to financial difficulties and inavailability of drilling equipment, and is now the subject of this present study.

4.2 Existing Water Supply Facilities

4.2.1 Water Sources and Intake Facilities

The Ventanilla water supply system has no water source within the city boundries, and depends on pumped groundwater from Zapallal, 4km northeast of the centre of the city.

At present there are 3 wells, as shown in Fig.4.1 and 4.2, their capacities and other particulars are given in table 4.1.

It was found from the July 1980 investigation that out of the three wells initially drilled, only well No. 1 maintained planned discharge rates, while well No. 2 was inoperative because of motor trouble and well No.3 although in operation, had a discharge rate and operating time well below designed values.
Furthermore, the present investigation revealed that after well No. 2 resumed operation well No. 1's discharge rate dropped by 30% and well No. 3 became inoperative because of a large fall in the groundwater table.

The yearly variation in the groundwater table is shown in Fig. 4.3. Because of the above mentioned phenomenon, the Ministerio De Agricultura, in charge of the groundwater development rights, decided to prohibit development in this area. This necessitated measures to find new water sources.

4.2.2 Transmission Facilities

As shown in Fig. 4.1 and 4.2, the water taken from each well is sent to the valve chamber and then pumped to the pressure reducing chamber which is located on the top of the mountain laying between Zapallal and Ventanilla. It is then taken by force of gravity through two transmission pipe lines to storage reservoir No. 1.

There are two pipes installed of reservoir No. 1. One is a distribution pipe of 10 inch diameter, and supplies water to residential areas A2 and A3, and to the industrial area higher up. The other a connection pipe is of 8 inch diameter, linking reservoir No. 1 with reservoir No. 2.

There are also two pipes at reservoir No. 2. Both of them serve as distribution pipes, one supplying water to the residential area A1 and the commercial area, and the other supplying water to the industrial area lower down.

Since the height of reservoir No. 2 is lower than that of reservoir No. 3, gravity can obviously not be used to convey the water. It needs therefore, to be pumped up, however, at the moment the pump is dismantled so the water has to be taken to reservoir No. 3 by means of a pipe branching from the connection pipe between reservoirs No. 1 and No. 2.

4.2.3 Storage Facilities

At present there are three storage reservoirs in Ventanilla, with capacities, form and construction as shown in table 4.2.

The total storage capacity is therefore some 4,000 m.cu. According to available data, the present planned maximum daily requirement is 13,740 m.cu. (159 litres/sec x 86,400) Consequently, the present storage capacity is equivalent to only 7 hours of the maximum daily requirement. This is rather less than that specified in Japanese water supply works, i.e. 8 to 12 hours equivalent of the maximum daily requirement.

In the meantime, E.S.A.L. has arranged to repairs it considers necessary to damaged valves at the reservoirs.

4.2.4 Distribution System

The water Distribution system of Ventanilla has been designed so that the entire area to be served can be divided into several distinct districts according to their respective topographical conditions and consumers. In addition it has also been planned

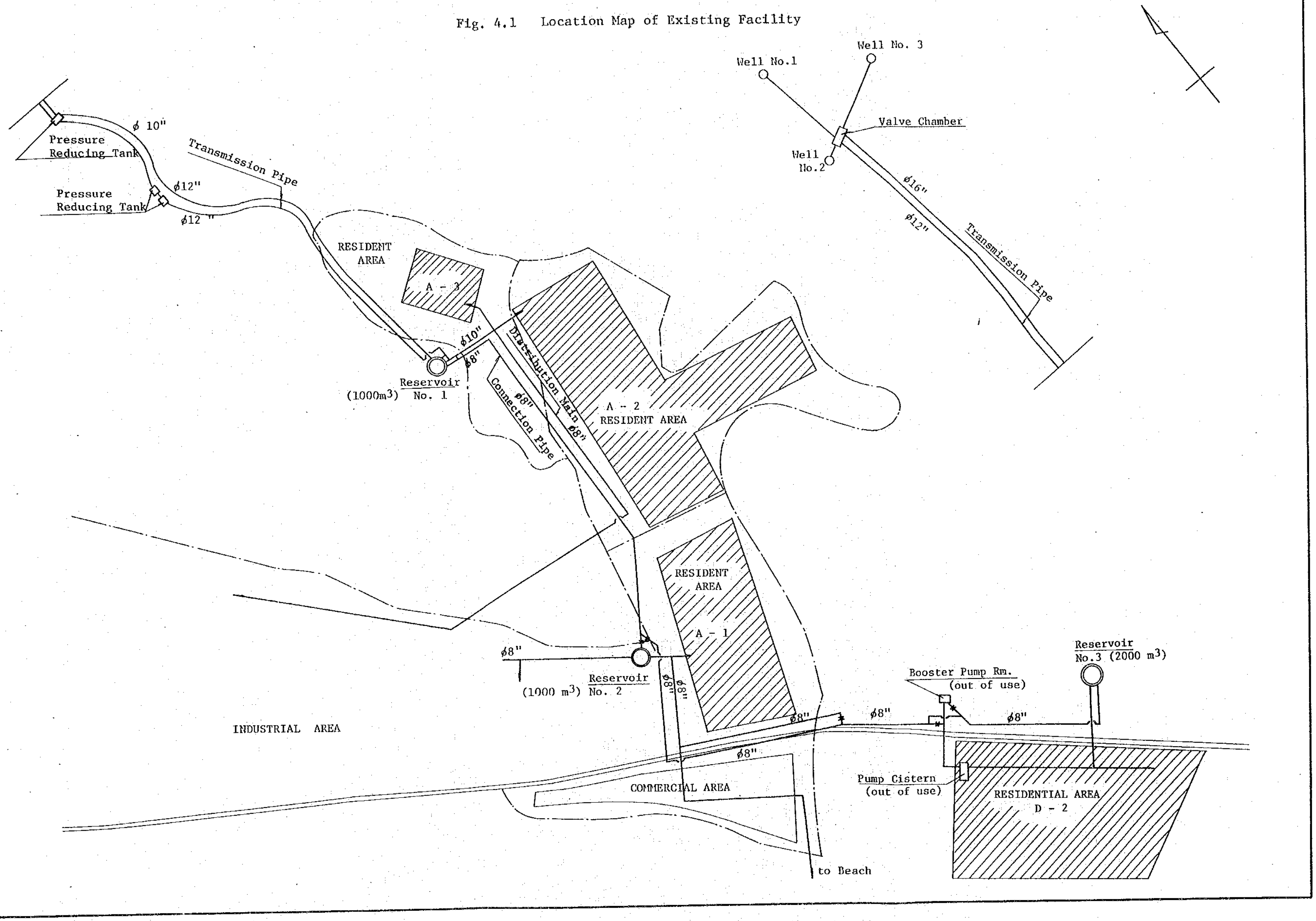
Table 4.1 Operational Profile of Existing Wells

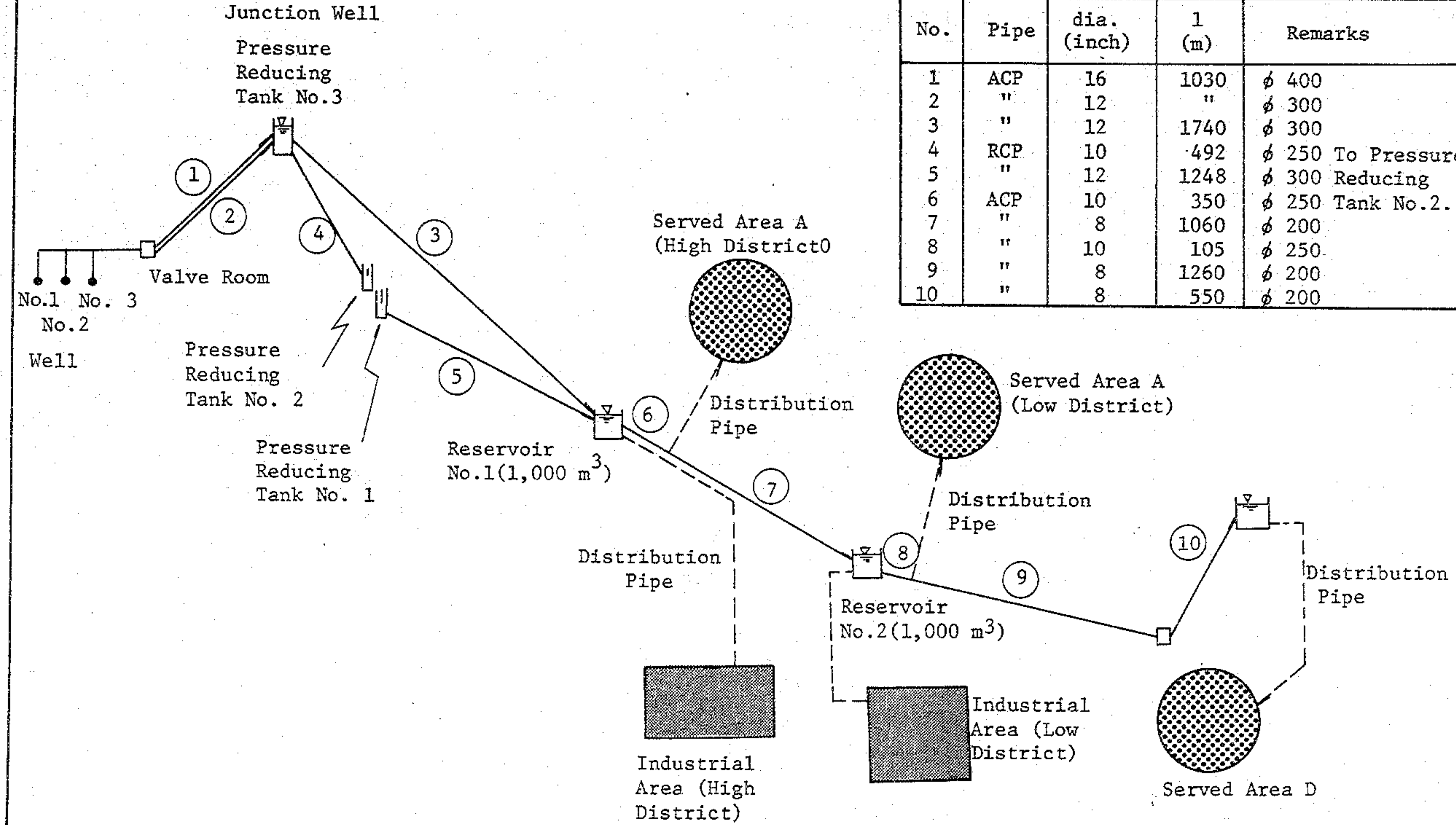
Well No.	Year of Construction	Well Depth	Planned Discharge	Discharge Rate(ℓ/s) and Operation Hour(hd)	
				Jul '80	Sep '80
No.1	1961	80	60	70ℓ/s 24h/d	50ℓ/s 24h/d
No.2	1961	80	60	Damaged	70ℓ/s 24h/d motor damaged 1976
No.3	1970	80	60	20ℓ/s 13h/d	No.2 inoperative due to fall in water table

Table 4.2 Profile of Reservoirs

Reservoir No.	Capacity	Shape	Structure
1	1,000 m.cu.	Cylinder	Prestressed Conc.
2	1,000 m.cu.	"	"
3	2,000 m.cu.	"	"

Fig. 4.1 Location Map of Existing Facility





Existing Pipes

No.	Pipe	dia. (inch)	1 (m)	Remarks
1	ACP	16	1030	ϕ 400
2	"	12	"	ϕ 300
3	"	12	1740	ϕ 300
4	RCP	10	492	ϕ 250 To Pressure
5	"	12	1248	ϕ 300 Reducing
6	ACP	10	350	ϕ 250 Tank No.2.
7	"	8	1060	ϕ 200
8	"	10	105	ϕ 250
9	"	8	1260	ϕ 200
10	"	8	550	ϕ 200

Fig. 4·2 Existing Conveyancing and Distribution System

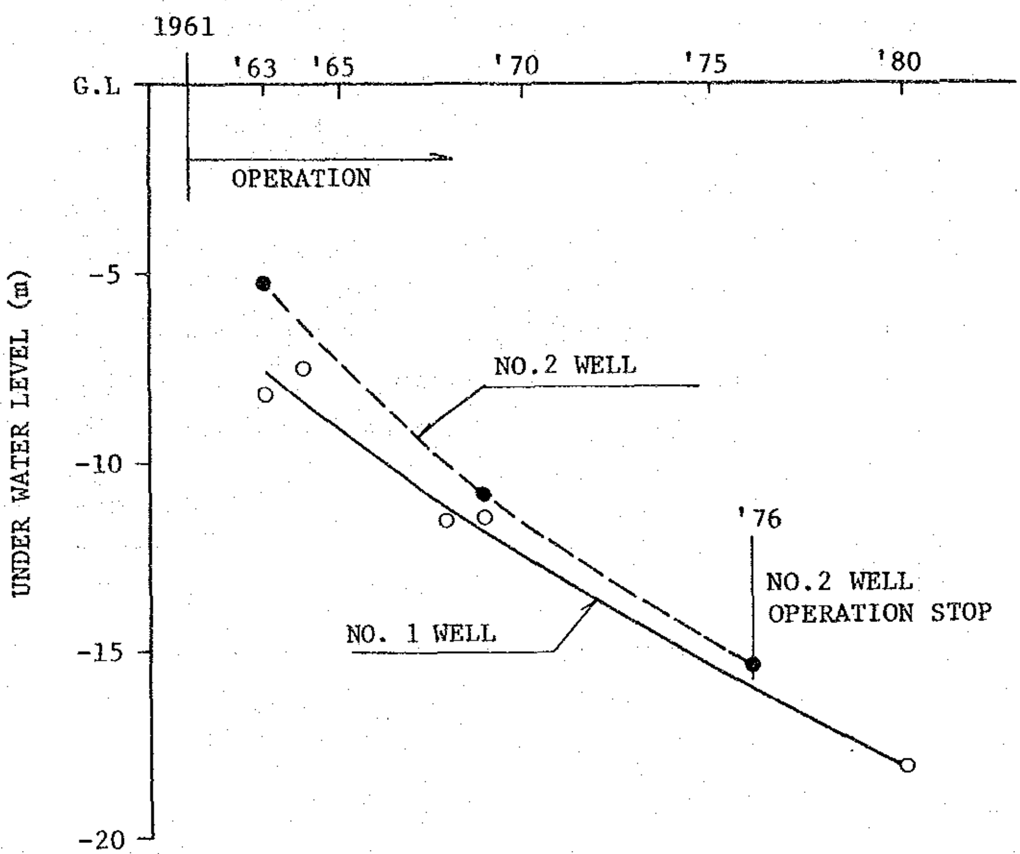


Fig. 4.3 VARIATIONS IN THE GROUND WATER TABLE IN ZAPALLAL

so as to supply water by means of gravity from the reservoirs.

Chlorination is not practiced as the water is extracted from deep wells.

The distribution pipes form an extensive network and they are considered to be well maintained. The pipe material is exclusively AC pipe with diameters of 3, 4, 6 and 8 inches. Valves and fire hydrants have been installed where necessary.

There are about 2,900 service faucets from the mains to consumers, however, none of these have as yet meters to measure water consumption. Of the service faucets, those installed in the Miguel Grau housing estate in district D, fed by reservoir No. 3, suffer from big leakages due to severe corrosion caused by chlorine containing soil.

4.2.5 Water Charges

Water rates for each catergory of use are shown below

Domestic	(Soles/month)	: 250 - 370
Commercial	(Soles/month)	: 420
Industrial	(Soles/month)	: 1,000 - 31,000

[* 1 Soles ≑ 0.67 yen]

Since there aren't any water meters, water charges have been based on the size of connections and have collected on a monthly basis for each connection.

4.3 Problems and Means of Improvement

4.3.1 Outline of Facilities as Planned by Peru

An outline of the planned facilities required by the Government of Peru was sent with the official note to the Japanese Ministry of Foreign Affairs through the Japanese Embassy in Peru. However, there was no detailed description with respect to the work.

With respect to the facilities therefore, only verbal information and some drawings were received. In addition a plan by the Ministerio de Pesqueria to supply water to a fishing base, to be constructed in the future, was also acquired.

From the above information and other data available, 6 deep wells (Q = 50 litres/sec/well) are to be constructed at the new water source, from which, the water is to be taken to Ventanilla by means of the route shown in Fig. 4.4, and extended to the commercial district via districts A in Zapallal and Ventanilla.

Other work is to include construction of 3 storage reservoirs (3,000 m.cu.) in addition to the existing reservoirs (4,000 m.cu. in all) to cope with future demands.

The above outlines the facilities planned by the Government of Peru and is summerized below.

1) Intake Facilities

deep wells, 6 off,	discharge rate - 50 ℓ/s/well	
	total discharge	300 ℓ/s

2) Distribution Facilities

Pumping System

pipes	dia = 20", ACP, class A-10 x	8,207m
	dia = 16", ACP, class A-10 x	868m
	dia = 12", ACP, class A-10 x	700m
	dia = 10", ACP, class A-10 x	1,050m

Gravity System

pipes	dia = 14", ACP, class A- 5 x	1,585m
	dia = 12", ACP, class A- 5 x	1,839m

Note

class A-10 has a maximum designed static water pressure of 10 hg/sq.cm.

class A- 5 has a maximum designed static water pressure of 5 hg/sq.cm.

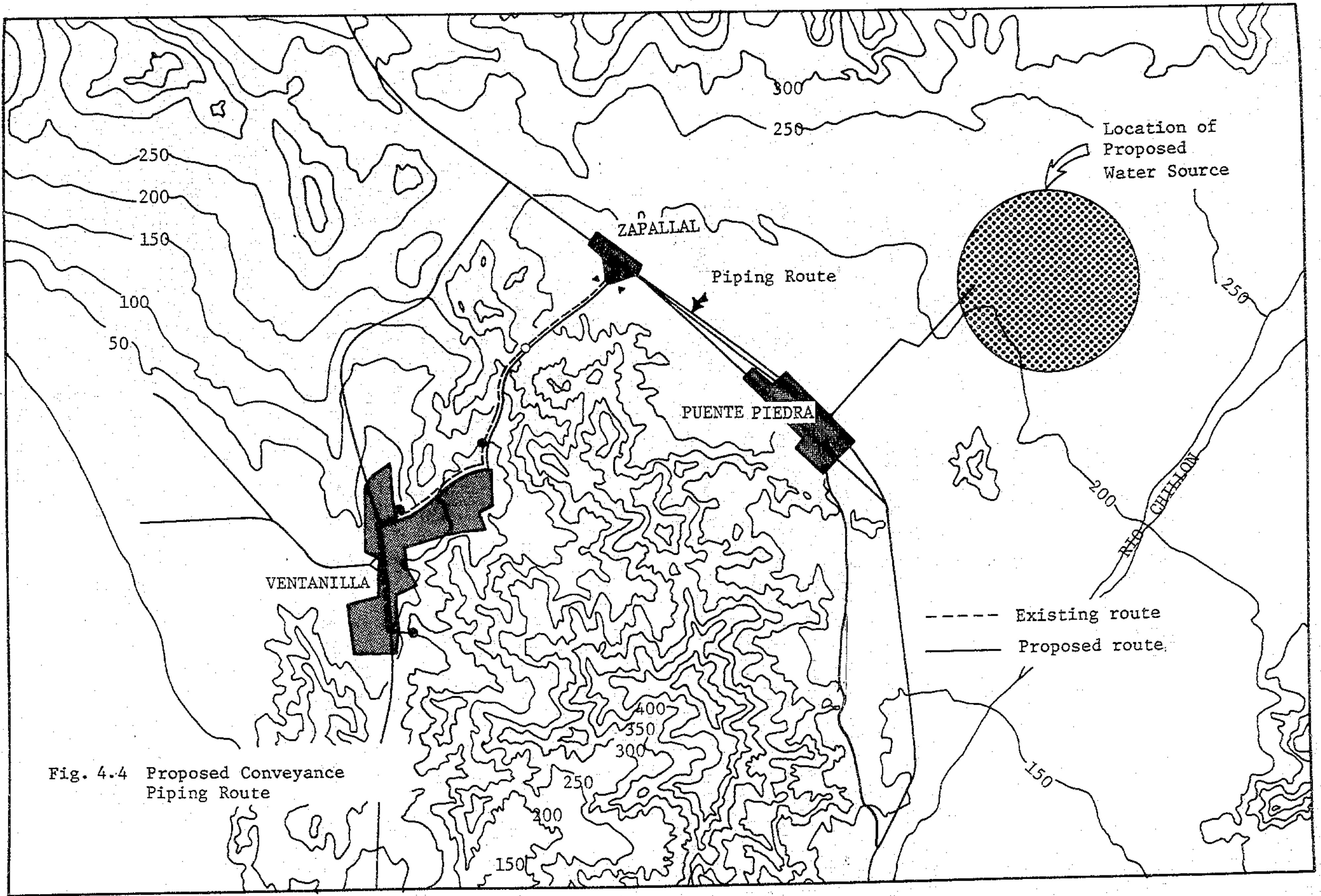


Fig. 4.4 Proposed Conveyance Piping Route

3) Storage Facilities

reservoirs, 3 off, prestressed concrete construction
effective capacity 3,000m.cu. each.
total capacity 9,000m.cu.

4.3.2 Problems and Means of Improving Facilities Planned by Peru

1) Intake Facilities

Intake facilities are planned to be constructed 2 - 4 km. northeast of Puente Piedra to extract the groundwater.

According to the planning report of E.S.A.L., 6 wells with a discharge rate of 50 ℓ/sec (4,320 m.cu./day) each, are to be constructed, and are to have an operational period of 18 hours per day to met the future water demands of Ventanilla.

Following is a comparison of well discharges and the future water demand of Ventanilla.

Planned total discharge

50 ℓ/sec/well x 6 wells x 86,400 sec/day x 18/24
= 19,440 m.cu./day.

Planned maximum daily supply

254 ℓ/sec x 86,400 sec/day = 21,950 m.cu./day

Therefore, the planned total discharge is less than the required maximum daily supply even assuming the planned discharge rate of 50 ℓ/sec is attained. A description of the optimum discharge rates of the wells is given in detail in section 5.

2) Transmission Facilities

. Pipeline Routes

In planning pipelines between the water source and Ventanilla, there exists a topographical problem; i.e. there are mountains laying between the water source and Ventanilla with heights of between 350 and 400 m. while the water source is at a level

of 200 m. The shortest pipeline route therefore presents some difficulties, such as the necessity of using high lift pumps, pipe materials capable of withstanding high water pressures and installing pipes underground etc..

Taking into account these kind of topographical constraints when planning pipeline routes, the existing pipeline route running over the mountain pass between Zapallal and Ventanilla seems to be the most appropriate in terms of height. Although a detour is involved it is perhaps the optimum route.

If this route is adopted, the difference in height between the water source and the highest point in the mountain pass at 35 m. is not sufficient to present any real technical problems.

As shown in Fig. 4.4 the pipeline route planned by the Government of Peru starts from the water source in Puente Piedra and extends along the Panamerican Highway to Zapalla. It then runs along the same route as the existing pipeline.

Method of Transmission

According to the drawing showing the planned pipeline, from the Peruvian Government, a collection pipe from 3 wells is to be connected directly and in sequence to the transmission main and then taken to the pressure reducing chamber located in the mountain pass.

However, at the same time there is other information in respect to this plan which indicates the construction of 6 deep wells.

Clearly there is some conflict between the two, though, this is now thought to be due to a staging of the work. However, the number of wells is not a problem, whereas, connecting the wells to each other in order and then to the main pipeline is. This involves some operational problems, such as adjusting pressures etc., eventually resulting in failure to reach designed discharge levels.

Considering also, the rather long distances involved, and the high mountains (about 9km from the water source area), the pressure at the delivery head of the pumps will have to be as high as 90 - 100m. Therefore, it is suggested that the wells be grouped in twos or threes, connected to a junction well and then the water taken to its destination.

This system has the merits of guaranteeing design discharge levels; protecting pipes etc., while the other one involves operational and maintainance problems leading to several problems for the system as a whole.

Regarding the method of transmission by means of gravity beyond the junction well in the mountain pass, the slope of the mountain is quite steep and protection for the pipes and inclusion of pressure reducing chambers will be necessary. In regard to this the plan prepared by the Ministerio De Pesqueria showed appropriately located pressure reducing chambers. The rough cost estimates shown in table 4.3.includes for pressure reducing chambers in the items to be provided domestically, although E.S.A.L. itself has not really been clear on this. However, installation of pressure reducing chambers must certainly have been taken into account in their plan.

Examination of the Capacity of the Transmission Pipes.

Before examining the capacity of the transmission pipes, the planned maximum daily supply, the planned water quantity (10% increase of maximum daily supply), the potential discharge rate of each well (50 ℓ/sec), the daily operational time period, etc., should be confirmed. They are as follows:-

Planned maximum daily supply : 254 ℓ/sec
(21,950 m.cu./day)

Planned intake acount : 254 ℓ/sec x 1.1 = 280 ℓ/sec
(24,140 m.cu./day)

Planned maximum amount of water transmitted : 280 ℓ/sec x 24/18 = 373 ℓ/sec

Well discharge : 50 ℓ/sec/well

Table 4.3 Estimated Budget

Foreign Contribution		
DESCRIPTION		COST
1. Wells and Rig	(1) Drilling and equipping of wells	113,000,000
	(2) Auxiliary equipment for the drilling rig	98,000,000
	(3) Additional material for the wells(50lps and 6 wells)	109,000,000
	(4) Spare parts and materials for drilling	53,000,000
	(5) Technical supervision	20,000,000
	Sub Total	393,000,000
2. Conveyance line	Conveyance line, equipment, spare parts and additional material	234,000,000
	Sub Total	234,000,000
3. Storage Reservoirs	Three 3000 m^3 storage tank equipment, spare parts and additional material	90,000,000
	Sub Total	90,000,000
4. Training	Training 8 Month/man	4,000,000
	Sub Total	4,000,000
Total		¥721,000,000

National Contribution	
DESCRIPTION	COST
Research, Definitive design, Constitution (Distribution pipes, Sewerage system, conveyence line, Storage Reservoirs), Materials, Various.	s/. 201,000,000
Total	s/. 201,000,000

Based on the above conditions the diameters of the water pipes as provided by E.S.A.L. are written below. Pipe materials and lengths included in the present plan are also given, table 4.4.

After looking at various information and data, about the pipeline tabulated above, it was found that the plan was prepared based on the plan for supplying water to the fishing base of the Ministerio De Pesqueria. Therefore, the lengths of each pipeline were checked according to this plan and the pipe diameters according to the planned quantities.

In the meantime, values for the pipe diameters as against flow rates designated by E.S.A.L., were made available. Table 4.5 gives these values along with the hydraulic gradients and velocities. From the table, it can be seen that the pipe diameters have been determined so as to maintain a hydraulic gradient of a constant 3%, which is considered reasonable.

Based on the above data, flow capacities for each pipe as against different hydraulic gradients were calculated and are shown in table 4.6.

With respect to the routing of the pumping system, there is some 35m in difference between the heights of Zapallal and Ventanilla through the mountains, see Fig. 4.5. Considering therefore the technical and economical inconveniences, such as the required capacities of pumping facilities, high pressure pipework, etc., involved with high values of the hydraulic gradient, it is recommended that the hydraulic gradient be 5‰ maximum.

Table 4.4 Summary of Transmission Pipes

Piping System	Pipe Dia (inch)	Class	Length (m)
Pump	20	A-10	8,207
"	16	"	868
"	12	"	700
"	10	"	1,050
Gravity	14	A-5	1,585
"	12	"	1,839

Table 4.5 Standard Pipe Diameters against Flow

Pipe Dia (inch)	Flow (ℓ/sec)	Hydraulic Gradient (‰)	Velocity (m/sec)
16	120	3	0.96
14	84	3	0.87
12	56	3	0.79
10	35	3	0.71
8	19	3	0.62

Note: The C value of the Hazen-Williams Formula = 110

Table 4.6 Flow Capacity of Each Pipe

Pipe Dia inch	Hydraulic Gradient (I)		
	3 ‰	4 ‰	5 ‰
10	35	41	46
12	56	66	74
14	84	98	110
16	120	140	160
20	220	250	280

Note : Calculated using the Hazen-Williams Formula with C=110

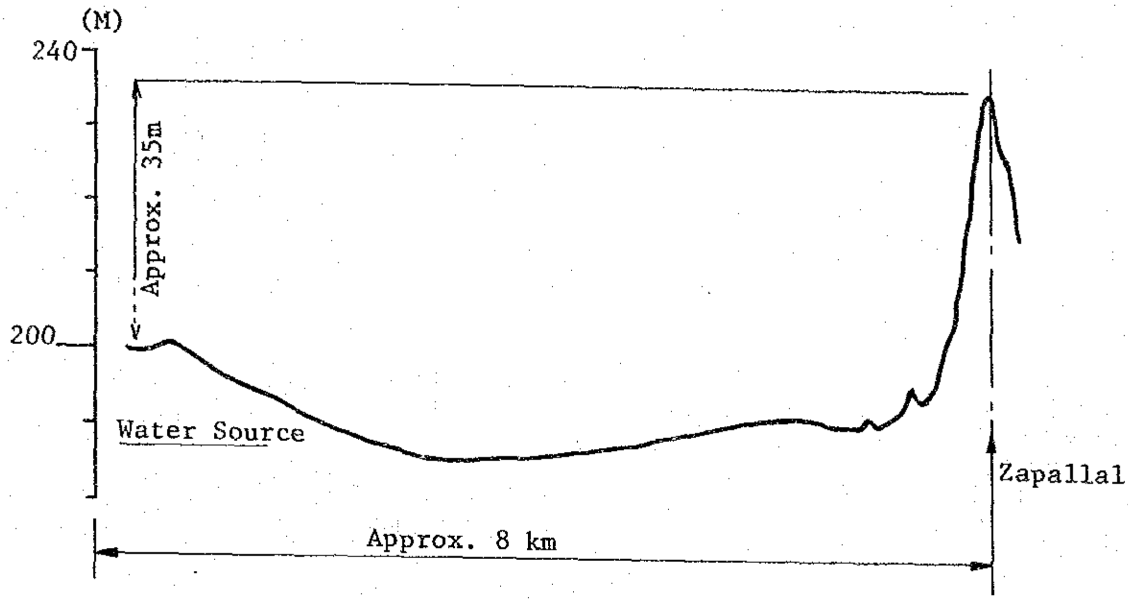


Fig. 4.5 Topographical Section of Pipe Route

Considering the above and also referring to the values shown in table 4.6, it can be seen that even a diameter of 20", which is presently being considered, along with 18 hours of well operation time is insufficient to give the designed maximum quantity.

With respect to the routing of the gravity system after the mountains, it is intended that the water be taken up to either the existing storage reservoir or to the new reservoir to be constructed near the city boundry, though this is still needs clarification.

Since the difference in height between the mountains and the delivery points is more than 100 m., it is thought that the present capacities of existing pipelines will be sufficient.

The capacities of the pipes, and relationships in terms of height between facilities, materials and distances, are tabulated in Fig. 4.6 and based on these, hydraulic calculations have been carried out.

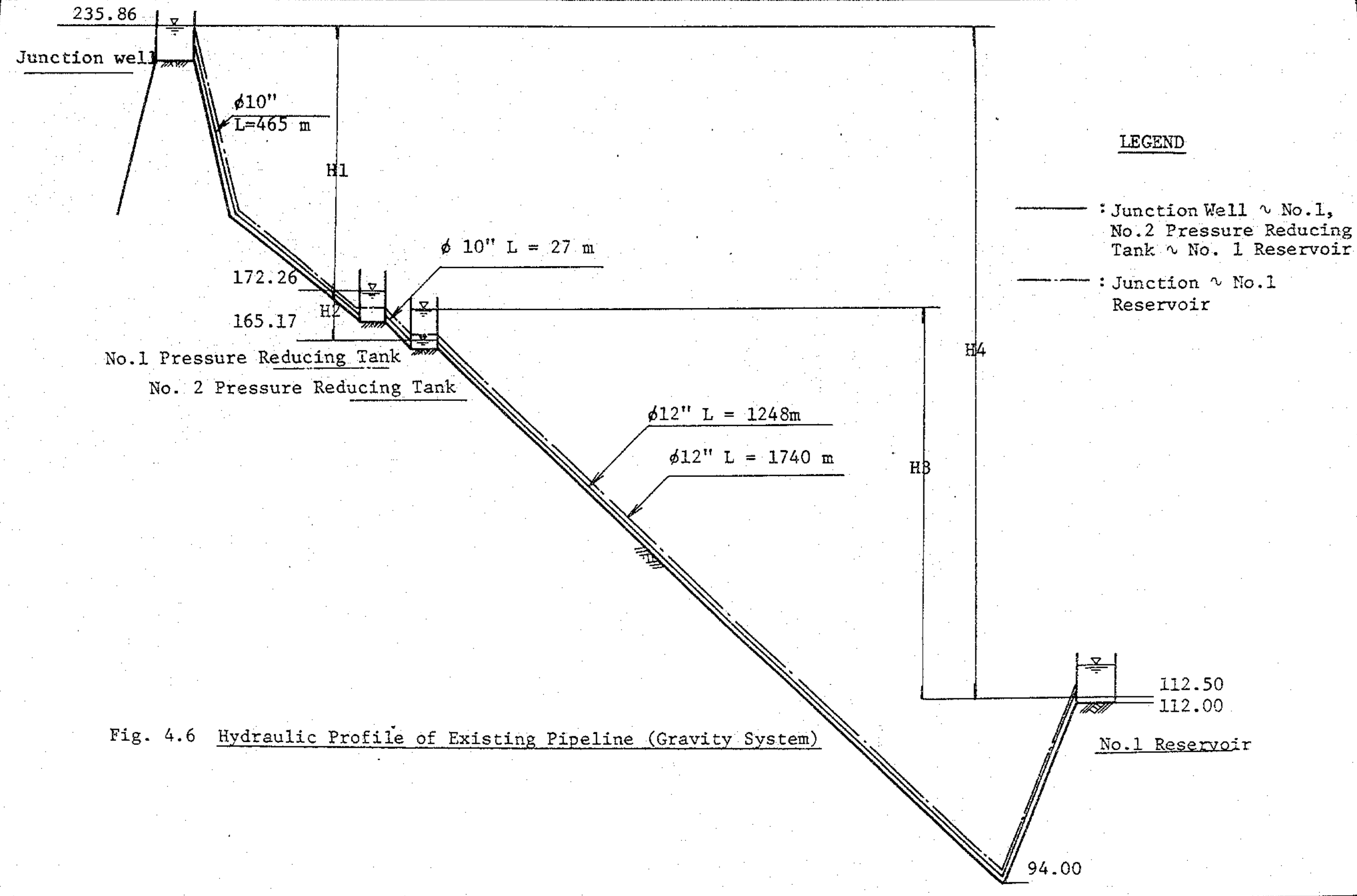


Fig. 4.6 Hydraulic Profile of Existing Pipeline (Gravity System)

A) Condition of Calculation

Friction loss coefficient	$\lambda = 0.02$
Influent loss coefficient	fe = 1.0
Bending loss coefficient	fb = 30° .... 0.073 45° .... 0.183 90° 0.99
Valve loss coefficient	fv = 0.0 (Full open)
Effluent loss coefficient	fo = 1.0

B) Existing pipe Route (1) ..... Route with pressure reducing chamber

(1) Junction well to No.1 Pressure reducing chamber

Dia.ϕ 10" (D = 0.25m), Length L = 465m

Difference of water level

$H_1 = 235.86 - 172.26 = 63.6\text{m}$

Number of bends

30° ..... 4 Nos.
45° 1

} ∴ fb=4x0.073+0.183 = 0.475

$$Q = \frac{\pi \times (0.25)^2}{4} \sqrt{\frac{2g \times 63.6}{(1+1+0.475+1+0.02 \frac{465}{0.25})}}$$

= 0.049 x 5.536

= 0.271 m.cu./sec

(2) No. 1 to No.2 Pressure reducing chamber

Dia.ϕ 10" (D = 0.25m), Length L = 27m

Difference of water level

$H_2 = 172.26 - 165.17 = 7.09$

Nos. of bends None

$$Q = \frac{\pi \times (0.25)^2}{4} \sqrt{\frac{2g \times 7.09}{(1+1+1+0.02 \frac{7.09}{0.25})}}$$

= 0.049 x 6.241

= 0.306 m.cu./sec

(3) No. 2 Pressure reducing chamber to No.1 reservoir

Dia.ø 12" (D = 0.3m), Length L = 1,248m

Difference of water level

H_3 = 166.82 - 112.50 = 54.32m

Nos. of bends 30° ...... 9 Nos.

45° ...... 4 Nos.

fb = 9x0.073+4x0.1

= 1.389

$$Q = \frac{x\ (0.3)}{4} \sqrt{\frac{2g \times 54.32}{(1+1+1.389+1+0.02\ \frac{1,248}{0.3})}}$$

= 0.07065 x 3.486

= 0.246 m.cu./sec

C) Existing Route (II) ..... (Additional)

(1) Pressure reducing chamber to No.1 reservoir

Dia.ø 12" (D = 0.3m), Length L = 1,740m

Difference of water level

H_4 = 235.86 - 112.50 = 123.36 m

Nos.of bends 30°..... 13 Nos.

45° .... 5 Nos.

90° 1

fb=13x0.073+5 x0.183+0.99

= 2.854

$$Q = \frac{x\ (0.3)}{4} \sqrt{\frac{2g \times 123.36}{(1+1+2.854+1+0.02\ \frac{1,740}{0.3})}}$$

= 0.07065 x 4.454

= 0.315 m.cu./sec

From the above calculation, it becomes obvious that the capacity of the two existing pipelines up to No.1 reservoir is about 550 ℓ/sec in total, more than sufficient and far beyond the designed maximum reqirement of the future. Consideration therefore is only required in respect of the routing after No. 1 reservoir, since the pipelines even for future use, already exist up to this point.

4.3.3 Storage Facilities

Three p.c. storage reservoirs with a capacity of 3,000 m.cu. each are planned to be constructed in addition to the existing storage facilities of 4,000 m.cu.

With regard to practice in Japan, the storage capacity is generally given as the equivalent of 8 to 12 hours of the designed maximum daily supply, plus an allowance for fire fighting. For a city having a population of about 40,000 the storage capacity would be say 8 hours equivalent of the maximum daily supply plus some 500 m.cu. for fire fighting.

Using the above for a calculation, then,

Planned maximum daily supply = 21,950 m.cu./day

Required storage capacity = 21,950 x 8/24 + 500
= 8,000 m.cu.

Accordingly, the additional storage capacity required is 4,000 m.cu. when using Japanese design criteria.
Therefore it seems that the storage capacity now being planned is rather excessive. Really, the storage capacity should be determined from the specific water uses of a town, however, a capacity of 10 hours equivalent of the daily maximum supply, plus 500 m.cu. for fire fighting is thought to be sufficient, even taking into consideration periods when the facilities are out of order. Therefore a storage capacity of 10,000 m.cu. (21.950 x 10/24 + 500) i.e., an addition of 6,000 m.cu. (3 x 2,000 or 2 x 3,000 m.cu. reservoirs) is considered adequate.

SECTION 5 GROUNDWATER INVESTIGATIONS

SECTION 5 GROUNDWATER INVESTIGATIONS

5.1 Hydrogeological Conditions

5.1.1 Previous Investigations

Previous investigations of groundwater so far under-taken in this area can be separated into two as follows.

The first, carried out by France in cooperation with Peru in 1971, was to prepare hydrogeological maps of the Greater Lima and Callao area give the general view of the hydrogeological conditions. In addition, in 1980, another survey, as part of the Mantaro Transfer Project, was carried out by Britian, also in cooperation with Peru, to clarify the groundwater conditions along the Rimac, Chillon and Lurin rivers.

The second, carried out for the purpose of groundwater development by the Ministerio De Pesquería through the agency of a private consulting firm. However, the Ministerio De Pessquería considered the investigation unsatisfactory and requested the Ministerio De Agriculture to carry out further investigations in 1978. These investigations finally established the groundwater development plan.

5.1.2 Geology

The geological make up of the Puente Piedra and Carabayllo areas, is composed of alluvial deposits and baserock of Jurasic Volcanics and Piroclastics.

The baserock forms the mountainous area to the north and the west, and projects through the alluvial layer. The rocks belonging to the volcanic and Piroclastic groups are comparatively soft. Composed of ash, mineral fragments and volcanic gravels, it is from the geological point of view impervious, forming an acuifers in the area.

The sedimentary layers are composed of clay, sand and gravels. The horizontal formation is extremely irregular and formed into alluvial

cone deposits.
The gravels are mainly round in shape with a diameter of 20 - 50 cm being common. The 'matrix' between gravels is made up of sand, clayey sand and clay. These alluvial layers form a water containing bed in the area.

5.1.3 Use of the Groundwater

Within the new watersource area planned on the right hand side of Chillon River, there are, over an area of 42 sq.km., 119 existing wells in production. Of these, 26 are deep well with casings, 6 wells are open drilled with casings, the other 87 remaining as open drilled wells. At present there are 85 wells in operation, out of which 8 are spring wells. For 1978, the total discharge amounted to 8,866,452 m.cu.

The groundwater is mainly used for agricultural purposes, but also partly for drinking, giving to animals and by industry.

5.1.4 Structure of the Aquifer

The geological make up of the water retaining bed is of alluvial cone deposits consisting of sand, gravel and clay between gravels. Boring tests were conducted down to a depth of 100m, and the electric prospecting survey gave the thickness of the aquifer as between 100 and 250 m, see Fig. 5.1.

In some ways the prospective site shows two distinct features, one, the structure of the Rio Chillon groundwater valley, and the other, the structure of a groundwater reservoir.

Electronically, the nature of the aquifer can be divided into two layers, the upper layer with a high resistivity and the lower layer with a corresponding low resistivity. The upper layer had a resistivity from 100 to 150 ohms m with a depth down to 20 - 30m and the lower layer of 30 to 50 ohms m.

The value of the resistantial transversal (R.T.), which is taken to be in proportion to the transmissibility, (R.T. = resistivity x thickness) ranges from 5×10^2 ohm m to 25×10^2 ohm m and is comparatively high for the eastern district.

5.1.5 Groundwater Flow

The groundwater level in this area ranges from 185 to 200m below sea level, and has the nature of free groundwater.

The configuration of the groundwater level is as shown in Fig. 5-2. If flows towards the west with a slope of 0.45% in the north, and of 1% along the Chillon River. The groundwater is replenished mainly by infiltrating water upstream, i.e., from the underflow of the Chillon River, and also by infiltrating water from irrigation sources.

According to the report of the Mantaro Transfer Project, replenishment over the River Chillon Basin amounts to 0.7 m.cu./sec..

Measurements of variations in the groundwater table taken from 1969 to 78 reveal that the seasonal variation is 4 - 6m for deep wells and 2 - 4m for shallow ones, with a rise annually of 1m from 1969 to 74 and 1m fall annually from 1975 to 78.

During the present investigation it was also found that there was a 0.5 - 1m fall occuring in the year.

5.1.6 Aquifer Coefficients

Pumping tests were carried out by the Ministerio De Pesquería at 8 deep wells within the project area. As a result, it was found that the transmissibility falls in the range 9 to 10.5 x 10^{-3} m.sq./sec., with an average value of 28 x 10^{-3} m.sq./sec.

In addition, the storage coefficient falls in the range 0.01 - 0.066, with an average value of 0.03. This indicates that the groundwater in this area has the nature of free groundwater.

5.1.7 Water Quality

1) Chemical constituents

In regard to the chemical constituents of the groundwater, the results of the analysis carried out by the Laboritorio de la Dieccion General de Aguas y Suelos are shown in the form of a diagram in Fig. 5.5.

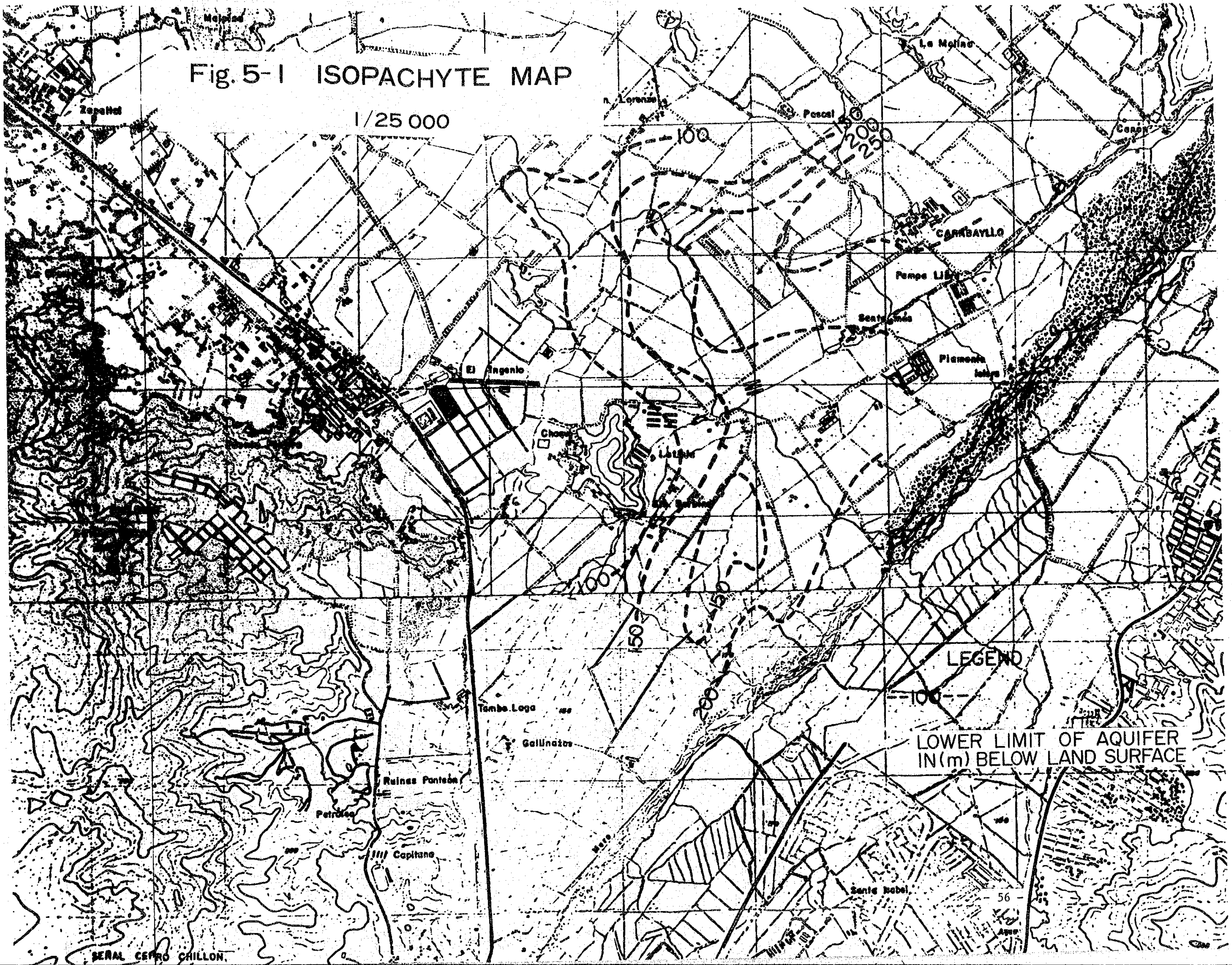


Fig. 5-1 ISOPACHYTE MAP

1/25 000

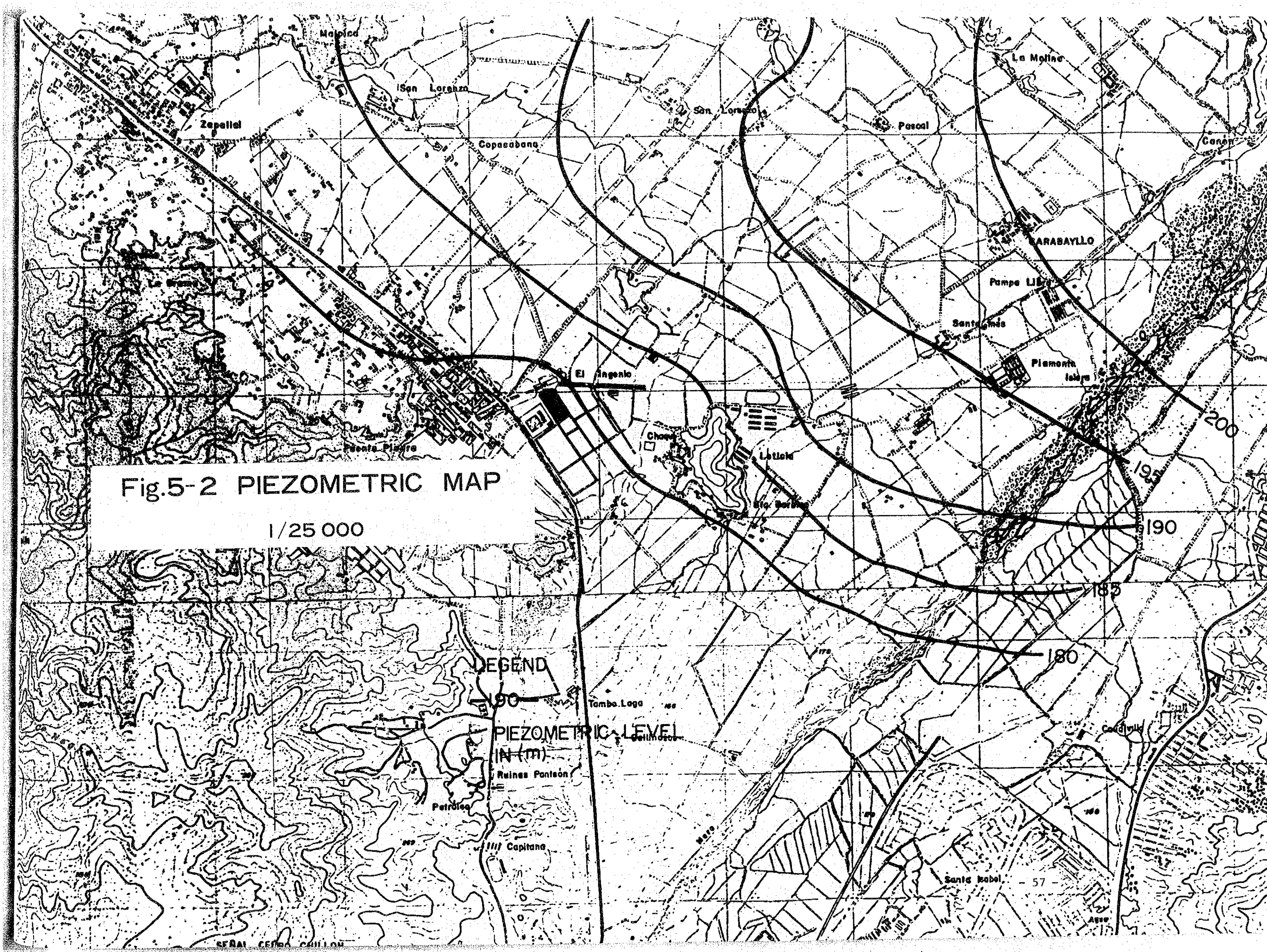


Fig.5-2 PIEZOMETRIC MAP

1/25 000

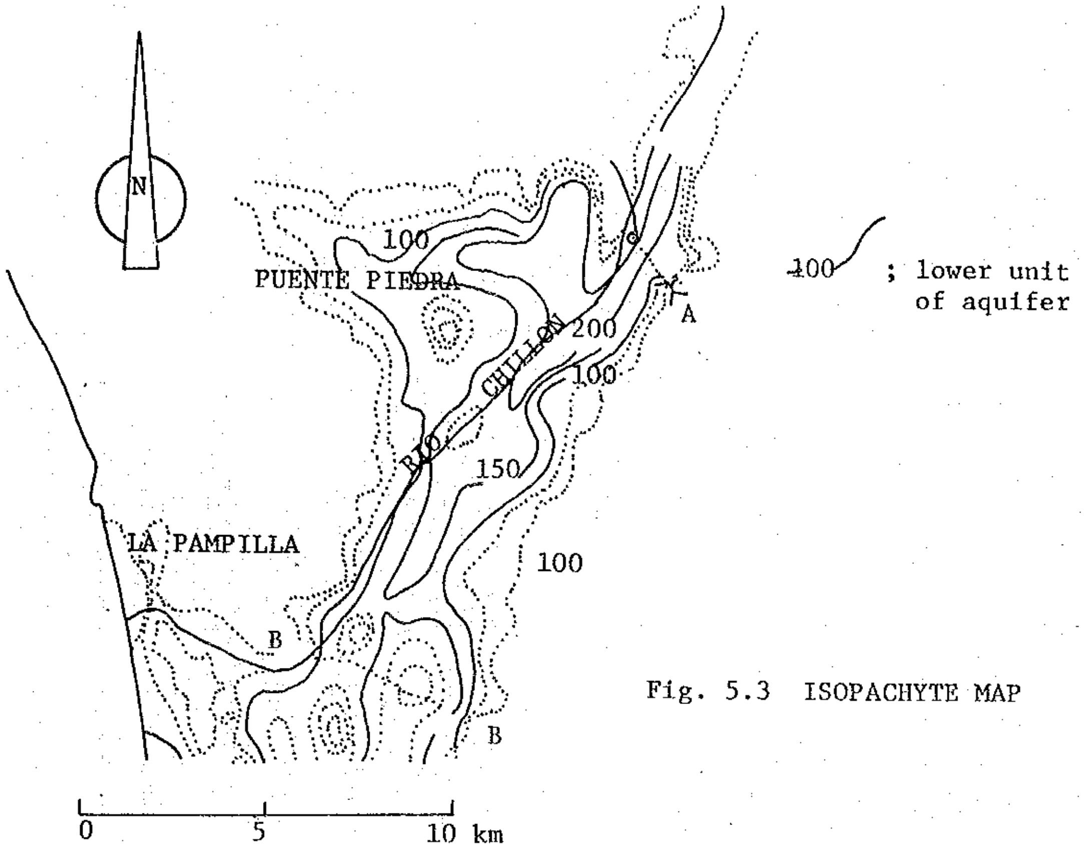


Fig. 5.3 ISOPACHYTE MAP

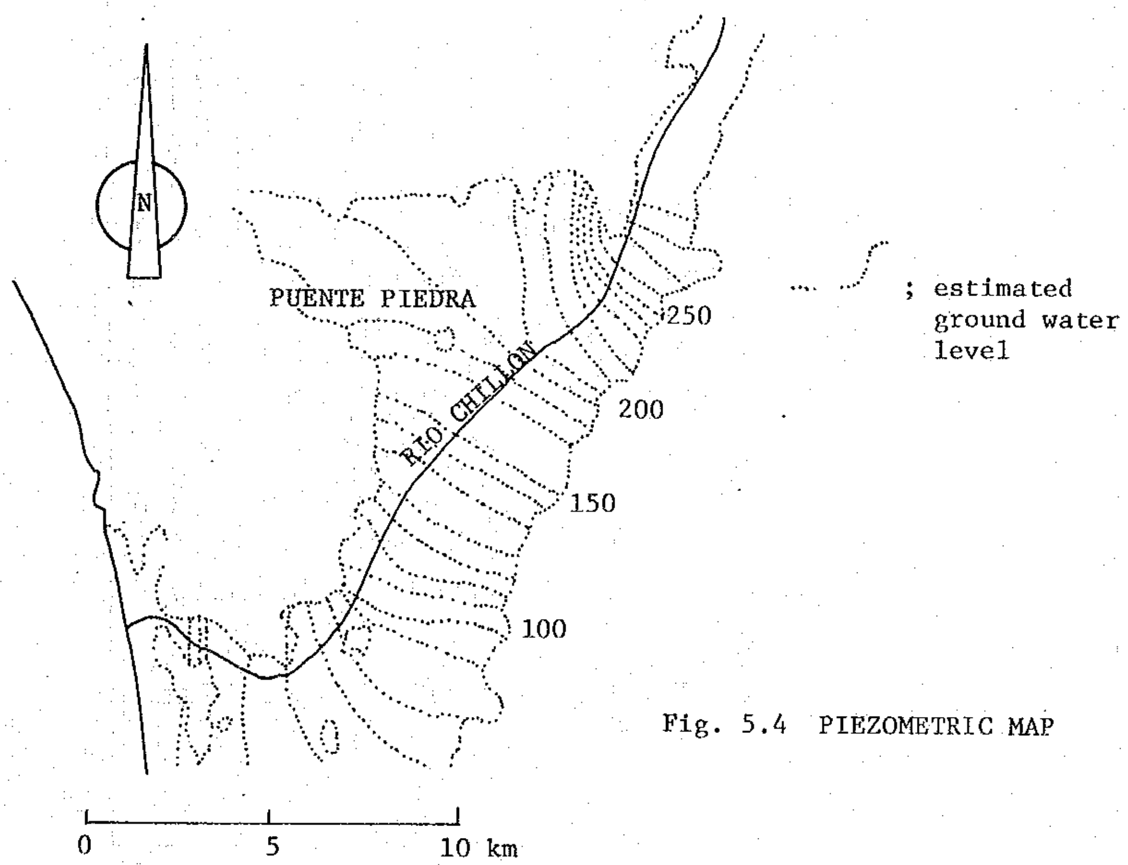


Fig. 5.4 PIEZOMETRIC MAP

Table 5.1 Characters of Aquifer

Well No.	Transmissibility (m.sq./sec)			Permiability (m/sec)	Storage Coefficient (%)	Observation
	Draw Down	Recovery	Average			
15/01/05- 4	7×10^{-3}	17×10^{-3}	10×10^{-3}	2.2×10^{-4}	-	PUMPING WELL
15/01/05- 5	17×10^{-3}	22×10^{-3}	19×10^{-3}	6.1×10^{-4}	-	"
15/01/05- 40	22×10^{-3}	11×10^{-3}	23×10^{-3}	4.3×10^{-4}	-	"
15/01/05- 41	18×10^{-3}	-	18×10^{-3}	-	1.0	OBS.WELL OF 15/01/05-40
15/01/16- 44	-	32×10^{-3}	32×10^{-3}	7.0×10^{-4}	-	PUMPING WELL
15/01/16- 45	105×10^{-3}	-	105×10^{-3}	-	6.6	OBS.WELL OF 15/01/16-44
15/01/16-101	11×10^{-3}	11×10^{-3}	11×10^{-3}	2.0×10^{-4}	-	PUMPING WELL
15/01/16-141	9×10^{-3}	-	9×10^{-3}	-	2.2	OBS.WELL OF 15/01/16-101
15/01/16-182	50×10^{-3}	50×10^{-3}	50×10^{-3}	-	-	PUMPING WELL
15/01/16-183	36×10^{-3}	-	36×10^{-3}	-	3.0	OBS.WELL OF 15/01/16-182
15/01/16-183	45×10^{-3}	40×10^{-3}	42×10^{-3}	11×10^{-4}	-	PUMPING WELL
15/01/16-185	39 x 10	33×10^{-3}	36×10^{-3}	19×10^{-4}	-	"
OBSERVATION WELL	49×10^{-3}	-	49×10^{-3}	-	3.5	OBS.WELL OF 15/01/16-185

Table 5.2 Hydrogeological Condition of The Proposed Intake Area

Factor	Data	Remarks
GEOLOGY OF AQUIFER	Alluvial Pebble Layer	Matrix Sand and Clay
THICKNESS OF AQUIFER	Average 150 m (100m ∿ 250 m)	From Electric Survey
RESISTIVITY OF UPPQR LAYER	100m ∿ 150 Ω-m	Thickness 120 ∿ 30 m
RESISTIVITY OF LOWER LAYER	30 ∿ 50 Ω-m	Thickness 120 ∿ 200 m
STATIC WATER LEVEL	185 ∿ 200 m	Below Sea Level
GRADIENT OF STATIC WATER LEVEL	0.45% 1.0%	0.45%; Central area 1% ; along Rio Chillon
TRANSMISSIBILITY	28 x 10^{-3} m.sq./sec	9 ∿ 105 x 10^{-3} m.sq./sec
PERMEABILITY	7.4 x 10^{-4} m/sec	2.0 ∿ 19 m/sec
STORAGE COEFFICIENT	0.03	0.01 ∿ 0.06

Table 5.3 Result of Chemical Analysis

No	Name of Well	Hard-ness °th F	C.E. mmhos/cm. a 25° C	CATION (meq/1t)					ANION (meg/1t)						Class
				Ca^{++}	Ma^{++}	Na^{+}	K^{+}	Total	Cl^{-}	$SO_4^{=}$	HCO_3^{-}	NO_3^{-}	CO_3^{--}	Total	
15/01/05- 5	CAP.La Malina Alto	840	1.84	13.12	3.42	3.0	0.09	19.63	2.3	10.47	3.40	2.5	0.0	18.67	$CaSO_4$
21	Pueblo Vicio	820	2.13	13.08	3.32	2.0	0.06	18.46	1.85	12.74	3.89	0.0	0.0	18.48	"
23	CAP.Moriategui-Agua Bendita	620	1.50	9.48	2.84	1.95	0.07	14.34	1.85	8.0	2.9	1.3	0.0	14.05	"
15/01/16- 60	Balfazar Centeno Leon	550	1.21	8.6	2.32	1.80	0.01	12.82	1.79	7.5	2.95	0.0		12.24	"
153	Genaro iguchi-Haras 33	520	1.36	7.76	2.72	1.50	0.06	12.04	1.3	6.4	2.9	1.0	0.0	11.60	"
166	Jose Balbuena B: Sn.Alejandro	670	1.96	10.48	3.04	3.40	0.10	17.02	1.79	13.70	4.05	0.0		19.54	"
192	Pancha Paula-2	620	1.38	9.8	2.6	2.1	0.08	14.58	1.9	7.8	3.6	1.8	0.0	14.60	"
195	CAP. Gallinazos	370	1.10	5.72	1.80	1.20	0.07	8.79	1.1	4.9	2.0	0.6	0.0	8.60	"

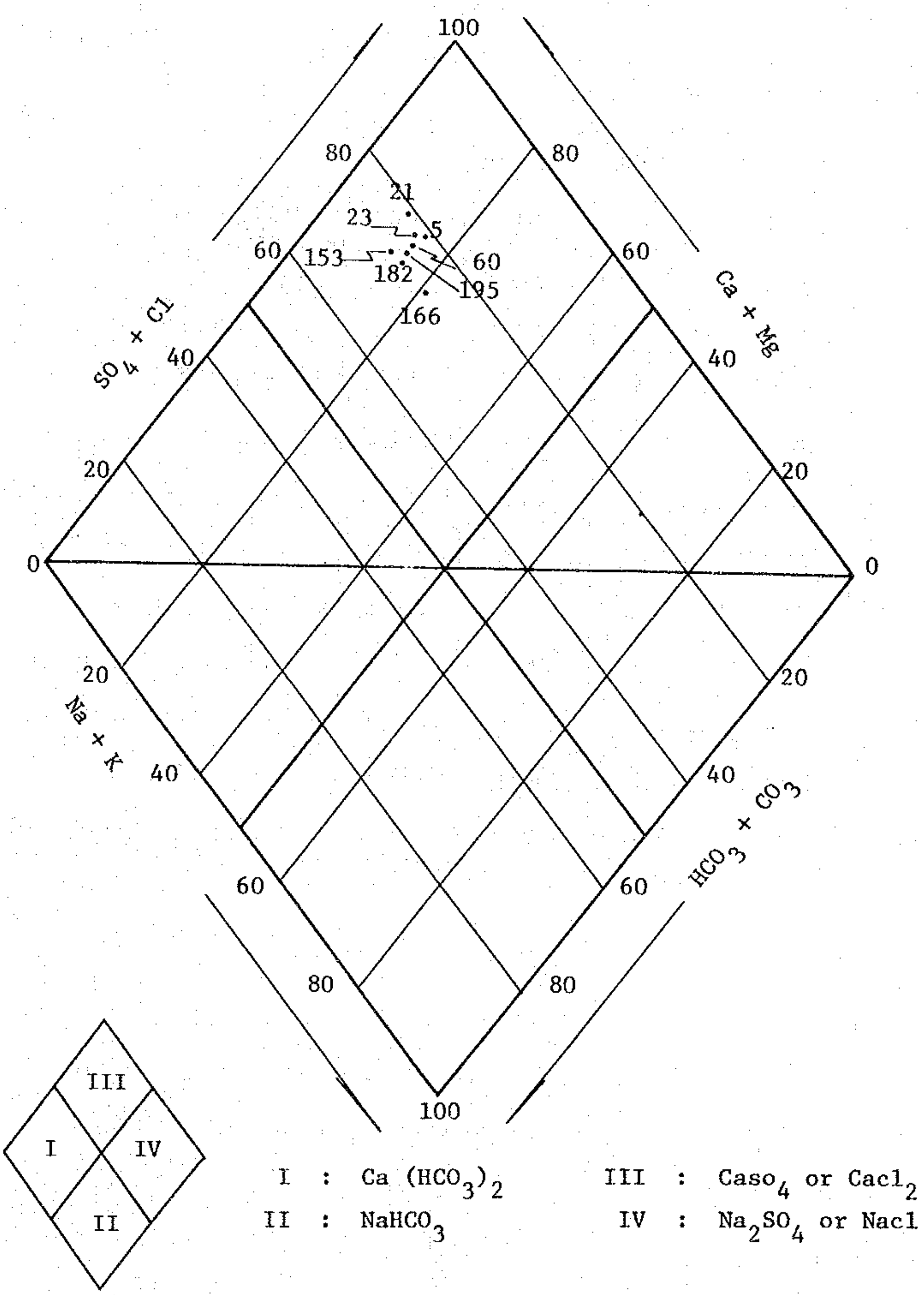


Fig. 5.5 KEY DIAGRAM OF GROUND WATER FOR PUENTE PIEDRA

Table 5.4 Result of Chemical Analysis for Drinking

Parametros		Muestra de Agua - Ventanilla			
		No. 1	No. 2	No. 3	No. 4
Amonio, como nitrogene	mg/lt.	0.0	0.0	0.0	0.0
Nitrates, como nitrogene	mg/lt.	19.0	9.0	2.1	3.0
Nitrites, como nitrogene	mg/lt.	0.001	0.000	0.012	0.000
Mercurie, como Hg	mg/lt.	0.00	0.00	0.00	0.00
Cebre, como Cu	mg/lt.	0.00	0.00	0.00	0.00
Hierro, como Fe	mg/lt.	0.02	0.02	0.02	0.25
Manganese, como Mn	mg/lt.	0.00	0.00	0.00	0.01
Plome, como Pb.	mg/lt.	0.00	0.00	0.00	0.00
Crome, como $CrO_4 (Cr^{+6})$	mg/lt.	0.00	0.00	0.00	0.00
Cadmie, como Cd	mg/lt.	0.000	0.000	0.000	0.000
Arsenice, como As	mg/lt.	0.00	0.00.	0.00	0.00
Residue total	mg/lt.	1,044	904	551	706

Lima, 13 de Octubre de 1980

REMITENTE : Ing. Carles Valenzuela Flores

FUENTE DE ABASTECIMIENTO: Agua subterranea - Peze

TIPO DE AGUA : Cruda (sin tratamiente)

FECHA RECOLECCION : 08 - 10 - 80

From these results the groundwater in this district is of the $CaSO_4$ type and is classified in the category of spring water and mineral water.

2) Suitability for Drinking

As for its suitability for drinking, the water contains sulfuric acid ions in high concentrations and tends to be mediocre, but it is within passable limits for drinking.

Other constituents were analysed by the reserch section of the Ministerio de Vivienda y Construccion and the results are shown in table 5.4. These results would confirm that the water is suitable for drinking.

5.2 Groundwater Development Plan

5.2.1 Selection of Area to be Developed

After examining carefully the hydrogeological conditions of the areas, the area between the eastern part of the Puente Piedra and the Chillon River is considered to be the most suitable.

5.2.2 Number of Deep Wells

Judging from the results of pumping tests (Fig. 5.6 and Table 5.5) the limit of the optimal discharge in this area was found to be 37.6 ℓ/sec. Therefore, the designed discharge rate of a well is 34.0 ℓ/sec., and a daily operational period of 18 hours gives 10 wells.

Thus, 34.0 ℓ/sec x 10 wells x 64,800 sec = 22,000 m.cu./day which is greater that the figure of 21,950 m.cu./day

5.2.3 Spacing of Wells

In determining the spacing of wells, a radius of influence is necessary.
Setting the transmissibility T at 2.8×10^{-2} m.sq./sec
Storage coefficient S at 3×10^{-3}
Discharge rate Q at 34.0 1/sec

Operational period t at 18 hours

h' at 0.1 m

then, the radius of influence is calculated from the following formula:-

$$R = \left(\frac{2.25.T.t}{X \times 10^{(h'T/0.183Q)}} \right)^{0.5} = 220$$

Therefore, the distance between wells should not be less than 440 m, to avoid interferance with each other.

This distance was used in regard to deep wells. The plan, determined from the results is as shown in Fig. 5.7.

5.2.4 Design Parameters for Deep Wells

With a well discharge of 34 l/sec., the recommended well diameter is 350 mm. Setting the void ratio of the aquifer at 0.3 and the opening ratio of the well 'strainer' at 0.2, the incoming flow velocity, V, at 0.018 m/sec. and the quantity Q at 0.0059 m.cu./sec., (Peru's standards specify the incoming velocity to be not more than 0.03 m/sec), then 29 m of strainer is needed to attain the designed discharge rate.

The above can be summerised as follows:-

borehole diameter	550mm
well casing diameter	350mm
well depth	100m
length of strainer	30m
optimum ratio of strainer	not less than 0.2

Fig. 5.6

THE YIELD
FOR NO23 WELL AT PUENTE
PIEDRA

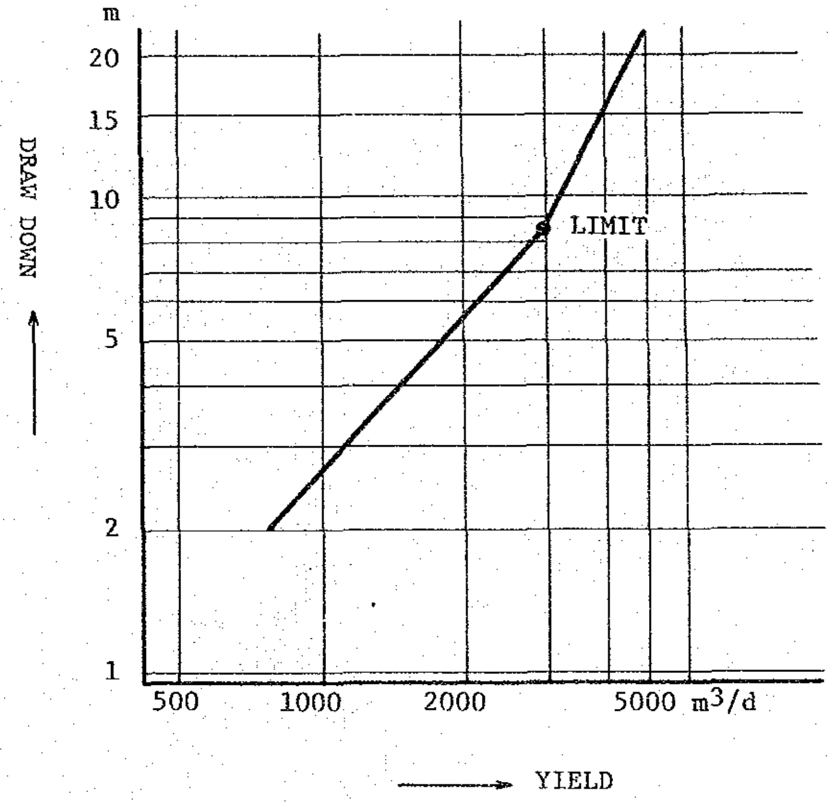


Table 5.5

THE YIELD
FOR EACH EXISTING WELL

Well N2	YIELD		Draw Down (m)
	Yield during 24 hr. m.cu/day	Yield as ℓ/s	
6	2200	25.5	10.0
32	4000	46.2	11.5
23	3000	34.7	8.5
58	3000	34.7	9.0
40	4300	49.7	9.0
101	2500	28.5	10.5
53	4000	46.2	12.5
46	3100	35.9	7.4
44	3200	37.0	8.6

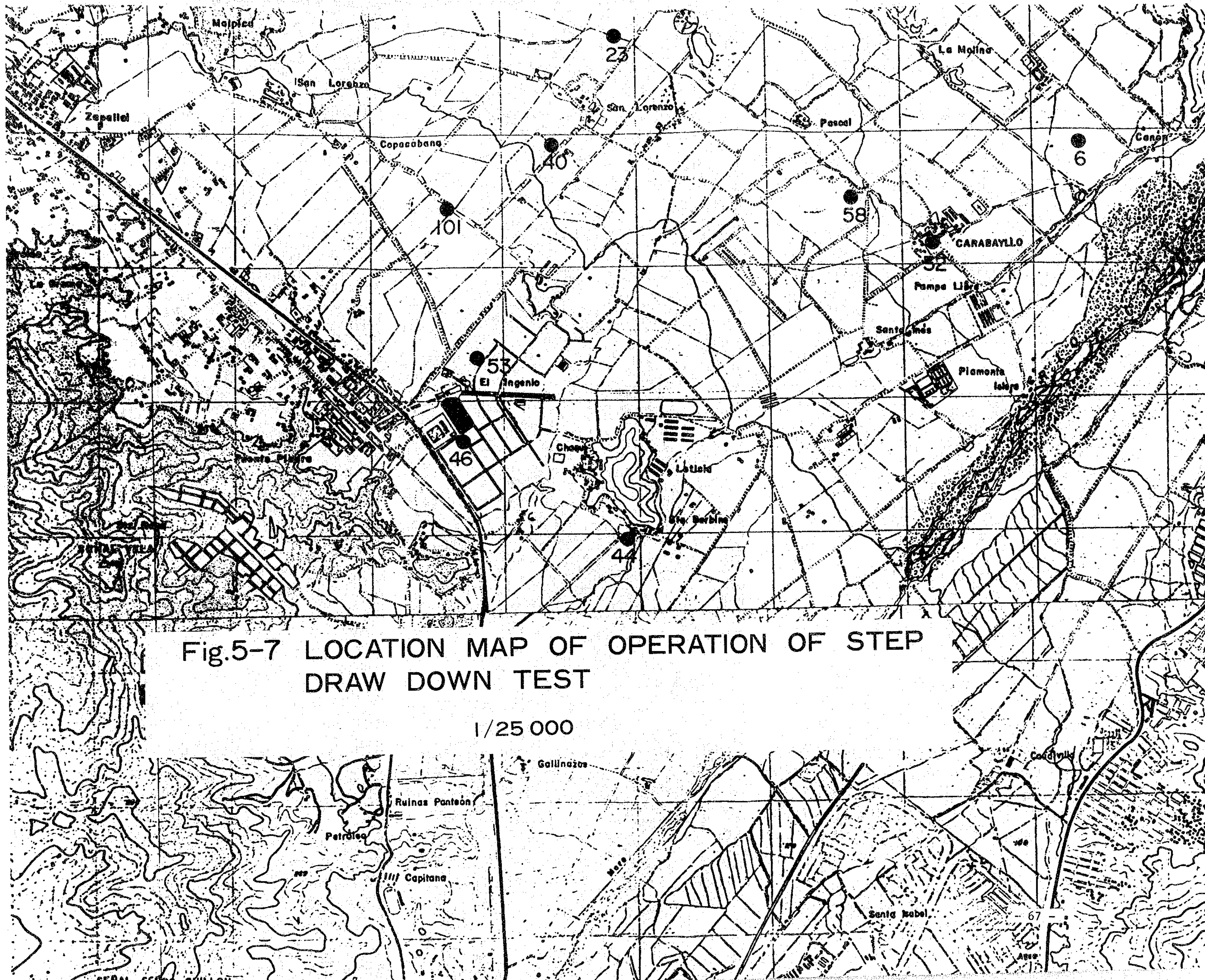


Fig.5-7 LOCATION MAP OF OPERATION OF STEP DRAW DOWN TEST

1/25 000

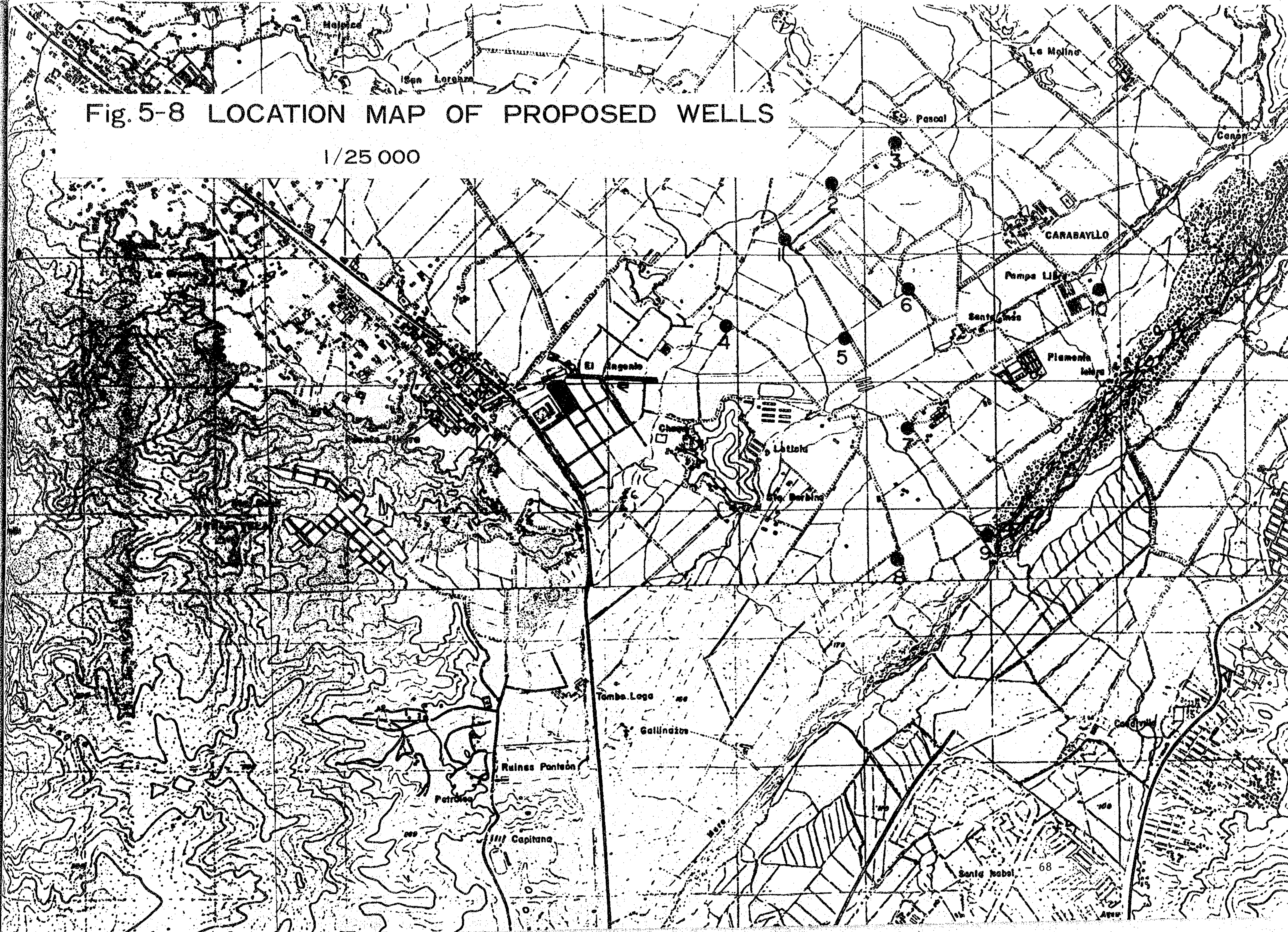


Fig. 5-8 LOCATION MAP OF PROPOSED WELLS

1/25 000

SECTION 6 CONDITIONS FOR CONSTRUCTION AND OPERATION AND MAINTAINENCE OF WATER SUPPLY FACILITIES

SECTION 6 CONDITIONS FOR CONSTRUCTION AND OPERATION AND MAINTAINENCE OF WATER SUPPLY FACILITIES

6.1 Present Condition of Construction Firms

In order to assess the capability of construction firms in Peru, a typical firm 'F' was selected for study.

Firm F is a general construction firm which has produced good results in the past five years, and is ranked within the top five firms.

Past work by the firm in Peru includes construction of the La Pampilla oil base, an artificial satellite tracking station and a sea produce processing centre. It is considered to have a high technical capability.

Since there are several contractors of equal capability, it is thought that the technical skills required to impliment the present programme can be found locally.

6.2 Availability of Construction Materials

A survey was made of locally available materials and equipment, including their specifications. As a result, it was found that the pump units are assembled locally from imported parts and then put on sale.

As regards pipe material, AC pipe is locally manufactured at factories where pressure test equipment and other testing apparatus is to hand. Special pipes of cast iron and other accessories are also locally available, though the cast iron pipes are in fact imported from Panama.

Cement, gravel, bricks, reinforcing bars (round or shaped), are all available on the local market.

6.3 Laws and Standards Relevant to Construction Works

Laws and standards relevant to the designing of construction works are set out by the Ministerio de Vivienda y Construccion and E.S.A.L., as are those with respect to architecture.

As for the water works, design standards on capacities of facilities are given, but technical standards on seismic design are only now being reviewed, therefore the present study adopts a horizontal seismic factor of Kh = 0.14.

Standards for materials are at present available, mostly for pipes and valves, and they conform with AWWA and ASTM standards.

6.4 Present Status of Construction Work

6.4.1 Well Drilling Work

Well drilling was carried out down stream of the River Chillon, by percussion. Since the layers consisted mainly of round gravels, drilling with a light bit required a long time. In fact, drilling work along the river took more than three months.

As a result, the permiability readings obtained at the drilled wells presented unsatisfactory values, which were hardly understandable in comparison to the original readings for the aquifer.

This is thought to be due to the intrusion of muddy water into the aquifer. Therefore, drilling in this district should be more expiditiously carried out by some other technique using suitable drilling equipment.

6.4.2 Pipelaying Work

As far as pipe laying works observed in the city of Lima are concerned, there is no difference between Peru and Japan, except for earth excavation, in which labour intensive methods are used in Peru.

6.4.3 Scaffolding

The most common material used for scaffolding is wood. Though steel plates and pipe are now reported to being gradually introduced. This would indicate some modernization of the construction industry. However, work still relies heavily on manual labour, mechanization being still quite rare on sites.

6.4.4 Earth Work

The soil condition in level areas consists of sandy gravels to a depth of 1 - 2 m. below the surface.

In hilly areas, almost no surface soil exists, only out crops of rock.

Except for those areas which are cultivated, plant life is rarely observed. Therefore very little site clearing work is necessary.

Although small bulldozers and power shovels are used for earth works in flat areas, rock excavation in hilly areas is mainly done by manual labour, sometimes using 'breakers'.

Judging from the use of old equipment with all its disadvantages, and the national characteristics of the Latin people, who are not paragons of efficiency, the work productivity level in this country can be said to be 2/3 to 1/3 of that in Japan.

6.4.5 Reinforced Concrete Work

Site visits were taken to see the construction of a storage reservoir near Lima air-port, and also to building sites in Lima.

Steel bar fixing work didn't differ from that in Japan. However, as far as concrete placing is concerned, it was observed that a uniform mix of concrete could not be provided since the concrete is mixed on site and concrete is in short supply.

It should be noted that PC structures to be included in this present project, will require concrete quality control when being built.

All concrete formwork is of wood. Formwork used on building sites is often of poor quality and construction, however, on the construction site of the storage reservoir, it was found that the cylindrical forms used were in no way inferior to those in Japan. Therefore there seems to be no forseeable problem in this regard, so long as the materials are acquired well in advance.

6.6 Maintenance and Control Techniques

In order to check the degree of maintenance and control techniques, discussions were held with Lima E.S.A.L. who are in charge of maintenance and control of the Ventanilla water supply system, and in addition, a site visit was paid to a water treatment plant in Lima (which was operated by E.S.A.L.). Consequently, it was found that key personnel were all conversant with maintenance and water supply and control techniques for treatment plants and were of comparable standard to those in Japan.

SECTION 7 PLAN OF FACILITIES

SECTION 7 PLAN OF FACILITIES

7.1 Outline of Facilities

The Ventanilla water supply project was designed for consumption within the Ventanilla area based on the present investigation with the population to be served as 40,000 and the maximum daily supply as 21,950 m.cu./day.

The facilities of the project comprise of intake, raw water conduits, (collection mains), transmission and storage facilities.

The location of facilities and pipe routes are shown in Fig. 7.1. About 10 km. east of Ventanilla in the Puente Piedra area located on the right hand side of the Chillon River and Carabyllo district, 10 deep wells will be drilled and water pumped up by use of submersible pumps installed in each well.

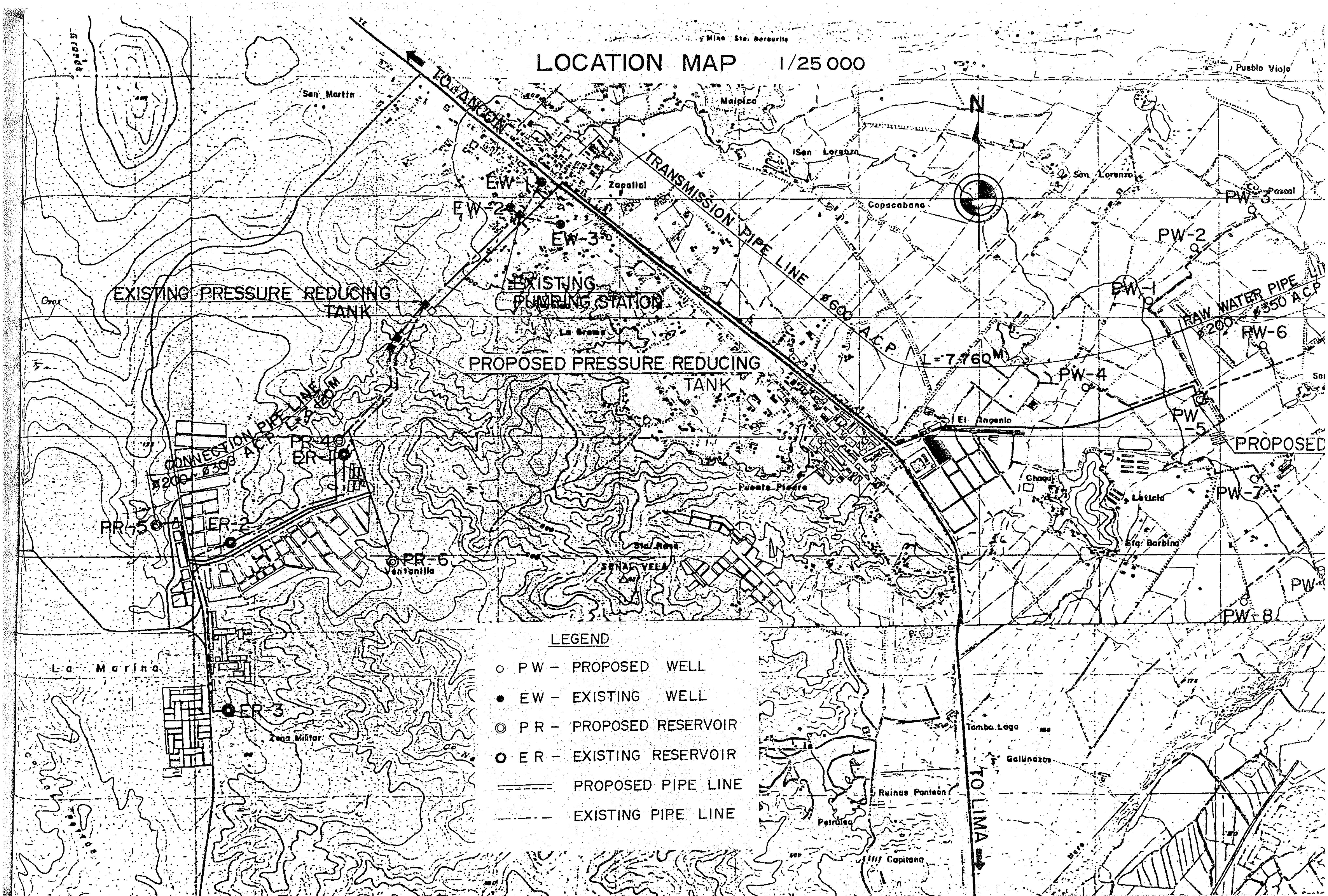
The pumped water will be taken to a pump well through raw water pipes of 8" diameter (200 mm.) and 14" diameter (350 mm.). The raw water flows firstly into a junction well and is then pumped up through the pump wells.

The transmission pipes are to be installed with diameters of 24" (600 mm) from the pump houses to Zapallal along the Panamerican highway, then taken to the pressure breaking chambers that are to be installed on the hill top between Zapallal and Ventanilla. From the pressure breaking chamber up to the storage reservoirs, the existing two pipelines will be used since they are capable of carrying the designed discharge quantity of water.

In addition to the existing three reservoirs (2 X 1,000 and 1 X 2,000 m.cu) an extra 3 (3 X 2,000 m.cu.) will be built. They will be interconnected with each other by new pipelines, see Fig. 7.1.

7.2 Design Parameters

Projected population to be served	40,000
Design year	1987
Estimated maximum demand per capita per day	390 liters



LOCATION MAP 1/25 000
TO ANCON
TRANSMISSION PIPE LINE
ø600 A.C.P.
L=7,760M
EW-1
EW-2
EW-3
EXISTING PUMPING STATION
EXISTING PRESSURE REDUCING TANK
PROPOSED PRESSURE REDUCING TANK
CONNECTION PIPE LINE
ø200 - ø300 A.C.P.
PR-4
ER-1
PR-5
ER-2
PR-6
ER-3
PW-1
PW-2
PW-3
PW-4
PW-5
PW-6
PW-7
PW-8
RAW WATER PIPE LINE
ø200 - ø350 A.C.P.
PROPOSED
TO LIMA
N
San Martin
Malpica
San Lorenzo
Zapallal
Copacabana
Pueblo Viejo
El Angenio
Puente Piedra
Chaqui
Leticia
Sta. Barbina
Sta. Rosa
Ventanilla
La Marina
Zona Militar
Tambo Loga
Gallinazos
Ruinas Panteon
Petroleo
Capitana
LEGEND
PW - PROPOSED WELL
EW - EXISTING WELL
PR - PROPOSED RESERVOIR
ER - EXISTING RESERVOIR
PROPOSED PIPE LINE
EXISTING PIPE LINE

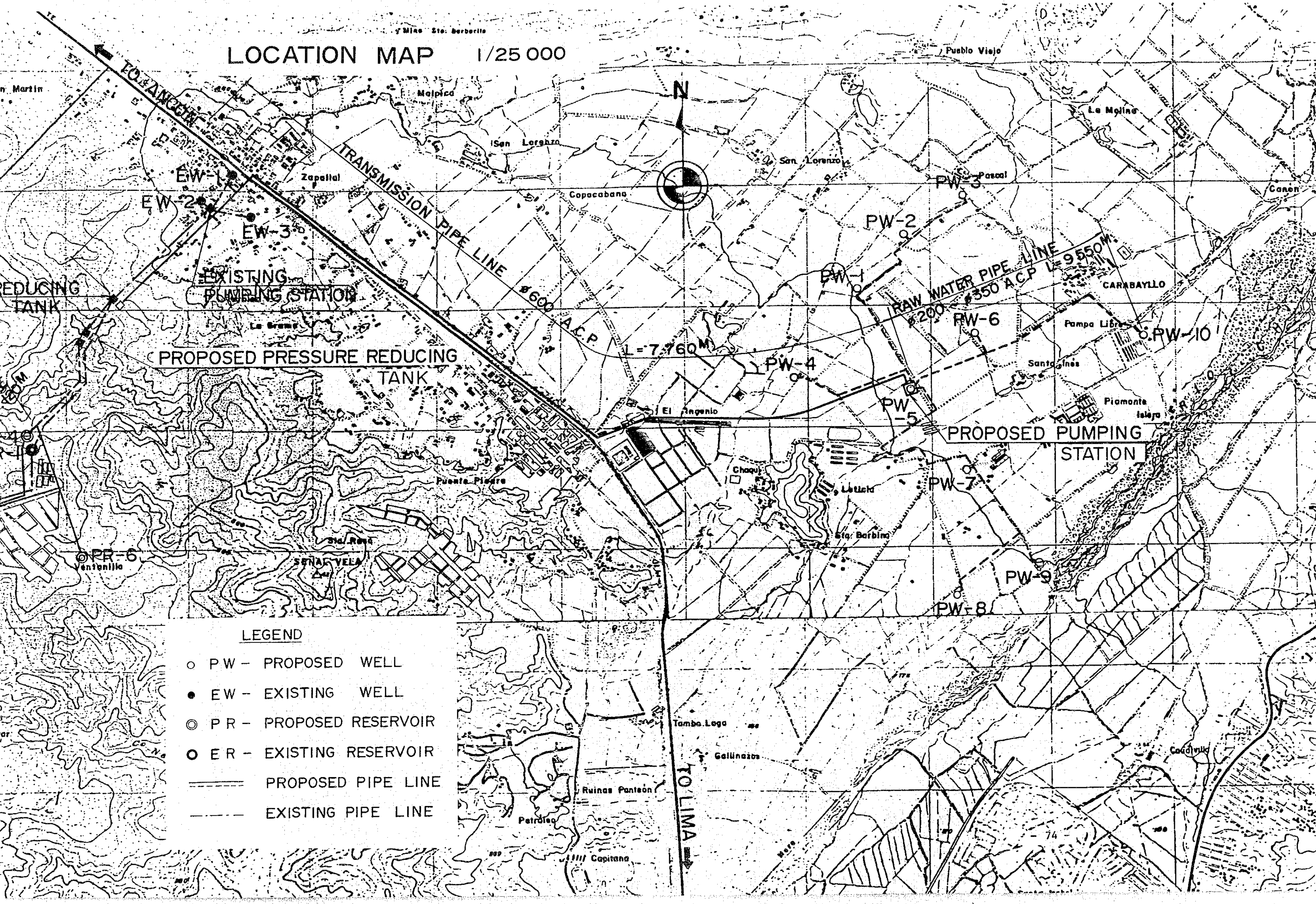

LOCATION MAP 1/25 000
N
TO ANCON
TO LIMA
TRANSMISSION PIPE LINE ø600 A.C.P. L=7,760M
RAW WATER PIPE LINE ø200 ~ ø350 A.C.P. L=9,550M
EW-1
EW-2
EW-3
EXISTING PUMPING STATION
REDUCING TANK
PROPOSED PRESSURE REDUCING TANK
PROPOSED PUMPING STATION
PW-1
PW-2
PW-3
PW-4
PW-5
PW-6
PW-7
PW-8
PW-9
PW-10
PR-6
Malpica
San Lorenzo
Zapallal
Copacabana
Pascal
La Molina
Pueblo Viejo
Canon
CARABAYLLO
Pampa Libre
Santa Ines
Piamonte
El Ingenio
Chaqui
Leticia
Sta. Barbina
Puente Piedra
Sta. Rosa
SENAL VELA
Ventanilla
La Grama
Tambo Loga
Gallinazos
Ruinas Panteon
Petroleo
Capitana
Caudivilla
LEGEND
○ PW - PROPOSED WELL
● EW - EXISTING WELL
◎ PR - PROPOSED RESERVOIR
O ER - EXISTING RESERVOIR
PROPOSED PIPE LINE
EXISTING PIPE LINE

Fig. 7.2 HYDRAULIC PROFILE