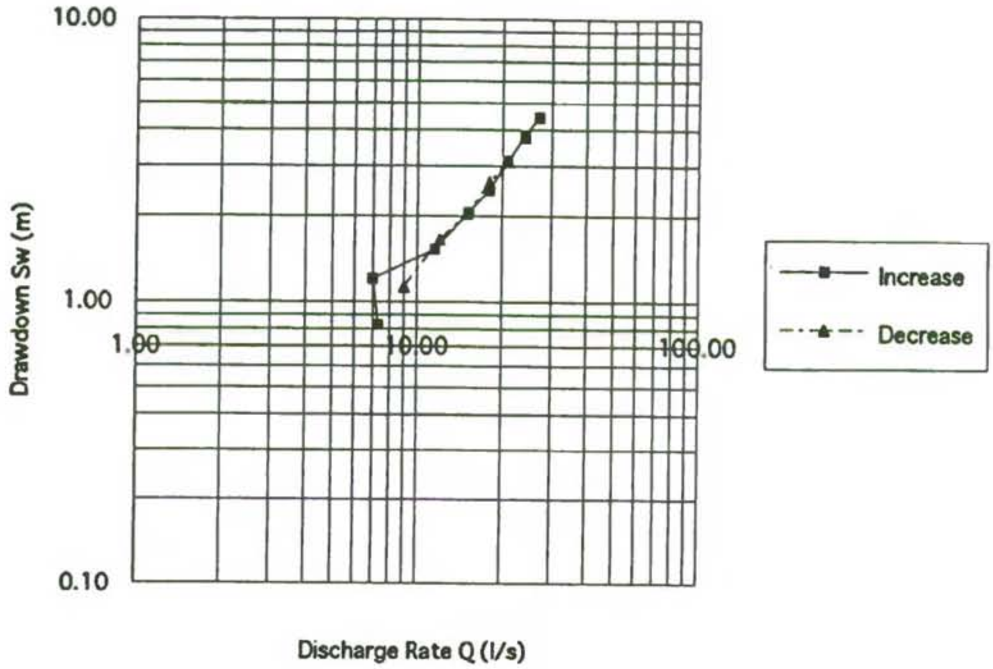

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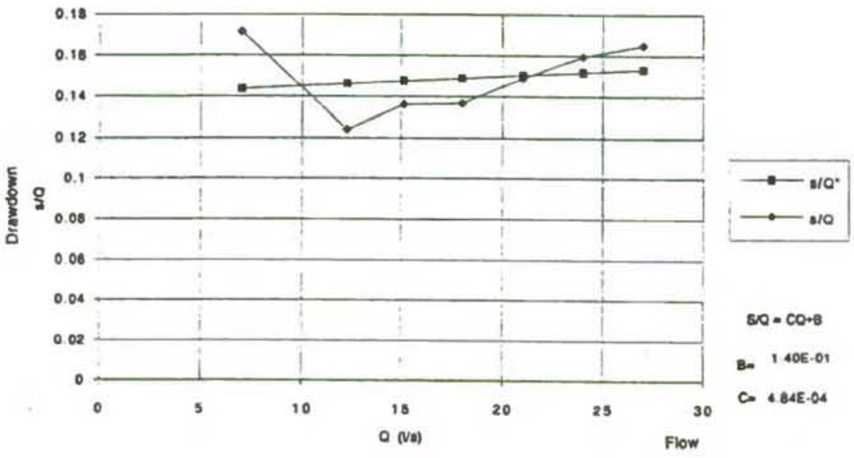

Fig. B-III, 2.40 Graphs for Step Drawdown Test (Well No.J-E)

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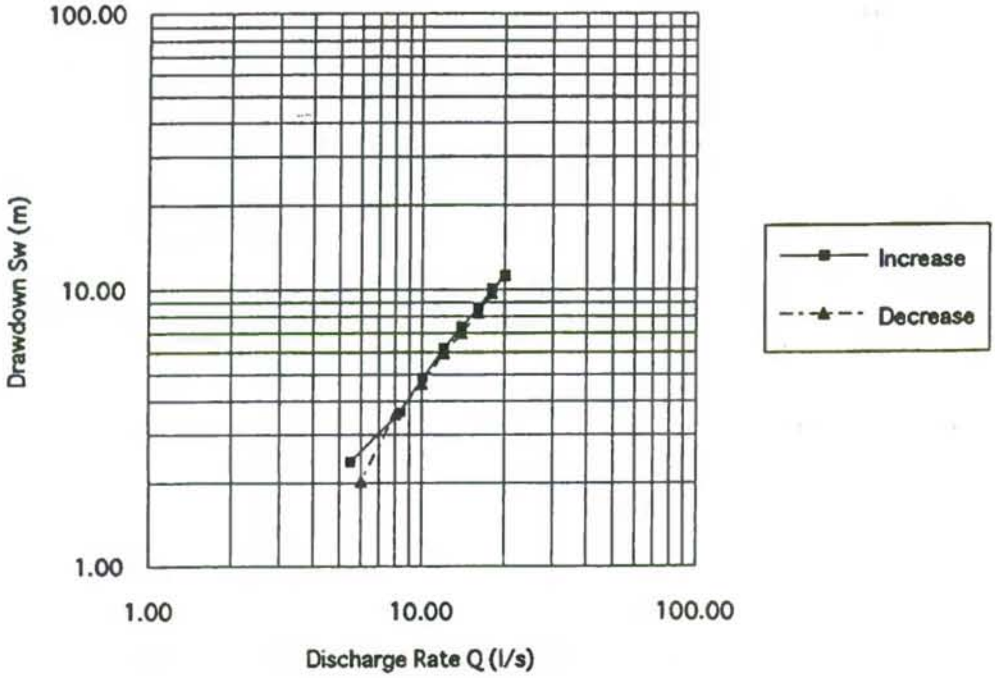

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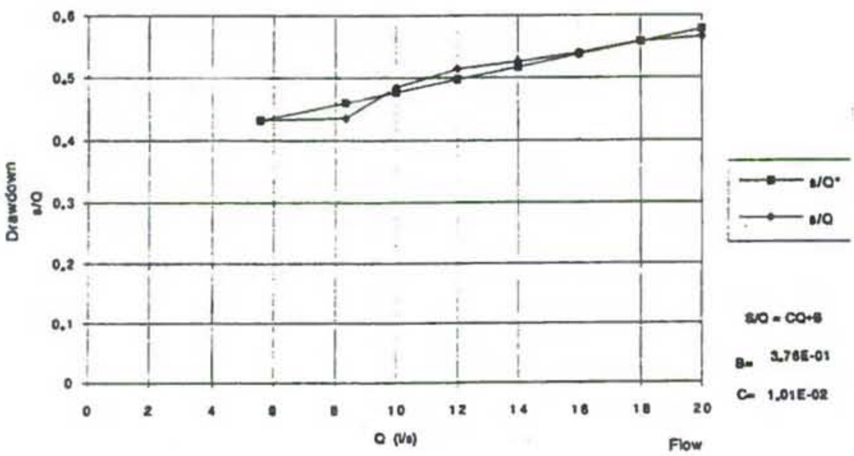

Fig. B-III, 2.41 Graphs for Step Drawdown Test (Well No.J-F)

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

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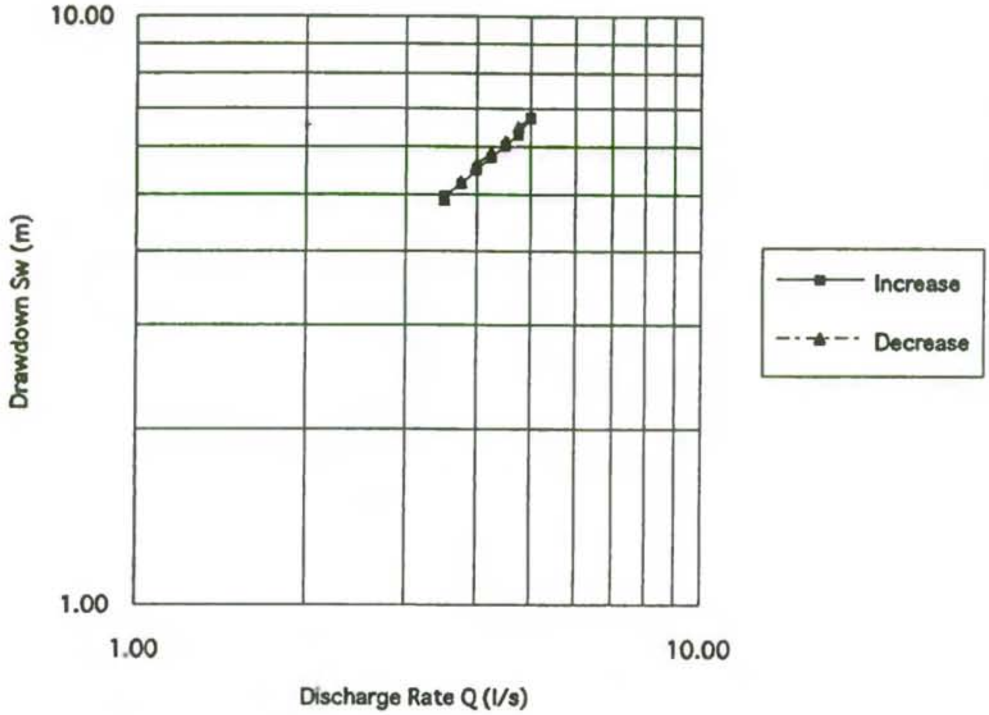

Q - s/Q Chart

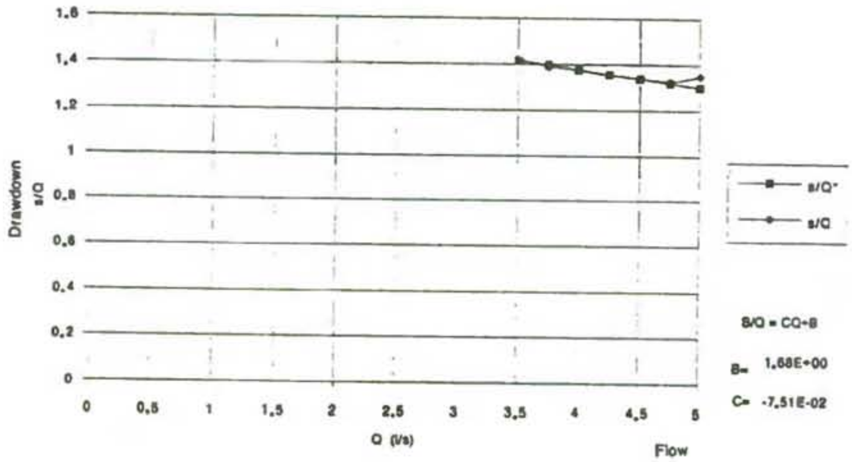

Fig. B-III, 2.42 Graphs for Step Drawdown Test (Well No.J-3)

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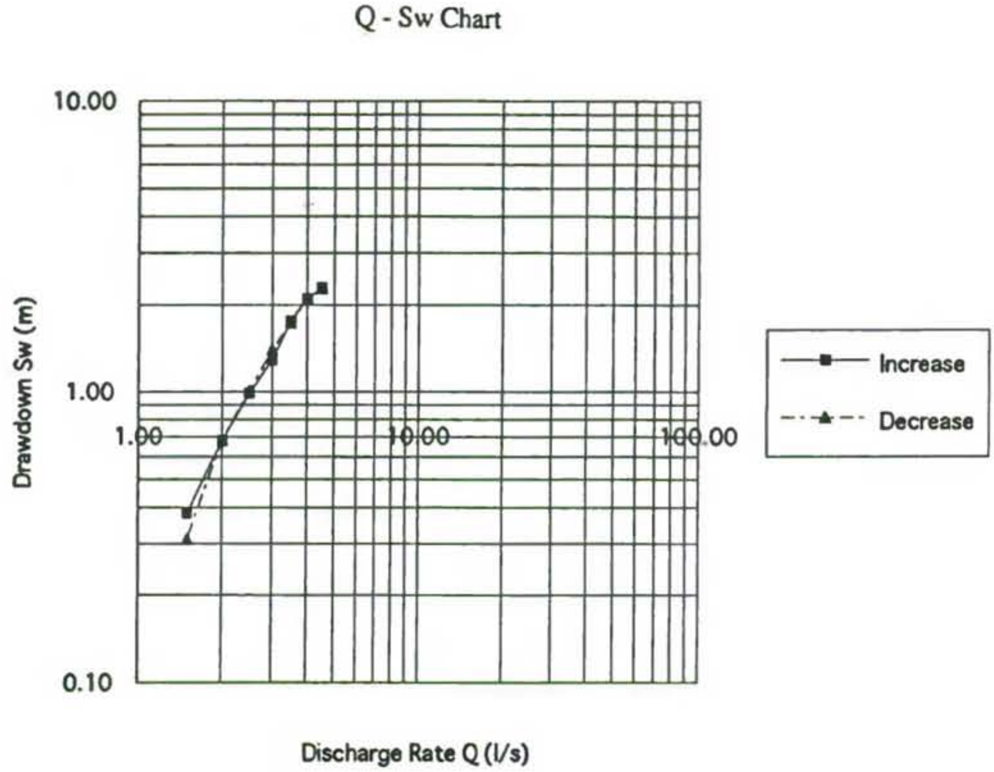

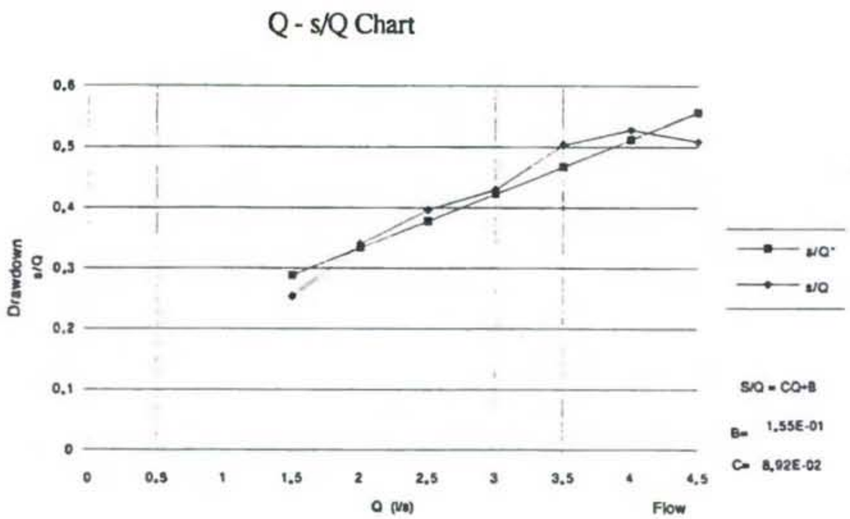

Fig. B-III, 2.43 Graphs for Step Drawdown Test (Well No.J-4)

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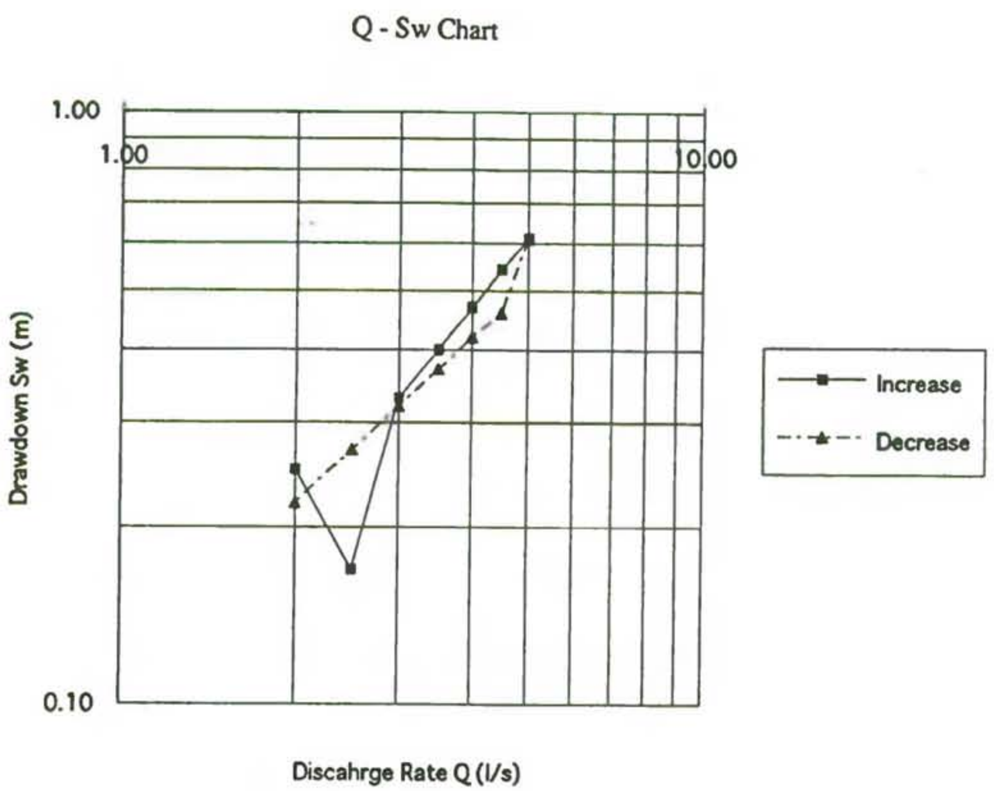


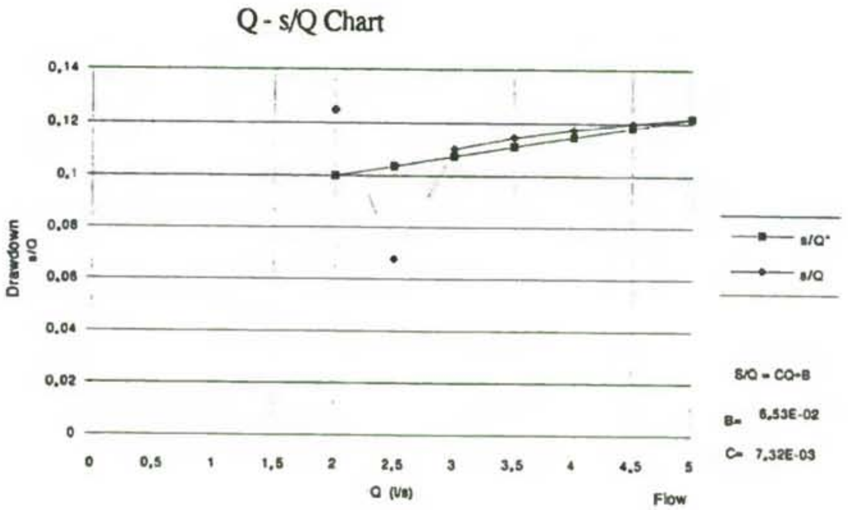
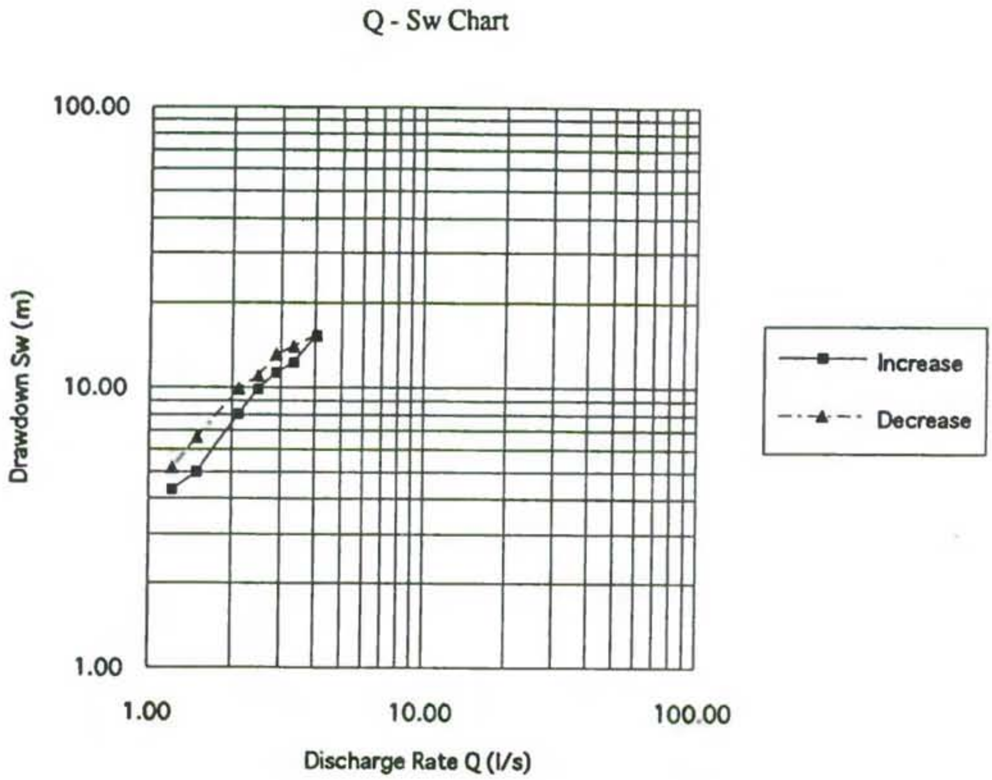


Fig. B-III, 2.44 Graphs for Step Drawdown Test (Well No.J-5)

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



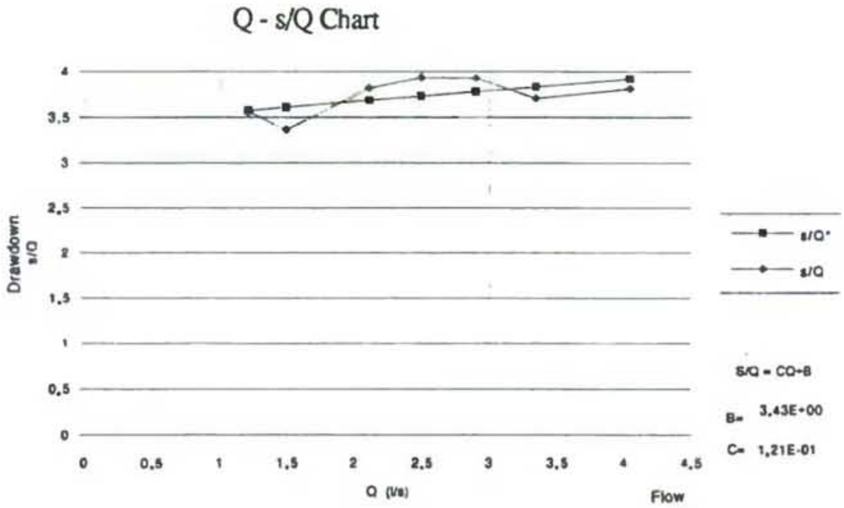
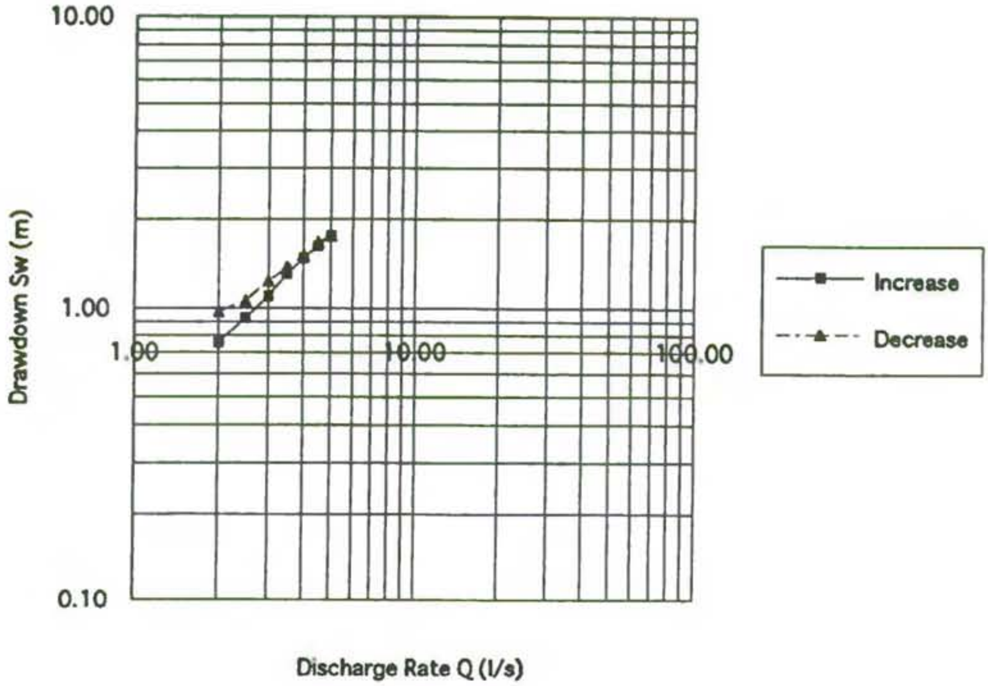


Fig. B-III, 2.45 Graphs for Step Drawdown Test (Well No.J-6)

< Gráficos Prueba de Gasto Variable (Pozo Nº J-6) >

Q - Sw Chart



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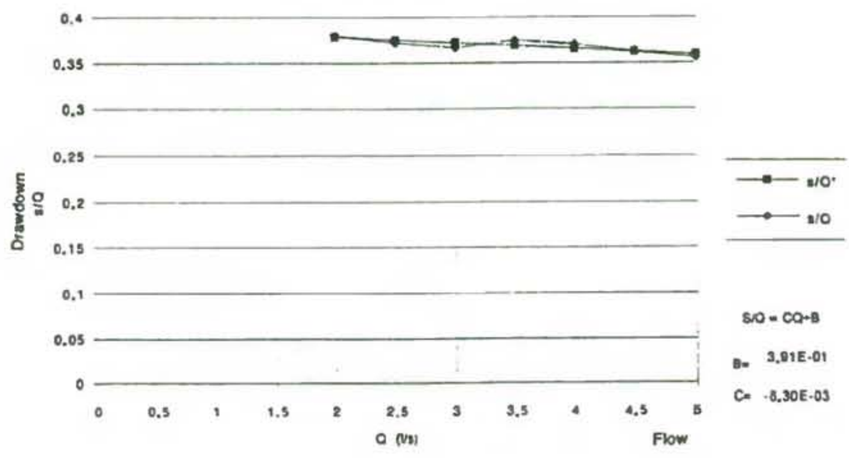

Fig. B-III, 2.46 Graphs for Step Drawdown Test (Well No.J-7)

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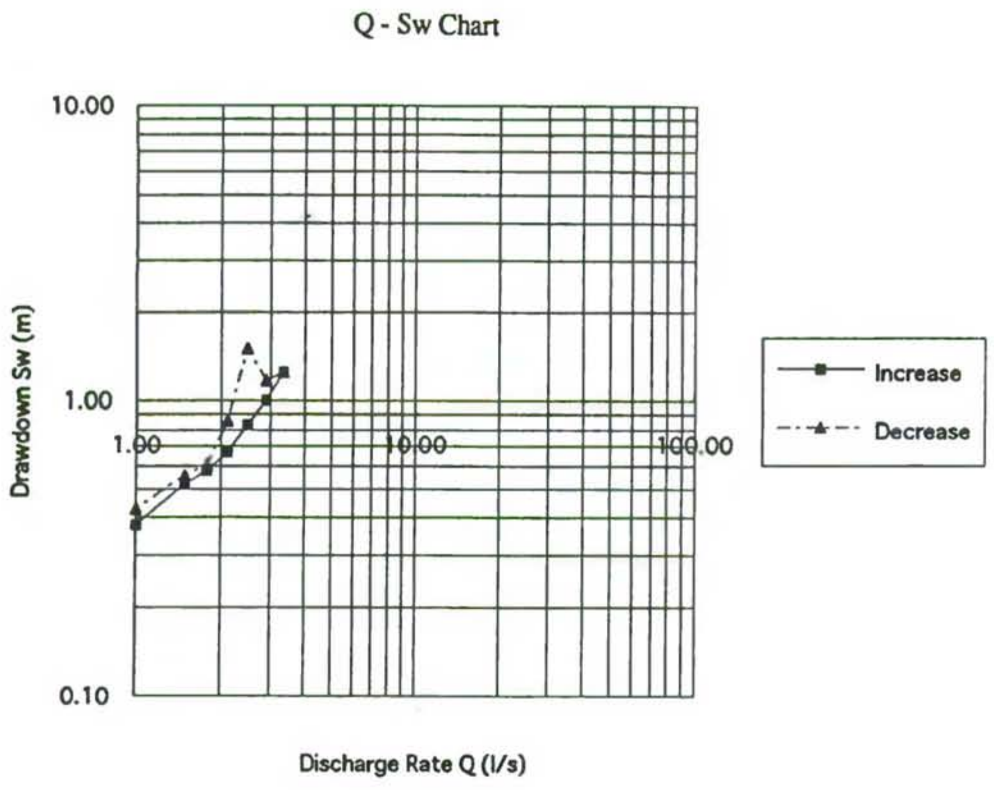

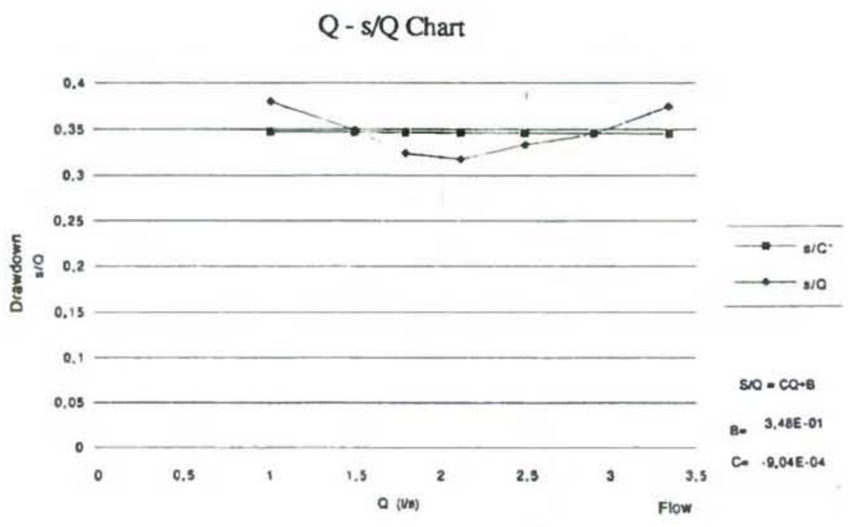

Fig. B-III, 2.47 Graphs for Step Drawdown Test (Well No.J-8)

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

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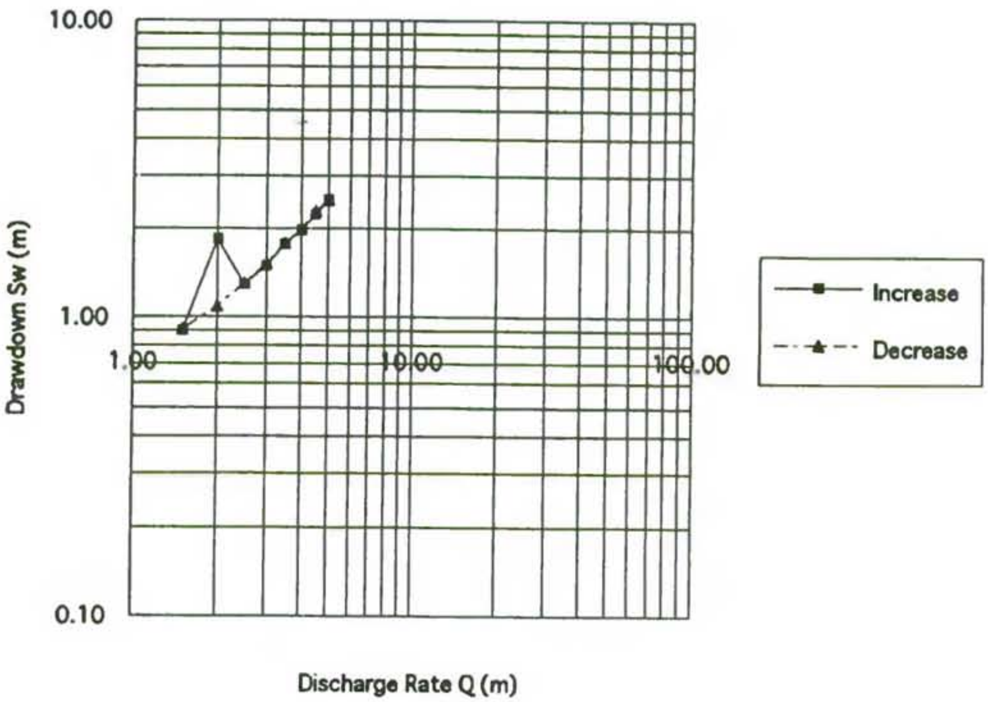

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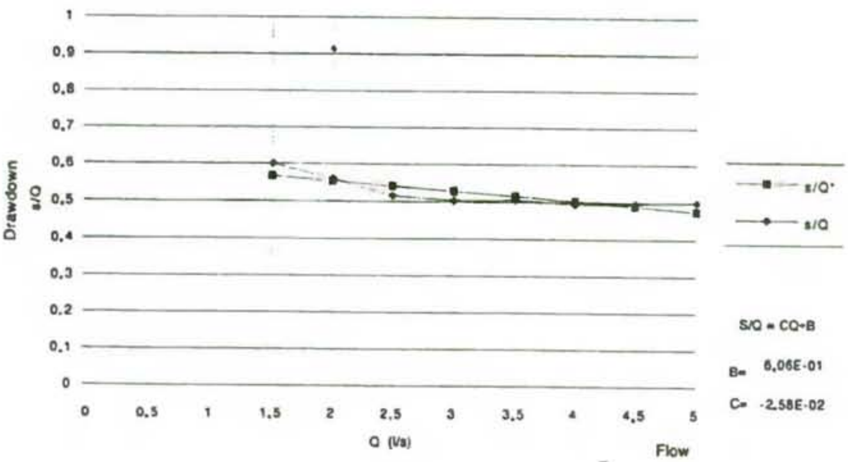

Fig. B-III, 2.48 Graphs for Step Drawdown Test (Well No.J-9)

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

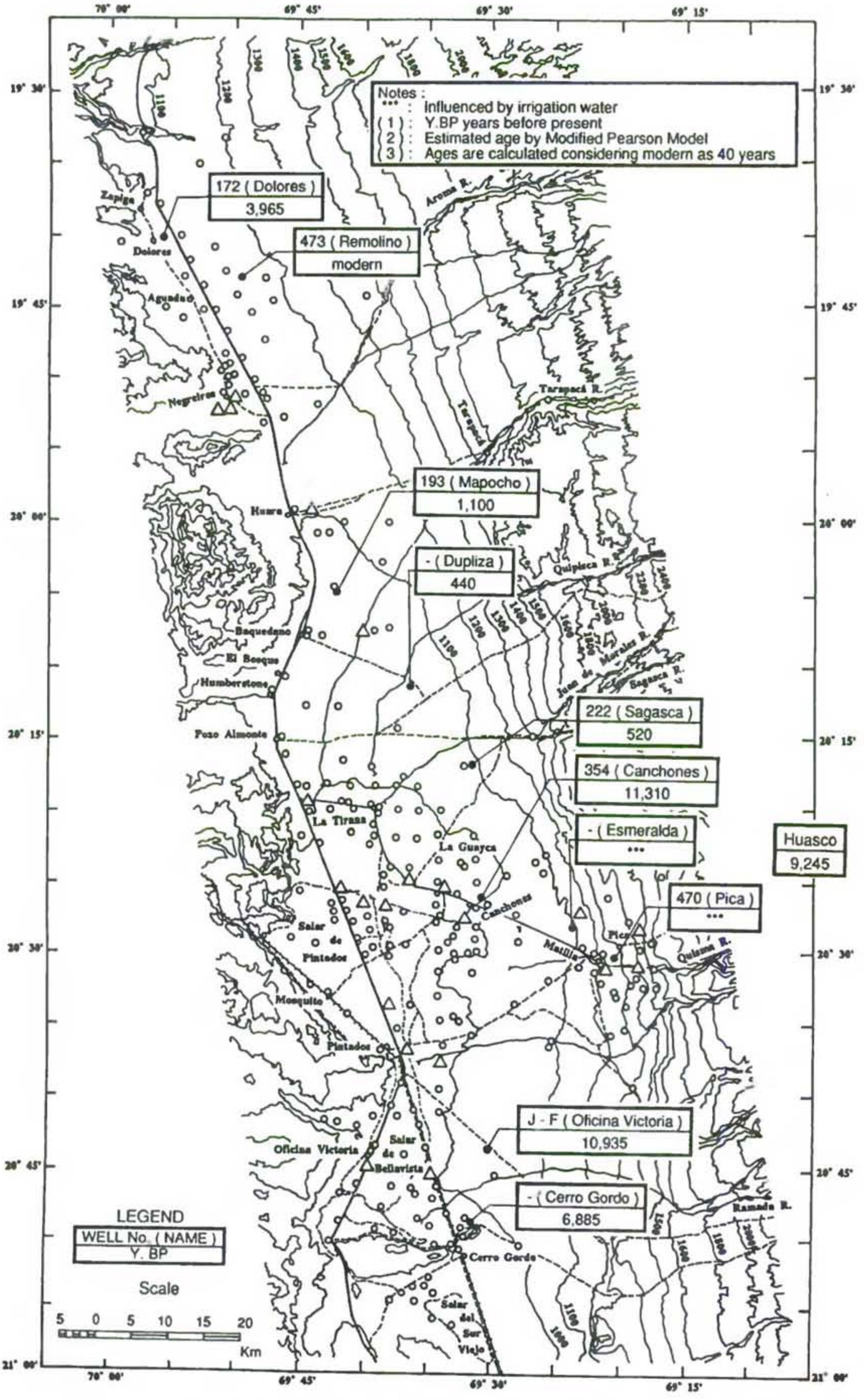

Fig. B-III, 2.49 Groundwater Age (by C - 14)

< Edad Agua Subterránea (por C - 14) >

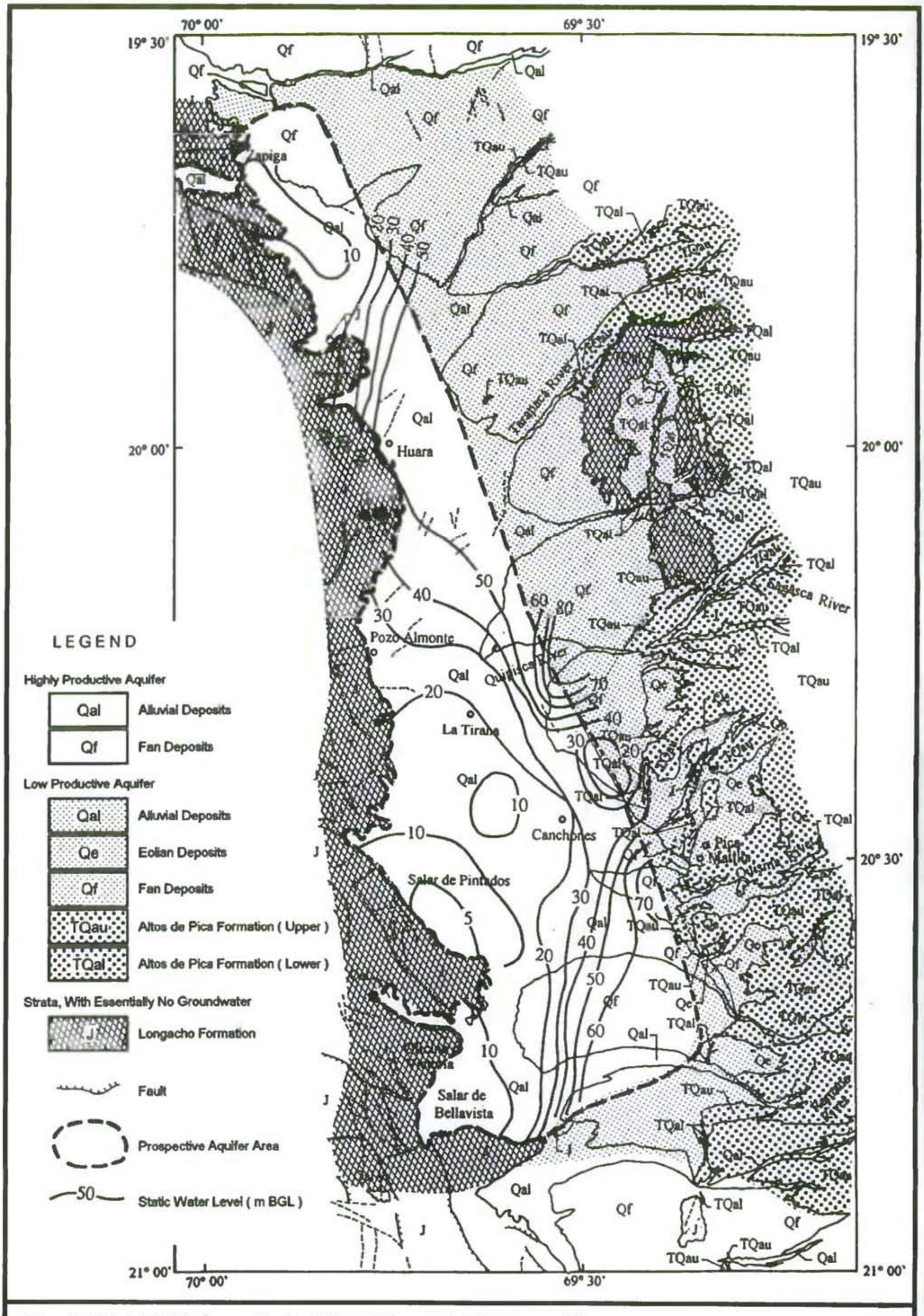

Fig. B-III, 2.50 Hydrogeological Map (Pampa del Tamarugal)

< Mapa Hidrogeológico (Pampa del Tamarugal) >

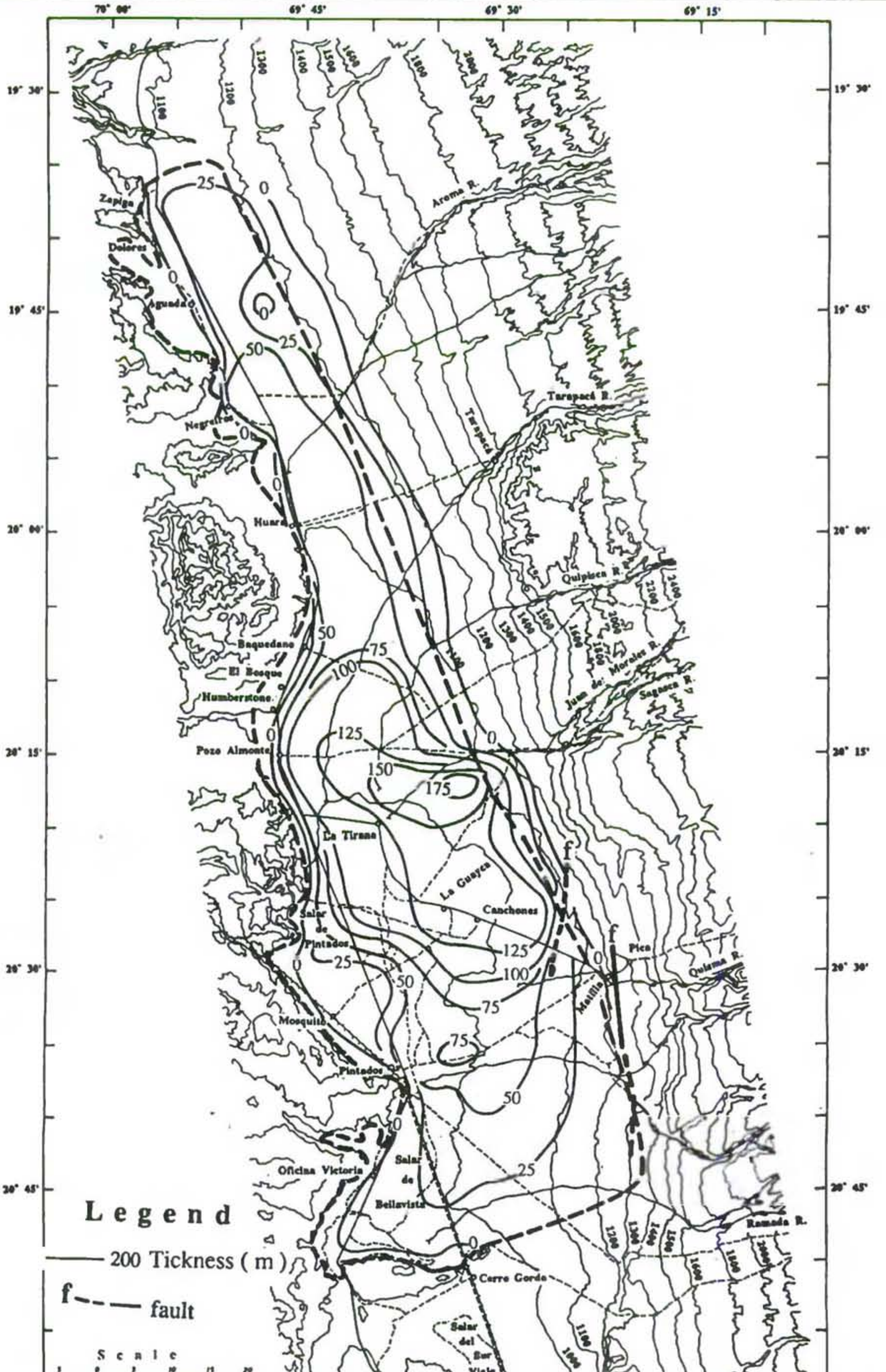

Fig. B-III, 2.51 Isopach Map of Aquifer (Pampa del Tamarugal)

< Mapa Isopaca Acuífero (Pampa del Tmarugal) >

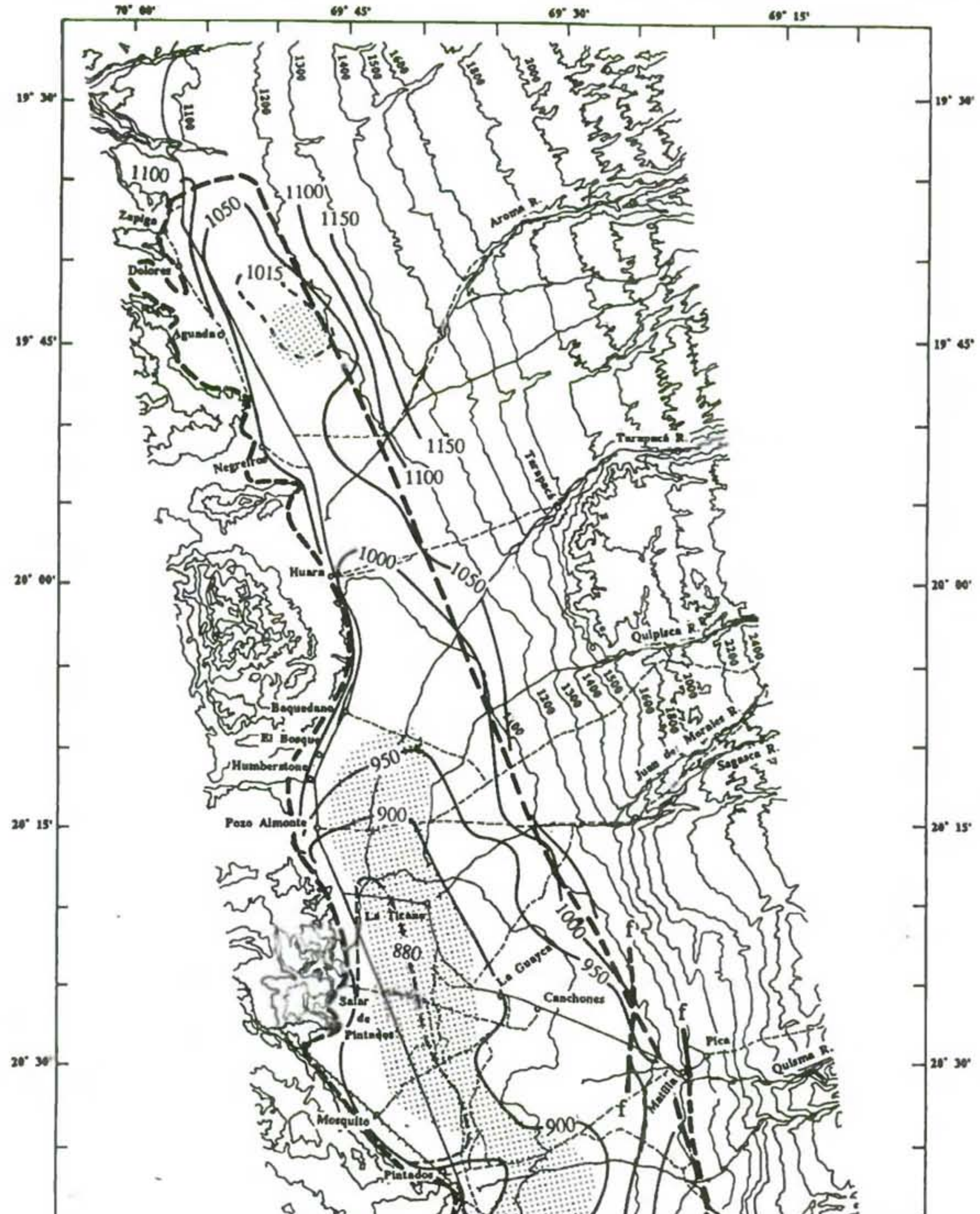

Fig. B-III, 2.52 Top of Aquifer (Pampa del Tamarugal)

< Superficie del Acuífero (Pampa del Tamarugal) >

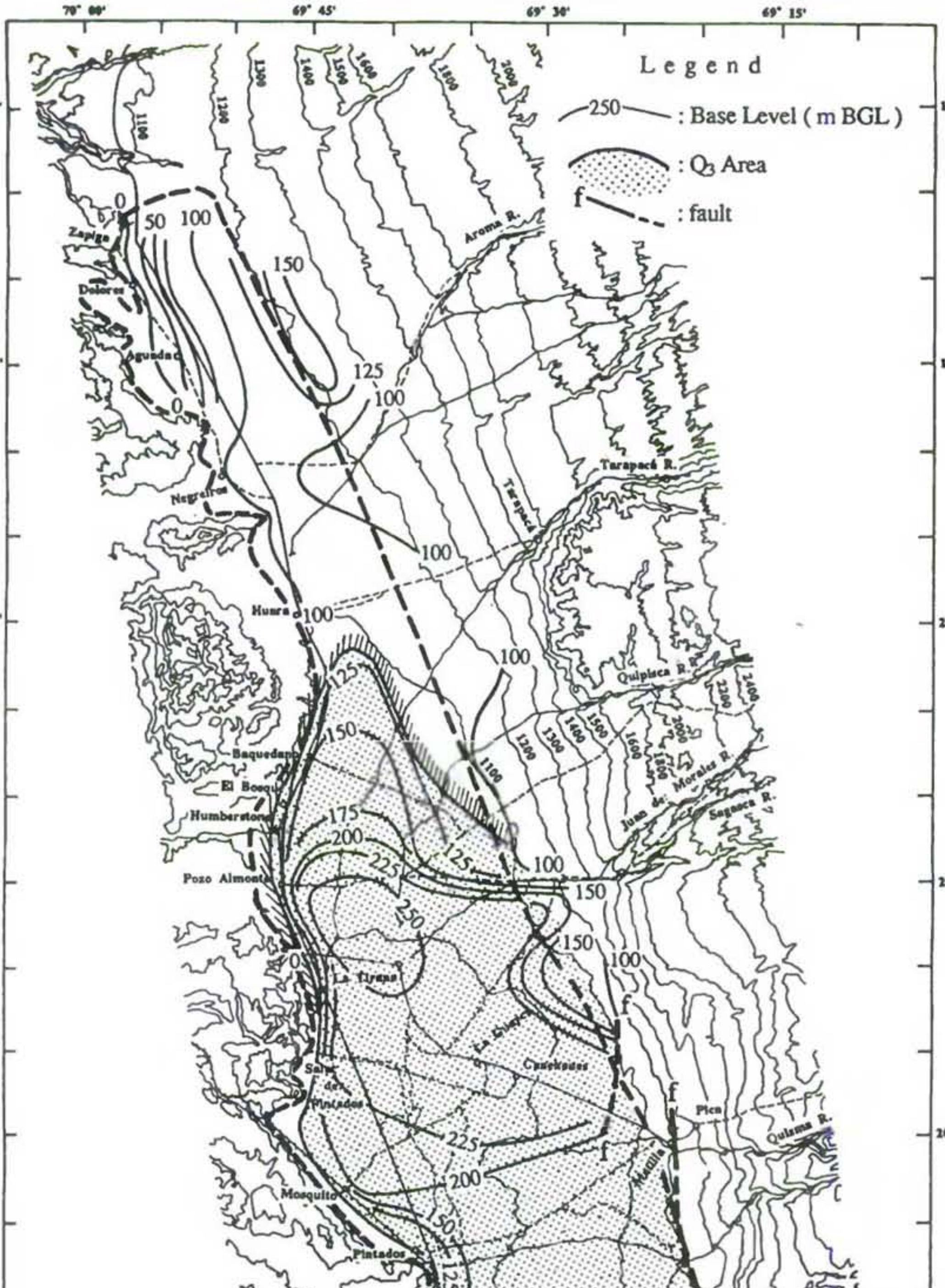

Fig. B-III, 2.53 Base of Aquifer (Pampa del Tamarugal)

< Fondo del Acuífero (Pampa del Tamarugal) >

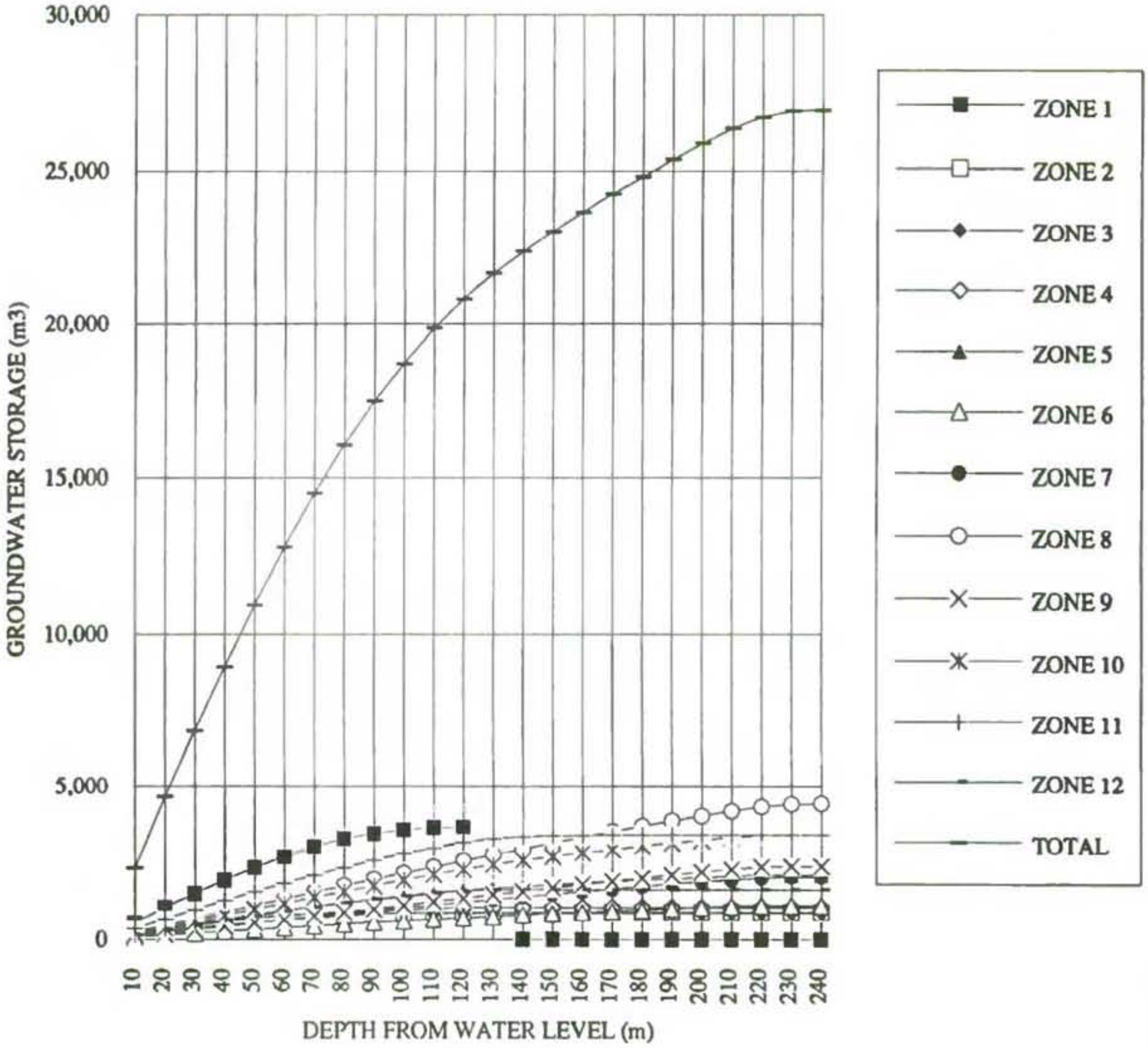

Fig. B-III, 2.54 Groundwater Storage (Pampa del Tamarugal)

<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	: 9.56×10^{-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 0.001 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.

References

<1: Cuadrangulos Pica, Alca, Matilla y Chacarilla, Carta Geologica de Chile (Escala 1: 50,000), 1962 for Instituto de Investigaciones Geologicas Chile by Carlos Galli Olivier y Robert J. Dingman.

<2: Isotopic and Chemical Study of the Water Resources in the Iquique Province, 1985 for IAEA by Magaritz M., Peña H., Grilli A. Orphanopoulos D., O. Suzuki and Aravena R.

<3: Análisis Programa de Desarrollo de Empresa de Servicios Sanitarios de Tarapaca, February 1991 for ESSAT by Bustamante y Schudeck Ingenieros Consultores Ltda.

<4: Modelo de Simulacion Hidrogeologico de la Pampa del Tamarugal, 1988 for DGA by Centro de Recursos Hidrauklicos, Departamento de Ingenieria Civil, Universidad de Chile.

Table B-III, 3.1. Ground Water Extraction (Pampa del Tamarugal)

<Extracción de Agua Suterránea (Pampa del Tamarugal)>

(Pampa Area)

Water Use	Well No.	Well Name	Extraction Rate		Total
	(BNA)		(m3/year)	(l/sec)	
Agriculture	381	CONAF	986	0.03	
	412	CONAF	654	0.02	
	363	Luis Quispe	394	0.30	0.35
Domestic	426	Esteban Lucic	1,314	0.04	
	316	David Chiang	263	0.20	
	312	Guillermo Araya	329	0.17	
	128	CORFO	183	0.01	
	-	Dupliza	1,892,160	60.00	
		Pta. Canchones (ESSAT)	18,914,508	599.78	
		Pta. Dolores (ESSAT)	14,622	0.46	660.65
Mining	984 or 985	ACF Minera	157,680	5.00	
		Oficina Mapocho	946,080	30.00	35.00
Total			21,929,173	696.00	696.00

(Other Area: Pica, Matilla, Esmeralda and Cascada)

Water Use	Well No.	Well Name	Extraction Rate		Total
	(BNA)		(m3/year)	(l/sec)	
Agriculture		Pica/Matilla	3,500,496	111.00	111.00
Domestic		Pica/Chintaguay (ESSAT)	1,630,430	51.70	51.70
Mining	221	Cia. Minera La Cascada	432,000	13.70	
	222	Cia. Minera La Cascada	648,000	20.55	34.25
Total			6,210,926	196.95	196.95

Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)>

DGA	11	21		30	10	18	20	25	28	13	31	32	45	57
BNA	171-K	164-7	473-5	104-3	170-1	101-9	179-5	102-7	103-5	173-6	105-1	106-K	191-4	131-0
CORFO	1930-6950	1940-6940	1940-6940	1940-6940	1940-6950	1940-6950	1940-6950	1940-6950	1940-6950	1940-6950	1950-6940	1950-6940	2000-6930	2010-6930
DATE	A-1	A-1	AN-3	C-3	A-3	B-3	B-5	D-1	D-2	A-6	A-2	A-3	C-1	A-1
81/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11				14.03		8.40	8.16	7.33	9.45		20.54	24.73		
12				14.24		8.15	8.29	7.00	9.30		20.92	25.03		
82/1				13.72		7.95	7.29		9.21		20.78	24.92		
2				14.32		7.24	8.40		9.24		20.67	25.00		
3				13.87		7.28	8.41		9.27		19.98	24.44		
4				13.96		7.97	8.31		9.37		20.01	24.74		
5				13.92		8.00	8.39		9.40		20.05	24.79		
6				14.48		7.98	8.36		9.42		20.75	25.36		
7				14.31		7.99	8.30		9.12		20.78	25.32		
8				14.10		7.81	8.00		9.00		21.00	25.00		
9				13.66		8.31	8.64		9.70		20.11	24.58		
10				14.64		8.24	8.67		9.66		21.12	25.32		
11				14.32		8.08	8.38		9.40		20.93	25.54		
12				11.60		8.26	8.60		9.41		20.92	22.24		
83/1				11.62			8.66		11.64		20.96	24.24		
2														
3				14.07		8.34	8.64		9.71		21.00	24.65		
4				14.10		8.37	8.68		9.77		21.04	24.73		
5				14.72		8.42	8.74		9.84		21.06	25.30		
6				14.65		8.43	8.75		9.84		21.05	25.52		
7				14.62		8.43	8.72		9.85		21.03	25.50		
8				14.15		8.30	8.65		9.65		19.70	25.00		
9				14.20		8.20	8.55		10.00		20.00	24.90		
10				14.35		8.20	8.50		10.80		20.85	24.83		
11				14.57		8.15	8.70		9.85			25.20		
12				14.50		8.35	8.78		9.80		20.89	25.20		
85/1				14.03	8.74	8.04	8.43		9.91		21.41	24.57		20.30
2				14.05	6.78	8.02	8.40		9.89		21.36	24.61		20.26
3				14.00	6.76	8.04	8.40		9.86		21.38	24.58		20.28
4				14.07	6.76	8.02	8.40		9.93		21.38	24.62		20.28
5				14.10	6.81	8.08	8.50		9.97		21.46	24.64		20.31
6				14.15	6.82	8.11	8.54		9.99		21.38	24.59		20.25
7				14.12	6.77	8.09	8.49		9.92		21.43	24.81		20.25
8				14.12	6.79	8.13	8.47		9.95		21.38	24.64		20.27
9				14.11	6.74	8.08	8.46		9.93		21.41	24.62		20.26
10				14.12	6.71	8.03	8.42		9.93		21.38	24.56		20.28
11				14.10	6.71	8.04	8.40		9.91		21.38	24.54		20.25
12				14.08		8.10	8.47		9.97		20.33	24.59		20.31
86/1	6.94			14.15		8.14	8.58				20.25	24.41		20.30
2														
3	7.00			14.09		8.14	8.54				20.31	24.60		20.40
4	6.98			14.13		8.18	8.56				20.34	24.63		20.40
5														
6	6.17			13.55		7.58	7.76				19.56	24.75		20.42
7														
8	6.80			14.08		8.18	8.66				20.39	24.92		20.42
9														
10	7.01			14.12		8.19	8.68				20.37	24.64		20.44
11														
12														
87/1														
2	6.91			14.16		8.24	8.71				20.38	24.64		20.44
3														
4	7.19			14.18		8.31	8.87				20.37	24.64		20.50
5														
6	7.16			14.18		8.33	8.89				20.36	24.63		20.46
7														
8														
9														
10	6.91			14.19		8.37	9.02				-			20.53
11														
12														
88/1														
2														

Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)> (2)

DGA	11	21		30	10	18	20	25	28	13	31	32	45	57
BNA	171-K	164-7	473-5	104-3	170-1	101-9	179-5	102-7	103-5	173-8	105-1	106-K	191-4	131-0
CORFO	1930-8950	1940-8940	1940-8940	1940-8940	1940-8950	1940-8950	1940-8950	1940-8950	1940-8950	1940-8950	1950-9940	1950-9940	2000-8930	2010-8930
DATE	A-1	A-1	AN-3	C-3	A-3	B-3	B-5	D-1	D-2	A-6	A-2	A-3	C-1	A-1
3	6.95			14.23		8.40								20.54
4	6.98			14.23		8.34								20.54
5														
6	6.96			14.23		8.38								20.53
7														
6	8.70			14.26		8.49								20.57
9														
10	6.94			14.23		8.38								20.58
11														
12														
89/1														
2														
3		15.38	12.06	14.83		8.59				8.08				
4														
5														
6														
7		15.37	12.06			8.60				6.55				
8		15.37	12.06	14.82		8.60				8.65	-			
9														
10		15.37	12.06	14.83		8.60				8.55	-			
11														
12		15.37	12.05			6.60				8.55	-			
90/1														
2				14.86		8.49				8.51				
3														
4														
5				14.86						8.36	-			
6														
7														
8											-			
9														
10														
11				14.87						8.74	-			
12														
91/1		15.41	12.04	14.48						8.72	-			
2		15.43	11.99	14.80						6.74	-			
3		15.41	11.99	14.80						8.74	-			
4		15.46	11.94	14.91						8.92	-			
5		14.28	12.05	14.46						8.80	-			
6														
7		15.41	12.06	14.35						8.73	-			
8		15.40	12.06	14.35						6.72	-			
9		15.37	12.06	14.34						8.96	-			
10		15.40	12.05	14.35						8.96	-			
11		15.38	12.06	14.38						8.18	-			
12		15.38	12.05	14.35						6.21	-			
92/1		15.38	12.05	14.37						8.67	-			
2				14.32										
3		15.43	12.08	14.38										
4		15.40		14.38										
5				14.39										
6		15.53	12.05	14.38										
7														
8				14.36										
9														
10				14.37										
11				14.36										
12				14.36										
93/1				14.38										
2		15.40	12.13	14.37										
3			12.09	14.40										
4														
5														
6			12.09	14.39										
7				14.40						8.85				
8			12.09	14.39						8.87				
9				14.41						9.09				
10			12.13	14.40						9.12				
11														
12														

SOURCE: OBSERVATION RECOEDS BY DGA

Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)> (3)

DGA	59	60	64	77	65	81	56	66	82	72		223	170	174
BNA	204-K	132-9	222-8	230-9	107-8	133-7	234-1	235-K	109-4	129-9	260-0	252-K	263-5	265-1
CORFO	2010-6930	2010-6930	2010-6930	2010-6940	2010-6940	2010-6940	2010-6940	2010-5940	2010-6940	2010-6940	2020-6910	2020-6910	2020-6920	2020-6920
DATE	C-3	C-4	D-2	D-6	C-2	D-10	D-12	D-13	D-16	D-5	C-13	C-5	A-2	A-4
81/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11									16.75					
12									21.14					
82/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
83/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
85/1	24.03			10.22			25.96			20.40				
2	24.07			10.20			25.98			20.44				
3	24.06			10.25			25.96			20.40				
4	24.11			10.26			25.97			20.40				
5	24.05			10.18			25.95			20.48				
6	24.10			10.16			25.86			20.46				
7	24.05			10.15			25.90			20.40				
8	24.09			10.20			25.93			20.45				
9	24.07			10.20			25.89			20.43				
10	24.03			10.18			25.91			20.36				
11	24.04			10.18			25.90			20.33				
12	24.00			10.13			25.92			20.49				
86/1	24.02			10.35		14.81	25.81							
2														
3	24.19			10.39		14.80	25.98			20.48				
4	24.20			10.37			26.02			20.55				
5														
6	23.92			10.37			26.11			20.59				
7														
8	24.27			10.41			26.01			20.61				
9														
10	24.27			10.37			26.02			20.66		40.09		
11														
12														
87/1														
2	24.26			10.44			26.04			20.66		39.80		
3														
4	24.32			10.48			26.09			20.68		39.81		
5														
6	24.32			10.55			26.07			20.69				
7														
8														
9														
10	24.36			10.51			26.13			20.70				
11														
12														
88/1														
2														

Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)> (4)

DGA	59	60	64	77	65	81	56	66	82	72		223	170	174
BNA	204-K	132-9	222-8	230-9	107-8	133-7	234-1	235-K	109-4	129-9	260-0	252-K	263-5	265-1
CORFO	2010-6930	2010-6930	2010-6930	2010-6940	2010-6940	2010-5940	2010-6940	2010-6940	2010-6940	2010-6940	2020-6910	2020-6910	2020-6920	2020-6920
DATE	C-3	C-4	D-2	D-6	C-2	D-10	D-12	D-13	D-16	D-5	C-13	C-5	A-2	A-4
3	24.61			10.56			26.13			20.72				
4	24.38			10.56			26.13			20.54				
5														
6	24.33			10.58			26.12			20.53				
7														
8	24.39			10.56			26.18			20.57				
9														
10	24.38			10.61			26.14		10.04	20.58				
11														
12														
89/1														
2														
3		24.53						20.64		20.93			19.48	16.50
4														
5														
6														
7		24.53						20.56		20.90			19.45	19.50
8		24.53						20.56		20.90			19.45	16.50
9														
10		24.53						20.56		20.90			19.45	16.50
11														
12														
90/1														
2														
3					8.92			20.56					19.16	16.49
4														
5		24.53			8.98			20.56		21.05			19.15	16.40
6														
7														
8		24.62			8.98			20.64		24.80			19.10	16.80
9														
10														
11		24.61			8.96			20.61		24.78			19.13	16.78
12														
91/1		24.61			8.95			20.61					19.11	16.77
2		24.58			9.00			20.66					10.08	16.75
3		24.56						20.68					19.08	16.74
4		24.60						20.68					19.07	16.76
5		24.57			9.06			20.69					19.10	16.66
6														
7		24.68			8.37			20.72					19.20	16.88
8		24.66			8.39			20.71					19.18	16.88
9		24.66			8.37			20.72					19.21	16.89
10		24.65			8.39			20.70					19.20	16.89
11					6.40								19.20	16.89
12					6.42			20.69					19.21	16.89
92/1		24.75			8.45			20.71					19.23	16.90
2		24.73						20.80		21.00			19.08	
3		24.76						20.82		21.31			19.07	17.04
4		24.75						20.83		21.00			19.07	17.02
5		24.81			8.49	14.55		20.81		21.35				
6														
7		24.79			8.47	14.55		20.61		21.32			19.08	17.02
8		24.75			8.46	14.57		20.77		21.32			19.40	17.15
9														
10		24.75			18.47	15.53		20.81		21.07			19.42	17.15
11		24.76			8.50	15.55		20.78		21.33	38.67		19.48	17.22
12		24.73			8.47			20.77		21.30			19.45	17.20
93/1		24.81			8.52	15.58		20.80		21.36	38.72		19.50	17.40
2		24.79			8.55	15.58		20.77		21.35	38.75		19.45	17.40
3		24.83			8.54	15.61		20.83		21.38	38.73		19.43	17.46
4														
5														
6		25.14						20.88					19.40	
7		24.86				15.65				21.39			19.35	
8		24.90				15.65				21.40			19.32	
9		24.91				15.71				21.41			19.28	
10		24.83				15.69				21.36			19.30	
11														
12														

Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)> (5)

DGA	212	224	183	185	209-B	197	200	203	226	210			77-B	107
BNA	135-3	267-8	277-5	279-1	280-5	293-7	296-1	299-6	179-3	273-2	148-5	466-2	311-9	316-K
CORFO	2020-6920	2020-6920	2020-6920	2020-6920	2020-6920	2020-6920	2020-6920	2020-6920	2020-6920	2020-6920	2020-6930	2020-6930	2020-6930	2020-6930
DATE	C-1	C-2	D-11	D-13	D-14	D-27	D-30	D-33	D-6	D-7	A-10	A-13	A-3	A-8
81/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
82/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
83/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
85/1	29.24													8.50
2	29.24													8.51
3	29.19													8.51
4	29.22													8.50
5	29.18													8.48
6	29.16													8.39
7	29.18													8.45
8	29.21													8.45
9	29.18													8.40
10	29.16													8.40
11	29.15													8.40
12	29.12													8.36
86/1	31.13													8.82
2														
3	31.54													8.71
4	29.38													8.70
5														
6	29.91								39.90					8.70
7														
8	30.65													8.64
9														
10														8.90
11														
12														
87/1														
2														9.11
3														
4														8.98
5														
6	30.62													8.91
7														
8														
9														
10	31.79													8.89
11														
12														
88/1														
2														

Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)> (6)

DGA	212	224	183	185	209-B	197	200	203	226	210			77-B	107
BNA	135-3	267-8	277-5	279-1	280-5	293-7	296-1	299-6	179-3	273-2	148-5	466-2	311-9	316-K
CORFO	2020-6920	2020-6920	2020-6920	2020-6920	2020-6920	2020-6920	2020-6920	2020-6920	2020-6920	2020-6920	2020-6930	2020-6930	2020-6930	2020-6930
DATE	C-1	C-2	D-11	D-13	D-14	D-27	D-30	D-33	D-6	D-7	A-10	A-13	A-3	A-8
3	32.53													8.96
4	32.82													8.97
5														
6	32.38													8.90
7														
8	32.38													8.96
9														
10	33.08													8.99
11														
12														
89/1														
2														
3			24.19	70.02	45.76	49.02	39.17				10.90		10.76	
4														
5														
6														
7			24.19		45.74	49.11	39.17				10.87		10.77	
8			24.19		45.76	49.10	39.17				10.87		10.77	
9														
10			24.31		47.56	49.15	39.32				10.87		10.77	
11														
12			24.30		45.74	49.15	39.34							
90/1														
2													10.80	
3			24.30		45.74	49.15	39.32							
4														
5			24.29		45.77	49.19	39.32				10.75		10.80	
6														
7														
8					45.77	49.14	39.32				10.75		10.90	
9														
10														
11			24.30		45.74	49.14	39.31				10.89		10.90	
12														
91/1			24.30		45.77	40.16					10.85	8.95	10.89	
2			24.35			40.14					10.97	8.94	10.94	
3			24.41			40.14					10.95	8.95	10.90	
4			24.48			40.16	49.56	45.68			11.04	8.94	11.01	
5			24.56			40.08	49.17	45.52			11.00		11.02	
6														
7			24.42			40.15	48.91	45.18			11.02	12.25	10.99	
8			24.40			40.14	48.94	45.58			11.00	12.27	10.99	
9			24.41			40.14	48.89	45.51			11.00	12.23	11.00	
10			24.40			40.14	48.90	45.50			11.00	12.24	11.00	
11											11.02	12.23	11.01	
12			24.40	40.14		40.13	48.70				11.09	12.24	11.07	
92/1			24.45			40.13	48.88	45.54			11.09	12.23	11.12	
2										8.81	11.17	12.59	11.14	
3										8.97	11.14	12.28	11.16	
4			24.44	40.00	49.25	45.46				8.46	11.13	12.30	11.15	
5										8.14			11.21	
6										8.12				
7			24.42			40.00	48.67	45.46			11.13	12.26	11.13	
8										9.44			11.18	
9														
10			24.45			40.00	48.67	45.46		9.43	11.13	11.26		
11										8.21	11.12	12.22	11.17	
12										8.22	11.11	12.21	11.17	
93/1										8.28	11.20	12.70	11.22	
2										8.26	11.18	12.70	11.22	
3			24.52	42.69	42.96	40.09	48.60	45.57		9.30	11.27	12.69	11.33	
4														
5														
6			24.50	41.76	44.94	40.05	48.59	45.63			11.27	11.27	11.36	
7				45.00				45.60					11.36	
8						40.05	48.50	45.55			11.25	12.60	11.38	
9				45.17	60.88	40.19	48.74	45.68			11.21	12.68	11.38	
10			24.50		60.80	40.90	48.66	45.60			11.20	12.66	11.39	
11														
12														

Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)> (7)

DGA	111	140	141	134	148			97	98	121	162	113	123	124
BNA	134-5	323-2	324-0	354-2	365-8	458-1	460-3	367-4	147-7	110-8	112-4	136-1	139-8	376-3
CORFO	2020-6930	2020-6930	2020-6930	2020-6930	2020-6930	2020-6930	2020-6930	2020-6940	2020-6940	2020-6940	2020-6940	2020-6940	2020-6940	2020-6940
DATE	B-5	C-2	C-3	D-17	D-28	D-34	D-36	A-1	B-1	C-1	C-2	D-1	D-10	D-11
81/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
82/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
83/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
85/1	7.78										7.55	12.08	12.85	7.79
2	7.80										7.52	12.10	12.86	7.79
3	7.79										7.55	12.09	12.81	7.78
4	7.80										7.57	12.12	12.77	7.81
5	7.66										7.60	12.12	12.75	7.87
6	7.64										7.50	12.09	12.81	7.86
7	7.69										7.56	12.09	12.85	7.90
8	7.73										7.57	12.09	12.90	7.65
9	7.74										7.55	12.05	12.87	7.82
10	7.71										7.55	12.04	12.86	7.81
11	7.70										7.58	12.10	12.86	7.85
12	7.65										7.54	12.04	12.86	7.78
86/1	8.31													
2														
3	8.31										7.71	12.24	13.32	7.98
4	8.35										7.75	12.23	13.35	8.00
5														
6	7.75										7.76	12.06	12.81	7.85
7														
8	8.07										7.78	12.14	13.31	8.04
9														
10	8.27										7.77	12.20	13.10	8.01
11														
12														
87/1														
2	8.47										7.81	12.19	13.44	8.09
3														
4											7.83		13.47	8.20
5														
6											7.88	12.34	13.42	8.27
7														
8														
9														
10											7.93	12.55	13.25	8.34
11														
12														
88/1														
2														

Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)> (8)

DGA	111	140	141	134	148			97	98	121	162	113	123	124
BNA	134-5	323-2	324-0	354-2	365-8	458-1	460-3	367-4	147-7	110-8	112-4	136-1	139-6	376-3
CORFO	2020-6930	2020-6930	2020-6930	2020-6930	2020-6930	2020-6930	2020-6930	2020-6940	2020-6940	2020-6940	2020-6940	2020-6940	2020-6940	2020-6940
DATE	B-5	C-2	C-3	D-17	D-28	D-34	D-36	A-1	B-1	C-1	C-2	D-1	D-10	D-11
3											7.95	12.64		8.48
4											7.98	12.64	13.41	8.46
5														
6											7.93	12.67	13.42	8.48
7														
8											7.99	12.66	13.42	
9														
10	12.65										8.99	12.65	13.42	
11														
12														
89/1														
2														
3		7.97				9.70	22.78				7.90			
4														
5														
6														
7						9.90	22.77				8.15			
8						9.90	22.78				8.16			
9														
10						9.90	22.78				8.16			
11														
12			2.38				22.78							
90/1														
2						9.90	22.77							
3														
4														
5						9.92	22.75							
6														
7														
8						9.90	22.77							
9														
10														
11						10.02	22.77							
12														
91/1						10.00								
2						10.10								
3											8.20			
4						10.10					8.20			
5						10.31					8.23			
6														
7						10.88	24.44				8.25			
8						10.64	24.41				8.25			
9						10.23					8.24			
10						10.25					8.25			
11														
12						10.24					8.25			
92/1						10.24					8.30			
2														
3		8.31												
4		8.31				10.20								
5		8.35			18.80									
6														
7		8.35			18.80	10.20								
8		8.33			18.80	10.79								
9														
10		8.35			18.77	10.20								
11		8.34		32.11	19.30	10.46								
12		8.30				10.44								
93/1		8.40		32.46	18.76	10.27								
2		8.42		32.44	18.76	10.25								
3		8.45		32.11	19.50	10.77								
4														
5														
6		8.49			19.51	10.75								
7		8.49			19.28	10.77					8.56			
8		8.49		31.50	19.30	10.76					8.55			
9		8.49		32.16	20.78	10.81					8.57			
10		8.49		32.10	20.78	10.83					9.30			
11														
12														

Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)> (9)

DGA	137		163	122	315	320	301	302				323	238	237
BNA	140-K	137-K	383-6	138-8	114-0	143-4	142-6	117-5	469-7	470-0	471-9	404-2	113-2	411-5
CORFO	2020-6940	2020-6940	2020-6940	2020-6940	2030-6920	2030-6920	2030-6920	2030-6920	2030-6920	2030-6920	2030-6920	2030-6920	2030-6930	2030-6930
DATE	D-15	D-20	D-19	D-9	A-2	A-2	B-1	B-2	BN-9	BN-10	BN-11	D-1	A-1	A-9
81/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11						54.73								
12	13.20													
82/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
83/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
85/1	12.11				70.08	55.01							4.65	
2	12.12				70.10	55.04							4.65	
3	12.10				70.14	55.00							4.65	
4	12.11				70.16	55.04							4.70	
5	12.05				70.08	54.98							4.56	
6	12.10				70.04	55.00							4.59	
7	12.05				70.08	55.04							4.65	
8	12.07				70.11	55.04							4.65	
9	12.05				70.11	55.00							4.62	
10	12.05				70.12	54.98							4.63	
11	12.10				70.13	54.98							4.66	
12	12.05				70.09	54.94							4.59	
86/1					69.10	54.24								
2														
3	12.22				70.24	55.22							4.75	
4	12.26				70.28	55.35							4.78	
5														
6	12.32				70.33	55.37							4.80	
7														
8	12.30				70.57	55.43							4.81	
9														
10					70.30	55.44	13.65						4.91	
11														
12														
87/1														
2	12.38				70.34	55.45	13.41						4.91	
3														
4	12.43				70.41	55.50							4.97	
5														
6	12.42				70.40	55.52							4.99	
7														
8														
9														
10	12.29				70.48	55.57							5.03	
11														
12														
88/1														
2														

Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)> (10)

DGA	137		163	122	315	320	301	302				323	238	237
BNA	140-K	137-K	383-8	138-8	114-0	143-4	142-6	117-5	469-7	470-0	471-9	404-2	113-2	411-5
CORFO	2020-6940	2020-6940	2020-6940	2020-6940	2030-6920	2030-6920	2030-6920	2030-6920	2030-6920	2030-6920	2030-6920	2030-6920	2030-6930	2030-6930
DATE	D-15	D-20	D-19	D-9	A-2	A-2	B-1	B-2	BN-9	BN-10	BN-11	D-1	A-1	A-9
3					70.49	55.58							5.01	
4					69.79	55.65							5.02	
5														
6					70.48	55.57							5.01	
7														
8					70.32	55.67							5.18	
9														
10					70.55	50.46							4.38	
11														
12														
89/1														
2														
3	12.56				71.18	55.91			21.22	28.35	20.01			
4														
5														
6														
7	12.46		5.73		71.18	55.95			21.85	28.42	20.01			
8	12.46				71.18	55.95			21.84	28.42	21.01			
9														
10	12.36		5.73		71.18	55.86				28.39	20.01			5.70
11														
12					71.18	55.86			21.84	28.45				
90/1														
2														
3	12.35		5.72											5.39
4														
5									22.27	28.35	18.81			
6														
7														
8	12.50		5.85		71.26			56.30						5.56
9														
10														
11	12.47		6.65		71.24			56.25	22.89	29.75				5.53
12														
91/1	12.50		5.80		71.26			56.25	22.86	29.75				5.50
2	12.49				71.25			56.21	22.88					5.53
3									22.89					
4	12.48				71.25			56.20	22.91					5.55
5	12.63				71.18			56.26	22.26		20.00			5.56
6														
7	12.58				70.84			55.81	21.78	30.80	20.85			5.64
8	12.61				70.83			55.80	21.70	30.81	20.88			5.64
9	12.60				70.94			55.85	21.73	30.78				5.64
10	12.60				70.09			55.83	21.70	30.76	20.86			5.63
11	12.45				70.90			55.85	32.36	31.44	20.30			5.66
12	12.62				70.90			55.91	39.46		21.00			5.71
92/1	12.67				70.88			55.89	23.52		21.10			5.73
2					70.80	55.95					20.36			
3					70.98	56.05					20.64			5.78
4					70.94	56.00				30.60				5.78
5					70.92	56.09			21.10	30.94	20.88			5.79
6														
7					70.90	56.05								5.78
8	12.52				70.95	55.97			22.14	30.83	19.43			5.79
9														
10	12.52				70.93	55.97			22.61	31.03	20.27			5.79
11	12.50				71.00	56.00			22.33	31.38	19.80			5.80
12	12.50				71.00	55.98			22.50	31.40	19.80			5.79
93/1					71.03	52.06				31.03	19.98			5.83
2					71.05	52.05				31.00	19.98			5.83
3					71.07	56.05			21.30	31.00	19.60	19.90		5.86
4														
5														
6					71.09				21.37	31.43	20.22			5.91
7					71.07	56.12					20.51			5.91
8					71.07	56.12					20.50	19.90		5.89
9					71.11	56.14						19.90		
10					71.13	56.12						19.90		5.91
11														
12														

Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)> (11)

DGA	230	254	256	257	265	249	259	253	260	263	264		235	247
BNA	412-3	118-3	141-8	144-2	151-5	120-5	119-1	121-3	426-3	150-7	427-1	116-7	430-1	145-0
CORFO	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6940	2030-6940
DATE	A-10	C-1	C-3	C-4	C-6	C-7	D-1	D-2	D-5	D-6	D-7	D-9	B-2	B-3
81/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11		4.44	7.25			3.14	16.15	28.46	9.24	4.03			4.50	
12			7.08			3.65	18.40			4.02				
82/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
83/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
85/1		3.90	7.11	7.69		3.70	16.21	28.78	10.40				4.70	2.33
2		3.90	7.13	7.65		3.73	16.19	28.75	10.40				4.74	2.31
3		3.85	7.15	7.67		3.75	16.15	28.78	10.41				4.73	2.26
4		3.86	7.20	7.69		3.78	16.16	28.78	10.44				4.76	2.30
5		3.81	7.02	7.64		3.59	16.14	28.81	10.48				4.78	2.26
6		3.77	7.04	7.58		3.63	16.13	28.77	10.46				4.70	2.26
7		3.84	7.12	7.65		3.70	16.15	28.75	10.44				4.78	2.31
8		3.86	7.17	7.70		3.75	16.19	28.77	10.46				4.75	2.35
9		3.85	7.12	7.68		3.70	16.17	28.75	10.45				4.74	2.31
10		3.86	7.13	7.70		3.70	16.15	28.75	10.42				4.73	2.32
11		3.85	7.12	7.73		3.70	16.11	28.78	10.41				4.73	2.31
12		3.81	7.16	7.73		3.70	16.11	28.75	10.38				4.69	2.26
86/1				8.37			16.26		10.30	17.57				
2														
3		4.01	7.51	7.90		3.84	16.25	29.04	11.65	17.63			4.92	2.51
4		3.98	7.51	7.90		3.85		29.06	10.50	17.68			4.97	2.55
5														
6		4.04	7.50	7.92		3.90	16.27	29.08	11.04	17.67			4.98	2.56
7														
8		4.06	7.37	7.94		3.95	16.31	29.10	11.82	17.68			4.99	2.56
9														
10		4.05	7.37	7.95		4.00	16.45	29.14	10.80	17.85			4.98	2.55
11														
12														
87/1														
2		4.09	7.39	8.00		4.08	16.31	29.18	11.39	17.65			5.04	2.57
3														
4		4.14	7.40			4.11	16.33	29.28	10.53	17.89			5.07	2.66
5														
6		4.13	7.42	8.04		4.18	16.38	29.33	11.63	17.86			5.05	2.66
7														
8														
9														
10		4.25	7.47	8.04		4.28	16.43	29.29	10.40	17.89			5.17	2.73
11														
12														
88/1														
2														

Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)> (12)

DGA	230	254	256	257	265	249	259	253	260	263	264		235	247
BNA	412-3	118-3	141-8	144-2	151-5	120-5	119-1	121-3	426-3	150-7	427-1	116-7	430-1	145-0
CORFO	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6930	2030-6940	2030-6940
DATE	A-10	C-1	C-3	C-4	C-6	C-7	D-1	D-2	D-5	D-6	D-7	D-9	B-2	B-3
3		4.26	7.50	8.02		4.34	16.44	29.35	10.49	17.92			5.16	2.75
4		4.28	7.48	8.02		5.18	16.37	29.37	10.59	17.80			5.15	2.75
5														
6		4.26	7.49	8.04		4.33	16.43	29.35	10.48	17.89			5.17	2.73
7														
8		4.32	7.66	8.05		4.56	16.35	29.44	10.53	17.91			5.40	2.83
9														
10		4.20	7.50	8.09		4.38	16.36	29.41	10.55				5.18	2.83
11														
12														
89/1														
2														
3	10.90	4.29	7.73			4.59	16.52	29.64			0.75		5.81	
4														
5														
6														
7	10.96	4.42	7.98			4.59	16.55	29.71			0.75		5.85	
8	10.96	4.42	7.98			4.59	16.55	29.71			0.75		5.85	
9														
10	10.94	4.41	7.98				16.55	29.68			0.75		5.85	
11														
12			7.98				16.55	29.68			0.75			
90/1														
2			7.88					29.68						
3	10.94	4.52											5.89	
4														
5		4.61											6.04	
6														
7														
8	10.90	4.59	7.91					29.64					6.00	
9														
10														
11	11.02	4.55	7.94					29.61					6.00	
12														
91/1	11.00	4.55	7.92					29.59				18.05	6.00	
2	11.00	4.61	7.93					29.56					6.04	
3														
4	11.05	4.57	7.94					28.81				18.10	6.05	
5	11.03	4.67	7.95					29.64				18.04	6.09	
6														
7	10.97	4.67	8.05					29.67				18.07	5.60	
8	10.99	4.69	8.05					29.70				18.04	5.57	
9	11.02	4.68	8.04					29.66				18.10	5.57	
10	11.00	4.69	8.04					29.68				10.07	5.59	
11	11.02	4.73	8.06					29.71				18.13	5.57	
12	11.09	4.74	8.09					29.73				18.10	5.67	
92/1	11.11	4.74	8.11					29.77				18.15	5.66	
2			8.34					29.75				18.09		
3	11.10	4.76	8.11					29.82				18.13	5.62	
4	11.08	4.76						29.80				18.15	5.62	
5		4.76	8.11					29.81					5.66	
6														
7		4.74	8.18					29.75				18.13	5.65	
8		4.78	8.13					29.80				18.10	5.64	
9														
10		4.76	8.11					27.78				18.18	5.65	
11		4.81	8.14									18.17	5.73	
12		4.81	8.11									18.15	5.72	
93/1		4.83	8.17									18.20	5.75	
2		4.83	8.16									18.20	5.72	
3		4.83	8.19									18.22	5.74	
4														
5														
6	11.10	4.89	8.22									18.24	5.76	
7		4.87	8.23									18.20	5.81	
8	11.10	4.89	8.23									18.21	5.82	
9		4.88	8.22									18.22	5.81	
10		4.88	8.22									18.22	5.83	
11														
12														

. Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)> (13)

DGA	236	326	267	269	271	275	276	280	283	287	281	286	284	
BNA	146-9	122-1	125-6	126-4	434-4	438-0	157-4	128-0	152-3	440-9	444-1	127-2	449-2	461-1
CORFO	2030-6940	2040-6910	2040-6930	2040-6930	2040-6930	2040-6930	2040-6930	2040-6930	2040-6930	2040-6930	2040-6930	2040-6930	2040-6940	2040-6940
DATE	B-4	A-1	A-1	A-3	A-4	A-6	A-7	C-1	C-2	C-4	D-3	D-5	D-2	D-2
81/1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11											17.19	19.02	0.70	
12														
82/1												19.49		
2														
3												19.04		
4												19.39		
5												19.39		
6														
7														
8														
9												19.12		
10														
11														
12														
83/1														
2														
3												18.94		
4														
5														
6														
7														
8														
9														
10														
11														
12														
85/1	1.27		9.92				15.60		1.83		17.98	19.39	0.70	
2	1.25		9.90				15.62		1.81		17.96	19.29	0.71	
3	1.25		9.90				15.63		1.83		17.99	19.33	0.68	
4	1.26		9.93				15.65		1.84		17.98	19.34	0.68	
5	1.23		9.88				15.57		1.80		17.95	19.39	0.74	
6	1.20		9.82				15.71		1.80		18.06	19.34	0.70	
7	1.26		9.89				15.66		1.85		18.03	19.38	0.73	
8	1.23		9.92				15.60		1.85		18.02	19.35	0.70	
9	1.23		9.90				15.55		1.76		17.99	19.36	0.72	
10	1.22		9.91				15.55		1.81		17.99	19.34	0.70	
11	1.25		9.86				15.52		1.80		17.95	19.34	0.68	
12	1.26		9.81				15.56		1.84		18.40	19.39	0.70	
86/1														
2														
3	1.26		9.95				15.63		1.85		18.10	19.36	0.70	
4	1.41		9.95				15.63		1.84		18.10	19.36	0.74	
5														
6	1.45		9.99				15.63		1.87		18.11	19.35	0.50	
7														
8	1.44		10.00				15.64		1.88		18.11	19.34	0.50	
9														
10	1.47		10.01				15.63		1.91		18.10	19.41	0.45	
11														
12														
87/1														
2	1.48		10.00				15.63		1.92		18.10	19.38	0.45	
3														
4	1.59		10.00				15.65		1.94		18.10	19.39	0.51	
5														
6	1.60		10.01				15.65		1.94		18.14	19.40	0.49	
7														
8														
9														
10	1.62		10.03				15.65		1.95		18.14	19.39	0.50	
11														
12														
88/1														
2														

Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)> (14)

DGA	238	326	287	269	271	275	276	280	283	287	281	286	284	
BNA	146-9	122-1	125-6	126-4	434-4	436-0	157-4	128-0	152-3	440-9	444-1	127-2	449-2	461-1
CORFO	2030-6940	2040-6910	2040-6930	2040-6930	2040-6930	2040-6930	2040-6930	2040-6930	2040-6930	2040-6930	2040-6930	2040-6930	2040-6940	2040-6940
DATE	B-4	A-1	A-1	A-3	A-4	A-6	A-7	C-1	C-2	C-4	D-3	D-5	D-2	D-2
3	1.68		10.03	39.29			15.66		1.96		18.14	19.40		
4	1.66		10.10	39.26			15.65				18.12	19.08		
5														
6	1.66		10.03	39.30			15.66		1.95		18.11	19.39		
7														
8	1.74		10.03	39.29			15.69		1.95		18.16	19.41		
9														
10	1.66		0.54	17.90			15.69		1.89		18.15	19.39		
11														
12														
89/1														
2														
3		89.30			10.84	10.65	15.82	7.66		1.97	18.27	19.57		10.73
4														
5														
6														
7		89.26			10.86	10.64	15.73	7.31		1.57	18.27	19.57		10.33
8		89.26			10.86	10.64	15.73	7.30		1.97	18.27	19.57		10.33
9														
10		89.24			10.86	10.84	15.73	7.30		1.97	18.26	19.55		10.33
11														
12		89.20				10.65	15.73	7.31		1.97	18.25	19.57		
90/1														
2						10.67	15.55	7.30		1.96	18.25	19.43	0.88	
3		88.90			10.84									10.31
4														
5		88.70												10.30
6														
7														
8		88.70			10.83	10.67	15.75	7.55		2.04	18.24	19.51	0.77	11.08
9														
10														
11		88.68			10.83	10.65	15.70	7.53		2.02	18.23	19.50	0.77	11.10
12														
91/1		88.70				10.84	15.70	7.50			18.23	19.50	0.77	11.08
2		88.88				10.88	15.73	7.49			18.22	19.52	0.77	11.05
3							15.75	7.44			18.20	19.51	0.76	
4		87.55				10.86	15.77	7.44			18.19	19.57	0.76	
5		87.71				10.89	15.73	8.32			18.18	19.50	0.76	
6														
7		87.86			10.91		15.75	7.97			18.20	19.51	0.79	11.52
8		87.86			10.90	10.69	15.73	7.97			18.18	19.50	0.79	11.51
9		88.87			10.93	10.69	15.80	8.03			18.22	19.57	0.78	11.51
10		87.85			10.92	11.24	15.78	8.00			18.19	19.55	0.78	11.53
11		87.60			10.92	11.25	15.78	8.02			18.22	19.54	0.79	
12		87.30			10.92		15.79	8.11			18.20	19.56	0.79	11.50
92/1		87.46			10.95	11.28	15.78	8.15			18.22	19.55	0.80	11.52
2		87.20			10.91	10.71	15.76	8.44			18.21	19.54	0.82	
3					10.93	10.73	15.76	8.43			18.23	19.53	0.81	11.51
4		87.40			10.94	10.74	15.75	8.40			18.19	19.50	0.80	11.50
5					10.93	10.73	15.70	8.24			18.21	19.53	0.83	
6														
7		86.75			10.93	10.70	15.70	8.24			18.19	19.52	0.80	11.45
8		86.55			10.91	10.70	15.73	8.30			18.19	19.51	0.81	
9														
10		86.55			10.94	10.72	15.73	8.29			18.19	19.51	0.80	11.48
11					10.02	10.71	15.75	8.56			18.20	19.51	0.80	11.51
12					10.90	10.71	15.73	8.55			18.20	19.50	0.80	11.50
93/1					10.93	10.72	15.75	8.62			18.20	19.51	0.81	
2		86.55			10.90	10.70	15.75	8.60			18.19	19.53	0.80	
3		86.33			11.34	10.73	15.76	9.27			18.20	19.52	0.83	
4														
5														
6		86.79			10.98	10.75	15.77	8.76			18.19	19.55		
7					10.95	10.75	15.76	8.53			18.21	19.53		
8		86.13			10.97	10.74	15.78	8.50			18.22	19.53		
9		85.93			10.96	10.75	15.76	8.61			18.21	19.54		
10		85.90			10.96	10.75	15.78	8.59			18.22	19.54		
11														
12														

Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)> (15)

DGA	296	298	292	294	299	290
BNA	153-1	451-4	453-0	155-8	160-4	124-8
CORFO	2050-6930	2050-6930	2050-6930	2050-6930	2050-6930	2050-6940
DATE	A-1	A-2	B-3	B-4	D-1	B-1
81/1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						2.31
12						
82/1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
83/1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
85/1	18.90		36.78	26.85		2.35
2	18.65		36.76	26.80		2.30
3	18.88		36.77	26.81		2.29
4	18.86		36.80	26.84		2.30
5	18.88		36.76	26.88		2.27
6	18.88		36.70	26.88		2.38
7	18.93		36.75	26.80		2.42
8	18.90		36.80	26.85		2.35
9	9.85		36.78	26.80		2.31
10	18.89		36.75	26.83		2.35
11	18.85		36.72	26.80		2.40
12	18.90		36.78	26.77		2.44
86/1						
2						
3	18.95		36.80	26.80		2.33
4	19.00		36.80	26.89		2.34
5						
6	19.01		36.83	26.89		2.34
7						
8	19.19		36.86	26.88		2.34
9						
10	19.00		36.80	26.90		2.32
11						
12						
87/1						
2	19.10		36.85	26.89		2.33
3						
4			36.34	26.89		2.38
5						
6			36.84	26.90		2.39
7						
8						
9						
10			36.87	26.91		2.39
11						
12						
88/1						
2						

Table B-III, 3.2. Variation of Groundwater Level (Pampa del Tamarugal)

<Variación de Nivel Estático (Pampa del Tmarugal)> (16)

DGA	298	298	292	294	299	290
BNA	153-1	451-4	453-0	155-8	160-4	124-8
CORFO	2050-6930	2050-6930	2050-6930	2050-6930	2050-6930	2050-6940
DATE	A-1	A-2	B-3	B-4	D-1	B-1
3			36.85	26.94		2.38
4			36.84	26.91		2.40
5						
6			36.81	26.93		2.38
7						
8			37.36	26.96		2.43
9						
10			36.84	26.97		2.40
11						
12						
89/1						
2						
3				27.21	13.28	2.39
4						
5						
6						
7				27.03	13.28	2.38
8				27.02	13.28	2.39
9						
10				27.02	13.28	2.39
11						
12				27.03	13.28	
90/1						
2				27.03	13.30	2.47
3						
4						
5						
6						
7						
8				26.78	13.28	2.46
9						
10						
11				26.83	13.27	2.47
12						
91/1				26.86	13.29	2.45
2				26.90	13.35	2.48
3				26.98	13.32	2.46
4				27.03	13.29	2.47
5				27.01	13.32	2.32
6						
7				26.99	13.33	2.68
8				26.99	13.32	2.68
9				27.02	13.34	2.49
10				27.04	13.34	2.53
11				27.00	13.33	2.54
12				27.00	13.32	2.54
92/1				26.98	13.36	2.49
2		12.35		26.97	13.35	2.50
3		12.37		26.96	13.31	2.51
4		12.37		26.94	13.31	2.47
5		12.47		27.01	13.36	2.51
6						
7		12.45		26.99	13.31	2.50
8		12.43		26.94	13.33	2.50
9						
10		12.32		26.93	13.31	2.50
11		12.34		26.92	13.33	2.51
12		12.35		26.88	13.31	2.49
93/1		12.34		26.93	13.33	2.50
2		12.35		26.95	13.33	2.52
3		12.33		26.94	13.34	2.51
4						
5						
6		12.37		26.96	13.32	2.49
7		12.36		26.94	13.36	2.52
8		12.35		26.96	13.39	2.52
9		12.36		26.94	13.37	2.54
10		12.30		26.94	13.35	2.54
11						
12						

Table B-III, 3.3 Groundwater Quality (Pampa del Tamarugal) (Nov. 1993 - Feb. 1994)

<Calidad de Agua Subterránea (Pampa del Tamarugal) (Nov. 1993 - Feb. 1994)>

																		HEALTH SIGNIFICANCE												
		B.N.A CODE	DGA CODE	NAME		TEMP	pH	TDS	Cond. µS	Turb.	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	SO4 mg/l	Cl mg/l	CO3 mg/l	HCO3 mg/l	NO3 mg/l	As mg/l	F mg/l	Cd mg/l	Cr mg/l	Pb mg/l	B mg/l	Fe mg/l	Mn mg/l	Zn mg/l	Cu mg/l	Al mg/l
				(STANDARD)			6.5 8.5	1000		5					250.0	250			10.000	0.050	1.50	0.005	0.050	0.05		0.30	0.100	5.00	1.000	0.20
	ZAPIGA	173	13	PTA. AP. DOLORES 6	Nov-93	20.0	8.34	636	1100	166	13.8	4.6	190.1	28.2	62.0	253.1		81.2	3.100	0.005		0.005		0.01	5.60	0.47	0.007		0.007	
					Feb-94		7.95	622	1126		12.7	4.5	186.7	31.0	48.0	256.7		82.4	0.089	0.034		0.001		0.02	7.59	8.22			0.011	0.30
					Average	20.0	8.15	629	1113	166	13.3	4.6	188.4	29.6	55.0	254.9		81.8	1.595	0.020		0.003		0.02	6.60	4.35	0.007		0.009	0.30
		178	19	SALAR DE ZAPIGA	Nov-93	25.5	8.87	976	1600	129	109.0	6.8	158.2	37.5	309.8	274.7	4.2	63.5	12.400	1.383		0.028		0.33	4.76	36.80	4.310		0.222	
					Feb-94		8.54	806	1415		84.0	12.5	156.4	32.5	201.7	278.3	3.0	36.0	1.662	0.319		0.001		0.06	3.97	1.35			0.021	2.70
					Average	25.5	8.71	891	1508	129	96.5	9.7	157.3	35.0	255.8	276.5	3.6	49.8	7.031	0.851		0.015		0.20	4.37	19.08	4.310		0.122	2.70
		165	23	SALAR DE ZAPIGA	Nov-93	25.0	9.07	856	1600	266	95.8	10.4	174.8	32.1	116.2	308.1		105.6	13.400	0.027		0.009		0.05	0.46	7.84	0.312		0.086	
		104	30	SALAR DE ZAPIGA	Nov-93	24.2	10.45	1881	2700	990	209.8	0.2	460.0	64.9	283.4	822.8	21.0	15.3	3.600	0.071		0.017		0.08	11.62	6.86	0.173		0.050	
A					Feb-94		10.07	1959	3385		218.0	0.5	453.1	77.3	312.2	847.6	49.8		0.319	0.143		0.001		0.07	10.07	2.28			0.053	3.10
					Average	24.2	10.26	1920	3043	990	213.9	0.4	456.6	71.1	297.8	835.2	35.4	7.7	1.960	0.107		0.009		0.08	10.85	4.57	0.173		0.052	3.10
		931		JOSEFINA 1	Nov-93	23.2	8.25	1879	2500	120	134.7	32.6	473.8	57.5	307.4	785.2		66.5	21.100	0.158		0.014		0.04	39.87	18.20	0.250		0.015	
					Feb-94		8.36	1820	3100		113.0	30.5	460.0	62.3	283.4	801.9		67.7	0.878	0.304		0.001		0.01	20.14	8.75			0.018	0.50
					Average	23.2	8.31	1849	2800	120	123.9	31.6	466.9	59.9	295.4	793.6		67.1	10.989	0.231		0.008		0.03	30.01	13.48	0.250		0.017	0.50
		947		POZO POCHA 1	Nov-93	23.6	8.73	1606	2900	171	64.9	36.8	450.8	60.6	312.2	547.3		82.4	50.500	0.007		0.014		0.04	13.31	35.50	0.620		0.021	
					Feb-94		7.97	1769	2875		102.5	37.9	427.8	68.5	487.5	585.0		59.8	0.288	0.040		0.001		0.01	10.41	19.65			0.025	0.60
					Average	23.6	8.35	1687	2888	171	83.7	37.4	439.3	64.6	399.9	566.2		71.1	25.394	0.024		0.008		0.03	11.86	27.58	0.620		0.023	0.60
	HUARA		45-B-D	POZO DUPLISA	Nov-93	24.5	7.74	1308	2100	143	166.5	26.4	207.0	28.9	509.1	247.4		114.7	8.200	0.029		0.011		0.05	5.28	0.05	0.007		0.011	
					Feb-94		8.13	1355	1965		173.5	26.5	213.9	34.0	487.5	251.7		161.1	7.058	0.041		0.002		0.01	4.47	0.03			0.011	0.30
					Average	24.5	7.94	1332	2033	143	170.0	26.5	210.5	31.5	498.3	249.6		137.9	7.629	0.035		0.007		0.03	4.88	0.04	0.007		0.011	0.30
	AVERAGE - A					23.7	8.65	1344	2182	284	115.2	17.7	308.7	47.3	288.2	481.5	6.5	72.0	9.430	0.197		0.008		0.06	10.58	11.23	0.811		0.042	1.25
		196	46	BAQUEDANO No. 3	Nov-93	25.2	8.46	1811	3500	193	79.9	29.3	535.9	54.3	12.5	939.8		153.2	6.000	0.015		0.015		0.03	6.67	4.05	0.402		0.024	
					Feb-94		7.91	1764	3255		83.6	30.5	506.0	13.0	<0.5	958.0		171.5	0.924	0.021		0.001		0.02	13.21	3.53			0.018	1.30
					Average	25.2	8.19	1787	3378	193	81.8	29.9	521.0	33.7	12.5	948.9		162.4	3.462	0.018		0.008		0.03	9.94	3.79	0.402		0.021	1.30
		226	50	HUMBERSTONE 2	Nov-93	26.0	7.30	2025	2900	161	230.5	8.8	448.5	50.1	525.9	594.5		156.8	9.400	0.088		0.018		0.06	10.78	3.54	0.027		0.020	
					Feb-94		7.60	2299	3770		229.5	44.0	473.8	59.3	456.7	882.4		150.1	3.209	0.258		0.001		0.02	20.91	8.35			0.019	0.40
					Average	26.0	7.45	2162	3335	161	230.0	26.4	461.2	54.7	491.3	738.5		153.5	6.305	0.173		0.010		0.04	15.85	5.95	0.027		0.020	0.40
	HUARA	955		NORIA Nº95	Nov-93	18.3	7.59	2782	4200	146	244.1	19.7	710.7	55.1	658.0	863.6		227.6	3.500	0.731		0.022		0.07	5.94	0.08	0.008		0.028	
					Feb-94		8.28	2936	4280		236.5	39.5	657.8	63.3	830.9	883.4		223.3	0.831	0.581		0.001		0.02	11.17	0.22			0.040	0.50
					Average	18.3	7.94	2859	4240	146	240.3	29.6	684.3	59.2	744.5	873.5		225.5	2.166	0.656		0.012		0.05	8.56	0.15	0.008		0.034	0.50
				SONDAJE DE HUARA	Nov-93	29.0	7.98	2944	4400	221	468.9	31.6	434.7	39.1	1450.5	451.3		61.0	6.500	0.028		0.018		0.10	9.52	4.86	0.250		0.130	
		-	-	POZO PORVENIR A	Nov-93	26.2	8.12	1157	1500	116	148.3	18.8	187.7	28.2	451.5	254.9		63.5	4.100	0.005		0.009		0.03	7.55	0.76	0.248		0.011	
					Feb-94		7.62	1171	1770		138.0	23.5	197.8	29.5	451.5	264.1		66.5	0.463	0.007		0.001		0.04	7.28	2.68			0.014	0.40
					Average	26.2	7.87	1164	1635	116	143.2	21.2	192.8	28.9	451.5	259.5		65.0	2.282	0.006		0.005		0.04	7.42	1.72	0.248		0.013	0.40
		202	53	PORVENIR	Nov-93	22.6	7.68	1104	1300	277	136.3	20.4	187.7	22.7	403.5	207.0		117.2	9.200	0.057		0.008		0.03	4.26	2.53	0.032		0.007	
					Feb-94		7.90	1142	1650		137.0	20.0	184.0	25.5	401.0	241.7		129.4	3.065	0.022		<0.001		<0.01	9.05	2.23			0.029	0.60
					Average	22.6	7.79	1123	1475	277	136.7	20.2	185.9	24.1	402.3	224.4		123.3	6.133	0.040		0.008		0.03	6.66	2.38	0.032		0.018	0.60
		240	81A	SARA TIRANA	Nov-93	23.8	8.56	2951	4000	107	155.5	34.8	892.4	84.5	17.3	1696.6		62.9	7.300	0.005		0.023		0.06	10.15	4.77	0.265		0.020	
					Feb-94		8.26	2660	5345		28.7	6.9	901.6	97.0	13.9	1548.4		62.8	0.219	0.010		0.001		0.02	18.15	2.04			0.018	0.50
					Average	23.8	8.41	2805	4673	107	92.1	20.9	897.0	90.8	15.6	1622.5		62.9	3.760	0.008		0.012		0.04	14.15	3.41	0.265		0.019	0.50
B		311	77B	LA TIRANA 104 A	Nov-93	24.4	8.98	866	1600	186	23.0	3.6	257.6	41.1	104.7	348.1		85.4	2.700	0.005		0.007		0.01	5.60	0.17	0.005		0.005	
					Feb-94		8.12	886	1511		19.7	3.3	266.8	48.5	90.0	362.3		94.6	1.284	0.021		0.001		<0.01	4.01	0.36			0.004	0.80
					Average	24.4	8.55	876	1556	186	21.4	3.5	262.2	44.8	97.4	355.2		90.0	1.992	0.013		0.004		0.01	4.81	0.27	0.005		0.005	0.80
		316	107	BOSQUE JUNOY 15	Nov-93	19.2	7.58	994	1500	144	152.3	23.2	138.5	30.5	331.4	211.3		102.5	3.900	0.034		0.006		0.03	2.70	0.05	0.004		0.007	
					Feb-94		8.14	1022	1570		137.5	23.0	144.9	32.5	355.5	224.0		103.1	1.284	0.056		0.001		<0.01	3.14	0.06			0.006	0.20
					Average	19.2	7.86	1008	1535	144	144.9	23.1	141.7	31.5	343.5	217.7		102.8	2.592	0.045		0.004		0.03	2.92	0.06	0.004		0.007	0.20
		381	149	BOSQUE JUNOY	Nov-93	23.9	7.40	2693	4700	178	367.0	66.3	455.4	63.3	494.7	1152.8		89.1	4.400	0.200		0.023		0.08	6.67	0.60	0.036		0.020	
		354	134	P. CANCHONES H	Nov-93	26.3	7.70	1299	2100	158	146.7	6.8	262.2	19.2	619.6	158.1		76.3	10.100	0.035		0.012		0.03	1.73	0.07	0.900		0.009	
					Feb-94		8.15	1312	1905		136.5	14.0	262.2	26.4	620.0	174.4		71.4	7.058	0.043		0.002		<0.01	3.22	0.08			0.007	0.20
					Average	26.3	7.93	1305	2003	158	141.6	10.4	262.2	22.8	619.8	166.3		73.9	8.579	0.039		0.007		0.03	2.48	0.08	0.900		0.008	0.20
		323	140	PTA. AP. HISPANIA	Nov-93	26.6	7.65	1446	2500	196	214.4	34.7	188.6	37.5	451.5	391.7		116.6	11.100	0.021		0.009		0.05	10.78	14.80	1.050		0.018	
					Feb-94		8.15	1494	2230		199.0	35.5	225.4	41.5	437.1	410.5		142.8	1.806	0.047		0.001		0.01	8.84	12.40			0.011	0.20
					Average	26.6	7.90	1470	2365	196	206.7	35.1	207.0	39.5	444.3	401.1		129.7	6.453	0.034		0.005		0.03	9.81	13.60	1.050		0.015	0.20
		113	238	PINTADOS RADIO	Nov-93	25.2	9.65	19200	31900	166	620.0	130.0	5612.0	450.0	2862.6	9363.8		157.4	4.100	1.131		0.201		0.31	4.55	0.72	0.330		0.130	
					Feb-94		7.39	19964	35325		655.0	125.0	6670.0	54.5	2641.5	9642.4		175.0	0.377	0.260		0.006		0.10	6.05	9.30			0.165	1.90
					Average	25.2	8.52	19582	33613	166	638	127.5	6141.0	252.3	2752.1	9503.1		166.2	2.239	0.696		0.104		0.21	5.30	5.01	0.330		0.148	1.90
		146	236	MOSQUITOS 1	Nov-93	23.2	9.20	1418	2100	183	62.5	11.1	414.0	44.2	155.6	676.4		50.6	3.900	0.021		0.012		0.03	12.25	1.66	0.017		0.009	
					Feb-94		7.81	2707	4430		361.5	66.0	471.5	76.5	456.3	1173.4		97.6	3.801	0.114		0.002		0.02	15.08	0.34			0.018	0.40
					Average	23.2	8.51	2062	3265	183	212.0	38.6	442.8	60.4	306.0	924.9		74.1	3.851	0.068		0.007		0.03	13.67	1.00	0.017		0.014	0.40

Table B-III, 3.3 Groundwater Quality (Pampa del Tamarugal) (Nov. 1993 - Feb. 1994)

<Calidad de Agua Subterránea (Pampa del Tamarugal) (Nov. 1993 - Feb. 1994)>

		BNA CODE	DGA CODE	NAME		TEMP.	pH	TDS	Cond. µS	Turb.	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	SO4 mg/l	Cl mg/l	CO3 mg/l	HCO3 mg/l	NO3 mg/l (HEALTH SIGNIFICANCE)	As mg/l (HEALTH SIGNIFICANCE)	F mg/l (HEALTH SIGNIFICANCE)	Cd mg/l (HEALTH SIGNIFICANCE)	Cr mg/l (HEALTH SIGNIFICANCE)	Pb mg/l (HEALTH SIGNIFICANCE)	B mg/l	Fe mg/l	Mn mg/l	Zn mg/l	Cu mg/l	Al mg/l
				(STANDARD)			6.0-8.5	1000		5					250.0	250			10.000	0.050	1.50	0.005	0.050	0.05		0.30	0.100	5.00	1.000	0.20
B	PINTADOS	144	257	SALAR PINTADOS 3	Nov-93	25.4	4.11	1087	2500	335	24.6	3.0	351.9	32.8	17.3	628.5			28.500	0.005		0.007		0.06	3.52	51.70	3.950		0.087	
					Feb-94		4.91	1066	2050		21.6	3.0	356.5	38.5	1.0	643.4			1.612	0.016		0.001		<0.01	4.42	45.80			0.050	0.40
					Average	25.4	4.51	1076	2275	335	23.1	3.0	354.2	35.7	9.2	636.0			15.056	0.011		0.004		0.06	3.97	48.75	3.950		0.069	0.40
		421	251	SALAR PINTADOS 1	Nov-93	25.7	9.35	742	1300	434	3.0	0.2	233.5	13.7	8.6	212.7	13.2	247.7	9.100	0.020		0.008		0.02	0.80	6.53	0.030		0.012	
					Feb-94		8.65	736	1110		1.9	0.1	241.5	17.8	2.9	215.5		256.3	0.403	0.016		0.002		<0.01	1.18	11.80			0.032	1.20
					Average	25.7	9.00	739	1205	434	2.5	0.2	237.5	15.8	5.8	214.1	13.2	252.0	4.752	0.018		0.005		0.02	0.99	9.17	0.030		0.022	1.20
		415	231	SALAR PINTADOS 2	Nov-93	28.6	8.75	465	700	408	9.4	1.5	119.6	12.5	12.5	86.5		215.4	7.200	0.005		0.006		0.19	0.48	17.50	0.185		0.027	
					Feb-94		7.81	477	635		10.0	1.4	125.4	14.7	8.2	94.3		222.7	0.331	0.013		0.002		0.06	1.10	12.14			0.014	0.80
					Average	28.6	8.28	471	668	408	9.7	1.5	122.5	13.6	10.4	90.4		219.1	3.766	0.009		0.004		0.13	0.79	14.82	0.185		0.021	0.80
		222	64	OJ MORALES	Nov-93	29.4	7.62	903	1700	147	179.4	9.2	100.3	21.5	353.0	141.8		87.3	10.100	0.006		0.007		0.03	1.25	0.02	0.006		0.007	
		143	320	PINTADOS PICA 2	Nov-93	?	9.66		1091											0.028										
					Feb-94		9.75	635	955		1.6	0.1	209.3	26.0	61.0	128.0	77.4	131.8	0.059	0.042					1.46					
					Average		9.71	635	1023		1.6	0.1	209.3	26.0	61.0	128.0	77.4	131.8	0.059	0.035					1.46					
		114	315	PINTADOS PICA 3	Nov-93	31.0	8.07	641	800	112	27.5	3.0	161.0	17.6	157.5	96.4		173.3	4.400	0.018		0.007		0.09	0.85	0.91	0.043		0.045	
					Feb-94		7.87	560	920		27.5	3.1	140.7	18.9	81.6	101.4		186.7	0.132	0.016		0.002		0.06	1.49	0.44			0.019	0.40
					Average	31.0	7.97	600	860	112	27.5	3.1	150.9	18.3	119.6	98.9		180.0	2.266	0.017		0.005		0.08	1.17	0.68	0.043		0.032	0.40
	AVERAGE - B					25.3	7.99	2415	4027	105	154.6	24.2	641.3	48.7	444.4	984.4	2.4	122.4	4.658	0.108		0.012		0.05	6.37	6.14	0.210		0.029	0.28
C		447	272	SALAR BELLAVISTA	Nov-93	23.8	11.35	13870	24400	182	1025.0	5.0	3772.0	509.9	1037.4	7423.9		91.5	4.800	0.028		0.141		0.28	14.46	0.25	0.061		0.092	
					Feb-94		11.20	14259	25960		1020.0	0.1	4140.0	63.3	1537.0	7373.6	124.8		0.420	0.302		0.003		0.16	20.30	0.40			0.102	1.20
					Average	23.8	11.28	14064	25180	182	1023	2.6	3956.0	286.6	1287.2	7398.8	62.4	45.8	2.610	0.165		0.072		0.22	17.38	0.33	0.061		0.097	1.20
		440	287	SALAR BELLAVISTA	Nov-93	24.8	9.24	56311	66300	212	576.9	304.0	18998.0	1910.0	13160.2	21121.1	144.6	87.9	8.300	13.815		0.530		0.71	118.32	3.02	0.680		0.345	
					Feb-94		9.41	55352	87890		330.0	258.0	17940.0	1930.0	12487.8	22191.7	213.6		1.122	8.671		0.016		0.19	112.97	1.50			0.310	1.70
					Average	24.8	9.33	55832	77095	212	453.5	281.0	18469.0	1920.0	12824.0	21656.4	179.1	44.0	4.711	11.243		0.273		0.45	115.65	2.26	0.680		0.328	1.70
		157	276	SALAR BELLAVISTA	Nov-93	20.5	8.70	581	864	168	11.0	2.1	158.2	16.0	135.4	79.8	4.8	167.8	6.100	1.214		0.006		0.06	2.25	1.17	0.032		0.031	
					Feb-94		8.45	546	810		9.5	1.9	147.2	16.0	133.0	68.1		169.0	0.942	0.685		0.002		0.07	2.95	5.39			0.035	5.40
					Average	20.5	8.58	563	837	168	10.3	2.0	152.7	16.0	134.2	74.0	4.8	168.4	3.521	0.950		0.004		0.07	2.60	3.28	0.032		0.033	5.40
		442	278	OF. VICTORIA - 2	Nov-93	20.6	7.80	728	900	173	28.7	6.2	175.7	15.6	153.7	128.7		216.7	2.800	0.230		0.006		0.05	1.99	0.17	0.015		0.006	
		444	281	SALAR BELLAVISTA	Nov-93	26.2	8.85	712	900	268	13.7	3.0	207.0	15.2	148.9	167.7	1.8	140.3	14.300	0.388		0.006		0.05	2.00	3.40	0.039		0.025	
					Feb-94		8.51	728	1095		13.1	3.3	213.4	17.9	152.7	171.2		155.0	1.525	0.504		0.001		0.03	2.82	13.35			0.036	4.10
					Average	26.2	8.66	720	998	268	13.4	3.2	210.2	16.6	150.8	169.5	1.8	147.7	7.913	0.446		0.004		0.04	2.41	8.38	0.039		0.031	4.10
		453	292	CHALLACOLLO 2	Nov-93	27.0	8.38	1080	1400	182	60.1	8.4	287.5	28.2	210.4	310.2		169.7	5.600	0.471		0.008		0.07	2.52	1.31	0.036		0.017	
					Feb-94		8.01	1152	1745		57.4	8.2	303.6	33.3	228.6	320.1		199.5	1.541	0.217		<0.001		0.04	1.75	2.56			0.021	1.20
					Average	27.0	6.20	1116	1573	182	58.8	8.3	295.6	30.8	219.5	315.2		184.6	3.571	0.344		0.008		0.06	2.14	1.94	0.036		0.019	1.20
		122	226	CHACARILLA	Nov-93	30.2	9.52	944	1300	370	2.2	0.2	308.2	15.2	249.8	137.2	9.6	209.9	11.400	0.611		0.007		0.05	10.36	42.80	0.215		0.030	
					Feb-94		8.95	919	1350		2.6	0.1	303.6	11.0	245.0	142.2	28.8	185.0	0.547	0.654		0.001		0.01	8.74	17.27			0.015	0.30
					Average	30.2	9.24	931	1325	370	2.4	0.2	305.9	13.1	247.4	139.7	19.2	197.5	5.974	0.633		0.004		0.03	9.55	30.04	0.215		0.023	0.30
		-	-	POZO SAN GENARO - ENAP	Nov-93	25.8	7.95	563	800	152	53.3	6.0	90.6	70.2	165.2	61.7		111.7	4.000	0.039		0.003		0.01	0.31	0.23	0.116		0.006	
	AVERAGE - C					24.7	9.11	11322	16532	222	242.3	46.2	3611.9	352.4	2298.5	4587.3	52.8	137.9	4.569	2.138		0.061		0.14	23.19	7.12	0.154		0.082	2.32
D	(JICA WELLS)			JICA J-3	Nov-93		7.05	442	736		33.1	4.4	99.4	16.1	108.1	98.9		80.5	1.360	0.087		0.002	0.02	0.01	2.38	0.04	0.050	0.90	0.004	0.10
					Feb-94		9.42	397	690	236	22.6	0.2	104.0	22.2	113.0	103.5	13.2	18.3	0.482	0.026		<0.001		0.03	2.16	1.84			0.007	0.80
					Average		8.24	420	713	236	27.9	2.3	101.7	19.2	110.6	101.2	13.2	49.4	0.921	0.057		0.002	0.02	0.02	2.27	0.94	0.050	0.90	0.006	0.45
				JICA J-4	Nov-93		7.47	2875	4700		208.0	43.0	738.8	74.0	450.0	1124.5		236.1	0.515	0.754		0.016	0.02	0.04	26.82	0.04	0.120	1.20	0.014	0.10
					Feb-94		8.06	2627	4310	250	179.0	51.5	625.6	69.5	477.9	1036.2		187.3	0.420	0.125		<0.001		0.01	31.18	4.98			0.021	0.30
					Average		7.77	2751	4505	250	193.5	47.3	682.2	71.8	464.0	1080.4		211.7	0.468	0.440		0.016	0.02	0.03	29.00	2.51	0.120	1.20	0.018	0.20
				JICA J-5	Nov-93		7.19	2686	4440		337.0	59.5	501.4	60.0	500.0	1095.1		130.6	1.916	0.054		0.015	0.02	0.05	25.14	0.22	0.009	1.47	0.014	0.10
					Feb-94		7.90	2673	4210	328	319.0	56.5	501.4	66.0	600.4	1055.3		73.8	0.319	0.013		<0.001		<0.01	5.61	17.05			0.019	0.30
					Average		7.55	2679	4325	328	328.0	58.0	501.4	63.0	550.2	1075.2		102.2	1.118	0.034		0.015	0.02	0.05	15.38	8.64	0.009	1.47	0.017	0.20
				JICA J-6	Nov-93		7.74	549	846		22.8	2.4	137.1	23.0	199.8	50.7		111.7	1.042	0.077		0.005	0.01	0.01	1.15	0.16	0.018	1.11	0.006	0.10
					Feb-94		8.31	520	800	300	14.4	1.8	139.8	25.0	204.1	51.4		83.0	0.253	0.016		<0.001		0.01	1.31	7.63			0.004	0.20
					Average		8.03	534	823	300	18.6	2.1	138.5	24.0	202.0	51.1		97.4	0.648	0.047		0.005	0.01	0.01	1.23	3.90	0.018	1.11	0.005	0.15
				JICA J-7	Nov-93		7.84	1669	3160		102.0	43.5	303.8	49.0	300.2	748.7		120.8	1.418	0.058		0.011	0.01	0.04	7.30	0.06	0.004	1.54	0.009	0.10
					Feb-94		8.06	1111	1840	254	112.5	22.0	216.2	43.5	221.0	391.0		104.3	0.535	0.015		<0.001		0.02	4.44	6.58			0.005	0.20
					Average		7.95	1390	2500	254	107.3	32.8	259.9	46.3	260.6	569.9		112.6	0.977	0.037		0.011	0.01	0.03	5.87	3.32	0.004	1.54	0.007	0.15
				JICA J-8	Nov-93		8.09	550	821		6.5	0.4	159.2	22.0	105.2	88.6		167.2	0.645	0.292		0.005	0.02	0.01	1.76	0.11	0.360	0.60	0.008	0.10
					Feb-94		8.06	657	1060	322	17.5	1.8	178.5	19.7	123.0	167.7		147.0	1.734	0.078		<0.001		0.02	2.61	2.40			0.004	0.02
					Average		8.08	603	941	322	12.0	1.1	168.9	20.9	114.1	128.2		157.1	1.190	0.185		0.005	0.02	0.02	2.19	1.26	0.360	0.60	0.006	0.06
				JICA J-9	Nov-93		7.07	3722	6040		351.5	60.5	851.0	63.5	800.2	1469.0		124.5	1.345	0.217		0.023	0.02	0.70	9.41	8.70	0.055	1.50	0.023	0.10
					Feb-94		7.68	3443	5600	532	253.0	40.5	874.0	62.0	1071.1	1063.5		77.0	2.058	0.126		0.001		0.01	5.97	33.00			0.043	0.30
					Average		7.36	3582	5820	532	302.3	50.5	862.5	62.8	935.7	1266.3		100.8	1.702	0.172		0.012	0.02	0.36	7.69	20.85	0.055	1.50	0.033	0.20

Table B-III, 3.3 Groundwater Quality (Pampa del Tamarugal) (Nov. 1993 - Feb. 1994)

<Calidad de Agua Subterránea (Pampa del Tamarugal) (Nov. 1993 - Feb. 1994)>

		B.N.A CODE	DGA CODE	NAME		TEMP.	pH	TDS	Cond.	Turb	Ca	Mg	Na	K	SO4	Cl	CO3	HCO3	HEALTH SIGNIFICANCE NO3	As	F	Cd	Cr	Pb	B	Fe	Mn	Zn	Cu	Al
									µS		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
				(STANDARD)			6.0-8.5	1000		5					250.0	250			10.000	0.050	1.50	0.005	0.050	0.05		0.30	0.100	5.00	1.000	0.20
D				JICA J-C	Nov-93		7.43	2316	3680		331.5	31.5	409.4	45.5	699.8	719.6		78.1	0.705	0.039		0.013	0.02	0.05	6.67	0.13	0.840	0.57	0.013	0.10
					Feb-94		7.54	3223	3850	245	556.5	10.5	428.3	26.3	1801.0	360.5		39.7	0.295	0.102		0.002		<0.01	5.65	5.52			0.025	0.70
					Average		7.49	2770	3765	245	444.0	21.0	416.9	35.9	1250.4	540.1		58.9	0.500	0.071		0.008	0.02	0.05	6.16	2.83	0.840	0.57	0.019	0.40
				JICA J-D	Nov-93		7.71	2562	4280		310.0	57.5	501.4	59.0	450.0	1052.5		130.6	1.440	0.005		0.014	0.02	0.05	23.24	3.90	0.018	1.17	0.019	0.10
					Feb-94		8.19	2498	4000	358	322.0	48.5	446.2	64.0	542.7	1021.0		52.5	1.230	0.014		0.001		<0.01	19.32	22.43			0.018	0.60
					Average		7.95	2530	4140	358	316.0	53.0	473.8	61.5	496.4	1036.8		91.6	1.335	0.010		0.008	0.02	0.05	21.28	13.17	0.018	1.17	0.019	0.35
				JICA J-E	Nov-93		7.28	2597	4290		354.0	58.0	437.0	60.0	699.8	855.4		130.6	2.450	0.038		0.013	0.02	0.06	24.50	0.04	0.030	1.11	0.012	0.10
					Feb-94		8.00	2303	3770	292	304.5	56.0	393.3	63.0	476.5	941.6		67.7	0.131	0.008		0.003		0.01	14.82	16.25			0.014	0.20
					Average		7.64	2450	4030	292	329.3	57.0	415.2	61.5	588.2	698.5		99.2	1.291	0.023		0.008	0.02	0.04	19.66	8.15	0.030	1.11	0.013	0.15
				JICA J-F	Nov-93		7.56	1290	2180		73.0	24.0	322.0	36.5	199.8	487.1		147.1	0.918	0.197		0.005	0.01	0.03	3.51	0.11	1.400	1.20	0.007	0.10
					Feb-94		8.07	1627	2480	303	100.9	27.9	377.2	70.0	408.3	432.5		209.0	0.907	0.397		0.002		0.01	4.98	1.55			0.010	0.20
					Average		7.82	1459	2330	303	87.0	26.0	349.6	53.3	304.1	459.8		178.1	0.913	0.297		0.004	0.01	0.02	4.25	0.83	1.400	1.20	0.009	0.15
	AVERAGE - D						7.81	1924	3081	311	196.9	31.9	397.5	47.3	479.6	655.2	13.2	114.4	1.005	0.124		0.008	0.02	0.06	10.45	6.03	0.264	1.12	0.014	0.22
AVERAGE (A + B + C + D)						24.6	8.39	4251	6455	230	177.2	30.0	1239.8	123.9	877.2	1677.1	18.7	111.7	4.916	0.642		0.022	0.01	0.06	12.65	7.63	0.360	0.56	0.042	1.02
	PICA	252	223	POZO CONCOVA	Nov-93	32.6	8.35	229	400	201	18.4	0.2	46.5	1.6	33.1	25.9		97.6	5.600	0.005		0.004		20.01	0.02	0.92	0.015		0.007	
					Feb-94		8.44	228	312		17.2	0.2	47.8	1.6	32.0	27.6	2.4	97.6	1.158	<0.005		0.002		<0.01	0.30	0.85			0.001	0.20
					Average	32.6	8.40	228	356	201	17.8	0.2	47.2	1.6	32.6	26.8	1.2	97.6	3.379	0.005		0.003		20.01	0.16	0.89	0.015		0.004	0.20
		263	170	LA CALERA Nº3	Nov-93	29.8	8.05	1462	2700	148	81.8	7.7	408.3	15.6	614.8	220.5		70.2	43.500	0.027		0.010		0.02	13.94	0.63	0.034		0.009	
					Feb-94		8.39	1186	1890		9.0	0.8	404.8	19.5	298.0	322.0		130.6	1.468	0.053		0.001		<0.01	3.86	0.56			0.007	0.40
					Average	29.8	8.22	1324	2295	148	45.4	4.3	406.6	17.6	456.4	271.3		100.4	22.484	0.040		0.006		0.02	8.90	0.60	0.0		0.0	0.40
		270	213	ESMERALDA 7	Nov-93	32.2	8.82	601	1300	165	19.8	0.5	175.7	5.1	261.8	75.9		54.9	7.000	0.059		0.007		0.01	1.57	1.56	0.025		0.006	
	AVERAGE					31.5	8.41	741	1320	171	29.2	1.9	216.8	8.7	247.9	134.4	0.6	90.2	11.745	0.036		0.005		6.68	3.94	0.90	0.025		0.006	0.30

SAMPLED AND ANALYZED BY DGA AND JICA STUDY TEAM IN NOVEMBER 1993.
SAMPLES OF JICA WELLS WERE TAKEN AFTER PUMPING TEST. OTHERS WERE SAMPLED WITHOUT PUMPING (WELLS WERE NOT IN USE).
TDS IS CALCULATED FROM CONDUCTIVITY BY USING EQUATION MENTIONED IN CHAPTER 3, B-I (SEE FIG. B-I, 3.3.2)

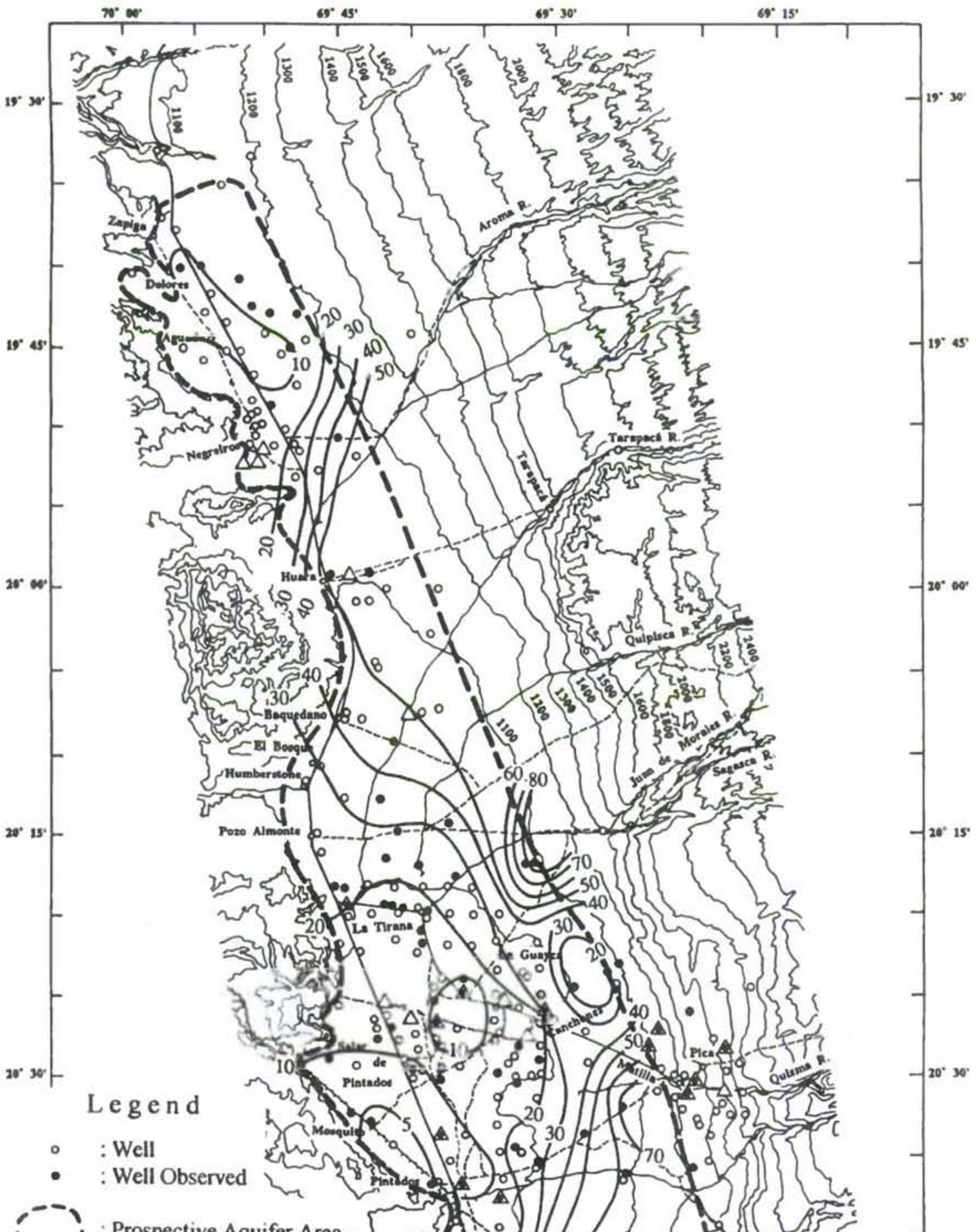

Fig. B-III, 3.1 Static Water Level (1993)

< Nivel Estático (1993) >

Unit. : m BGL

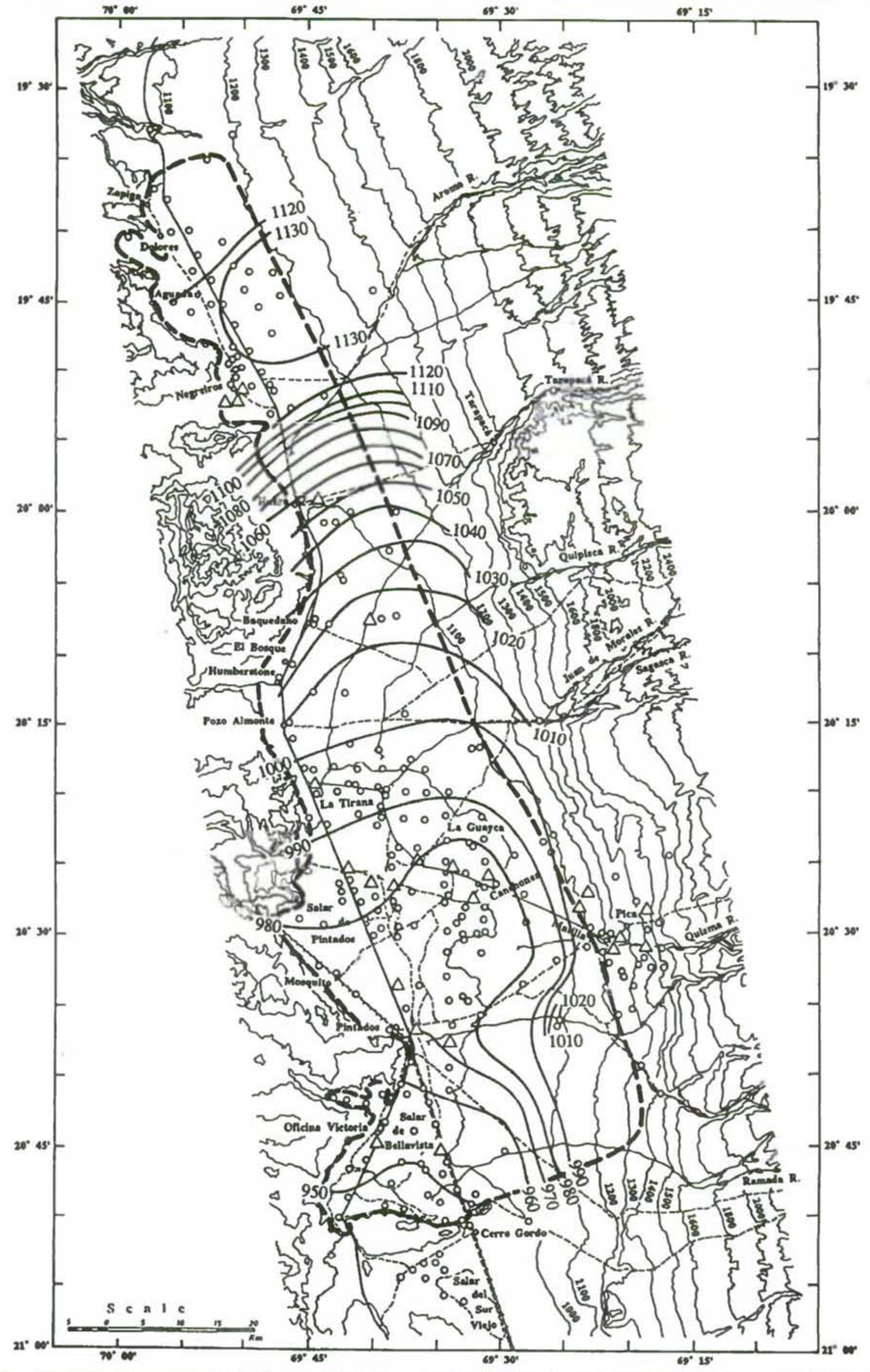

Fig. B-III, 3.2 Static Water Level (1993)

<Nivel Estático (1993) >

Unit : m MSL

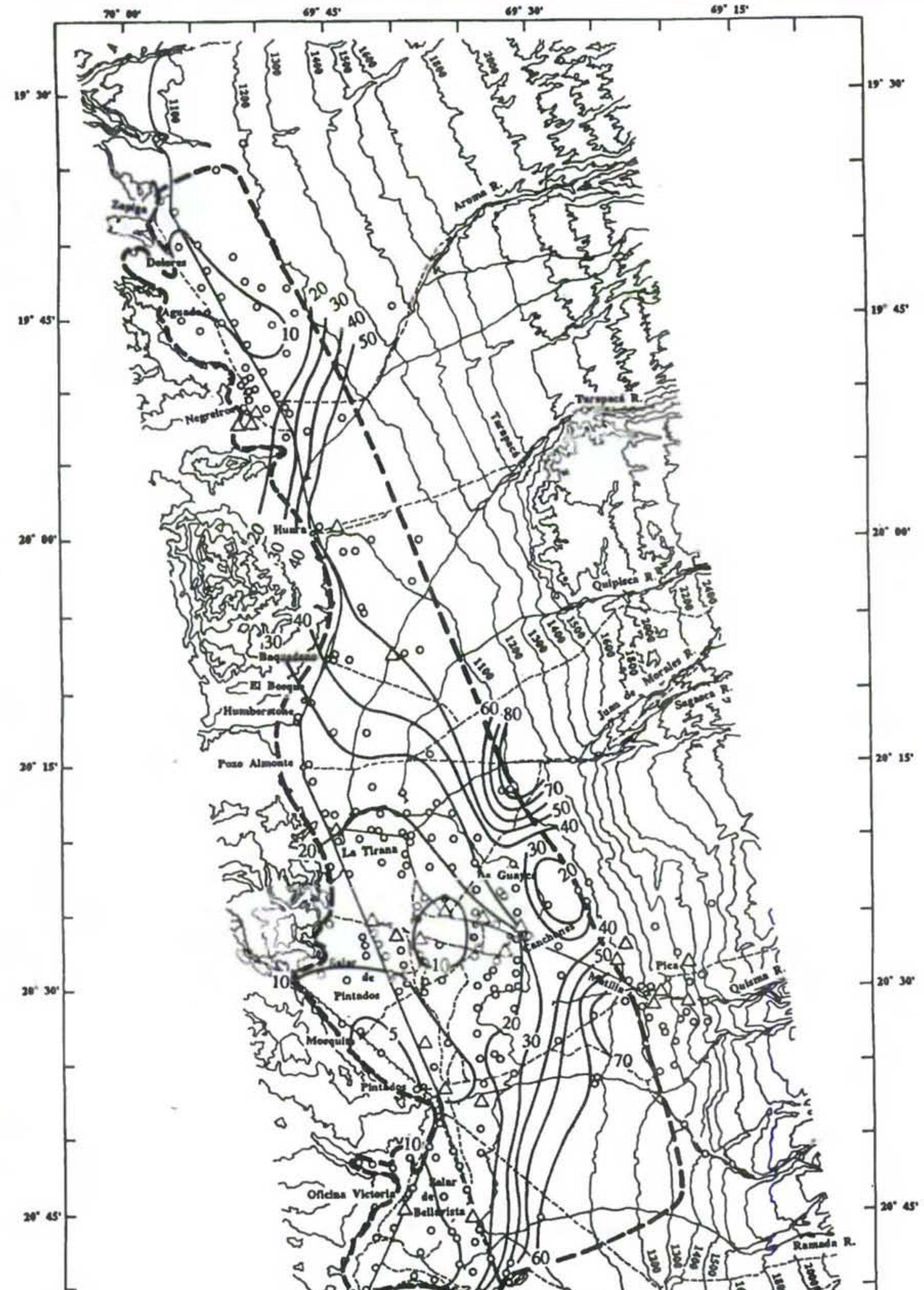

Fig. B-III, 3.3 Static Water Level (1960's)

<Nivel Estático (1960's) >

unit: *BGL*

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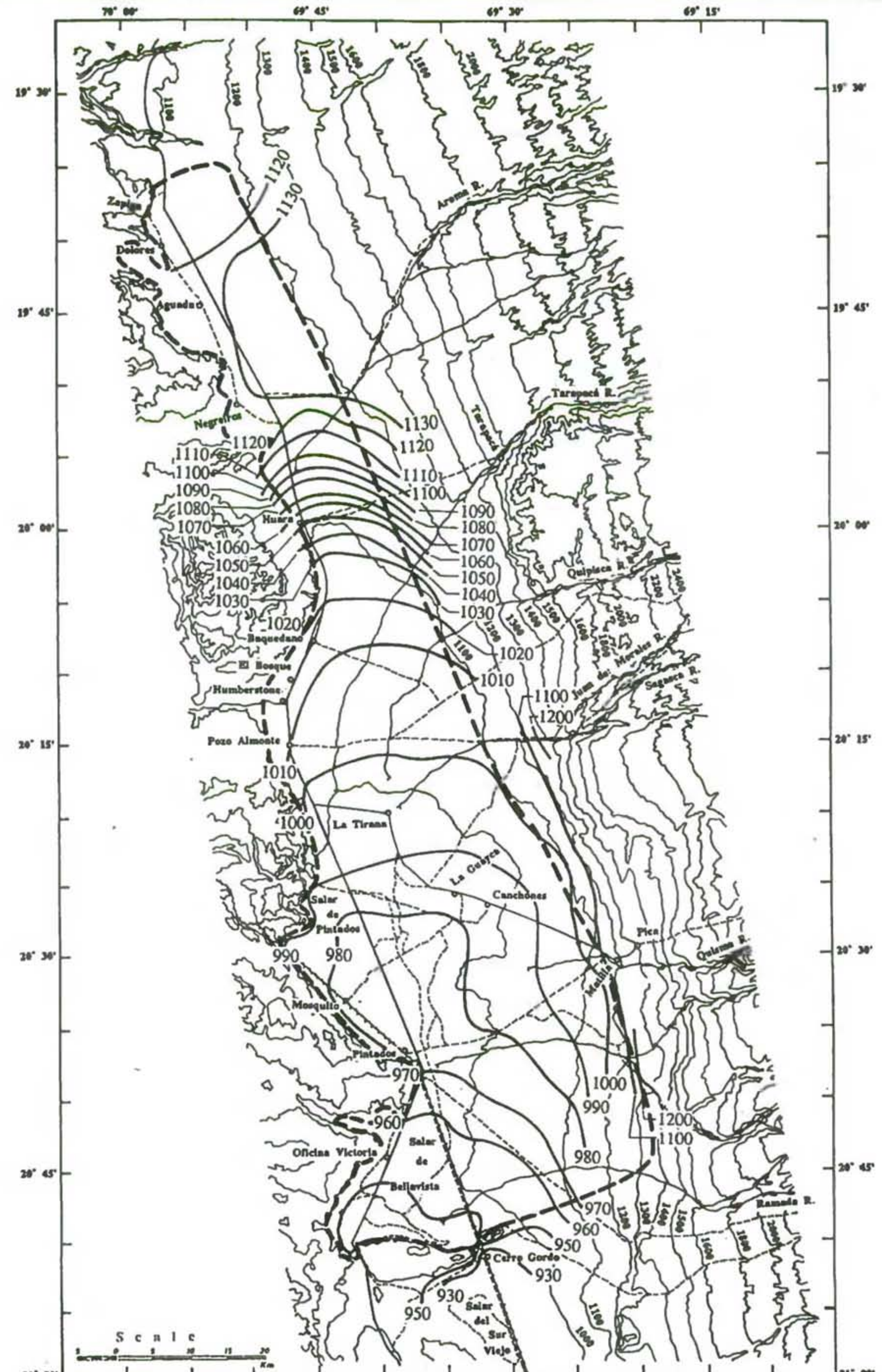

Fig. B-III, 3.4 Static Water Level (1960's) unit: m*BGL*

<Nivel Estático (1960's) > *unidad: mBGL*

Unit : MSL

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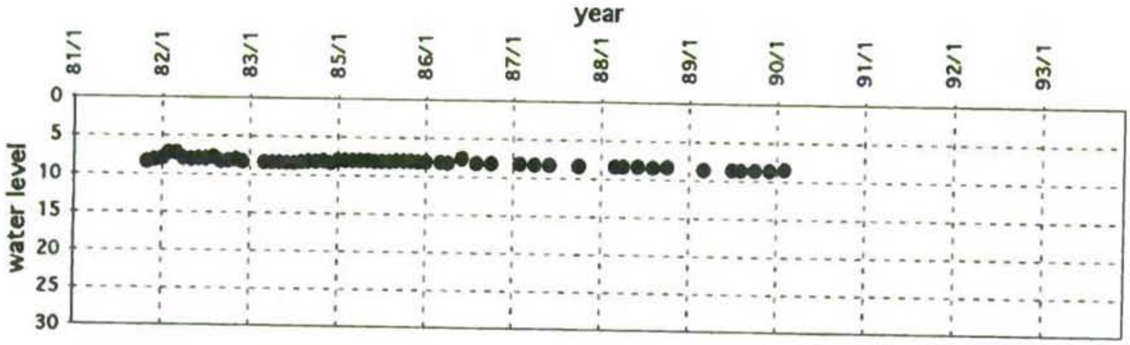
(ZAPIGA)

101-9 (1940-6950 B-3)



104-3 (1940-6950 C-3)

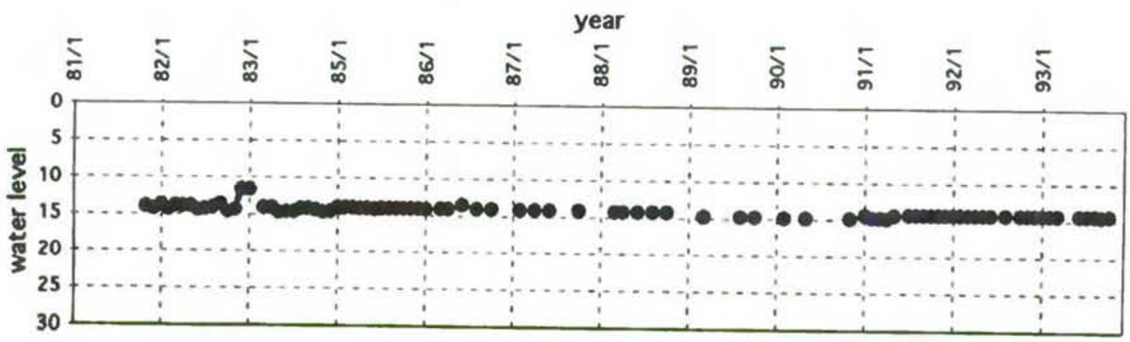


Fig. B-III, 3.5 (1) Variation of Groundwater Table in Pampa del Tamarugal

< Variación de Nivel Estatico en Pampa del Tamarugal >

(POZO ALMONTE - SALAR DE PINTADOS)

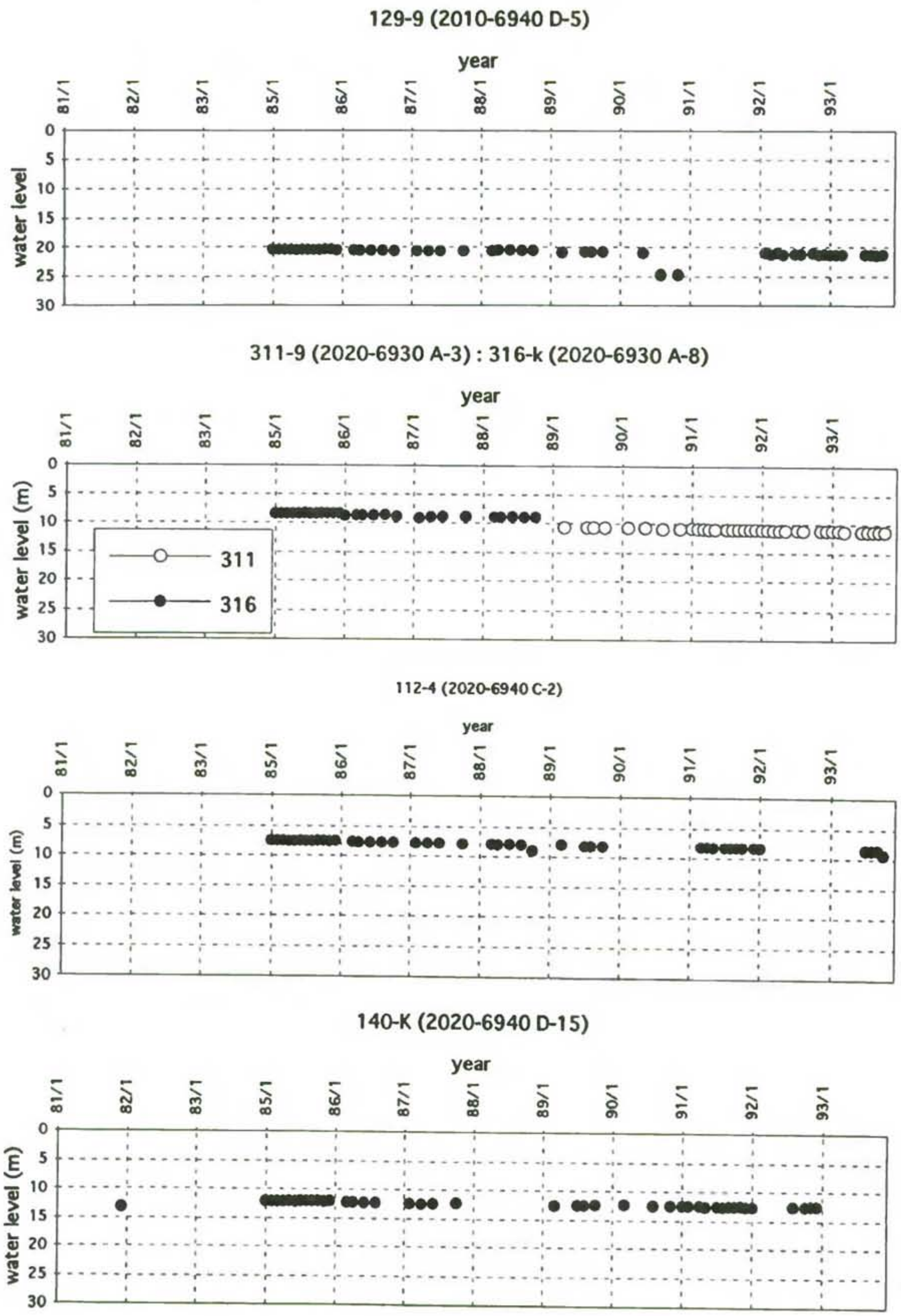
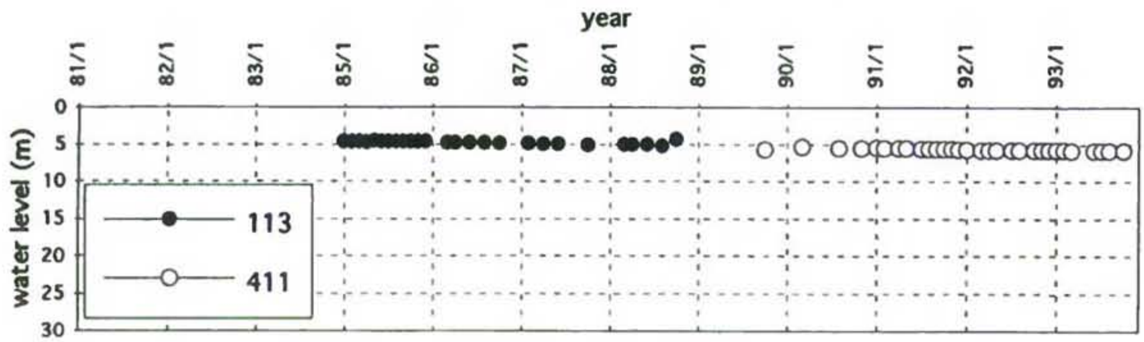


Fig. B-III, 3.5 (2) Variation of Groundwater Table in Pampa del Tamarugal

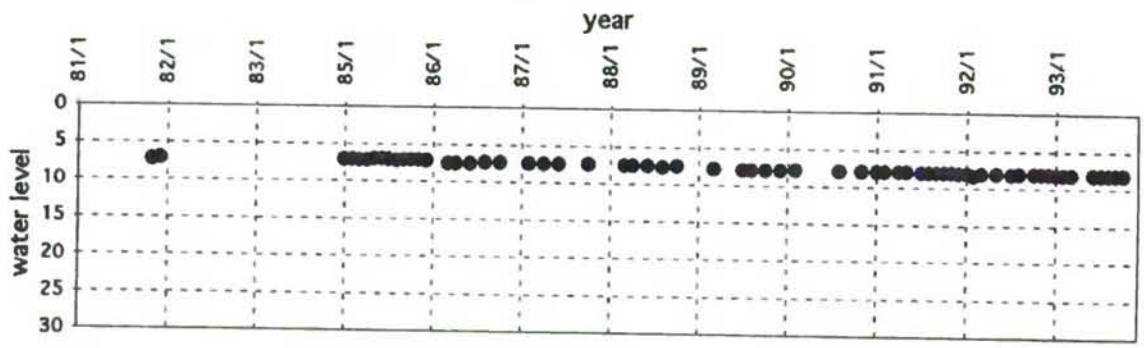
< Variación de Nivel Estatico en Pampa del Tamarugal >

(POZO ALMONTE - SALAR DE PINTADOS)

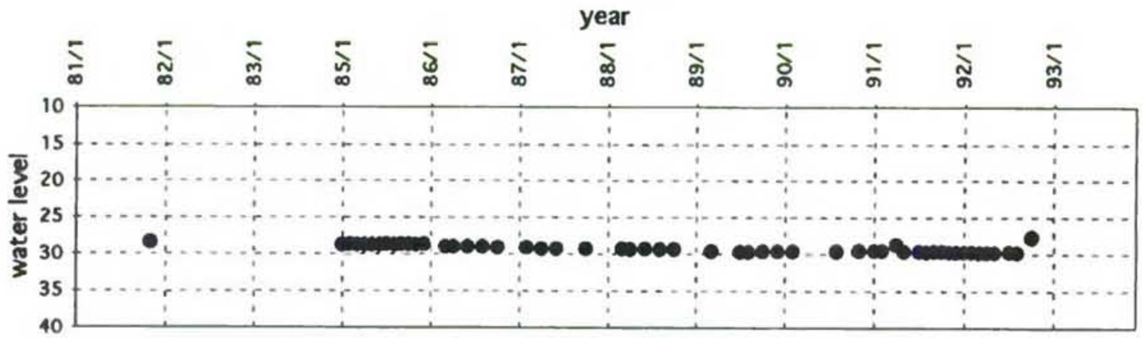
113-2 (2030-6930 A-1) : 411-5 (2030-6930 A-9)



141-8 (2030-6930 C-3)



121-3 (2030-6930 D-2)



430-1 (2030-6940 B-2)

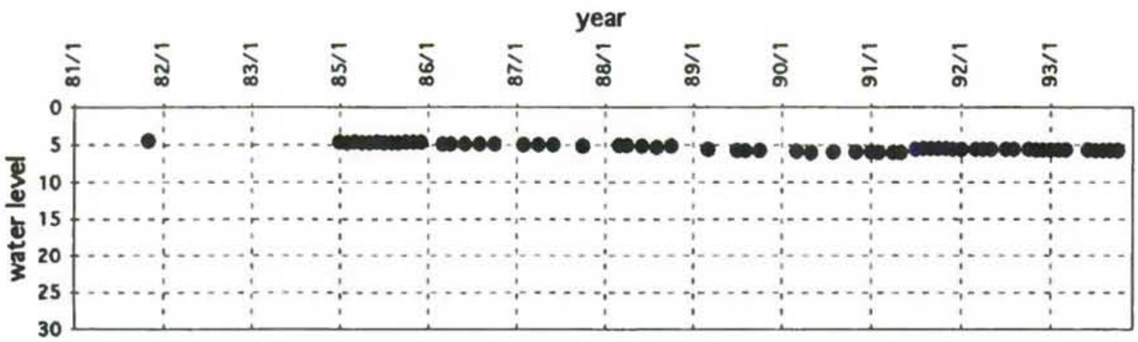
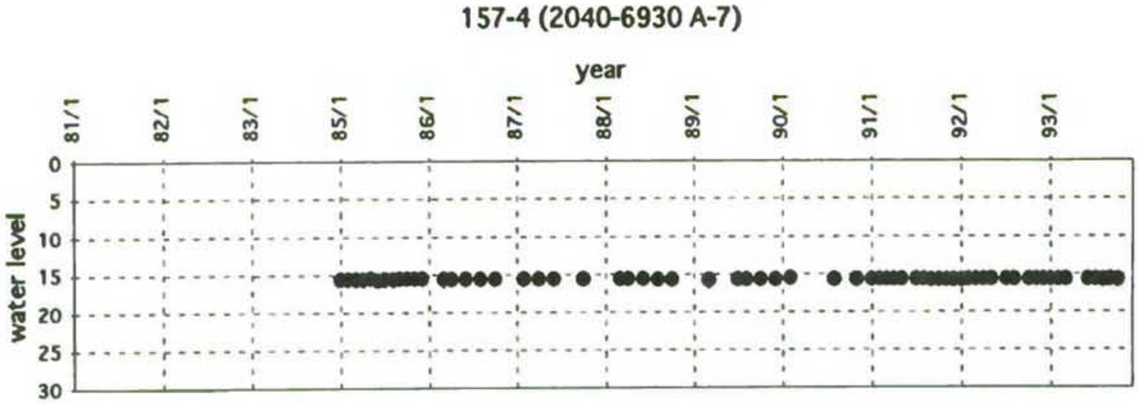
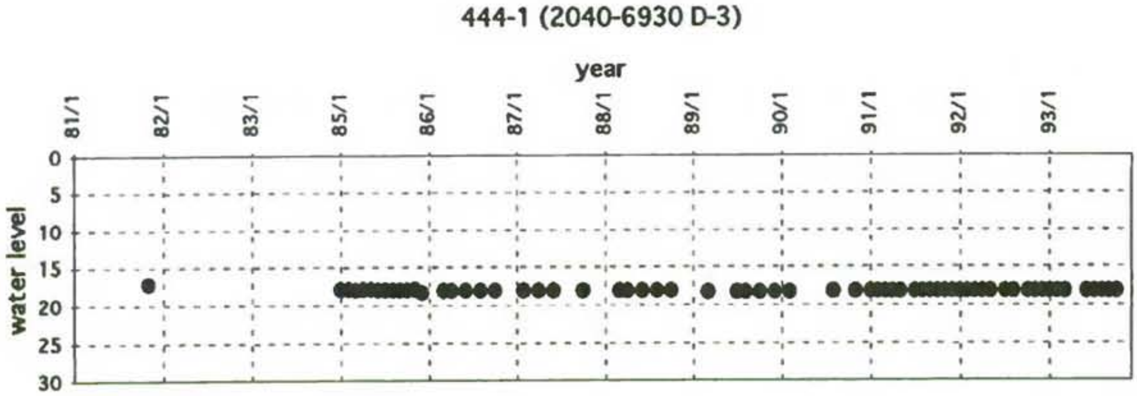


Fig. B-III, 3.5 (3) Variation of Groundwater Table in Pampa del Tamarugal

< Variación de Nivel Estatico en Pampa del Tamarugal >

(OFICINA VICTORIA - SALAR DE BELLAVISTA)





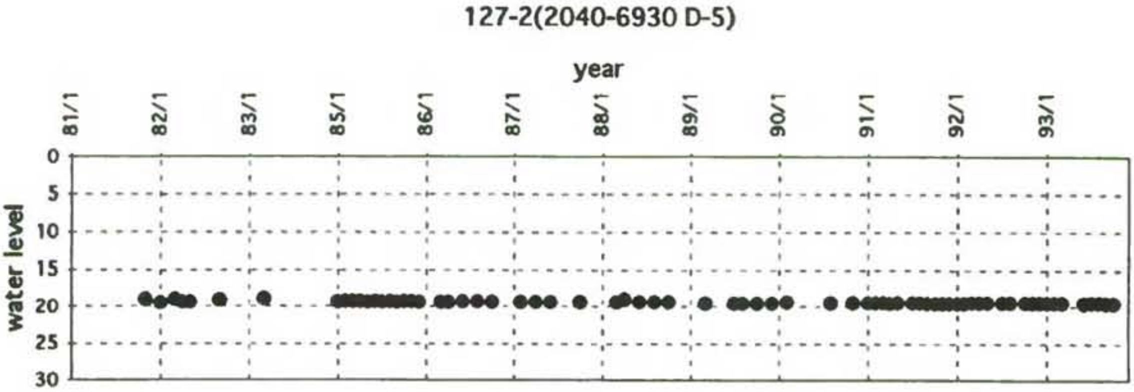
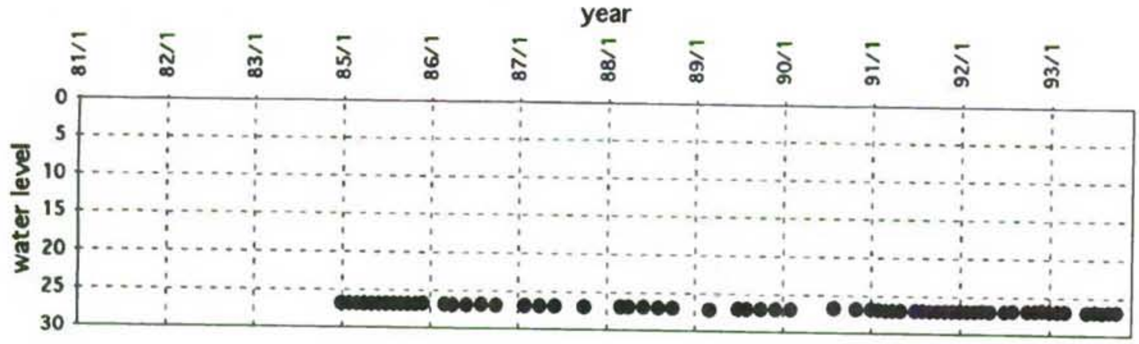


Fig. B-III, 3.5 (4) Variation of Groundwater Table in Pampa del Tamarugal

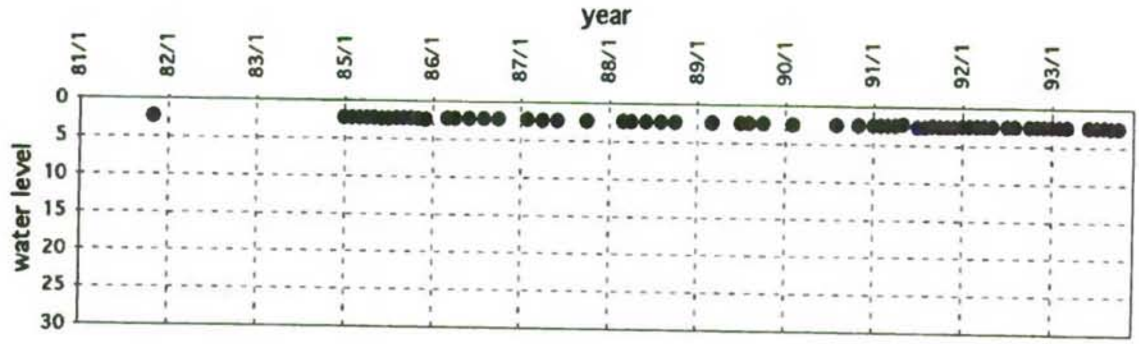
< Variación de Nivel Estatico en Pampa del Tamarugal >

(OFICINA VICTORIA - SALAR DE BELLAVISTA)

155-8 (2050-6930 B-4)



124-8 (2050-6940 B-1)



122-1 (2040 6930 A-1)

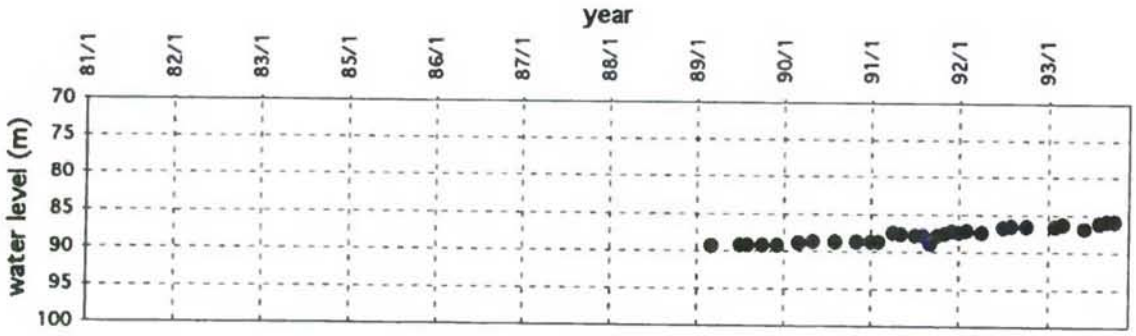
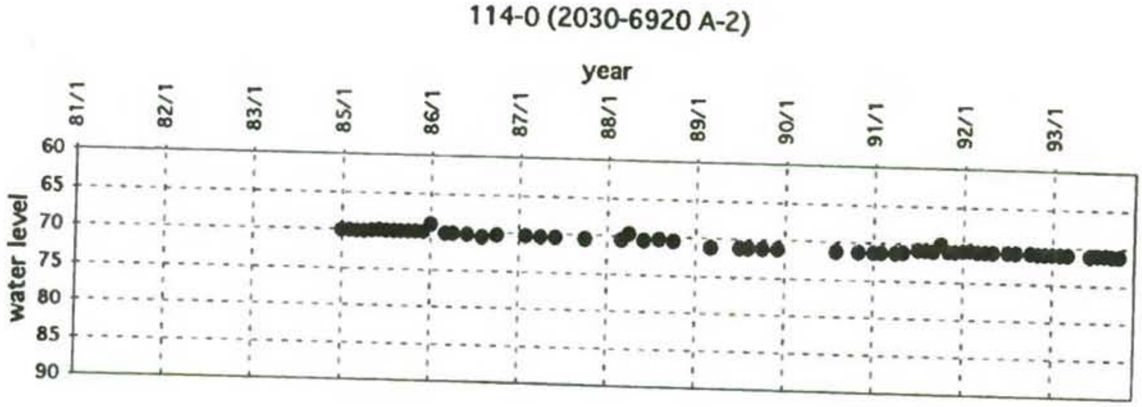


Fig. B-III, 3.5 (5) Variation of Groundwater Table in Pampa del Tamarugal

< Variación de Nivel Estatico en Pampa del Tamarugal >

(PICA)



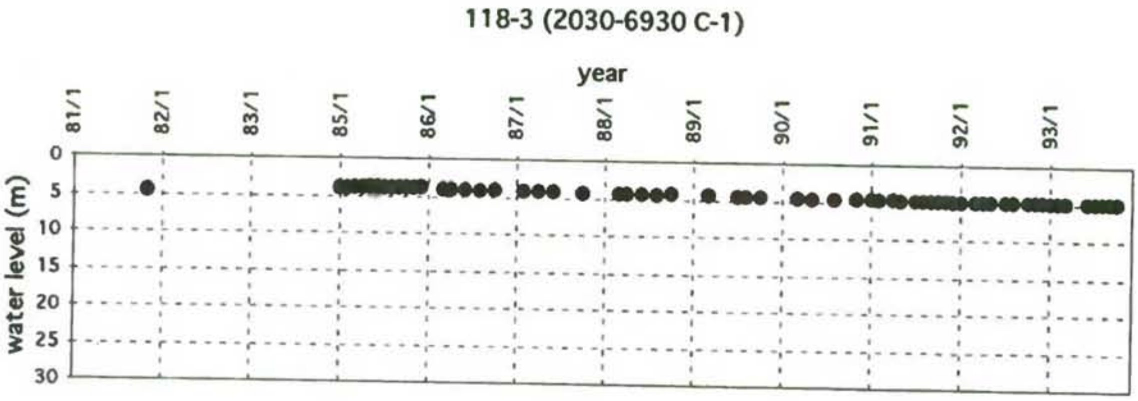


Fig. B-III, 3.5 (6) Variation of Groundwater Table in Pampa del Tamarugal

< Variación de Nivel Estatico en Pampa del Tamarugal >

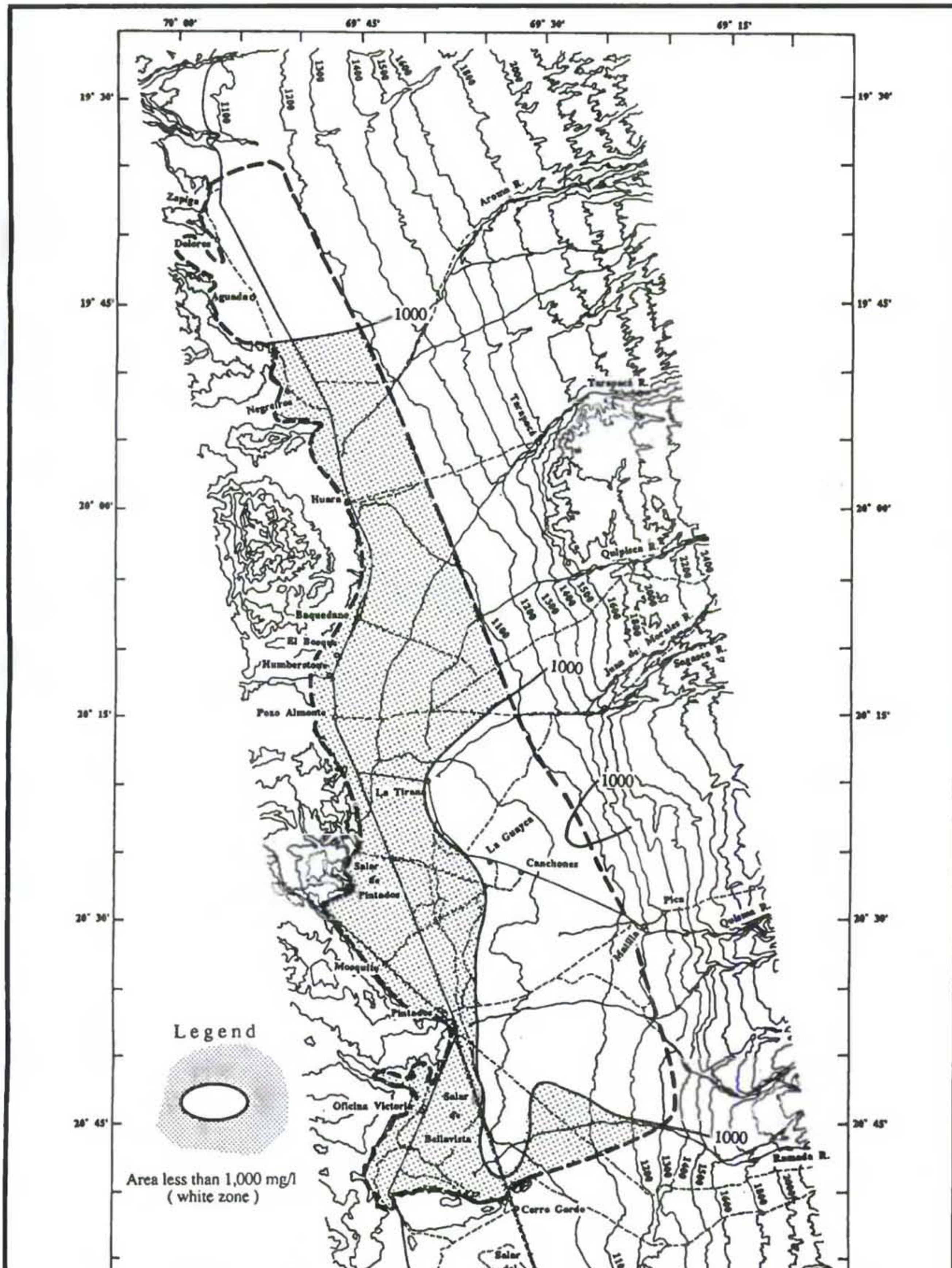


Fig. B-III, 3.6 Distribution of TDS (Pampa del Tamarugal)

< Distribución de TDS (Pampa del Tamarugal) >

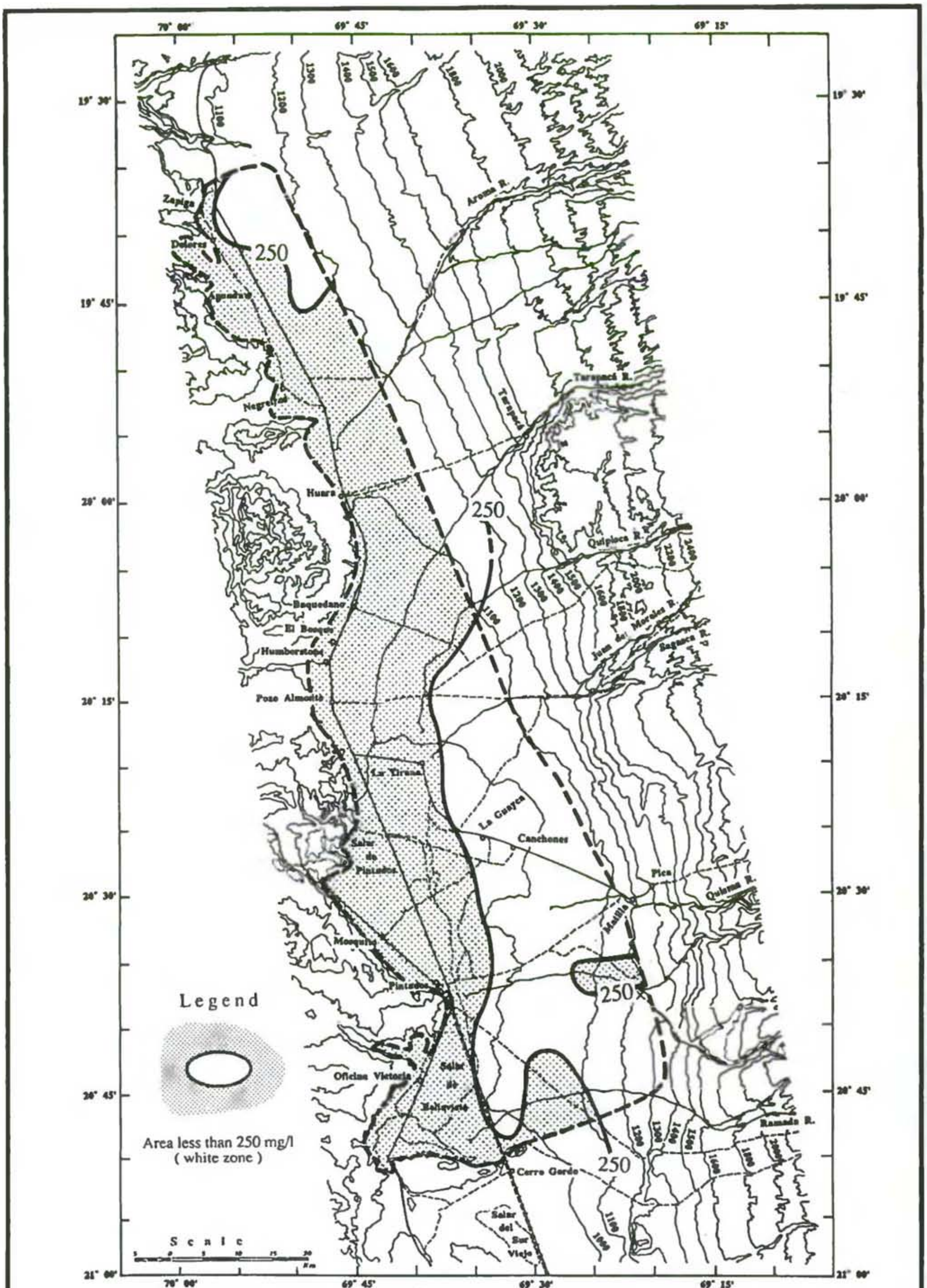


Fig. B-III, 3.7 Distribution of Cl (Pampa del Tamarugal)

< Distribución de Cl (Pampa del Tamarugal) >

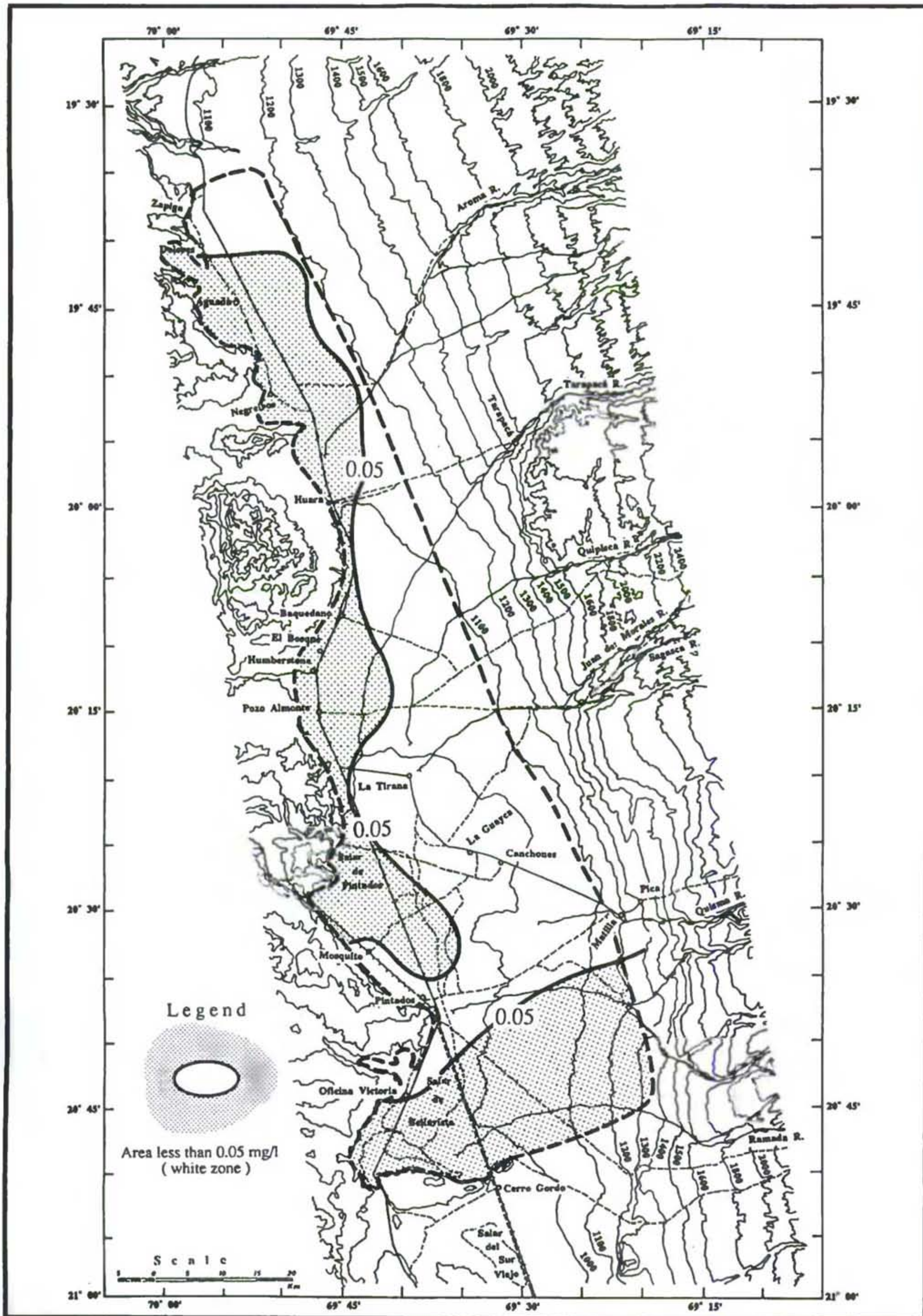


Fig. B-III, 3.8 Distribution of As (Pampa del Tamarugal)

< Distribución de As (Pampa del Tamarugal) >

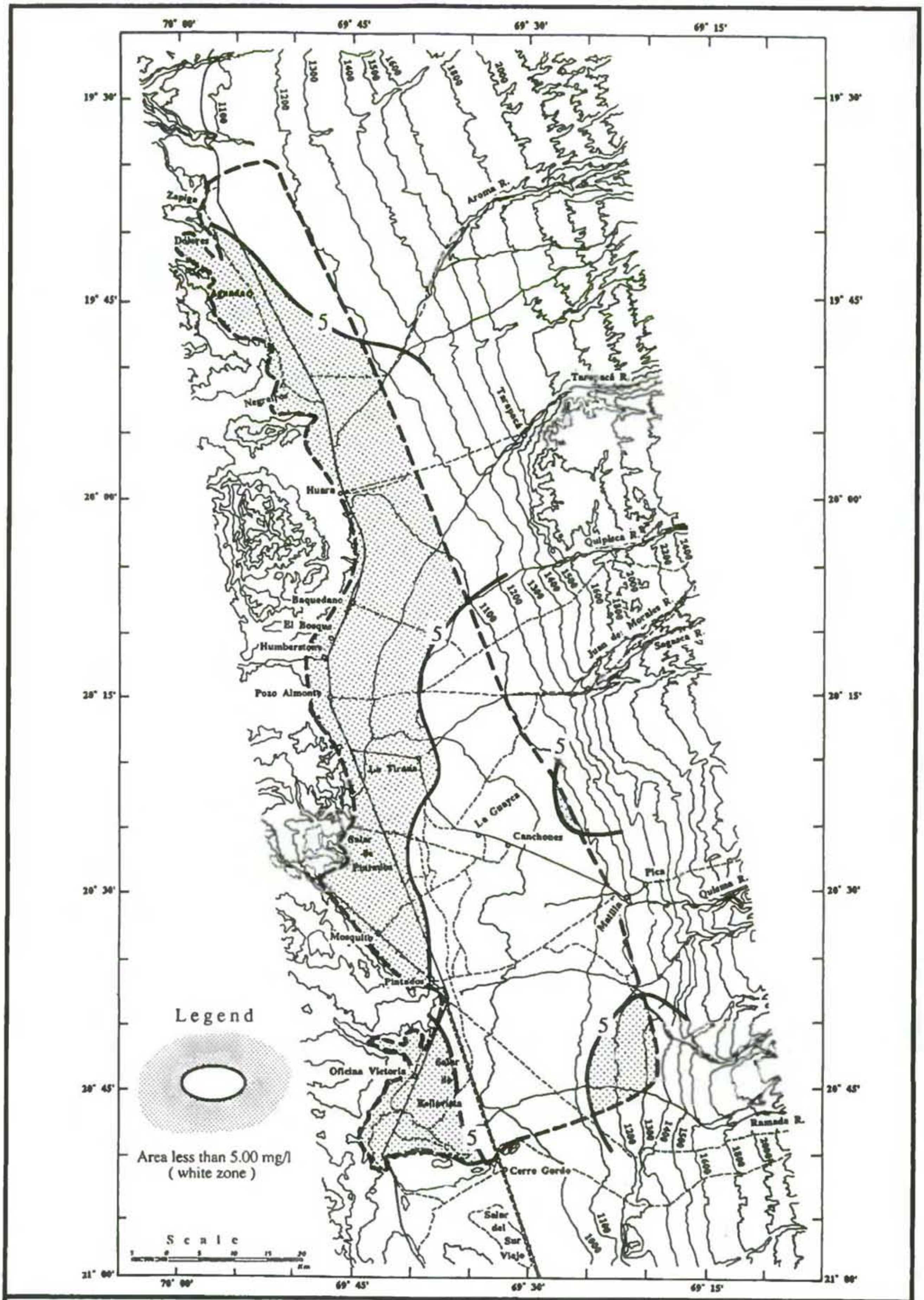


Fig. B-III, 3.9 Distribution of B (Pampa del Tamarugal)

< Distribución de B (Pampa del Tamarugal) >

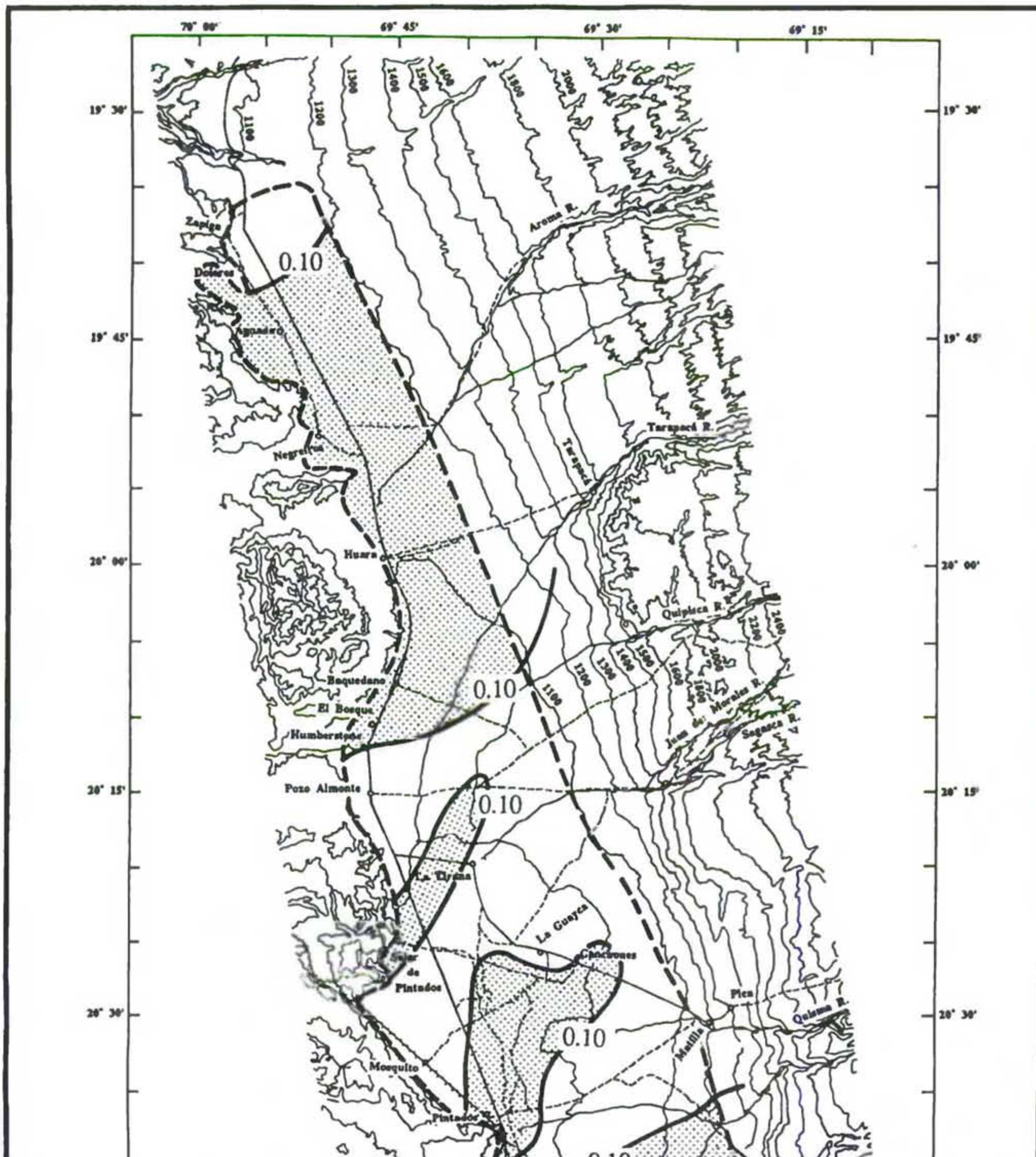


Fig. B-III, 3.10 Distribution of Mn (Pampa del Tamarugal)

< Distribución de Mn (Pampa del Tamarugal) >

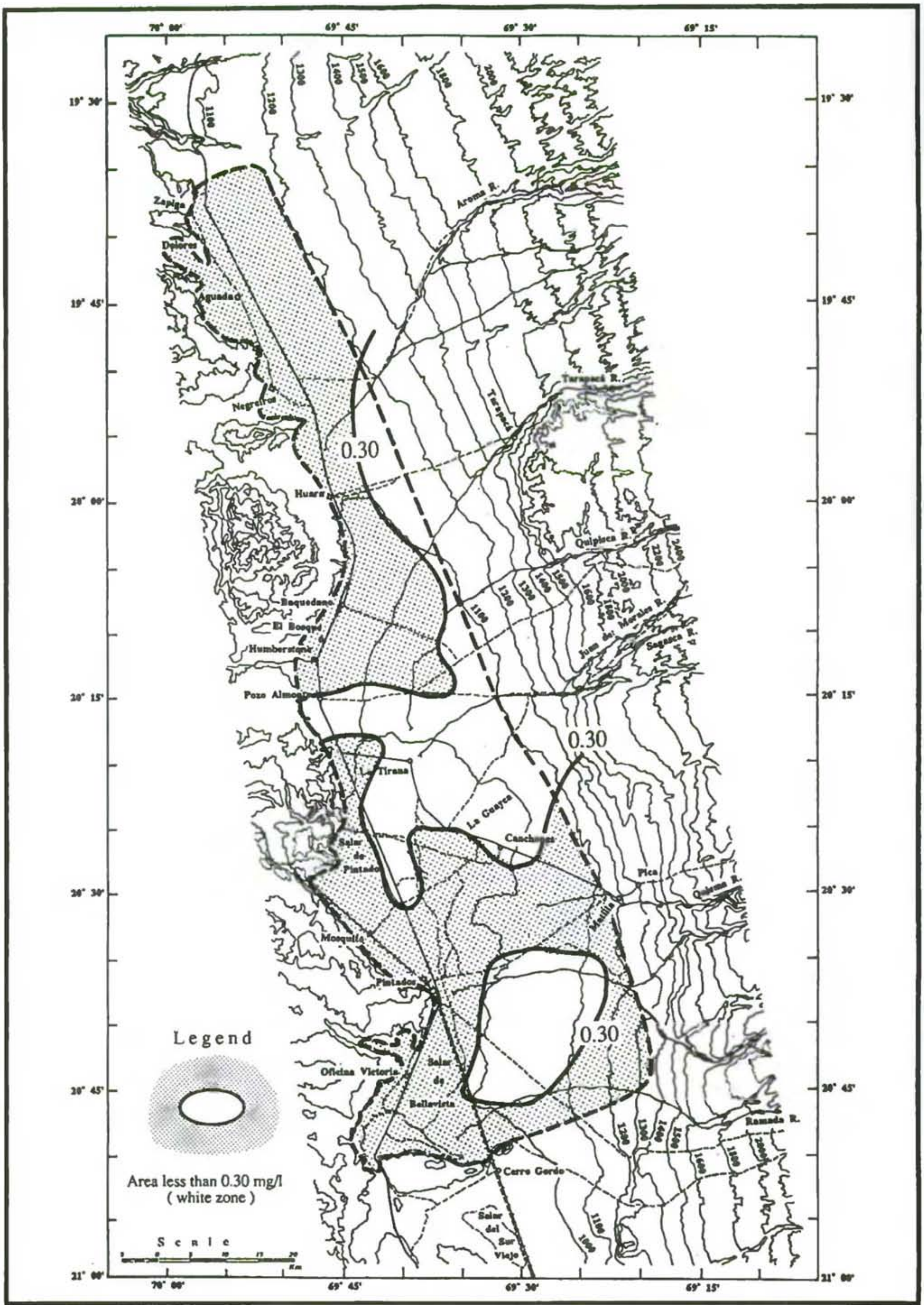


Fig. B-III, 3.11 Distribution of Fe (Pampa del Tamarugal)

< Distribución de Fe (Pampa del Tamarugal) >

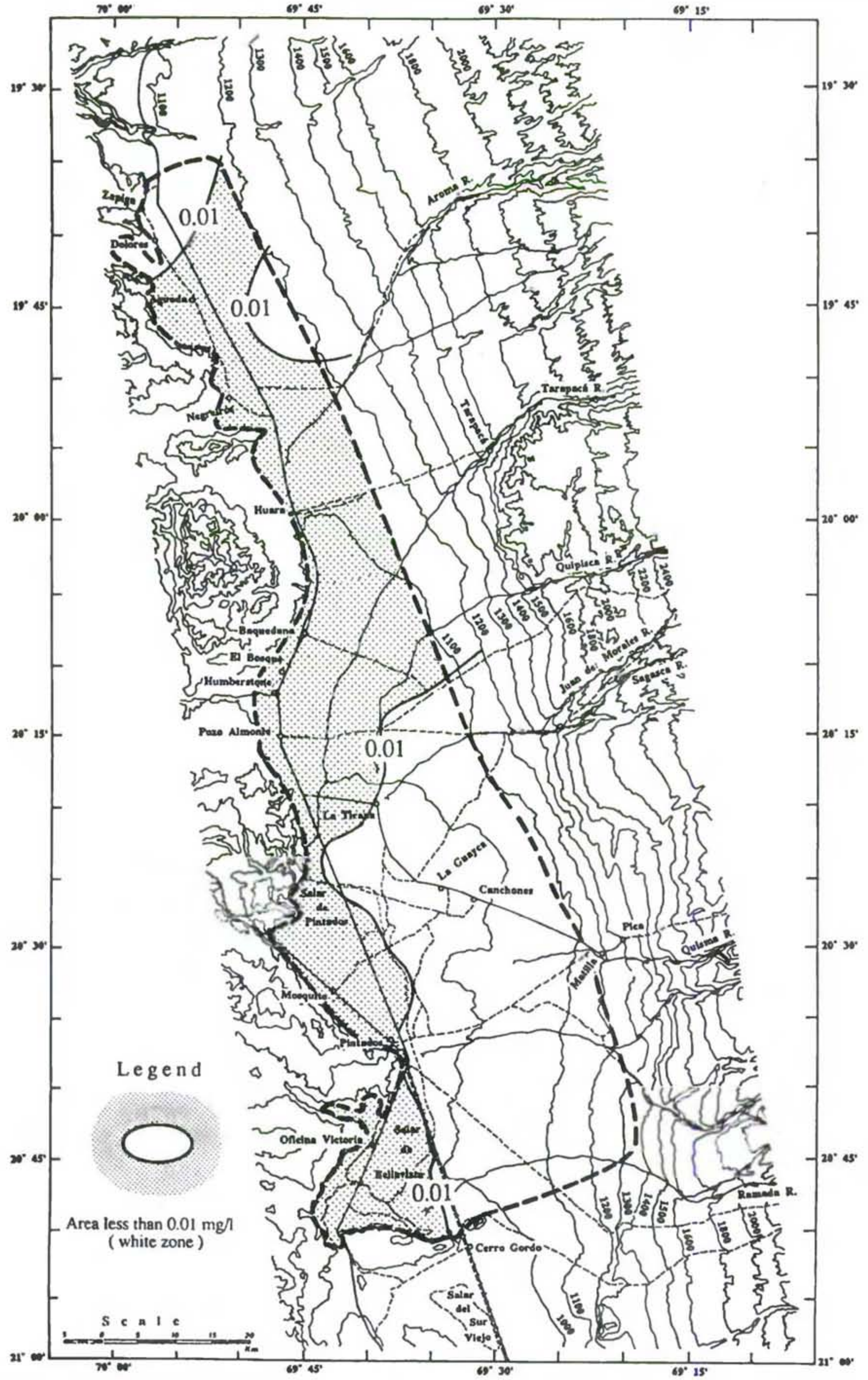
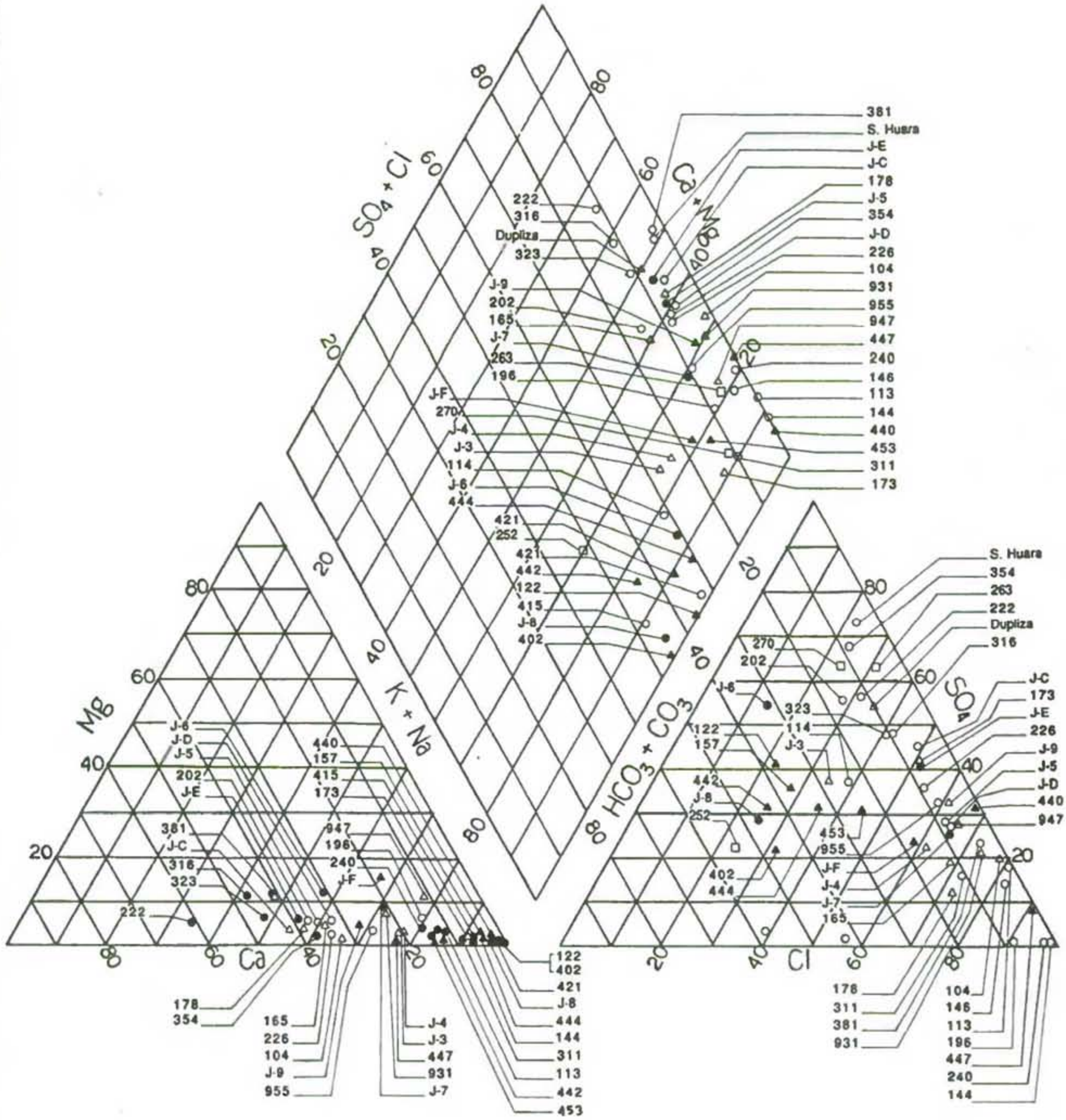


Fig. B-III, 3.12 Distribution of Cd (Pampa del Tamarugal)

< Distribución de Cd (Pampa del Tamarugal) >



L E G E N D

△ ZONE 1: Dolores- Zapiga- Huara

○ ZONE 2: Huara- Baquedano- Pozo Almonte

● ZONE 3: Pozo Almonte- Canchones- Pintados

▲ ZONE 4: Bellavista

□ ZONE 5: Pica- Matilla- Calera

Fig. B-III, 3.13 Tri-linear Diagram of Major Ions (Pampa del Tamarugal)

< Diagrama Tri-Lineal de Iones Mayores (Pampa del Tamarugal)>

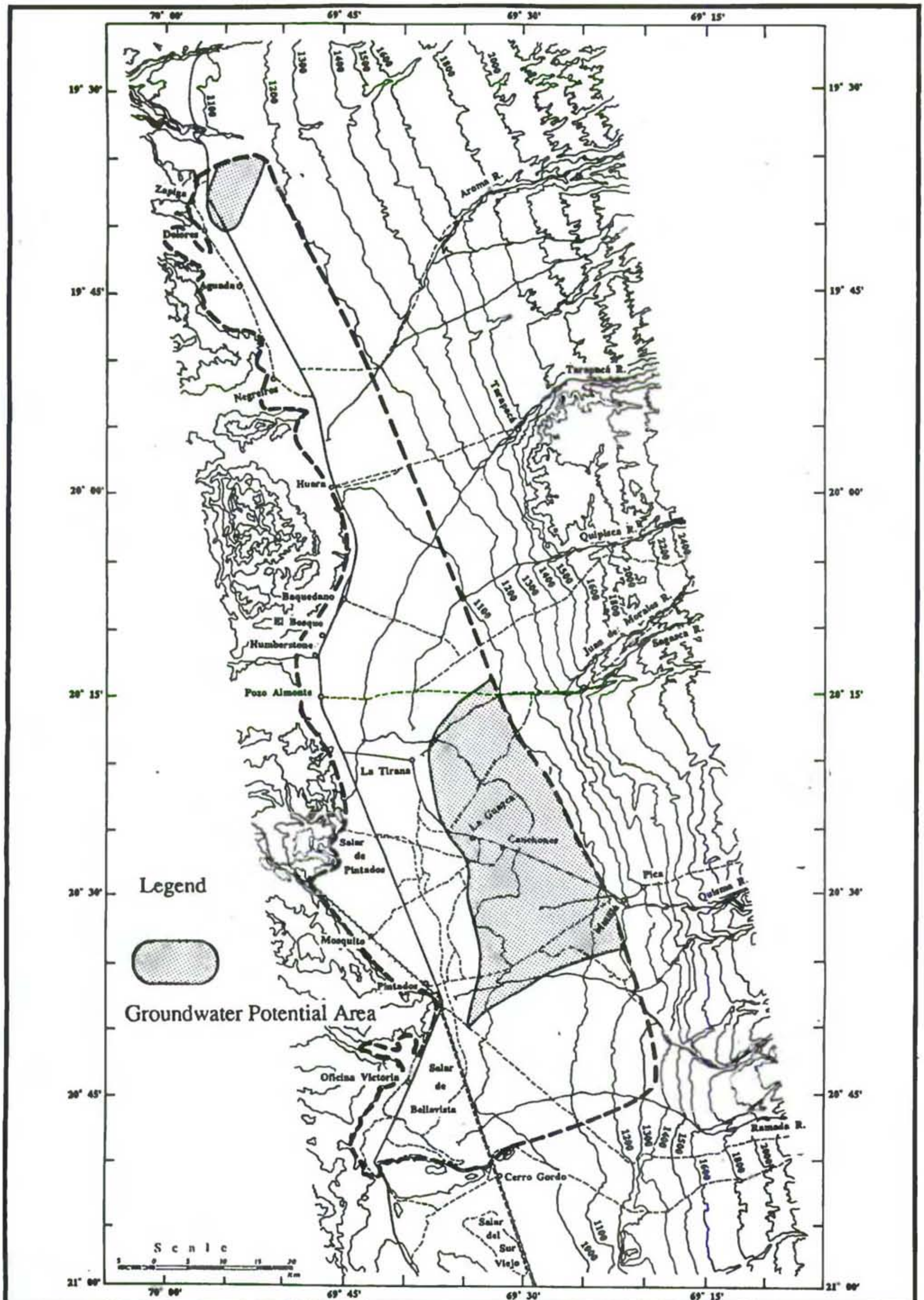


Fig. B-III, 3.14 Prospective Aquifer Area

< Area de Aculferos Probables >

Chapter IV. GROUNDWATER DEVELOPMENT POTENTIAL

4.1 Existing Water Balance

4.1.1 Recharge to Groundwater

Recharging sources to the groundwater in the Pampa del Tamarugal Baasin are the surface water of quebradas (small rivers) and fissure water from the east (Altiplano). Several rivers flow into Pampa and recharge the groundwater with their surface water. Surface flow rate of each river are estimated in the Supporting Report C (Surface Water). Main rivers are Qdas. Aroma, Tarapacá, Quipisca, Juan de Morales, Sagasca, Quisma, Chacarilla and Ramada from north to east. Total flow rate of these rivers is estimated to be 967 l/sec (Ref., Chapter III of Supporting Report C: Surface Water).

Besides the above, it must be taken into consideration that the fissure water flows into the aquifers in Pampa from Altiplano. It is estimated to be 289 l/sec (Ref., Chapter II of B-IV in this report).

4.1.2 Discharge from Groundwater

Groundwater in Pampa discharges from the Basin by pumping and evaporation/ evapotranspiration through Tamarugo forests and Salars.

ESSAT pumped up 547 l/sec of groundwater at the Canchones and Dolores well fields in 1992. Real consumption in Pampa is assumed to be 47 l/sec. Irrigation in Pampa also depends on groundwater. Its real consumption is estimated to be 119 l/sec (Chapter VI of Supporting Report C; Water Use). Real consumption of mining water is estimated to be 17 l/sec (Chapter VII of Supporting Report C; Water Use). Groundwater evaporates at Salar de Pintados and Bellavista. The average evaporation rate from Salars between 1985 and 1993 is estimated to be 145 l/sec on the basis of the static water level. Evapotranspiration from Tamarugo trees is estimated to be 904 l/sec by averaging the evapotranspiration rates from 1985 to 1993 based on the Fig. E.2.4 (<1) in the Supporting Report E: Environment. Evaporation rate from the Salars is estimated to be 145 l/sec by using the table shown below.

S.W.L (mBGL)	Evaporation Rate (mm/day)
1m<	1.00
1-2m	0.36
2-3m	0.086
3-4m	0.02
4-5m	0.0048
5-6m	0.0011

source: <1 (Grill, Vidaly and Grain (1986))

Static water level of wells in Pampa del Tamarugal has been depressed as mentioned in Chapter III of this report. Their average drawdown rate between 1985 and 1993 is estimated to be 7 cm/year on the basis of the data measured by DGA. This drawdown rate is equivalent to the 514 l/sec of water storage since groundwater storage between 0 m and 10 m BGL is estimated as 2.316×10^9 m^3.

4.1.3 Water Balance

Pampa del Tamarugal is a hydrogeologically closed basin and no surface water flows out from the Basin. Therefore, the water balance of the basin is expressed by the following formula.

$$\Delta Q = (R_R + R_{FH} + R_{FO}) - (P + D + I + M + E_T + E_S)$$

where,

- ΔQ : change of groundwater storage (514 l/sec)
- R_R : recharge from the rivers (976 l/sec, Supporting Report C)
- R_{FH} : recharge from the fissure water from Salar del Huasco and the other basin (X l/sec)
- P : pumping rate by ESSAT (547 l/sec, Supporting Report C)
- D : real consumption of domestic water (47 l/sec, Supporting Report C)
- I : real consumption of irrigation (119 l/sec, see Supporting Report C)
- M : real consumption of mining (17 l/sec, see Supporting Report C)
- E_T : evapotranspiration from Tamarugo (904 l/sec, Supporting Report E)
- E_S : evaporation from Salars (145 l/sec)

Then,

$$-514 = (976 + X) - (547 + 47 + 119 + 17 + 145 + 904)$$

$$X = 289 \text{ (l/sec)}$$

This result shows that the aquifers of Pampa del Tamarugal Basin receive an amount of 289 l/sec of water through fissures of Basement Rocks from Altiplano including Salar del Huasco Basin.

4.2 Evaluation of Groundwater Development Potential

Groundwater storage in Pampa del Tamarugal Basin is estimated to be 26.9 x 10^9 m^3 (Ref. Chapter II). As mentioned in Chapter III, the static water level in Pampa del Tamarugal has been lowered. It is 7 cm/year in average for the whole Pampa area. This is equal to a 16.2 x 10^6 m^3 of reduction of storage (0.06 % of total storage volume).

Future total water demand in Pampa del Tamarugal Basin is estimated in Supporting Report C. Evaporation from Salar and evapotranspiration from Tamarugo trees are also estimated in 4.1, Chapter IV of this Report. The existing and future yearly reduction of the groundwater storage in 1992 and 2015 are estimated to be 16.2 million m^3/year and 63.0 million m^3/year. Then, the total reduction of the groundwater storage during 23 years until 2015 is estimated at 911 x 10^6 m^3 (3.4% of the existing groundwater storage of 26.9 x 10^9 m^3).

If future demand after 2015 is same as that of 2015, it needs 676 years to completely consume the whole groundwater storage in Pampa del Tamarugal.

Total water consumption of stored water in Pampa increases up to 302.6 x 10^3 m^3/day, if all the water application in Pampa del Tamarugal is adopted. It is 2.54 x 10^3 m^3 of consumption volume and is equal to the 9.4 % of total storage of groundwater in Pampa. In this case, the life of aquifers in Pampa del Tamarugal is estimated to be approximately 245 years.

It is, therefore, concluded that the groundwater development potential is large enough to meet the future water demand.

The future groundwater level distribution resulted by the groundwater development is estimated in next Clause.

4.3 Construction of Simulation Model

4.3.1 Mathematical Model

In this study, the computer program " UNISSF "; Unified Normal and Inverse Sub-Surface Flow analysis program was applied to simulate groundwater and assess the impact of the groundwater development plan in Pampa del Tamarugal. The UNISSF was developed by the Information -Technology Promotion Agency, Japan (IPA) by entrusting to Century Research Center Co, Ltd. (CRC).

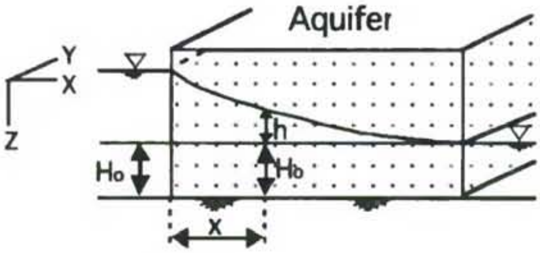
This program is based on the finite element method widely used in numerical analysis and quasi-three-dimensional groundwater analysis. Mathematical model of the program is shown as excerpt from the user's manual report.

1) Dominant equation

The dominant equation relating to infiltration handled here is based on Dupuit's hypothesis* that the head is equal on the perpendicular section of the aquifer.

Using Dupuit's hypothesis, the continuation formula relating to three-dimensional (x, y, z) flow is, from $Vz = 0$ is, as follows.

$$S\frac{\partial h}{\partial t}+\frac{\partial}{\partial x}\{(H0+h)Vx\}+\frac{\partial}{\partial y}\{(H0+h)Vy\}=0 \quad \text{.........................} \quad (1)$$



S : *coefficient of storage*

Vx, Vy, Vz : *apparent flow velocity in* x, y, z *directions*

q : spring flow or discharge per unit time

Putting Darcy's formula of motion (equation 2) into equation (1) yields:

$$\left.\begin{aligned} Vx &= -Kx\frac{\partial h}{\partial x} \\ Vy &= -Ky\frac{\partial h}{\partial y} \\ Vz &= -Kz\frac{\partial h}{\partial z} \end{aligned}\right\} \quad \text{..} \quad (2)$$

* This hypothesis means that the direction of infiltration flow is mainly on the horizontal plane, that is, the perpendicular components of flow are very small. Therefore, when the perpendicular components are too large to be ignored as compared with the horizontal components, the analysis based on Dupuit's hypothesis is not applicable.

$$S\frac{\partial h}{\partial t}=\frac{\partial}{\partial x}\left\{Kx(Ho+h)\frac{\partial h}{\partial x}\right\}+\frac{\partial}{\partial y}\left\{Ky(Ho+h)\frac{\partial h}{\partial y}\right\}+q$$

$$=\frac{\partial}{\partial x}\left(Tx(h)\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(Ty(h)\frac{\partial h}{\partial y}\right)+q \quad \text{..........} \quad (3)$$

Where *Tx, Ty* : coefficients of transmissivity in *x, y* directions, being functions of heard *h*

This is the dominant equation relating to infiltration using Dupuit's hypothesis.

From equation (3), after finite element formulation by using the weighted remainder method, the solution is obtained under proper initial conditions and environmental conditions.

2) Quasi-three-dimensional handling

The analysis by the dominant equation shown here can be easily applied in the multi-stratum ground, and it is called the quasi-three-dimensional infiltration flow analysis.

That is, using the coefficient of transmissivity and coefficient of storage as the function of level, the multi-stratum ground can be handled, and not only the confined aquifer but also the unconfined aquifer and transference between the two can be also handled, which is different from the conventional horizontal two-dimensional infiltration flow analysis.

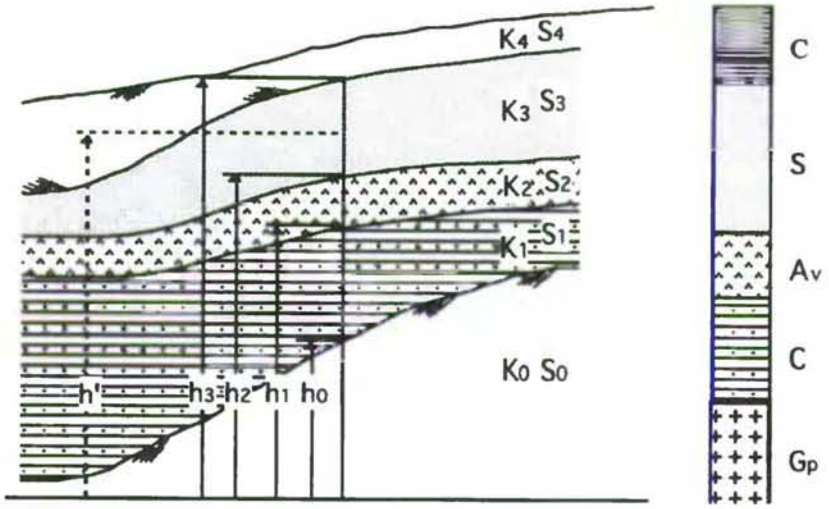
The coefficient of transmissivity *T* is defined as the sum of products of coefficient of permeability *Ki* and layer thickness b_i of each aquifer. That is,

$$T=\sum_{i=0}^{n} K_i \cdot b_i$$

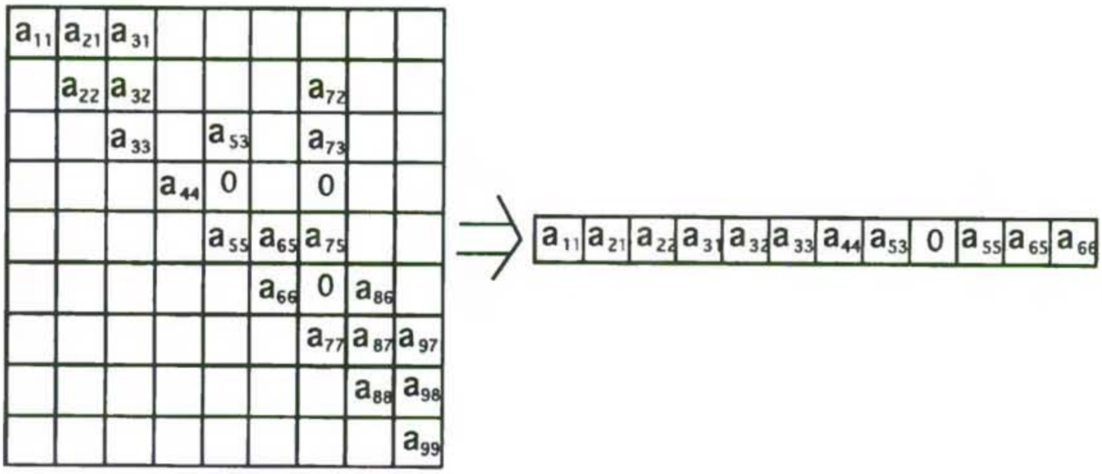
Meanwhile, the coefficient of storage *S* is, in the case of a confined aquifer, defined as the product of the coefficient of specific storage S_S * and the aquifer thickness *b* of the stratum to be analyzed, and in the case of an unconfined aquifer, it is defined as the volume of water discharged from the gap in the soil of unit volume (= effective porosity) due to lowering of the level.

The stratum section and columnar section of a typical aquifer are shown in following figure.

* Equal to the coefficient of volumetric compression, being expressed as Ss = 0.001 ρh (cm^{-1})



The coefficient of transmissivity, regarding as the function of level, can be expressed as shown below.



When handled similarly, the coefficient of storage is as shown above.

(1) Confined aquifer

When the free water surface reaches the upper end of the permeable bed, the permeable bed is confined. In the above figures, h is greater than h_3. In this region, the coefficient of transmissivity T is constant, and is expressed as follows.

$$T = K_o b_o + K_1 b_1 + K_2 b_2 + K_3 b_3 (= CONST)$$

Also the coefficient of storage S is constant, being the sum of the products of coefficient of specific storage Ss and layer thickness of each layer, and is expressed as follows.

$$S = S_4 = Ss_0 b_0 + Ss_1 b_1 + Ss_2 b_2 + Ss_3 b_3 (= CONST)$$

(2) Unconfined aquifer

When the free water surface is lowered (h becomes less than h_3 in Figs. 2 and 3) and the permeable bed becomes unconfined, the coefficient of transmissivity T decreases as the water level drops as the function of groundwater level, and the coefficient of storage becomes the value of the effective porosity* in the area of the location of the level (stratum).

For example, when the level is h' ($h_2 < h' < h_3$), T' and S' are :

$$T' = K_o b_o + K_1 b_1 + K_2 b_2 + K_3 b_3 (h - h_2)$$

$$S' = S_3$$

When the free water surface is further lowered to the basement (h is less then h_o), the coefficient of transmissivity and coefficient of storage become zero at that point. Such phenomenon is a problem of wide-area groundwater, and is often experienced at the boundary of the mountain and plain field.

3) Initial conditions and boundary conditions

The theoretical solution is obtained under proper initial conditions and boundary conditions.

(1) Initial condition

$$h(x_i, 0) = h(x_i)$$

(2) Boundary conditions

(i) Boundary with known head

$$h(x_i, t) = h_b(x_i, t)$$

.... When the level is constant, or the periodic change of level is known, such as the boundary facing the river, lake or sea.

---

* The coefficient of storage S of the unconfined aquifer is expressed as follows.

$S = Sy + Ssb \cdot b$

where Sy : specific yield, synonymous with effective porosity

Ss : coefficient of specific storage

b : layer thickness

($Sy >> Ss \cdot b$)

(ii) Boundary with known in-out flow

$$Q(X_i, t) = Q_b (X_i, t)$$

4) Finite element method

(1) Formulation

Dominant equation

$$\frac{\partial}{\partial x}\left(Tx(h)\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(Ty(h)\frac{\partial h}{\partial y}\right)+q=S(h)\frac{\partial h}{\partial t} \quad \cdots\cdots (1)$$

When the entire region is divided into a finite number of elements, as far as the structure is continuous, equation (1) is approximately established in each element.

When the weighted remainder method is applied in formulation, it follows that

$$R=\frac{\partial}{\partial x}\left(Tx(h)\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(Ty(h)\frac{\partial h}{\partial y}\right)+q-S(h)\frac{\partial h}{\partial t} \quad \cdots\cdots (2)$$

The optimal approximate solution of equation (1) is obtained by minimizing this remainder R in all elements.

The following equation is established by the Galerkin method selecting the shape function as the weight.

$$\iint_s \{N\} R ds = 0 \quad \cdots\cdots (3)$$

Where N : shape function

Solving equation (3) yields finally the following equation.

$$\left(\frac{1}{4t}[C]+[K]\right)\{h\}_{t+\Delta t}=\{F\}_{t+\Delta t}+\frac{1}{\Delta t}[C]\{h\}_t \quad \cdots\cdots (4)$$

where

$$[C]=\iint_{se} S^e \{N\}\{N\}^T ds$$
$$[K]=\iint_{se} [B]^T \begin{bmatrix} Tx & 0 \\ 0 & Ty \end{bmatrix} [B] ds$$
$$[C]=\iint_s Q\{N\} ds - \int r_2 q \{N\} ds$$

For handling of the time term, however, the regression difference was used. Analysis is possible by solving equation (4) with respect to the total head *h*.

Since the materials constants handled here, *T*, *S*, are the functions of water level, it is necessary to improve the solution by iterative calculation.

To solve the simultaneous linear equations of (4), basically, the Gaussian elimination method is used, but in consideration of saving of memory and increase of calculation speed, the skyline method is employed.

The skyline method is briefly described below.

(2) Skyline method

The skyline method is a kind of band matrix, but it is different from the band matrix in the following points.

1) Data is handled in row unit.
2) Those corresponding to the band width are variable in each row.
3) The product sum type calculation formula is used.

calculation formula ([a] · {x} = [b])

i) LU splitting

K = in the sequence of 2, 3, ..., N

J =in the sequence of 1, ..., K-1

$$a^{\star}_{jk} = a_{jk} - \sum_{i=1}^{j-1} a'ij \ \ a^{*}ik$$

$$a'_{jk} = a^{\star}_{jk} / a'ij$$

$$a'_{kk} = a_{kk} - \sum_{i=1}^{k-1} a'ik \ \ a^{*}ik$$

where $a^{\star}_{jk}$: the value before dividing by pivot *a'ii*

(equivalent to component of U of LU splitting)

a'_{jk} the value after dividing by pivot *a'ii*

(equivalent to component of L of Lu splitting)

ii) Calculation of right side

Forward elimination

K = in the sequence of 2, 3, ..., *n*

$$b'_k = \left(b_k - \sum_{i=1}^{k-1} l_{ki} b'_i \right) / l_{kk}$$

Regression substitution

K = in the sequence of n, n-1, ..., 2

Xk = (b'k at that point)

i =in the sequence of 1, ..., K-1

$$New\ \ b'_i = b'_i - U_{ki} X_k$$

$$X_1 = (final\ \ b_1)$$

4.3.2 Parameter of Groundwater Basin

1) Shape of Basin and Calculation Mesh System

An area of Pampa del Tamarugal for groundwater simulation is shown as Fig. B-III, 4.1. The boundary of the area is sharply cut by the basement rocks of the Andes Mountains in the east and the Coastal Range in the north. On the other hand, the northern and southern boundaries don't like that but the basement rocks are located in shallow underground around them. However, it can be assumed that both boundaries are bordered with the basement rocks completely in terms of groundwater simulation. The simulation area is approximately 5,500Km^2.

Fig. B-III, 4.2 shows a calculation network for the groundwater simulation. The network consists of 348 elements and 301 nodes. The interval of basic mesh is 5Km and finer one is half of basic mesh: 2.5Km. The fine mesh networks are mainly set in the areas where JICA test wells are located or great fluctuation of groundwater level caused by withdrawals, transpiration, influent streams and so forth is predicted.

2) Boundary Condition

It seems that there's no recharge of groundwater from the Coastal Range alone the west boundary. However, the recharge from the Andes Mountains, Salar del Huasco

Basin in particular is expected, while the recharge from northern or southern boundary can be neglected in the groundwater simulation model.

3) Distribution of Aquifer

Data about horizontal and vertical distribution of aquifers was established using the illustrated figures listed as follows based on bowling inventory including JICA test wells, existing geological materials and so forth.

- Geological profile (Pampa del Tamarugal) Fig. B-III, 1.5-1.6
- Isopach Map of Aquifer Q_3 (Pampa del Tamarugal) Fig. B-III, 2.51
- Top of Aquifer Q_3 (Pampa del Tamarugal) Fig. B-III, 2.52
- Base of Aquifer (Pampa del Tamarugal) Fig. B-III, 2.53

The data was set up as a kind of geological input data at all calculation nodes. Two kind of aquifers: Q_3 and Q_4 in ascending order are recognized from a hydrogeological point of view. A distribution of Q_4's thickness was regarded as a difference between surface level and top level of aquifer Q_3. A conceptual geological section for simulation is illustrated as Fig. B-III, 4.3. Q_3 and Q_4 can be regarded as conglomeratic facies and sandy facies respectively, although each of aquifers varies in lithofacies. They are conformable to each other without continuous impermeable layer. Therefore, it seems that they are unconfined aquifers as a whole.

4) Coefficient of Aquifer

In general, coefficient of aquifer is determined by the analysis of boring logs, pumping test results and so on. However, in this case, it is difficult to classify Q_3 and Q_4 into many sections based on coefficient of aquifer. Because there's not enough data unfortunately to do reasonably. In case of this simulation, the coefficient of aquifer was adopted as follows.

- Permeability
  Q_3: $K=1.0\times10^{-3}$ cm/sec
  Q_4: $K=1.0\times10^{-4}$ cm/sec

- Strativity
  Q_3: $S=0.35$
  Q_4: $S=0.30$

5) Discharge of Groundwater

Discharge of groundwater in the study area consists of transpiration from Tamarugo forest and groundwater withdrawal. There is no surface discharge to the out of the basin because all rivers there infiltrate into the basin. Since a distribution of Tamarugo forest is recognized within simulation area as shown in Fig. B-III, 4.4, the discharged volume (1,019 l/s) was input at related nodes after dividing it equally. The divided volume of transpiration at each nodes in 1993 is 2,257m3/day/node.

Then, groundwater withdrawal volume estimated as 696 l/s in total was distributed at related nodes on the basis of the interview. Some of pumped up groundwater volume is restored to underground again. It is assumed that 30% of agriculture water use or 60% of domestic and mining water use is restored except for Canchones where pumping up water is supplied to Iquique city directly. Discharge condition is shown in Fig. B-III, 4.4.

6) Recharge of Groundwater

Recharge of groundwater to the area comes from seven influent streams and basement rocks, since precipitation in Pampa del Tamarugal is negligible. The recharged water volume from influent streams was divided somewhat among nodes along each stream lines. The total recharged water volume through them is estimated at 976 l/sec on the basis of hydrological analysis.

Recharge from basement rocks may be regarded as so called "Black Box", but it is assumed that the major source of it is fault system or fissures of Altiplano and its value is estimated about 288 l/sec on the basis of analysis of water balance in the study area as shown in 4.1. The groundwater recharge along the simulation boundary including it from the basement rocks was calculated in the simulation program automatically in order to reproduce the present groundwater level there in stead of inputting recharge volume in calculation nodes directly. In the case of this groundwater simulation, it is better way to construct the simulation model.

7) Initial Groundwater Level

Initial groundwater level was input according to the static water level contour map in 1993. (see, Fig. B-III, 3.2 Static Water Level (1993))

4.3.3 Reproducibility of Model

On the basis of above mentioned simulation conditions, the establishment of groundwater simulation model was conducted. At that time, reproducibility of simulation model is judged by the present static water level. In general, reproducibility of the model is checked by the degree of accordance between present condition and simulated one after steady analysis of groundwater fluctuations. The groundwater simulation model for Pampa del Tamarugal shown as follow was established by a process of trial and error. The result of simulation seems to be almost satisfied with reproducibility of present groundwater condition.

The reason why Pampa del Tamarugal is regarded as steady stage in terms of groundwater condition is that there's almost no fluctuation by years and even no seasonal change. Although drawdown of groundwater level per year on average in Pampa del Tamarugal is in approximately 10cm, this doesn't interrupt above mentioned assumption.

4.4 Simulation Result of Future Groundwater Condition

Two future groundwater simulation cases were conducted using the constructed groundwater simulation model. Case 1 is the case that water rights in the simulation area selected by the study team from which have been applied to the government by present would be adopted in the target year 2015. Case 2 is all of them would be adopted by the target year 2015.

These cases have also two sub-cases respectively. Sub-case 1 is the case that 40% of groundwater withdrawal volume for mining would be consumed actually. Sub-case-2 is 60 % of it would be consumed. Furthermore, above mentioned each case consists of 3 time-cases: 2015 as the target year, 2043 as 50 years after and 2093 as 100 years after. The simulation condition after the target year is assumed as the same of the year.

- Simulation Cases
  - Case 1
    - Case 1-1
      - 2015 (Target Year)
      - 2043 (50 years after)
      - 2093 (100 years after)
    - Case 1-2
      - 2015 (Target Year)
      - 2043 (50 years after)
      - 2093 (100 years after)
  - Case 2
    - Case 2-1
      - 2015 (Target Year)
      - 2043 (50 years after)
      - 2093 (100 years after)
    - Case 2-2
      - 2015 (Target Year)
      - 2043 (50 years after)
      - 2093 (100 years after)

4.4.1 Input Data for Future Groundwater Simulation

1) Groundwater Discharge in Future

Groundwater discharge of each case in the target year 2015 is shown in Fig. B-III, 4.7 to 4.10. The recharge in these figures means that the return to the groundwater again at different sites after consumption of distributed water from groundwater sources. As for transpiration, it is assumed that the area of Tamarugo would be almost same as present but its transpiration would be increased approximately 45% with growing up in future.

2) Recharge of Groundwater in Future

Recharge of each case from influent streams in future is shown in Fig. B-III, 4.5. The variation of influent values aren't due to climate change but water-use change in the up-stream area.

4.4.2 Result of Future Groundwater Simulation

Result of total 12 cases of future groundwater simulation is illustrated in Fig. B-III, 4.11 to 4.21. It's better to express drawdown of groundwater between present (1993) and future in order to evaluate an impact of groundwater development plan. Table B-III, 4.1 shows a degree of impact by each case as maximum drawdown of groundwater.

4.4.3 Evaluation of Groundwater Simulation Results

1) Case 1

Impact magnitude of Case 1-1 and Case 2-2 are almost same in the target year. Their greatest impact: 8 m drawdown is shown near the project site. However, the impact magnitude and effected area would deteriorate in 2043 and 2093 than the target year. Thirty meter drawdown of groundwater is predicted near the project site in 2093. Since there are about 6 shallow wells near the project site at present which their depth is less than 13m, it is feared that they might be dried-up. On the other side, it seems that an impact to Tamarugo forest would be slight, because the project site is located away from the forest and groundwater level in the forest areas would not become deeper than the limit groundwater level for Tamarugo's growth.

2) Case 2

It is remarkable that an impact to the groundwater by an agricultural development plan (CAPPTA Project) in the northern part of the study area and mining development plan in the south-western part of the area is very great. It is anxious about reduction of forest area, since they are located in Tamarugo forest and their drawdown of groundwater is great Though effected area around the project site would be enlarge slightly in this case than Case 1, there's no extreme change among these cases.

Case 2-2 is the most serious case that maximum drawdown would be assumed 40m in the northern part of the study area and 55m in the south-western part of the area after 100 years from present.

4.5 Change of Water Quality in Future

Proposed new groundwater development area, La Tirana, is located near th area of existing well field. Groundwater storage in this area is estimated to be 10.7×10^9 m^3. On the one hand, total exploitation of groundwater in Canchones and La Tirana well fields are estimated to be 530×10^6 m^3. It is 5.0 % of the total storage in the well field area. Therefore, water quality of groundwater in the both well field will not cause a change for the worse within the Project period.

Table B-III, 4.1 Maximum Drawdown of Groundwater between Present and Future
<Descenso Máximo de Agua Subterránea entre el Presente y Futuro>

(Unit: m)

Case	Area	2015 Target Year	2043 50 Years After	2093 100 Years After
Case 1-1	Northern	2	5	10
	Project Site	**8**	**20**	**25**
	Southern	2	5	10
Case 1-2	Northern	4	10	10
	Project Site	**8**	**20**	**30**
	Southern	2	5	10
Case 2-1	Northern	10	30	40
	Project Site	**8**	**20**	**30**
	Southern	8	30	30
Case 2-2	Northern	10	30	40
	Project Site	**10**	**20**	**30**
	Southern	15	40	55

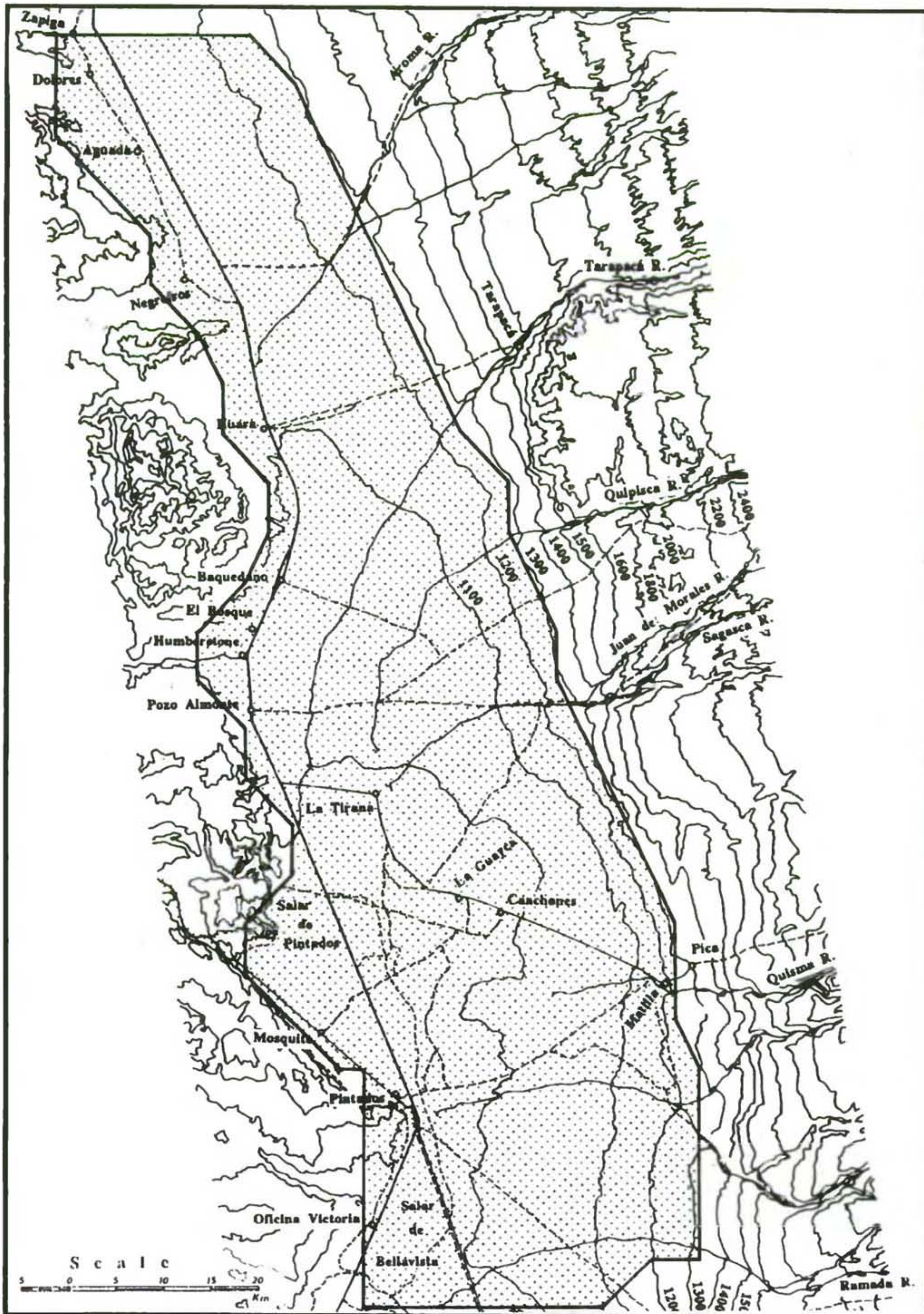


Fig. B-III, 4.1 Groundwater Simulation Area in Pampa del Tamarugal
<Area de Simulacion del Nivel Freatico en Pampa del Tamarugal>

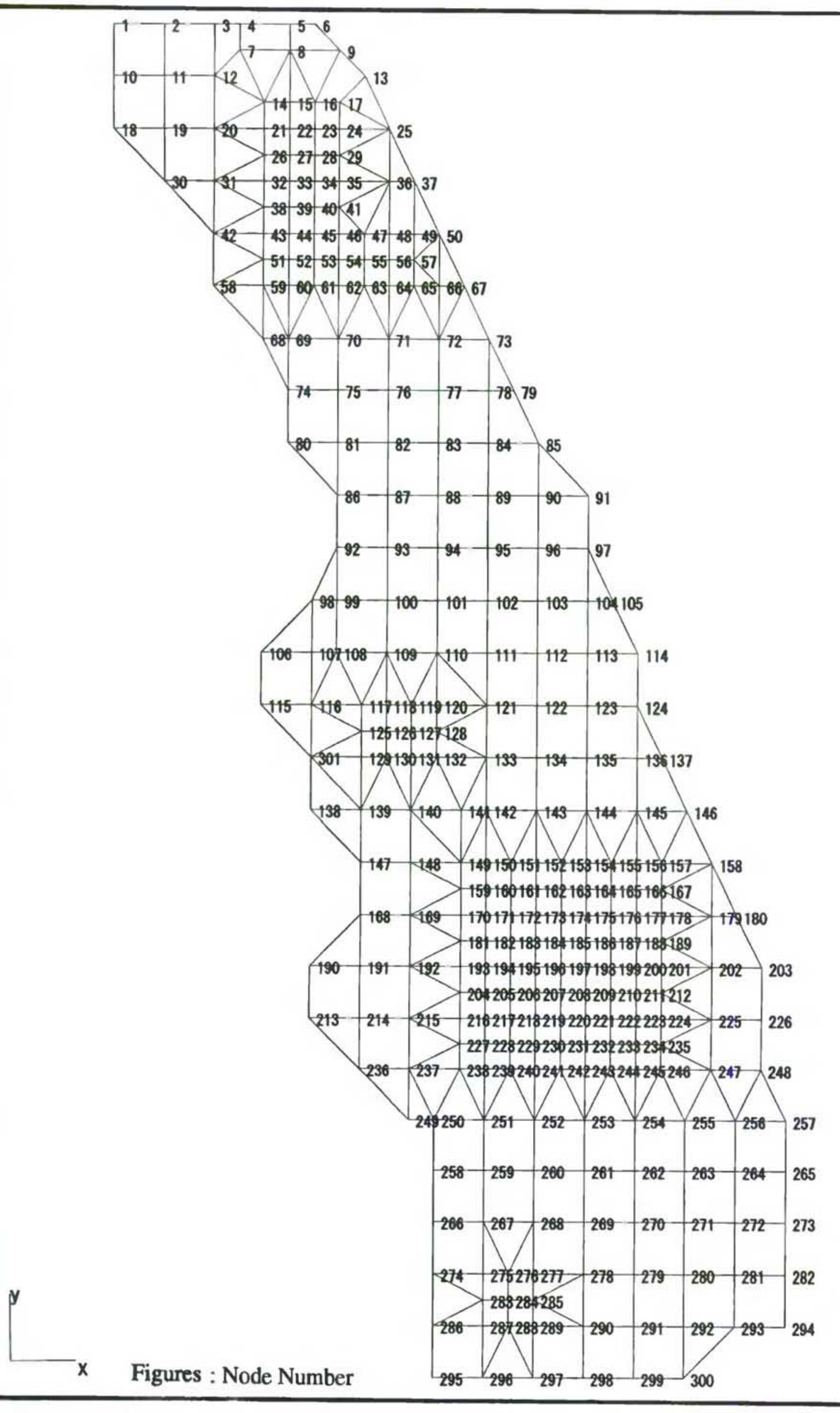


Fig. B-III, 4.2 Calculation Network for Groundwater Simulation
<Red de Calculo para la Simulacion del Nivel Freatico>

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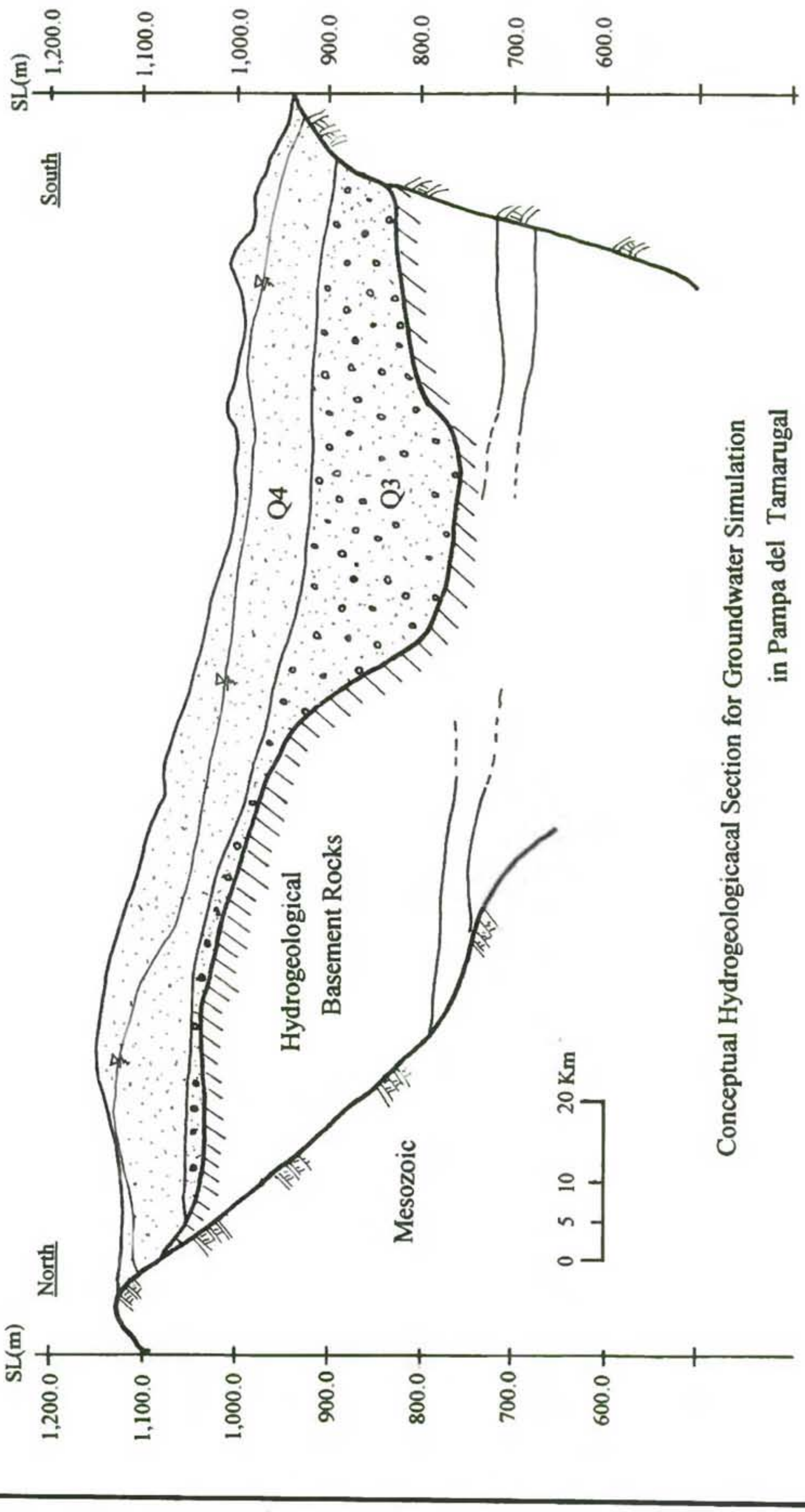


Fig. B-III, 4.3 Conceptual Hydrogeological Section for Groundwater Simulation
<Corte Transuersal Hidrogeologico de la Simulacion del Nivel Freatico>

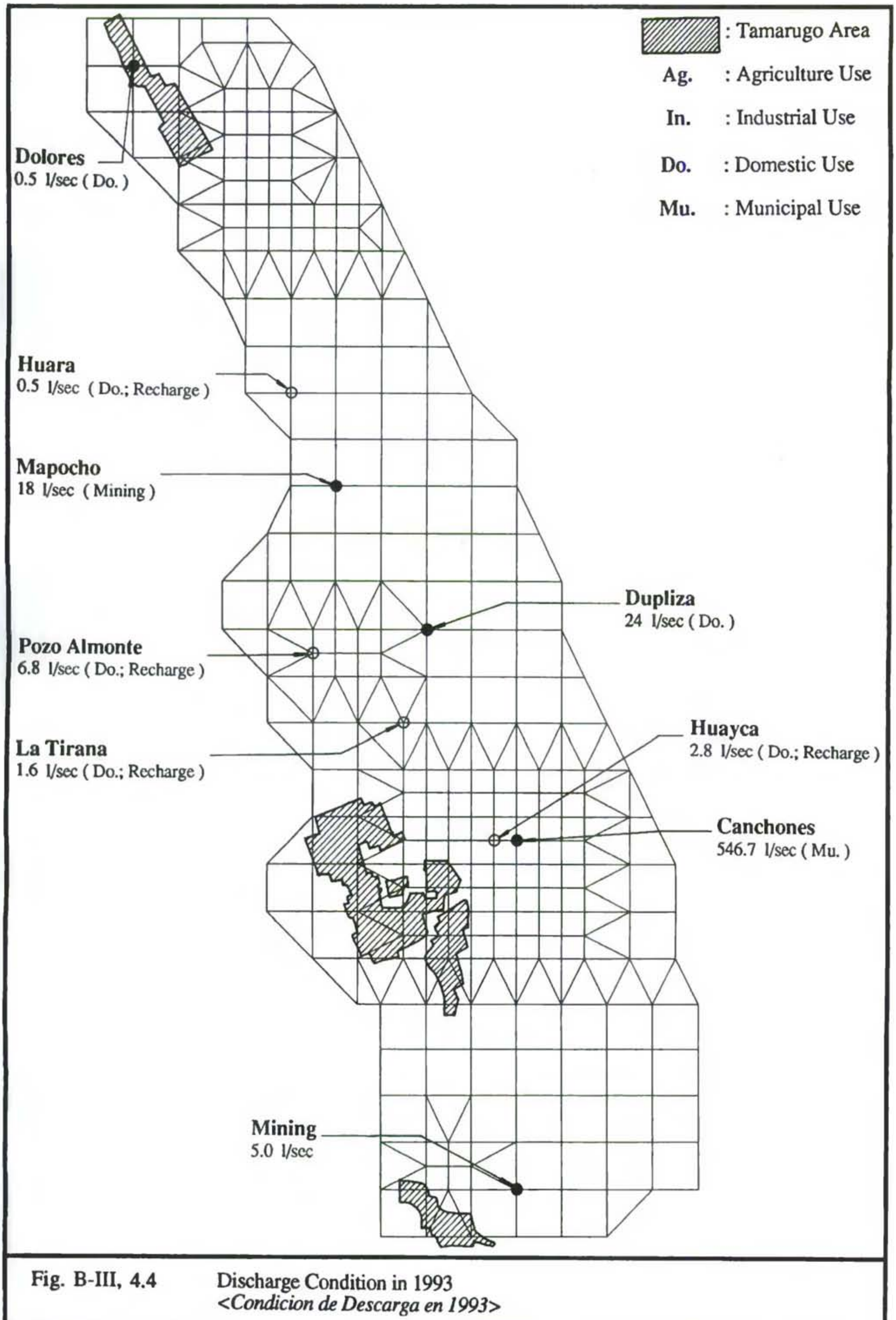


Fig. B-III, 4.4 Discharge Condition in 1993
<Condicion de Descarga en 1993>

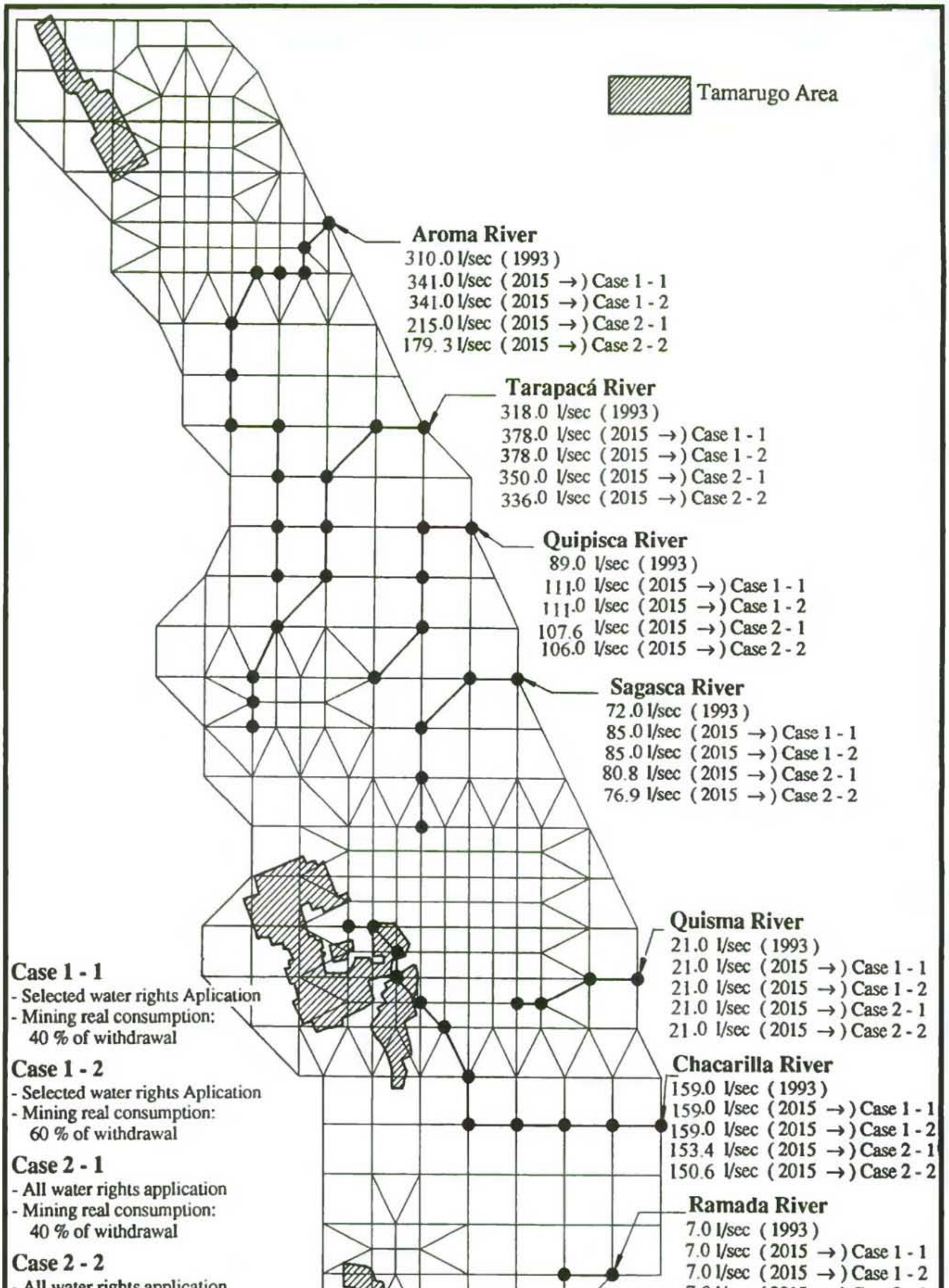


Fig. B-III, 4.5 Modeled River Water Inflow

< Modelo de Afluencia de Agua de Río >

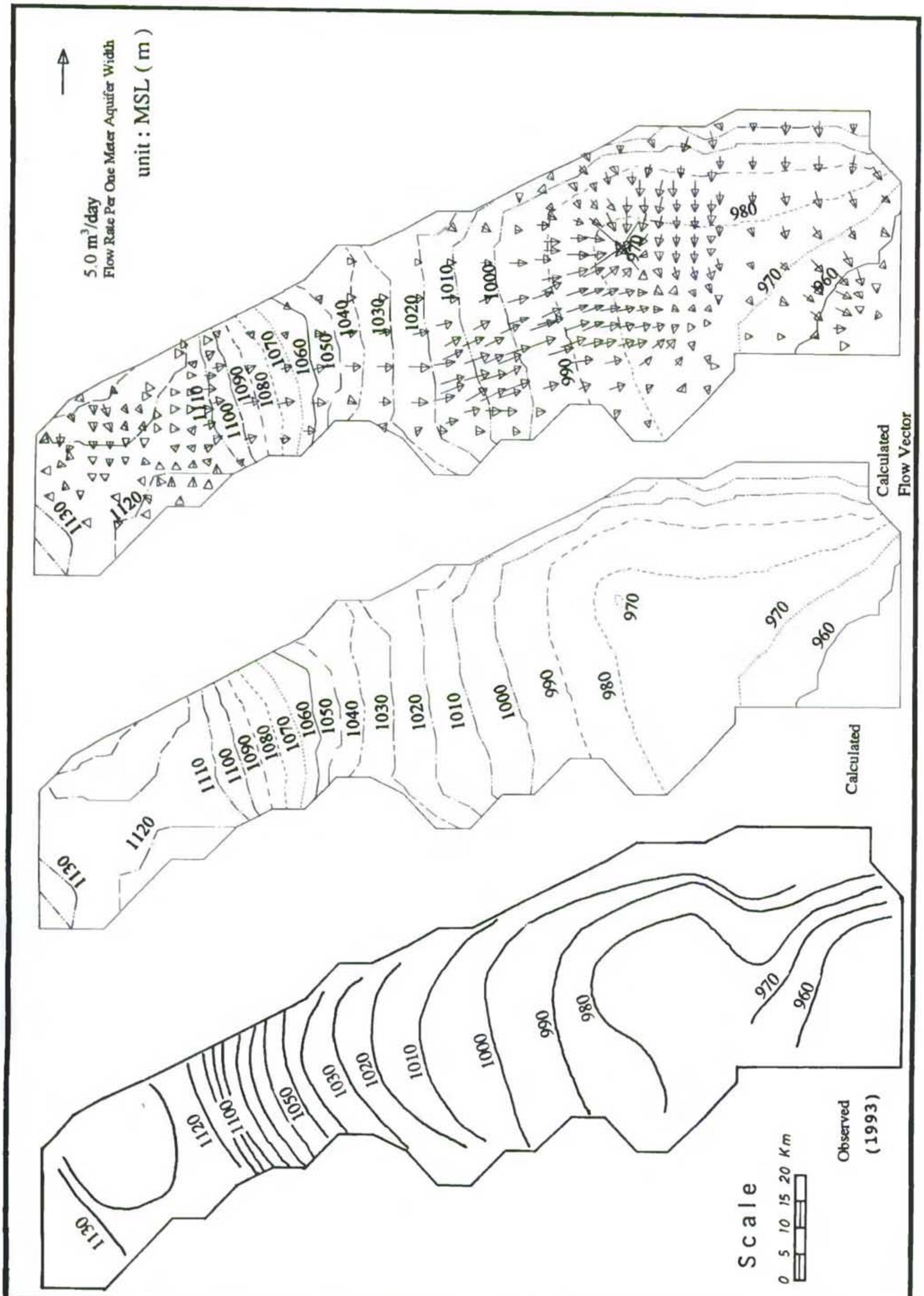


Fig. B-III, **4.6** Comparison Between Observed and Calculated Groundwater Level
<Comparacion Entre Mueles Freaticos Observados y Calculados>

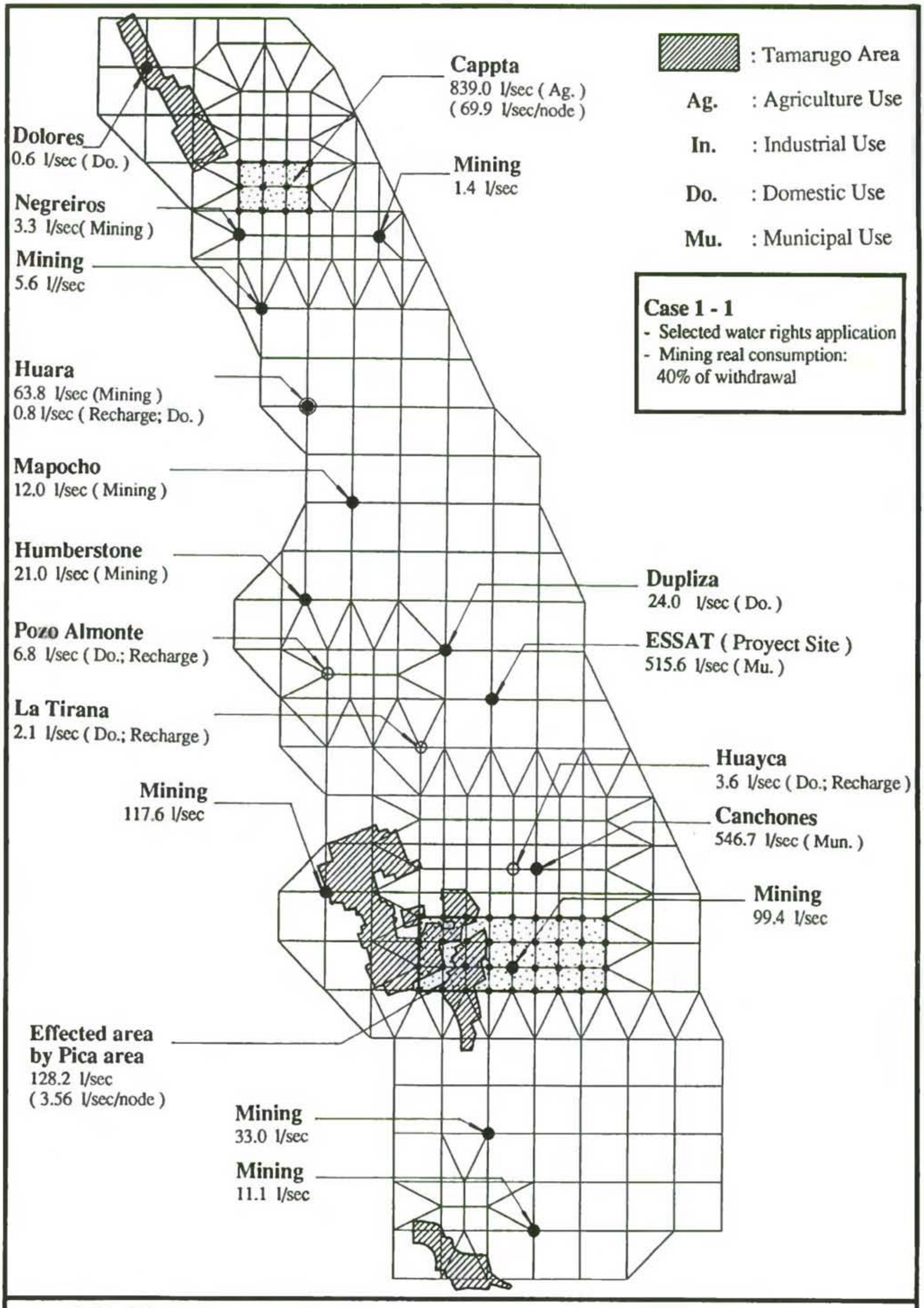


Fig. B-III, **4.7** Discharge and Recharge Condition in 2015 Case 1 - 1

<Condicion de Descarga y Recarga en el Año 2015 Caso 1-1>

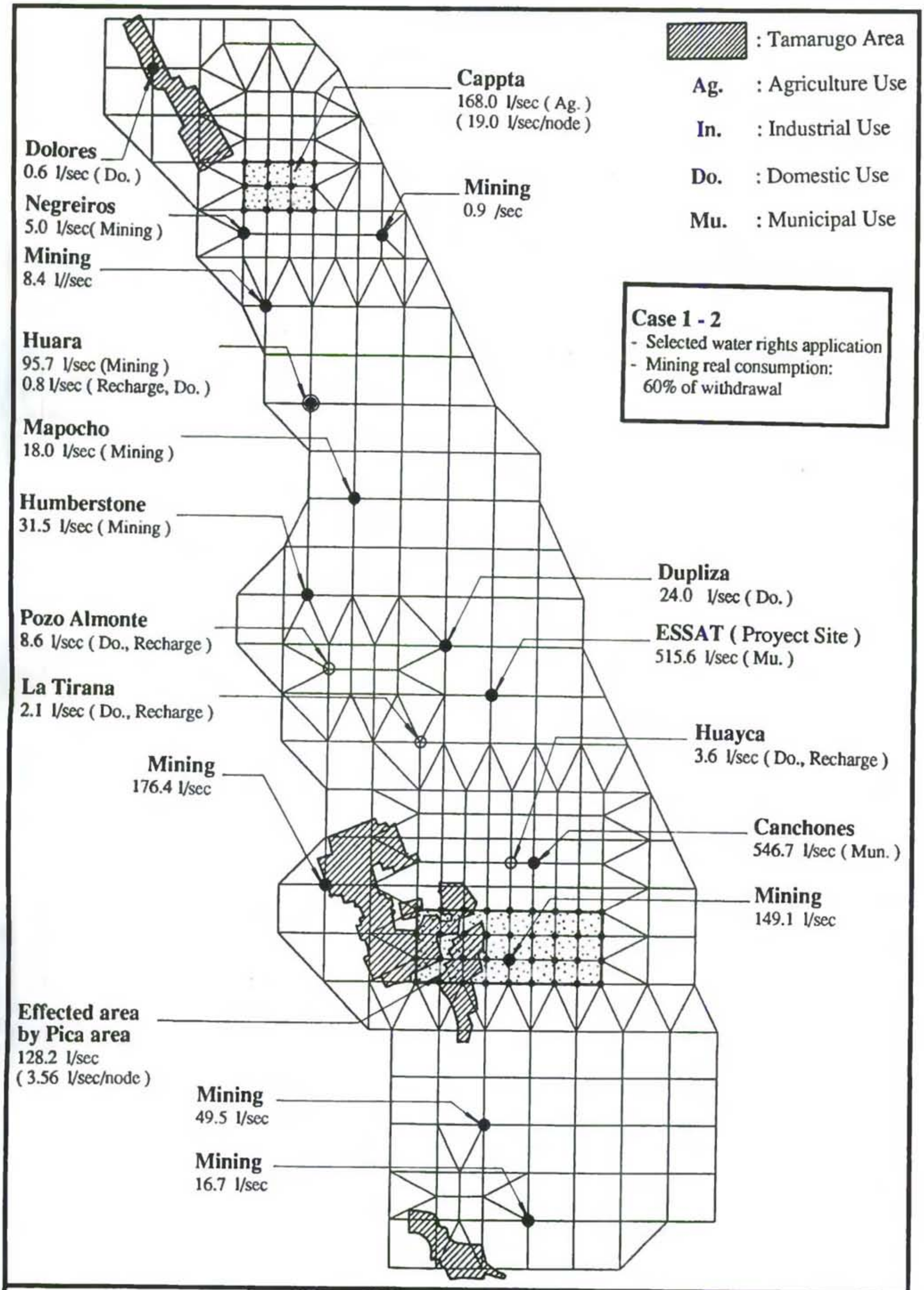


Fig. B-III, 4.8 Discharge and Recharge Condition in 2015 Case 1 - 2

<Condicion de Descarga y Recarga en el Año 2015 Caso 1-2>

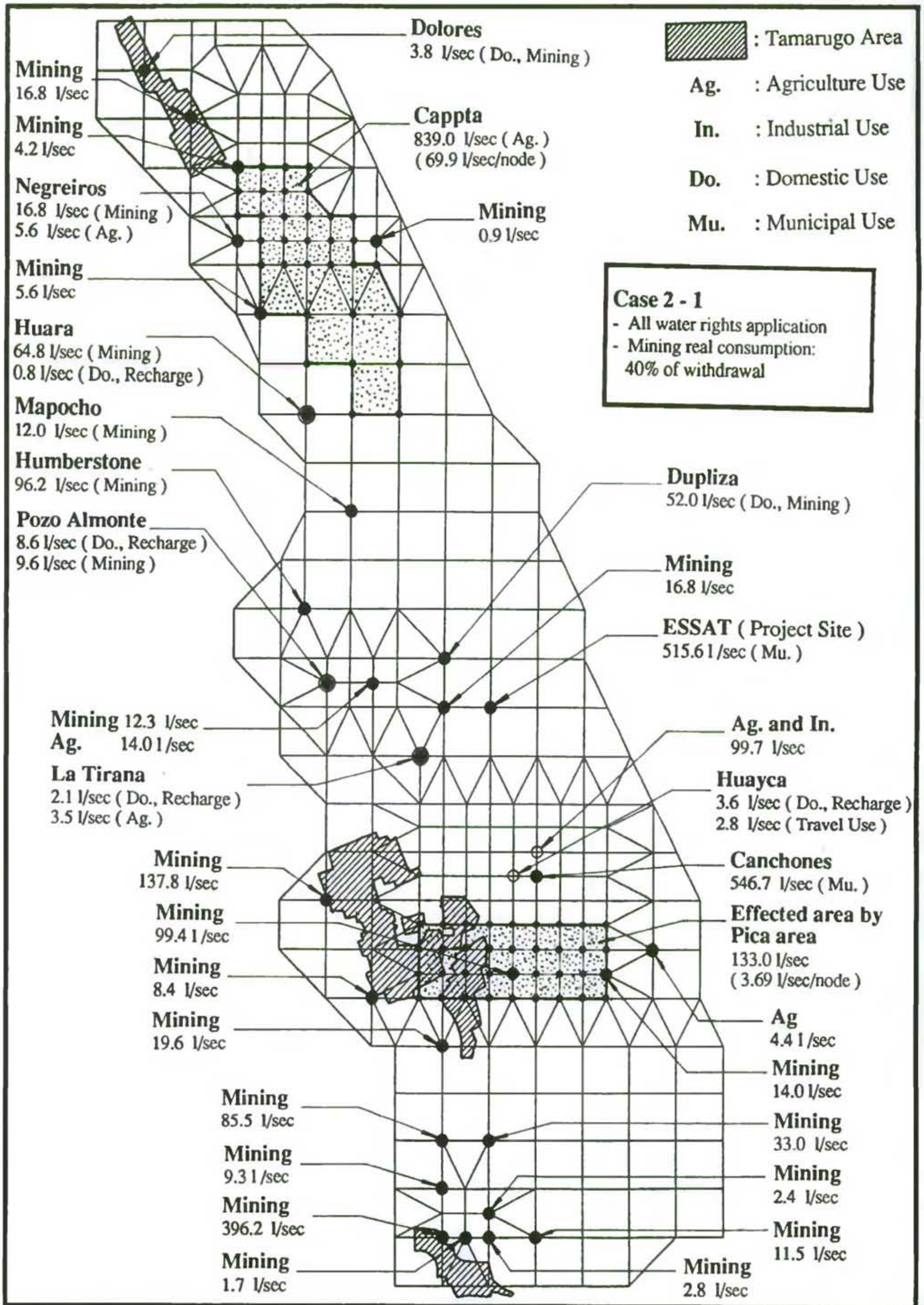
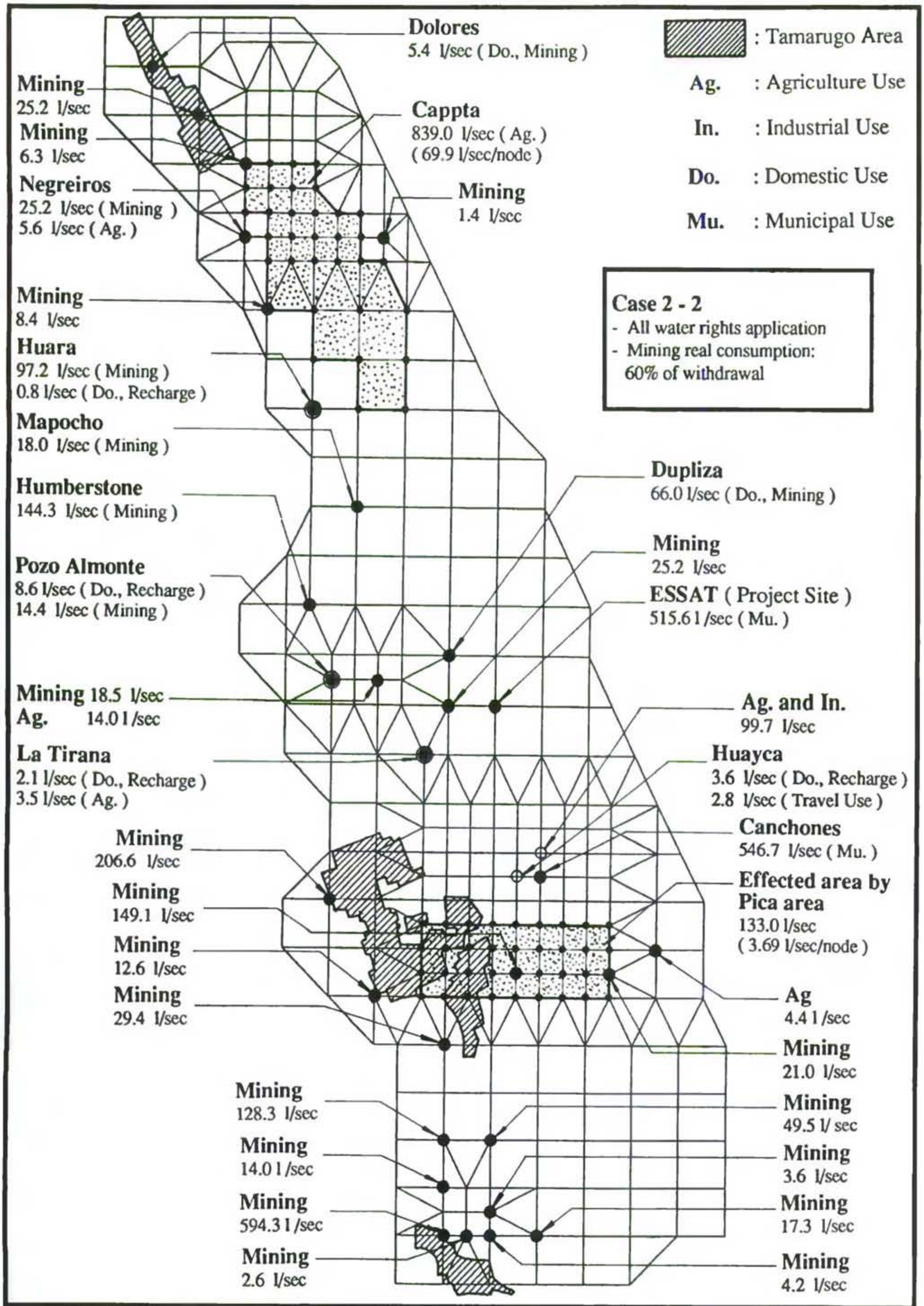


Fig. B-III, 4.9 Discharge and Recharge Condition in 2015 Case 2 - 1

<Condicion de Descarga y Recarga en el Año 2015 Caso 2-1>



FigB-III, 4.10 Discharge and Recharge Condition in 2015 Case 2 - 2

<Condicion de Descarga y Recarga en el Año 2015 Caso 2-2>

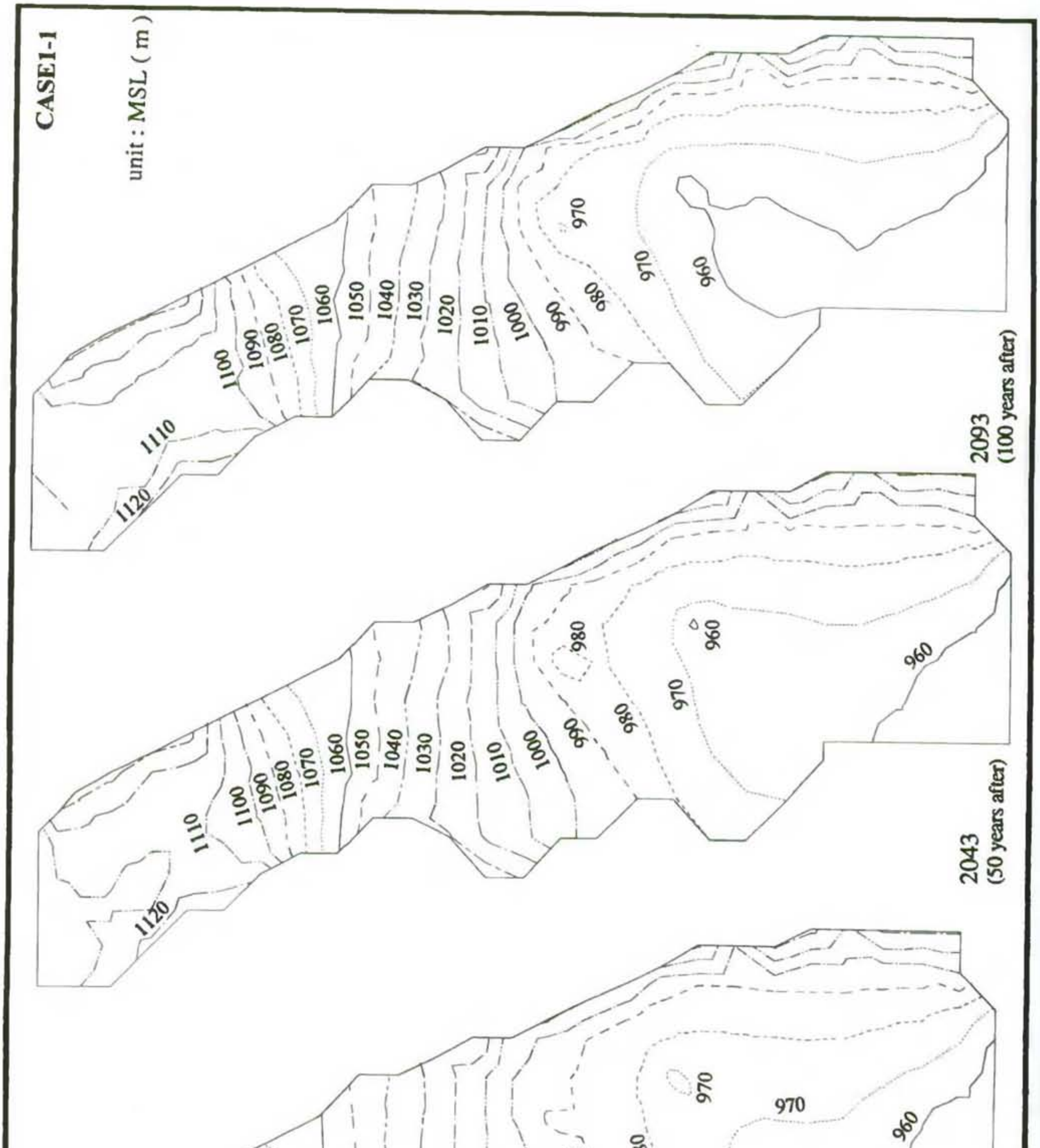


Fig. B-III, 4.11 Simulated Groundwater Level in Future — Case 1 - 1

< Simulación Futura del Nivel de Agua Subterránea > — *Caso 1 - 1*

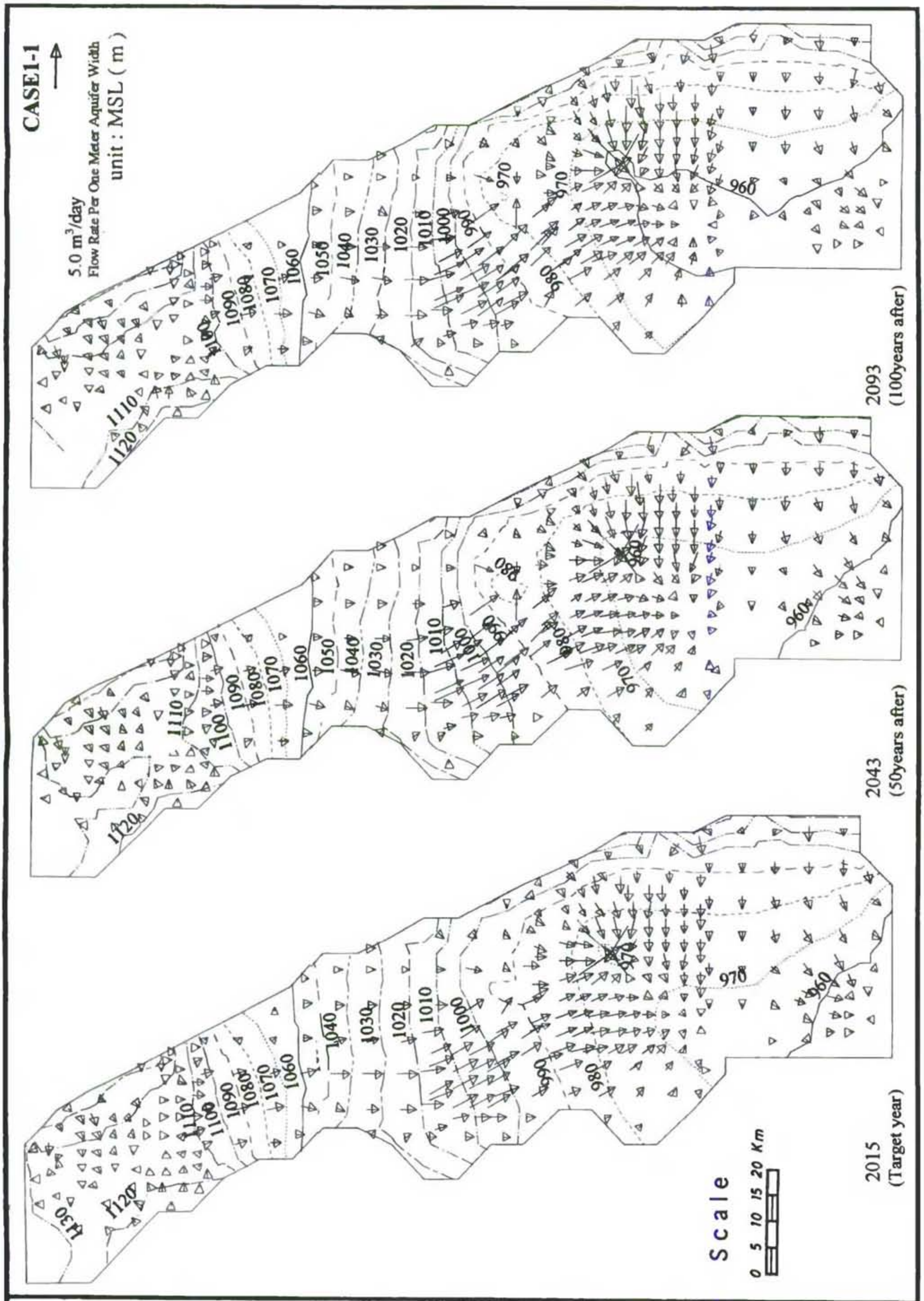


Fig. B-III, 4.12 Simulated Groundwater Level and Flow Vector in Future — Case 1 - 1

< Simulación Futura del Nivel de Agua Subterránea y Vectores de Flujo > Caso 1 - 1

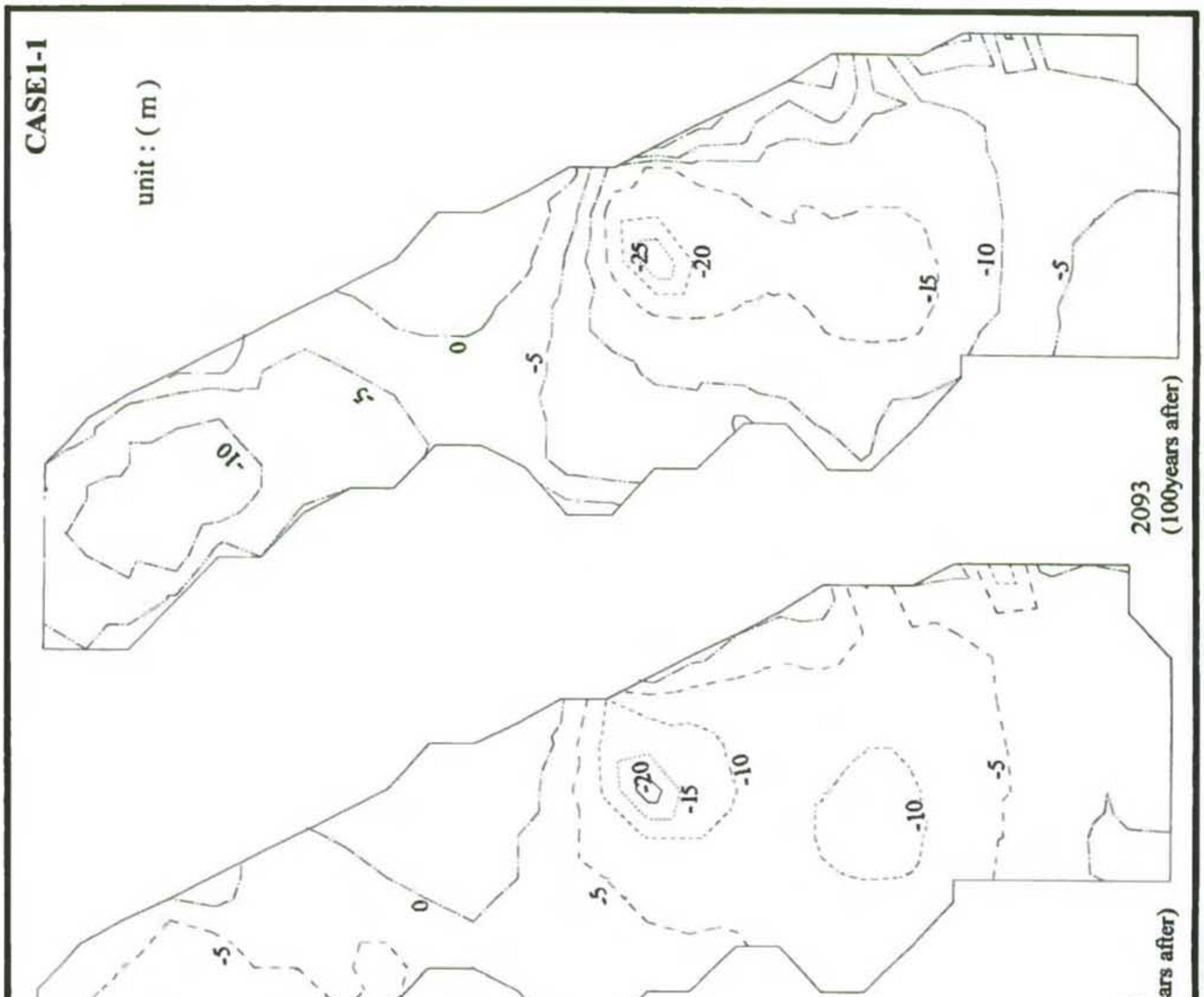


Fig. B-III, 4.13 Drawdown of Groundwater Level Between Present (1993) and Future (2015; 2043 & 2093) Case 1 - 1

< Descensos Simulados entre el Presente (1993) y el Futuro (2015; 2043 y 2093) > Caso 1 - 1

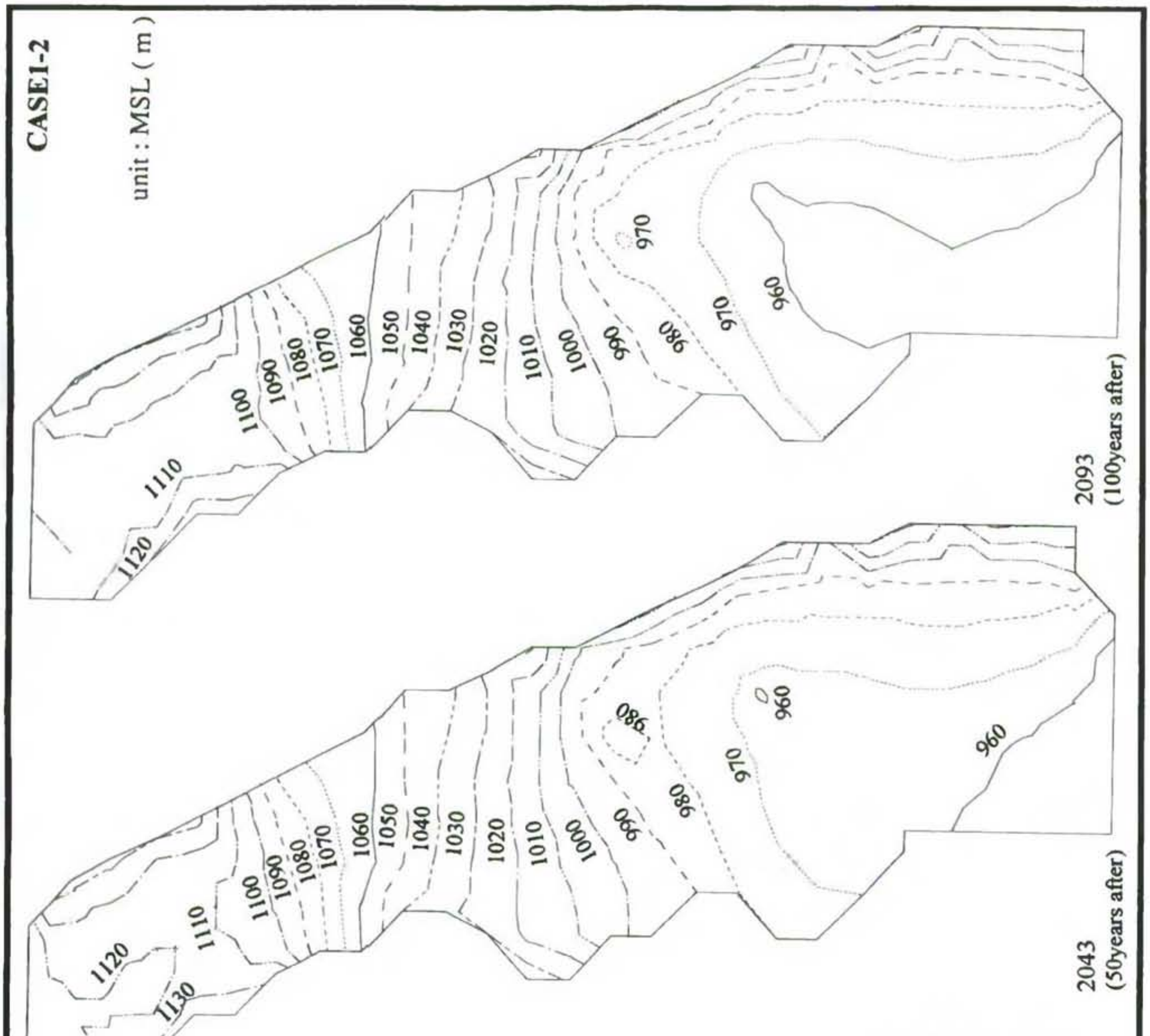


Fig. B-III, 4.14 Simulated Groundwater Level in Future — Case 1 - 2

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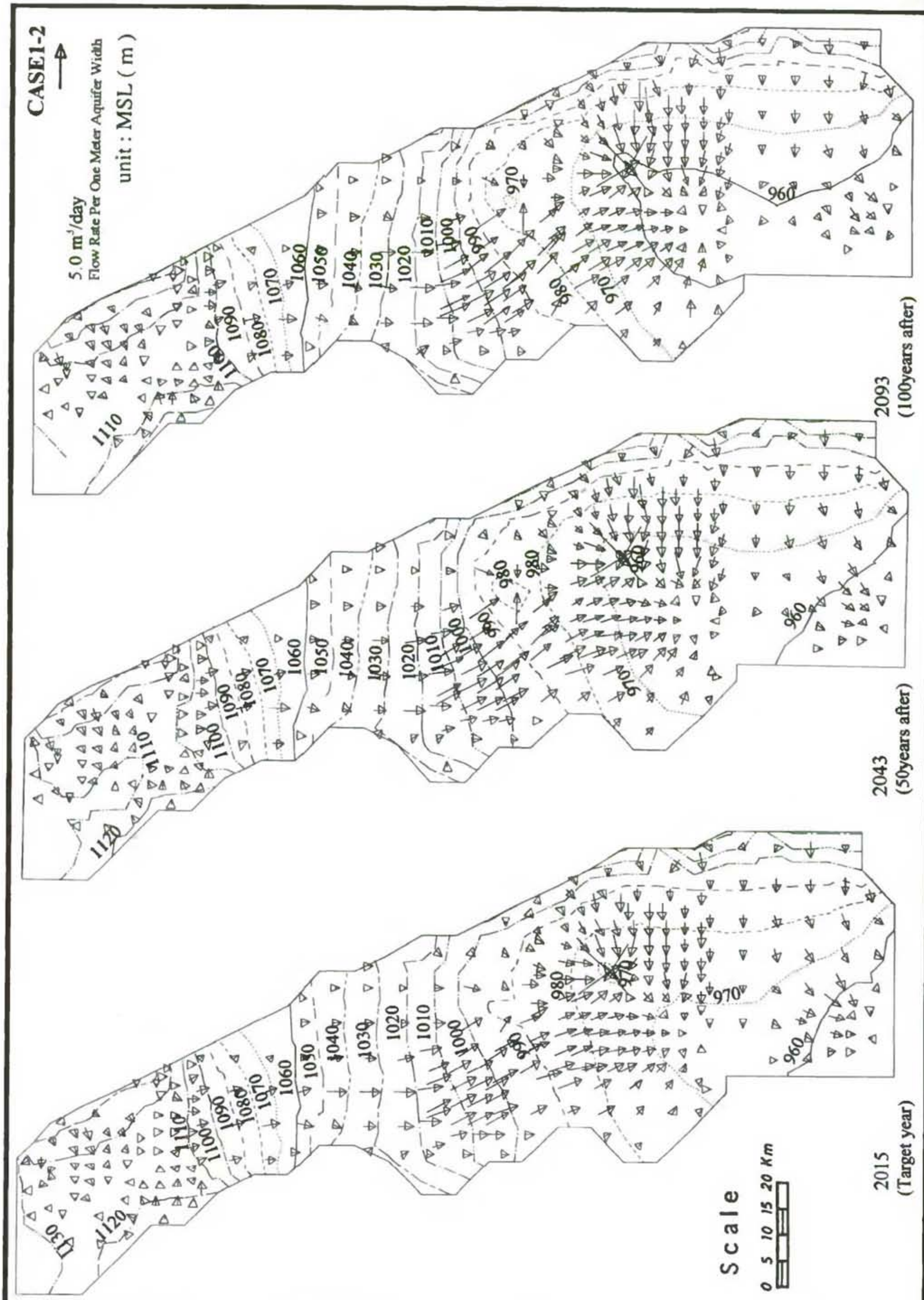

Fig. B-III, 4.15 Simulated Groundwater Level and Flow Vector in Future Case 1 - 2

< Simulación Futura del Nivel de Agua Subterránea y Vectores de Flujo > Caso 1 - 2

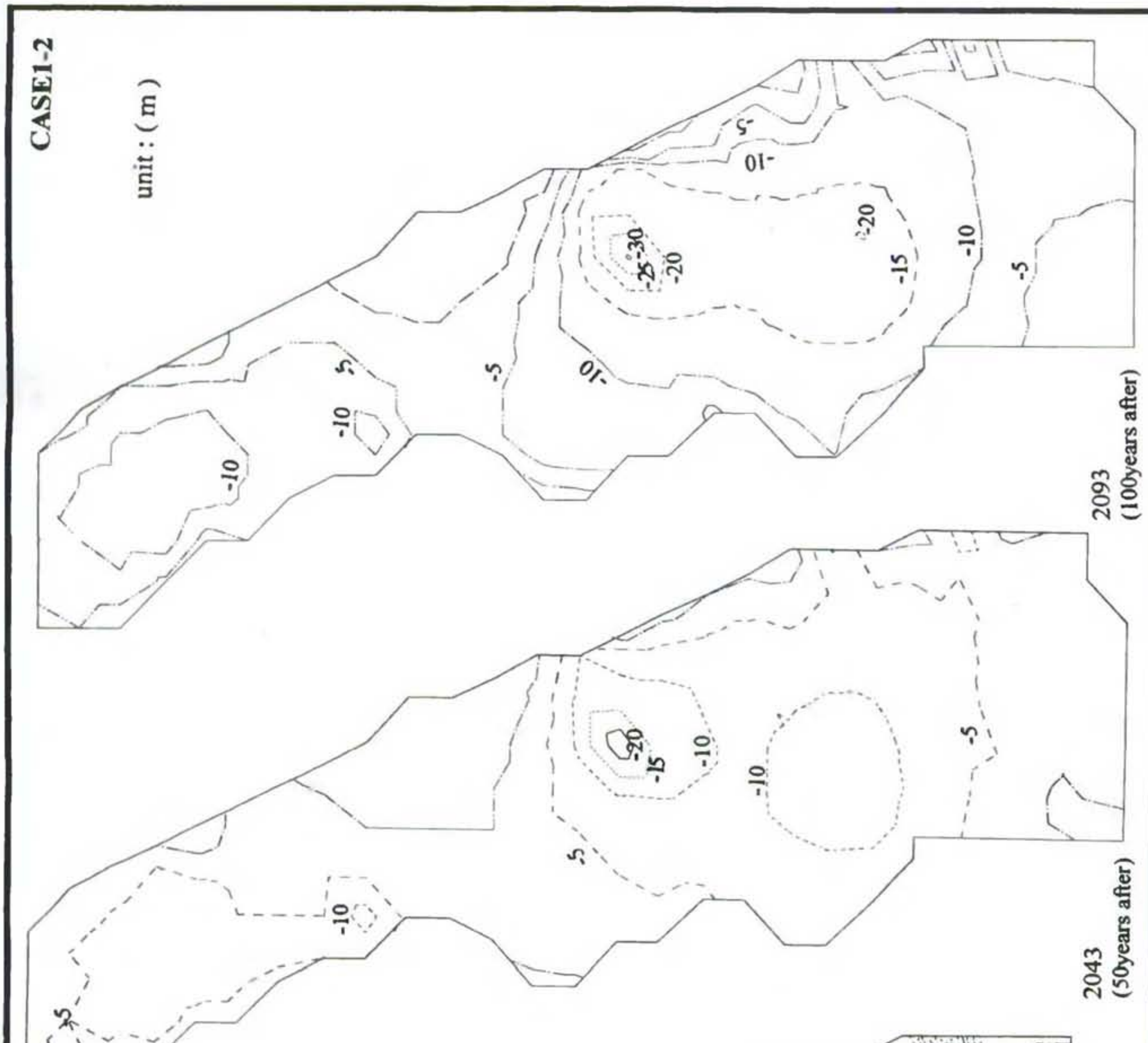

Fig. B-III, 4.16 Drawdown of Groundwater Level Between Present (1993) and Future (2015; 2043 & 2093) Case 1 - 2

< Descensos Simulados entre el Presente (1993) y el Futuro (2015; 2043 y 2093) > Caso 1 - 2

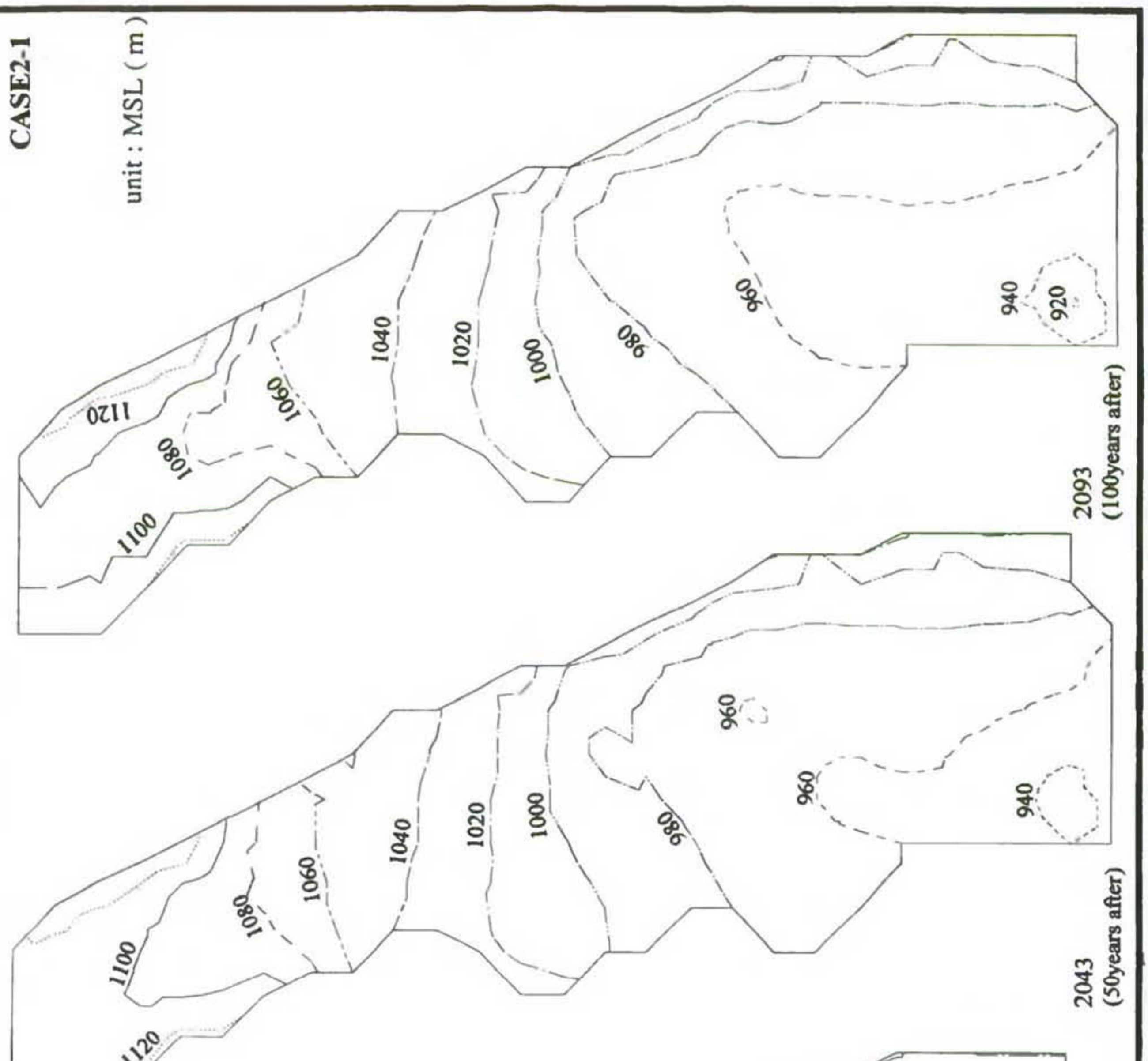

Fig. B-III, 4.17 Simulated Groundwater Level in Future Case 2 - 1

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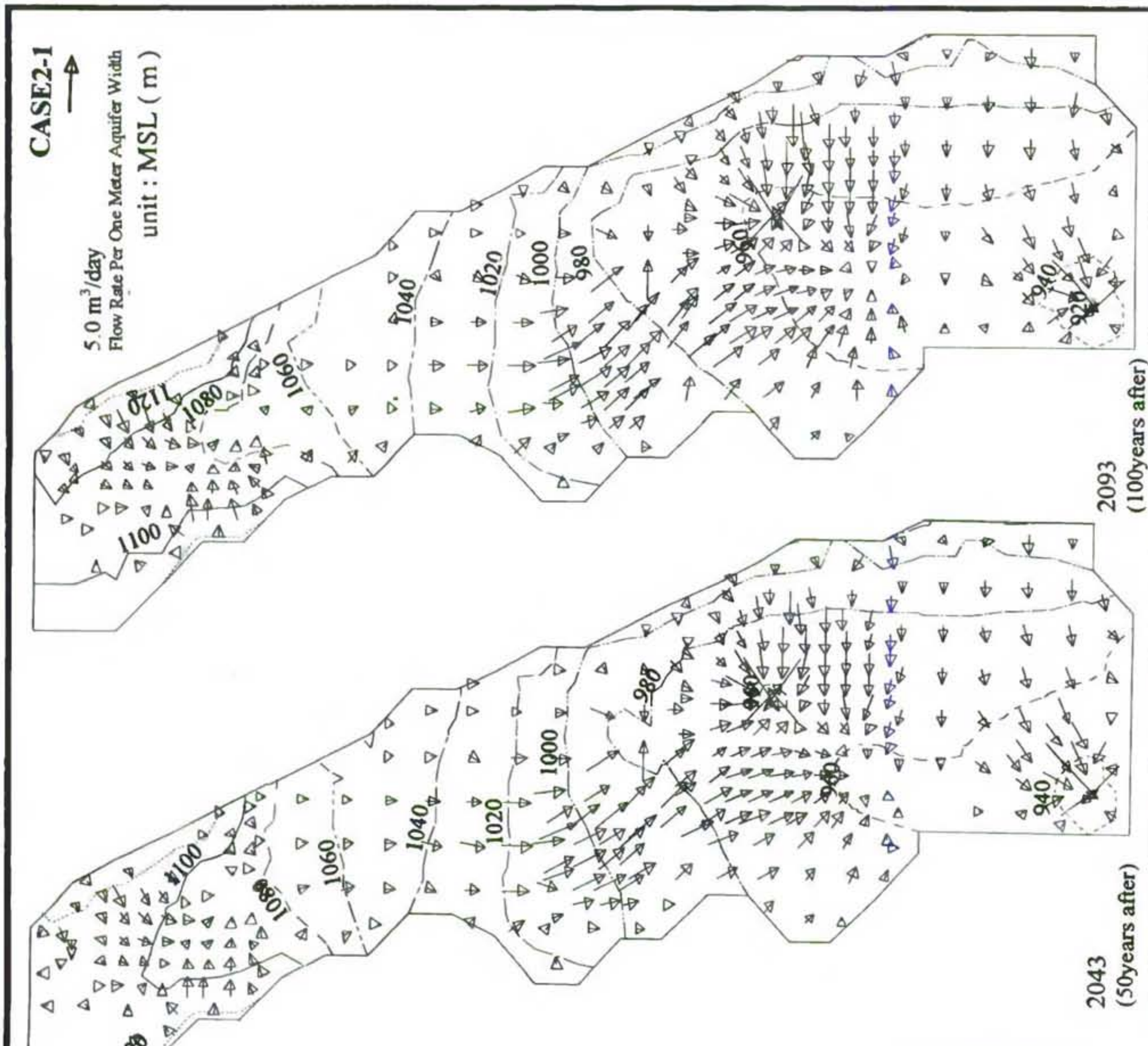

Fig. B-III, 4.18 Simulated Groundwater Level and Flow Vector in Future Case 2 - 1

< Simulación Futura del Nivel de Agua Subterránea y Vectores de Flujo > Caso 2- 1

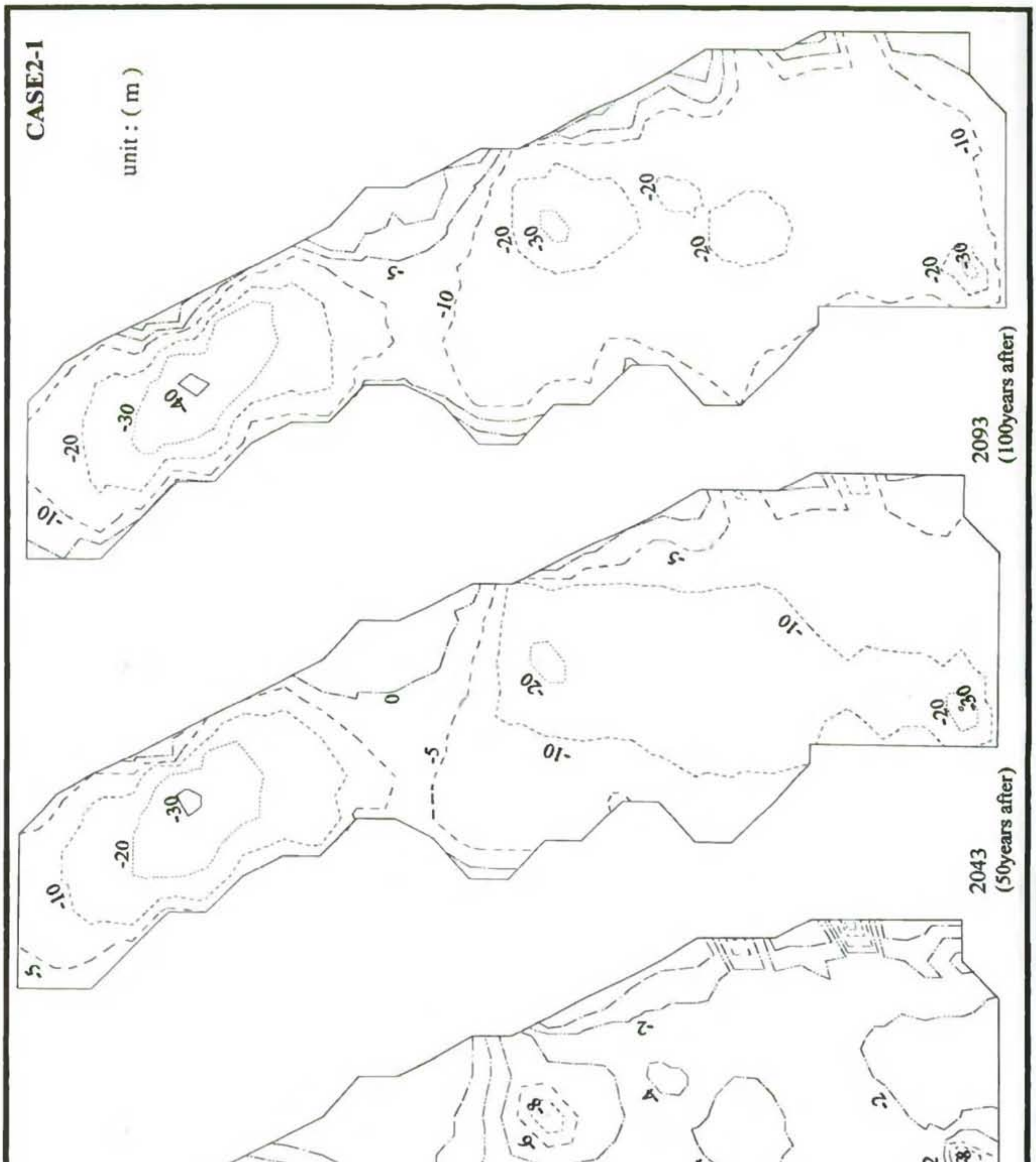

Fig. B-III, 4.19 Drawdown of Groundwater Level Between Present (1993) and Future (2015; 2043 & 2093) Case 2 - 1

< Descensos Simulados entre el Presente (1993) y el Futuro (2015; 2043 y 2093) > Caso 2 - 1

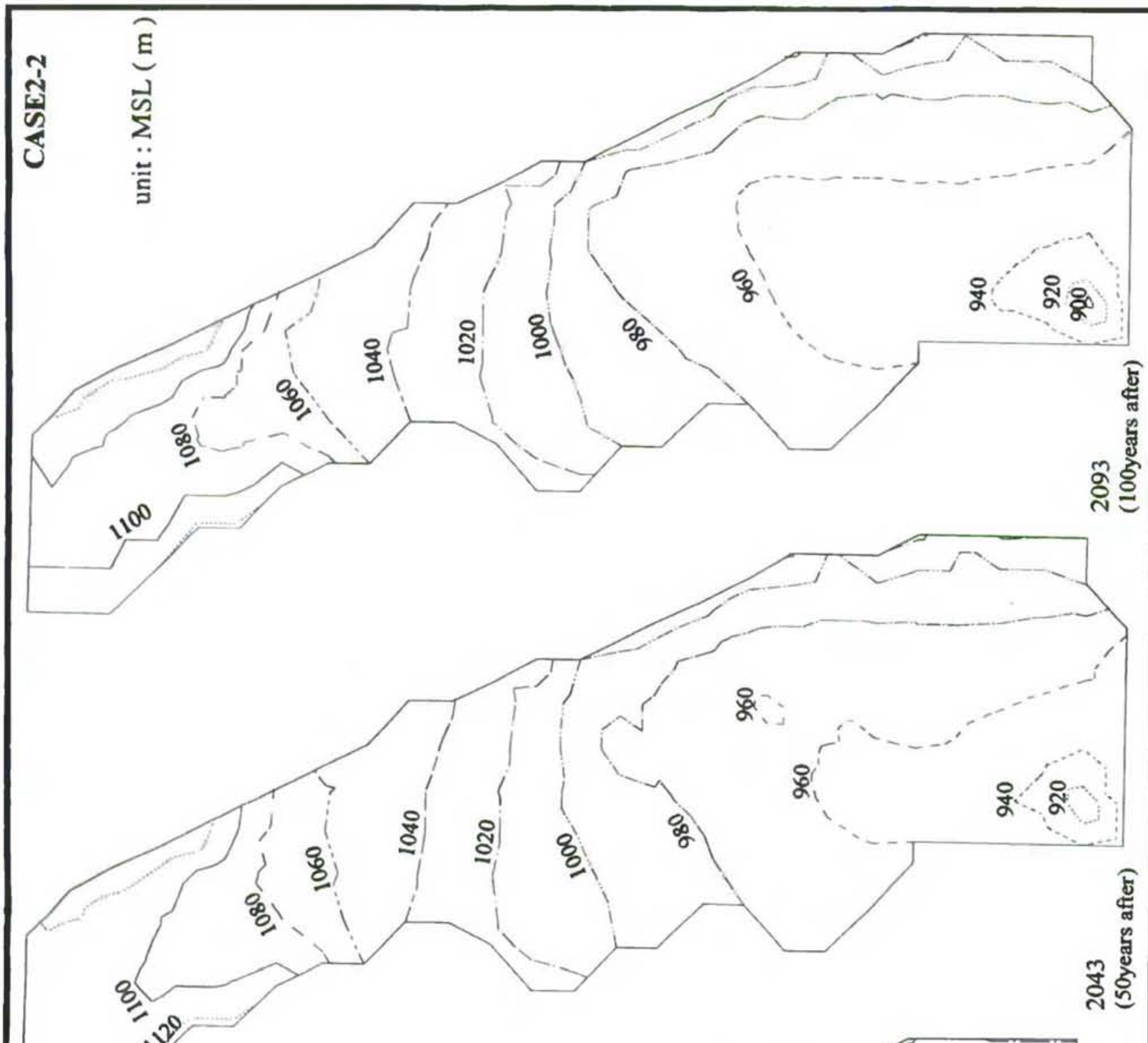

Fig. B-III, 4.20 Simulated Groundwater Level in Future — Case 2 - 2

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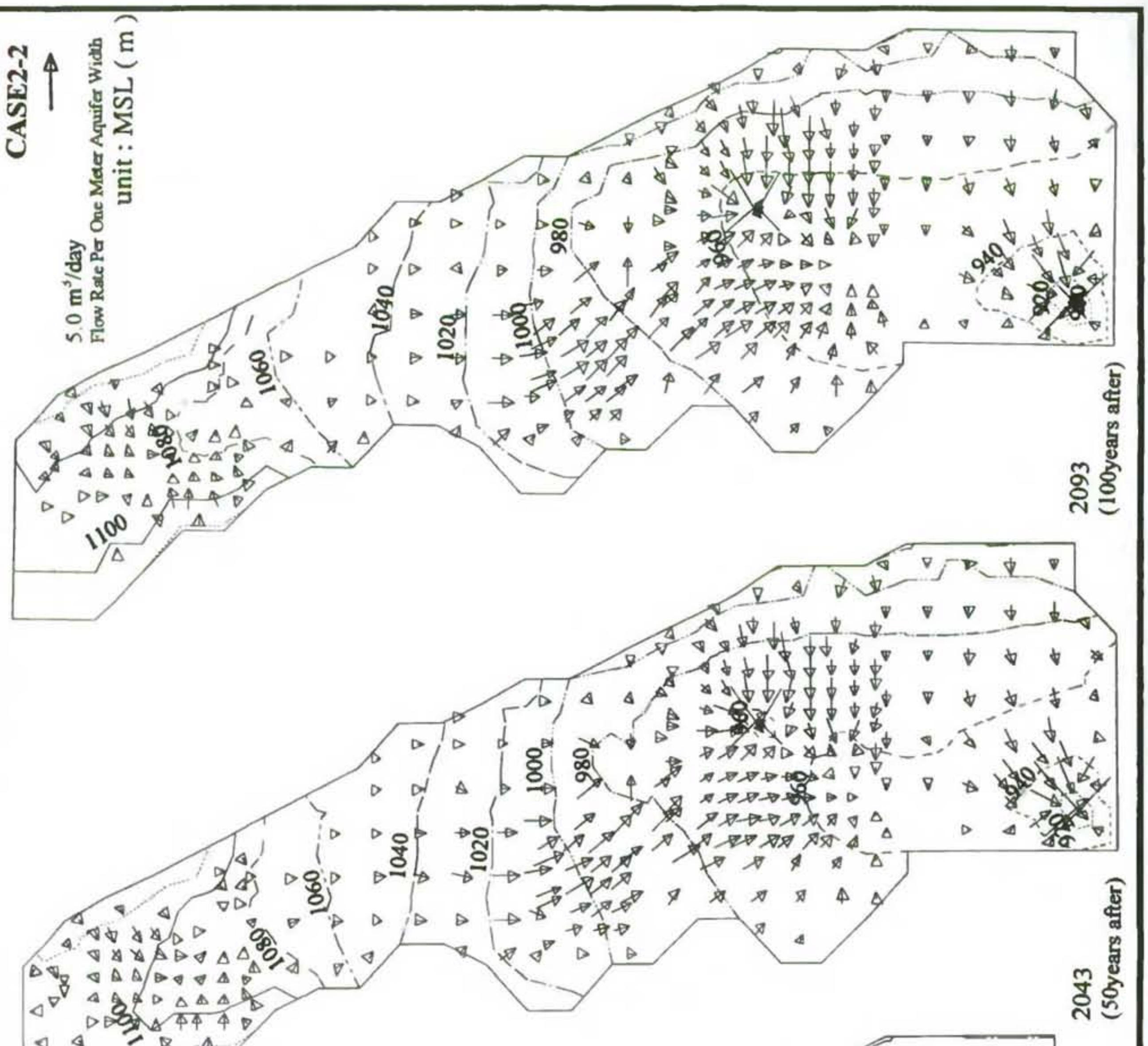

Fig. B-III, 4.21 Simulated Groundwater Level and Flow Vector in Future Case 2 - 2

< Simulación Futura del Nivel de Agua Subterránea y Vectores de Flujo > Caso 2 - 2

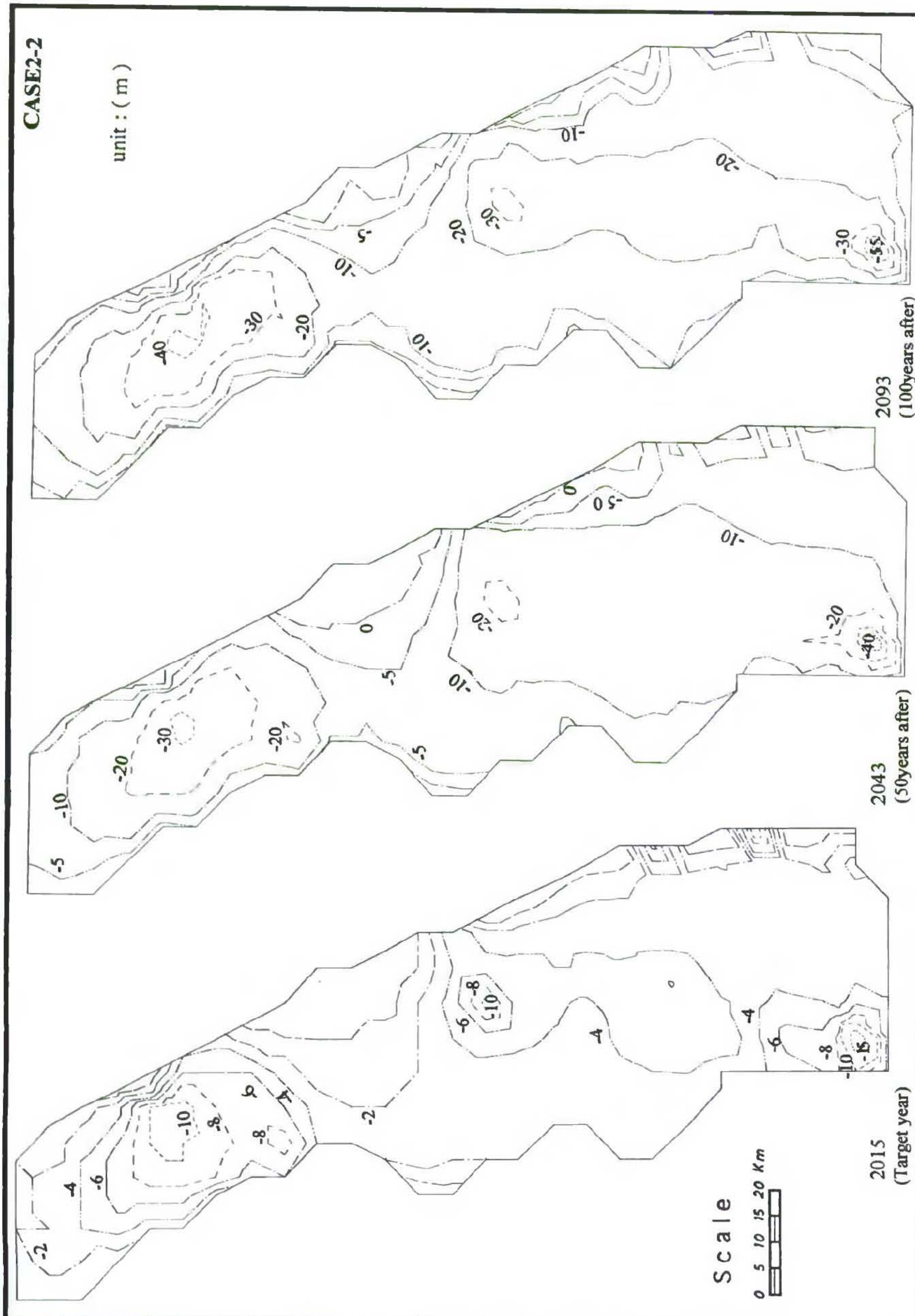

Fig. B-III, 4.22 Drawdown of Groundwater Level Between Present (1993) and Future (2015; 2043 & 2093) Case 2 - 2

< Descensos Simulados entre el Presente (1993) y el Futuro (2015; 2043 y 2093) > Caso 2 - 2

Chapter V. GROUNDWATER MONITORING PLAN

Declination of water level in Pampa del Tamarugal is 7 cm/year in average. If groundwater development project starts to services, the rate of declination will be accelerated in acertain degree. Although no significant drawdown is caused by the project as mentioned in Chapter IV of this Report, it is important to continue the observation of wells on both water level and water quality.

Proposed wells to be monitored are mentioned below. It is important to continue observation at the same wells and never to change monitoring wells. Items of water quality analysis are same as that of the Azapa Valley.

Total number of 12 wells are selected for the observation as follows. For location, refer to Fig. B-II, 2.1.

Well No.	Well Name	Interval of Observation	
		Water Level	Water Quality
104	Salar Zapiga	every 2 months	once a year
173	PTA AP Colores 6		
178	Salar de Zapiga		
132	EL Carmelo 2		
221	O.J. Morales 1		
129	PTA. Sara 3A		
256	Loreto 3		
263	La Calera 3		
264	La Calera 2		
265	Esmeralda 6		
270	Esmeralda 7		
277 or 293	Esmeralda 11 or 28		
316	Bosoue Junoy 15		
354	P. Canchones H		
363	Salar Pintados		
112	Salar Pintados		
114	Pintados Pica 3		
117	Matilla 5		
402	Chacarilla 1		
113	Pintados Radio		
415	Salar Pintad 2		
426 or 150	Estacion Pinta 4 or 1		
430	Salar Pintados		
146	Mosquitos 1		
434	Salar Belavista		
157	Salar Belavista		
128	Salar Bellavista		
440	Salar Bellavista		
127	Salar Bellavista		
447	Salar Bellavista		
J-C	Huara	continuously	once a year
J-D	Baquedano		
J-E	La Tirana		
J-F	Ramada		
J-3	Aguada		
J-4	Negreiros		
J-5	Pozo Almonte		
J-6	Canchones		
J-7	Conaf		
J-8	Pintados		
J-9	Oficina Victoria		

B-IV SALAR DEL HUASCO BASIN

TABLE OF CONTENTS

B-IV SALAR DEL HUASCO BASIN

LIST OF TABLES

B-IV SALAR DEL HUASCO BASIN

LIST OF FIGURES

B-IV SALAR DEL HUASCO BASIN

Chapter I. TOPOGRAPHY AND GEOLOGY

1.1 Topography

The Salar del Huasco Basin occupies the parts of Altiplano, as shown in Fig. B-I, 1.1, and is situated at the altitude between 3,800 and 4,200 m. Drainage systems of the basin are shown in Fig. B-III, 1.1 shows that the basin is closed and no river flows out from the basin.

Fig. B-IV, 1.1 gives the topographic figure of Salar del Huasco, which is interpreted from aerial photographs taken during 1966 and 1967. The figure of Salar del Huasco is as follows.

Area of wet land	: 27 km^2
Area of water surface	: 2 km^2
Total area of salt lake	: 29 km^2

Depth of the salt lake was measured during phase 2 study. It revealed that salt lake is generally very shallow and do not exceed 20 cm of depth (see, Supporting Report E).

1.2 Geology

1.2.1 Methodology of Geological Analysis

On the details of the methodology, refer to the part of San Jose River Basin (B-I, 1.1).

1) Interpretation of LANDSAT Images

As for the Salar del Huasco Basin, one (1) scene of image, path 002-row 074 was used for the interpretation.

2) Interpretation of Aerial Photographs

31 sheets of black and white aerial photographs taken in 1977 and 1979 were used for the interpretation.

1.2.2. General Geological Features of Basin

Geology in the Salar del Huasco Basin was summarized based on the interpretation of LANDSAT images and existing reports (<1 to 4); A geological map, a geological profile and geological cross sections are shown in Fig. B-IV, 1.2, 1.3 and 1.4 respectively. Stratigraphic classification is shown below;

Geologic Age	Formation	Lithology	Units
Quaternary	Recent Deposits	unconsolidated alluvial, eolian and fan deposits	Qal, Qe, Qf
	Pastillos Ignimbrite	lapilli tuff with intercalation of claystone, siltstone and diatomite	Qip
	Collacagua Formation	lake deposits consisting of gravel, mud and volcanic breccia	Qc
	Volcanic Rocks	andesite and dacite (lava flow and lava dome)	Qv
Tertiary		andesitic and dacitic lavas sand pyroclastics. intensely to moderately eroded.	TPv, TMv
	Huasco Ignimbrite	totally or partially welded tuff, rhyolitic and dacitic ignimbrite, grayish and pinkish color	Tsh

1) General Geology of Basin

(1) Huasco Ignimbrite (Upper Tertiary) (Tsh)

It consists of totally or partially welded rhyolitic and dacitic ignimbrite of grayish and pinkish in color. It seems to be more than 100 m in thickness. Member 4 of Altos de Pica Formation in Pica is correlated to this Huasco ignimbrite (<4). Joints and fissures are well developed in both Altos de Pica Formation and Huasco Ignimbrite. It is observable on the image and aerial photographs that this ignimbrite is intensely fractured.

(2) Volcanic Rocks (TMv, TPv, Qv)

The Volcanic Rocks are composed of andesitic and dacitic lava flow and pyroclastics. These are derived from different stages of volcanic activities; Late Miocene (TMv), Pliocene (TPv) and Early Pleistocene (Qv). TMv is strongly eroded as a whole. While TPv is eroded near the crater, the rocks form a volcanic cones. The volcanoes formed by Qv have been weakly eroded and the shape of crater is still clear.

TMv is cut by fault of N-S direction at the western end of thedistribution area. The Huasco Basin is located on the west of the fault, therefore, there is a high possibility that TNv is underlain by the Huasco Ignimbrite. Furthermore, the volcanic breccia (Qcl) of the lower part of the Collacagua Formation could be correlated with TMv.

(3) Collacagua Formation (Qc)

The drilling results of H-1, J-G and J-10 revealed the details of this formation (<1 and 2.2, Chapter II). The formation is 100 m to 200 m in thickness and is divided into three (3) units based on its lithology; the Upper, the Middle and the Lower. It is lake deposits sedimented in the Huasco Basin. It seems that the Collacagua Formation is correlative with Tt and TPt described by <2 judging from the lithology and the stratigraphic relation with other formations. Although <2 described the Collacagua Formation as Tertiary deposits, the Study Team considered the formation as Quaternary deposits based on <3.

(i) Lower Unit (Qcl)

The lithology is volcanic breccia in the well H-1, changing to gravel, sand and mud in wells No. J-G and J-10. It is more compact compared with other units.

(ii) Middle Unit (Qcm)

The lithology is gravel, sand and mud in the well No. H-1, and gravel in well No. J-G and J-10.

(iii) Upper Unit (Qcu)

Gravel, sand and mud appear in the well No. H-1 and are overlain by the salt crust. It is mainly composed of gravel in well No. J-G and J-10.

The Upper Unit and the Middle Unit are composed mainly of gravel to the north of the Salar. In contrast to this, the sediments consist of gravel and mud in the Salar.

(3) Quaternary Volcanic Rocks (Qv)

It consists mainly of andesite and dacite which form strato volcanoes and lava domes distributed in the eastern side of the Salar. Dacite is compact in the lava dome.

(4) Pastillos Ignimbrite (Qip)

It is divided into two (2) units; The Upper and the Lower. The Lower Unit consists of scarcely welded volcanic ash and mud flow deposits abundant in lapilli and pumice. The upper Unit is composed of dacitic tuff with intercalation of siltstone and diatomite. The Pastillos Ignimbrite is thought to be correlative with the Collacagua Formation (<3). However, the Study Team divided the Pastillos Ignimbrite from the Collacagua Formation, judging from the difference of the lithology of the both; the former consists of acidic pyroclastic rocks and the latter consists of alluvial deposits. It seems that the former is underlain by the latter.

(5) Recent Deposits (Qf, Qe, Qal)

The Recent deposits are divided into three (3) units; Fan deposits, Eolian deposits and Alluvial deposits.

The Alluvial deposits are unconsolidated and composed mainly of gravel and sand, deposited in the valleys. The Fan deposits appear in the fan distributed in the northeast of the Salar and are composed of reworked fine to coarse volcanic ash with clastics of dacite.

2) General Geological Structure of the Basin

As mentioned in the part of Pampa del Tamarugal, many fractures with NE-SW direction are found on the welded tuff in the area from Collacagua to Altos de Pica. On the aerial photographs, these are mostly normal faults dipping NW or SE. The western side of Salar del Huasco is bounded by the fault which is extended to the north and meets the Collacagua River at the northern end.

1.2.3 Hydrogeology in Salar del Huasco

As mentioned in 1.1 of this Chapter, the Salar del Huasco Basin is a hydrologically closed basin; only the Collacagua River flows into the basin from the north. However, surface water of the river completely infiltrates into the under ground recharging the Collacagua Formation. The Collacagua Formation is the most prospective aquifer in

the Salar del Huasco Basin. Several springs occur at the western margin of the salt lake yielding fresh water. No rivers flow out from the basin. The change of water level of the Salt Lake is not so much. This feature suggests that the inflow rate of the Collacagua River balances with the trans-evaporation rate from the surface of the Salt Lake and the outflow through the joints and fissures of the rocks (water balance is mentioned in Chapter III).

Geology of the Salar del Huasco Basin is classified into following five (5) units;

Recent Deposits (Qf, Qe, Qal)
Pastillos Formation (Qip)
Quaternary Volcanic Rocks (Qv)
Collacagua Formation (Qc)
Huasco Ignimbrite (Tsh)

Among these, the Collacagua Formation is the most prospective aquifer of the basin. Hydrogeological descriptions of each unit are given below;

(1) Recent Deposits (Qf, Qe, Qal)

The Recent Deposits are thin unconsolidated sediments and have low permeability as a whole because the deposits are abundant in clay, silt and fine-grained volcanic ash. However, the deposits consist mainly of fluvial deposits which are poor in fine-grained materials in the area along the Collacagua River. Therefore, this deposits are not considered to be a aquifer in the basin.

(2) Pastillos Formation (Qip)

Although the Upper Unit is weakly welded and abundant in pumice, it is considered to be low permeable.

The Lower Unit is of low permeability because it consists of mud flow deposits and intercalated with many clay and silt layers.

(3) Volcanic Rocks (TMv, TPv, Qv)

Although the rocks itself is compact, it is moderately permeable because joints and fissures are well developed in the rocks. In case of strato volcano, high permeable pyroclastics are intercalated with lavas. There is less possibility that the Quaternary Volcanic Rocks form aquifers judging from the distribution.

(4) Collacagua Formation (Qc)

The formation is formed by coarse-grained alluvial deposits of highly permeable. Therefore, it is considered that the Collacagua formation is the most prospective aquifer in the basin. However, the lower part is less permeable compared with the middle and upper units, because it occasionally contains pyroclastics and is compacted as a whole.

The static water level of groundwater in this formation is 10 mBGL at the well No. J-G and 30 mBGL at No. J-10. The gradient of static water level between the wells is approximately 3/1000, since the distance between the wells is 7 km.

(5) Huasco Ignimbrite (Tsh)

Joints and fissures are well developed in the rocks so far as observed in the outcrops. Therefore, it is considered to be permeable in a certain degree. However, it seems to be difficult to meet groundwater properly by drilling. To give a instance of the water well drilling in the welded tuff, " The history of well drilling in the Pica area shows that only one (1) good well has been obtained in approximately 40 attempt"(<4). This fact shows that it is difficult to develop the groundwater in the welded tuff (including ignimbrite). However, there is a possibility that a part of the groundwater in the basin flows out to Pampa del Tamarugal basin through the joints, fissures and faults (<5).

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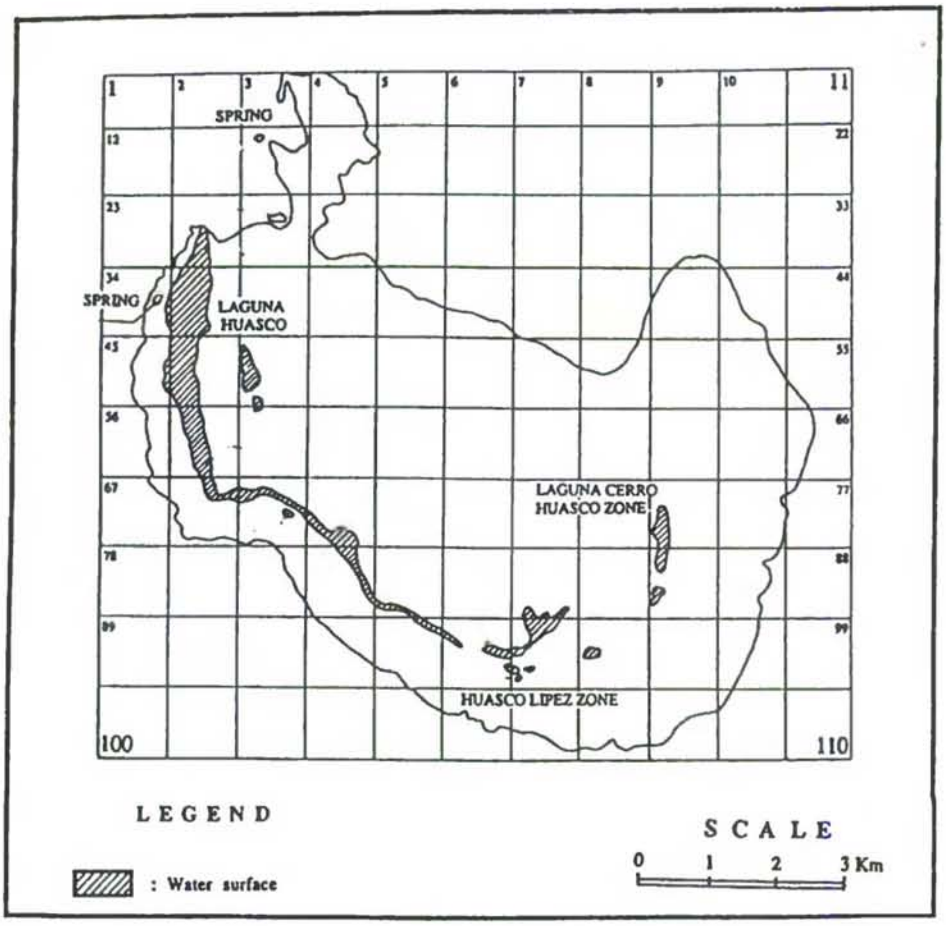

Fig. B-IV, 1.1 Topographic Figure (Salar del Huasco)

< Figura Topográfica (Salar del Huasco)>

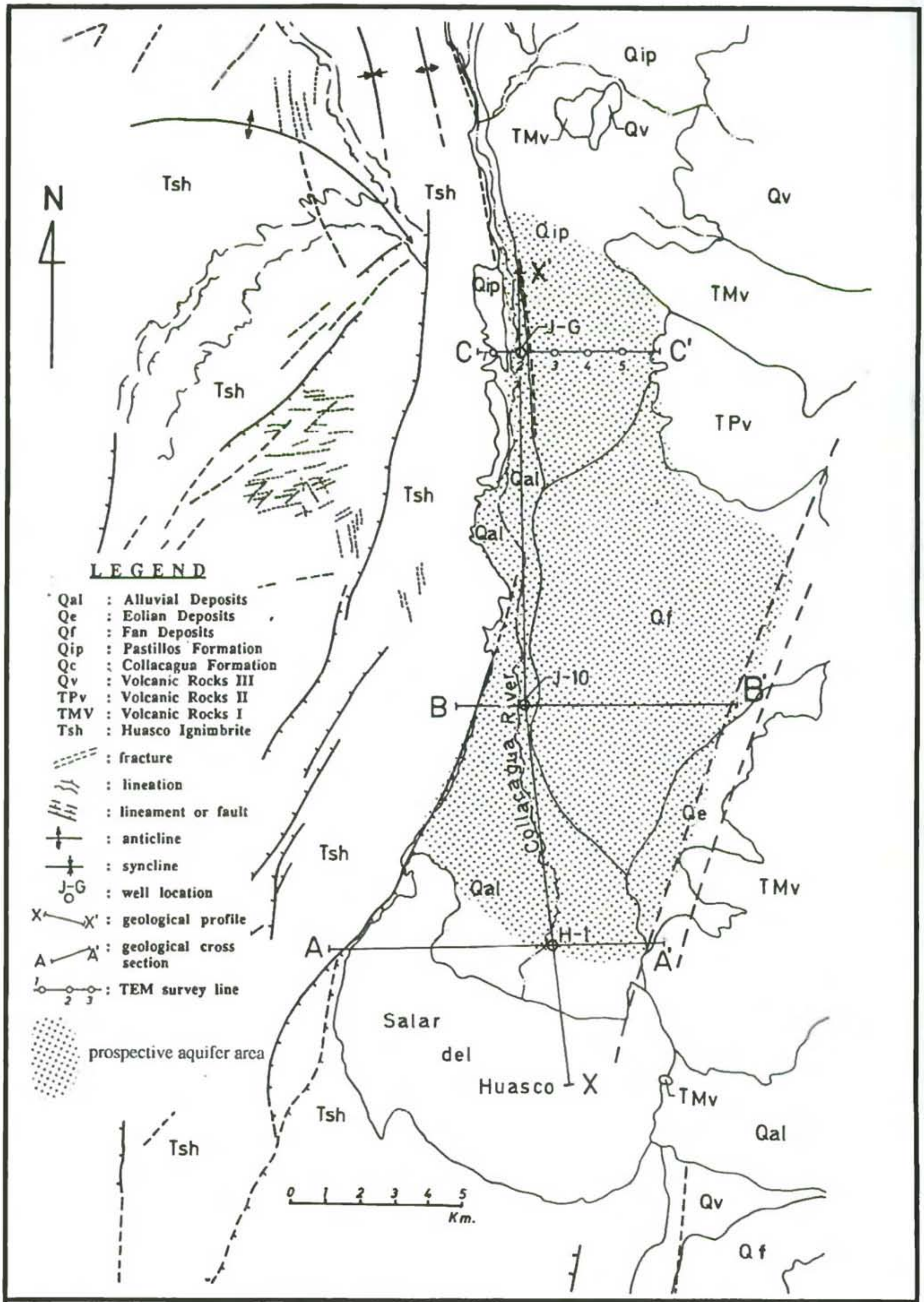

Fig. B-IV, 1.2 Geological Map (Salar del Huasco)

< Mapa Geológico (Salar del Huasco) >

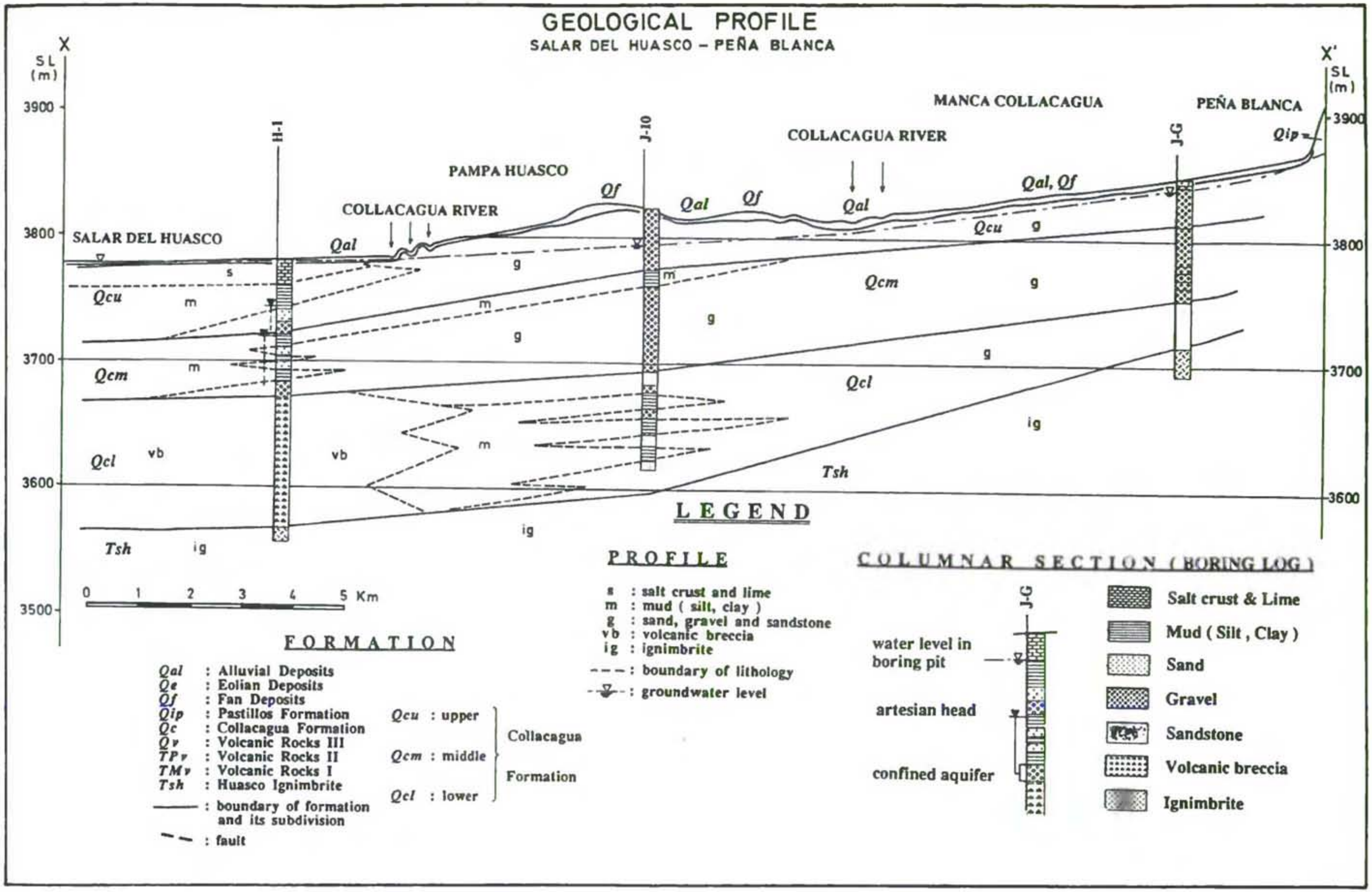

Fig. B-IV, 1.3 Geological Profile (Salar del Huasco)
<Perfil Geológico (Salar del Huasco)>

Fig. B-IV 1.4 Geological Cross Section

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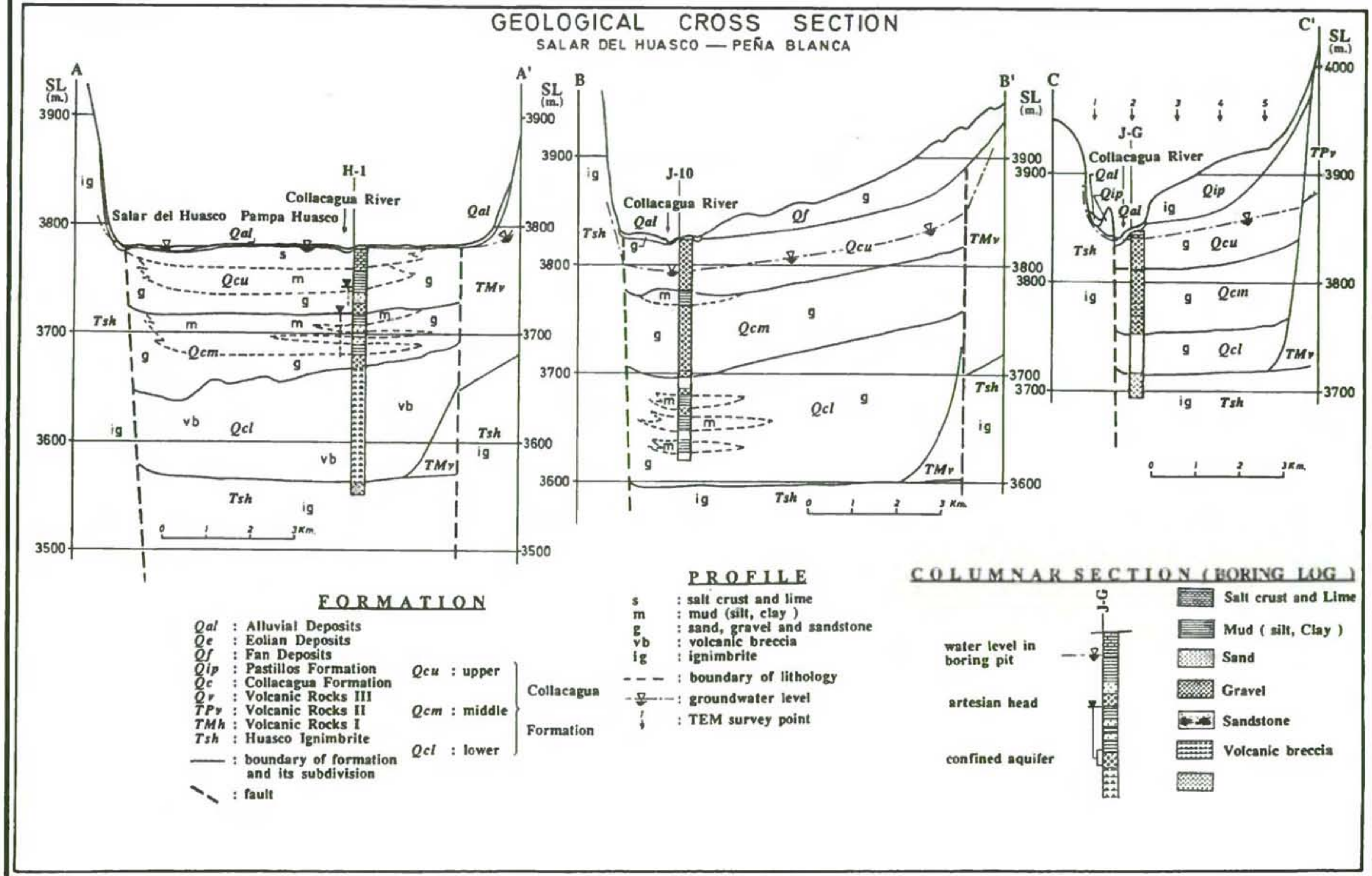

THE STUDY ON THE DEVELOPMENT OF WATER RESOURCES IN NORTHERN CHILE

JICA

Chapter II. AQUIFER OF HUASCO BASIN

2.1 Existing Data

Although two (2) bore holes were drilled in the Salar del Huasco Basin, only one (1) datum is available. Pumping test was not done. The stratigraphic column is cited in the Data Book.

There are springs along the western side of the Salar. Water quality analysis were executed on the water from these springs as well as on the river water of the Collacagua (<1).

2.2 Supplementary Geological Survey

The following geological surveys were executed by the JICA Study Team, to supplement the existing geological data. The survey locations are shown in Fig. B-IV, 2.1.

a) Electromagnetic Survey	5 survey points (1 line)
b) Boring Survey	
(a) Drilling	
Test well drilling	1 well
Observation well drilling	1 well
(b) Pumping Test	2 wells
c) Water Quality Analysis	2 wells (JICA wells)
d) C-14 analysis	1 well (JICA well)

2.2.1 Electromagnetic (TEM) Survey

1) Survey Area

Transient Electro Magnetic (TEM) survey is conducted at north of Salar del Huasco (Fig. B-IV, 2.1). One (1) TEM line was set perpendicular to the main axis of Collacagua River. A total of 5 stations were set at interval of 1000m each as shown below.

Quantity of TEM Work

	Profile	Stations	Station Interval
	SH-1	5	1000 m
Total		5	

2) Methodology of Study

For the details of the methodology, see B-II, section 2.3.1 of chapter II.

3) Survey Results.

An apparent resistivity curve at the station No.2 is shown in Fig. B-IV, 2.2. A geological profile is made by the apparent resistivity curve of each station. A geoelectrical profile along the Line SH-1 is shown in Fig. B-IV, 2.3. The resistivity structure along the profile is classified as six (6) layers. The geophysical characteristics of each layer is summarized as follows.

a) The first layer shows a resistivity value, higher than 350 ohm-m. This resistivity represents a dry layer composed of sand and gravel. On the other hand, at only station No.5, the resistivity of the layer is relatively low (100 ohm-m) due to the wet condition beside the river.

b) The second layer shows a resistivity range of 55 to 90 ohm-m. The layer is distributed in all the stations except No.5. It is considered as a expected aquifer.

c) The third layer shows a resistivity value of 190 ohm-m. This layer exists only at the station No. 2. Due to high value of the resistivity, the layer is considered as a impermeable bed.

d) The forth layer shows a resistivity range of 11 to 12 ohm-m. The layer is expected as a aquifer. However, its rather lower resistivity than that of the second layer indicates that the layer is contaminated. The layer is distributed in the stations No.1 and No.2.

e) The fifth layer shows a resistivity range of 14 to 42 ohm-m. The layer is distributed in all the stations. However, the depth to the boundary of the sixth layer is not clear. The layer is also considered as a aquifer.

f) The sixth layer shows a resistivity range of 3 to 7 ohm-m. This layer is considered as a aquifer with concentration of dissolved solids because resistivity value is extremely low.

4) Interpretation with Boring Log

Geoelectric profiles, described in the above section, are analyzed based on the boring log including observed lithology and geophysical logging data. Fig B-IV, 2.3 shows analyzed resistivity profile interpreted by using inverted geoelectrical sections and boring logs. Interpretation for each resistivity profile is summarized as follows.

Following table shows summary of interpreted relation between lithological formation and resistivity range.

Layer	Depth (m.bgl)	Resistivity Range(ohm-m)	Lithology	Interpretation
1 st	0 - 108	55 - 90	gravel, clayey to sandy gravel	Expected Aquifer
2 nd	>108	190	clayey sandstone rhyolite	Impermeable Layer

2.2.2 Boring Test

1) Location and Depth of Well

One (1) test wells of J-G and one (1) observation wells of J-10 are placed on the line of the TEM survey (see, Fig. B-IV, 2.1). Location, drilling depth and casing size of each well are summarized as follows.

Well No.	Location	Latitude	Longitude	Elevation (m.msl)	Casing (inch)	Depth (m.bgl)
J-G	Salar del Huasco	20° 06' 29.5"	68° 49' 00.4'	3,850	8-5/8"	157
J-10	Salar del Huasco	20° 11' 38.0"	68° 49' 52.9'	3,825	5-1/2"	207

2) Methodology of Well Construction

For the details of the methodology, see, B-II, Section 2.3.2 of Chapter II.

3) Result of Boring Test

The results of the boring test are shown in Table B-IV, 2.1. The well data for each well, including lithological column, casing design, well logging and drilling rate are shown in Fig. B-IV, 2.4 for test well and in Fig. B-IV, 2.5 for observation well with scale of 1:1000.

(1) Well No. J-G (see Fig.B-IV, 2.4)

i) Lithology

The well was drilled up to 157m depth. In the whole sequence, two (2) formations, Quaternary Collacagua Formation (upper, middle and lower) and Tertiary Huasco Ignimbrite were observed. Based on the result of geophysical logging and lithology observed, following three (3) major layers are classified.

(J-G)

Layer	Depth (m)	Classification	Lithology	Formation	Period
1 st	0 - 30	Surface Deposit	sand and gravel	Collacagua	Quaternary
2 nd	30 - 108	Aquifer	clayey to sandy gravel	Collacagua	Quaternary
3 rd	108 - 157	Impermeable Layer	clayey sandstone Rhyolite	Collacagua Huasco Ignimbrite	Quaternary Tertiary

ii) Well Logging

Spontaneous potential (SP) indicates a range of -55.5 to -58 mv. From the lithological point of view, a relative basement line (relative 0 line) which is the boundary between permeable formation (gravel sand) and impermeable formation (mud) is estimated as - 57.5 mv. Gamma ray indicates 30 to 70 cps at 50m from surface and 60 to 100 cps at below 50m. This range is in well coincidence with lithological observation of clean gravel at 38m from surface and clayey gravel at below 38m. The range of resistivity is also in coincidence with TEM's resistivity, especially 30 to 100 ohm-m at depth from 30 to 108m. A slow increase rate of water temperature curve from surface to 110m depth (17° to 18°C) indicates groundwater flow.

iii) Determination of Casing Design

In order to determine the position of screen pipe, the following interpretation were made by lithological and well logging data. Decided casing design is shown in Fig, B-IV, 2.4.

a) 1 st layer (Surface Deposit)

The layer consists of coarse sand at surface and fine gravel at lower part. It is estimated as highly permeable, based on the SP and gamma ray values. However, the layer is interpreted as dry, because of very high value of resistivity. Blank casing pipes were installed in this layer.

b) 2 nd layer (Aquifer)

The layer is considered to have permeability lower than 1st layer because of clayey matrix. The range of SP and gamma ray also indicates higher value which can be interpreted as low permeability. However, the range of resistivity (30 - 90 ohm-m) shows approximately same value with the TEM result (55 - 90 ohm-m). This range was classified as most promising aquifer by the TEM analysis. Therefore, the layer is expected as aquifer.

The screen pipes were installed at the depths from 30.81 to 54.84m and 60.82 to 102.91m of this layer.

c) 3 rd layer (Impermeable bed)

Due to high value of gamma ray and resistivity (more than 100 ohm-m), the layer is considered as dry or impermeable. The temperature curve also shows stable line at upper layer. Blank casing pipes were installed in this layer.

(2) Well No. J-10 (see, Fig. B-IV, 2.5)

i) Lithology

Upper, Middle and lower Collacagua Formation of Quaternary were observed in the whole sequence. The total drilling depth is 207m. Based on the results of geophysical logging and lithological observation, following four (4) major layers are classified.

(J-10)

Layer	Depth (m)	Classification	Lithology	Formation	Period
1 st	0 -49	Surface Aquifer	clayey gravel	U. Collacagua	Quaternary
2 nd	49 - 63	Impermeable layer	silty clay	M. Collacagua	Quaternary
3 rd	63 - 147	Shallow Aquifer	clayey gravel	M. Collacagua	Quaternary
4 th	147 - 207	Deep aquifer	mudstone, clayey gravel, sandstone	L. Collacagua	Quaternary

ii) Well Logging

On the gamma ray, three (3) different ranges are observed; 30 to 70 cps from surface to 55m depth, 50 to 100 cps at depth from 55 to 160m and 20 to 200 cps at depth from 160 to bottom. Clay intercalation is observed at depths of 167m and 192m by the high value of gamma ray. Based on the lithology and gamma ray, a relative basement line of the SP is estimated as -9.2mv. In consideration of SP and gamma ray curves, higher permeability can be expected from surface to 150m. The resistivity value is high at 40m from surface and at middle part (90 to 140m depth). The water temperature gradually increases from surface to bottom.

iii) Determination of Casing Design.

Casing design is decided as shown in Fig. B-IV, 2.5, based on the following interpretation for each layer.

a) 1 st layer (Surface Aquifer)

The layer is considered to has the highest permeability among four (4) layers by the SP and gamma ray. Based on the lithological observation, clayey, but well sorted fine gravel is confirmed in this layer. The layer is expected as aquifer except upper layer which has extremely high resistivity value (more than 500 ohm-m).

A short interval of 39.02 to 51.03m at lower layer is selected for screen installation.

b) 2 nd Layer (Impermeable Layer)

The layer is compared of single thin bed (14m thickness) of sandy to silty clay. The layer is classified as impermeable layer.

c) 3 rd Layer (Shallow Aquifer)

The layer is consists of mainly clayey gravel of Middle Collacagua Formation. Based on the resistivity range and gamma ray, the layer is expected as promising aquifer.

The screen pipes were installed at depth from 86.53 to 146.51m of this layer.

d) 4 th Layer (Deep Aquifer)

The layer is composed of alternating sandy clay and clayey gravel of Lower Collacagua Formation. The aquifer is found out at the layer of clayey gravel by the resistivity.

Two (2) positions were selected for screen pipes at the depths from 161.81 to 167.81m and 172.83 to 184.79m.

2.2.3 Pumping Test

1) Methodology of Pumping Test

For the details of the methodology, see B-II, section 2.2.3 of Chapter II.

2) Result of Pumping Test

(1) Aquifer Constants

Aquifer constants are analyzed by using the graphs shown in Fig. B-IV, 2.6 to 2.7. The results of this analysis are summarized in Table B-IV, 2.2 and 2.3. The tables include pumping data and aquifer constants calculated by two (2) methods mentioned above. The aquifer constants for two (2) wells are summarized as follows;

Well No.	Transmissibility (m^3/day/m)	Permeability (cm/sec)
J-G	156.39	2.74×10^{-3}
J-10	191.38	2.46×10^{-3}

A similar value of the aquifer constants in all item is obtained at both wells. A range of 156 to 191 m^3/day/m of transmissibility indicates that the aquifer has moderate groundwater potential. Considering the proportion of the each lithology, it is presumed that a range of 2.4×10^{-3} to 2.7×10^{-3} cm/s represents the permeability of clayey gravel.

iii) Well Capacity

Well capacity is evaluated by the amount of critical discharge and safe yield. The Q-Sw chart for to examine the critical discharge and Q-s/Q Chart for to obtain the well efficiency and area of influence are shown in Fig. B-IV, 2.8 to 2.9. The capacities for two (2) wells are summarized as follows;

Well No.	Critical Discharge (l/s)	Safe Yield (l/s)
J-G	more than 25.00	6.70
J-10	more than 5.00	1.75

Critical discharge is estimated as more than 25 l/s at J-G and more than 5 l/s at J-10. It is confirmed that the amount of critical discharge is larger than maximum pumping rate capacity. Safe yield is estimated as 6.7 l/s at Test Well and 1.75 l/s at Observation Well.

2.2.4 C-14 Analysis

One (1) sample was taken fron the JICA Well No. J-G.

The result of the analysis is as shown below;

Well No.	Tritium (TU)	C-14 (pmc)	Age (Y.BP)*	Average Age**
J-G	<0.8	7.8	8,690-9,800	9,245

Y.BP : years before present

* : Estimated age by Modified Pearson Model

Tritium contents is close to 0, therfore, the groundwater age is older than at least 40 years. C-14 data shows an old age, 9,245 Y.BP. C-14 age is rather old.

It is suggested that velocity of the groundwater in the Salar del Huasco Basin is very small.

2.3 Configuration of Aquifer

Few hydrogeological study has been executed in the Salar del Huasco Basin before this Study. However, it is believed that the principle aquifers appear in the basin-fill alluvial deposits and the underlying Altos de Pica formation and the basin is hydrologically in a dynamic equilibrium (<2, <3 and <4).

The basin is topographically closed by mountains and it has an ovoid shaped depression elongated to the north and south as shown in Fig. B-III, 1.1. Thus, the figure of the aquifers are governed by this topographical condition. The width of the basin is about 10 km in the south of the basin and extension to the north is about 25 km judging from the topography.

A series of study by the Study Team revealed that the prospective aquifers appear in the Collacagua Formation and the distribution of aquifers are restricted by the faults in the east and west, by Quaternary to Tertiary Volcanic Rocks in the north and south. The figures of the aquifers in the basin is shown in Fig. B-IV, 1.2, 1.3 and 1.4.

The aquifers extend from the Salar to approximately 6 km north of Peña Blanca. The distance is about 30 km. However, the Salar area is not suitable for aquifer, because it seems that clayey sediments increase in the Salar and groundwater quality is bad. Therefore, the Salar area is excluded from the aquifer area. Accordingly, the prospective aquifer area is about 126 km^2; 20 km in length and 4.5 to 7 km in width. The thickness of aquifer is 130 to 210 m, averaging 170 m.

2.4 Hydrogeological Characteristics of Aquifer

Geology of the Salar del Huasco Basin is divided into three formations; the Alluvial Deposits, the Collacagua Formation and the Huasco Ignimbrite. The Alluvial Deposits is of hydrogeologically no value because it is very thin and overlies as the top of the sediments. The Collacagua Formation is composed mainly of sand and gravel so that it is considered as prospective aquifer in the area. JICA Well No. J-G and existing well No. H-1 penetrated into the Huasco Ignimbrite as shown in Fig. B-IV, 1.3. The Huasco Ignimbrite is covered by the Collacagua Formation which consists of three (3) units (lower, middle and upper) as mentioned in 1.2.2 of Chapter I. The Lower Collacagua Formation is composed of mainly sand in J-G. It increases its thickness toward the well J-10, however, it is intercalated with mud layers. Finally, it changes its lithology to volcanic breccia in the well No. H-1. The middle and upper part of the Collacagua

Formation is composed mainly of gravel. It is intercalated with mud, and salt crust and lime. Therefore, the Collacagua Formation is permeable in the well No. J-G and J-10.

Aquifer constants are shown in following table.

Well No.	Specific Yield	Transmissibility	Permeability
	(l/sec/m)	(m^3/day/m)	(cm/sec)
J-G	0.74	156	2.74×10^{-3}
J-10	1.23	191	2.46×10^{-3}
Average	0.99	174	2.60×10^{-3}

Both wells show moderate specific yield and transmissibility. Permeability is rather small compared to that of sand and gravel beds.

In addition to this, Huasco Ignimbrite is also considered to store the groundwater because many fractures are developed in this rocks as mentioned in 1.2.2. However, the groundwater stored in this rocks is a type of fissure water, therefore, it is difficult to estimate the groundwater storage of this rocks.

Groundwater level is generally shallow; 27m in the well J-G and 5m in well J-10.

2.5 Estimation of Groundwater Storage

Groundwater storage of Salar del Huasco Basin is shown in Table B-IV, 2.4 and Fig. B-IV, 2.10. These present the estimated groundwater storage in the area from Salar to Peña Blanca where DGA's observatory station is located.. Total volume of groundwater storage is estimated as follow;

$$S_{\text{Total Storage}} = \mathbf{465 \times 10^6 m^3}.$$

The estimation was made based on the one (1) geological profile and three (3) geological sections dividing the area into two (2) zones as shown in following table;

Zone	Geological Section	Area
1	sect. A-A to B-B'	Salar to J-10
2	sect. B-B' to C-C'	J-10 to J-G (Peña Blanca)

Conditions applied in the estimation are as follows;

a) Climate condition will remain constant during the estimated period.
b) The extent of the estimation is limited to the area from Salar to Peña Blanca, because no stratigraphic column of well is available toward the upper reaches from Peña Blanca.
c) Effective porosity of aquifer is assumed to be 30 % as a whole, considering the materials which compose the aquifer.

2.6 Groundwater Quality

Groundwater quality analysis was executed by DGA and the Study Team on the JICA Wells and two (2) springs which occurred at the margin of the Salar. Results of the analysis are shown in Table B-IV, 2.5.
From the table, it is interpreted that:

a) Most of ion contents are less than standard for drinking water. The parameters are TDS, Mg, Na, SO4, Cl, Cd, Cr, Pb, Cu and Al.
b) As content is higher than standard at the both JICA Wells and one of the spring (H-0).
c) B content is higher than standard at the well No. J-G and spring H-3.
d) Fe contents is much higher than standard (4.30 to 18.00 mg/l) at the JICA Wells. However, these contents could be influenced by riser pipe in pumping test because new pipes are used at the test.

Fig. B-IV, 2.11 shows the composition of major ions together with spring water, salt lake water, and the surface water of the Collacagua River.

a) Groundwater of well J-G , spring water of H-3 and surface water of the River are plotted in the area among carbonate alkali type, noncabonate alkali type and carbonate hardness type. This type of water is rather normal as a water in the volcanic zone.
b) Groundwater of the well J-10 is plotted in the area of non carbonate hardness type. It means that the water of the well J-10 consists mainly of chemical compounds of Ca/Mg and SO_4/Cl.

2.7 Evaluation of Groundwater Development Potential

2.7.1 Existing Water Balance

The Salar del Huasco Basin is hydrologically closed; only the Collacagua River flows into the Salar collecting surface water from its tributaries and no surface water flows out from the Basin. The surface water of the Collacagua River entirely infiltrates into the underground before reaching the Salar. Water of the Salar evaporates from its surface. Some portion of groundwater seems to flow out through fissures toward the Pampa. Water in the Basin is balanced with those factors.

Surface water of the Collacagua River is calculated in Supporting Report C. It is 809 l/sec. Evaporation rate in the Salar del Huasco Basin was measured by DGA during 1981-1982 (<6). The rate was 1935mm/year by evaporation pan. Considering that the evaporation rate by pan is generally larger than that of actual evaporation, an approximately 75 % of evaporation rate by pan is adopted for the evaporation rate from the water surface. However, data on the evaporation rate from the wet land are not available. Then, the evaporation rates of Pampa del Tamarugal (<6) are applied to estimate the total volume of evaporation. Depth to water level in the wet land is very small because the water depth of the Salar is 16 cm in maximum. The evaporation rate from the wet land is considered to be more larger than the rate mentioned in <6. Therefore, the size of water area is regarde to be 6 km^2, although actual size of the wet land is 2 km^2 for calibration. Taking all these factors into consideration, evaporation from the salt lake is calculated in the following table.

Area			Evaporation Rate		Total Evaporation			
Water Area	6	km^2	1.5	m/year	9,000,000	m^3/year	285.39	l/sec
Wet Land	25	km^2	0.365	m/year	9,125,000	m^3/year	289.35	l/sec
Total Area	31	km^2		m/year	18,125,000	m^3/year	574.74	l/sec

Water level of the salt lake is almost constant, therefore, change of the storage volume of the Basin is considered to be zero (0).

Water balance of the Salar del Huasco Basin is given following formula;

$$\Delta Q = R_R - (R_F + E_S)$$

where,

ΔQ	: variation of groundwater volume (0 l/sec)
R_R	: recharge from the rivers (809 l/sec, see Supporting Report A)
R_F	: outflow through fissures (l/sec)
E_S	: evaporation from Salars (575 l/sec)

Then,

$$R_F = R_R - E_S = 809 - 575 = 234 \text{ (l/sec)}$$

This result shows a possibility that 234 (l/sec) of groundwater flows out to Pampa through the fissures recharging the groundwater in Pampa del Tamarugal.

2.7.2 Groundwater Development Potential

Aquifers in Salar del Huasco Basin are recharged by surface water of the Collacagua River and discharge water by evaporation through salt lake, and by flowing out through fissures to Pampa, as mentioned in 2.7.1. Groundwater storage in the Basin is estimated to be 465 x 10^6 m^3 in 2.5 of this Report. In consideration of groundwater development potential, this storage groundwater is not an object of development.

It is impossible to clarify the location and/or range of fissures through which groundwater flows out to Pampa del Tamarugal Basin. Exploitable groundwater is limited to the water which flows into the salt lake. 809 l/sec of surface water infiltrates into aquifers, however, 234 l/sec of groundwater flows out through fissures. Therefore, a volume of exploitable groundwater is,

809 - 234 = <u>575 (l/sec)</u>

Groundwater development potential is considered to be 575 l/sec. If groundwater is developed in the Salar del Huasco Basin, it will be unavoidable that the salt lake is dried up to balance with the decrease of recharge from groundwater.

An interpretation on radius of influence was made to decide the spacing of production wells. Aquifer constants are given by the pumping tests mentioned in 2.2 of this Chapter. Formula for determination of the radius of influence is mentioned in Chapter III of B-II. Conditions of production well construction are planned as follows;

Diameter of well	: 17-1/2" (444.5 mm)
Diameter of casing	: 12" (318.5 mm)

Production rate : 40 l/sec
Allowable drawdown : 40 m
Drilling depth : 150 - 200 m

Following table gives details of radius of influence.

	R (m)	Q (m3/sec)	T (m3/sec/m)	S	t (sec)	time
J-G	76	0.04	1.81E-03	0.3	43200	0.5 day
	94	0.04	1.81E-03	0.3	64800	0.75 day
	108	0.04	1.81E-03	0.3	86400	1 day
	419	0.04	1.81E-03	0.3	1E+06	10 day
	592	0.04	1.81E-03	0.3	3E+06	1 month
	1451	0.04	1.81E-03	0.3	2E+07	6 months
	2066	0.04	1.81E-03	0.3	3E+07	1 year
J-10	83	0.04	2.21E-03	0.3	43200	0.5 day
	102	0.04	2.21E-03	0.3	64800	0.75 day
	118	0.04	2.21E-03	0.3	86400	1 day
	456	0.04	2.21E-03	0.3	1E+06	10 day
	645	0.04	2.21E-03	0.3	3E+06	1 month
	1580	0.04	2.21E-03	0.3	2E+07	6 months
	2250	0.04	2.21E-03	0.3	3E+07	1 year

Radius of influence is 110 to 120 m (220 to 240 m in diameter)when pumping period is one (1) day. It increases up to 420 to 460 m (840 to 920 m in diameter) when 10 days continuous pumping operation is executed. Considering these results, spacing of production wells are decided to be 1000 m.

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Table B-IV, 2.1 Result of Boring Test of Salar del Huasco Area

< Resultado de Prueba de Sondaje en el Area del Salar del Huasco>

Well No.	Bore hole Depth (m)	Casing Pipe		Screen Pipe		Geological Conditions of Aquifer			Geophysical Data	
		Size (inches)	Total Length (m)	Position (m)	Total Length (m)	Lithology	Formation	Period	Well Logging Resistivity (ohm-m)	TEM Resistivity (ohm-m)
J-G	157	8-5/8"	96.03	30.81 -54.84	66.12	gravel clayey gravel	Collacagua (Qcm)	Quaternary	30 - 90	55 -90
				60.82 -102.91		clayey gravel sandy gravel			25 -90	55 -90
J-10	207	5-1/2"	116.70	39.02 -51.03	89.95	gravel	Collacagua (Qcu)	Quaternary	70 -300	-
				86.53 -146.51		clayey gravel	Collacagua (Qcm)		40 - 500	-
				161.81 -167.81		clayey gravel	Collacagua (Qcl)		25 -80	-
				172.83 -184.79		sandy mudstone clayey sandstone			40 - 80	-

Table B-IV, 2.2 Result of Pumping Test (Salar del Huasco)

<Resultado de Prueba de Bombeo (Salar del Huasco) >

Well No.	Pumping Data (by Constant Test)				
	Static Water Level (m)	Pumping Rate (l/s)	Dynamic Water Level (m)	Drawdown (m)	Specific Yield (l/s/m)
J-G	5.86	25.00	39.76	33.90	0.74
J-10	26.56	5.00	30.64	4.08	1.23

Table B-IV, 2.3 Aquifer Constants (Salar del Hasco)
<Coeficientos de Acúiferos (Salar del Hasco)>

Well No.	Aqufer Constant		Test Method				Average
			Theis		Jacob		
			Constant	Recovery	Constant	Recovery	
J-G	ransmissibilit	(m3/s/m)	9.60E-04	2.65E-03	1.19E-03	2.44E-03	9.08E-04
	Storage Coefficient		1.50E-09		2.29E-11		7.64E-10
	Permeability	(m3/s/m)	1.97E-13	5.43E-13	2.44E-13	5.00E-13	1.86E-13
J-10	Transmissibi	(m3/s/m)	2.10E-03	2.41E-03	2.03E-03	2.32E-03	1.09E-03
	Storage Coefficient		1.17E-10		1.41E-10		1.29E-10
	Permeability	(m3/s/m)	1.45E-07	3.53E-08	4.16E-13	4.10E-08	1.02E-08
Average	Transmissibi	(m3/s/m)	1.53E-03	2.53E-03	1.61E-03	2.38E-03	9.98E-04
	Storage Coefficient		8.11E-10		8.21E-11		4.46E-10
	Permeability	(m3/s/m)	7.23E-08	1.77E-08	3.30E-13	2.05E-08	5.12E-09

Table B-IV, 2.4 Estimation of Groundwater Storage

<Estimación de Reservas de Agua Subterránea >

DEPTH (m BSWL)	ZONE 1 (SALAR-SECT.A) (m3)		ZONE2 (SECT. A-B) (m3)		TOTAL (SALAR-SECT. B)	
		SUM		SUM		SUM
10	7,825,313	7,825,313	18,049,406	18,049,406	25,874,719	25,874,719
20	7,809,559	15,634,871	17,992,408	36,041,815	25,801,967	51,676,686
30	7,800,404	23,435,275	17,954,409	53,996,224	25,754,813	77,431,499
40	7,791,607	31,226,882	17,892,662	71,888,885	25,684,268	103,115,767
50	7,788,057	39,014,939	17,835,663	89,724,549	25,623,720	128,739,488
60	7,956,760	46,971,699	18,049,406	107,773,955	26,006,166	154,745,654
70	7,938,742	54,910,440	17,954,409	125,728,364	25,893,151	180,638,805
80	7,747,257	62,657,697	17,612,421	143,340,785	25,359,678	205,998,482
90	7,731,493	70,389,190	17,541,173	160,881,958	25,272,666	231,271,148
100	7,714,515	78,103,705	17,455,676	178,337,634	25,170,191	256,441,339
110	7,701,485	85,805,190	17,360,679	195,698,313	25,062,164	281,503,503
120	7,652,754	93,457,944	16,743,199	212,441,512	24,395,953	305,899,456
130	7,603,412	101,061,355	15,175,751	227,617,263	22,779,162	328,678,618
140	7,554,885	108,616,240	12,682,083	240,299,346	20,236,968	348,915,586
150	7,490,758	116,106,998	11,162,133	251,461,478	18,652,890	367,568,476
160	7,410,938	123,517,935	11,043,387	262,504,865	18,454,324	386,022,800
170	7,315,313	130,833,248	10,900,892	273,405,757	18,216,204	404,239,004
180	7,203,750	138,036,998	10,734,647	284,140,403	17,938,397	422,177,401
190	6,932,813	144,969,810	10,330,910	294,471,314	17,263,723	439,441,124
200	5,641,875	150,611,685	8,407,223	302,878,537	14,049,098	453,490,222
210	3,362,813	153,974,498	5,011,085	307,889,622	8,373,898	461,864,120
220	1,083,750	155,058,248	1,614,947	309,504,569	2,698,697	464,562,817
230	0	155,058,248	0	309,504,569	0	464,562,817
	155,058,248		309,504,569		464,562,817	

NOTE: "BSWL" means below the static water level in 1993.

Table B-IV, 2.5 Groundwater Quality

<Calidad de Agua Subterránea>

														HEALTH SIGNIFICANCE											
TYPE	NAME	DATE	TEMP.	pH	TDS	Ca	Mg	Na	K	SO4	Cl	CO3	HCO3	NO3	As	F	Cd	Cr	Pb	B	Fe	Mn	Zn	Cu	Al
			(C)			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
(STANDARD)				6.0-8.5	1000		125	200		250	250			10.00	0.050	1.50	0.005	0.050	0.050		0.30	0.10	5.000	1.000	0.20
JICA WELL	J-G	Dec-94		7.5	747	37.5	28.4	159.2	17.2	95.0	83.7	0	326		0.055		0.002	0.010	0.030	2.59	4.30	0.61	0.480	0.011	0.10
	J-10	Dec-94		6.1	623	82.2	10.9	68.1	35.0	325.0	49.6	0	52		0.460		0.005	0.020	0.040	0.39	18.00	1.40	6.710		
SPRING	H-0	Dec-93	16.1	8.1	388	47.6	13.0	78.6	7.5	98.7	32.6	0	110		0.060					1.00					
		Jan-94	15.0	8.0	384	47.0	9.8	81.2	7.7	95.9	32.9	0	110		0.060					1.00					
		Average	15.6	8.04	386	47.3	11.4	79.9	7.6	97.3	32.8	0	110		0.06					1					
	H-3	Nov-93	15.5	8.3	466	41.5	5.9	76.6	6.4	88.3	40.0	0	207		0.030					1.20					
		Dec-93	20.3	7.9	453	40.5	5.8	76.0	6.7	82.7	36.4	0	205		0.030					0.90					
		Jan-94	17.0	8.8	456	41.3	5.8	75.9	7.1	85.9	36.6	0	204		0.030					1.10					
		Average	17.6	8.3	458	41.1	5.8	76.2	6.7	85.6	37.7	0	205		0.03					1.07					

Note: Sampled and Analyzed by DGA and the JICA Study Team.
Spring waters are analyzed by the Arturo Prat University.

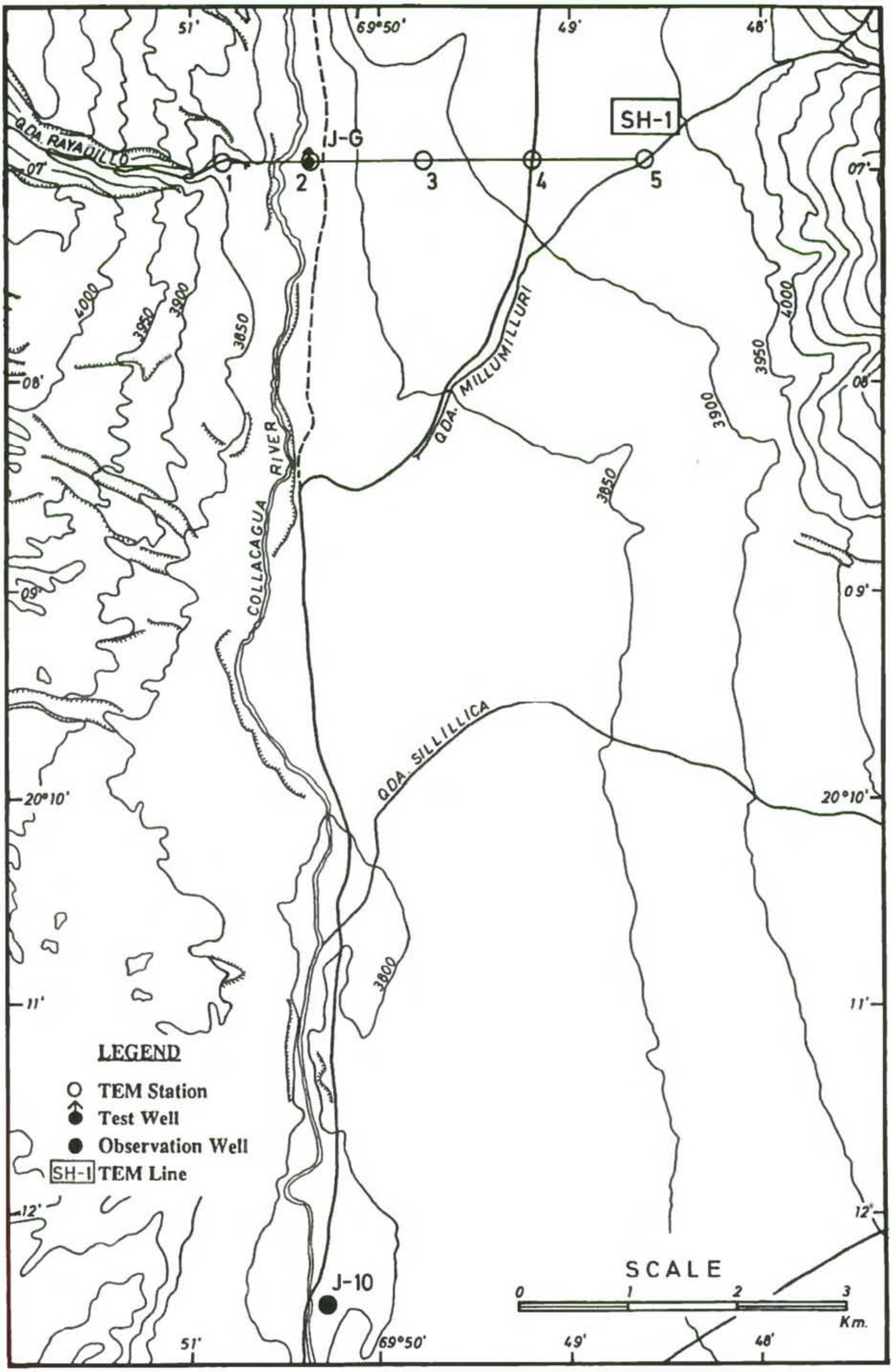


Fig. B-IV, 2.1 Location of TEM Station and Test/Observation Well in Salar del Huasco Area

<Ubicación de las Estaciones TEM y pozos de Prueba y Observación en el area del Salar del Huasco >

SH-1 Nº 2 (JICA Well J-G)

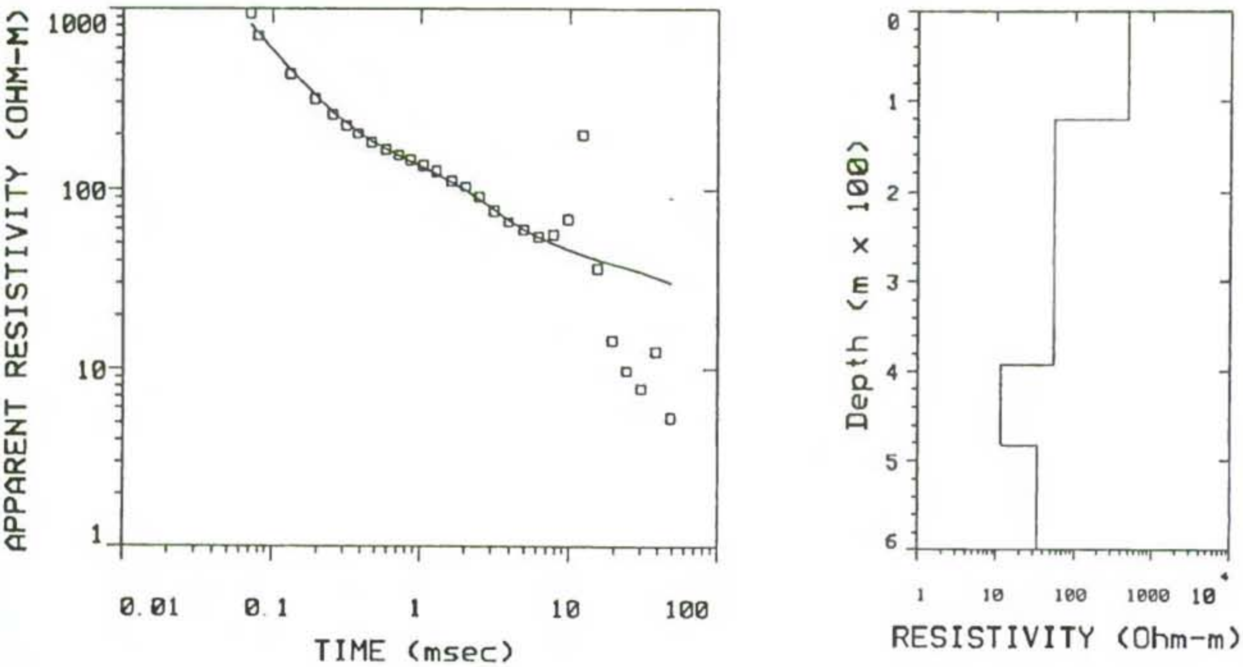


Fig. B-IV,2.2 Measured Aparent Resistivity Curves and Inverted Geoelectrical Section in Salar del Huasco Area

< Curvas de Resistividad Aparente Medidas y Secciones Geoeléctricas Invertidas en el Area del Salar del Huasco >

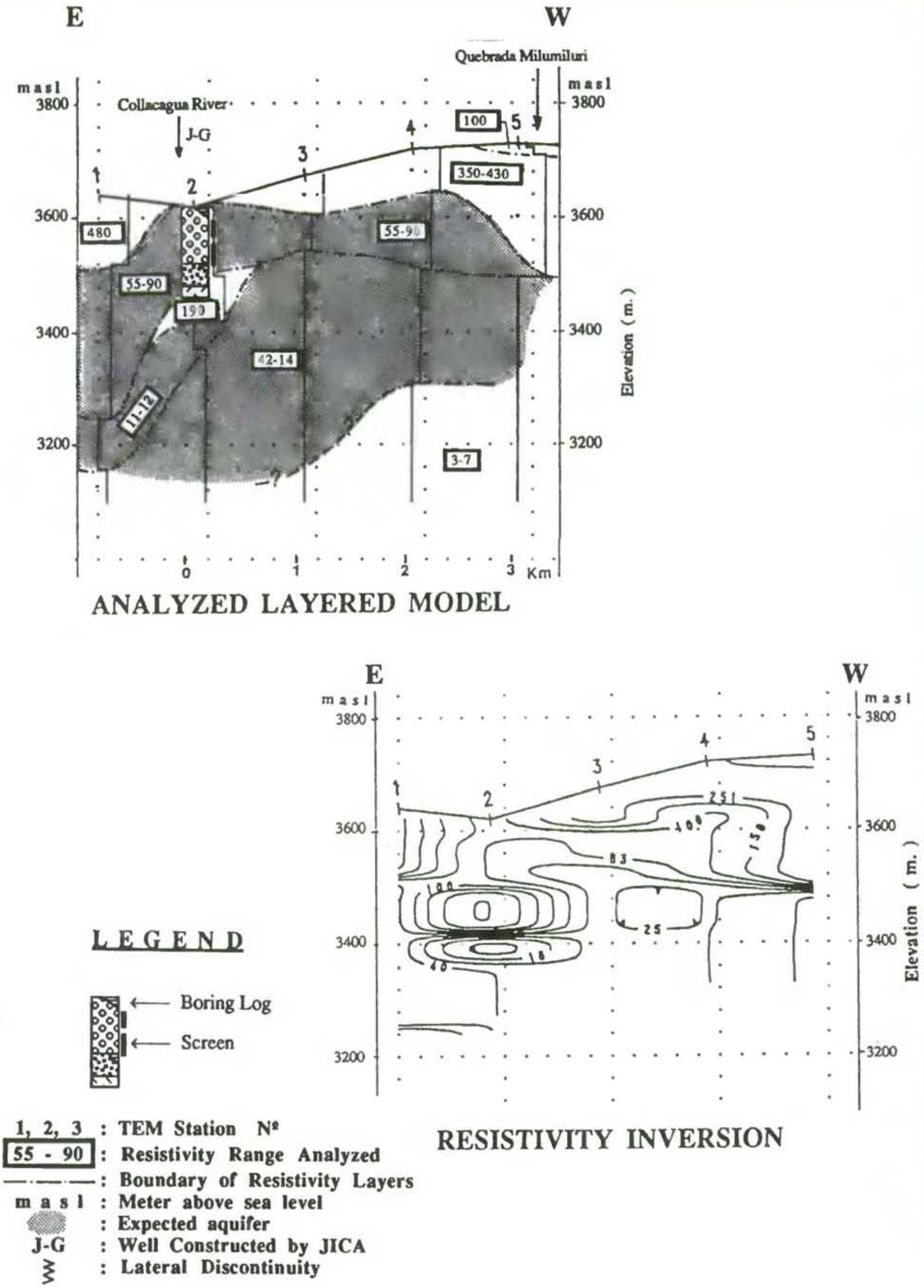


Fig. B-IV,2.3 Analized Resistivity Profile of SH-1 in Salar del Huasco Area

< Perfil de Resistividad Analizado del SH-1 en el Area del Salar del Huasco >

Fig. B-IV, 2.4 Well Data for J-G (Sheet No. 1)

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

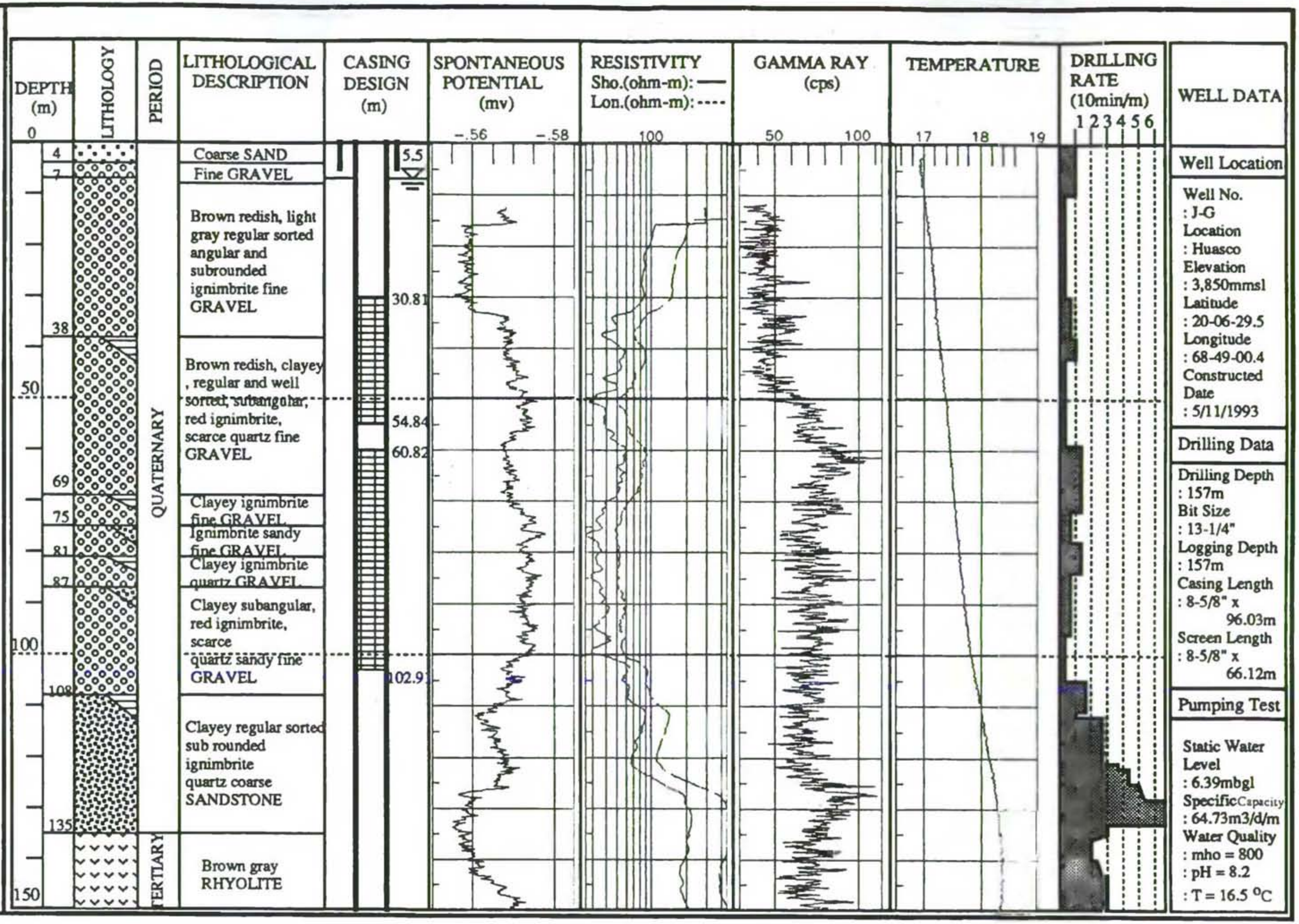


Fig. B-IV, 2.4 Well Data for J-G (Sheet No.2)

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

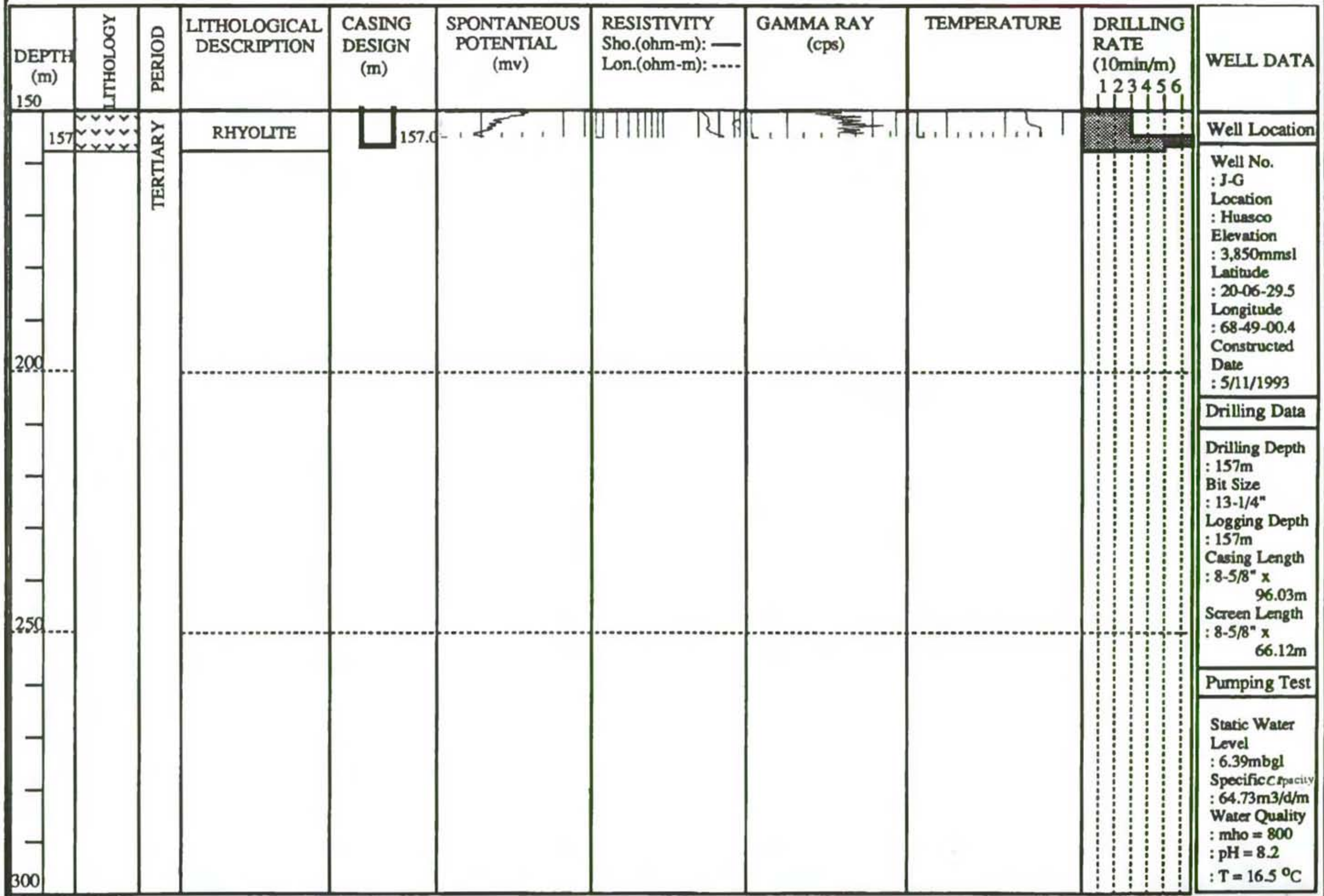
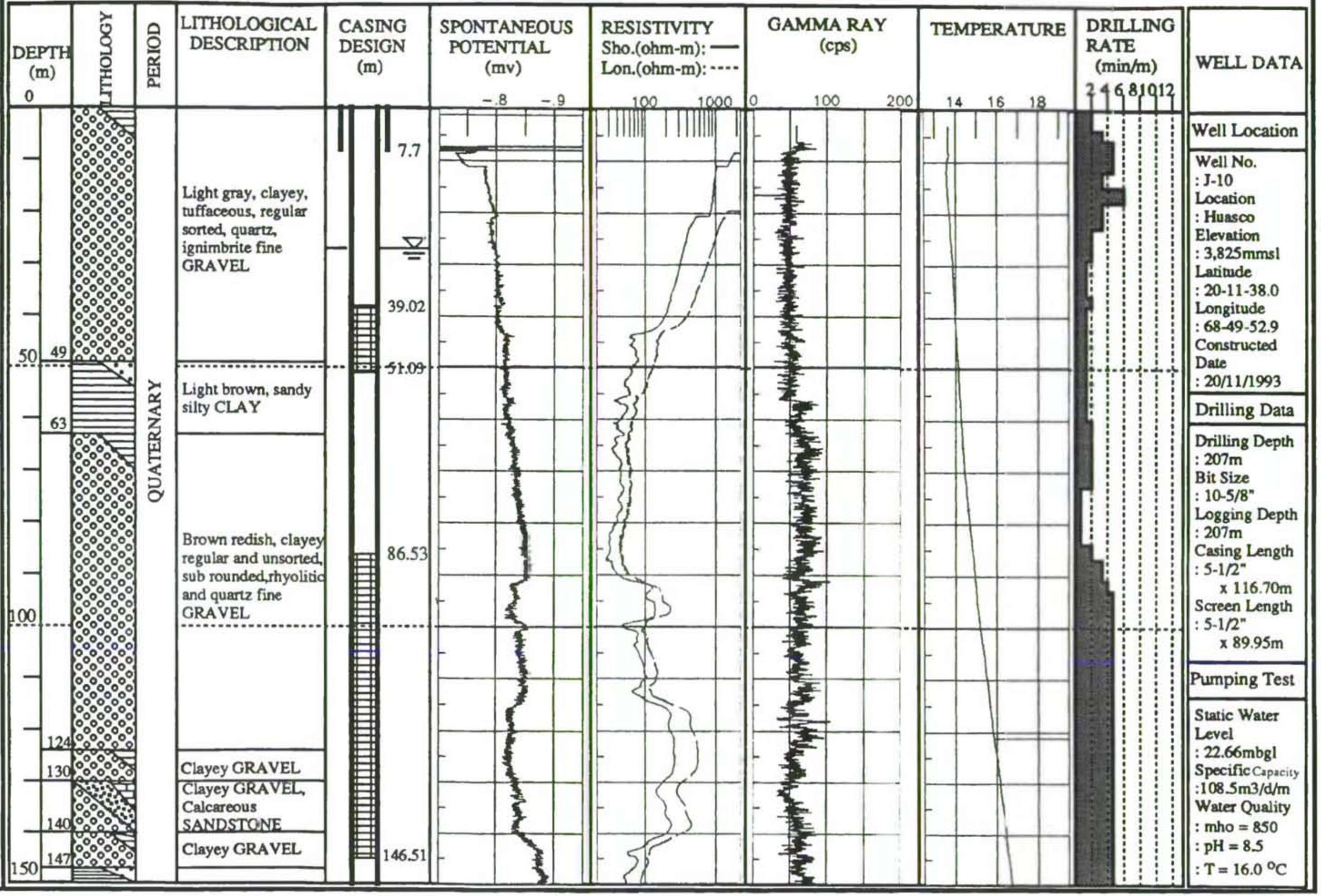


Fig. B-IV, 2.5 Well Data for J-10 (Sheet No. 1)

< *Información del Pozo J-10 (Hoja Nº 1)* >



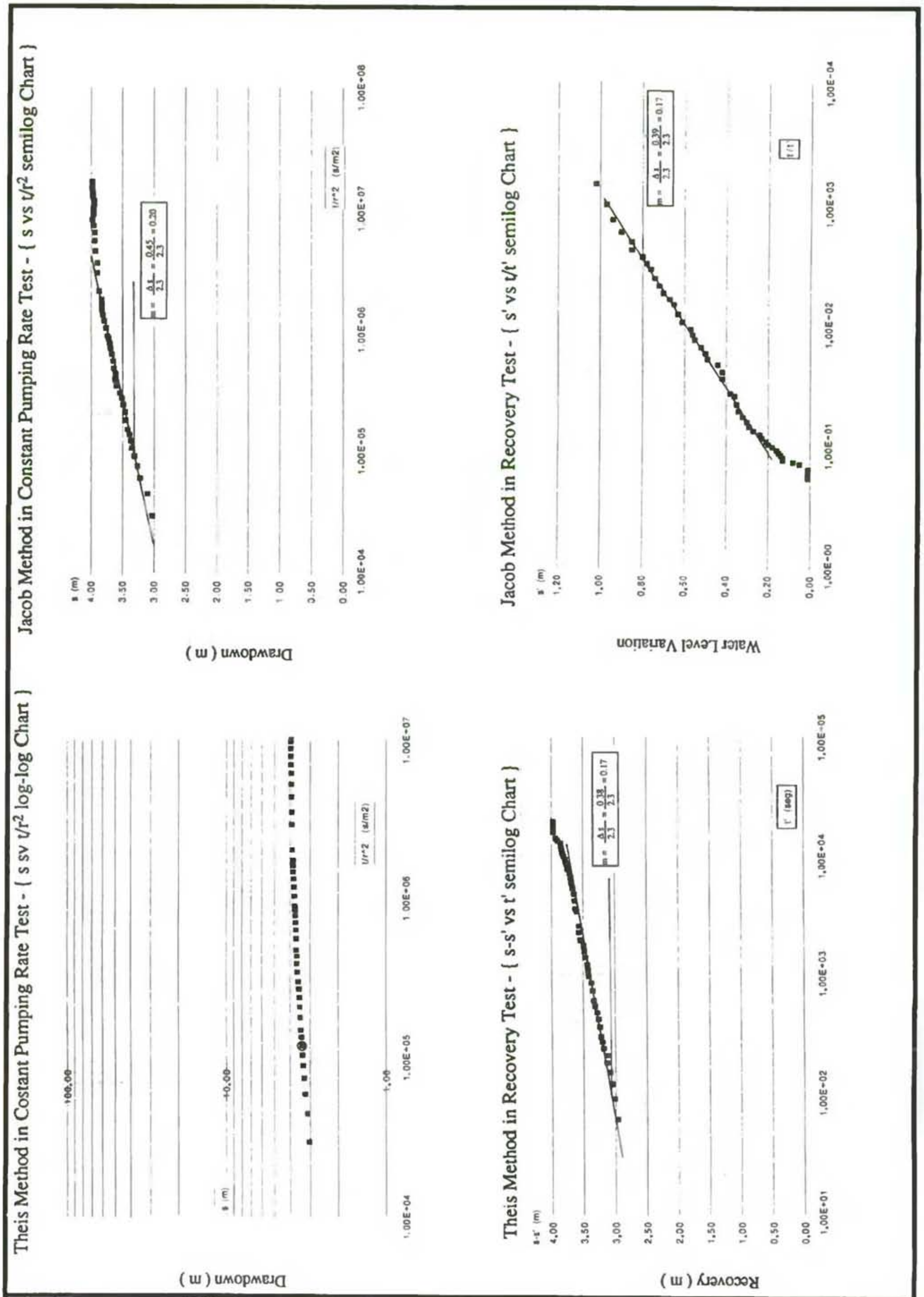
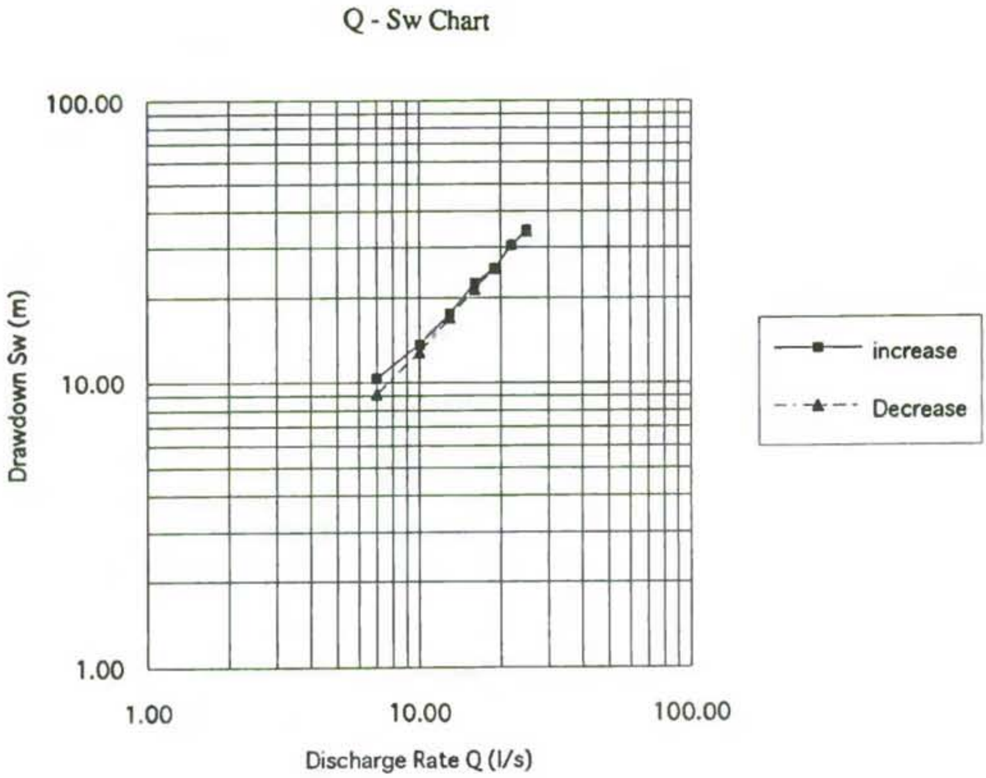


Fig. B-IV, 2.7 Graphs for Theis and Jacob Method Analysis (Well No.J-10)

< Gráficos para los Métodos de Análisis Theis y Jacob (Pozo Nº J-10) >



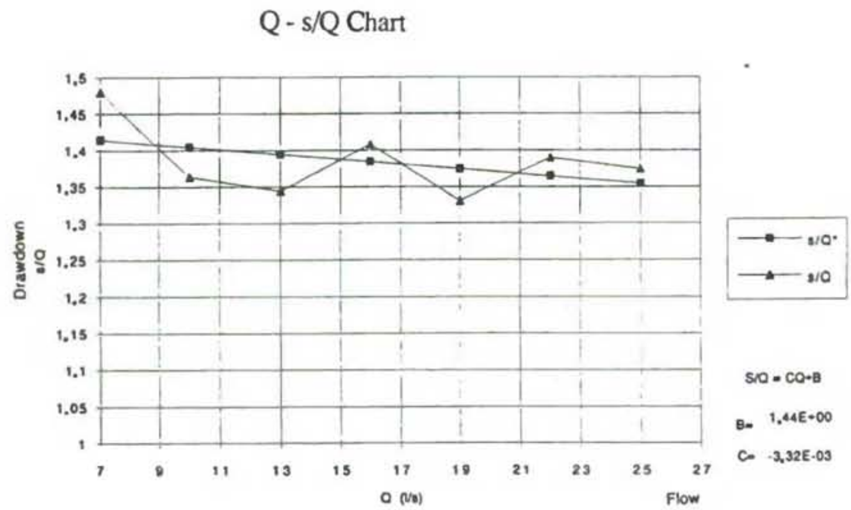
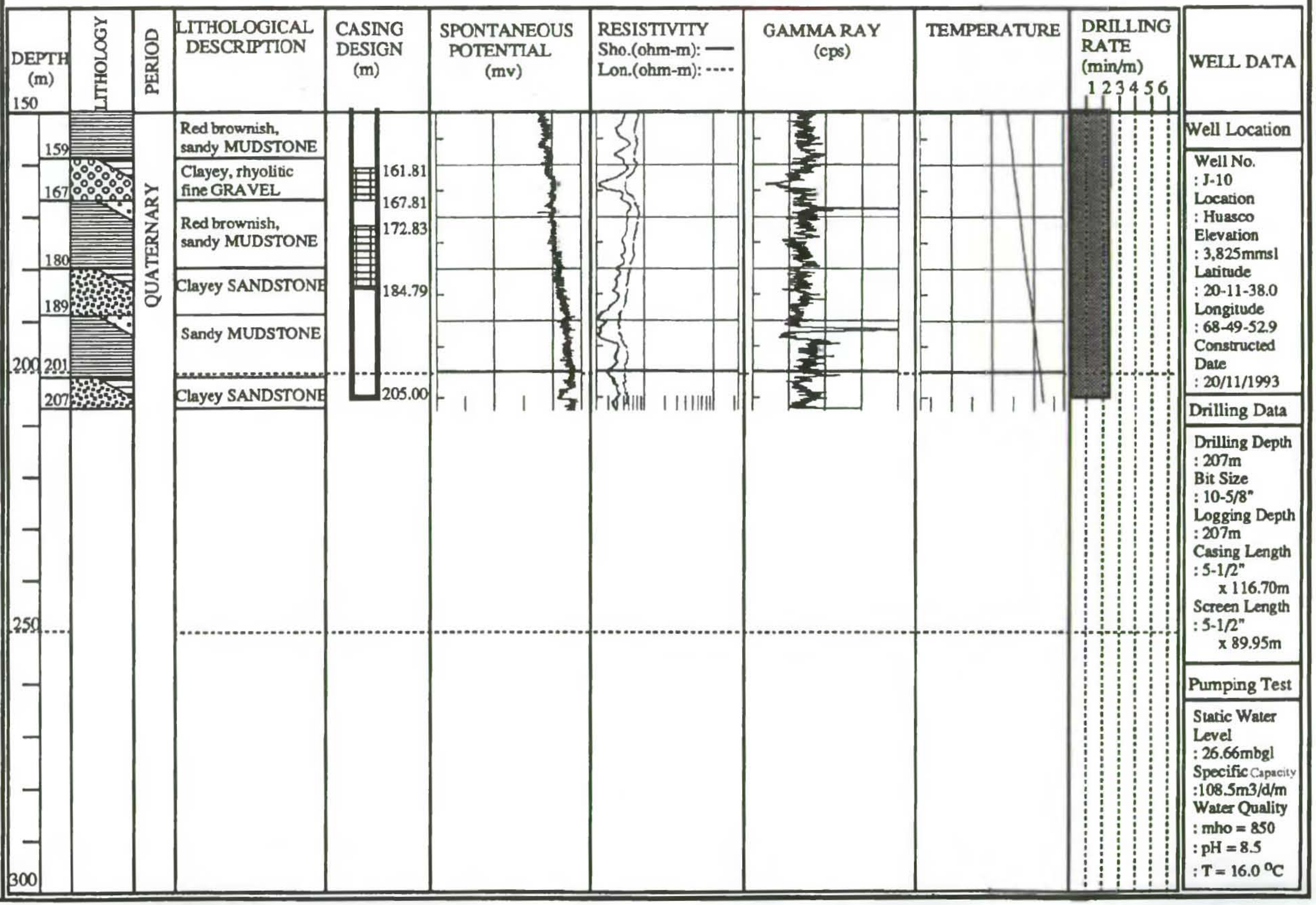


Fig. B-IV, 2.8 Graphs for Step Drawdown Test (Well No.J-G)

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

Fig. B-IV, 2.5. Well Data for J-10 (Sheet No. 2)

< Información del Pozo J-10 (Hoja Nº 2) >



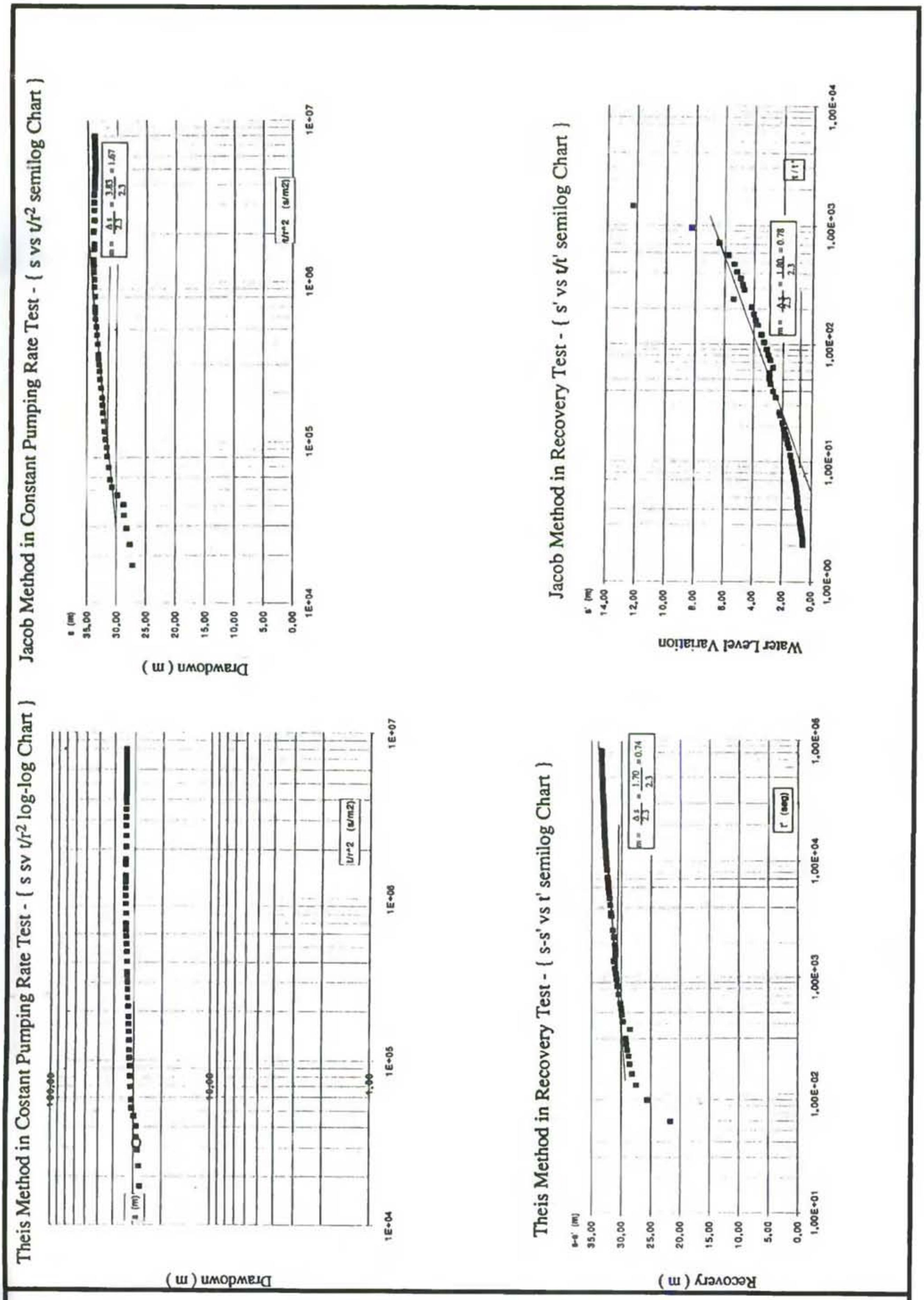
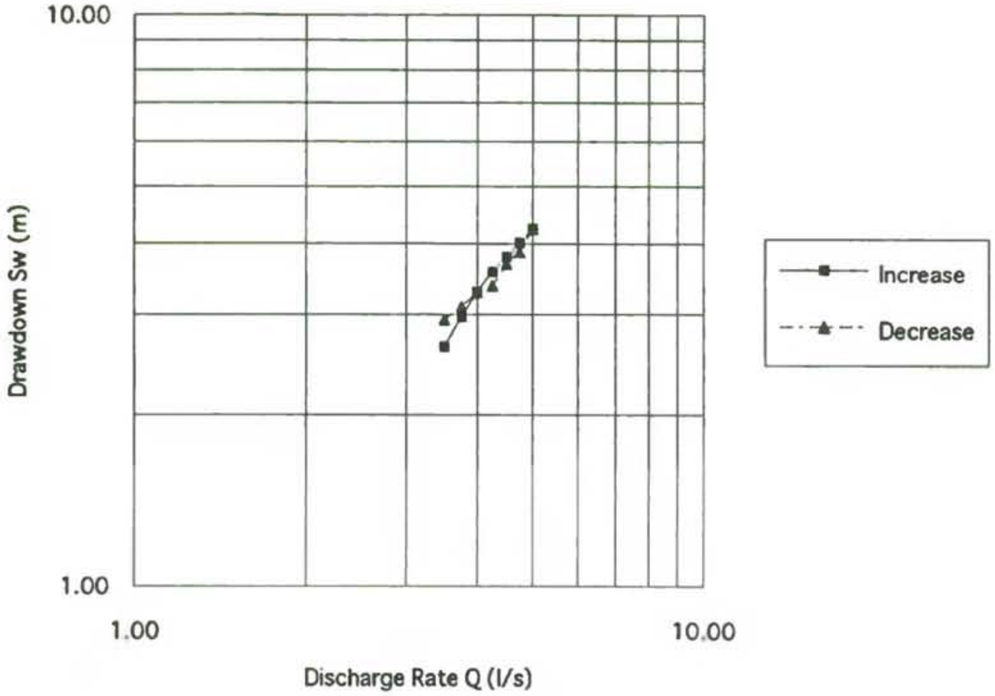


Fig. B-IV, 2.6 Graphs for Theis and Jacob Method Analysis (Well No.J-G)

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

Q - Sw Chart



Q - s/Q Chart

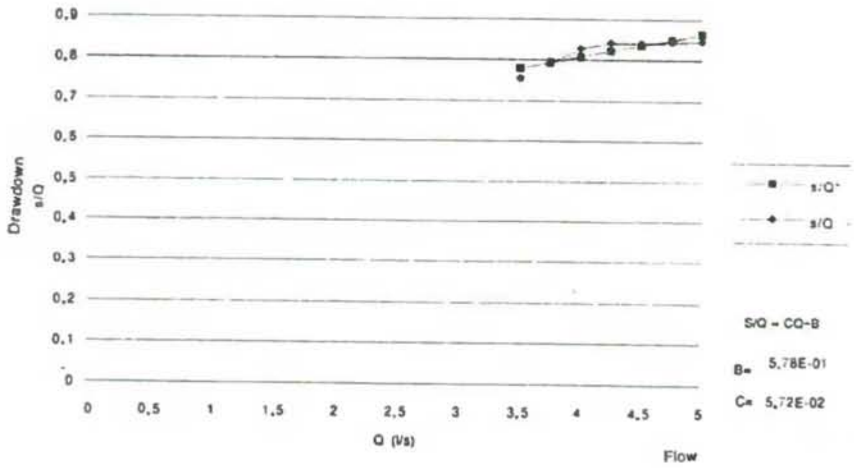


Fig. B-IV, 2.9 Graphs for Step Drawdown Test (Well No.J-10)

< Gráficos Prueba de Gasto Variable (Pozo Nº J-10) >

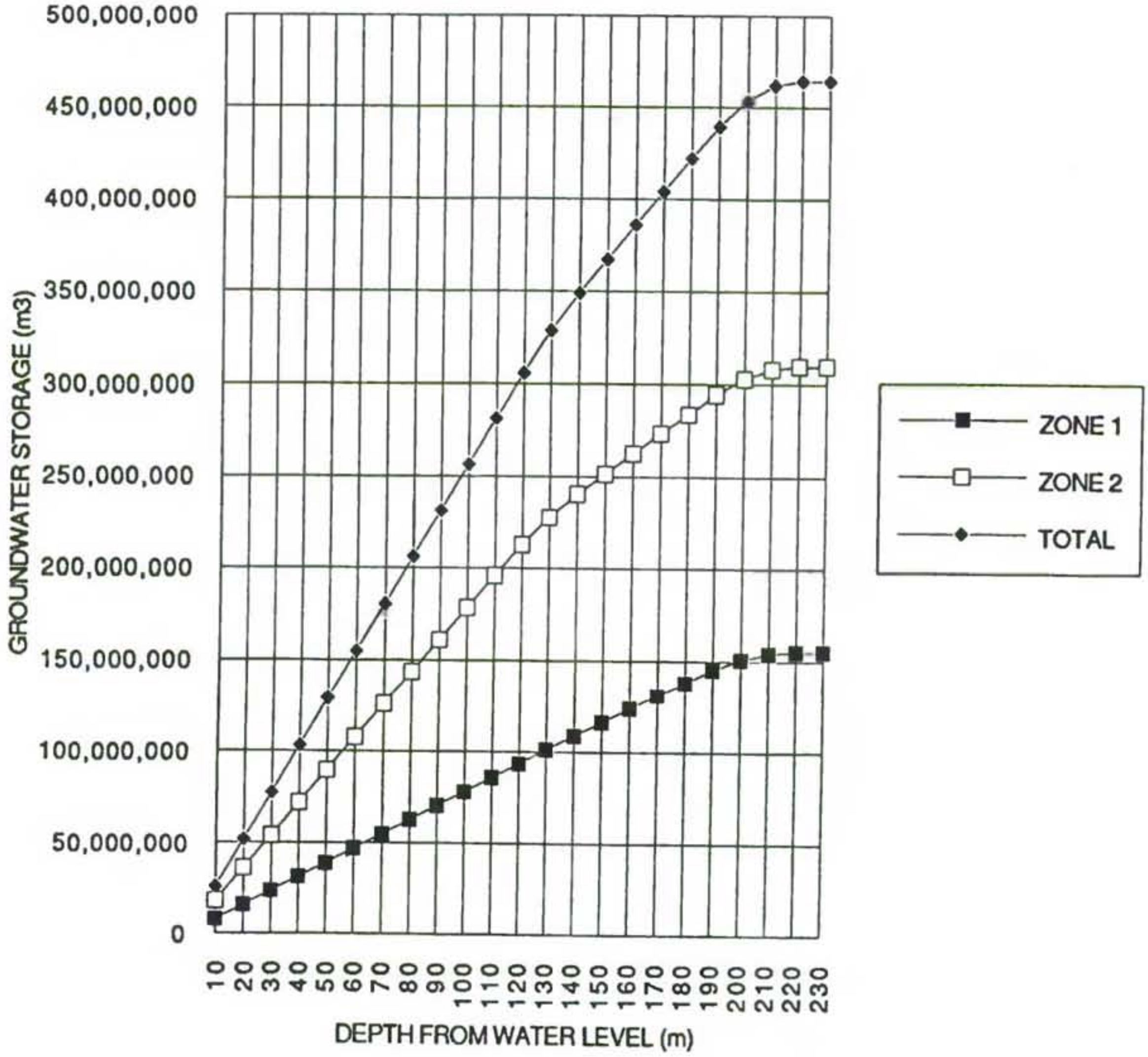


Fig. B-IV 2.10 Groundwater Storage

<Reservas de Agua Subterránea>

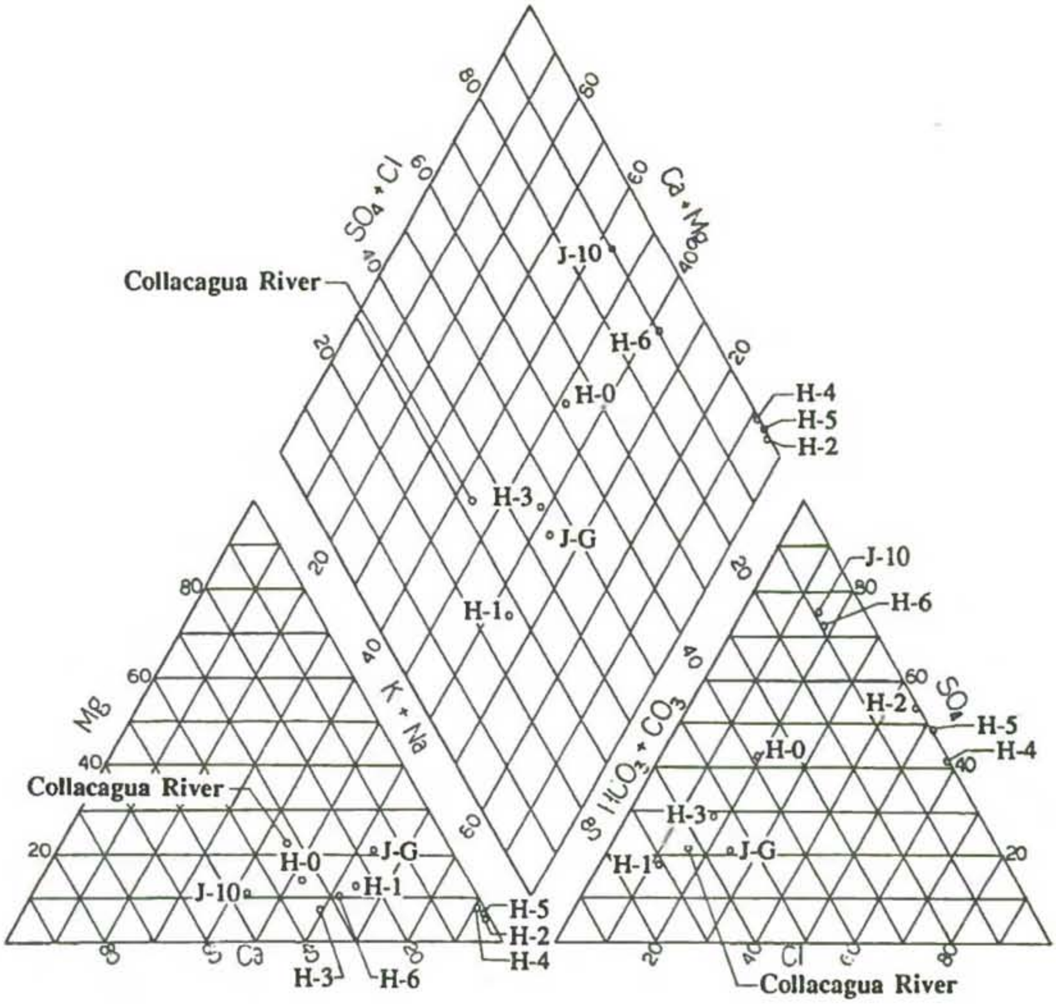


Fig. B-IV, 2.11 Trilinear Diagram of Maayor Ions

< Diagrama Trilinear de Iones Principales >

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