BRAZIL SMALL COMMUNITY WATER TREATMENT PLANT EVALUATION

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PREFACE

This report is a result of a visit by the author to Curitiba, Parana, Brazil during August, 1986 to gather technical, economic and social information relating to the impact on the availability of potable water to rural communities of the Centre-funded project 77-053. The IDRC file for this project is 3-A-86-4123. A trip summary and supplemental information is contained in the accompanying report, "Trip Summary Report for Brazil Community Water Treatment Plant Evaluation" submitted by the consultant.

The staff at SANEPAR, particularly Dr. Carlos Richter, was most cooperative in giving their time and making every effort to obtain the information requested by the consultant. Their efforts are gratefully acknowledged.

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1. INTRODUCTION

In 1977, Dr. Carlos A. Richter, an engineer with the state water and sewerage company, SANEPAR, of Parana, Brazil, submitted a proposal to IDRC for pilot and prototype evaluation of a water treatment plant for small communities (population less than 5,000). The design incorporated two unique features to reduce costs, operator functions and maintenance in these rural plants while providing water of good quality. The plants were a modular package plant design.

The primary feature of the plants was a pebble bed or granular media hydraulic flocculator which reduced flocculation time to 1/4 to 1/5th of flocculation times in conventional flocculators; there are no mechanical mixers required in the pebble bed flocculator. The second feature of the plant was a self-backwashing sand filter. The backwash cycle was accomplished by siphoning water from the clear water reservoir; the siphon was actuated by headloss reaching a preset level. Previous to this work very limited experience with siphon backwash filters had been obtained in Brazil by another group and their design was patented. SANEPAR proposed a modification of the patented design.

The principal investigator in the project, Dr. Richter requested funds to be used to purchase equipment to monitor water quality in the pilot and prototype units. The theoretical and cost information on the package plant along with data from the experiments is described in the report Water Treatment Plant for Small Communities by C.A. Richter *et al.* on file at IDRC. A photograph of Dr. Richter for future use of IDRC personnel is given in Fig. 1.

1.1 Objectives of the Consultancy

Since the IDRC project's completion, a number of plants had been constructed and further operating experience as well as other information should exist. The purpose of this consultancy was to obtain information on the technical, economic and sociocultural aspects of these water treatment plants. In particular, an assessment of the plants was to be made to determine if a detailed report on their operation was worthwhile for dissemination to other parts of South America or the developing world. The detailed terms of reference for this consultancy are given in Appendix A.

2. BACKGROUND INFORMATION

2.1 The State of Parana

The state of Parana is located in the southern part of Brazil in a temperate climate. Temperatures can reach freezing in the winter although this is not common. The population is approximately 8,000,000 and a high percentage of the population is of European extraction from primarily Germany, Poland, The Netherlands and Italy. There is also a significant number of people with a Japanese extraction. There is only one small reserve for a native populace. The state is typical of Brazil in integration of all races and cultures.

Detailed socioeconomic and other information on the state can be found in the report Mensagem a Assembleia Legislativa, 1986, submitted along with this report. Literature and other documents provided for the consultant by SANEPAR and submitted with this report are listed in Appendix B. The average family size is near five which is the design figure used by SANEPAR for a house connection.

In general Parana is one of the wealthier states of Brazil. The cooler climate was offered as one reason for lack of a significant migrant population. Its proximity to Sao Paulo and Rio de Janeiro as well as the European and Japanese ancestry are other reasons for the productivity of the state. Agriculture is the primary industry with about 1/4th of Brazil's total agricultural output produced in Parana.

Education at the primary and secondary levels is free and compulsory for all children from 7 to 14 years of age. At the primary level free lunches are offered to the children as a convenience and incentive to attend school. It was acknowledged by more than one person that there were some problems with school attendance in the rural areas. Children were removed from school to help in the fields.

University education is expensive and only the wealthy are able to afford it. The universities in Parana graduate 200 engineers in all disciplines each year.

The state is approximately rectangular in shape with an east-west distance of 647 km and a north-south dimension of 468 km. It has an area of 400,000 km^2. There are 311 municipalities. The urban population is 5,500,000.

With respect to water supply, the state is blessed with an abundance of rivers and droughts are not a problem. Groundwater supply is not generally feasible except for small surface wells because of the common subsurface granite formations that make well drilling inordinately expensive.

2.2 SANEPAR

By federal legislative mandate (a national plan set 15 years ago) all states of Brazil have a water and sewerage company. SANEPAR, created in 1964, is Parana's water/sewerage company. Before the creation of SANEPAR the municipalities were responsible for their own water supply and wastewater disposal. The state companies are fairly autonomous. Their directors are politically appointed.

A partial organizational chart of SANEPAR is given in Fig. 2. By the admission of outsiders and personnel within SANEPAR, SANEPAR is the best organized and operated water company in Brazil. It has been used as a model for other water companies in Brazil. The headquarters of SANEPAR is located in Curitiba. The complex is well equipped with modern business machinery. The availability of funds to support extra activities such as the excursion into the surrounding communities for this consultancy was not a problem. SANEPAR also would have paid for a round trip air ticket for the consultant to fly to Sao Paulo if necessary to satisfy the needs of this consultancy.

SANEPAR will fully operate systems for communities with a population of 1,000 or greater. (See section 6 for information on Pro-Rural, a group within SANEPAR which provides assistance to villages with populations less than 1,000.) Municipalities have the option of turning over their water/sewerage systems operations to SANEPAR or maintaining their own control. The municipalities maintain ownership of the systems in any case. In 1972 SANEPAR operated 16 water systems and today they operate 459 systems. There are 46 independently operated water systems: one for a large city of about 100,000 inhabitants and 45 systems for small communities of about 2,000 inhabitants.

Eighty-seven percent of the urban population has their water service supplied by SANEPAR; the other 13 percent is served by untreated water, surface wells and other sources. All urban people will eventually be served by SANEPAR. The largest water system is Curitiba's with a flow of 4.1 m^3/s, 208,600 single connections and 319,700 multi-connections. The smallest water system is Nova Concordia's with a flow of 0.4 m^3/hr, 15 single connections and 15 multi-connections.

The water supply systems are essentially 100 percent metered. They record an average of 30 percent losses in their distribution systems which is very impressive. Besides monitoring consumption rates, the meters are used for water and sewerage (where it exists) tariff assessment.

As of May 1986, SANEPAR operated 37 sewerage systems (there were 5 independent systems) which served 24 percent of the urban population. Wastewater disposal in non-sewered areas is primarily by septic tank and tile fields although cesspools, casual tipping and open ditches are also used.

There are currently 4,562 SANEPAR employees throughout the state. SANEPAR performs all duties from operation of systems to fee collection and design services. Communities with a population in the range of 1,000-5,000 have an operator who is also responsible for all local administrative tasks, meter reading and bill collection. The latter tasks usually take up more than 50 percent of the operator's time. Cities with a population greater than 5,000 have one or more full time plant operators and separate administrative staff.

New systems are financed by a 50 percent loan from the national and state banks, respectively. In 18 years the loans must be fully repaid. The national bank uses a revolving fund for financing new water and sewerage systems. Further information on the operations and finances of SANEPAR may be found in the report Relatorio Gerencial.

SANEPAR has had a complete operator training program for water and wastewater treatment plant operators for some time. The federal government provided funds for SANEPAR to design and build an operator training school fully equipped with pilot sized treatment modules, laboratories and classrooms. The school, located in Curitiba, was christened in July of this year. Classes will begin in the near future.

The instructional program was also designed by SANEPAR. All states will send operators to this school for the 1 1/2 year course. Most of the common modifications to water treatment plant unit operations are available in the school. An activated sludge unit and a stabilization pond were the two wastewater treatment operations currently in the school. There was a mini-distribution system with meters and pressure gauges, valves and other appurtenances.

Each water and wastewater treatment facility is built with its own laboratory. Water treatment plants have the capabilities of analyzing pH, alkalinity, color, permanganate demand, chlorine residual and turbidity which are done on a routine basis at all plants. Chemical supply is not a problem.

SANEPAR operates 3 regional laboratories, located in Curitiba, Londrina and Moringa, that are responsible for bacteriological and physical-chemical analyses of raw and treated water. These laboratories are staffed by senior staff with advanced degrees typically consisting of a chemical engineer and a biologist. There are 6-7 supporting chemical technicians. The labs contain equipment to analyze constituents from heavy metals to pesticides. Bacteriological monitoring is carried out according to WHO guidelines for frequency of analysis versus population served. Samples are collected and iced for transport to the regional lab.

There are national regulations for surface water quality but it is the responsibility of the state to monitor streams and lakes. SUREHMA (equivalent to our Ministry of the Environment) is the agency responsible for this monitoring. There is significant pollution of streams in Parana because of the lack of wastewater treatment. SUREHMA also monitors water quality at the tap as a check on SANEPAR.

SANEPAR is committed to and delivers a quality product. Water treatment works are designed to deliver water with less than one turbidity unit of suspended matter. Water treatment works visited that were constructed or upgraded during the past 15-20 years were sound designs using Brazilian made components, hydraulic unit operations and manually controlled operations.

3. PROJECT HISTORY

3.1 Project Conception

The project was conceived by Dr. Richter and other personnel at SANEPAR in an effort to provide a low cost, low maintenance and reliable water treatment plant for rural communities in SANEPAR's program of expanding piped, treated water to Parana's population. SANEPAR is directly responsible for providing water and sewerage to most of Parana's communities with populations of 1,000 or larger. At the time of this project most of the larger communities were serviced with water and emphasis was focused on smaller communities.

Except for IDRC's assistance there was no technical or financial assistance from any other outside agency. SANEPAR funded the bulk of the project with its own resources and manpower. The proposal was made to IDRC to obtain equipment in exchange for SANEPAR's services. It became readily apparent to this consultant that Dr. Richter is a pre-eminent water supply engineer, theoretically and practically. The other personnel involved in the project are listed in the proposal and co-authored the report _Water Treatment Plant for Small Communities_. All personnel are presently with SANEPAR.

To Dr. Richter's and the consultant's knowledge this work was the first use of the pebble bed flocculator in South America. Dr. Richter had read about experience with the pebble bed flocculator in India (probably Bhole's work[1]) and the concept seemed reasonable. The design proposed by Richter differed from the design used in India.

3.2 Project Results

The theoretical, experimental and cost results from the pilot and prototype studies are well documented in the report Water Treatment Plant for Small Communities for which Richter was the senior author. Richter has a fair command of the English language and the report was translated into English with the assistance of another engineer at SANEPAR. The studies were satisfactorily completed to provide the information required for design.

The membrane filtration (MF) equipment for bacteriological analyses supplied as a result of IDRC support was SANEPAR's first experience with this procedure. Formerly the more tedious MPN technique was used. As a result of experience gained on this project with the MF technique, all regional laboratories implemented the MF technique.

There is one significant omission from the report submitted to IDRC. There were problems with the seal in the priming siphon for the siphon backwash filter in the Aracuaria prototype unit. These problems were corrected. There was also a prototype plant constructed at Borrazopolis that also experienced problems with the priming siphon seal. These were also corrected and the results given in the report are correct for a seal that does not allow air leakage.

The construction problems with the seal led to the decision to abandon the siphon backwash for the filter. It was reasoned that if quality control in the construction of this apparatus was a problem for firms in Curitiba, better results could not be expected in rural areas. The reader is referred to section 4.3.1 for further discussion of this problem.

The siphon backwash filter which operates in an essentially constant rate mode was replaced with a pump backwashed declining rate filter. It is well established that effluent from a declining rate filter is of better quality than effluent from a constant rate filter. Richter was well aware of this fact from his previous experience with filtration when SANEPAR made this design decision. The slightly more complex operation of a manually backwashed declining rate filterwas not a problem for the well-trained operators in Parana.

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1. Bhole, A.G. and V.A. Mhaisalkar, "Study of a Low Cost Sand-Bed-Flocculator for Rural Areas", *Indian Journal Environmental Health*, 19, 1, 1977, pp.33-53.

An economic study was made comparing the costs of the siphon backwash filter with the costs of the pump backwashed filter and there was little economic advantage of the former compared to the latter. The former requires extra head at the beginning of the plant which requires a constant consumption of energy and possibly larger pump. The latter requires, of course, an additional pump and more operator attention.

4. OPERATIONAL RESULTS FROM WATER TREATMENT PLANTS

4.1 Village Locations and Characteristics

As noted above, water supply at the small community level was a priority with SANEPAR when this project was initiated. These communities had no treated water supply. Water was obtained from individual surface wells or surface waters. Observation of existing wells in villages without piped water supply generally showed them to be bucket wells that were elevated, covered and of good construction. The covers were often in place. There was not one handpump seen. These or wind driven pumps are not used in Parana. A few outhouses of mediocre construction were also observed in these communities.

Piped water with individual house connections was to be supplied. No sociocultural surveys of the water/sanitation needs and desires of the local inhabitants were taken. The question of providing yard taps or even standpipes to reduce water consumption, costs and wastewater production was not even considered. Sewers were not planned for in the immediate future.

There was demand for piped water and people are generally able to afford it. SANEPAR obtained estimates that 20 - 30 percent of the households in rural areas with piped water supply available were not hooked up. SANEPAR provides the water meter and house connection; it is up to the household to provide in-house plumbing. Households are not hooked up because they are satisfied with their well supply or they are unable to afford SANEPAR's tariff or both. SANEPAR thought the former reason was the most common reason for lack of a hookup. SANEPAR does not have difficulties collecting bills in rural or urban areas. Information on water and wastewater tariffs for SANEPAR is contained in the booklet "Politica Tarifaria". The current tariffs for water and sewerage are given in Table 1. Note that there is a minimum charge for each category regardless of the quantity of water consumed. The current official exchange rate is 13.7 Cruzeiros to the U.S. dollar.

The primary selection criterion for locating the pebble bed containing water treatment plants was the quality of the raw water, i.e., if turbidities were too high for a slow sand filter (≥ 50 turbidity units (TU)) for a significant time during the year). Political considerations also played some role in ordering the implementation of treatment works.

Twenty-eight plants listed in Table 2 have been constructed since 1982-83. There are 10 plants listed in Table 3 currently under construction. The locations of existing and future plants are given on Fig. 3. The communities usually have populations in the range of 1,000 to 5,000. Richter had provided advice on two additional plants constructed in the northern state of Ceara and 3 or 4 plants constructed in the southern state of Santa Catarina.

4.2 Previous Water Treatment Plant Designs for Small Communities

Previous designs for small communities included a variety of configurations usually incorporating flocculation, sedimentation, filtration and disinfection; some of these were so complicated as to require more than one operator as opposed to less than one operator required to operate the design proposed as the result of these studies. The early designs were followed by a standard baffled hydraulic flocculator, plain sedimentation, constant rate rapid filter and disinfection system.

There was a design, developed by Richter, that was standard immediately preceding the pebble bed unit. The significant features of this design were a contiguous configuration of a centrally located mechanical flocculator surrounded by four lamella sedimentation basins and four declining rate filters. The unit is constructed of concrete and the common walls significantly reduce the amount of concrete and construction materials required. The costs of this unit were about 60 percent of the costs of the conventional unit.

The flocculator is a tapered flocculation unit with a variable speed mixing motor and paddles that may be located at different heights. Detention time in the flocculator is 20 minutes. The filters are declining rate and the output from three filters is used to backwash one. The backwash is controlled by manually operated valves operated by one handle.

The capacity of this unit is 10-12 L/s or higher. This is the minimum flowrate required to allow one filter to be backwashed by other filters. A minimum of four filters is needed to allow one filter to be backwashed by the others. All plants are designed for a flow of 150 L/cap/day and an average of 5 persons per hookup. Actual consumption in the rural areas is in the range of 80 L/cap/day. There is only about a 10 percent variation in consumption throughout the year. Consequently these plants are operated for only a fraction of a day (usually from 5 to 12 hours a day) in smaller communities. This unit is referred to as the concrete unit later on.

All components for this plant are manufactured in Brazil. The design is excellent; however, when Richter presented this design at a conference for South Americans it was rejected. The reason for rejection was the lack of availability of the flocculator motor in other South American countries. Labelled slides of this unit and other units and sites visited during this consultancy have been submitted with this report.

4.3 The Treatment Plant Design

4.3.1 The Siphon Backwash Filter

It was previously mentioned that the construction and maintenance problems with the seal in the priming siphon of the siphon backwashed filter eliminated this feature from these plants. The Aracuaria plant which had one is now not functioning because this community has been hooked into the Curitiba system. The Borrazopolis plant which was also one of the original prototype plants for study also has a siphon backwash filter.

It was agreed by Richter that the siphon backwash filter is operationally superior to other filters particularly in the rural areas. The possibility of having the priming siphon seal, which is a small component, prefabricated in, Curitiba for example, by a reputable firm with careful quality control was explored by the consultant. Richter noted that the filter still had to be covered and sealed on site (figures are in the report submitted to IDRC and the design drawing for the Aracuaria plant is submitted as a supplemental document). This also prevents viewing the filter which is a disadvantage. It was countered that the filter box could be left open and extended in height to achieve the same backwashing cycle period. This would require more backwash water than Richter's design and only a small cost penalty. This option was not considered by Richter.

4.3.2 The Flocculator and the Treatment Plants

The pilot studies from the IDRC supported research produced one of the curves in Fig. 4 for turbidity removal versus the Camp number, GT (G is the velocity gradient and T is the detention time), for flocculation of raw water. GT values in the range of 14,000 to 16,000 produce the best flocculated water. An unusual result of this work is the high G values (50–80 s^{-1}) that produce a well flocculated effluent that readily settles. Media sized in the range of 1/2–3/4" nominal diameter (standard U.S. sieve series are used for media classification, therefore media sizes are in English units) is optimum.

Between the time when the pilot and prototype studies were performed, Richter was moved from the design division to the development division. The field designs were made by other personnel with some consultation from Richter but the design engineers were reluctant to design flocculators with this high of a G value. G values near 30 s^{-1} and GT values of 9,000 corresponding to a detention time of 5 min. were designed. The settled effluent quality curves for three plants are indicated on Fig. 4. It is observed that settled effluent quality is not as good as possible with proper GT values; however, quality is quite acceptable which demonstrates the flexibility of the pebble bed flocculator under varying operating conditions. The sand filter is able to handle settled water of this turbidity but will have to be backwashed more often.

The total treatment system is referred to as the metal compact unit. The total package including flocculator, lamella sedimentation and declining rate filter is designed into one module with a capacity of about 5 L/s. When requirements exceed this another module is brought in. When the water requirements are less than this the plant is operated at its constant design rate for a portion of the day.

The installation costs of the concrete and metal compact units are given in Table 4. "OTN" refers to a government "paper money" cost figure for the items in this and the following table. Roughly the costs of the metal compact design are 40-50 percent of the costs of a conventional treatment plant. Operating costs are approximately the same for the conventional, concrete and metal compact plants. Table 5 provides information on construction costs of other components of water and wastewater systems.

4.4 Operation of Metal Compact Treatment Plants

In fact, 4 of the metal compact plants that have been installed have had the media removed and are operated as a sludge blanket flocculator which is a more sophisticated process. This is not a problem for operators in Parana because they have all taken a 120 hour course and are familiar with a variety of modifications to the unit operations.

The flocculator and lamella sedimentation basin are stacked; thus all the sludge removed must seep through the pebble bed flocculator. It is recommended that the flocculator-sedimentation unit be drained once a day for sludge removal and best performance but Richter doubts if this operation is normally performed at this frequency. Performance still remains satisfactory and there are not many difficulties reported with respect to clogging of the flocculator. Richter recommends that the flocculator and sedimentation basin be placed in a horizontal configuration to eliminate sludge generated in the sedimentation basin from having to pass through the flocculator which exacerbates the clogging potential.

There is one important exception to the above. Operating experience has shown that the pebble bed flocculator cannot tolerate water that contains silt or sand. Clogging will definitely be a problem and the media must be removed to clean the flocculator. Plants that experience this problem are all located in the western part of the state which was too great of a distance to make a site visit feasible.

Typical physical/chemical operating data from various plants are included with this report. Bacteriological data are given on the computer printouts submitted with this report. Data on total coliform count and total chlorine residual for samples from residential areas taken by SUREHMA and SANEPAR, respectively are given. It is seen that SUREHMA's total chlorine residuals and total coliform counts are lower and higher, respectively than those measured by SANEPAR. This was explained by poor sampling techniques and procedures by SUREHMA's unqualified personnel. SANEPAR is now training SUREHMA personnel. There was no opportunity to verify or discuss these discrepancies with SUREHMA personnel.

The laboratories of all the treatment plants that were visited (see the trip report) were clean and in good working order. Analyses were in progress and the daily log sheets were filled in. It appeared that our visits were not known in advance to the treatment plant operator and this was confirmed by Richter on the day after our visits.

4.5 Sociocultural and Health Aspects of the Improved Water Supplies

There have been no formal sociocultural surveys or studies related to the installation or impact of the water treatment plants on the local communities. Given the demand for clean piped water and the lack of complaints, SANEPAR feels that the benefits are obvious. Certainly there was property value appreciation with the installation of the treatment works. Also there was one job created in each community for the plant operator.

Likewise there have been no morbidity and mortality studies in these communities either before or after the installation of these plants. SANEPAR does not engage in these studies and was unaware of any group that would have made them. Turbidity and chlorine residuals of the finished water indicate water with a low risk of harboring pathogens. Diarrhea was thought to be the most common waterborne disease. This disease is also commonly transmitted through poor hygienic practices.

5. OTHER RESEARCH ON WATER TREATMENT

Richter does not feel that the pebble bed flocculator is a primary choice for the rural areas although operating experience with it has been good except when silt is present in the raw water. This is a problem readily checked for. A primary reason for lack of enthusiasm over the pebble bed flocculator is the development of a screen flocculator which consists of a series of screens which can have variable mesh sizes. The screens can be constructed very inexpensively out of a durable fiber such as nylon; central manufacture and transport of them is therefore not a problem. Most of the experimental work on the screen flocculator is completed and some plants have been constructed with them installed.

Research on the pebble bed flocculator continues to be carried out at the Universidade Federal de Santa Catarina by Mauricio Seno. Where electricity is a problem, the pebble bed flocculator would be a viable option.

CETESB, the state water company of Sao Paulo, had also conducted studies on the performance of pebble bed flocculators during the past two years. Richter had provided some advice during the design of their experiments. Fig. 5 is a plot of some of their results. Extremely high velocity gradients, significantly higher than Richter's optimum range, had been used in most of the studies and poor treatment resulted. Data obtained in the regions found by Richter to be optimal generally proved to provide the best treatment.

CETESB is also conducting research on fluoride removal. Fluorides occur in some waters in the state of Sao Paulo at levels up to 30 mg/L. Mr. Jorge Rafael Alchera, the engineer who conducted the pebble bed flocculation studies is associated with the fluoride research. A more resilient form of activated alumina has been developed. Mr. Alchera was requested to inform IDRC of his work.

Richter feels that the slow sand filter is the most reasonable option for small communities, particularly those with a population less than 1,000. When turbidities are high he suggests using a horizontal roughing filter. SANEPAR will be initiating research on roughing filters. It is difficult to argue this point given the multi-removal capabilities of a slow sand filter and the consultant has advocated the slow sand filter as a first consideration in his own courses.

6. PRO-RURAL

Pro-Rural is a specialty group within SANEPAR that is exclusively concerned with the water and wastewater needs of communities with populations less than 1,000. The average community size serviced is 500. Engineer Antonio Carlos Nery described the operation of the group. The program is only one year old and was started from donation from the Inter-American Development Bank (BID). This money soon was exhausted and the state took over funding this program.

The work of Pro-Rural begins with a survey by ACARPA, an agronomical institute (not associated with SANEPAR) that has made sociological surveys of villages to find if there is a demand for water supply. ACARPA has qualified social workers and technical persons in the field. If water is a priority, the village report which is the basic document is turned over to Pro-Rural. However, ACARPA remains involved in all phases of a village project.

Pro-Rural then performs a technical assessment of the water treatment/supply options for the village. If the community is near a large community with water treatment then hookup to this system may be recommended. Otherwise either a gravity supply must be possible or electrical energy must be available. If none of these three conditions are met, decisions for the community are deferred to a later time when projects for all communities who fulfill one of these requirements have been completed. The only water treatment considered at this time is disinfection except in the case of hookup to a larger system.

When one of the above conditions is met, Pro-Rural conducts a prefeasibility study. Designs are based on the availability of low cost materials in the vicinity of the community. The financial resources of the community are considered in the design. Research is being conducted on low cost materials for distribution lines. The prefeasibility study is presented to a community meeting. Energy, chemical and other costs are explained at this meeting. Seventy percent of the community members to be benefited must sign a statement agreeing to the community costs, their participation in construction and willingness to take over responsibility for the system once it is installed. SANEPAR also requests a community association be formed to administrate the water works system.

The agreement made above is between the state, SANEPAR and the community. The community must supply land, bricks, cement and labor. SANEPAR supplies technical expertise and capital equipment. Each household must supply labor during the construction phase of the distribution system or pay to have their portion of the work done. No water meters are supplied in the systems.

Research has been performed in 180 communities; 60 were eliminated because they did not satisfy all the program requirements. The 70 percent community written agreement is the largest cause of elimination. Nine teams composed of one engineer, one technician and one survey instrument performed the initial technical survey for the 180 communities in 45 days. There are 4 engineers, 4 designers and 4 accountants working on the remaining 120 communities.

Although the distances between houses in these villages are normally much greater than distances between houses in larger communities the costs of systems for these small communities have been only 50 percent of costs of a normal SANEPAR system. There are 40 designs completed at this time and ten works in construction. It normally takes about 3 months to build a system.

There is no complementary work done on wastewater disposal. The state Health Secretariat has a program for septic tank/leaching pit systems for wastewater disposal. SANEPAR is in the process of developing a booklet on sanitation and integrated water and wastewater systems for small villages. A series of manuals developed by Pro-Rural have been submitted with this report.

7. SUMMARY AND CONCLUSIONS

For a minimum investment, IDRC obtained a high return from this project. This is not unusual considering the competency of the staff at SANEPAR, particularly the principal investigator, Dr. C. Richter, who is one of the foremost water treatment engineers in South America. SANEPAR functions in a state that is relatively well developed and quality water delivered at each household is demanded. The water treatment plants designed as a result of this study took into account constraints of rural areas in Brazil or many places in the world to deliver a good quality water. The more than 40 plants to be ultimately installed will provide treated piped water to communities that previously relied on primarily surface bucket wells and untreated surface water supplies.

The pebble bed flocculator has proven to be an innovative water treatment operation for rural areas. Within the situations where it is appropriate to design (no silt in the raw water), it has performed well even at lower GT values than the optimum which demonstrates its ability to perform over a range of conditions. Clogging problems have not been a major difficulty. However, only a limited recommendation can be made regarding the pebble bed flocculator; a primary reason for this reservation is further work by Dr. Richter on the screen flocculator as an improved low retention time flocculator. Data on the latter unit was not examined nor were observations of it made but the consultant has confidence in the work of Dr. Richter to accept his statements that it was a better option. On an a priori basis it appears to be logical.

Dr. Richter has agreed to write up a detailed summary of the operating experience with the pebble bed flocculator which can be disseminated to other developing countries. There should be no need of further IDRC work in assistance with this report. The pebble bed flocculator will remain a viable option in some circumstances.

Construction problems with the siphon backwash filter eliminated this promising feature from the plants being constructed. The better quality of the declining rate filter must be weighed against the superior operational performance of an automatically backwashed filter. The latter factor will be the overriding consideration in many developing countries. A prefabricated quality inspected priming siphon and an open extended box filter, in the opinion of the consultant, should be further examined and field tested.

An ancillary benefit of the IDRC project was the experience gained on the MF bacteriological analysis and its subsequent implementation as a standard procedure in quality control laboratories.

The work of Pro-Rural appears to wholly meet IDRC objectives in rural low-income communities. It would be worthwhile to have an assessment of this project in one or two years for possible propagation as a model to other developing countries.

The fluoride removal work at CETESB should be examined by IDRC for possible application in high fluoride areas in other parts of the world.

Fig. 1. Dr. Carlos A. Richter

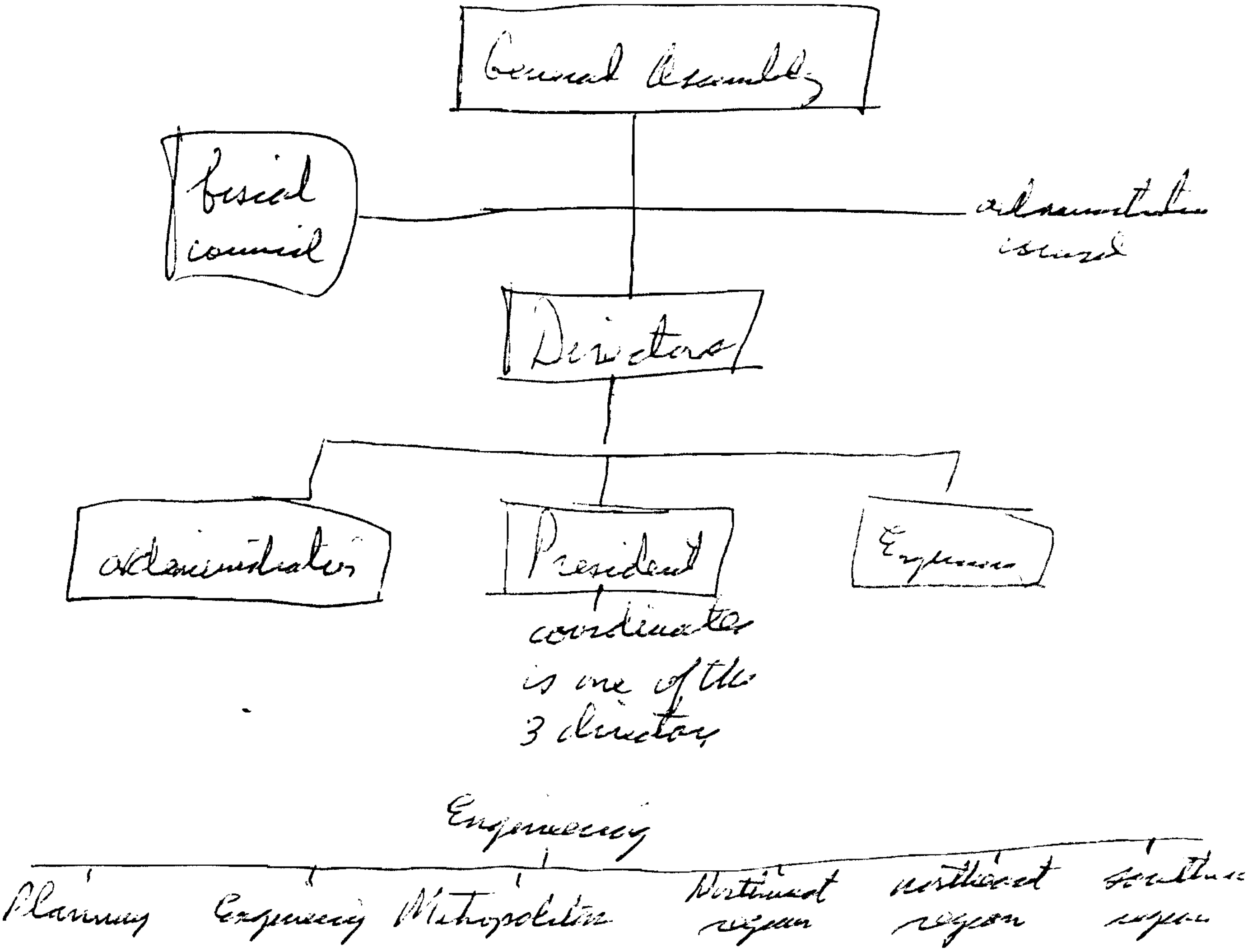
General Assembly
fiscal council
Directors
administrator
President
coordinator is one of the 3 directors
Engineering
Planning
Engineering
Metropolitan
northeast region
southern region

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TABLE 1 WATER AND WASTEWATER TARIFFS

VALORES TARIFÁRIOS CONVERTIDOS EM CRUZADOS E VIGENTES A PARTIR DE 01 DE MARÇO DE 1986

CATEGORIA/FAIXA DE CONSUMO	NOVAS TARIFAS (CZ$)
RESIDENCIAL	
Até 10 m^3	13,70
11 a 15 m^3	13,70 + 1,99/m^3 excedente a 10 m^3
16 a 25 m^3	23,65 + 2,56/m^3 excedente a 15 m^3
26 a 50 m^3	49,25 + 3,55/m^3 excedente a 25 m^3
Acima de 50 m^3	138,00 + 4,95/m^3 excedente a 50 m^3
COMERCIAL	
Até 15 m^3	35,04
Acima de 15 m^3	35,04 + 3,17/m^3 excedente a 15 m^3
PÚBLICA	
Até 15 m^3	34,80
Acima de 15 m^3	34,80 + 3,17/m^3 excedente a 15 m^3
TARIFA DE ESGOTO: 90% DA TARIFA DE ÁGUA	

TABLE 2 PLANTS CONSTRUCTED SINCE 1982

WATER TREATMENT PLANTS WITH PEBBLE BED FLOCCULATORS IN OPERATION:

		capacity
1.	Boa Vista da Aparecida	20 ℓ/s
2.	Chopinzinho	20
3.	Carambeí	10
4.	Imbituva	20
5.	Mangueirinha	15
6.	Nova Prata	28
7.	Foz do Chopim	10
8.	Renascença	10
9.	Ramilândia	10
10.	Reserva	10
11.	Três Barras do Paraná	20
12.	Verê	10
13.	Tapejara do Oeste	10
14.	Ortigueira	15
15.	Panema	10
16.	Alto Piquiri	25
17.	São Marcos	8
18.	São Dimas	30
19.	Cândido de Abreu	20
20.	Araucária	
21.	Lunardelli	10
22.	Nova Prata do Iguaçu	20
23.	Pérola do Oeste	12
24.	Rio Azul	20
25.	Vera Cruz do Oeste	10
26.	Salto Samuel - Rondônia	15
27.	Borrazópolis (SYPHON)	20
28.	Paraipaba - Ceará	12

TABLE – PLANTS UNDER CONSTRUCTION

WATER TREATMENT PLANTS WITH PEBBLE BED
FLOCCULATORS IN CONSTRUCTION:

		capacity
1.	Curiúva	15 ℓ/s
2.	São João do Ivaí	30
3.	São José da Boa Vista	15
4.	Tibagi	30
5.	Borrazópolis	10
6.	Capitão Leônidas Marques	30
7.	Mandirituba	10
8.	Jardim Guaraituba	30
9.	Balsa Nova	10
10.	General Carneiro	12

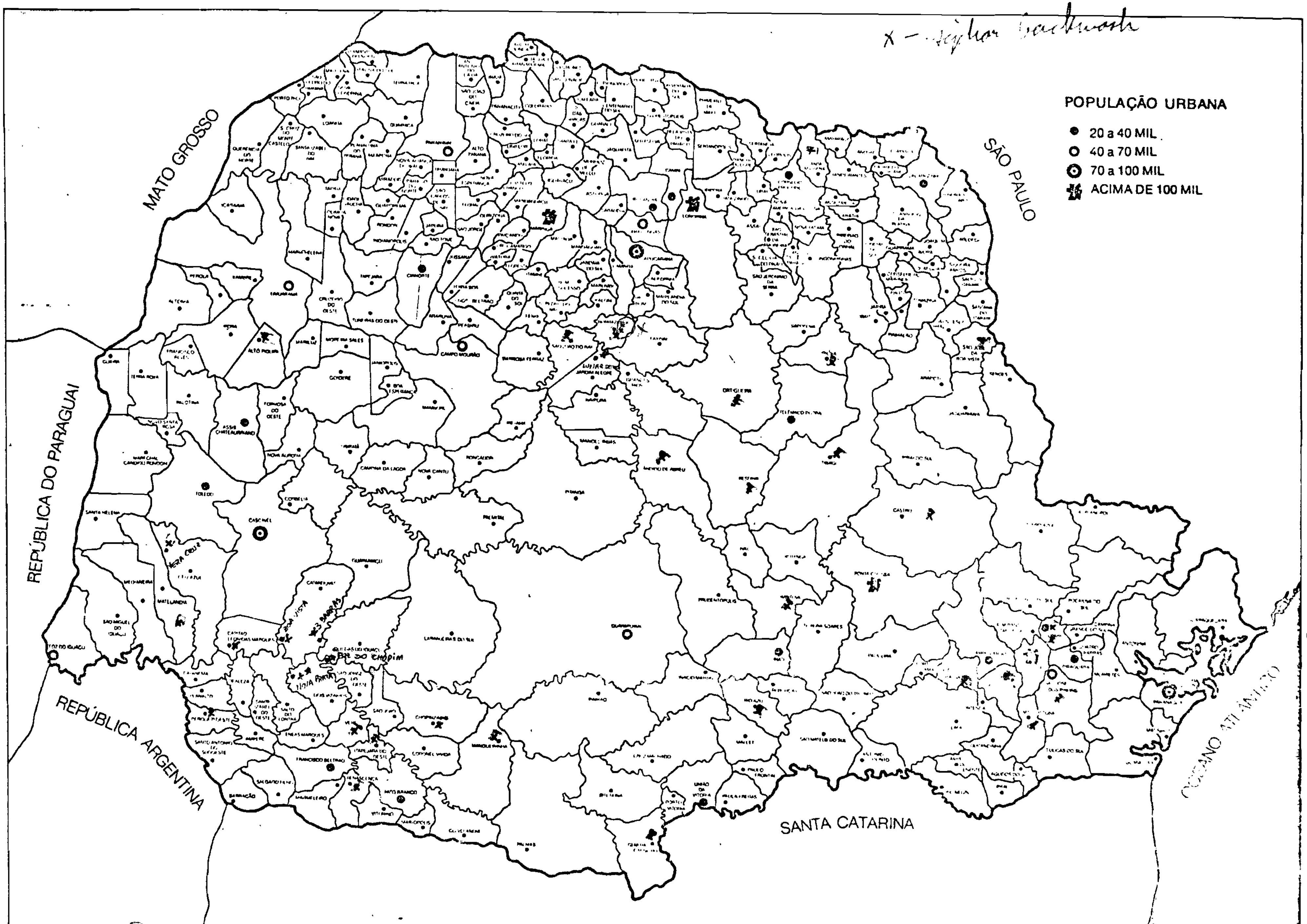

FIG. 3 LOCATIONS OF WATER

$X = 0{,}72 + 0{,}87 \cdot \ln Y$

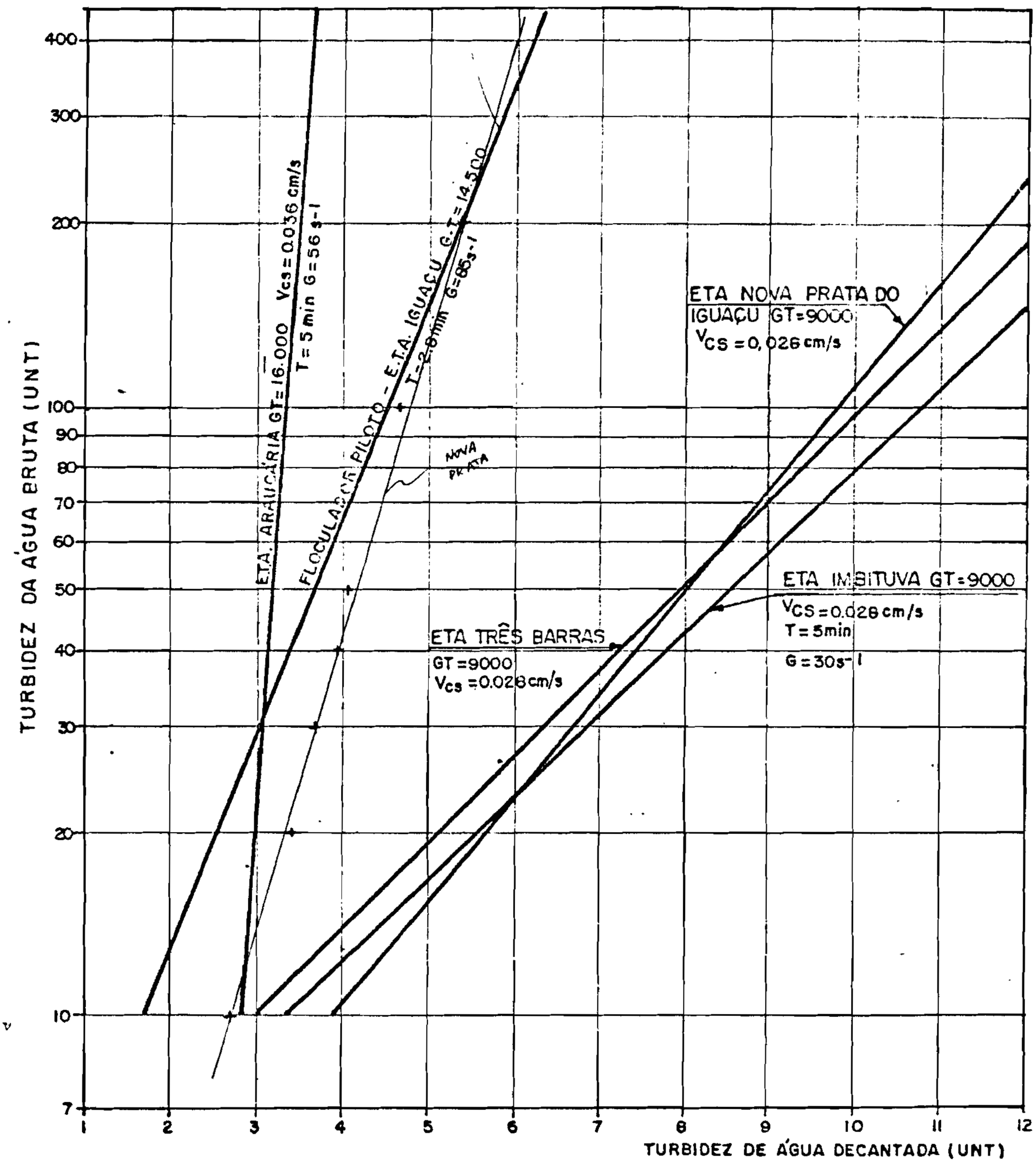

FIG.1-FLOCULADORES DE PEDRAS
INFLUÊNCIA DO NÚMERO DE CAMP. GT.
NA FLOCULAÇÃO

FIG. 4 Turbidity removal for pilot studies and field GT designs

TABLE 4. COSTS OF TREATMENT PLANTS

CUSTO MÉDIO DE RESERVATÓRIOS

(cisternas)

- POLIESTER/METALICO (CUBA - UNIDADE)

CAPACIDADE (M^3)	Cz$	OTN
25	60.435,00	568
50	102.144,00	960
75	122.360,00	1.150
100	164.920,00	1.550

- CONCRETO (UNIDADES)

25	52.785,00	496
50	79.907,00	751
75	118.636,00	1.115
100	161.196,00	1.515

CUSTO MÉDIO DE ETAs — Water Treatment Plants

1 US$ = 13,70 Cz
20.00

- METÁLICA/COMPACTA (UNIDADES)

CAPACIDADE (L/S)	× Cz$	OTN
3,0	113 840,00	1.075
6,0	191.520,00	1.800
10,0	356.440,00	3.350
15,0	500.000,00	4.700
20	480.000,00	4.530
30	675.000,00	6.360

- CONCRETO TIPO CEPIS

12,0	587.647,00	5.523
20,0	677.768,00	6.370

TABLE 5. CONSTRUCTION COSTS OF WATER SYSTEM COMPONENTS

CUSTO MÉDIO POR ITEM OU UNIDADE CONSTRUTIVA

U N I D A D E	CZ$	OTN
≈ 180 m deep — wells - PERFURAÇÃO DO POÇO	212.800,00	2.000
well pumps - CAPTAÇÃO EM POÇO	138.320,00	1.300
river intake - CAPTAÇÃO EM RIO	101.824,00	957
pumping station - ELEV.DE ÁGUA TRATADA	143.001,00	1.344
- ADUTORA OU REDE EM PVC (adduction or distr. pipes / distribution)	Cz$ / M	OTN/M
DN 150	310,00	2,91
DN 100	172,00	1,62
DN 75	128,00	1,20
DN 50	94,00	0,88
DN 32	72,00	0,68
taps - LIGAÇÕES PREDIAIS house connection	Cz$	OTN
CUSTO MÉDIO POR UNIDADES charged to customer	519,00	4,883

APPENDIX A

TERMS OF REFERENCE