ENVIRONMENTAL HEALTH PROGRAM

INNOVATIVE AND LOW COST TECHNOLOGIES UTILIZED IN SEWERAGE

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INNOVATIVE AND LOW COST TECHNOLOGIES UTILIZED IN SEWERAGE

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PROLOGUE

This publication is the product of the last contract of the late Jose Martiniano de Azevedo Netto with the Pan American Health Organization and is a *significant example of a relationship of more than 40 years duration --a relationship* that was characterized always with a touch of daring, and clever, innovative approaches to the solution of environmental health problems and risks.

The contribution of Azevedo Netto to sanitary engineering goes far beyond his countless books, papers and articles. Thousands of public health and sanitary engineering professionals in Latin America have been affected and influenced by his inspiring and dedicated teachings and instruction.

Azevedo Netto was born in Brazil in 1918, graduated as a civil engineer from the University of Sao Paulo, and earned his masters degree in sanitary engineering from Harvard University and his doctorate in public health from the University of Sao Paulo.

The professional life of Professor Azevedo Netto, as he liked to be called, took him to all continents as a teacher and as technical advisor to governments and institutions such as Pan American Health Organization, the World Bank, Inter-American Development Bank and others. A founding member of the Inter-American and the Brazilian Associations of Sanitary and Environmental Engineering, Azevedo Netto raised the consciousness of the importance of sanitary engineering to improvement of peoples' health and quality of life.

This publication, "Innovative and Low Cost Technologies Utilized in Sewers," represents the essence of Azevedo Netto's technical thinking and his constant search for alternative solutions that would allow benefits to a larger segment of the population despite the scarcity of financial resources.

Jose Martiniano de Azevedo Netto died in Sao Paulo on June 25, 1991. I trust that this document, which is dedicated to his memory, will inspire other sanitary engineers to pursue the development of alternative technologies for sewers.

I am sure this edition in the Technical Series produced by the Environmental Health Program of the Pan American Health Organization will be an important addition to your engineering library.

Horst Otterstetter
Coordinator
Environmental Health Program

CONTENTS

Page

1. BACKGROUND

1.1 *PIPED WATER SUPPLY*

The distribution of potable water through pressure pipes became common after the introduction of cast iron pipes. The use of wooden pipes was forbidden in London, in 1871. In the same year the Watering Committee of Philadelphia imported from England a small quantity of cast iron pipes to replace bored logs.

In Rio de Janeiro the first cast iron transmission line was installed in 1876.

The old system of water supply through stand posts (public fountains) became progressively replaced by pressure distribution systems in the following cities:

Paris	1854
Porto Alegre	1866
Montevideo	1871
Sao Paulo	1878
Bogota	1888
Amsterdam	1896

1.2 *BACKGROUND OF SEWERAGE*

References to sanitation works in ancient times usually mention the Cloaca Máxima built in Rome before Christ. The Cloaca was a large sewer measuring 3.20 x 4.20 m to drain the lower part of the city. Its construction was started by Tarquinio, the Old (616-578B) and finished by his son. It was a great work at that time, but it was not conceived to serve as a popular sewerage system.

Storm sewers preceded sanitary sewers system. In 1815, the London authorities permitted the discharge of domestic wastes into storm sewers of the city.

As the new invention of the water closet was becoming popular in Europe in spite of the disposal problem, in 1847 the discharge of sewage into storm drains became compulsory in London.

At that time sanitary sewers began to exist and Mankind decided to use water to discard filthy wastes. Large quantities of water started to be used for that purpose.

The increased use of water after the industrial production of cast iron pipes and the invention of centrifugal pumps were important factors towards the collection of liquid wastes. Water began to have a dual use: as a supplied clean liquid and as a carrier of wastes, becoming polluted as early as 1875 according to a report published on the pollution of rivers by Julius W. Adams.

In 1857 Rio de Janeiro was one of the first cities in the world to contract the construction of a modern sewerage system.

The following information shows the chronology of introduction of sewerage systems:

Paris	1833 (combined system)
London	1847
Brooklyn	1857
Rio de Janeiro	1857
Providence	1869
Philadelphia	1875
Buenos Aires	1888

1.3 SEWERAGE AND PUBLIC HEALTH

"The strong feeling that Public Health is a valuable municipal asset and depends to a large extent upon good sewerage has been a leading cause of the willingness of taxpayers to embark on expensive sewerage undertakings".

Leonard Metcalf and Harrison P. Eddy

History shows that sewerage was not introduced as an improvement of comfort for a better way of life. It was imposed as a consequence of epidemics of cholera. Since 1832, when cholera invaded Europe, people was afraid of the asiatic infectious disease prompting public administrators to begin implementing sewerage programmes. The pathogenic bacteria that causes cholera was discovered by Robert Koch in 1883.

1.3.1 EPIDEMICS AND CONSTRUCTION OF SEWERAGE SYSTEMS

The relationship between the construction of sewage system and epidemics of cholera is shown below.

1832 - Paris:	Epidemics of cholera
1833 - Paris:	Construction of the first sewer
1854 - London:	Great epidemics of cholera, with 10,675 deaths
1855 - London:	Creation of the Metropolitan Board of Works, to build sewers
1873 - Memphis:	Epidemics of cholera
1879 - Memphis:	George Waring Jr. was contracted to develop the Sewerage Plan
1892 - Hambourg:	Epidemics of cholera, with 17,000 cases
1893 - Hambourg:	Extension of the sewerage system
1892 - Santos:	Several epidemics
1892 - Santos:	Contract of Prof. E. Fuertes (Cornell Univ.) to design the sewerage system.

It is difficult to get reliable statistical evidence of the public health benefits that result from the introduction of sewerage into communities because other sanitary improvements such as water supply may have much influence on the data and because of unsanitary disposal of sewerage systems effluent. But there are several statistical information from european countries that may be comparable to the present situation in Latin America.

The case of Nottingham, for example, when sewerage was introduced, during the first 10 years typhoid fever cases dropped from 2.7 per cent to 0.18 per cent of the houses connected sewers.

At Sanzig the typhoid fever rate per 100 000 fell from 108 in five years to 18 in similar period, after the introduction of sewerage (1).

The existence of good systems of potable water and adequate sewerage or sanitation systems are essential parts of the Primary Health Care attention, as recognized by the Alma Ata International Conference of 1978.

1.4 WATER SUPPLY AND SEWERAGE

"Water and Wastewater, like the "Colonel's Lady and Judy O'Grady, are sisters under their skins" (2).

The interdependence of water supply and sanitary wastewater disposal is very pronounced and the greater the urbanization of a region the closer this relationship is emphasized.

In Latin America and the Caribbean, at present, we observe a pronounced lag between water supply and sewerage works. This problem, which represents a concern for national authorities and financing agencies was discussed during a special meeting organized by PAHO in which several International Agencies participated, in Washington, 1986. Many causes, factors and reasons have been given to explain this lag. One of them is the high cost of traditional sewerage (3).

1.5 SEWERAGE AND SANITATION

The word sewerage designates the removal of sewage or liquid wastes by means of a system of conduits. It is applied for water carriage systems.

The term <u>sanitation</u> may have different meanings in Spanish and Portuguese. Even in English we may say "water sanitation" with a different meaning.

Most of times sanitation has an ample meaning: "the development and practical application of sanitary measures for the sake of cleanliness, protecting health, etc. (The Random House Dictionary). Other times sanitation has a more restricted meaning, being applied to designate individual solutions for excreta disposal.

2. SEWERAGE SYSTEMS

2.1 *SANITATION SYSTEMS*

For the disposal of excreta without water carriage there are various types of dry privies ("sanitation" systems) (5). Several publications have been dedicated to this issue.

2.2 *PUBLIC HEALTH IMPORTANCE OF SEWERAGE*

We may say that sewerage works are a consequence of water supply: With piped water large quantities of liquid wastes are produced and have to be removed and properly disposed. Otherwise sewage infiltrates the soil, contaminating ground water or flows along the surface of soil and streets, polluting the ground and streets, becoming a threat to human health, and particularly to children. Ignorant of the danger posed by sewage, children are more exposed to the transmission of diseases. On the other hand, improper disposal of sewerage system discharges, pollutes rivers and spreads diseases.

The Public Health Service of the United States has studied the correlation between coliform and salmonellas in sewage. While the "production" of E. Coli is estimated as 10^{13} organisms per day, a sick person or carrier may discharge 10^{11} to 10^{13} S. Typhosa per day (4).

2.2.1 *TYPES OF SEWERAGE SYSTEMS*

There are three traditional types of water carriage systems:

1) The oldest, developed since 1833 in Paris, is the combined system ("Tout-á-l'égout");

2) The partially separate system, in which some rain water from private properties (Yards and roofs) are discharged into the sanitary sewers. This system which was adopted in British cities, was proposed to Rio de Janeiro, in 1857;

3) The separate system, in which rain water is entirely excluded. This system was created by George Waring Jr. in the United States (1879).

There are alternatives for this system (New Technologies).

In the combined system, sewers have to be large enough to receive all storm flows, or most of them; they are costly and during dry weather they are liable to silt. Sewers are laid at great depths.

The author and others have compared these types of systems reaching the conclusion that the combined system in general cases is not applicative to tropical regions, where rainfall is more intense and where unpaved streets may be common (6).

2.2.2 *CONVENTIONAL SEWERAGE SYSTEM (SEPARATED TYPE)*

The conventional type of sewerage has been adopted since the end of last century and continues to be applied in all countries.

A suggested manual for designing is the WPFC Manual of Practice No. 9 "Design and Construction of Sanitary and Storm Sewers", Water Pollution Control Federation, Washington, D.C., 1969.

The simplified Sewerage System was developed at the beginning of this decade as a pilot Plan for small towns. After five years of good experimental results the system was adopted by the Brazilian National Norm 9649/1986.

2.2.3 *ORIGIN OF THE SEPARATE SYSTEM*

The first system was designed for the city of Memphis, Tenn., in 1879. Complete Instructions about the system were published in 1898 by A. Prescott Folwell. Very few changes and improvements were introduced since then.

2.2.4 *BASIC PRINCIPLE: SEPARATION OF STORM WATER*

Separate sewers exclude rain water as much as possible. The exclusion depends on permanent inspection and control. In the United States 5% has been considered a maximum allowed for illicit connections. A good study about this problem was completed in Scotland. A reasonable percentage of "erroneous" admission of rain water should be considered in design.

2.3 *LIMITING FACTORS (REASONS FOR THE LAG BETWEEN WATER AND SEWERAGE)*

There are several reasons for the delay in the improvement of sewerage in the Region.

2.3.1 COST OF SERVICE

Studies about water rates indicate that urban populations should pay at most 5% of their minimum wage for water supply. If this percentage doubles with sewerage charges, the trend will be towards limiting the people interest in having sewerage connections.

2.3.2 LEVEL OF HOUSE PLUMBING (QUALITY OF INTERNAL INSTALLATIONS)

Low coverage or poor quality of plumbing restrains the number of connections.

2.3.3 CONSTRUCTION DIFFICULTIES TO MAKE CONNECTIONS

Installations below the street level, non-existence of open passages for the house connection are common obstacles.

2.4 HYDRAULIC CHARACTERISTICS

Conduits function almost exclusively as open-channel free flow in partially filled pipes. Sewers have to maintain self cleansing velocities or adequate tractive forces. The old hydraulic formulas of Chezy, Kutter, Bazin and others could be substituted by more modern expressions such as the Universal formula. Manning formula is extremely used due to its monomial structure that brings simplicity.

2.5 TECHNICAL CONSIDERATIONS IN DESIGN OF SEWERAGE

2.5.1 VELOCITY OF FLOW

a) Minimum

UNITED STATES	0.60 m/s (*)
BRAZIL	0.50 m/s (**)
FRANCE	0.45 m/s

(*) This velocity is considered for sewers flowing at full section

(**) Velocity at the expected depth of flow, at initial stage of works.

b) Maximum

United States-England	2.40 - 3.00 m/s
Brazil	5.00 m/s

It is a mistake to consider 3.00 or 4.00 m/s. Research has shown that velocities above these limits cause less erosion (8).

2.5.2 DEPTH OF FLOW INSIDE SEWER (WETTED SECTION)

- Ideal: Between 0.20 D and 0.80 D; maximum flow 0.95 D.
- In some countries: 0.30 D to 0.75 D (D = Diameter of sewer)

2.5.3 DEPTH OF SEWERS UNDER STREETS

In many cases conventional sewers are laid at great depths. Construction of deep trenches are very expensive. On the other hand, low depths increase the risk of damage by traffic loads and make difficult the drainage by gravity in some cases.

2.5.4 MINIMUM SLOPES OF SEWERS

There are technical rules for fixing adequate grades for sewers. An old and common table is:

TABLE 1: MINIMUM OF SLOPE OF SEWERS IN RELATION TO DIAMETER

DIAMETER OF SEWER	MINIMUM SLOPE M/M
8"	0.0040
10"	0.0030
12"	0.0022
15"	0.0015
18"	0.0012

This table may be misleading, as slope is not a function of diameter. Slope shall be computed in accordance with the flow as it will be shown.

2.5.5 MINIMUM SIZE OF SEWERS

Minimum size (diameter) of sewers depends on water consumption.

United States	8"
Brazil and other Latin American Countries	6"

Brazilian Norms allow the use of 4" pipes for secondary branches not too long, In the case of 4" sewers connections should be of 3".

2.5.6 MANHOLES

Manholes are an expensive part of the sewerage system. The first systems had no manholes. Later came the tendency to go to extreme, putting manholes at too frequent intervals. This practice is objectionable because of the unnecessary additional cost and the inevitable injury to pavements produced by the impact of traffic (9).

Modern technology shows that most manholes could be eliminated or substituted. New design offers simpler and cheaper types of manholes.

3. SIMPLIFIED SEWERAGE SYSTEM

3.1 *INTRODUCTION*

The conventional sewerage system of the separate type was introduced, at the first time, in the city of Memphis, Tennessee, by Eng. George Waring Jr., in 1879, without the expected success. After this pioneer work Waring Jr. proceeded with his investigations and experiences, having built improved systems in other cities such as Keen, N.H. (1883), Norfolk, Va, (1884 Stanford, Co. (1885), San Diego, Ca. (1888) and even Paris, France, (1883).

In 1888 Waring Jr. wrote his classical book "Sewerage and Land Drainage" presenting the basic criteria for the design of sewers.

It is curious to notice that in the last 100 years only few changes were introduced in design, and some of them for worse. During this same period a remarkable progress has occurred to other technical areas such as plumbing, pumping and wastewater treatment.

3.2 *ORIGIN OF INNOVATIONS*

After considering that the excessive cost of sewerage was restraining the important benefit in developing regions, the Author has decided to review all the conventional technology and criteria of design. His findings brought an unexpected surprise: Several points of the existent norms and criteria should have been changed a long time ago. Some important guidelines and instructions are not compatible with modern knowledge.

The case of Sao Paulo (Metropolitan population: 17,000 000) is a good example. Since 1980 the population coverage has decreased from 70% to about 50% at this time.

There are several reasons for this decline, the most significative one being the high cost of sewerage works. It was thought that Sao Paulo could not to pass 100 years more continuing in identical situation: An initiative should be taken to change the trend.

In 1975 the Author presented and discussed a paper at the Brazilian Congress of Sanitary Engineering with the title "Saneamento viável e accessivel" (10).

An important step for the adoption of innovative solutions was taken by SABESP, the Company of Water Supply and Sewerage of the State of Sao Paulo, in 1981, creating a special Program for small towns. Simplified systems were built in several communities, at a very low cost. In 1983 a paper about the applied innovations was presented at the Anglo-Brazilian Seminar (11).

3.3 *NORMS AND DESIGN CRITERIA HAS TO BE CHANGED*

The experience has led us to the conclusion that we could update standards of design of conventional sewers. It was found that some criteria in use has no technical support and that few changes could improve the accuracy of design and, at the same time could reduce construction costs considerably.

Going further, if we wish a greater reduction of costs we could introduce additional innovations simplifying further more the system.

3.4 *PRINCIPAL INNOVATIONS*

- Introduction of more precise methods of calculation and control of self-cleaning conditions. Substitute the old criteria of checking velocities on basis of full or half full wetted sections. These are particular conditions not happening in all cases. The old practice of considering hypothetical velocities came from the use of hydraulic tables. At present time the use of computers changes the method of calculation and the real velocity can be easily determined.

- Slopes of sewers should be established as a function of flow of the first stage of works. It is not correct to increase diameter of pipe in order to reduce gradient. Diameter of pipe should not be increased if the flow does not justify the increase.

- In tropical or subtropical regions depth of sewers can be reduced to the minimum compatible with house connections and the protection against external loads.

- Taking in consideration the existence of improved equipments for cleaning and maintenance of sewers the number of manholes can be reduced to a minimum and new types of appurtenances can be adopted to reduce costs.

3.5 PERIOD OF DESIGN

The adoption of long periods of design leads to huge works, increasing the initial cost of investment, in such way that it may impair the viability of the plan.

Another aspect to be considered is the following: As a result from too long periods of design the flow in the sewers for many years will be such below the one for which it is designed; that velocities will be lower and the performance of the system will be worse than expected.

With shorter periods, of the order of 20 years, considering the construction by stages, the effects of possible errors in estimates of growth of population, number of connections and flows may be minimized and can be readjusted. Along the years, if necessary, auxiliary and relief sewers may be built without difficulty.

One may, also, expect the improvement of economical conditions of the community along the time, making easier additional investments in the future.

3.6 SYSTEM LAYOUT

To serve the same area, with the same extension of sewers, one may conceive different configurations of the collecting system, with diverse costs.

The designer with experience is able to recognize and visualize the most convenient arrangement, taking in consideration the repartition of flows, sizes of sewers and slopes (as a function of flows) and, consequently, reducing the final depth of sewers (Less excavation).

Alternative solutions could be compared for the selection of the most advantageous one, reducing depth, excavation and construction costs. One has to have in mind that increasing flow along a sewer may reduce slopes.

3.7 VELOCITIES OF FLOW

Velocities of flow are a traditional basis for designing sewers. What velocities should we consider and adopt? It is not the best option to consider the flow velocity at full section or at half section, because these velocities happen at particular situations that do not correspond to practical cases.

Maximum velocity occurs at 0.81 D and maximum flow happens at 0.95 D. D = Diameter of pipe.

It is more accurate to check velocities that correspond to the estimated flows. For the minimum velocity we shall consider the peak flow at the beginning of first stage and the maximum velocity is calculated for the maximum peak flow at the end of final stage.

The minimum velocity should not be less than 0.45 or 0.50 m/s. It is better to accept a lower value for the "real" flow, than to fix a higher value for an hypothetical flow (Full section).

Another question to be checked is the possibility of occurrence of sulfides in larger sewers at low slopes.

Regarding maximum values of velocity there are two conditions to be observed:

1. From the results of an ample research done in Holland it is found that a velocity of flow between 4.0 and 5.0 m/s causes less erosion than velocities between 2.5 and 4.0 m/s.

2. We should avoid occurrence of mixtures of air and wastewater (Velocities over 4.6 m/s in 8" sewers).

3.8 TRACTIVE FORCE: A NEW CRITERIA

Hydraulic engineers dedicated to design of channels, attempting to avoid sedimentation and erosion, have adopted the tractive force as a good design criteria (13).

As a new criteria of design to calculate sewers, the tractive force is considered a more practical method that takes into account the shape and wetted area of the conduit. Its application permits control of erosion, sedimentation and of the production of sulfides.

The average tractive force can be calculated by the expression:

$$F = 100\, R_H I$$

Where:

F = Tractive force, kg/m^2
R_H = Hydraulic Radius, m
I = Slope, m/m

As a minimum the recommended value for F is 0.12 kg/m^2.

Taking into account the cross-section effectively being occupied, it leads to a prudent and more economical design, with more convenient slopes.

3.9 MINIMUM SIZE OF SEWERS

For secondary sewers it is advantageous to adopt pipes of small diameter in order to raise the level of the liquid and, consequently to increase the velocity of flow.

In the United States when the construction of sewerage systems began the minimum size of sewers was 6 inches in more than 70% of the system.

An ample experience in Latin America proves plainly that 6" pipes work very well. In France and in England 6" pipes are also adopted. In the past (1952) Building Blue Laws of England permitted private sewers of 4 inches.

In small Brazilian towns 4" lateral or branch sewer is being used in residential areas. In this case a 4" sewer may have a maximum length of 200 to 400 meters, serving no more than 50 houses.

The difference in construction cost when smaller size pipes are used is not significant, except when pipes need to be imported.

3.10 MINIMUM FLOWS AT THE BEGINNING OF SEWERS

At the beginning of small sewers (first sections) it is not accurate to consider average flow (Maximum linear distributed flows), because few connections will produce a higher simultaneous discharge based on the number of fixtures.

In Brazil the national Standard considers 1.5 liters/sec., as the minimum simultaneous flow in a small sewer. This value of flow is kept along few blocks up to the point where 1.5 liter/sec will equal the maximum linear distributed flow.

3.11 SLOPES OF SEWERS

The minimum grade to be adopted for self cleansing conditions does not depend directly on the diameter of sewers.

The classic tables giving diameters versus slopes (gradients) have induced engineers to commit serious mistakes in design, always when they increase the size of pipes with the idea to reduce slope. Doing this the hydraulic conditions become worse instead of improving (The possibility of occurrence of deposits increases with this inappropriate proceeding).

Those classic tables come from last century:

TABLE 2: MINIMUM SLOPES (GRADES) IN SELECTED COUNTRIES

DIAMETERS	U.S.	ENGLAND	FRANCE	BRAZIL
6"	0.0060	0.0056	0.0040	0.0060
8"	0.0040	0.0038	0.0030	Θ
10"	0.0030	0.0029	0.0025	Θ
12"	0.0022	0.0024	0.0020	Θ

Θ: Depends on the flow

Confirming the previous observation L.B. Escritt has commented: "Sewer designers often develop the bad habit of putting in a larger-size sewer than required by the flow, so as to give the appearance on paper of a self cleansing gradient. The self cleaning gradient depends mostly on the flow, not merely on the size of the pipe installed, and at a small flow a small-diameter pipe will keep cleaner than a larger pipe laid to the same gradient (13).

The best way to determine the gradient of a sewer is to apply the hydraulic expression:

$$S = 0.0001\ Q^{-2/3} \quad (*)$$

Where:

S = minimum slope, m/m

Q = Hour peak flow at the first stage of works, m^3/sec.

The result from this expression may be used for any diameter.

(*): For deduction of this expression, see "Hydraulic of Sewer" (Annex).

3.12 DEPTH OF FLOW IN SEWERS (PARTLY FILLED SECTIONS)

Sewer designers try to ensure a liquid depth above a minimum limit, and on the other way a depth not higher that a certain upper limit, to keep always a free flow inside the pipe.

The available experience recommends to maintain the water level above 0.2 d. With this depth of flow the velocity will be about 0.56 (56%) of the velocity at full section. If the velocity in a sewer flowing full is 2.0 ft/sec., the velocity at 0.2 D would result 1.1 ft/sec. To have a velocity of flow of 0.45 m/sec at 0.2 D, the velocity at full section has to be 0.80 m/sec (2.6 ft/sec).

We never should increase the diameter of a sewer if the existent flow does not require the increase (that is: if the existent flow is less than the flow at 0.8 D at same slope).

It is better and safer to adopt the limit of 0.40 or 0.45 m/s a minimum true velocity at 0.2 D, than to adopt a "nominal" velocity of 2.0 ft/sec (0.61 m/sec) for the hypothetical flow at full section.

About the maximum depth of flow, after analyzing hydraulic principles, we find out the advantage of fixing as a maximum limit for the depth of flow (h/D) the value 0.8 D (80% of diameter). We know that at this level in a circular sewer we reach the highest velocity. The empty part of the section above 0.8 (that is 0.2 D) is used for ventilation, movement of gases, serving additionally for exceptional flows.

3.13 DEPTH OF SEWERS (DEPTH OF TRENCHES)

At the starting point of small sewers the minimum depth should be sufficient:

a) To make possible all house connections.

b) To have a layer of soil over the crown to protect the pipe against external loads.

If the sewer will be under the street pavement the minimum protection cover could be 3 ft (0.90 m). Then the depth of the trench should be at least 1.10 m. If sewers are built under walking ways the protection layer can be reduced. In the case of construction under the pedestrian way, the minimum depth of a 6" sewer could be 0.90 m (Depth of the trench) (14).

Construction cost varies exponentially with depth of trench. Deep sewers may become very expensive.

3.14 CELLAR CONNECTIONS AND FIXTURES UNDER THE STREET LEVEL

Before the introduction of the modified sewerage system in Brazil it was common to lower sewers to great depths in order to make possible direct connections from fixtures installed at levels below the street.

This practice required the construction of long extensions of sewers at great depths, at increased costs, just to serve a relatively small number of basements.

This represents a considerable increase of costs, not only of the sewer, but also of all house connections, in addition to creating inconvenience and a public health problem in case of sewer clogging and consequent flood of basements with contaminated water.

At the initial times of separate sanitary sewerage in the United States George Waring Jr. has recommended: "No cellar drain should be connected directly with the sewer".

3.15 AUXILIARY SEWERS

Auxiliary sewers (double sewers) are adopted to facilitate construction and to reduce costs. The following cases should be considered:

1. Wide streets, where the total cost of all house connections will be high.

2. Streets with expensive pavement (A common case in Latin America, where the sewerage many times come later than pavement).

3. Streets with intense traffic.

4. Very deep sewers with difficult and expensive connections.

5. A second sewer ("relief sewer") to increase the capacity of an existent sewer.

The second sewer is installed under one of the walkways. When both sewers are built at the same time they are installed one at each side of the street.

3.16 MANHOLES

The first separate sewage systems did not have manholes. Later, under the influence of the combined systems, a few manholes were introduced (in combined systems manholes are necessary for the removal of grit and sand that settles during low flows of dry seasons).

With time the number of manholes increased due to more strict and severe standards. The "density" of manholes increased from 1:200 to 1:50 m, an expensive exaggeration.

This practice should be considered an objectionable abuse, because it increases costs without benefits.

At the same time new types of cleaning machines and equipments were developed and introduced into the market, but their beneficial use was not properly considered in the theoretical design of conventional sewerage. If properly utilized these new tools could change the practice.

3.17 NEW TYPES OF INSPECTION AND CLEANING DEVICES

In the conventional systems small sewers start at a manhole. This is not the case of modified systems where all manholes at the beginning of sewers are substituted by low cost terminal inspection and cleaning tubes ("TIL").

Intermediate manholes along straight sewers are substituted by "passage" inspection tubes.

Special models of underground boxes are being used for changes of slope, or change of pipe size.

3.18 HOW TO SUBSTITUTE MANHOLES

We can, and we should, reduce the number of manholes. We cannot eliminate all manholes of a new system: some are necessary as measurement point, others are required for sampling and some may be recommended for larger sewers dropping points, deep sewers, multiple intersections, etc.

In the city of Sao Paulo the total cost of manholes in a system amount to 13%. It has been estimated that in future designs this cost can be reduced to about 5% or less.

The remaining manholes could be of a simpler type. It is common to use precast models made of few standard parts, without the dangerous steps.

TABLE 3: SOLUTION FOR ELIMINATION OF MANHOLES

POINT	ALTERNATIVE SOLUTION
Initial point of a sewer	Terminal inspection tube
Long straight sewer	Vertical inspection tube ("pass.")
90° curve	Two separated 45° curves
Insertion of a sewer into another	Y branch and one 45° curve
Increase of diameter	Underground concrete box
Increase of slope	Underground concrete box

During the last decades new types of machines and mechanical equipments to clean sewers were developed, with capacity to clean more than 200 m of extension of sewer line. These equipment, by themselves, could justify the elimination or substitution of several manholes, and could indicate the need to review the existing norms of design.

Now all projects of sewerage should include a plan and complete specifications of machines and cleaning equipments for maintenance of sewers.

Normally it is no more necessary for a maintenance worker to step down through a manhole to inspect or clean a sewer.

Solutions for substitutions of manholes are shown in Figures 1-8. Simplified manholes and inspection tube are shown in Figures 9-12.

3.19 COMPUTATION MODELS AND PROGRAMS

With existent new programs the calculation and drawings of sewerage systems become very easy and practical. There are already available programs to apply the new technology (modified systems).

One of the best and more complete program was developed by the late sanitary engineer William M. Jones for use with a PC-IBM and compatible. Furthermore, the hydraulic calculations the programs computes quantities for budget and gives all indications for drawings.

Another complete program was recently developed by Engevix, a consulting firm of Rio de Janeiro (Eng. Samuel Fuchs).

Advances in technology of sewerage allow significant cost savings.

▸ **Curves and junctions without manholes**

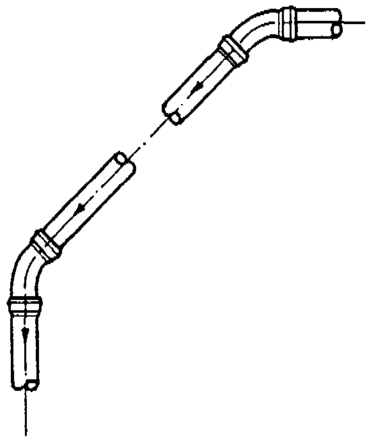


Figure 1. Substitution of 90° curve by two separated 45°

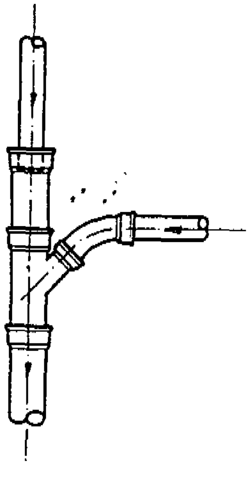


Figure 2. Junction at 45°

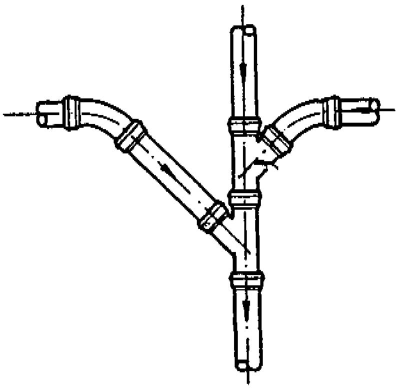


Figure 3. Substitution of a cross junction by two 45° junctions

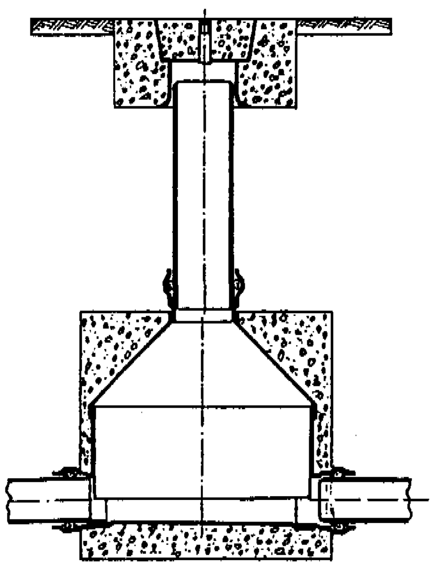


Figure 4. Industrialized type of "manhole" (inspection device)

- **Inspection devices and underground boxes**

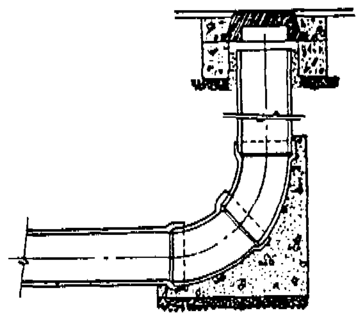


Figure 5. Inspection terminal

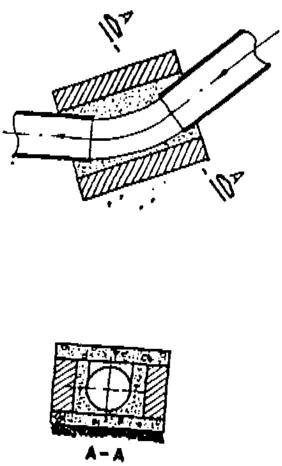


Figure 6. Underground box for curve (change of direction ≤45°)

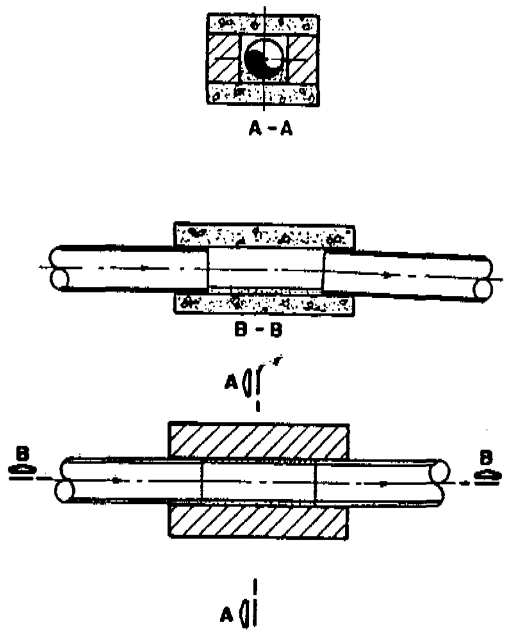


Figure 7. Underground box for change of gradient

Figure 8. Underground box for change of pipe size

▸ Simplified manholes and inspection tube

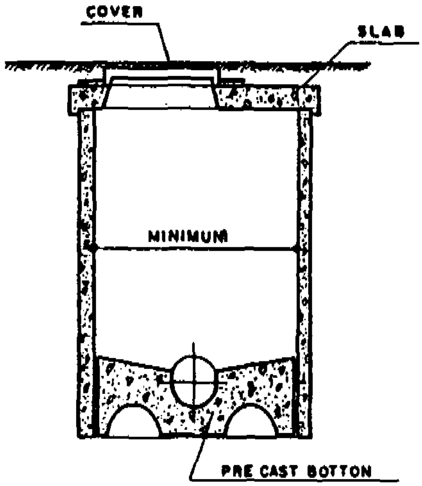


Figure 9. English type manhole

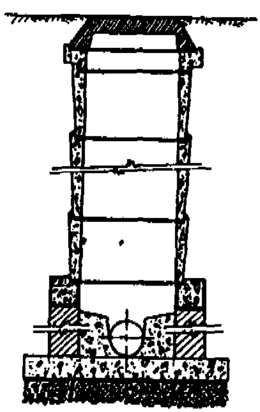


Figure 10. Concrete pipe manhole

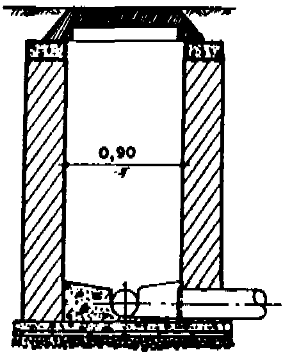


Figure 11. Small diameter manhole

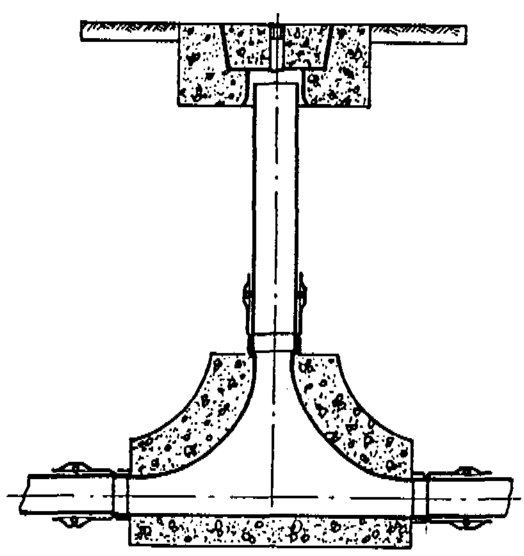


Figure 12. Inspection tube intermediary type

The innovative technology has not yet been assimilated by engineers and official regulatory agencies, outside some Latin America Countries. In Brazil the described innovations have been applied and more than 50 sewerage systems are already in operation for several years.

The common practice prevailing during all this century is not necessarily appropriate today. Design practices need to be modified to ensure better solutions.

If desired, the new concepts and principles can be applied progressively, step by step, according to local conveniences and following the increasing confidence of the engineers.

If a city has already sewerage plans to be implemented, these plans could be easily reviewed for few modifications and adaptations. Experience shows that substantial savings could result from the adaptation to the new technology.

From the experience in South America we may have an idea of the reduction of costs:

Conventional sewerage system

Construction cost per capita (1989 - US$):

Collecting system	\$150.00 - \$300.00
Low cost wastes treatment	\$ 30.00 - \$ 50.00

Modified conventional systems

Collecting system	\$ 90.00 - \$160.00
Low cost wastes treatment	\$ 20.00 - \$ 40.00

3.20 HOW TO DESIGN MODIFIED SEWERAGE

The new technology includes a series of changes and procedures applied towards the objective of simplifying works and reducing costs. The purpose is not to reduce efficiency and safety or to create a "second class" solution. The idea is to take advantage of today's technology.

Basically, the modified solution includes the following innovations:

1) For each town or city it is necessary to find out, for each district, the population density, economic level of the people and quality of plumbing installations in the houses. The objective of this survey is to find out which areas should benefit of the first stage and to identify the areas where alternative solutions could be more appropriate, as well as to estimate the probable number of future connections.

   More than one type of solution could be adopted, depending on local conditions and density of population.

2) Adopt no more than 20 years as a period of design, considering the construction by stages.

3) Try to optimize the layout of the collecting sewers in order to reduce depths and costs.

4) Adopt 6 inches as minimum diameter of sewers and 4 inches for house connections, for small communities we may consider the use of 4" pipes for the initial part of secondary sewers and, in this case, 3" for house connections.

5) To make the best use of the pipes one should design sewers considering them partly full with a maximum depth of flow of 0.8 D and a minimum of 0.2. The diameter of the pipe should not be increased without justification (slope is not a justification).

6) No cellar drain should be connected directly to the sewer. Do not lower the entire collecting system for this purpose.

7) The initial sewer depth (depth of the trench) should be the minimum, just to make possible the house connections.

8) The minimum slope to be adopted should be calculated in function of the expected initial flow (first stage expected flow - peak flow at the first stage).

9) The "real" flow velocity should be known, instead of considering the "nominal" one for a sewer flowing full (which is not the case).

10) Velocities of flow should be checked for estimated flows:

Minimum velocity, first stage peak hour:	0.45 or 0.50 m/s
Maximum velocity, final stage, peak hour:	4.50 or 5.00 m/s

11) Auxiliary sewers could be designed in order to reduce costs.

12) Tractive Force as a criteria of design is more precise than the use of velocity at full section. It is, also, more economical.

13) Consider an adequate value for the flow at the beginning part (few blocks) of small sewers.

14) Eliminate superfluous manholes and substitute the other ones by new inspection and cleaning appurtenances simpler and cheaper. For remaining manholes choose the simplest types.

15) Try to avoid the use of flush valves in the house plumbing system and seek to use "five liter flush water closets".

16) Computer programs are already available for the design of simplified sewerage. Some programs perform all hydraulic calculations, checking results and giving quantities information for the preparation of budgets and drawings.

17) Cleaning machines and maintenance equipments should be selected and specified to be included as a part of the project (15).

3.21 *CONCLUSIONS*

The following conclusions may be reached:

1) During 100 years of designing, construction and operation of sewerage systems a considerable experience and know-how was gained. We should take profit from this experience.

2) Since last century criteria and standards of design did not change as it could have been expected. During this long time hydraulic knowledge was improved, new types of pipe were introduced and advanced equipments for maintenance were developed.

3) Some points of imprecision and some mistakes still persist in designing which should be corrected or substituted.

4) A new technology should be considered, analyzed and adopted specially in developing countries, to reduce costs for the benefit of the population.

5) Innovations could be introduced by steps: to begin with, we should adopt a better methodology of design, eliminating and substituting superfluous appurtenances, introducing a better manner to establish slopes, reducing excessive depths of sewers and adopting a more precise way to analyze velocities of flow, etc.

6) After gaining more confidence other innovations could be introduced.

3.22 *EXAMPLE OF DESIGN AND MODIFIED SEWERAGE SYSTEM*

A small town with 15,350 inhabitants, 110 hectares of urban area, 26 km of streets, 2790 houses is supplied on the basis of 200 liters of water per person per day.

Estimates made are:

Future population, after 20 years	25,500
Future extension of streets	45 km

Future number of houses	4,600
Estimated future number of connections	4,140
Future population to be connected	22 800
Estimated initial number of connections	2,200
Estimated initial population with connections	12,100

Coefficients to be adopted:

Maximum day flow	1.2
Maximum hour flow	1.5

a) Initial sewerage flow (peak hour at average day)

initial population x estimated daily sewage flow x peak factor: number of seconds/day

$$\frac{12{,}100 \times 200 \times 0.80 \times 1.5}{86{,}400} = 33.6 \text{ liters/sec}$$

Flow per meter of sewer: $\frac{33.6}{26{,}000} = 0.0013$ liters/sec. per m

To this value we should add:

Infiltration	0.0004
Illicit rain admission	0.0002

Total flow to be considered 0.0019 liters/sec. per m

b) Final stage flow (peak hour at maximum day)

$$\frac{22{,}800 \times 200 \times 0.80 \times 1.5 \times 1.2}{86{,}400} = 76.0 \text{ liters/sec/}$$

Per meter of sewer:

$$\frac{76.0}{45{,}000} = 0.0017$$

Plus infiltration and illicit water admission: 0.0023 l/s per m

Flow velocities and tractive forces are to be calculated for first and final stages.

For the initial sections of small sewers the flow to be considered is 1.5 liter/sec. After several blocks the calculated flow would increase to a point where it would exceed 1.5 and should prevail. This distance can be calculated.

$$\text{distance} = \frac{1.5}{0.0023} = 652 \text{ meters}$$

TABLE 4
SIMPLIFIED SEWERAGE SYSTEM
EXAMPLE: HYDRAULIC CALCULATION

SECTION		LENGTH (EXTENSION) m	FLOW (l/s)			SIZE (DIAMETER) D INCHES	SEWER SLOPE m/m	GROUND ELEVATION		SEWER ELEVATION		SEWER DEPTH		LIQUID DEPTH h/D m	FLOW VELOCITY m/s	TRACTIVE FORCE Kg/m²
UPSTREAM	DOWNSTREAM		IN SECTION	UPSTREAM	DOWNSTREAM			UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM			
CT-1	UB-1	140	1,5*	0,0	1,5	6"	0,008	147,60	147,05	146,40	145,28	1,20	1,77	0,23	0,42	0,28
UB-1	MH-1	90	1,5*	1,5*	1,5	6"	0,008	147,05	146,16	145,28	144,56	1,77	1,60	0,23	0,42	0,28

(*) Minimum considered flow.

Min. slope: $I = 0,0001\ Q^{-2/3}$

$Q = 1,5$ l/s

$I = 0,0077$

Tractive force:

$$F = 1000\ R_H\ I$$

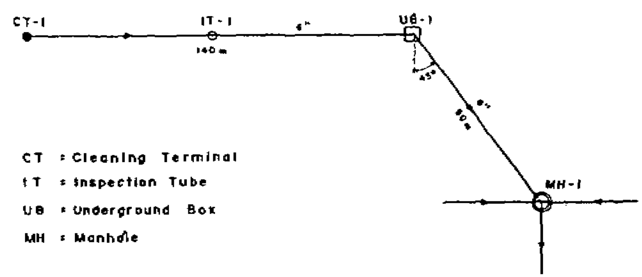
For $D = 0,15$ (6") and $I = 0,008$ m/m

$R_H = 0,035$ m

$F = 1000 \times 0,035 \times 0,008 = 0,28$

Flow: 0,0022 liters/sec per meter of sewer.

Min. flow = 1.5 liters/sec.



CT = Cleaning Terminal
IT = Inspection Tube
UB = Underground Box
MH = Manhole

TABLE 5
BASIC DATA ABOUT SIMPLIFIED SEWERAGE
SABESP, STATE OF SÃO PAULO, SAR-1989

TOWNS	UBIRAJARA	QUEIROZ	STA. CLARA D'OESTE	TRES FRONTEIRAS	NIPOA	MONTE APRAZIVEL
Present population	3,760.00	1,940.00	2,065.00	4,755.00	3,200.00	20,315.00
Final project population	7,482.00	3,772.00	2,927.00	8,414.00	7,364.00	26,370.00
Urban density (in hab/hectare)	37.00	61.00	93.00	183.00	734.00	1,166.00
Initial number of connections	0	0	0	228.00	0	2,297.00
Final number of connections	1,496.00	754.00	585.00	1,683.00	1,473.00	5,274.00
Total length of sewers, m.	9,203.00	4,868.00	3,521.00	2,624.00	9,366.00	12,407.00
4" sewers (length), m.	2,343.00	1,429.00	1,056.00	787.00	3,911.50	2,290.00
6" sewers (length), m.	6,860.00	3,439.00	2,465.00	1,837.00	5,454.50	10,117.00
8" and 10" sewers (length), m.	0	0	0	0	0	0
Pipe material	Ceramic	Ceramic	Ceramic	Ceramic	Ceramic	Ceramic
Water consumption per person (l/day)	94.00	82.60	129.20	109.00	109.00	109.00
Period of project (years)	20	20	20	20	20	20
Minimum depth of sewers in streets, m.	1,50	1,50	1,50	1,50	1,20	1,50
Minimum depth of sewers in side walks, m.	1,20	1,20	1,00	1,00	1,00	1,00
Maximum depth of sewers in streets, m.	3,60	2,80	2,00	2,00	2,30	2,20
Maximum depth of sewers in side walks, m.	1,50	1,50	1,50	1,50	1,50	1,50
Minimum gradient (slope) m/m	0.007	0.007	0.007	0.007	0.007	0.007
Maximum gradient (slope) m/m	0.40	0.40	0.30	0.30	0.30	0.30
Number of manholes	61	32	23	17	46	62
Number of clean, terminals	5	3	12	1	19	24
Number of underground boxes	29	27	34	7	39	30
Maximum flow of sewage (l/s)	7.50	3.50	3.95	9.60	7.20	29.90
Number of pumping stations	0	0	0	0	0	0
Total cost of works (US$)	347,628.00	54,134.00	118,975.00	143,376.00	297,917.00	685,807.00
Construction date	1984/1989	1984/1989	1984/1989	1984/1989	1986/1989	1984/1989
Average cost per meter of sewer (US$)	37.77	34.65	33.79	33.75	31.84	40.28
Average cost per person (US$)	155.60	0.91	151.60	87.00	117.80	118.70
Operation & maintenance cost per person (US$) (1st. month)	0.78	0.90	0.55	0.91	0.68	0.71
Stoppages (constructions) per year	13	0	30	8	8	58

4. *CONDOMINIAL SYSTEM OF SEWERAGE*

4.1 TECHNICAL CHARACTERISTICS OF THE SYSTEM

The condominial system comprises three parts: the public collecting sewers, the treatment unit and the collective connection branch. The name condominial comes from condominium system of connections inside each block. Each house in the block connects to the collective pipe through a small inspection box (17).

The public sewers along streets are laid under the walkway. Not all streets will have sewer and some streets do not have sewers along their entire length. The total extension of public sewers will be less when compared to the conventional sewerage system.

The urban area is divided according to the hydrographic basins and sub-basins. The system is not constructed for the whole town: after approval and commitment of the people living in one block the works are implemented for that block. The whole system comprises several micro-systems.

The treatment plant is a simple one: stabilization ponds (high load) or anaerobic filter for a small part of the town. For larger installations an up-flow anaerobic reactor can be adopted.

4.2 HYDRAULIC CHARACTERISTICS AND DESIGN CRITERIA

The basic collecting system is designed as a simplified system, the minimum size of sewers being 6".

The condominial branch for connections inside each block is a 4" shallow pipe with a minimum slope of 1%.

A 4" pipe with a water depth of 0.8 D and 1% slope can discharge 5.25 liters/sec and can serve more than 100 persons.

Inside blocks manholes are substituted by inspection shallow boxes.

4.3 ORIGIN AND CONDITIONS FOR APPLICATION

A similar system was adopted in the past to solve problems in few Latin American countries. Lately, in 1981 the system was reintroduced and redeveloped in Northeast of Brazil where it is being adopted by several States.

Urban aspects, topography and arrangement of the houses were important factors for this design. Existent houses in those States were built closely, without lateral passages for laying connections. The construction of a connection would destroy part of expensive floor of the house. Besides this problem it was observed that in each house most of the wastes were produced in the back of the building (where bathroom and kitchen were located).

With such conditions it was easier to make the connections towards the back yard. Then came the idea to have one collective sewer to receive connections from all houses inside the block. The collective sewer from each block has one or two connections to the public sewer.

Individual separate connections are also permitted.

Sometimes the back yard is at a low level in relation to the front street, and in this case the condominial sewer has the advantage of easy connections and shallow public sewers.

The condominial sewer inside a block is built along successive private properties (lots) with the permission of the owners. To make possible the adoption of the system it is required ample support and participation of the users.

When a town has already the conventional or the simplified system in some of its parts, it will be more difficult to convince the people to accept the condominial idea.

4.4 SERVICES AND INFRASTRUCTURE SUPPORT

The adoption of the original model requires joint efforts of the Sewerage Company, of the local Authority (Municipality) and of the interested people.

The Government Organization in charge of sewerage has to have an efficient action to promote the project, to explain the system, to convince the people and to secure the local participation in the construction, maintenance and operation of the condominial part. The Organization designs the whole system, constructs and operates the street public sewers and treatment units.

The Municipality is responsible to get and offer the required land (lot) for the pumping station (if necessary) and treatment plants.

The future users are responsible for the construction of the condominial part, its operation and maintenance.

4.5 OPERATION AND MAINTENANCE EXPERIENCE

The condominial system was adopted and is being operated in a large number of towns. The Brazilian State of Rio Grande do Norte (population 2,300,000) prepared in 1984 the State Sewerage Master Plan adopting officially the condominial system for extensive application.

The most important example is in the town of Petrolina (population 150,000), in the State of Pernambuco, where the system is in operation since 1984.

The principal problem that has been encountered is the bad use of the connection: discharge of solid materials and garbage.

Other problems are more difficult access to the condominial sewer and the fact that the collective sewer is built along several private properties (a legal document should be required to secure inspection and control, to avoid construction over the sewer).

4.6 ADVANTAGES AND DISADVANTAGES

The principal advantages are:

1) Easy construction and lower cost of house connections;

2) Less extension of public collecting sewers;

3) Practical elimination of interceptors;

4) Simpler and cheaper treatment units;

5) Use of more common materials;

6) Low construction cost of the entire system;

7) Lower cost of operation;

8) More participation of the population;

9) Larger number of connections;

10) More interest of the users.

Disadvantages are mainly the bad use of connections and less maintenance care of the condominial part.

Legal problems regarding the occupation of private property can be solved.

4.7 AVERAGE CONSTRUCTION COSTS

In Brazil we find sufficient data about construction costs of public collecting systems and treatment installations, information about the condominial part is not so complete because this part has been built by users of the system with help from the municipality.

The following average values per capita were obtained:

Collecting public sewers	US$40.00 to US$50.00 per capita
Treatment plant	US$10.00 to US$30.00 per capita
Condominial part	US$15.00 to US$25.00 per capita

Total average cost: US$85.00 per capita

Comparing these values with the conventional construction costs of US$200.00 per capita they result 57.50% less expensive.

For operation and maintenance the average charge varies from US$0.30 to US$0.50 per capita per month (these figures correspond to 40% of the water tariff).

4.7.1 EXAMPLES

The following condominial systems are in operation in Brazil (a sample of several ones):

TABLE 6: LOCATION OF CONDOMINIAL SYSTEM IN BRAZIL

STATE	TOWN	POPULATION	CONSTRUCTION COST/CAPITA 1989 US$
Rio Grande do Norte	Natal	564,000(*)	75.00
Rio Grande do Norte	Parelhas	16,150	105.00
Pernambuco	Recife	1,400,000(*)	100.00
Pernambuco	Petrolina	150,000	80.00
Paraiba	Sapé	55,000	68.00

* A small part of the city

At this time there are more than 40 towns using the condominial system.

4.8 SUGGESTIONS, RESEARCH AND IMPROVEMENT

The success of this plan depends entirely on the attitude of the users. Good communication, explanation, convincement and training are a must.

To avoid bad use of the internal sewers the users should be prepared to keep the system in good order, avoiding the discharge of solid wastes and rain water.

The Sewerage Company should get a legal document securing the right of way for inspection, control and repairs. Future Norms and regulations about Land subdivision should include a clause reserving space for the condominial sewers (rules for occupation of the lots).

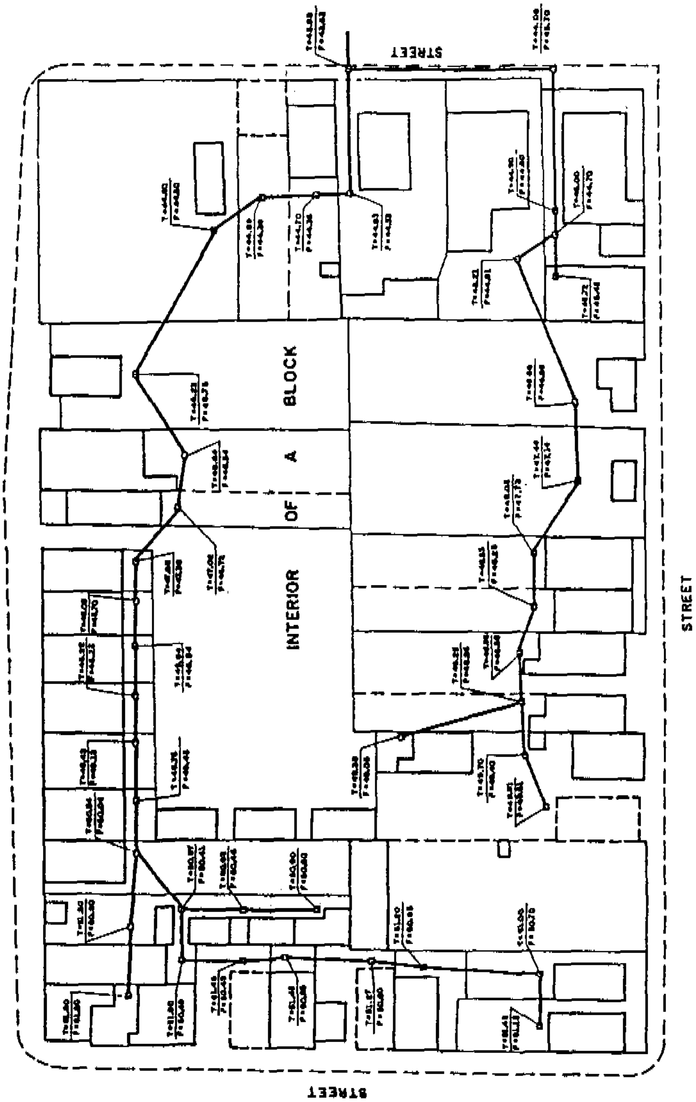


Figure 13. Condominial system
Condominial branch sewer (inside a block)

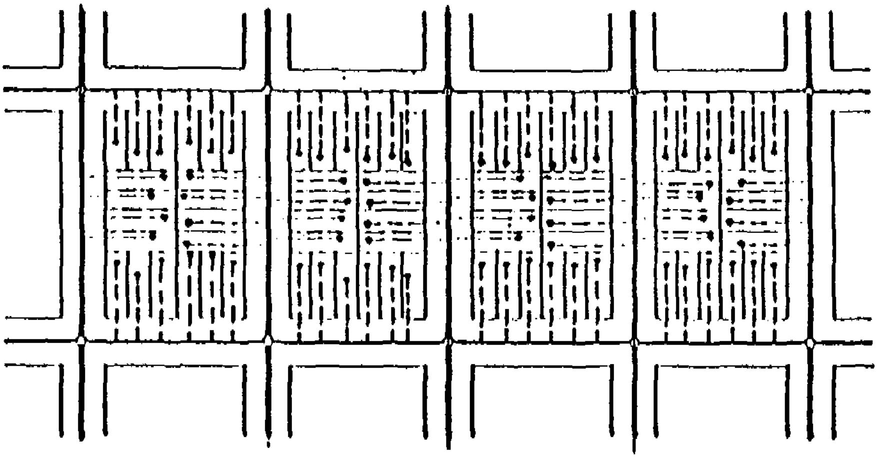


Figure 14. Conventional system
Several street sewers and 72 connections to the sewers

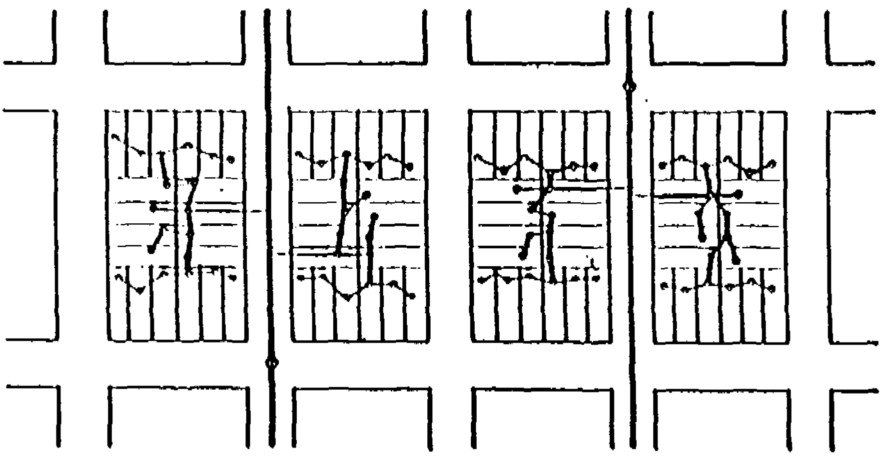


Figure 15. Condominial system
Two-street sewers and only four connections to the street sewers

5. *SMALL BORE SYSTEM*

5.1 SMALL BORE, SOLIDS FREE SYSTEM

The small bore model may be considered a technical combination of individual disposal system and an effluent collecting system of small pipes that receive and transport settled sewage, free of suspended solids pipes, therefore does not require definite slope.

The system was originated in United States, in the 70s, to solve problems of small communities where the soil had a low capacity to receive effluent from septic thanks. The system was conceived by engineers of the US Department of Agriculture (18).

The idea was applied to places such as Westbore, Wisc. (1974), Mt Andrew, Alabama, and several other villages.

The international literature mentions similar systems in few places in Australia, Turkey and some Pacific Islands.

In Brazil the system was developed independently by Prof. S. E, Cynamon, in 1979 (19).

Septic tanks provide sedimentation, retention of solids and digestion of sludge (Primary Treatment), producing a solid free effluent.

5.2 HYDRAULIC CHARACTERISTICS

The solids free effluent may be discharged into very small, shallow PVC pipes, working by gravity, at full section, without the need of limitations for slope, velocity or tractive force.

Diameter of pipes may be of 3" (75 mm), according to Brazilian experience. The slope of the pipe may be small or even negative in a particular section, depending only on hydraulic gradient, but the outlet of septic tanks and its effluent pipe should be always at an elevation above the energy line of the collecting sewer.

Hydraulic formulas of Manning or Hazen-Williams may be applied.

Water velocities along pipes shall be higher than a minimum velocity required to move mixtures of air or gases with liquid, downward pipes after curves:

$$V \geq 1.36 \sqrt{9.8D \sin \phi}$$

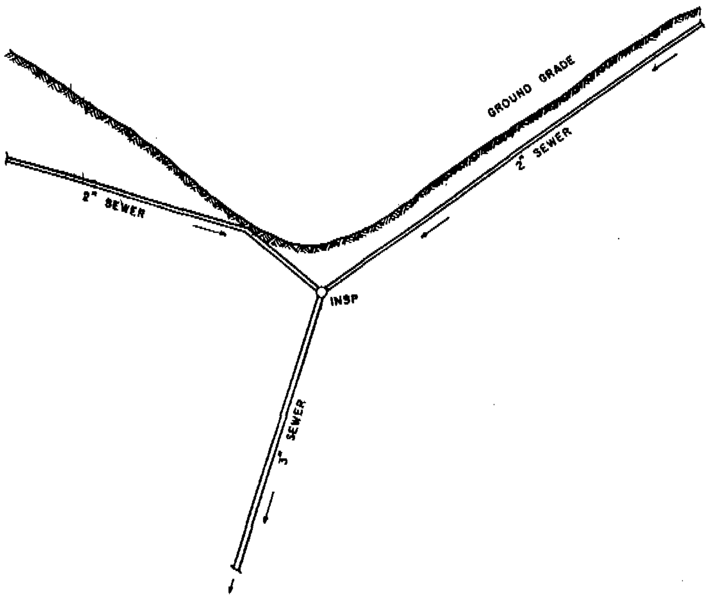
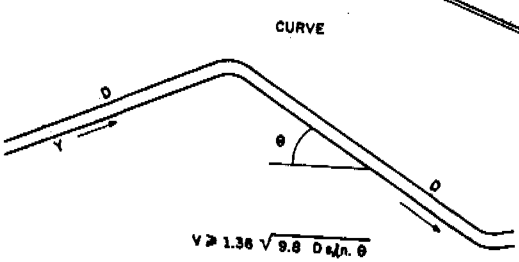
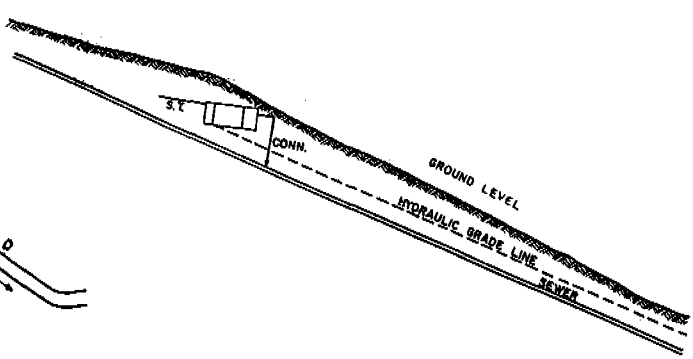


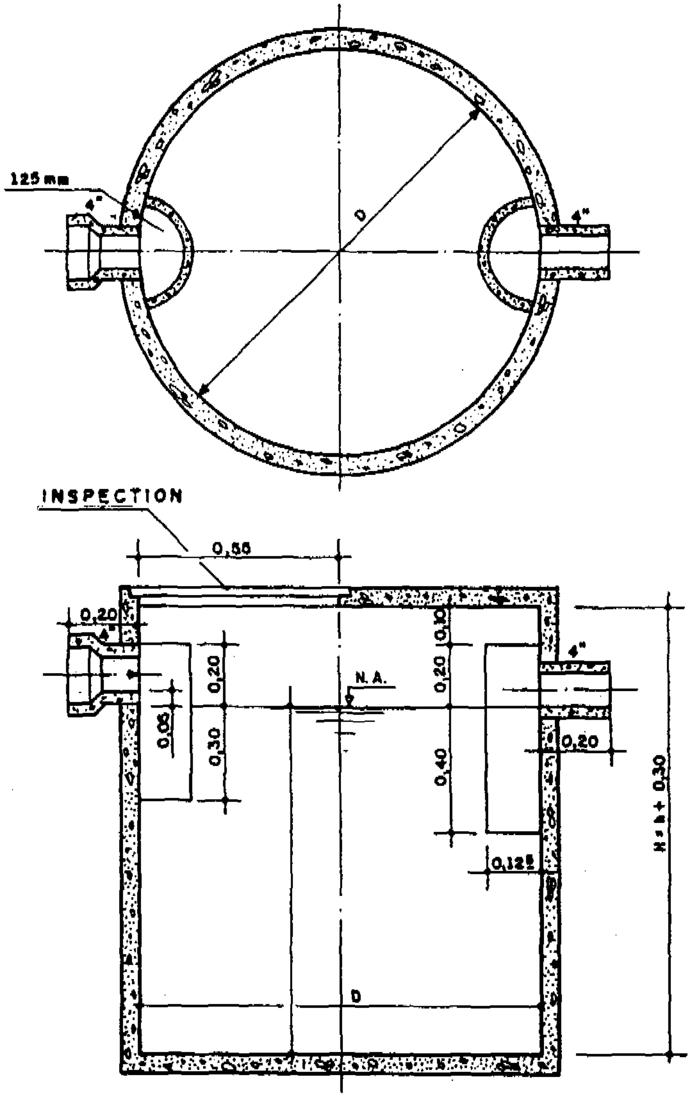
Figure 16. Small bore system



Velocity down curves



Connections and hydraulic grade line



DIMENSIONS

D	h	H
1,20	1,10	1,40
1,15	1,20	1,50
1,10	1,30	1,60

Figure 17. Typical adapted septic tank

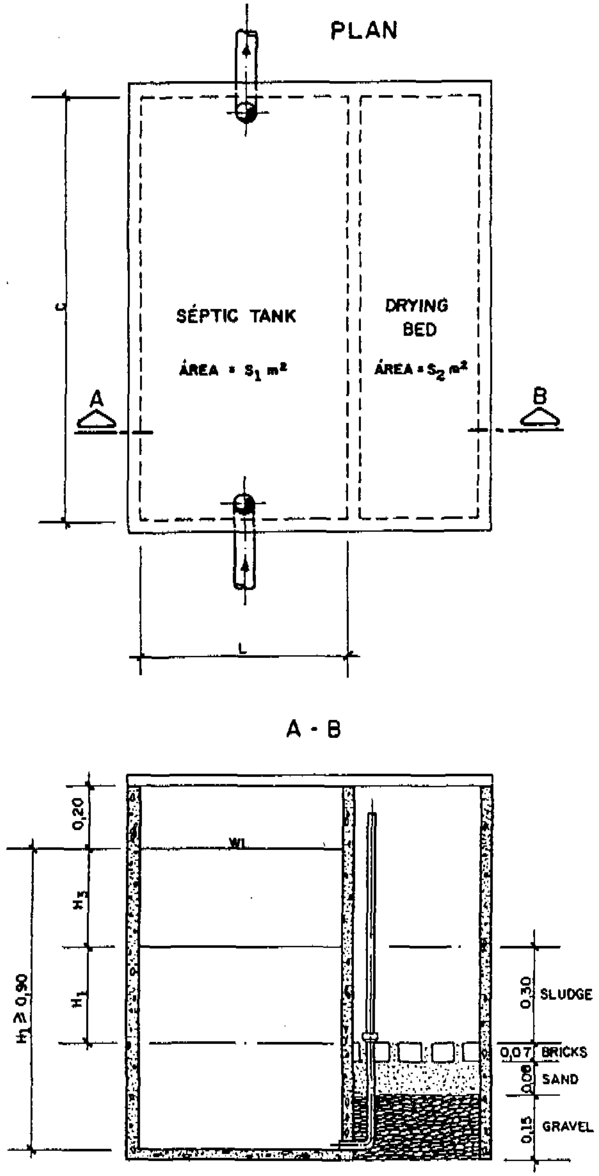


Figure 18. Septic tank with drying bed 3(Cynamon type)

5.3 *DESIGN CRITERIA*

The septic tank is the important part of the system. Septic tanks should be adapted, redesigned and easily produced or constructed. Since the volume of the tank depends on the water consumption per person, its volume become smaller in developing countries.

To evaluate flow the American engineers John D. Dimmons and Jerry O. Newman, of the U.S. Department of Agriculture, consider two cases:

a) With the effect of storage of effluent in an "interceptor" tank:

Q/house = 0.4 gal/min x N (N = Number of houses)

b) Without storage tank:

Q/house = 0.6 gal/min x N

or = 0.0069 liter/sec x p (p = number of persons)

Another way to estimate flows is to consider the volume of sewage discharged daily per person and apply a coefficient to get the maximum discharge. Considering for instance 150 liters of waste per person per day and a coefficient of 4.1 we find values similar to those recommended by the American engineers without storage (accumulation). This is the method being applied in Brazil.

Using a probabilistic method to find simultaneous flows (as the Hunter Method) the results will be higher. This is not the case because along pipes the intensity of flow reduces (deaden effect) and septic tanks work as regulators of flow.

The following table gives the flow to be expected based on different criteria.

TABLE 7: MAXIMUM FLOW FROM A SMALL NUMBER OF HOUSES

NUMBER OF HOUSES	NUMBER OF USERS	HUNTER SIMULT. FLOW (1)*	MAXIMUM DISTR. FLOW (2)*	AMERICAN WITH STORAGE (3)*	CRITERIA WITHOUT STORAGE (4)*
1	5.5	0.5	0.36	0.025	0.038
2	11	1.0	0.07	0.05	0.076
4	22	1.7	0.15	0.10	0.15
6	33	2.2	0.23	0.15	0.23
8	44	2.6	0.33	0.19	0.30
10	55	3.0	0.38	0.24	0.38
15	83	3.8	0.57	0.36	0.57
20	110	4.5	0.76	0.48	0.76
30	165	6.0	1.14	0.72	1.14
40	220	7.2	1.53	0.96	1.52
50	273	7.9	1.90	1.20	1.88
75	413	11.4	2.85	1.80	2.85
100	550	14.0	3.80	2.40	3.80

(1) Based on 10 fixture units per house, not considering the reduction of intensity of flow along lines (deaden effect) and influence of septic tank.

(2) Considering 150 liters of waste per day per person and 4.1 as a coefficient.

(3) On the basis of 0.4 gal/min. per house, with interceptor tank.

(4) On the basis of 0.6 gal/min. per house, without interceptor tank.

* lit/s

5.4 CONDITIONS FOR APPLICATION

The small bore is a system better adapted to small communities, fringe areas, littoral villages, etc. It has been applied to places of low density of population, large lots where soil has poor coefficients of infiltration. The system is also suitable to isolated group of houses and rural settlements.

In the United States common examples are serving 10 to 100 houses.

In Brazil the system was applied to a small town and to few fringe urban areas. The best example is the small town of Brotas, State of Ceará with the following characteristics:

Design population

First stage	1,335 inhabitants
End of Plan	6,000 inhabitants
Present Population	1,084 inhabitants
Sewage volume/person/day	100 liters
Minimum diameter of sewer (PVC line)	1 1/2 inch
Maximum diameter of sewer	4"
Septic Tank	Special model with drying bed, locally erected by user with precast concrete plates
Final Treatment (secondary, biologic)	Anaerobic filter

Example of design

Calculate two sections of a collecting system in a fringe area of a small town.

The upper section is 110 m long and will receive effluent from 20 houses (110 persons). The second section will receive the flow from the first line and will serve 12 houses (66 persons).

The flows will be:

Upper section: 0.0069 x 110 = 0.76 liter/sec.
Second section: 0.76 + 0.0069 x 66 = 0.76 + 0.46 = 1.22 liter/sec.

The Williams-Hazen formula will be used to calculate friction loss. See Table No. 9 with computations. A profile of the lines has to be drawn showing the position of septic tanks discharges above the hydraulic grade line (Figure 19).

5.5 SERVICE ORGANIZATION AND INFRASTRUCTURE SUPPORT

The design and construction of the small bore system of Brotas was done by Eng. Szachna E. Cynamon with the help of Eng. C. F, Dawer, both engineers of the SESP Foundation, following a contract firmed with the Municipality of Itapipoca (the head of the County at the time). There was a substantial participation of the local population during the construction work.

Control, maintenance and Operation by SESP Foundation is done by a trained Sanitary Inspector living in Brotas. The Foundation gives all technical support. The Brotas system is in operation since 1987, with excellent results.

5.6 ADVANTAGES AND DISADVANTAGES

The system is very simple, easily understood by the people. It uses common pipes laid on shallow trenches.

Construction costs are minimum, about one third of the simplified sewerage and one fifth of the cost of conventional system. Besides this advantage, the system provides the primary treatment built and operated by the users.

Disadvantages: Dependency of a good operation of septic tanks and its permanent control. Users have to remove dried sludge.

The system in only applicable to domestic users.

5.7 AVERAGE CONSTRUCTION COSTS

The available information in the case of the town of Brotas is:

TABLE 8: AVERAGE COST IN US DOLLARS PER CAPITA FOR VARIOUS SYSTEMS

Collecting system	US$22.0
House connections	US$16.0
Septic tanks (installed)	US$20.0
Complementary sewage treatment plant	US$10.0
Other expenses (design, supervision)	US$ 8.0
TOTAL:	US$76.0

5.8 OPERATIONAL PROBLEMS AND COSTS

A problem that may occur is the clogging of pipe due to the lack of cleaning septic tanks. This did not happen in Brotas yet, but the septic tanks there are of a special design.

Operational costs are very low: US$0.25/month per person (about 40% of the water bill).

5.9 SUGGESTIONS, RESEARCH AND IMPROVEMENT

As it has been mentioned, septic tanks are an essential part of the system. In large communities it is possible to have a vacuum machine to clean septic tanks regularly, following an established program.

For small places this would not be possible and the cleaning operation have to be executed by users, under some kind of control.

Eng. Szachna Cynamon has designed an interesting model of septic tank that simplifies cleaning (discharge of digested sludge and drying). Attached to each septic tank it is built a very simple drying bed of small size. The required area for the small bed foes not exceed half of the area of the tank.

The digested sludge is discharged periodically (say every month or after 2 months) through a simple pipe system without valve.

The operational control can be accomplished systematically by simple visual observation.

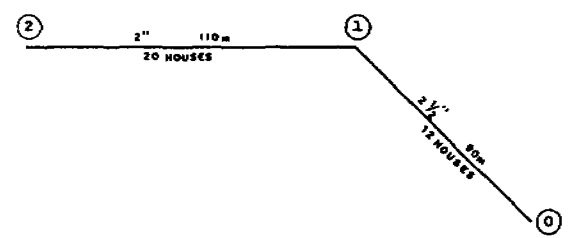
The disposal of the dried sludge is also very simple because the original volume is considerably reduced and the dried material may be useful for gardens and orchards.

TABLE 9: SMALL BORE SYSTEM
EXAMPLE: HYDRAULIC CALCULATION

LINE SECTIONS		LENGTH	GROUND ELEVATIONS		GROUND SLOPE	Nº OF HOUSES	Nº OF PERSONS	SECTION FLOW	TOTAL FLOW	PIPE SIZE	FRICTION LOSS	HEAD LOSS	PIPE ELEVATION		GRADIENT ELEVATION		GRADIENT SLOPE	FULL CAPACITY OF PIPE
DOWN	UP	m	DOWN	UP	m/m			L/s	L/s	INCHES	m	m	DOWN	UP	DOWN	UP	m/m	L/s
0	1	90	144,50	145,10	0,0066	12	66	0,46	1,22	2½"	0,0048	0,43	143,50	144,10	144,00	144,54	0,006	1,40
1	2	110	145,10	145,70	0,0054	20	110	0,76	0,76	2'	0,0046	0,51	144,10	145,20	144,54	145,20	0,006	0,85

<u>OBS.:</u>

Column (6) - 5,5 persons per house.
(7) - q = 0,0069 p
(10) - Williams Hazen, C = 130



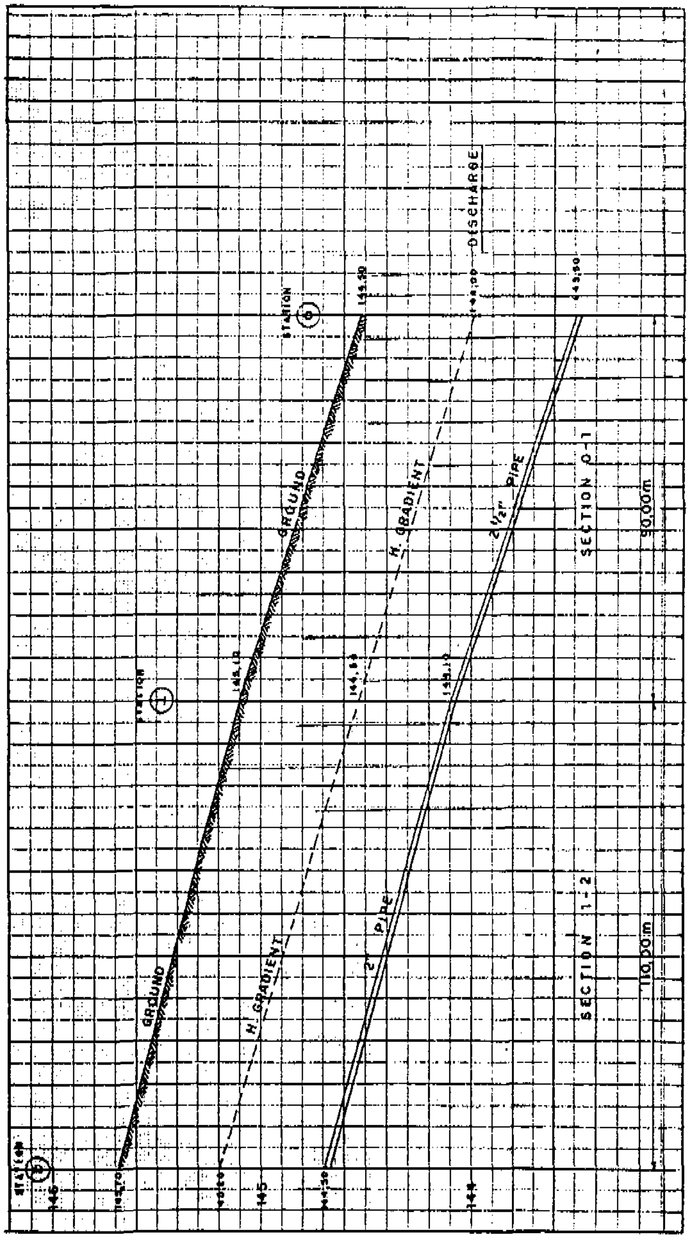


Figure 19. Profile

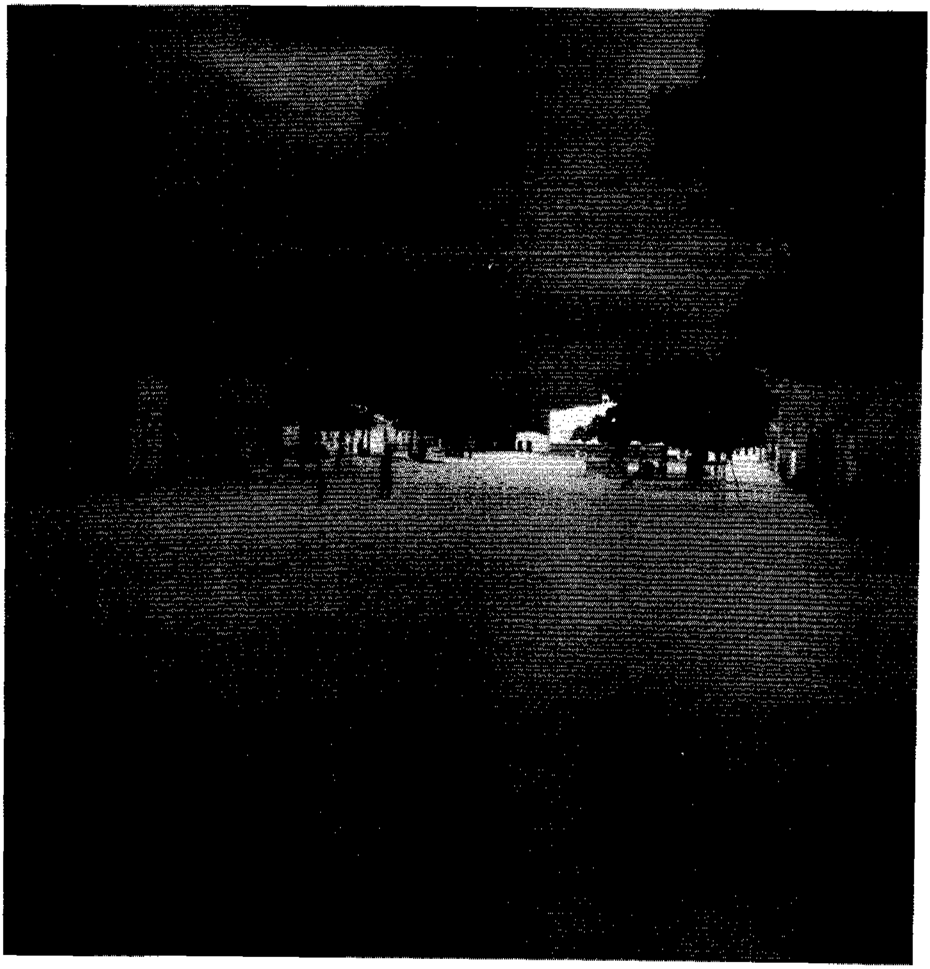


Figure 20. Brotas, the small town where a solids free system was applied

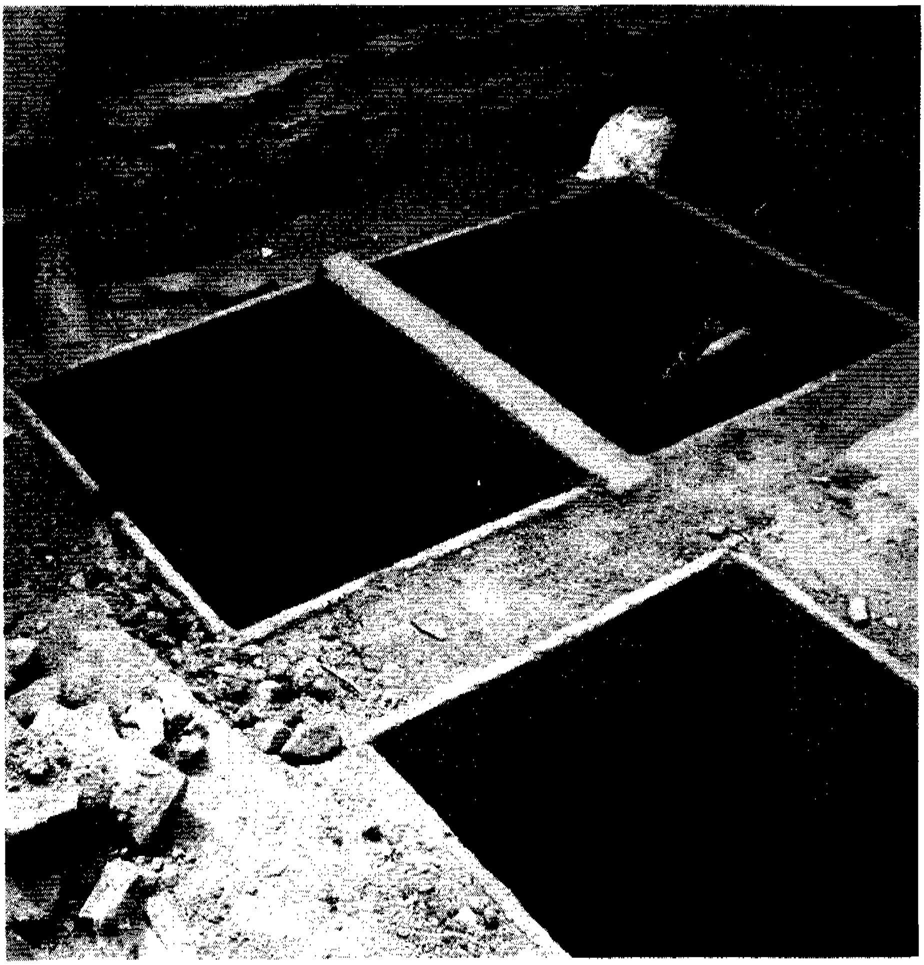


Figure 21. Septic tank of a new type, locally made with drying bed in Brotas

6. SMALL SEWAGE PUMPING STATIONS

6.1 THE NEED OF PUMPING

In small schemes the designer should try to avoid pumping installations. The problems that may occur with such installations, in the developing world are:

1) Need for permanent, capable and expensive operators;

2) Interruption or lack of electric energy;

3) Difficulty to repair pumps, electric motors and electrical parts;

4) Difficulty to acquire or to import spare parts.

But, there are cases in which pumps are necessary either to avoid too deep and too expensive sewers, or to reach a level for treatment and disposal of the effluent.

6.2 SIMPLEST TYPES OF PUMPING STATIONS

The simplest type of installation uses submersible sets of pump/motor (Flight type of pump and similar units).

In this case the only structure is the suction well where the pumps (minimum 2 units) are located.

The minimum volume of the well may be determined by the expression:

$$V = 1.5\,Q$$

Where:

V = minimum volume, m3
Q = pump flow, m3/min.

SABESP, the Water Supply and Sewerage Company of Sao Paulo, has standardized sewage pumping installations.

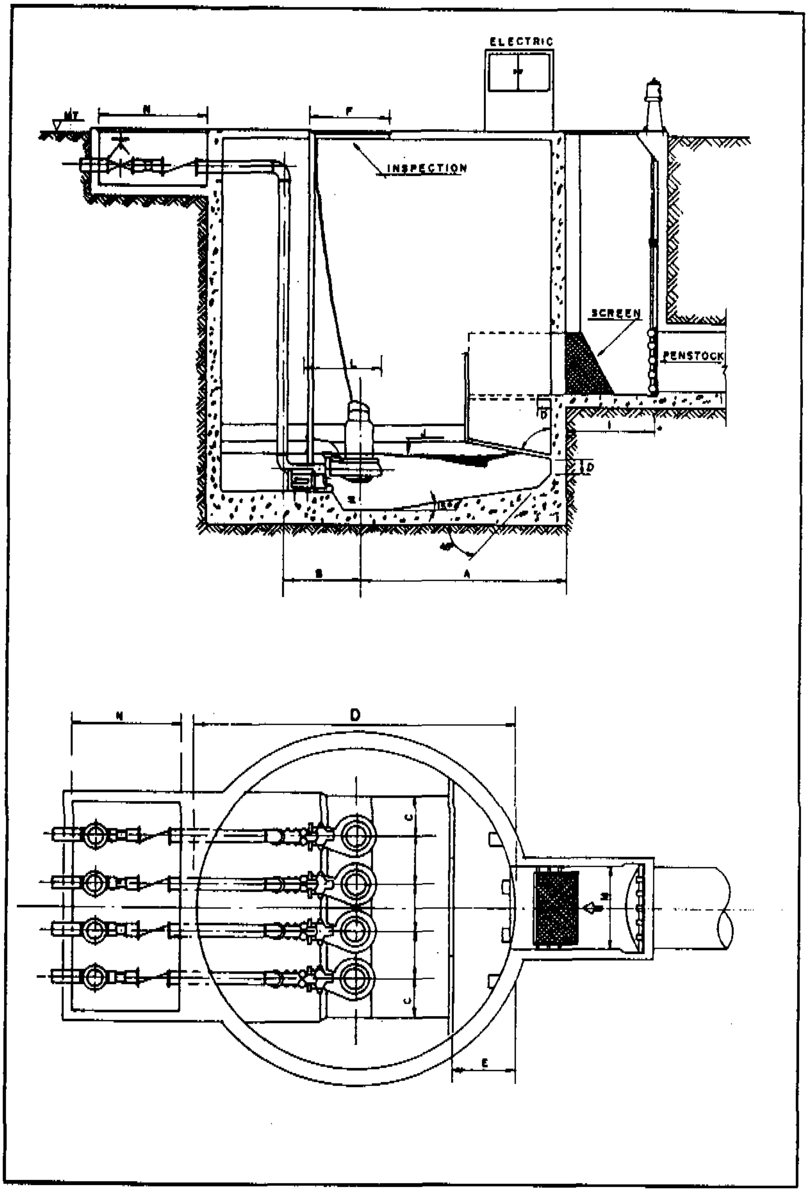


Figure 22. Standard pumping station (SABESP)

TABLE 10: STANDARD PUMPING STATION -DIMENSIONS-

PUMPS FLOW, L/s	2 PUMPS			3 PUMPS			4 PUMPS			MIN. DIMENSIONS, m		
	D	A	E	D	A	E	D	A	E	B	D	C
50	1.50	0.80	0.60	2.00	1.10	0.82	2.50	1.45	1.00	0.50	0.15	0.24
60	1.58	0.85	0.65	2.10	1.20	0.95	2.75	1.60	1.15	0.52	0.17	0.25^{5}
70	1.68	0.95	0.70	2.25	1.32	1.05	2.92	1.70	1.20	0.55	0.18^{5}	0.28
80	1.81	1.00	0.75	2.42	1.46	1.15	3.15	1.95	1.35	0.61^{5}	0.19^{5}	0.29^{5}
90	1.88	1.10	0.82	2.60	1.55	1.20	3.40	2.10	1.48	0.65	0.20	0.31
100	2.10	1.35	1.00	3.00	1.80	1.30	3.98	2.30	1.65	0.75	0.22	0.33
150	2.25	1.55	1.12	3.45	2.10	1.45	4.30	2.55	1.85	0.85	0.25	0.40
200	3.00	1.75	1.25	3.80	2.35	1.55	5.00	2.78	2.10	1.10	0.30	0.48
250	3.35	2.00	1.38	4.20	2.60	1.65	5.70	3.00	2.30	1.20	0.33	0.51
300	3.65	2.20	1.50	4.80	2.95	1.75	6.30	3.35	2.60	1.30	0.36	0.60
350	4.10	2.52	1.85	5.20	3.20	1.93	7.00	3.60	2.85	1.40	0.42	0.62
400	4.45	2.65	1.95	5.75	3.45	2.15	7.55	3.90	3.10	1.50	0.45	0.69
450	4.75	2.80	2.05	6.10	3.70	2.32	8.10	4.30	3.40	1.60	0.49	0.71
500	5.00	2.90	2.10	6.50	3.90	2.73	8.70	4.70	3.65	1.70	0.51	0.72

ANNEX

ANNEX A
HYDRAULIC FORMULAS

Manning's Formula

$$V = \frac{1}{n} R_H^{2/3} I^{1/2}$$

For small circular sewers, with n = 0.013 this formula may be simplified:

Substituting: $V = \frac{Q}{A}$ and $R_H = R$

$$Q = \frac{1}{n} R^{2/3} I^{1/2}$$

$$Q = \frac{1}{n} R^{2/3} I^{1/2}.A$$

$$Q^3 = \frac{1}{n^3} R^2 I^{3/2} A^3$$

$$(AV)^3 = \frac{1}{n^3} R^2 I^{3/2} A^3$$

$$V^3 = \frac{1}{n^3} R^2 I^{3/2}$$

$$V^4 = \frac{1}{n3} R^2 I^{3/2} \frac{Q}{A}$$

$$V = \left(\frac{1 \ R^2}{n^3}\right) 1/4 \ I^{3/8} Q^{1/4}$$

Since $\left(\frac{R^2}{A}\right)^{1/4} = 0.61$ and n = 0.013

We find:

$V = 15.8 \ I^{3/8} Q^{1/4}$, which is a simplified formula.

A practical way to compute slopes: for a minimum velocity of 0.50 m/s:

$$0.50 = 15.8 \ I^{3/8} Q^{1/4}$$

$$I = \frac{15.8^{-8/3}\ Q^{(1/4)\ (-8/3)}}{0.50^{-8/3}}$$

$$I = \frac{-0.50^{8/3}\ Q^{-2/3}}{15.8^{8/3}}$$

$$I = 0.0001\ Q^{-2/3}$$

The tractive force

The tractive force is the physical stress exerted by a flowing liquid on the pipe wall. It is a tangential force. Considering uniform movement along a section of pipe, the average tractive force will be:

$$F_t = \frac{W \sin \phi}{pL}$$

Where:

W	=	Weight of the liquid in section
$\sin \phi$	=	sin of the angle with horizontal
p	=	wetted perimeter
L	=	Length of the section

Since $W = \delta\ AL$

δ	=	specific weight of the liquid
A	=	wetted area

$$F_t = \frac{AL \sin \phi}{pL} = \delta\ R_H \sin \phi$$

Com $\delta = 1000\ kg/m^3$

$$F_t = 1000\ R_H I$$

Sedimentation (Deposit of solids) is a function of tractive force.

ANNEX B
HYDRAULIC TABLES

ELEMENTS OF CIRCULAR SEWERS

LIQ. DEPTH h/D	k_1 p	k_2 A	k_3 R_H	k^4 V	k_5 Q
1.0	3.14	0.78	0.25	1.00	1.00
0.95	2.69	0.77	0.29	1.11	1.07
0.9	2.50	0.74	0.30	1.15	1.07
0.85	2.35	0.70	0.30	1.16	1.03
0.8	2.21	0.67	0.30	1.16	0.98
0.75	2.09	0.63	0.29	1.15	0.91
0.7	1.98	0.59	0.29	1.14	0.84
0.65	1.98	0.54	0.28	1.11	0.76
0.6	1.77	0.49	0.28	1.08	0.67
0.55	1.67	0.44	0.26	1.04	0.58
0.5	1.57	0.39	0.25	1.00	0.50
0.45	1.47	0.34	0.23	0.94	0.42
0.4	1.37	0.29	0.21	0.88	0.33
0.3	1.16	0.20	0.17	0.72	0.19
0.25	1.05	0.15	0.15	0.65	0.14
0.2	0.93	0.11	0.12	0.56	0.09

To calculate:

Wetted perimeter: $p = k_1 D$

Area of flow: $A = k_2^2 D^2$

Hydraulic Radius: $R_H = k_3 D$

Corrected V: $V = k_4 \text{ Vfull}$

Corrected Q: $Q = k_5 \text{ Qfull}$

MAXIMUM FLOW: SEWERS WORKING AT 0.8 D

SLOPE m/m	DIAMETER 6"	DIAMETER 8"	DIAMETER 10"	DIAMETER 12
0.003	7.16	16.02	29.81	49.39
0.004	8.28	18.53	34.47	57.10
0.005	9.27	20.74	38.56	63.89
0.006	10.27	22.73	42.27	70.00
0.007	10.99	24.56	45.68	75.66
0.008	11.75	26.26	48.84	80.90
0.009	12.46	27.86	51.81	85.83
0.010	13.14	29.37	54.63	90.48

Q in liters/sec. (Ganguillet-Kutter formula with $n = 0.013$)

MINIMUM SLOPES

Q liters/sec	I_{MIN} m/m
1.5	0.0077
2.0	0.0062
3.0	0.0050
4.0	0.0040
5.0	0.0034
6.0	0.0030
7.0	0.0027
8.0	0.0025
9.0	0.0023
10.0	0.0022
15.0	0.0017
20.0	0.0014
30.0	0.0010
40.0	0.0009

Results from the expression $I = 0.0001\ Q^{-2/3}$

Minimum practical slope: 0.0008 (Q = 44 liters/sec)

Q in liters/sec. (Ganguillet-Kutter formula with n = 0.013)

MINIMUM FLOW (h/D = 0.2) AND
MAXIMUM FLOW (h/D = 0.8 D)

SLOPE I, m/m	6"		8"		10"		12"	
	Q_{min}	Q_{max}	Q_{min}	Q_{max}	Q_{min}	Q_{max}	Q_{min}	Q_{max}
0.003	0.66	7.16	1.47	16.02	2.74	29.81	4.56	49.39
0.004	0.76	8.28	1.70	18.53	3.16	34.47	5.24	57.10
0.005	0.85	9.27	1.90	20.74	3.54	38.56	5.87	63.89
0.006	0.93	10.16	2.09	22.73	3.88	42.27	6.43	70.02
0.007	1.01	10.99	2.25	24.56	4.19	45.68	6.95	75.66
0.008	1.08	11.75	2.41	26.26	4.48	48.84	7.43	80.90
0.009	1.14	12.46	2.56	27.86	4.76	51.81	7.88	85.83
0.010	1.21	13.14	2.70	29.37	5.02	24.63	8.31	90.48

Q in liters/sec. (Ganguillet-Kutter formula with n = 0.013)

Table indicates when D should or could be increased.

Q_{min} do not use less than 1.5 liter/sec.

SEWERS: SMALL SLOPES - FLOW VELOCITIES (m/s) AND DISCHARGES (liters/sec)

DEPTH OF FLOW (Y/D) = 0,2 – 0,8 Q = 1 – 60 liters/sec

		D= 4" (100mm)			D= 6" (150mm)				D= 8" (200mm)				D= 10" (250 mm)				D= 12" (300mm)		
		I			I				I				I				I		
WATER DEPTH Y/D	COEF.	0.010	0.015	0.020	0.004	0.005	0.006	0.007	0.003	0.004	0.005	0.006	0.002	0.003	0.004	0.005	0.002	0.003	0.004
0,3	V=0.72 Q=0.19	V=0.50 Q=1.0	V=0.61 Q=1.3	V=0.78 Q=2.8			V=0.42 Q=2.0	V=0.52 Q=2.4		V=0.43 Q=3.6	V=0.48 Q=4.0	V=0.58 Q=4.8		V=0.44 Q=5.8	V=0.51 Q=6.7	V=0.61 Q=8.0	V=0.42 Q=7.8	V=0.51 Q=9.6	V=0.59 Q=11.1
0,4	V=0.88 Q=0.33	V=0.61 Q=1.8	V=0.75 Q=2.2	V=0.95 Q=2.8	V=0.41 Q=2.8	V=0.46 Q=3.1	V=0.51 Q=3.4	V=0.63 Q=4.2	V=0.46 Q=5.4	V=0.53 Q=6.2	V=0.59 Q=7.0	V=0.71 Q=8.4	V=0.44 Q=8.2	V=0.54 Q=10.0	V=0.62 Q=11.6	V=0.71 Q=13.8	V=0.51 Q=13.5	V=0.62 Q=16.6	V=0.72 Q=19.2
0,5	V=1.00 Q=0.50	V=0.70 Q=2.7	V=0.85 Q=3.3	V=1.08 Q=4.2	V=0.47 Q=4.2	V=0.53 Q=4.7	V=0.58 Q=5.2	V=0.72 Q=8.1	V=0.52 Q=8.1	V=0.60 Q=9.4	V=0.67 Q=10.6	V=0.81 Q=12.7	V=0.50 Q=12.4	V=0.61 Q=15.2	V=0.71 Q=17.6	V=0.85 Q=21.0	V=0.58 Q=20.5	V=0.71 Q=25.2	V=0.82 Q=29.1
0,6	V=1.08 Q=0.67	V=0.75 Q=3.7	V=0.92 Q=4.5	V=1.16 Q=5.7	V=0.51 Q=5.6	V=0.57 Q=6.3	V=0.63 Q=7.0	V=0.78 Q=8.5	V=0.56 Q=10.9	V=0.65 Q=12.6	V=0.72 Q=14.2	V=0.87 Q=17.0	V=0.54 Q=16.6	V=0.66 Q=20.4	V=0.77 Q=23.6	V=0.92 Q=28.1	V=0.63 Q=27.5	V=0.77 Q=23.8	V=0.88 Q=39.0
0,7	V=1.14 Q=0.84	V=0.80 Q=4.6	V=0.97 Q=5.6	V=1.23 Q=7.1	V=0.54 Q=7.1	V=0.60 Q=8.0	V=0.66 Q=8.7	V=0.82 Q=10.6	V=0.59 Q=13.7	V=0.68 Q=15.9	V=0.76 Q=17.8	V=0.92 Q=21.3	V=0.57 Q=20.8	V=0.69 Q=25.5	V=0.81 Q=29.5	V=0.97 Q=35.3	V=0.66 Q=34.4	V=0.81 Q=42.3	V=0.93 Q=49.0
0,8	V=1.16 Q=0.98	V=0.81 Q=5.4	V=0.98 Q=6.5	V=1.25 Q=8.3	V=0.55 Q=8.2	V=0.61 Q=9.3	V=0.67 Q=10.2	V=0.83 Q=12.4	V=0.60 Q=16.0	V=0.70 Q=18.5	V=0.78 Q=20.8	V=0.94 Q=24.9	V=0.58 Q=24.3	V=0.71 Q=29.8	V=0.82 Q=34.5	V=0.98 Q=41.0	V=0.67 Q=40.2	V=0.82 Q=49.4	V=0.95 Q=57.[illegible]
0,9	V=1.15 Q=1.07	V=0.80 Q=5.9	V=0.98 Q=7.1	V=1.24 Q=7.1	V=0.54 Q=10.0	V=0.61 Q=10.1	V=0.67 Q=11.1	V=0.83 Q=13.6	V=0.60 Q=17.4	V=0.69 Q=20.2	V=0.77 Q=22.7	V=0.93 Q=27.2	V=0.57 Q=26.5	V=0.70 Q=32.5	V=0.81 Q=37.6	V=0.98 Q=44.9	V=0.67 Q=43.9	V=0.81 Q=53.9	V=0.94 Q=62.4
1,0	V=1.00 Q=1.00	V=0.70 Q=5.5	V=0.85 Q=6.7	V=1.08 Q=8.5	V=0.47 Q=8.4	V=0.53 Q=9.5	V=0.58 Q=10.4	V=0.72 Q=12.7	V=0.52 Q=16.3	V=0.60 Q=18.9	V=0.67 Q=21.2	V=0.81 Q=25.4	V=0.50 Q=24.8	V=0.61 Q=30.4	V=0.71 Q=35.2	V=0.85 Q=42.0	V=0.58 Q=41.0	V=0.71 Q=50.4	V=0.82 Q=58.3

ANNEX C
BRAZILIAN NORM (16) FOR SEWERAGE SYSTEM

The Brazilian Norm (Standards) for designing sewerage systems is the A.B.N.T. - NBR 9649. An extract of the Norm is:

Topographic maps

Scale 1: 2,000 or better
Contour lines: each meter

Design flows

It is required to calculate maximum flows for first and final stages.

Initial or first stage: peak hour flow at average day.

Final stage: peak hour flow at maximum day.

Estimated flows should include allowances for infiltration water from the ground.

Minimum flow at the beginning of small sewer is 1.5 liter/sec (to take in account simultaneous flows from house fixtures.

Size of sewers

Minimum diameter 4" (only for few blocks, branch sewers)
6" for most sewers;

Slopes or gradient

Minimum slope should be calculated (and not adopted)

Velocity of flow

Minimum velocity: about 0.50 m/s
Maximum velocity: 5.00 m/s
Critical velocity = 6 $(gR_H)1/2$

Wetted section

Maximum: 0.75 D
Minimum: 0.20 D

If flow velocity is higher than critical velocity the maximum wetted section should be 0.50 D.

Ground water infiltration

0.05 to 1.00 liter/sec per km of sewer.

Manholes

Simpler type with a minimum width of 0.80 m

Manholes are eliminated by other inspection and cleaning devices:

- Cleaning Terminal (at the beginning of small sewers).
- Underground boxes (at intermediate points, changes of slopes, small curves, etc.).
- Inspection tubes (at intermediate points, etc.).

Depth of sewers

(Depth of trenches)

Minimum depth: Sewers under streets: 0.90 + D

Sewers under walkways: 0.65 + D

HYDRAULIC FORMULA: Manning with n = 0. 013

ANNEX D
EQUIPMENTS FOR MAINTENANCE

Sewage works, as all works and installations can not function without adequate attention, care and maintenance procedures for conservation, lasting and good performance.

Any Sewerage System may present problems of obstructions that may be caused by several reasons, the most common being undue use (bad use) of the system.

The responsible Authority of the service should have in mind this event and should be prepared to repair, having proper tools, machines and special equipment for cleaning the clogged pipes.

To make sure the proper Engineering Plans and Technical Project should specify and include as a part of the Project, the required equipment and machines for maintenance.

Most of stoppages occur inside the houses or properties, in the internal plumbing system, as well as in the house connections.

In the city of Sao Paulo, for example, there are 75 blocking per 1,000 km of sewers each month. Problems inside private property are more frequent.

These are three types of common machines:

I. Flex Cleaner
II. Rodding Machines
III. Flushing Machines

To give an idea of the number of equipment per 200 km of sewers, to be considered in a Project, we may consider the following suggestions.

EQUIPMENTS FOR CLEANING SEWERS

EQUIPMENT	MOST COMMON USE	NUMBER OF UNITS PER 200 KM
Flex Cleaner	Plumbing installations, drains, small branches	3
Sewer Rodder	Sewers	1
Sewer Jet	Sewers	1

There are also larger machines, the suction type, such as "Vac All" and special machines to remove solids, "Bucket Machines."

ANNEX E
COMPARISON OF SEWERAGE SYSTEMS

	CONVENTIONAL SYSTEMS	SIMPLIFIED SYSTEM	CONDOMINIAL SYSTEM	SMALL BORE SYSTEM
APPLICATION	General, to high economical level of population.	General.	Residential areas, depends on topography, urban characteristics and the arrangement of houses. Depends on promotion and general acceptance.	For domestic use. Low density areas where soil has low capacity of absorption of effluents. Small communities, villages, camping, etc.
TECHNICAL CHARACTERISTICS	The most common, well known system. In accordance with traditional standards.	Innovation technology needs change of standards of design. Sewers are not too deep. Precise criteria for designing. Economic use of auxiliary sewers.	Uses collective connections shallower public sewers built under walkways.	Solids free collecting systems. Small diameter plastic pipes. Requires septic tanks.
ADVANTAGES	Well known. Complete developed technology.	More economical. Smaller size of pipes. Shallower sewers. Better control of design. Eliminate superflous manholes.	Complete participation of users (in all phases). Easy construction of houses connections. Shallower sewers. Construction by steps. Lower cost of construction and maintenance. Larger number of connections. Less extension of public sewers.	The lowest cost of construction. Easy operation. Investment of primary treatment by beneficiaries. Use small, common plastic pipes as sewers. Low cost connections.
DISADVANTAGES	Higher construction cost. Criteria of design not precise. Excessive number of manholes. Expensive type of manholes. Gradient of sewers not well defined. Deeper sewers.	Less known. Needs change of standards. Basements are not connected.	For domestic application. Problems of operation (bad use of sewers). Problems of right of way (property and land passages). Difficult of access. Poor maintenance. Lack of legislation.	Depends entirely on the proper operation of septic tanks.
Basic Costs (Brazilian Experience) Construction Costs/Capita (US$ 1988) Not including public sewage treatment	Collecting system: US$200 - $300 House connections: US$ 20 - $ 40 Total cost: US$220 - $340	Collecting system: US$100 - $160 House connections: US$ 20 - $ 40 Total cost: US$120 - $200	Collecting system: US$40 - $60 House connections: US$10 - $20 Total cost: US$50 - $80	Collecting system: US$10 - $20 Septic tanks: US$10 - $20 House connections: US$ 5 - $10 Total cost: US$25 - $50

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