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LOW-COST HOUSING: PROVISION OF INFRASTRUCTURE SERVICES */

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CONTENTS

SUMMARY

A study of the drinking water supply and sanitation networks (basic services) of ten housing developments in Santiago, Chile, allows a number of conclusions to be drawn concerning the relationship which exists between the costs of the services, the layout of the housing development and the criteria adopted in designing the networks of basic services.

The design and layout of the basic service networks in the housing developments examined followed, in general, traditional practice. The sole sanitation technology adopted in all cases was that using conventional sewers. This document analyses some of the criteria adopted in designing the drinking water supply and sewerage networks as well as their impact on the final cost of the services.

The correlation between the costs of the drinking water supply and sewerage networks and the number of dwellings per unit area in the cases studied clearly reveals a declining trend in costs as the density of occupation increases. The study also clearly establishes the existence of a relationship between the cost of the basic service networks and the dimensions and layouts of the unit in a housing project.

There is a tight link between the design of the basic service networks and the layout of the housing units and groups. It is possible to optimize the service networks by applying criteria and design standards which, while remaining technically satisfactory, help to reduce costs. In addition, proper choice of housing densities, of the dimensions and layouts of the units and the layout of the housing development as a whole will help to bring down the cost of providing the basic service networks.

INTRODUCTION

This study forms part of a research project into low-cost housing carried out by the Institute of Housing of the Faculty of Architecture and Town Planning of the University of Chile. The starting point for the research was provided by the various conclusions drawn from previous studies, which indicate that in the area of low-cost housing, designed to meet the needs of the lowest-income sectors of the population, the solutions adopted in Chile during the last three decades have included minimal solutions in which the land alone is provided, as well as a variety of intermediate forms of gradual or incremental development and others providing finished dwellings. The history of housing in Chile reveals that levels of housing investment have been inadequate under all governments, which largely accounts for the rising housing deficit, and for the fact that the adoption of solutions providing completed low-cost housing necessarily leads to a diminution in the coverage provided, thereby increasing the problem. In addition, it may be mentioned that the major changes which have occurred in the results achieved by action to solve housing problems are due to the way in which the limited existing resources have been distributed, rather than to any substantial increase in the levels of investment.

In these circumstances, all the pointers seem to indicate the urgent need to seek new forms of low-cost housing which provide for gradual improvement drawing on the wide range of past Chilean experience of which full use has not been made, and complemented by experience from other countries.

The specific objectives of the research were to draw up a classification and appraisal of the various typologies of incremental housing developed in Chile and to use this as a basis for proposing further alternative typologies as part of the general objective of systematizing experience of housing in Chile.

The main issues considered in defining the housing typology were as follows:

- the system: its components and interaction with its surroundings
- the process: starting points, stages and targets
- participation: its role and structure
- technology: inputs, productive processes and systems
- funding: types, sources and stages of financial support.

On this basis, the research placed particular stress on aspects covering the system and the process and attached secondary importance to the other topics.

The proposal and examination of typological alternatives includes different scales of housing, from the most general to the most specific. These include, among others:

- types of formal organization at the city level;
- structural typology of housing developments;
- infrastructure analysis (drinking water supply and sanitation);
- typology of the subdivision of large housing blocks;
- typology of the grouping of lots into blocks, and
- relationship between the number and frontage of the lots and the cost of the infrastructure service networks.

The ECLAC/UNCHS Joint Unit on Human Settlements which carries out studies into the provision of infrastructure services to low-income settlements drew up an agreement with the Institute of Housing to carry out the study into aspects linked to drinking water supply and sanitation services, as part of the research carried out by the Institute into low-cost housing.

The purpose of the research into drinking water supply and sanitation services is to analyse aspects of design, codes, norms, operating efficiency and the reaction of users to the supply of the services in question in ten low-income development in Santiago, Chile. The research sought to analyse the drinking water supply and sanitation services at three levels: that of the housing unit, the housing development and the city or urban centre. This document sets out some of the results and conclusions drawn from a first phase of analysis of these cases at the level of the "housing complex". In view of the limited funds available for the study, no examination was made during this first stage of aspects linked to the operational efficiency and the reaction of the users to the basic services provided.

I. CONCEPTUAL FRAMEWORK

The need to make better use of the scarce resources available for low-income housing projects makes it necessary to develop a strategy for optimizing each of the factors involved in the process of construction or formation of housing in these sectors. These factors include technology, construction processes, materials, financing, codes and norms, legislation, cultural and social patterns, management and administration of a housing sector, planning, town and services planning, etc.

The provision of basic infrastructure services, in this case, drinking water supply and sanitation services, is one of the elements of urbanization which has a direct incidence on the living standards of low-income settlements. In this context, the term "living standards" designates the "appraisal made by a variety of observers or participants of the factors which make up a human settlement and their relationship with a given environment; their importance may vary from one group to another in accordance with variables of an essentially social, cultural and economic nature".1/

Optimization of the costs of providing drinking water supply and sanitation services, which represent factors of urbanization, is thus deeply influenced and determined by the above elements which affect the process of construction or formation of housing in low-income sectors. This study endeavours to illustrate a number of aspects of these elements with regard to technology, codes and standards, urban planning and the design of services.

It is possible to lay down an arbitrary definition of traditional technologies as being the set of techniques --and of underlying concepts-- which have been developed over the years and whose soundness is generally accepted by the official and professional bodies involved in the provision of drinking water supply and sanitation services (hereafter designated by "basic services"). Simultaneously, in order to lower costs and increase the number of beneficiaries, a growing proportion of systems providing basic services have been built using designs, construction techniques and materials which cannot be considered traditional. It may be stated that in the great majority of housing and basic service projects carried out by the region's public sector in general, and in Chile in particular, conventional technologies have been adopted. Confirmation of this is provided by the insignificant number of codes, standards and regulations officially published with regard to non-conventional basic service systems.2/

Consequently, it may be observed that the ten housing developments considered in this study possess conventional drinking water supply and sanitation systems. In fact, it is possible to replace the word "sanitation" by "sewerage" since this is the only sanitation technology used in all cases.

As the analysis of the ten cases studied does not allow any comparison to be made between the various technological alternatives for providing basic services, an attempt has been made to investigate in greater depth those aspects related to the codes and standards used in the design and construction thereof, together with their relationship with urban planning/design, particularly at the level of the housing development. It will be possible for subsequent studies to complement the analyses made at the level of the housing development with studies at the level of the housing unit, city or urban centre.

For the purposes of this study the following assumptions have been made:

a) Code of practice, is a regulation which describes the recommended practices for the design, manufacture, installation, maintenance or use of equipment, installations, structures or products;
b) Standard is a technical specification or other rule based on consensus and which has been approved by a recognized standard organization for repeated or continuous application.
c) A housing development:
    - is a part of the city and must consequently observe the existing urban structure of the sector in which it is located;
    - must possess a clear formal and spatial structure as well as of its parts (land, housing, infrastructure and the relevant urban services), and
    - must possess a clearly order hierarchy of space at four levels: public, semi-public, semi-private and private.

Among other things, analysis of the ten cases studied in Santiago, Chile, confirms a number of conclusions drawn by previous studies in the field.3/

a) The choice of the layout of a housing complex automatically determines the cost of services;
b) Costs may be lowered in two ways: i) by lowering the level of the services, which constitutes a policy decision, or ii) optimizing the layout of the housing development at the desired level, which involves a design decision;
c) Costs are minimized when the design of the infrastructure services in general is efficient and when there is an economic distribution of the basic networks and house connections;
d) In housing developments with a reticulated layout, diversity in the types of layout of lots and dwellings may ensure higher densities and lower costs for the basic service networks.*/

II. METHODOLOGY

A. Features which are to be analysed

In accordance with its objectives, the study endeavours to gather all the available information in order to carry out an appraisal of the criteria adopted in designing drinking water supply and sewerage networks in the housing developments studied. An attempt will be made to carry out this appraisal by means of a comparative analysis of the design parameters adopted in the different estates concerned. These are of different layout and were built at different times. Consequently, the cases studied cover low-income housing in Santiago, Chile, ranging from the year 1956 (Miguel Dávila) to 1980 (Los Nogales).

Simultaneously, an investigation will be made of the impact of the spatial layout of a housing development on the basic service networks. Since the levels of services provided are similar in virtually all the cases studied, the indicator chosen to assess this impact is that of the final cost of the services. Simultaneously, a number of theoretical examples will be provided in order to complement the information available from the cases studied and clarify the impact of the scale and layout of the housing lots and blocks on the cost of the basic service networks.

In view of the difficulty of gathering on-the-spot data relating to the physical characteristics and design of the basic service networks at the level of the housing development, it was decided to obtain the information from the design and as constructed drawings of the existing systems in each housing development.

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*/ These conclusions are drawn from the study into the provision of conventional drinking water supply and "sewerage" services (at various levels) to a variety of housing developments of different types and with different layouts.

There was no justification for studying in all cases the basic service networks over the whole of the surface of each housing development. In large developments it was decided to adopt a smaller area of each development, which was representative of the characteristics of the whole. It was considered that if the area to be studied was properly chosen, it would ensure that errors in calculating occupational densities, costs of services per unit area or dwelling and the average characteristics (dimensions) of the services for the housing development as a whole would be minimized.

In order to compare the costs of the services in the developments studied on the same basis, the same unit costs of installed services were applied to the quantities of services in each housing development. The unit costs adopted were calculated for March 1984 (1 U.F. = Ch$ 1 869.70 = US$ 21.26) and are based on estimates made by the Metropolitan Company for Sanitary Works in Santiago.

B. Information requirements and sources

The basic information relating to the housing developments was obtained by the Institute of Housing (University of Chile) from a variety of governmental and private sources. Information relating to basic service networks and costs was drawn from the records kept by the Metropolitan Company for Sanitary Works in Santiago.

The information includes:

a) The description of the housing development:
   - layout of the lots, roads, etc.
   - total surface
   - number and surface of the dwellings
   - number of inhabitants and gross density.

b) The description of the basic services:
   i) Drinking water supply:
      - layout of the distribution network
      - dimensions and quantities of the components making up the network
      - design details (inhabitants per dwelling, average water demand, demand factors, fireflow, working pressure, size of circuits and distance between fire hydrants)
      - costs.

   ii) Sewerage:
      - layout of the sewerage network
      - dimension and number of components making up the network
      - costs.

III. CASE ANALYSIS

A. General data on the housing developments studied

The government was mainly responsible for the construction of all the housing developments studied, with the exception of Villa La Reina, where community committees and co-operatives took responsibility for the development with support from the council. The developments are the result of different modalities, and range from squatter settlements, upgrading through site-and-services to definitive dwellings. In a number of cases, the construction of housing was carried out by private enterprises, in others by self-help programmes or by combinations of both methods. In only one of the housing developments, Villa La Reina, were the basic services installed by means of self-help methods. The layout of the lots and roads and the housing developments is shown on the plans of the drinking water supply and sewerage networks. Table 1 provides a summary of the basic characteristics of the ten housing developments studied.

B. Description of the drinking water supply and sewerage systems

Generally speaking the design and layout of the basic service networks followed conventional criteria. From the design, this is apparent in the factors used in calculating and sizing the drinking water supply networks as shown in table 2.

Nevertheless, it is apparent that in the case of the Miguel Dávila low-income development the values for average water supply and factor of maximum hourly demand are considerably different from those used in the remaining cases. In this respect, it should be mentioned that in designing the services for the Miguel Dávila low-income development, a sample was taken of consumption in the month of February, on the assumption that the highest daily rates of consumption would be recorded during that month, and an assessment of the variation of consumption during the day was also carried out. The figures of 151 litres per person per day (lppd) and 1.06 for the factor of maximum hourly demand were obtained from this research. In the remaining cases, the average supply values (250-300 lppd) and demand factor (a daily maximum of 1.5, an hourly maximum of 1.5) were established on the basis of the design practice of the relevant authority, who carried out no specific research into the developments being designed. By way of reference, the present actual demand per inhabitant in middle-class households (with small gardens) in cities located in temperate zones in the region fluctuates between 180 and 200 litres per inhabitant per day.4/

Table 2 shows that the number of inhabitants per dwelling adopted in designing the services (6.5) is in all cases higher than the number adopted in the urban project for the housing development (4.0-5.7 inhabitants per dwelling). For purposes of comparison, according to the census of low-income settlements in Santiago, carried out in August 1985, the average occupational levels of formally established dwellings, which consequently possess one house connection to each service network, are 6.28 in the case of normal low-income settlements, 6.76 in the case of site and services projects and 7.5 in the case of spontaneous settlements. The average for Santiago is approximately 4.0 inhabitants per dwelling.

The layout of the basic service networks is also based on traditional design criteria. Consequently, the mains are outside the property boundary and each connection provides services to only one dwelling or lot. The minimum diameters employed are 75 millimetres in the case of drinking water pipes and 175 millimetres for sewers. Only in the case of the Miguel Dávila low-income development are some mains within the property boundaries, as are the connections to the mains providing services to two dwellings or more. It should be mentioned that in the case of low-income housing projects connections to the mains are allowed to provide services to more than one dwelling and a minimum diameter of 50 millimeters is accepted for drinking water pipes and 150 millimeters for sewage pipes (under special circumstances).

The description of the principal characteristics of the basic service networks in the ten housing developments studied is given in tables 3 to 13 and figures 1 to 19.

Table 1

DESCRIPTION OF THE HOUSING DEVELOPMENTS STUDIED a/

Name/year	Location: Commune	Surface area (m^2)	Number of dwellings	Surface of dwelling (m^2)	Number of inhabitants	Gross density (pers. per ha.)
Miguel Dávila (1956)	San Miguel	660 000	2 238	65 b/	12 309	186.5
San Gregorio (1959)	La Granja	1 993 000	4 384	36 - 38	25 000	125.0
Villa La Reina (1966)	La Reina	385 000	1 592	36	6 368	165.4
El Bosque (1970)	Conchalí	241 700	744	37	2 976	123.1
Villa Perú (1970)	La Florida	143 592	568	36 - 43 b/	2 272	158.2
Nuevo Amanecer (1972)	La Florida	487 000	1 248	37 - 45	6 240	128.1
Santa Anita (1972)	Lo Prado	128 806	980	35 - 51 b/	4 970	385.9
Los Pozos Areneros (1973)	San Miguel	41 133	352	42 - 58	1 760	429.6
Carampangue (1979)	Quilicura	35 312	287	43	1 450	410.8
Los Nogales (1980)	Puente Alto	67 868	401	24	1 623	239.4

a/ Approximate values.

b/ Other types are to be found in the same development.

Table 2

DESIGN FACTORS: DRINKING WATER SUPPLY

Housing development/year	Persons per dwelling: Housing project	Persons per dwelling: Services project	Average water supply (lppd)	Demand factors: Daily max. over daily average	Demand factors: Hourly max. over daily max.	Fireflow (l/s/hydrant)	Length of circuits/rings (m)	Minimum working pressure (kgf/cm^2)	Distance between hydrants (m)
Miguel Dávila (1956)	5.5	-	151	-	1.06 a/	-	700 b/	-	140-180 b/
San Gregorio (1959)	5.7	6.0 a/	250	1.5 a/	1.5 a/	16	1 000	-	-
Villa La Reina (1966)	4.0	6.5	250	1.5	1.5	-	1 000	-	150
El Bosque (1970)	4.0	6.5	300 c/	1.5	1.5	16	1 000	1.2	180-200 b/
Villa Perú (1970)	4.0	6.5	250	1.5	1.5	-	1 000	1.6	150
Nuevo Amanecer (1972)	5.0	6.5	300	1.5	1.5	-	1 000	2.5	200
Santa Anita (1972)	5.1	6.5	300	1.5	1.5	16	500 b/	-	230-400 b/
Los Pozos Areneros (1973)	5.0	6.5	300	1.5	1.5	-	-	-	150-200 b/
Carampangue (1979)	5.1	6.5	250	1.5	1.5	-	350 b/	-	150-200 b/
Los Nogales (1980)	4.0	6.5	250	1.5	1.5	16	1 000-1 500 b/	-	200 b/

a/ Deduced from other design factors in the services project.
b/ Taken from the drawings.
c/ Future.

Table 3
SYMBOLS USED FOR THE DRINKING WATER AND SEWER NETWORKS

DRINKING WATER NETWORK

ESTATE: **COMMUNE:**	**COST OF NETWORK – MARCH 1984** (without house connection)* PER DWELLING: PER HECTARE:

*U.F. 1 = $Ch. 1 869.70 = US$ 21.26

Description of the section studied

Surface of plot: Number of dwellings: Density of dwellings: Length of pipe per dwelling (cost equivalent to 75 mm.):	Pipes 75 mm.: 100 mm.: 125 mm.: 150 mm.: 200 mm.: 250 mm.:	**VALVES** **(Nos.):** ○ **FIRE HYDRANTS** **(Nos.):** □

SEWERAGE NETWORK

ESTATE: **COMMUNE:**	**COST OF NETWORK – MARCH 1984** (without house connection)* PER DWELLING: PER HECTARE:

*U.F. 1 = $Ch. 1 869.70 = US$ 21.26

Description of the section studied

Surface of plot: Number of dwellings: Density of dwellings: Length of pipes per dwelling (cost equivalent to 175 mm.):	Pipes 175 mm.: 200 mm.: 250 mm.: 300 mm.: 350 mm.: 400 mm.: 450 mm.: 500 mm.: 600 mm.: **Manholes (Nos.):** ▫ □ Shown differently only for draughting purpose

Manholes are located:

- At the junction of pipes
- When the cross-section of pipes changes.
- At specific intervals on long stretches of straight pipes.
- When there is a change in direction in pipes.

Table 4
DRINKING WATER SUPPLY – SEWERAGE DATA

	MIGUEL DAVILA

DRINKING WATER NETWORK

ESTATE: MIGUEL DAVILA COMMUNE: SAN MIGUEL	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 5.36 U.F. PER HECTARE 210.30 U.F.

Description of the section studied

Surface of plot: 23.29 ha. Number of dwellings: 914 Density of dwellings: 39 Dw./ha. Length of pipe per dwelling (cost equivalent to 75 mm.): 8.89 m/dw.	Pipes 75 mm.: 2 900 100 mm.: 1 050 125 mm.: 1 857 150 mm.: 367 200 mm.: - 250 mm.: -	VALVES (Nos.): 50 FIRE HYDRANTS (Nos.): 14

SEWERAGE NETWORK

ESTATE: MIGUEL DAVILA COMMUNE: SAN MIGUEL	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 4.27 U.F. PER HECTARE 167.45 U.F.

Description of the section studied

Surface of plot: 23.29 ha. Number of dwellings: 914 Density of dwellings: 39 Dw./ha. Length of pipes per dwelling (cost equivalent to 175 mm.): 5.56 m/dw.	Pipes 175 mm.: 979 — 400 mm.: 93 200 mm.: 552 — 450 mm.: - 250 mm.: 1 852 — 500 mm.: 114 300 mm.: 164 — 600 mm.: - 350 mm.: 138 Manholes (Nos.): 45

Figure 1
DRINKING WATER SUPPLY NE WORK

MIGUE DAVILA

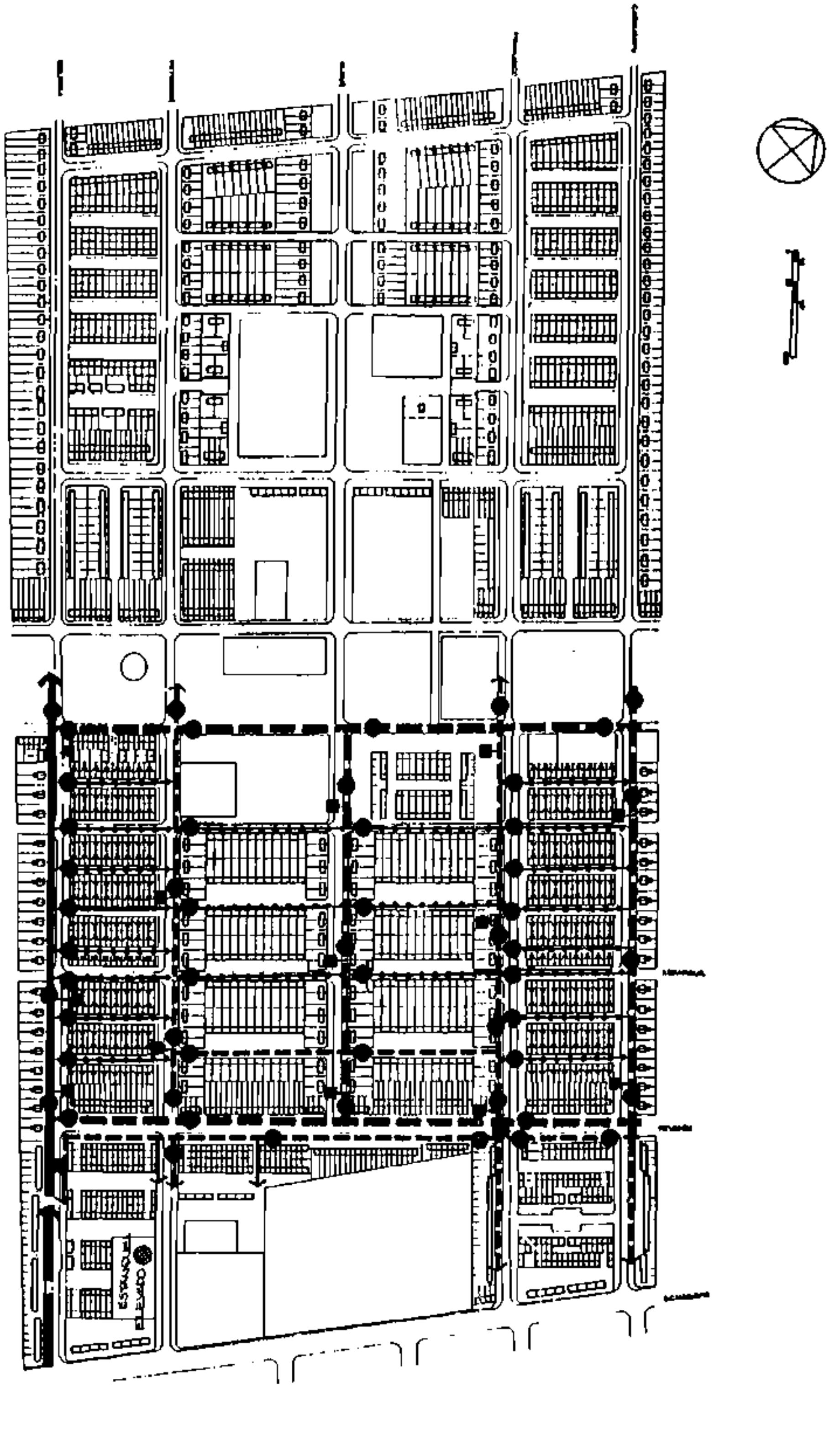


Figure 2
SEWERAGE NETWORK

MIGUEL DAVILA

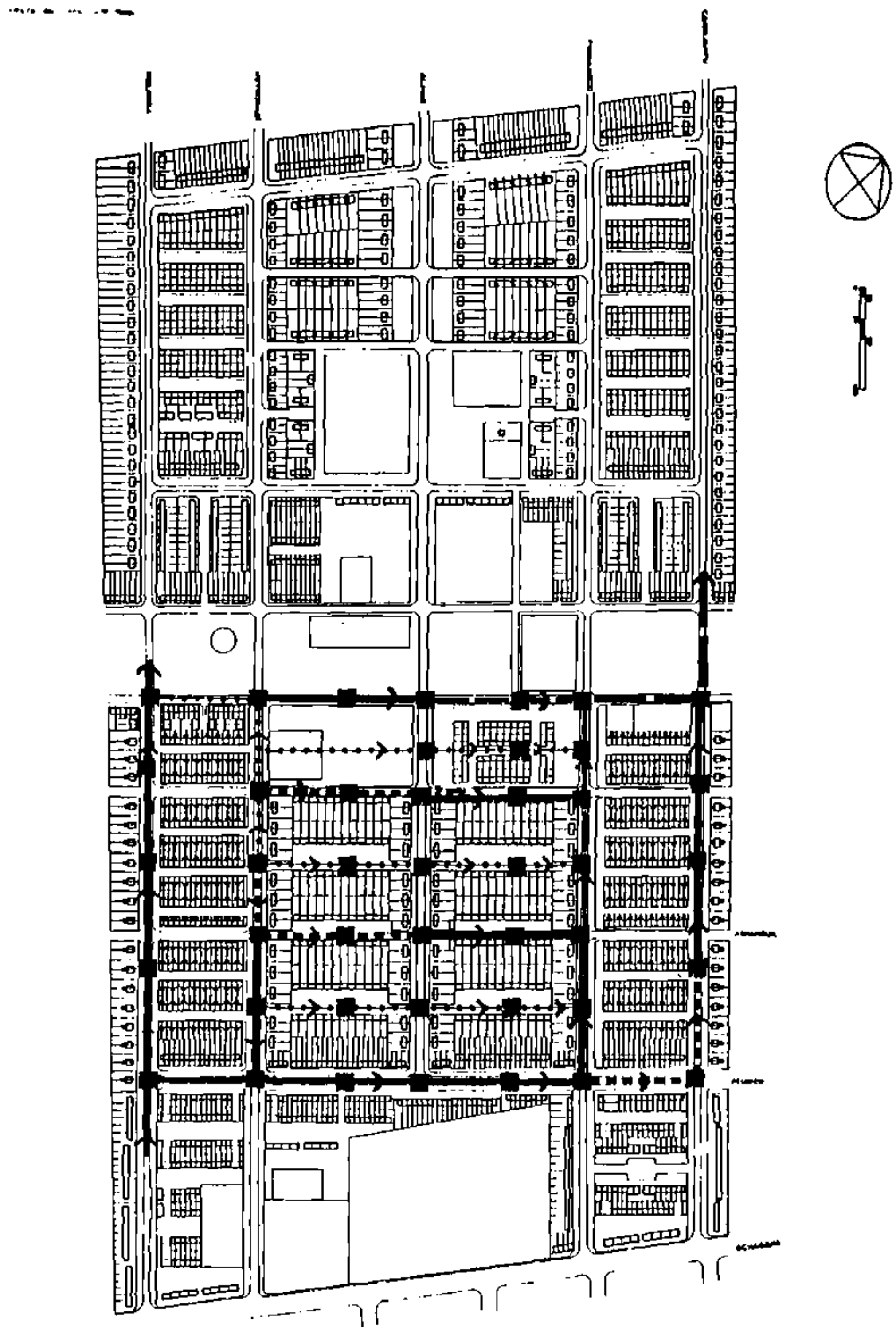


Table 5
DRINKING WATER SUPPLY – SEWERAGE DATA

	LOS NOGALES

DRINKING WATER NETWORK

ESTATE: LOS NOGALES COMMUNE: PUENTE ALTO	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 3.92 U.F. PER HECTARE 229.47 U.F.

Description of the section studied

Surface of plot: 4.30 ha. Number of dwellings: 252 Density of dwellings: 59 Dw./ha. Length of pipe per dwelling (cost equivalent to 75 mm.): 7.13 m/dw.	Pipes 75 mm.: 859 100 mm.: 148 125 mm.: 452 150 mm.: - 200 mm.: - 250 mm.: -	VALVES (Nos.): 5 FIRE HYDRANTS (Nos.): 2

SEWERAGE NETWORK

ESTATE: LOS NOGALES COMMUNE: PUENTE ALTO	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 3.91 U.F. PER HECTARE 229.07 U.F.

Description of the section studied

Surface of plot: 4.30 ha. Number of dwellings: 252 Density of dwellings: 59 Dw./ha. Length of pipes per dwelling (cost equivalent to 175 mm.): 4.72m/dw	Pipes 175 mm.: 534 — 400 mm.: 200 mm.: 154 — 450 mm.: 250 mm.: - — 500 mm.: 300 mm.: 328 — 600 mm.: 350 mm.: - Manholes (Nos.): 16

Figure 3
DRINKING WATER SUPPLY NETWORK

LOS NOGALES

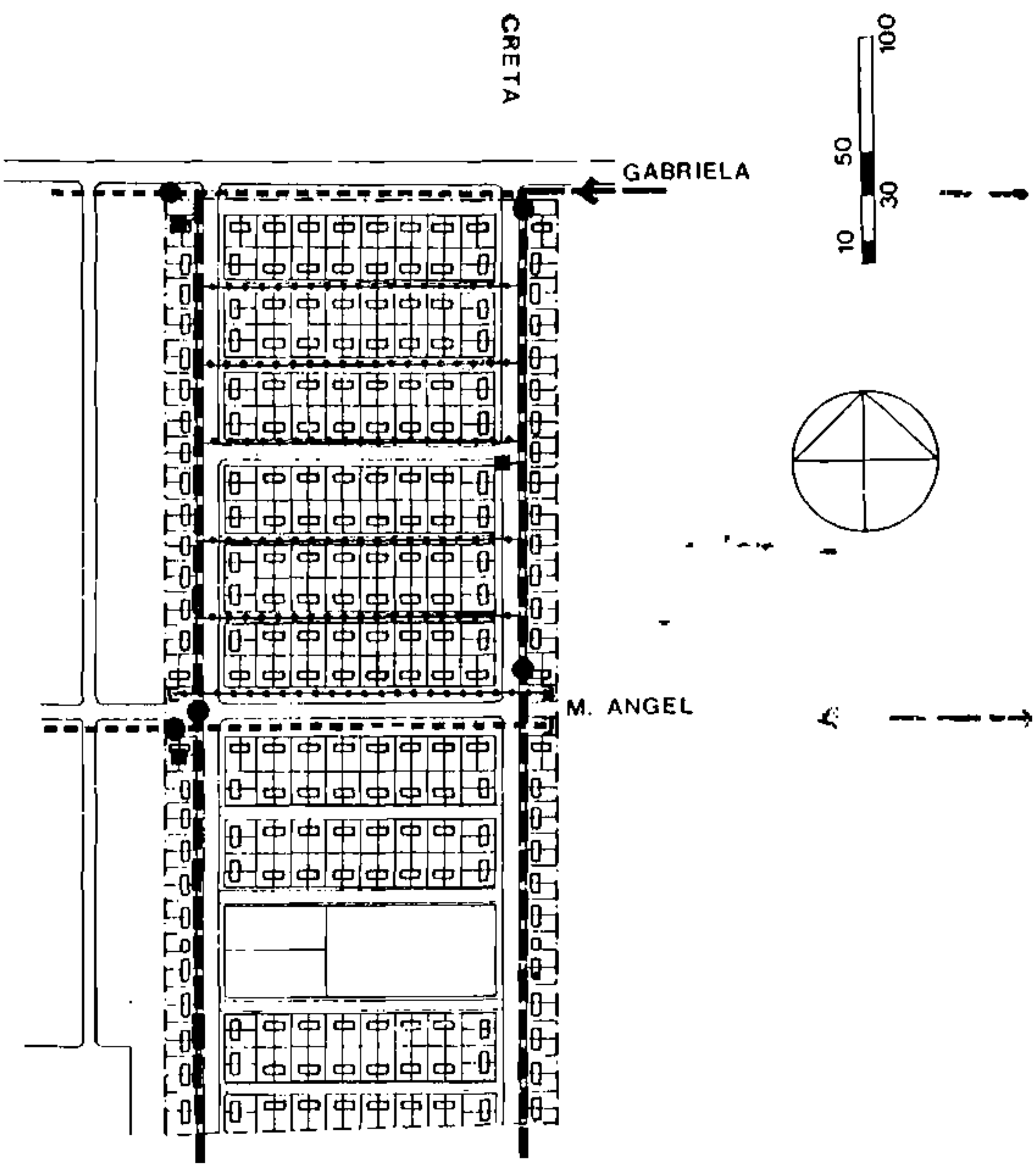


Figure 4
SEWERAGE NETWORK

LOS NOGALES

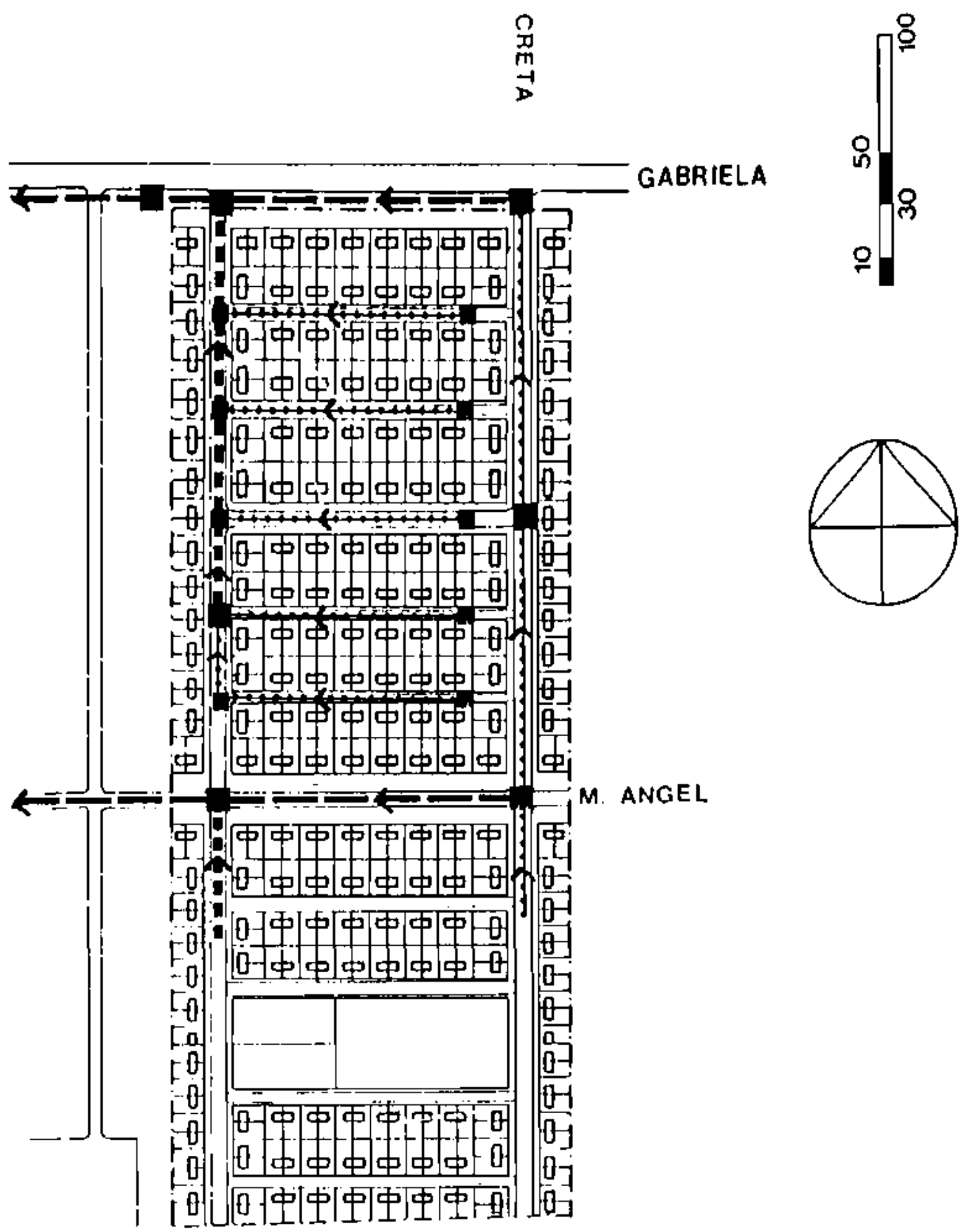


Table 6 DRINKING WATER SUPPLY – SEWERAGE DATA	
	SAN GREGORIO

DRINKING WATER NETWORK

ESTATE: SAN GREGORIO COMMUNE: LA GRANJA	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 8.43 U.F. PER HECTARE 205.05 U.F.

Description of the section studied

Surface of plot: 41.47 ha. Number of dwellings: 1 009 Density of dwellings: 24 Dw./ha. Length of pipe per dwelling (cost equivalent to 75 mm.): 15.48 m/dw.	Pipes 75 mm.: 4 384 100 mm.: 3 420 125 mm.: - 150 mm.: 1 536 200 mm.: 1 008 250 mm.: -	VALVES (Nos.): 41 FIRE HYDRANTS (Nos.): 13

SEWERAGE NETWORK

ESTATE: SAN GREGORIO COMMUNE: LA GRANJA	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 10.81 U.F. PER HECTARE 262.91 U.F.

Description of the section studied

Surface of plot: 41.47 ha. Number of dwellings: 1 009 Density of dwellings: 24 Dw./ha. Length of pipes per dwelling (cost equivalent to 175 mm.): 13.97 m/dw.	Pipes 175 mm.: 6 140 — 400 mm.: 220 200 mm.: 344 — 450 mm.: 180 250 mm.: 816 — 500 mm.: 784 300 mm.: 532 — 600 mm.: 376 350 mm.: - Manholes (Nos.): 131

Figure 5 **DRINKING WATER SUPPLY NETWORK**	
	SAN GREGORIO

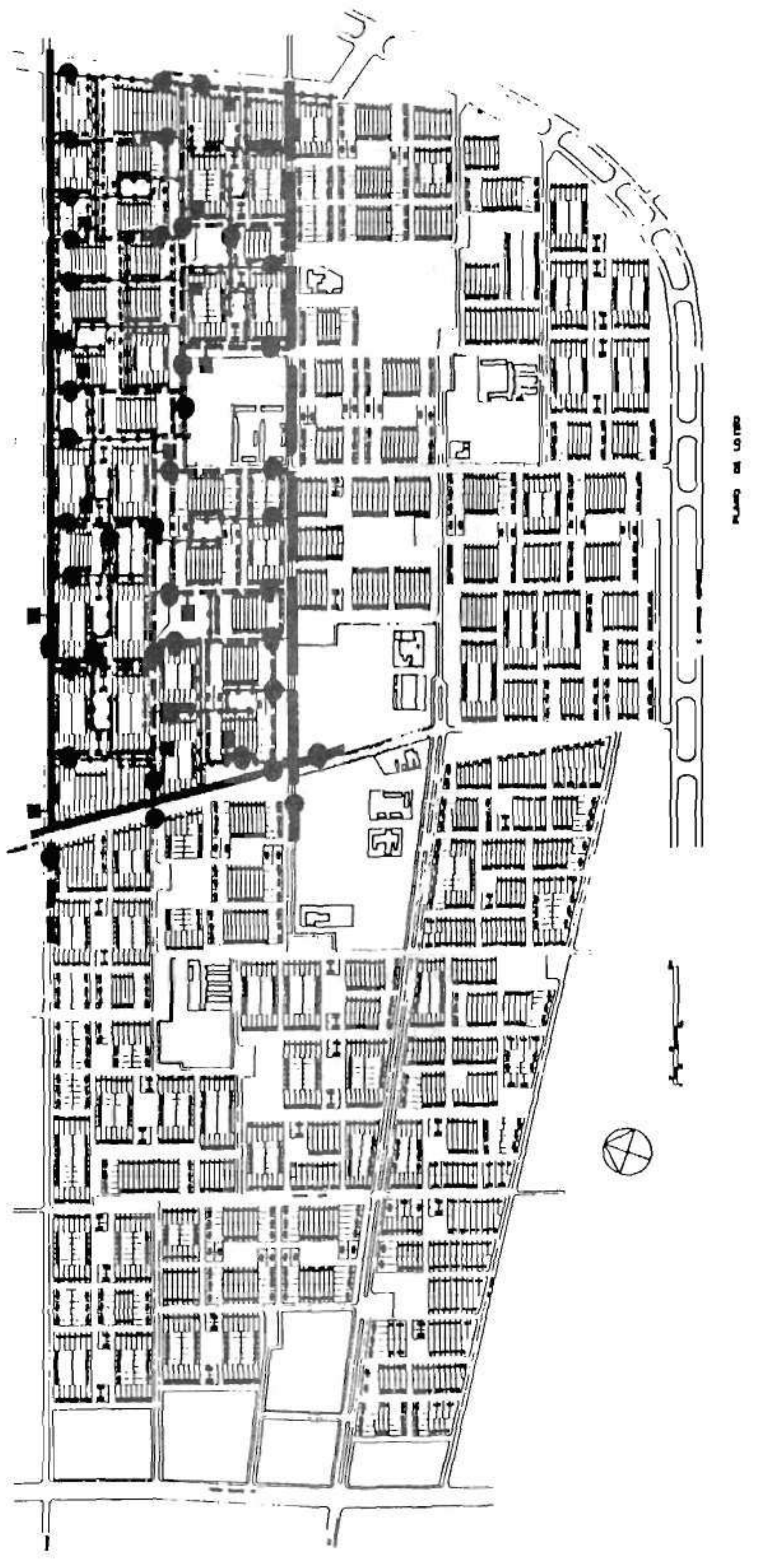


Figure 6
SEWERAGE NETWORK

SAN GREGORIO

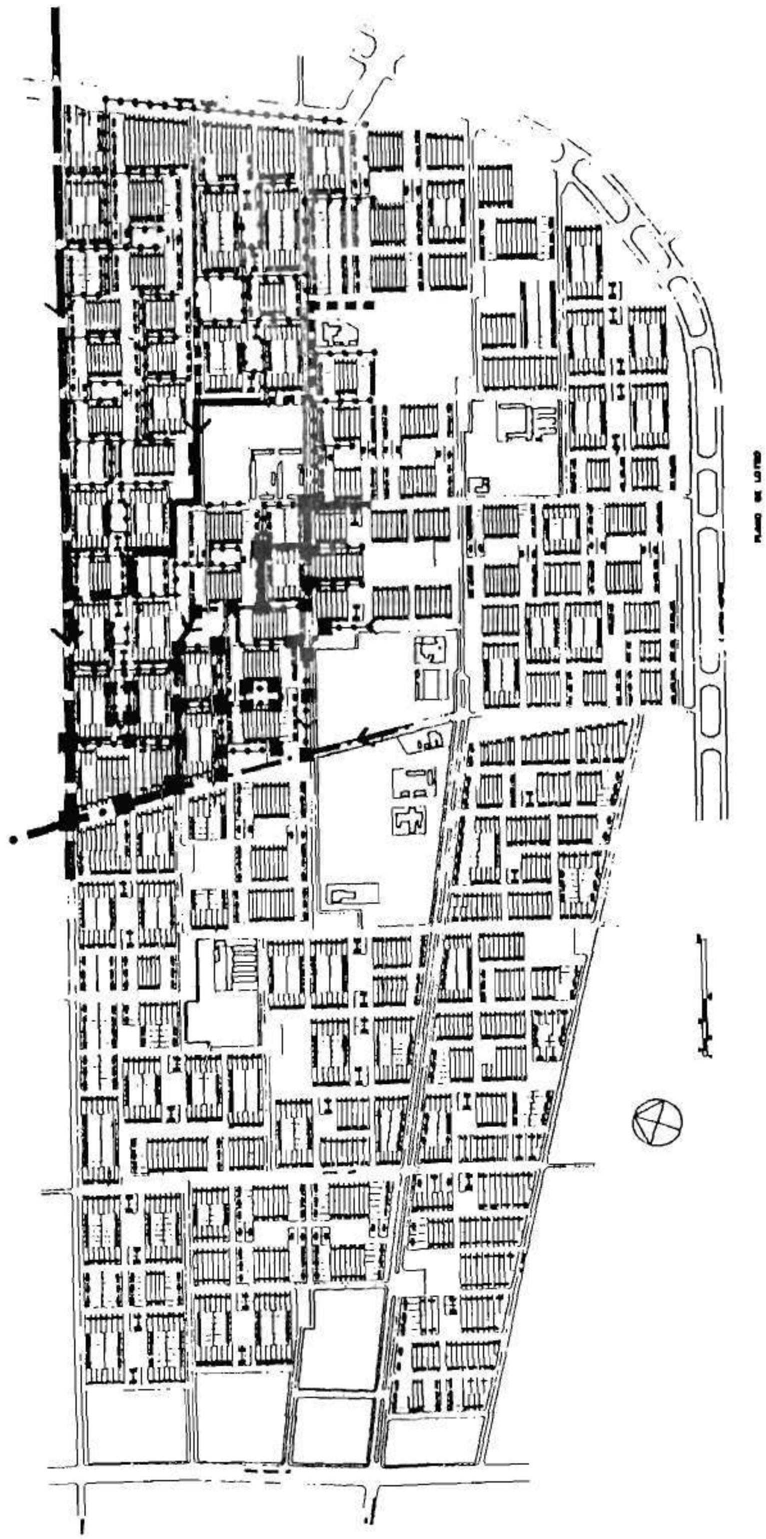


Table 7 DRINKING WATER SUPPLY – SEWERAGE DATA	
	VILLA LA REINA

DRINKING WATER NETWORK

ESTATE: VILLA LA REINA **COMMUNE:** LA REINA	**COST OF NETWORK – MARCH 1984** (without house connection) PER DWELLING: 6.01 U.F. PER HECTARE 303.39 U.F.

Description of the section studied

Surface of plot: 15.37 ha. Number of dwellings: 776 Density of dwellings: 50 Dw./ha. Length of pipe per dwelling (cost equivalent to 75 mm.): 10.93 m/dw.	Pipes 75 mm.: 1 900 100 mm.: 1 517 125 mm.: - 150 mm.: 1 538 200 mm.: 229 250 mm.: 135	**VALVES** (Nos.): 25 **FIRE HYDRANTS** (Nos.): 8

SEWERAGE NETWORK

ESTATE: **COMMUNE:**	**COST OF NETWORK – MARCH 1984** (without house connection) PER DWELLING: PER HECTARE

Description of the section studied

Surface of plot: Number of dwellings: Density of dwellings: Length of pipes per dwelling (cost equivalent to 175 mm.):	Pipes 175 mm.: 200 mm.: 250 mm.: 300 mm.: 350 mm.:	400 mm.: 450 mm.: 500 mm.: 600 mm.:
	Manholes (Nos.):	

Figure 7 DRINKING WATER SUPPLY NETWORK	
	VILLA LA REINA

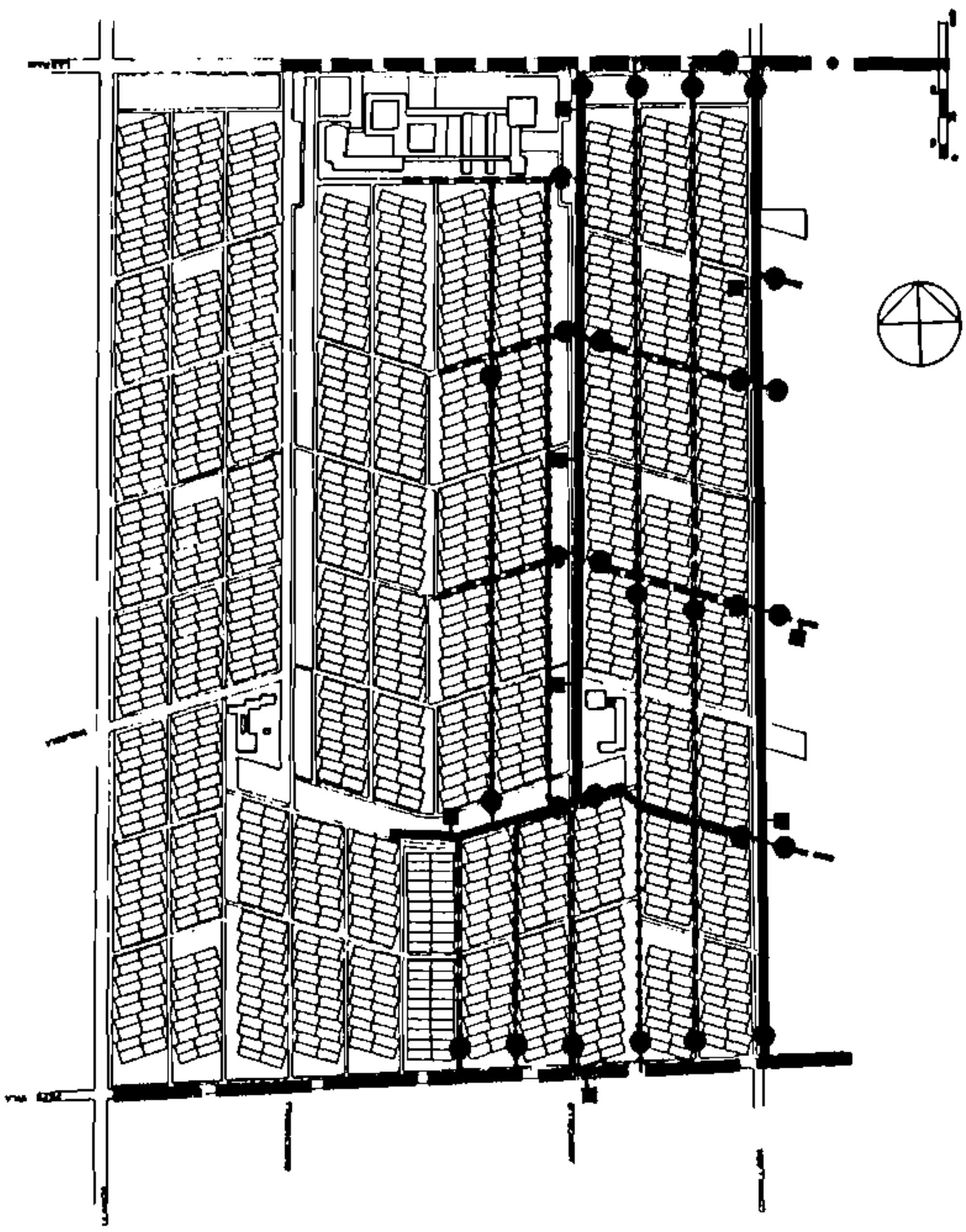


Table 8 DRINKING WATER SUPPLY – SEWERAGE DATA	
	EL BOSQUE

DRINKING WATER NETWORK

ESTATE: EL BOSQUE COMMUNE: CONCHALI	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 6.00 U.F. PER HECTARE 223.21 U.F.

Description of the section studied

Surface of plot: 9.40 ha. Number of dwellings: 350 Density of dwellings: 37 Dw./ha. Length of pipe per dwelling (cost equivalent to 75 mm.): 10.79 m/dw.	Pipes 75 mm.: 1 422 100 mm.: 1 352 125 mm.: 332 150 mm.: - 200 mm.: - 250 mm.: -	VALVES (Nos.): 12 FIRE HYDRANTS (Nos.): 5

SEWERAGE NETWORK

ESTATE: EL BOSQUE COMMUNE: CONCHALI	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 7.71 U.F. PER HECTARE 287.13 U.F.

Description of the section studied

Surface of plot: 9.40 ha. Number of dwellings: 350 Density of dwellings: 37 Dw./ha. Length of pipes per dwelling (cost equivalent to 175 mm.): 9.82 m/dw.	Pipes 175 mm.: 1 932 400 mm.: 200 mm.: 468 450 mm.: 250 mm.: - 500 mm.: 300 mm.: - 600 mm.: 350 mm.: 517 Manholes (Nos.): 35

Figure 8

DRINKING WATER SUPPLY NETWORK

EL BOSQUE

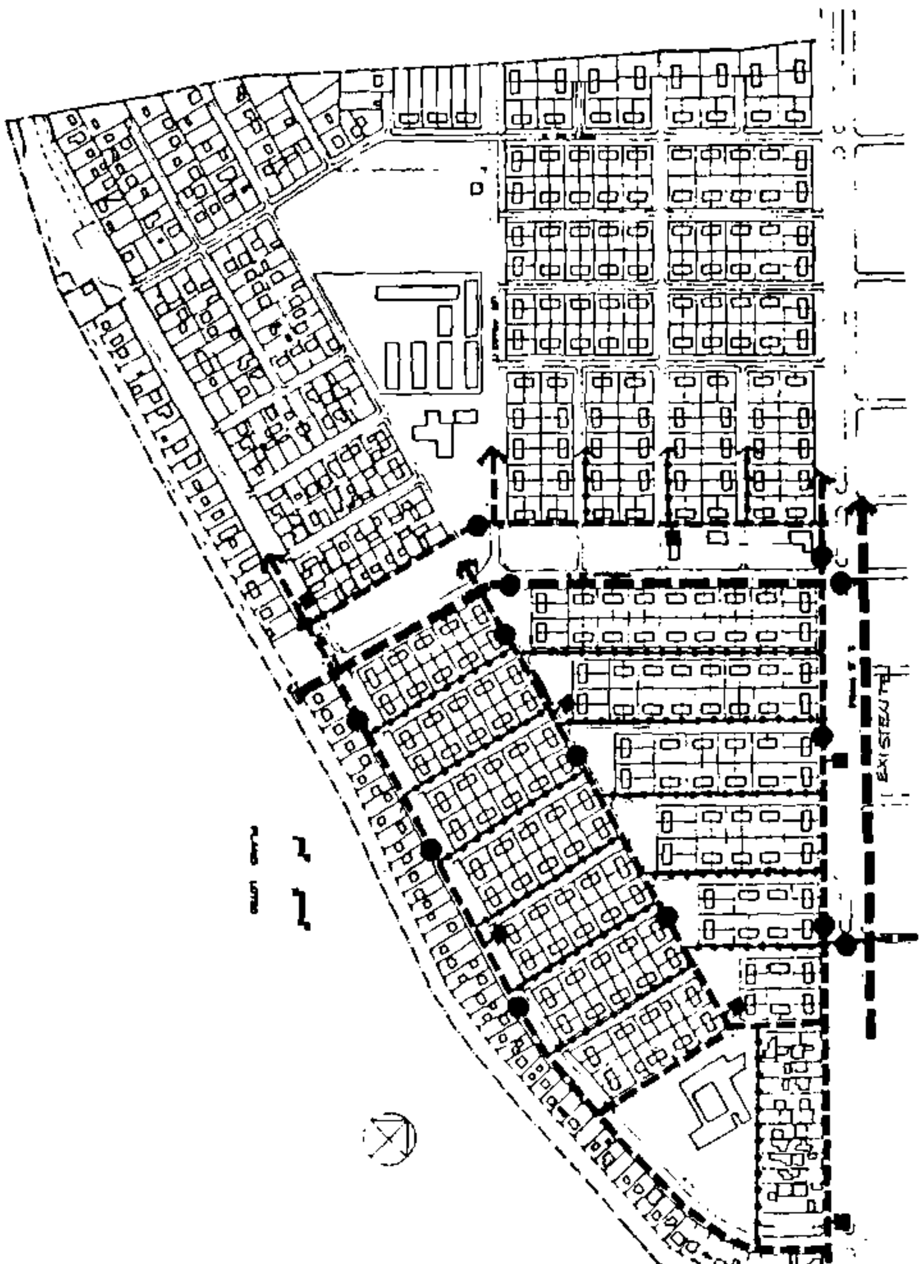


Figure 9 SEWERAGE NETWORK	
	EL BOSQUE

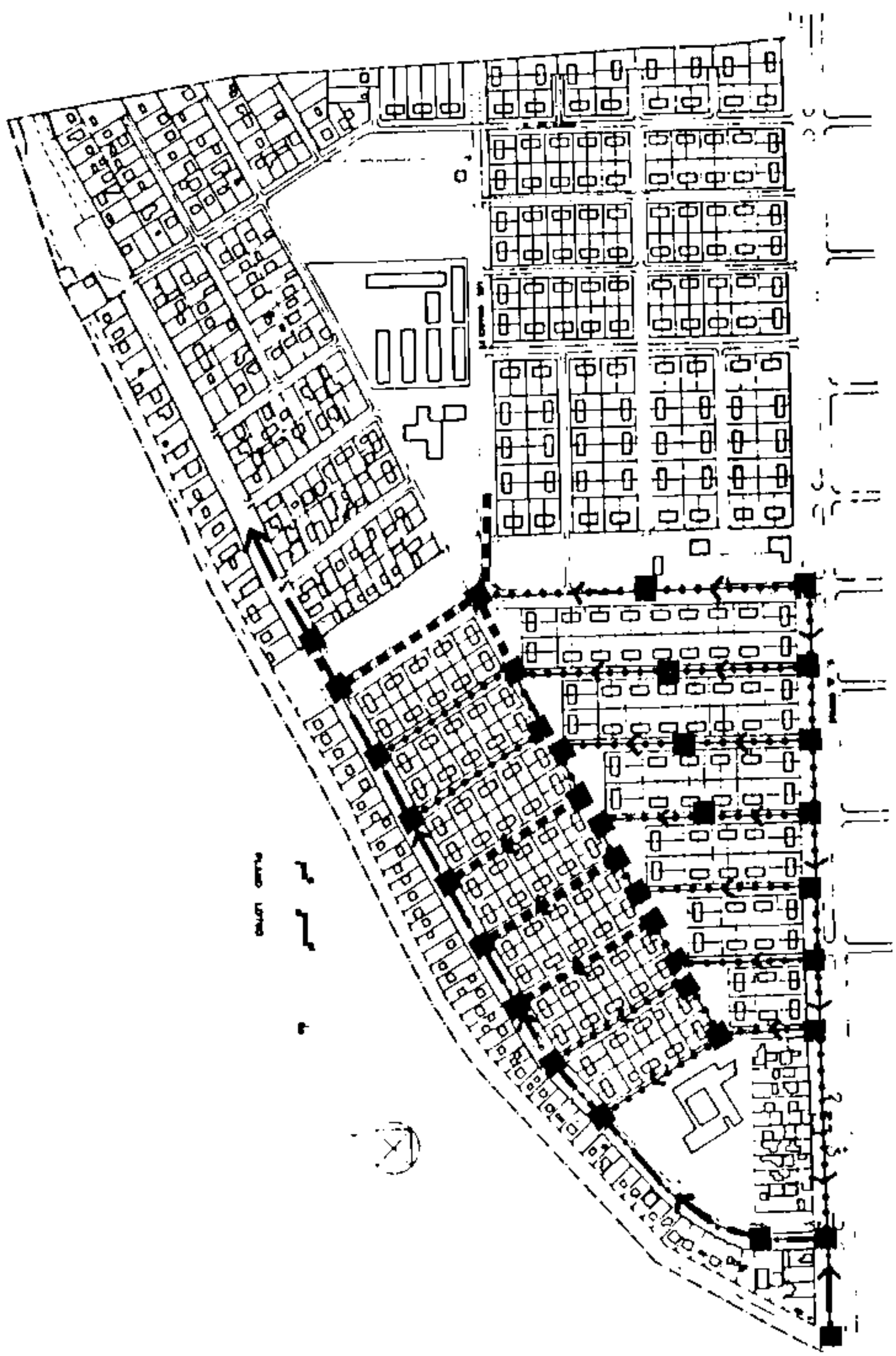


Table 9 DRINKING WATER SUPPLY – SEWERAGE NETWORK	
	VILLA PERU

DRINKING WATER NETWORK

ESTATE: VILLA PERU **COMMUNE:** LA FLORIDA	**COST OF NETWORK – MARCH 1984** (without house connection) PER DWELLING: 10.42 U.F. PER HECTARE 386.59 U.F.

Description of the section studied

Surface of plot: 3.88 ha. Number of dwellings: 144 Density of dwellings: 37 Dw./ha. Length of pipe per dwelling (cost equivalent to 75 mm.): 18.70 m/dw.	**Pipes** 75 mm.: 404 100 mm.: 524 125 mm.: - 150 mm.: 160 200 mm.: 368 250 mm.: -	**VALVES (Nos.):** 9 **FIRE HYDRANTS (Nos.):** 3

SEWERAGE NETWORK

ESTATE: VILLA PERU COMMUNE: LA FLORIDA	**COST OF NETWORK – MARCH 1984** (without house connection) PER DWELLING: 8.06 U.F. PER HECTARE 298.97 U.F.

Description of the section studied

Surface of plot: 3.88 ha. Number of dwellings: 144 Density of dwellings: 37 Dw./ha. Length of pipes per dwelling (cost equivalent to 175 mm.): 10.28 m/dw.	**Pipes**			
	175 mm.:	646	400 mm.:	170
	200 mm.:	388	450 mm.:	-
	250 mm.:	-	500 mm.:	-
	300 mm.:	-	600 mm.:	-
	350 mm.:	-		
	Manholes (Nos.): 15			

Figure 10
DRINKING WATER SUPPLY NETWORK

VILLA PERU

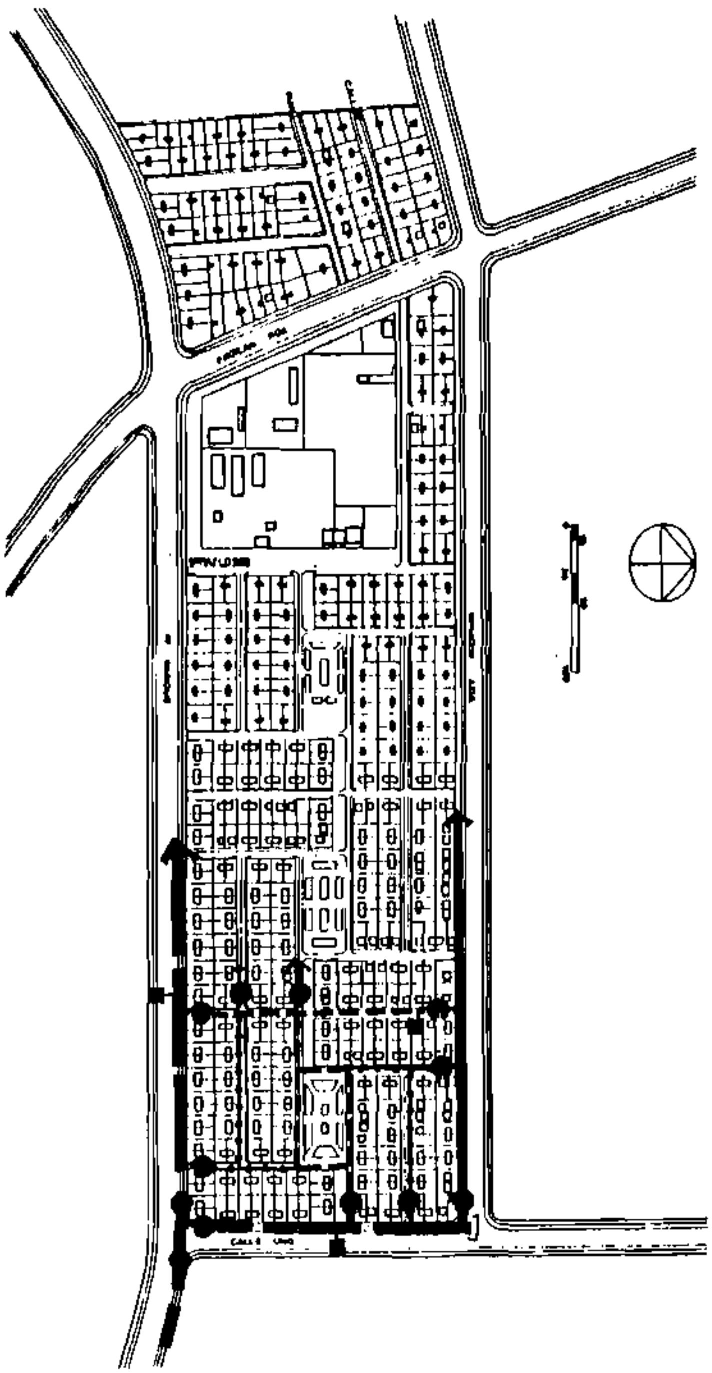


Figure 11 SEWERAGE NETWORK	
	VILLA PERU

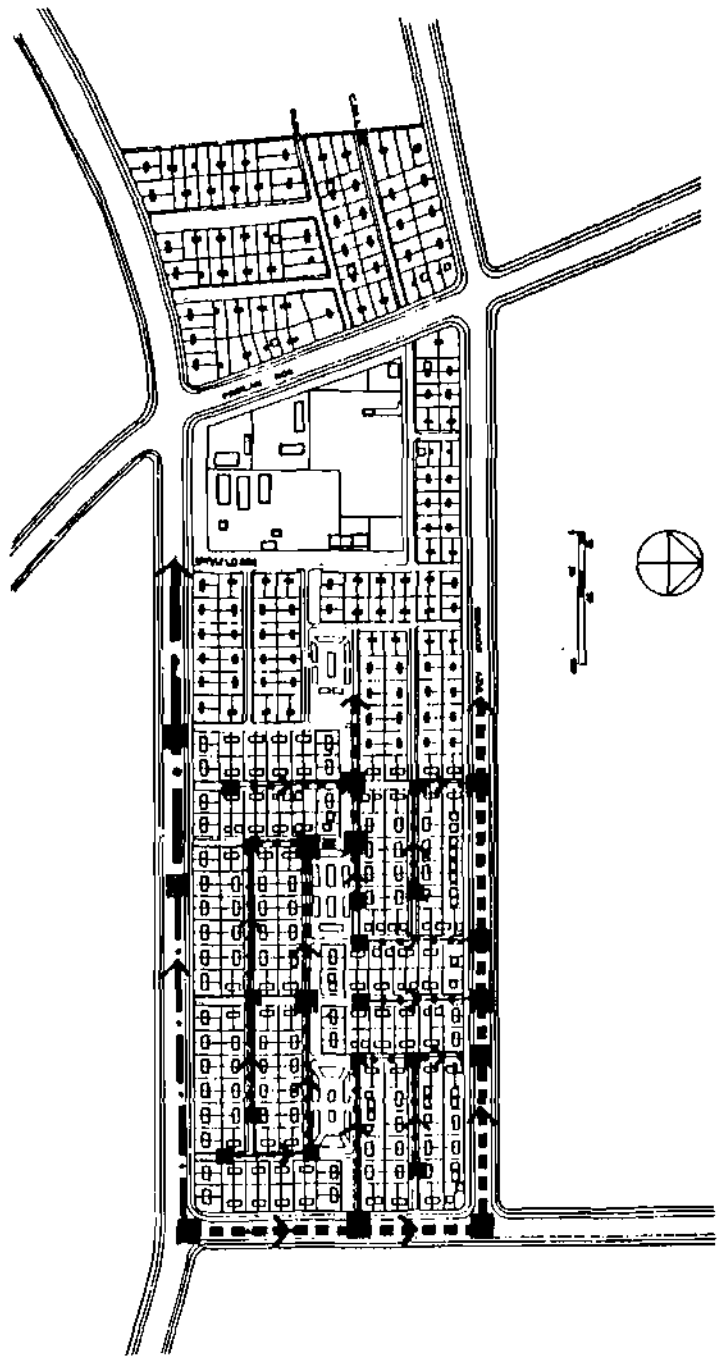


Table 10 DRINKING WATER SUPPLY – SEWERAGE DATA	
	NUEVO AMANECER

DRINKING WATER NETWORK

ESTATE: NUEVO AMANECER COMMUNE: LA FLORIDA	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 9.80 U.F. PER HECTARE 321.06 U.F.

Description of the section studied

Surface of plot: 14.95 ha. Number of dwellings: 490 Density of dwellings: 33 Dw./ha. Length of pipe per dwelling (cost equivalent to 75 mm.):18.21 m/dw.	Pipes 75 mm.: 853 100 mm.: 1 835 125 mm.: - 150 mm.: 1 240 200 mm.: 885 250 mm.: -	VALVES (Nos.): 19 FIRE HYDRANTS (Nos.): 9

SEWERAGE NETWORK

ESTATE: NUEVO AMANECER COMMUNE: LA FLORIDA	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 7.10 U.F. PER HECTARE 232.64 U.F.

Description of the section studied

Surface of plot: 14.95 ha. Number of dwellings: 490 Density of dwellings: 33 Dw./ ha. Length of pipes per dwelling (cost equivalent to 175 mm.): 8.76 m/dw.	Pipes 175 mm.: 1 720 — 400 mm.: 200 mm.: 1 305 — 450 mm.: 250 mm.: 890 — 500 mm.: 300 mm.: - — 600 mm.: 350 mm.: - Manholes (Nos.): 52

Figure 12
DRINKING WATER SUPPLY NETWORK

NUEVO AMANECER

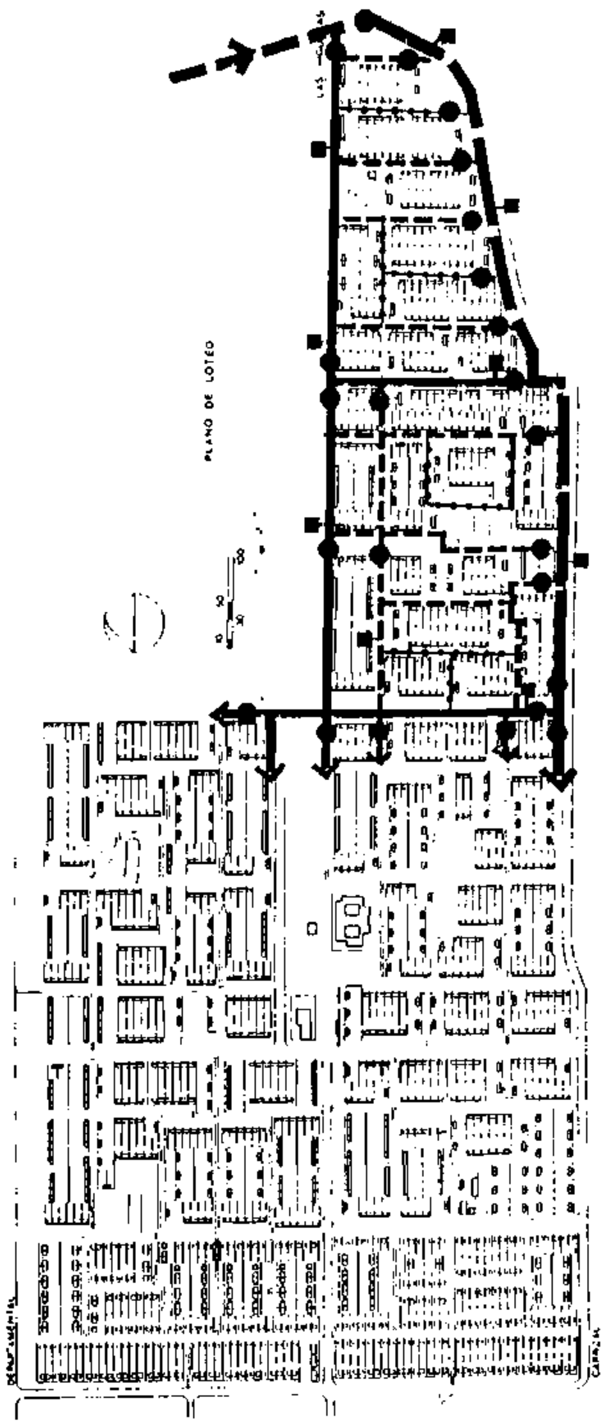


Figure 13
SEWERAGE NETWORK

NUEVO AMANECER

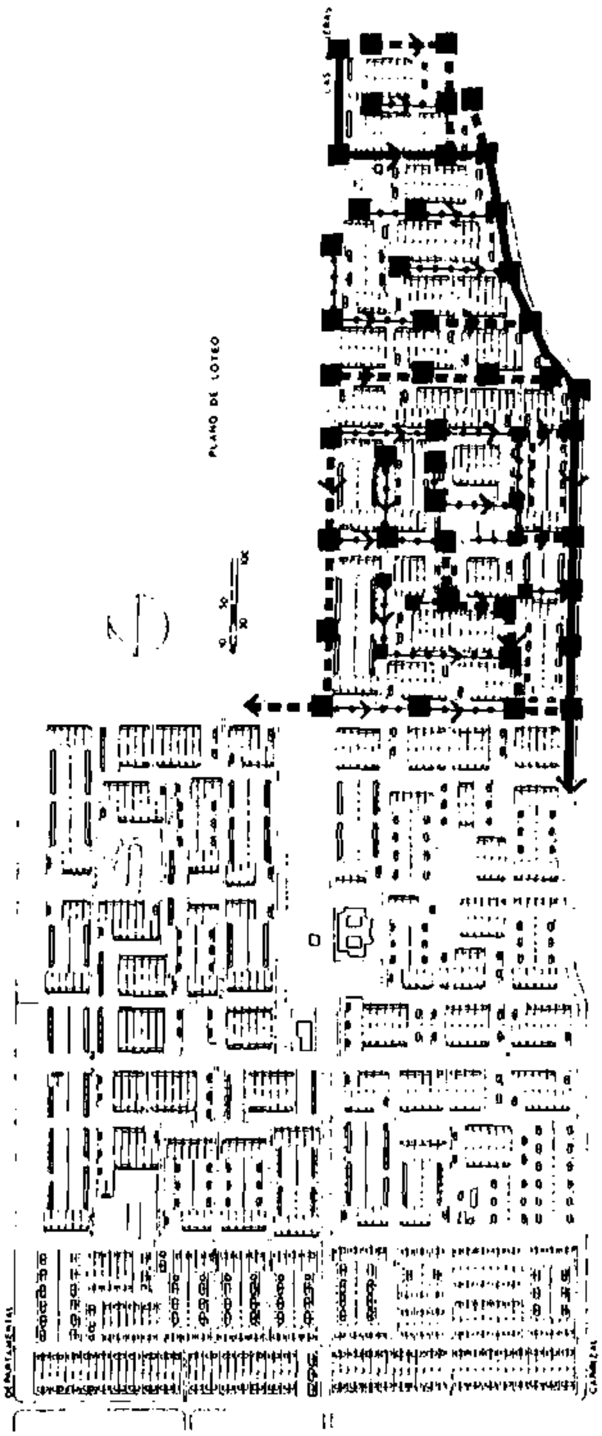


Table 11 DRINKING WATER SUPPLY – SEWERAGE DATA	
	SANTA ANITA

DRINKING WATER NETWORK

ESTATE: SANTA ANITA COMMUNE: LO PRADO	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 2.46 U.F. PER HECTARE: 133.71 U.F.

Description of the section studied

Surface of plot: 18.02 ha. Number of dwellings: 980 Density of dwellings: 54 Dw./ha. Length of pipe per dwelling (cost equivalent to 75 mm.): 4.31 m/dw.	Pipes 75 mm.: - 100 mm.: 3 155 125 mm.: - 150 mm.: - 200 mm.: - 250 mm.: -	VALVES (Nos.): 18 FIRE HYDRANTS (Nos.): 4

SEWERAGE NETWORK

ESTATE: SANTA ANITA COMMUNE: LO PRADO	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 2.40 U.F. PER HECTARE 130.69 U.F.

Description of the section studied

Surface of plot: 18.02 ha. Number of dwellings: 980 Density of dwellings: 54 Dw./ha. Length of pipes per dwelling (cost equivalent to 175 mm.): 2.82 m/dw	Pipes 175 mm.: 1 397 — 400 mm.: 200 mm.: 239 — 450 mm.: 250 mm.: 129 — 500 mm.: 300 mm.: 302 — 600 mm.: 350 mm.: 259 Manholes (Nos.): 42

Figure 14
DRINKING WATER SUPPLY NETWORK

SANTA ANITA

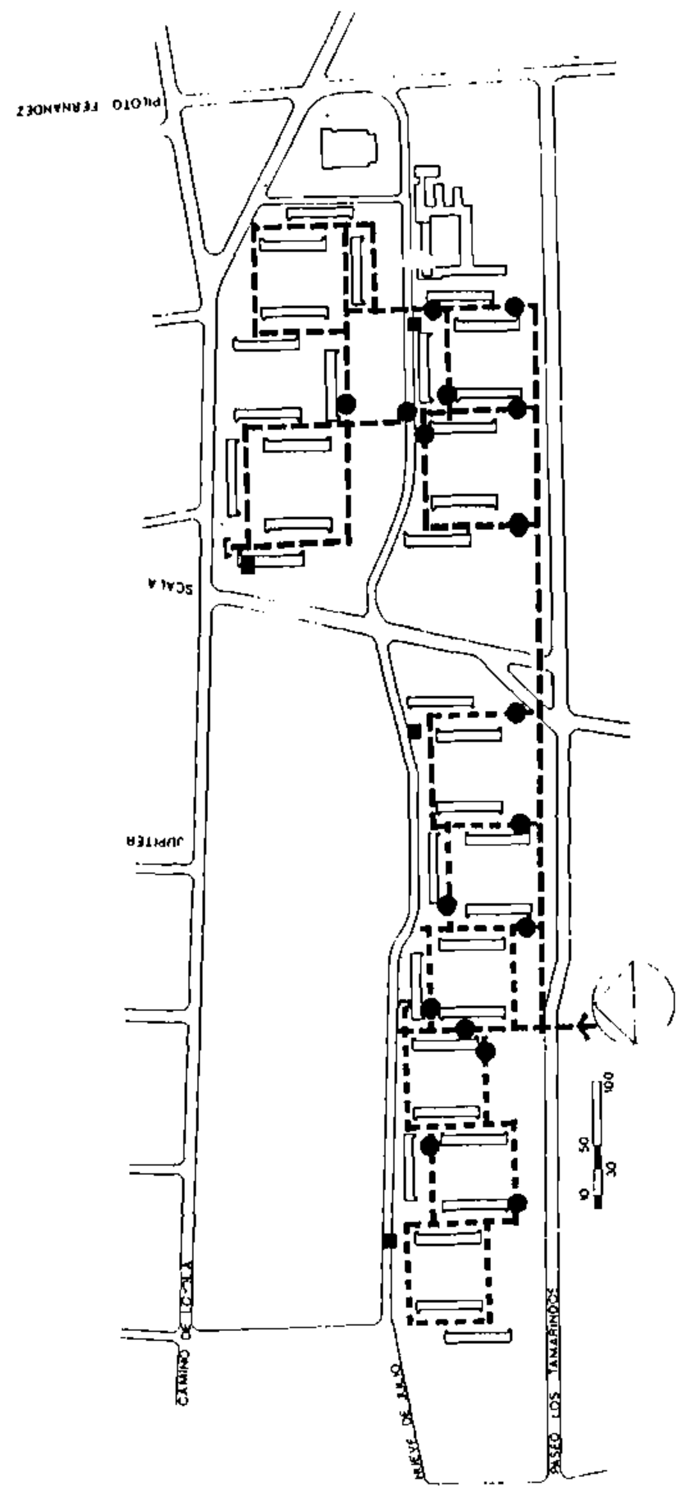


Figure 15 SEWERAGE NETWORK	
1	SANTA ANITA

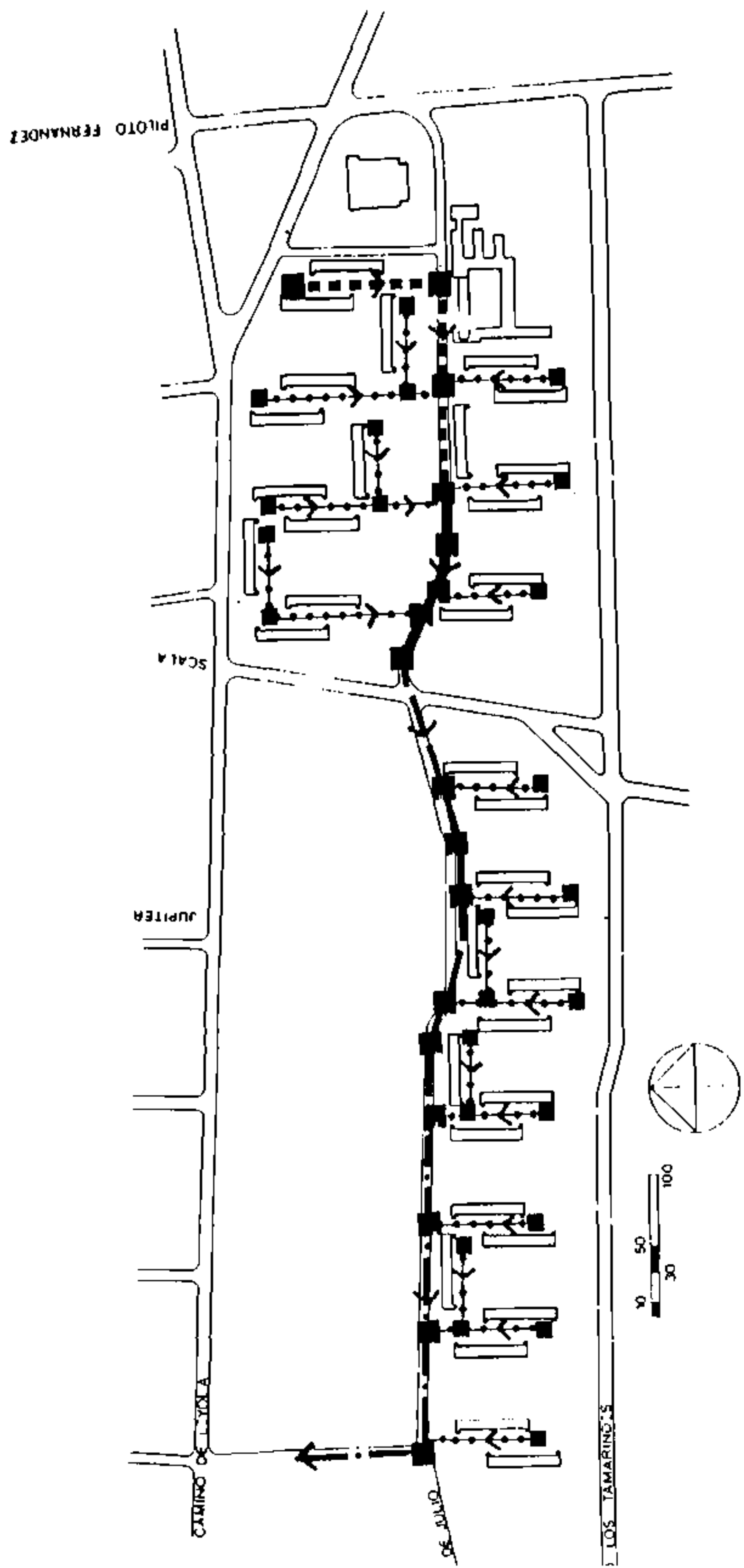


Table 12
DRINKING WATER SUPPLY – SEWERAGE DATA

	CARAMPANGUE

DRINKING WATER NETWORK

ESTATE: CARAMPANGUE COMMUNE: QUILICURA	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 3.11 U.F. PER HECTARE 248.25 U.F.

Description of the section studied

Surface of plot: 3.60 ha. Number of dwellings: 287 Density of dwellings: 80 Dw./ha. Length of pipe per dwelling (cost equivalent to 75 mm.): 5.20 m/dw.	Pipes 75 mm.: 254 100 mm.: 858 125 mm.: 54 150 mm.: - 200 mm.: - 250 mm.: -	VALVES (Nos.): 9 FIRE HYDRANTS (Nos.): 2

SEWERAGE NETWORK

ESTATE: CARAMPANGUE COMMUNE: QUILICURA	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 2.62 U.F. PER HECTARE 209.17 U.F.

Description of the section studied

Surface of plot: 3.60 ha. Number of dwellings: 287 Density of dwellings: 80 Dw./ha. Length of pipes per dwelling (cost equivalent to 175 mm.): 2.97 m/Dw.	Pipes 175 mm.: 802 — 400 mm.: 200 mm.: 45 — 450 mm.: 250 mm.: - — 500 mm.: 300 mm.: - — 600 mm.: 350 mm.: - Manholes (Nos.): 15

Figure 16
DRINKING WATER SUPPLY NETWORK

CARAMPANGUE

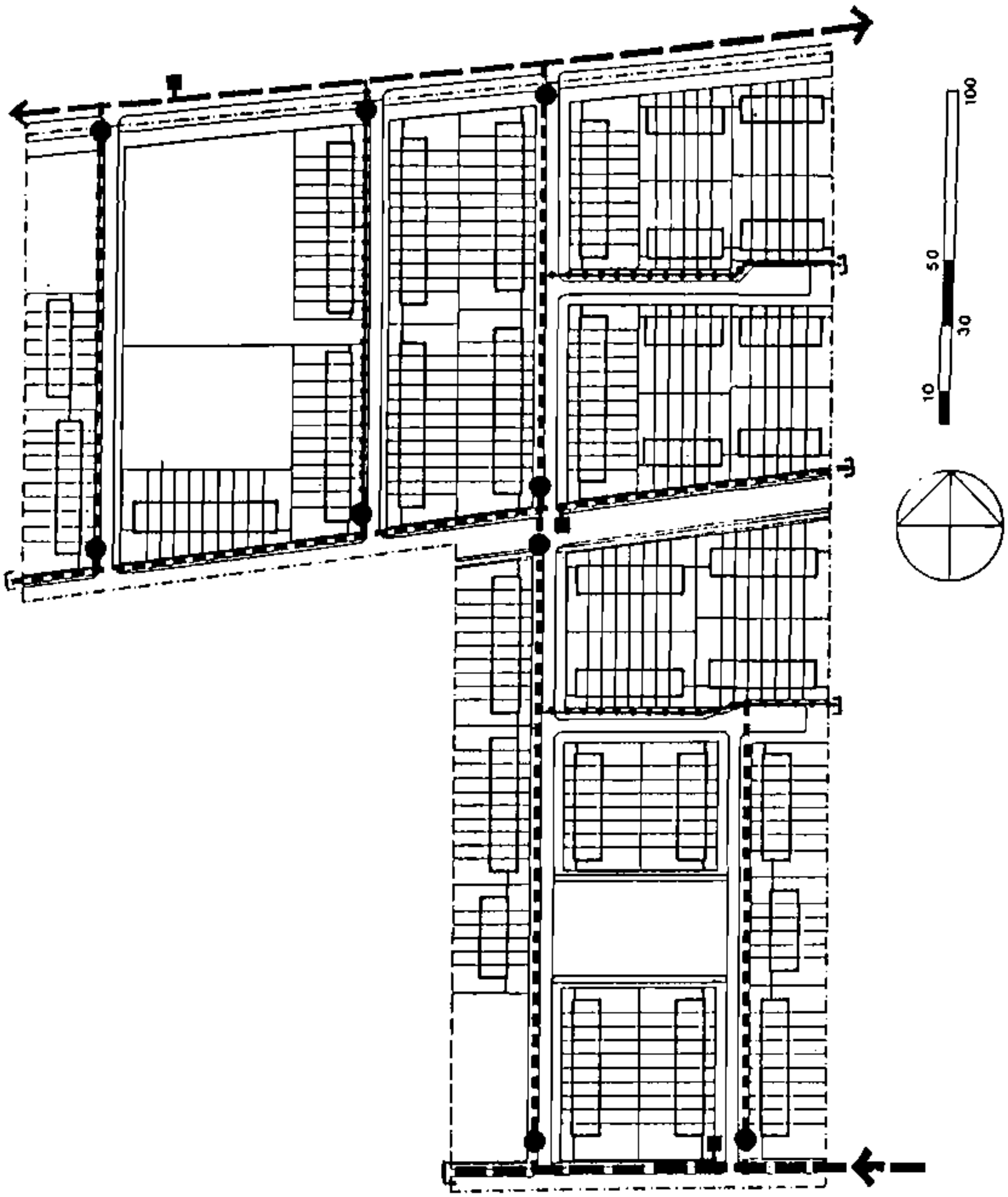


Figure 17 **SEWERAGE NETWORK**	
	CARAMPANGUE

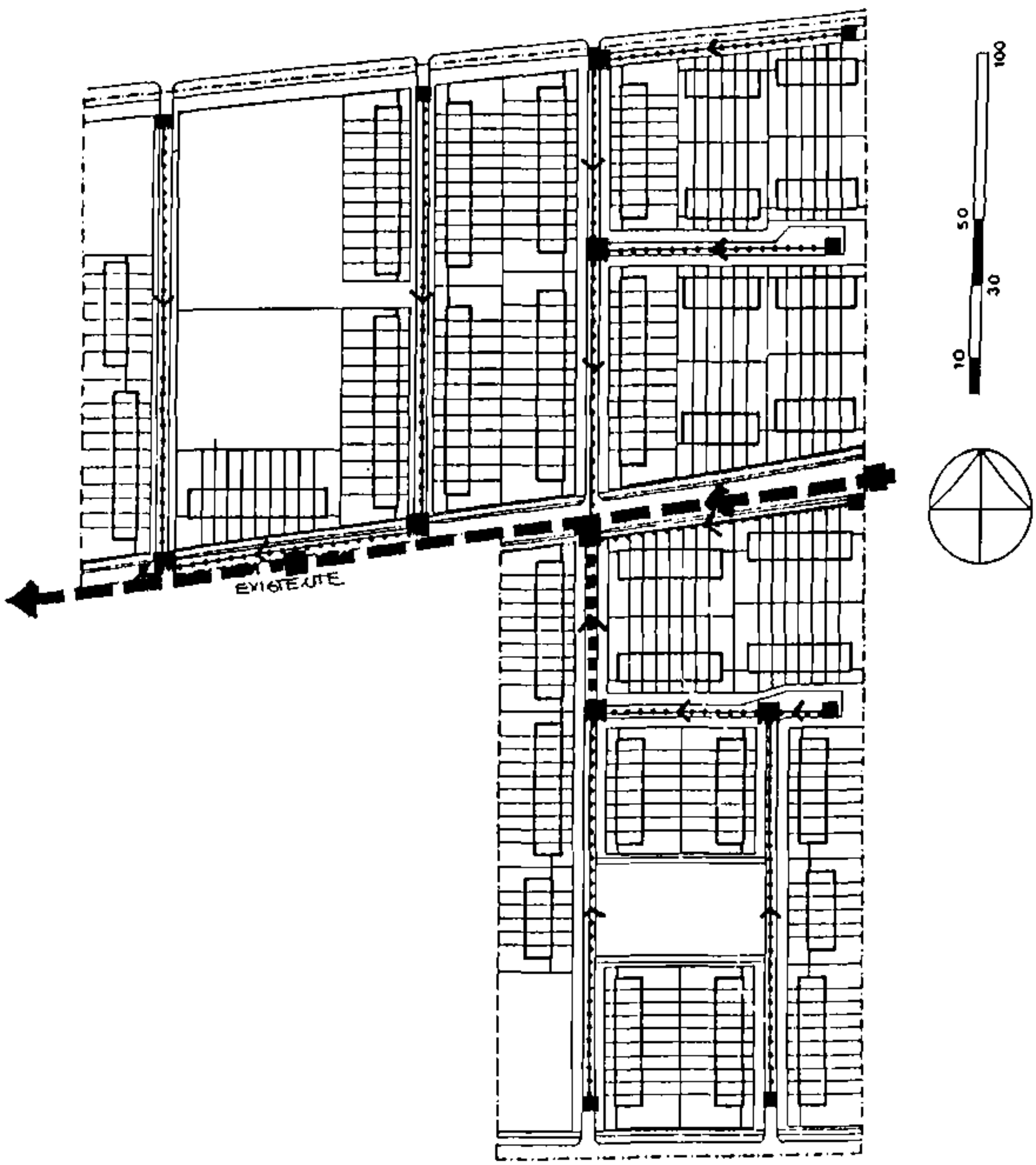


Table 13 DRINKING WATER SUPPLY – SEWERAGE DATA	
	LOS POZOS ARENEROS

DRINKING WATER NETWORK

ESTATE: LOS POZOS ARENEROS COMMUNE: SAN MIGUEL	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 1.89 U.F. PER HECTARE 141.08 U.F.

Description of the section studied

Surface of plot: 4.71 ha. Number of dwellings: 352 Density of dwellings: 75 Dw./ ha. Length of pipe per dwelling (cost equivalent to 75 mm.): 3.37 m/dw.	Pipes 75 mm.: - 100 mm.: - 125 mm.: - 150 mm.: 565 200 mm.: - 250 mm.: -	VALVES (Nos.): 4 FIRE HYDRANTS (Nos.): 2

SEWERAGE NETWORK

ESTATE: LOS POZOS ARENEROS COMMUNE: SAN MIGUEL	COST OF NETWORK – MARCH 1984 (without house connection) PER DWELLING: 1.51 U.F. PER HECTARE 112.74 U.F.

Description of the section studied

Surface of plot: 4.71 ha. Number of dwellings: 352 Density of dwellings: 75 Dw./ha. Length of pipes per dwelling (cost equivalent to 175 mm.): 1.74 m/dw.	Pipes 175 mm.: - 200 mm.: 553 250 mm.: - 300 mm.: - 350 mm.: - 400 mm.: 450 mm.: 500 mm.: 600 mm.: Manholes (Nos.): 10

Figure 18

DRINKING WATER SUPPLY NETWORK

LOS POZOS ARENEROS

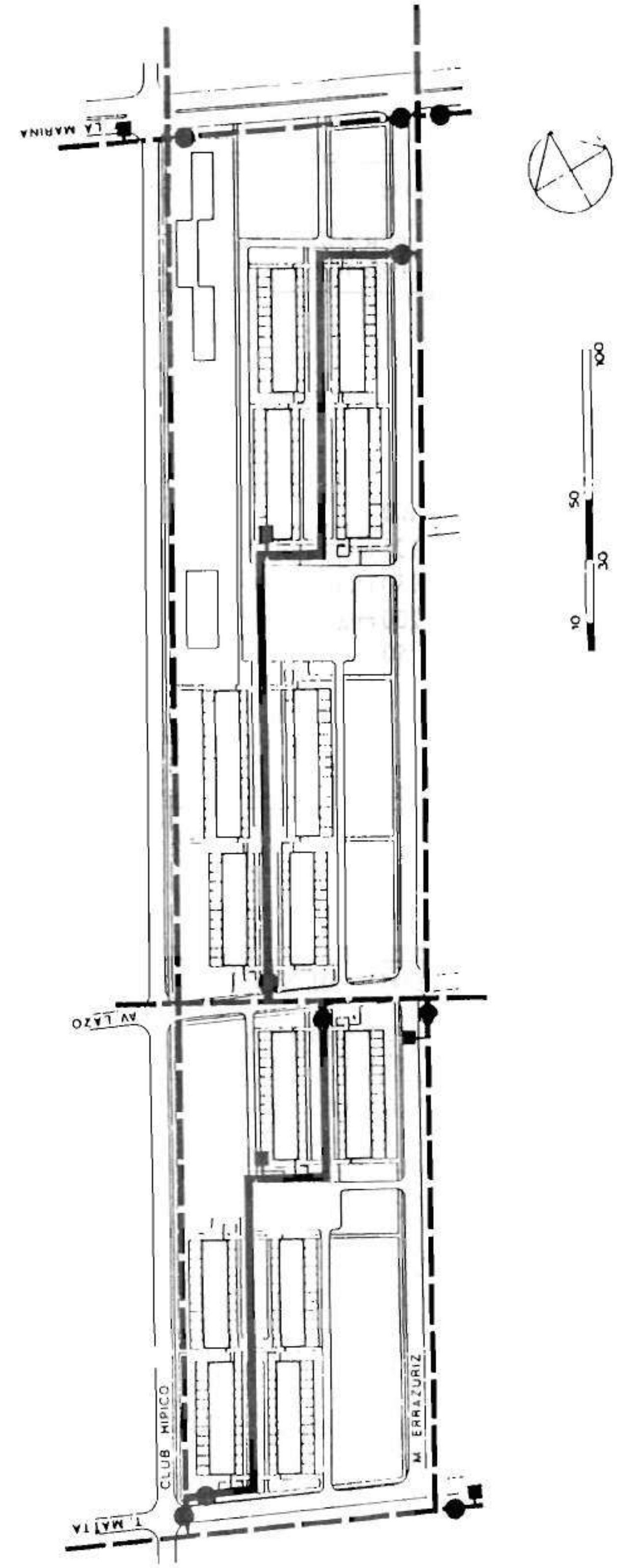
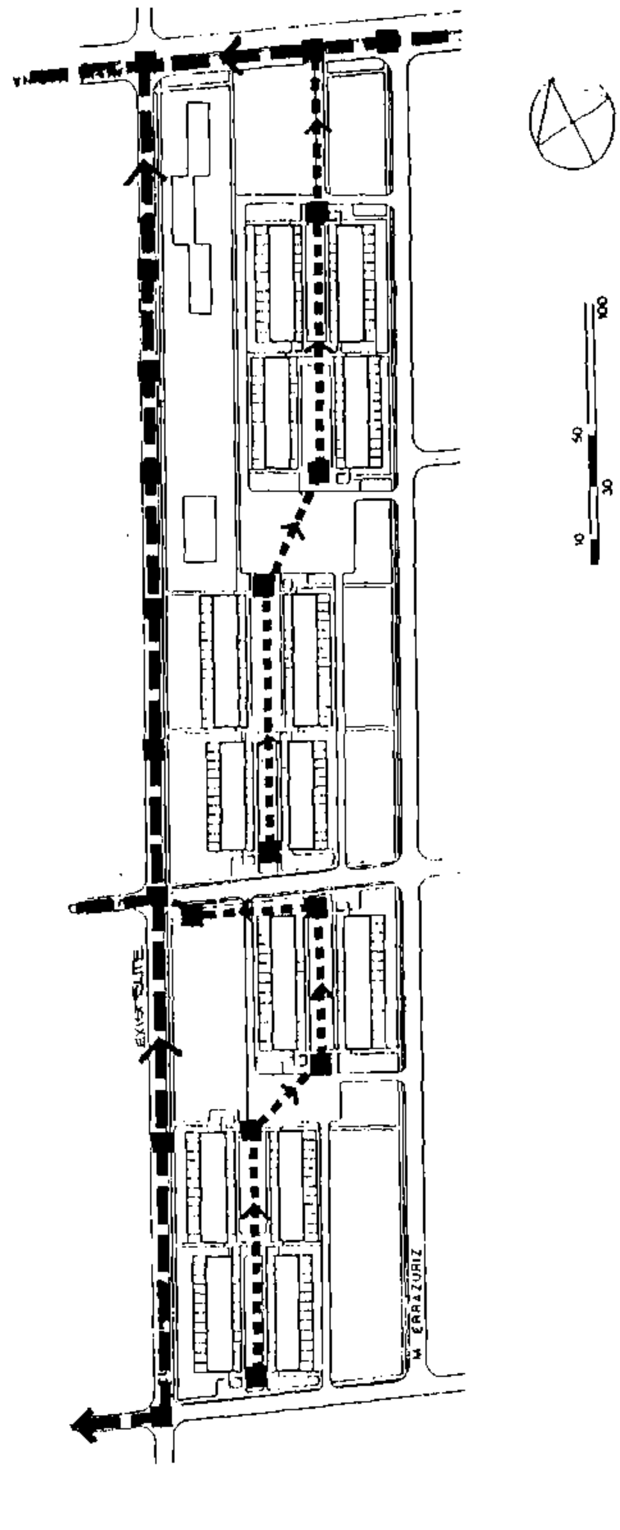


Figure 19
SEWERAGE NETWORK

LOS POZOS ARENEROS



IV. THE COST OF BASIC SERVICES AND HOUSING DESIGN

A. Design criteria for the drinking water supply and sewerage networks

In the cases studied, it is apparent that in general it is the drinking water distribution networks with the smallest circuits (Miguel Dávila, Santa Anita, Carampangue) whose relative costs in valves are higher.

Analysis of the costs of the basic service networks (see table 14) reveals that the stopcocks and their inspection chambers make up between 8 and 15% of the total cost of the drinking water distribution networks, which ranges from 3.0 to 10.0 U.F. (unidades de fomento) per dwelling. Fire hydrants account for between 1.0 and 1.5% of the total cost.

The number of valves installed in drinking water distribution networks depends on their layout and on the size of the circuits. Similarly, the number, dimension and distance between fire hydrants is linked to the fire risk in a given area and the range of the fire-fighting equipment. The Chilean standard requires that circuits be designed so that the total length of the pipes is less than 2 000 m and the whole of the circuit possesses the necessary stopcocks to allow it to be cut off from the rest of the network. It also requires all circuits to possess a minimum of one fire hydrant and the hydrants to be located so as to ensure that all buildings are within a maximum of 150 m therefrom.

In the cases studied, the length of the circuits is in general, 1 000 m or less and the distance between fire hydrants is approximately 200 m in most cases. Consequently, considerable savings could have been achieved by a more rational distribution of the circuits and improved location and reduction in the number of valves installed.

Since the fire hydrants do not have a major impact on the final cost of the distribution networks, it is desirable that the safety criteria at present applied be observed, particularly in view of the frequency of fires in low-income settlements, as well as the high risk of fires occurring on account of the materials used to construct dwellings therein.

The cost of the sewerage networks is similar to that of drinking water distribution networks, i.e., between 3.0 and 10.0 U.F. (unidades de fomento) per dwelling. In the case of sewers, the manholes represent a considerable proportion of the final cost of the networks, since they account for between 15 and 25% of the total cost.

Traditional practice in designing sewerage networks requires manholes to be located at the beginning of a sewer pipe, as well as the points of intersection between two or more sewers, and when there are changes in the diameter, slope or direction of the sewers, and at regular intervals (depending on the diameter of the pipe) on long straight sections. Any change in these design criteria would lead to the construction of non-conventional sewerage systems. There has so far been no adequate appraisal of the

Table 14

COSTS OF THE DRINKING WATER SUPPLY AND SEWERAGE NETWORKS a/

Housing development/year	Dwellings per ha b/	Drinking water			Sewerage	
		Total cost (UF/dwelling)	Valves as percentage of total cost	Fire hydrants as percentage of total cost	Total cost (UF/dwelling)	Manholes as percentage of total cost
Miguel Dávila (1956)	39	5.36	16.0	1.5	4.27	15.0
San Gregorio (1959)	24	8.43	7.0	0.8	10.81	16.0
Villa La Reina (1966)	50	6.01	8.0	0.9	-	-
El Bosque (1970)	37	6.00	9.0	1.2	7.71	17.0
Villa Perú (1970)	37	10.42	9.0	1.0	8.06	17.0
Nuevo Amanecer (1972)	33	9.80	6.0	1.0	7.10	20.0
Santa Anita (1972)	54	2.46	11.0	0.9	2.40	24.0
Los Pozos Areneros (1973)	75	1.89	9.0	1.6	1.51	25.0
Carampangue (1979)	80	3.11	15.0	1.2	2.62	26.0
Los Nogales (1980)	59	3.92	8.0	1.1	3.91	21.0

a/ Costs in U.F. as of March 1984. Excluding cost of house connections.
U.F. 1 = Ch$ 1 869.70 = US$ 21.26 (March 1984).
b/ In the area of the study.

experience acquired relating to the design, operation and maintenance of sewerage systems which adopt innovative criteria in order to diminish the number of manholes or lower the material and installation costs of the sewers. Consequently, it is difficult to advocate changes in this respect until proper research and assessment of experimental projects incorporating non-conventional design criteria has been carried out.

It would be possible to achieve some cost savings by constructing more suitably-sized manholes and using more realistic construction and installation standards for manholes and sewers.

B. Housing density

The correlation between the costs of the drinking water supply and sewerage networks and the number of dwellings per unit area in the housing developments studied reveals a certain declining trend in costs as densities increased (see figures 20 to 23).

Despite this, it is difficult to establish numerical relationships to estimate the costs of the service networks on the basis of information on housing densities. This is because costs do not only depend on housing density, but also on other factors such as the urban layout, design criteria and construction methods. In this respect, the curve which most closely fits the data obtained in the cases studied must merely be considered as indicative of a trend and in no case as representing a numerical function.

Figure 20

DRINKING WATER SUPPLY DISTRIBUTION NETWORK: OBSERVED VARIATION OF COSTS FOR DIFFERENT HOUSING DENSITIES

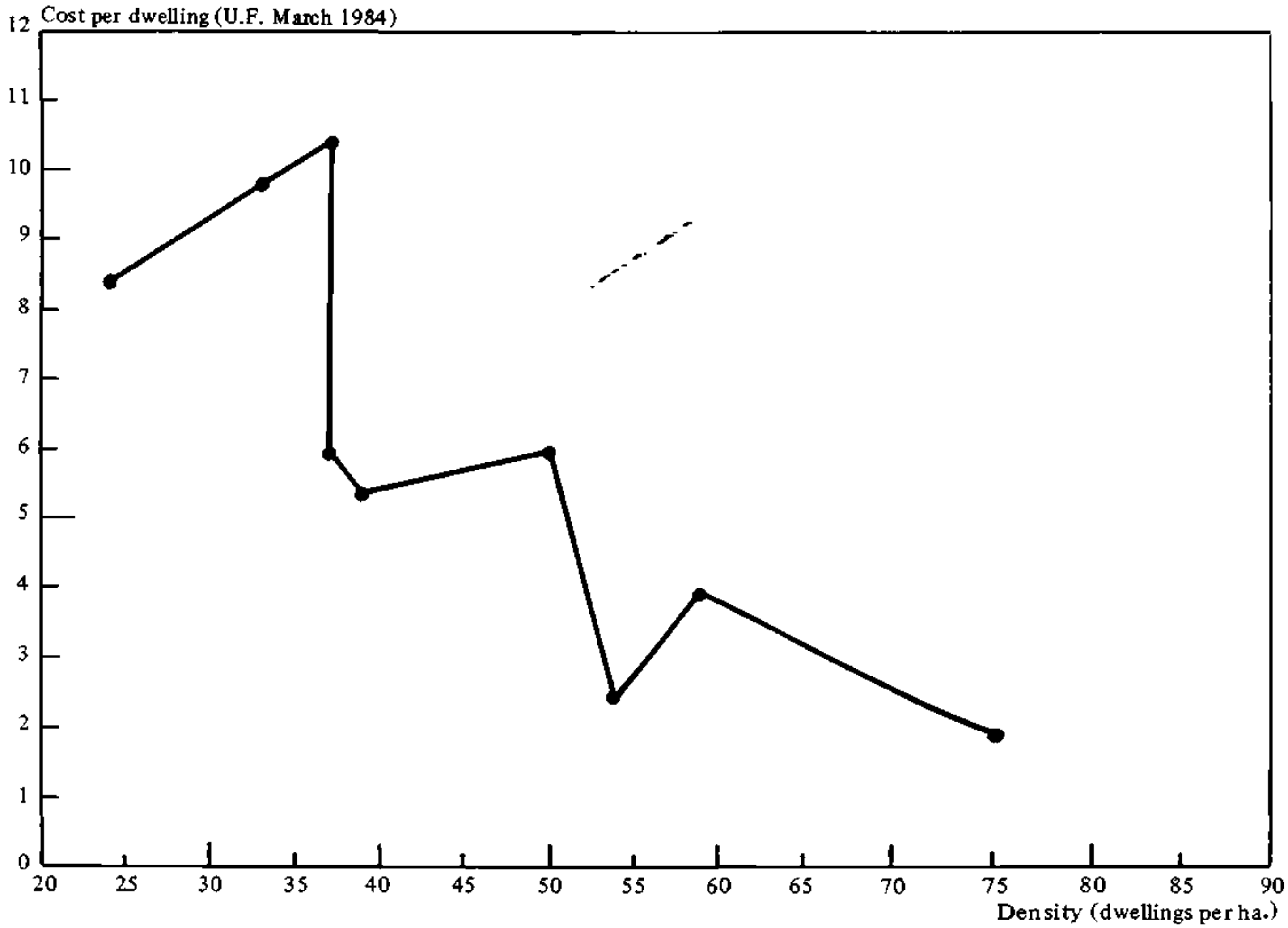


Figure 21

DRINKING WATER DISTRIBUTION NETWORK: ESTIMATE OF THE VARIATION IN COSTS WITH DIFFERENT HOUSING DENSITIES

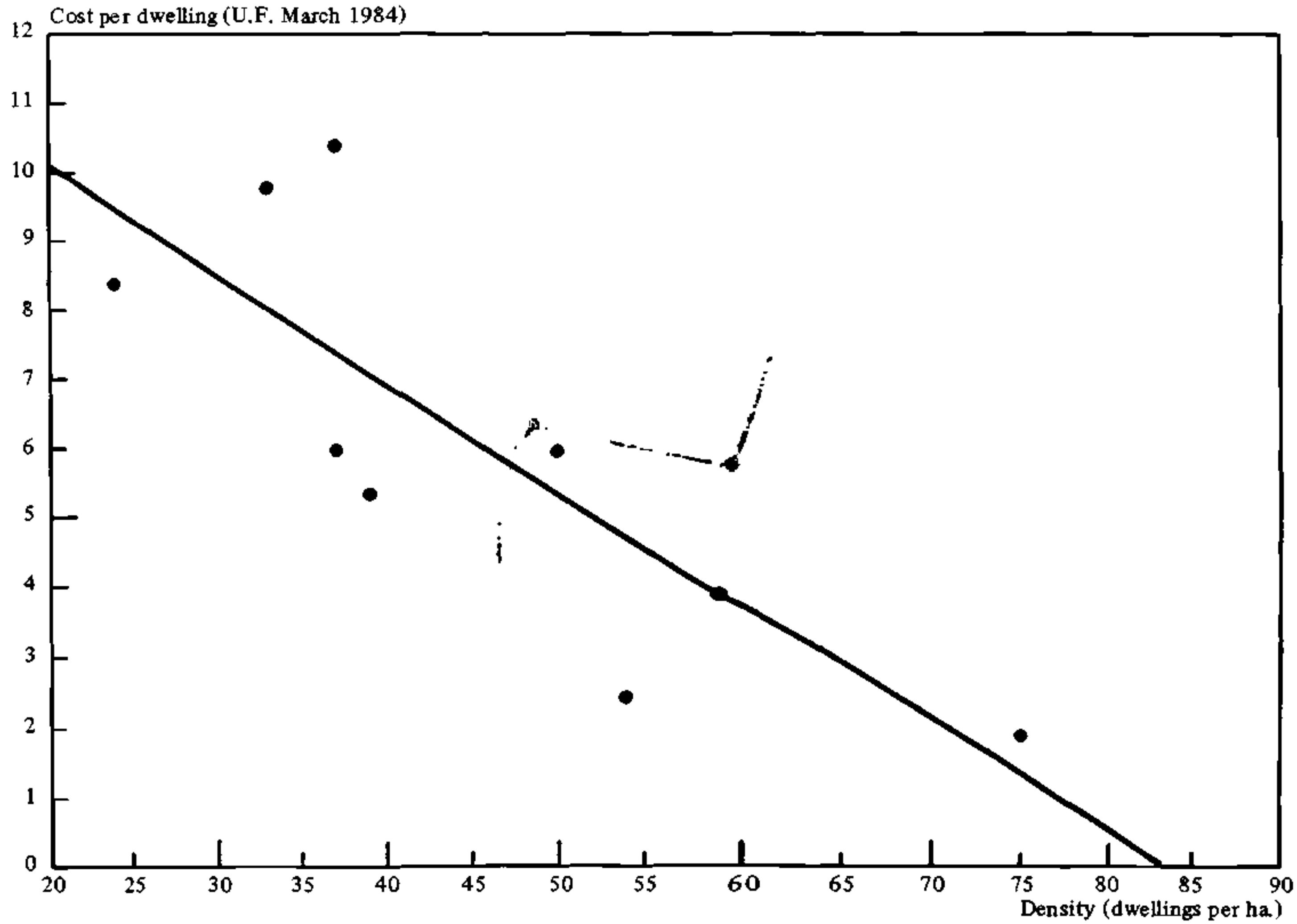


Figure 22
SEWERAGE NETWORK: OBSERVED VARIATION IN COSTS WITH DIFFERENT HOUSING DENSITIES

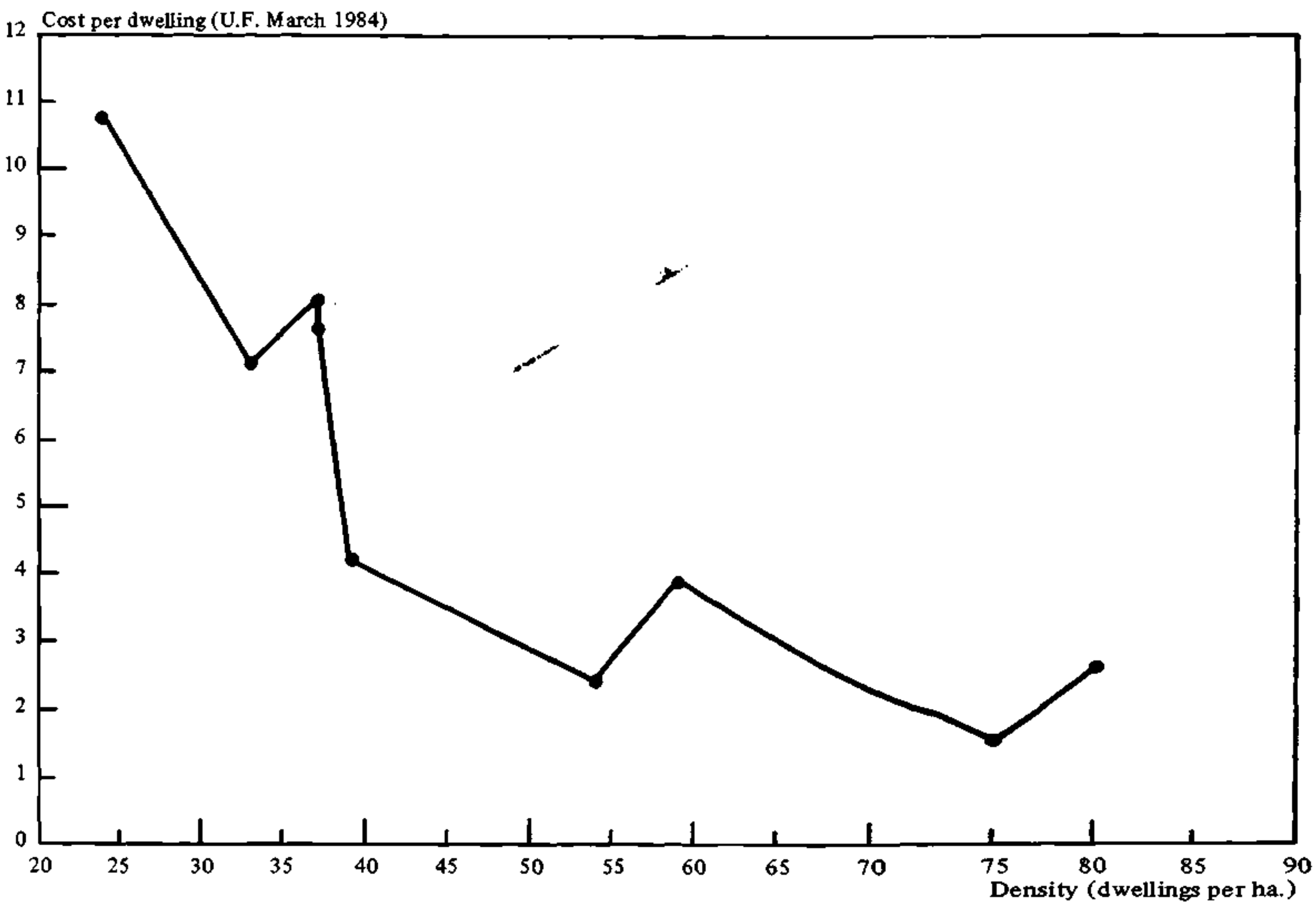
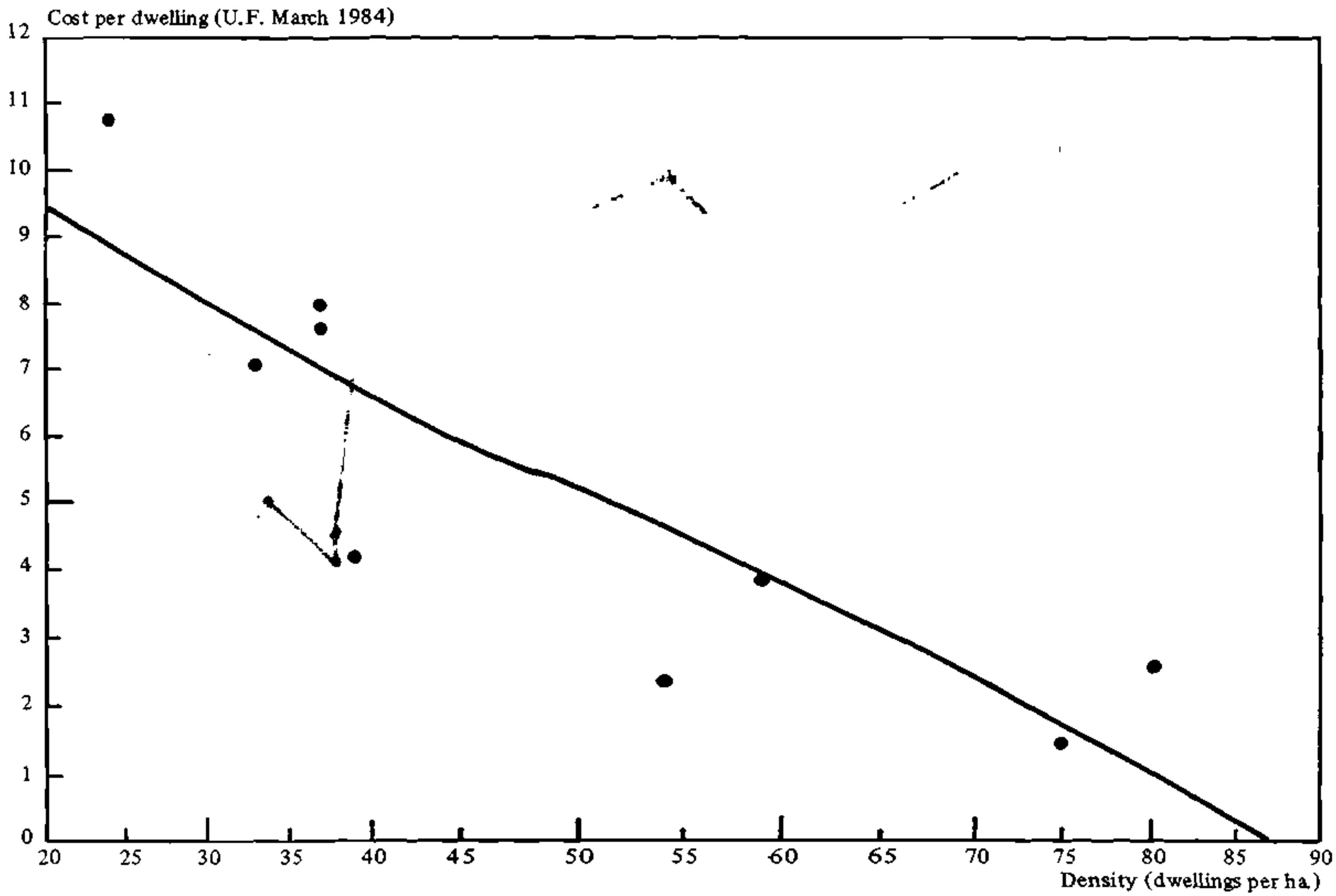


Figure 23

SEWERAGE NETWORK: ESTIMATE OF THE VARIATION IN COSTS WITH DIFFERENT HOUSING DENSITIES



C. The size and grouping of lots

In order to illustrate the impact of the size, layout and grouping of lots on the cost of service networks, calculations were made of the installation costs of the drinking water distribution pipes on lots representing various combinations of lot sizes and groupings (blocks). In every case the lots were of an average area of 100 m^2, an attempt was thus made to maintain similar levels of housing density. This theoretical calculation did not take into account the cost of the house connections nor that of the trunk mains, on the assumption that these costs are relatively constant in each lot. Consideration was also given to non-conventional design criteria to illustrate the possibility of applying them to housing programmes. A change of the design criteria would alter the costs of the services, while nevertheless maintaining the relative differences resulting from the different sizes and groupings of lots, and the conclusions reached would remain valid.

As regards their impact on the cost of the service networks, the optimum dimensions (layout) for a lot are closely linked to the dimensions (layout) of a group of lots (block), provided these adopt the reticulated type of urban layout. Thus, figures 24 and 25 demonstrate that for each layout of lots there is a given grouping which tends to minimize the cost of the service networks.

It is also clear that the costs of the services tend to increase when the dimensions of the lots are close to that of a perfect square or adopt forms in which the depth of the lot is far greater than its width (or frontage).

In lots of the size studied (100 m^2), the cost of the services network tends to fall sharply between small groups of 10 lots and blocks of 30 lots. Costs continue to decline for groups of 30 lots or more, but far less sharply.

As can be observed, there is a clear relationship between the cost of the basic service distribution networks and the sizes and groupings of the lots. The ceilings for optimizing these relationships provide basic urban and housing design criteria which determine the desirable or possible dimensions of the design of the dwellings and housing developments, taking into account factors such as size and the layout of the dwelling and rooms, vehicular and pedestrian access roads, etc.

Figure 24

RELATIONSHIP BETWEEN THE NUMBER OF LOTS AND THE COST OF THE SERVICES NETWORK: DRINKING WATER SUPPLY

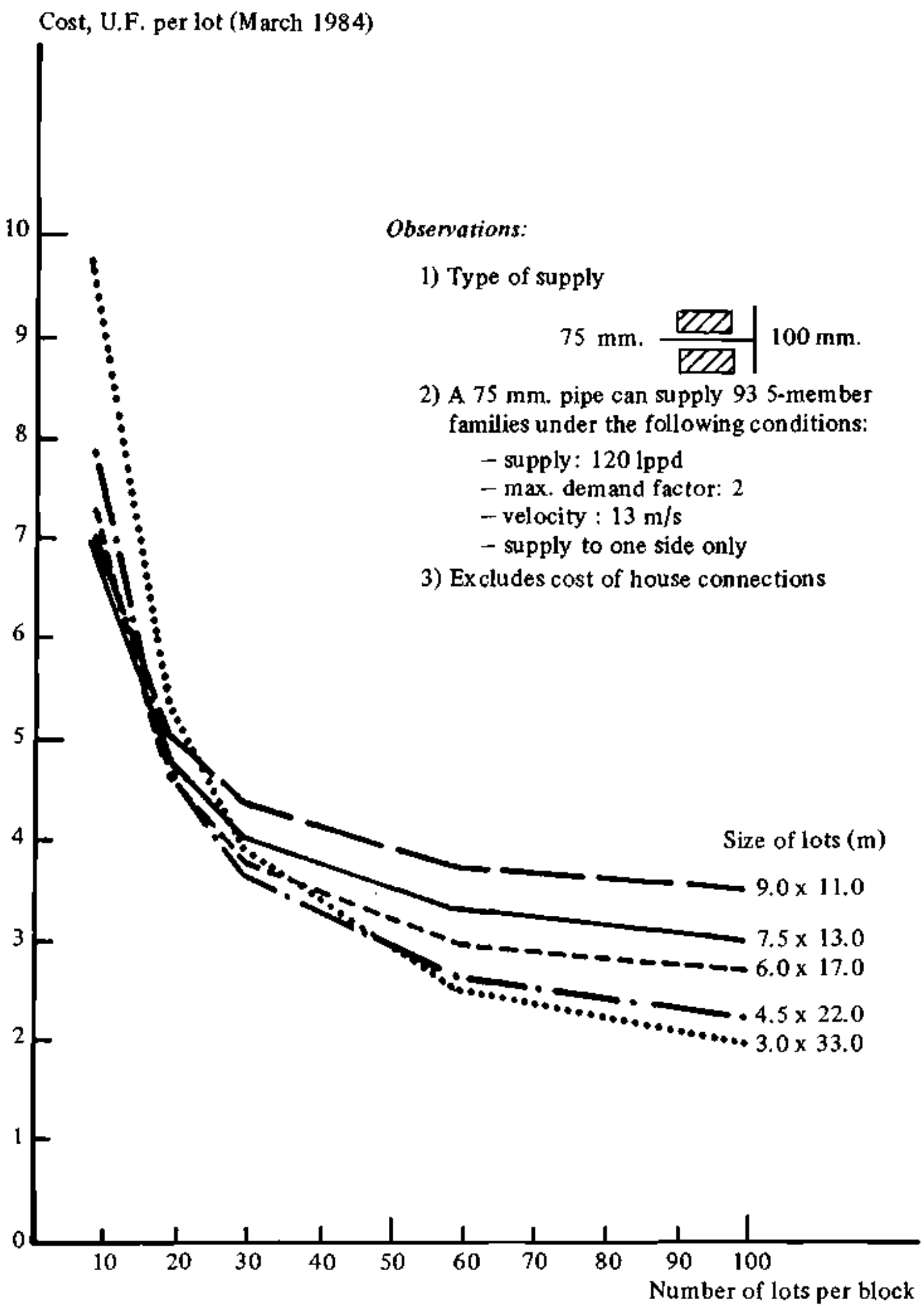
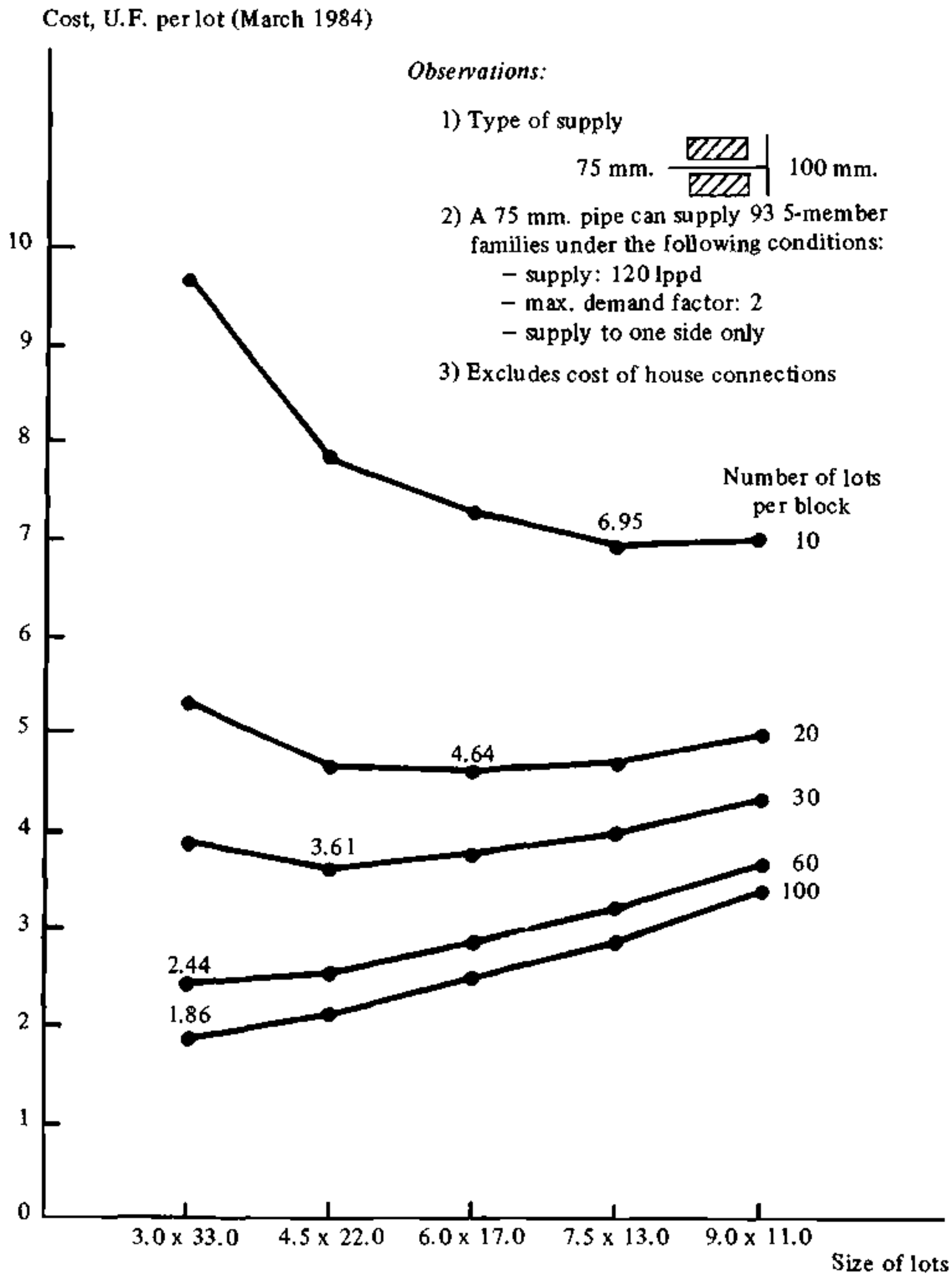


Figure 25

RELATIONSHIP BETWEEN THE SIZE OF LOT AND THE COST OF THE SERVICES NETWORK: DRINKING WATER SUPPLY



Notes

<u>1</u>/ Haramoto, B., Diseño, tipología habitacional: reflexiones sobre el asentamiento popular y el derecho a la calidad residencial; presented at the Seminar on Critical Poverty and Housing Needs, organized by ECLAC, 21-23 October 1986 (to be published shortly).

<u>2</u>/ Economic Commission for Latin America and the Caribbean, Codes, regulations and standards on water supply, sanitation and solid waste disposal with emphasis on low-income community requirements in Latin America and the Caribbean. ECLAC, Santiago, Chile, 1986 (LC/G.1374).

<u>3</u>/ Caminos, H. and R. Goethert, Urbanization Primer for Design of Site and Services Projects, World Bank, Washington, D.C., October 1976.

<u>4</u>/ Instituto Nacional de Normalización, Agua potable, conducción, regulación y distribución, NCh 691. Of. 78. Chile, April 1978.