...BOROUGH UNIVERSITY OF TECHNOLOGY
...artment of Civil Engineering

WEDC

Water and waste Engineering
for Developing Countries

4th WEDC Conference

engineering for health in hot countries

25th - 27th September 1977

PROCEEDINGS edited by JOHN PICKFORD

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MARK LANSDELL

sewerage sulphides and corrosion in venezuela

INTRODUCTION

The Republic of Venezuela, one of the few democratic countries of South America, is bounded by the Caribbean to the North, and by Guyana, Brazil and Colombia. It is located between the latitudes of 12°N and 3°N. The climate is tropical with temperatures ranging between 25° and 35°C although in the Andes temperature is dependant upon height (15° to 25° in the capital Caracas which is 1000 m above sea level). Humidities range from 80% to 90% with a slight variation according to the season.

Venezuela is also one of the few democratic oil-rich nations: both President and Government are elected by obligatory universal suffrage.

POPULATION

With the greatly increased income from oil revenues in the last twenty years the migration from the rural areas to urban centres has accelerated as the agricultural workers and illegal immigrants from neighboring countries seek their fortune and a more comfortable life in the cities, with the result that the urban population is now 80% of the total.

Table 1 compares the growth rates of some of the larger cities. From the table it is evident that most of the cities have increased their population more than six-fold in thirty years. As can be imagined this rapid growth has placed a tremendous burden on all urban services.

Public sector housing could by no means keep pace with the demand for low-cost housing accommodation with the result that large numbers of 'Ranchos' or shanties have sprung up around the larger cities. The ranchos bring with them a multitude of evils such as those caused by the complete lack of basic sanitary facilities, high infantile mortality, crime, access problems, etc, but the most serious and far reaching problem of all is the social disorder brought about by such developments. Illegitimacy rates and the incidence of venereal diseases are extremely high in these districts and the literacy rates of some of the larger cities have actually fallen in recent years. It is estimated that half a million people live under these conditions in the capital. Despite the poor living conditions, however, most of the ranchos have electric light and television, motor cars and water at nearby standpipes. Some enterprising ranchos even have direct piped water supplies.

TABLE 1: Population and growth rate of six major cities
(Population in thousands. Growth rate - geometric per annum)

CITY	POP. 1941	% P.A.	POP. 1950	% P.A.	POP. 1961	% P.A.	POP. 1971
CARACAS	354	7.8	693	6.1	1336	5.0	2183
MARACAIBO	122	7.6	236	5.4	422	4.4	650
VALENCIA	55	5.5	88	5.8	164	8.3	366
BARQUISIMETO	55	7.6	105	6.0	198	5.3	334
MARACAY	33	7.8	65	7.0	135	6.5	255
MATURIN	11	9.9	25	7.3	54	8.38	121

ADMINISTRATION OF WATER SERVICES

On the death of General J V Gómez in 1936 his thirty years of relatively brutal dictatorship came to an end. With the establishment of a democratic government attention was turned to the much neglected social and health needs of the nation. In 1943 the INOS (Instituto Nacional de Obras Sanitarias), an autonomous government institute for public health engineering works, was set up with its president directly responsible to the Minister of Public Works. INOS is charged with the provision of public water supplies in urban and, as of recently, rural areas, and with the provision of urban sewerage, both foul and surface water.

The water supplied is either derived from underground sources which receive chlorination or from surface sources which receive sedimentation aided by coagulation and flocculation followed by rapid sand filtration and chlorination. Unfortunately, owing to overloading of treatment plants, rationing, the shortage of adequately trained personnel and certain shortcomings in the distribution systems, the water is not generally relied upon for drinking and so bottled water or British candle filters are the order of the day. In 1976 INOS estimated that 85% of the urban population was served by a piped water supply direct to each house. Metering is universal and the tariff includes the cost of sewerage whether provided or not.

SEWERAGE

House drainage

The construction of sewers, though started in the capital at the turn of the century, was only started in earnest relatively recently with the creation of INOS. Since 1943 construction of foul sewerage has been rapid and last year it was estimated that sewers were available for 70% of the urban population.

There is, however, a considerable difference between population for which sewers are available and the population actually connected. This is due to certain practical difficulties involved in connecting houses of the single storey Spanish Colonial type which predominate throughout Latin America. In the larger cities this type of housing is being displaced by tall buildings as land prices rise.

The typical Venezuelan town is laid out in gridiron fashion arranged about the church and 'plaza' or central square. Each block is about 100 metres square and the houses front directly onto the street with no side access, with only the main front door and two or three characteristic barred windows shown to the street. Frontages are usually between 10 to 15 metres and the 'depth' of the plot may be up to half the block or 50 metres. Living accommodation is arranged about a central 'patio' or courtyard with a colonnade and verandah on two or three sides. The average Venezuelan in the coastal areas sleeps and takes his siesta in a hammock strung in the verandah area whilst in the cooler areas of the Andes and in the modern housing, the bed is more popular.

The kitchen is normally halfway down the length of the plot and lavatory facilities are at the bottom i.e. the part most distant from the street. This arrangement presents two drainage difficulties.

a) Inconvenience: the floor of the hall, front room and part of the verandah have to be broken up to allow the new house drains to be laid.

b) Because of the distance from the street of existing sanitary facilities, there is not usually enough fall unless the ground is dead level or there is a natural fall towards the street, which means that houses on the other half of the block have no chance of draining at all.

What generally happens when sewers are provided depends on the means of the householder. If he is well off, one of the rooms nearest the street will be converted into a bathroom and the kitchen drain diverted into the new house drain. In the case of a poorer family things will remain as they are, especially if the soakaway under the pit latrine is working satisfactorily.

Traditionally the patio is provided with a drain to remove rainwater to the street. Previously, when water was supplied from rainwater tanks or from a distant standpipe, the small amount of wastewater produced soaked away or was irrigated on the kitchen garden. However with the provision of direct piped supplies, the per capita water use rises considerably with the result that wastewater has to be diverted through the patio drain to the street. This results in small streams of grey water flowing in the gutters each side of the street, creating an excellent breeding ground for mosquitoes and flies. INOS therefore gives priority to those districts where this occurs.

The solution available to many householders is simply to tap the patio drain into the lateral provided by INOS in the pavement outside the house resulting in the connection of the surface water from the patio and making the system only partially separate.

Another problem occurs when a septic tank has been constructed to serve the owner's new WC. It is often the overflow from the septic tank which is connected to the sewer on the reasoning that the house drain is less likely to choke. What is overlooked is that an extremely septic liquor is discharged to the sewerage system with consequences that will be discussed later. Much of this work is done at weekends by a practical member of the family, with the result that inspection by the hard-pressed public health inspectors of the Ministry of Health is the exception rather than the rule.

In conclusion, the poorer the district the lower is the percentage of houses connected, except in the case of government housing when it is 100%.

Sewerage practice

Sewerage practice follows very much that of the USA. The minimum public sewer size is 8" diameter usually in precast concrete pipes with yarn and mortar joints. Where the water table is high clayware pipes with flexible joints are specified for sizes up to 16" diameter, whilst concrete pipes with rubber joints are specified for larger sizes. Circular manholes 1.20 m diameter are provided every 100 m maximum. Manhole covers are circular 0.6 m clear opening and the practice for a while was to perforate the covers with six 25 mm diameter holes, but this was discontinued on the grounds that children could not resist poking sticks down the holes and that with the characteristically heavy rains, too much water and sand entered the system. Sewer ventilation therefore relies on the rather small 2" diameter vent pipes required as minimum by the Ministry of Health code from the sanitation of (new or altered) buildings.

Gradients have to be sufficient to provide a velocity of 0.6 m/sec full (or half full). Mannings formula with $n = 0.015$ is used for design of sewers up to 21" and $n = 0.013$ for pipes 24" and over.

Sewer capacities are based on estimated 30 year growth using an average flow of 300 litres per person per day water consumption and assuming 80% of that reaches the sewerage system. The design flow is the average flow multiplied by a factor of three for population less than 20 000, reducing gradually to two for populations in excess of 200 000. Infiltration is taken at 20 m^3 /day per km of sewer depending on the height of the water table. If the above gives a theoretical sewer capacity lower than 1.5 litres/sec ha then this figure is used.

Sewage disposal

Since the foundation of INOS and the provision of a regular piped water supply to the greater part of the population, the amount of sewage produced has increased considerably. Sewerage systems constructed by INOS discharge either to the nearest water course, some distance below the town served or through long outfalls in the case of coastal cities and those on the banks of the Orinoco.

Where insufficient dilution is available and if topography and land prices permit, an oxidation pond system may be built. If not, then what is called a 'temporary discharge' has to be made into the receiving course. There are over fifty inland towns with populations over 10 000 but only about ten oxidation pond systems have been built. There is much to be done, therefore, in the field of sewage treatment. However it cannot be over-emphasized that many of the problems of sewage treatment plant operation stem from the sewerage system itself.

So it is essential for the success of schemes of sewerage and sewerage disposal that sufficient attention be paid to minutest of details, especially regarding standard designs or procedures in which the same mistake could be repeated many times (the perforated covers for instance). It is also important that the person directly involved on-site, be he inspector or foreman, knows why he is doing certain things which to him may seem unnecessary and to be sure that it makes sense to him, otherwise with the best will in the world, less effort will be made. This calls for considerable ingenuity and patience on behalf of those in charge, to whom a course in public relations would not go amiss.

THE SULPHIDE PROBLEM

Introduction

The author's office during the last three years has been preparing schemes of sewerage for the Island of Margarita which lies off the north coast of Venezuela about seventy miles from Trinidad. The island was created a free port in 1968 since when the development of towns and commerce has been rapid. For instance, the largest town, Porlamar, has a population of 40 000 rising by 6% per annum. At this rate the population will double every twelve years.

The island is relatively arid with rainfall and evaporation around 400 mm and 2000 mm respectively. This has meant that water for domestic use has to be supplied to the island from the mainland through a submarine pipeline 25 km long. An international contract has just been let for a new pipeline to raise the capacity from 800 l/s to 3 m^3/s .

At present the sewage from Porlamar and adjacent areas is discharged to the sea. It is the wish of the state government that no sewage should be discharged into the sea in resort areas and that if possible it should be treated and reused for irrigation of agricultural areas, golf courses etc. The intercepting sewer system to divert flows from existing outfalls is now under construction and design of the main pumping station, rising mains and treatment plant are under way.

One of the problems foreseen at an early stage was the possibility of septic conditions in the sewers and especially in the 3 km long rising mains to the treatment plant. This would present the possibility of damage to the interceptors and possible difficulties with the treatment process due to a high sulphide content(1). This would apply particularly to the early years of the system which has to have a fair amount of spare capacity to accommodate the rapid growth-rate. The author's office therefore presented INOS with proposals for a study of sulphide generation in the existing system, especially in the rising mains, and the means for its control.

Historical background

As with many engineering problems, somebody has usually encountered them before. A survey of the literature was therefore carried out; the more interesting points are as follows.

Pinson(2) has described the corrosion of Cairo's original main outfall sewer. The sewer was 1.6 m diameter in local cement concrete laid at a gradient of 1:2500 and received the discharge from rising mains served by the many ejector stations. The government chemist describing the corrosion phenomenon in 1920 mentions the formation of calcium sulphate in the body of the concrete caused by "gaseous sulphur compounds from the sewage penetrating into the concrete and there becoming oxidised to acid bodies, which attacked the lime of the cement. Since the formation of gaseous sulphur compounds cannot be avoided in the collector, the only possibility of preventing further damage is to get rid of these compounds as fast as they are formed by artificial ventilation and at the same time to make the walls of the collector at and above the water line as impermeable as possible by means of some protective coating. Any ventilation to be efficient must be very thorough since a small amount of air only would probably accentuate the mischief by providing facilities for the oxidation of the sulphur gases to sulphur acids".

The chemist recommended trial repairs by plastering with neat portland cement and also with one part portland cement and two parts of finely ground brick powder. He also recommended the periodical removal of the silt deposit from the sewer. The plastering was tried but after a year both coatings had deteriorated. The removal of the silt, which was between 300 and 600 mm deep proved extremely difficult. A flushing water supply was laid from a nearby canal and the sewer was flushed once a fortnight throughout 1922. This resulted in considerable removal of the silt. Forced ventilation of the sewer with a 32 hp fan accompanied by gas analyses of the sewer air was also carried out and a marked reduction in the hydrogen sulphide content was noted after the start of flushing and forced ventilation. However, the corrosion of the sewer continued. By 1922 roughly 100 mm of the concrete in the crown had deteriorated, this depth of damage being maintained evenly throughout its 13 km length. By 1930 deterioration had reached 150 mm, nearly half the thickness of the crown. By this time the sewer was overloaded and a new outfall sewer was constructed lined with "blue bricks in cement 1:1 pointed with gas proof material", horseshoe in section 1.8 m x 1.9 m at a gradient of 1 in 2200. It would be most interesting to know how this sewer has fared. Although the actual mechanism of hydrogen sulphide corrosion was not fully understood, the chemist's report of nearly sixty years ago exhibits a remarkable understanding of the problem and the practical means for its solution.

Between 1930 and 1960 studies of the sulphide corrosion problem were undertaken in the USA, South Africa and Australia simultaneously[3,4,5]. It was Parker[3] who identified the bacteria desulphovibrio desulphuricans living in the submerged slime layer of sewerage systems as being responsible for the reduction of sulphates to sulphides, and the bacteria Thiobacillus Concretivorous as the organism responsible for the oxidation of hydrogen sulphide to sulfuric acid on the wall of the sewer above the water line, with its remarkable capacity to survive conditions of pH1. The reader is referred to the very excellent work of Thistlethwayte[5] for a more thorough treatment of the subject.

The mechanism of sulphide production

The sulphide ion is produced bacteriologically under anaerobic conditions:

$$\text{Organic matter} + SO_4^{=} + \text{anaerobic bacteria} \longrightarrow S^{=} + H_2O + CO_2 \qquad (1)$$

Depending on the pH value of the sewage the sulphide ion may combine with free hydrogen ions to give hydrogen sulphide according to:

$$2\,H^+ + S^{=} \rightleftharpoons H2\ S \qquad (2)$$

Principal factors affecting these reactions are:

a) Total sulphur concentration

Sulphur exists as sulphates and organic sulphur. Human beings excrete approximately 2.6 g of sulphate as SO_4 per day.

b) Sewage strength

The oxygen demand has a direct influence on the production of H_2S. As the strength of the sewage increases, the rate of oxygen utilization increases and so the time taken for the system to reach anaerobic conditions decreases. The strength also indicates the amount of food available for biological reactions.

c) Sewage temperature

Biological reaction rates are said to double for every 10°C temperature rise.

d) Sewage velocity

High sewage velocities prevent deposition, and sufficient boundary shear stresses cut the sulphide producing slimes from the submerged surfaces. High sewage velocities also increase the rate of transfer of oxygen into solution thus limiting anaerobic bacterial action. High velocity, however, also increase emission of any H_2S from solution.

e) Dissolved oxygen concentration

A high dissolved oxygen concentration precludes the presence of hydrogen sulphide both by inhibiting anaerobic bacteria and also reoxidising any sulphide entering the sewage from the wall slimes.

f) Sewage retention time

Long retention times in sections of the system where septic (i.e. anaerobic) conditions occur lead to high sulphide concentrations. Thus rising mains are the most vigorous procedures of sulphides.

Corrosion of sewers

Whilst hydrogen sulphide remains in solution it is inoffensive. However, the following factors encourage its emission from sewage:

- high concentrations of dissolved H_2S;
- high velocity or sudden turbulence e.g. at drops or junctions;
- high relative velocity between sewage and sewer air;
- absence of surface films, oil, grease, etc.

Once in the atmosphere of the sewer H_2S may dissolve in the moisture of the walls where the sulphuric acid producers may begin their activities. The following are the main factors conducive to the formation of sulphuric acid on the sewer walls:

- high concentration of H_2S in the sewer air;
- high wall moisture pH;
- high relative humidity of sewer air;
- high rate of transfer of H_2S to wall moisture caused by rapid air movements, surface roughness etc.

The chain of processes which lead eventually to sulphuric acid production on the walls of sewers may be summarised as follows:

LOW VELOCITIES, LONG RETENTION IN RISING MAINS
leading to:
SEPTIC (ANAEROBIC) CONDITIONS
leading to:
PRODUCTION OF SULPHIDES IN SUBMERGED WALL SLIMES AND SILT
leading to:
RELEASE OF HYDROGEN SULPHIDE INTO SOLUTION (under low pH conditions)
leading to:
EMISSION OF H_2S INTO SEWER ATMOSPHERE (under conditions of high turbulence)

leading to:
ABSORPTION OF H_2S INTO WALL MOISTURE
leading to:
CONVERSION OF H_2S TO SULPHURIC ACID

SULPHIDE INVESTIGATIONS IN VENEZUELA

Sulphide production

Most of the corrosion cases cited in the literature have been due either to rising mains or siphons or to gravity sewers which run full during the greater part of the day. Investigation was therefore directed at existing rising mains known to be producing significant amounts of sulphides.

There are five existing rising mains in the Porlamar area, three of which have retention times in excess of one hour. One was not available for investigation for administrative reasons. The other two had been the subject of complaints because of smells in the vicinity of manholes on the sewers into which they discharge. One serves a government housing estate of 10 000 people and lifts the sewage sufficiently in order for it to gravitate to the Porlamar system 7 km distant. Its details are as follows:

Pumps: 2 FLYGT CP3151 IMP.480

Rising main: 10 inch diameter asbestos cement 2210 m long.

Static head 14.0 m

Sampling and gauging were carried out over several weeks and sulphide productions of the order of 6.0 mg/l were encountered, sulphide production being the difference between the sulphide contents entering and that leaving the rising main. Peak sulphide production was found to coincide with the peak BOD which was around 400 mg/l at 8 a.m. when retention time was one and a quarter hours. Sulphide production between the hours of 2 a.m. and 6 a.m. was practically zero whilst the BOD remained around 40 mg/l.

An interesting item of information arising from the gauging was that the sewage flow averaged 202 litres per head per day and the daily BOD contribution averaged 46 g/person. Sewage temperature averaged 30°C during the day whilst 29°C was registered at 6 a.m. Investigation revealled that the high sulphide values in the sewage entering the sump was due to the protecting screen having become blocked and the sewage backing up 300 m or so in the inlet sewer. The screen was blocked by an inordinate amount of rubbish and also because it was almost impossible to clean due to poor design.

The other pumping station serving approximately 1000 people in an old town called Pampatar has the following details:

Pumps: 2 FLYGT3126 IMP 460

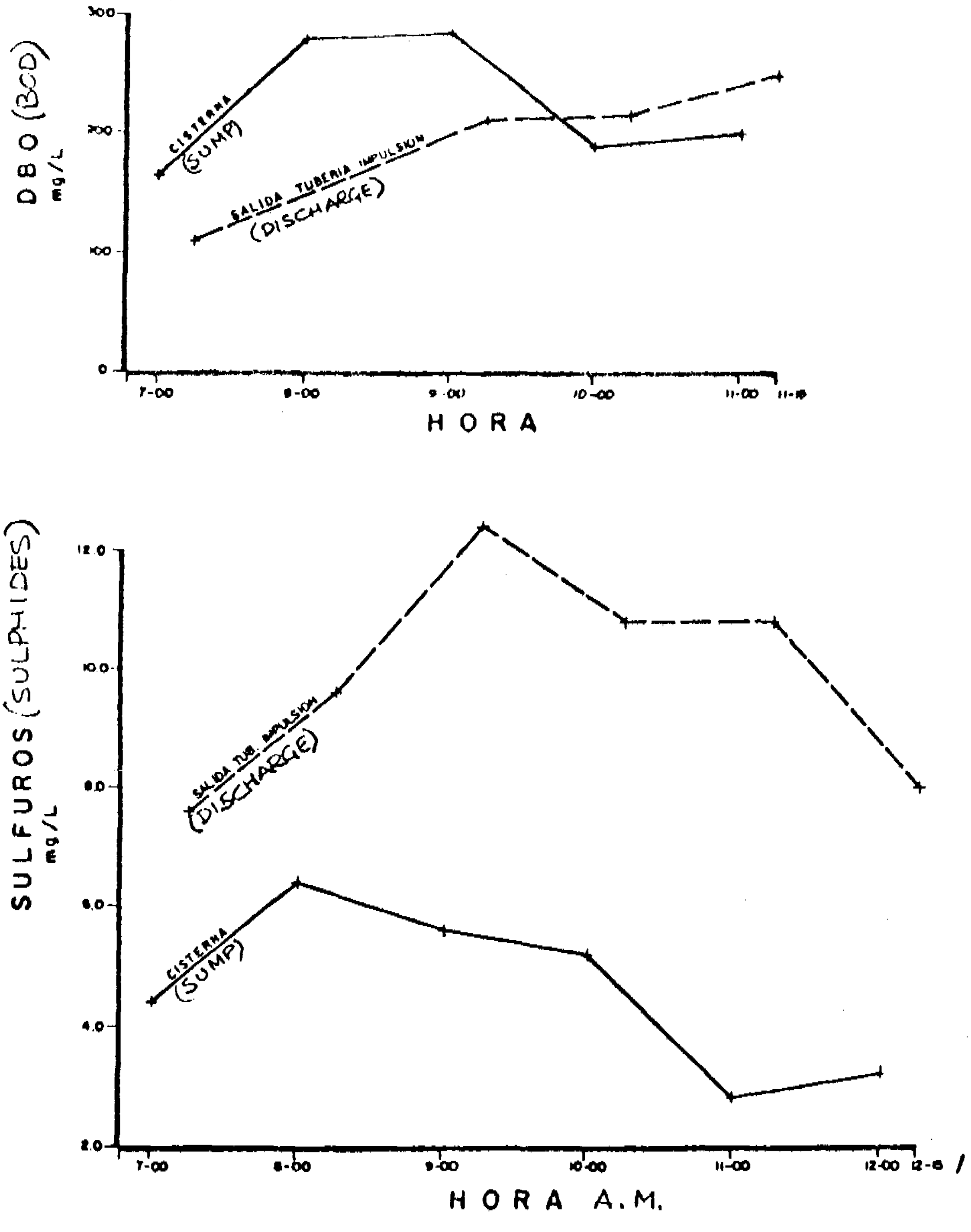
Rising main: 6 inch diameter asbestos cement 875 m long

Static head 8.10 m

Sampling revealled high concentrations of sulphide in the sewage entering the pump well with a maximum of around 6 mg/l$S^=$ at 8 a.m. This was increased to 12 mg/l by production in the rising main which also had a retention time of about one and a quarter hours at morning flow rates.

Pampatar is an example of an old town with a newly installed sewerage system. The high sulphide content in the sewage entering the well is due to the overflows from septic tanks which have been connected. Figure 1 shows the typical pattern of strength and sulphide concentrations.

FIGURE 1:



MUESTREO CONTINUO ESTACION DE BOMBEO 'PAMPATAR'
DIC. 10/76 (SIN AEREACION)

Corrosion investigations

In the case of the first system studied (Villa Rosa) severe damage had occurred in the first 300 m of 18" sewer downstream of the rising main in only fifteen months of service. Approximately 20 mm of the crown of the sewer had spalled away whilst walls of the manholes had been affected up to 50 mm in depth. These conditions persist up to a manhole 300 m from the rising main discharge at which point a drop of 1.5 m occurs. This manhole is the most severely affected due to increased liberation of H_2S at this point. Investigation further downstream revealed only slight blistering. The sewer is laid at 1 in 500.

Sampling of the sewer revealed the following (using floats):

TIME AT	DISTANCE m	VELOCITY m/s	TOTAL SULPHIDES mg/l	BOD mg/l
9.42	0 + 290 (upstream of drop)	0.54	8.0	290
10.2	0 + 940		6.2	247
10.35	01 + 940		5.6	240
10.57	2 + 840		4.8	240
11.22	3 + 940 (slight obstruction in M.H.)		4.8	302

The reduction of sulphides caused by emission at the drop is evident as is the progressive reduction of sulphides afterwards until the flow is held up by a slight obstruction causing slight septicity.

In the case of the Pampatar system the rising main discharges over the benching in the receiving manhole which has suffered considerably. The sewers, however, are of clayware and do not appear to have been affected. The benching concrete in manholes downstream has turned to a paste up to a depth of about 7 cm in eighteen months of service. The tapers do not seem affected, however. The residents in the streets along which the receiving sewer passes have sealed nearly all the manhole covers with putty to avoid the escape of H_2S from the system.

Sewers known to have flat gradients but not receiving rising mains were also sampled, including 2 km of 16 inch sewer laid at 1 in 670 but none have values higher than 1 mg/l sulphides at peak hour. A rising main with only 10 minutes retention time based on dwf showed a sulphide increase of 1 mg/l in the sewage which first issued when a pump started.

Control of sulphide production

It was evident that rising mains were responsible for significant production of sulphides and that if this could somehow be controlled then conditions in the downstream sewers would improve considerably. The literature cites many methods of control for existing rising mains, such as

- dilution
- aeration and oxygenation
- chlorination
- addition of: lime
  nitrates
  zinc and iron salts
  hydrogen peroxide

Any proposal involving the dosing of reagents of any description is fine in theory. Unfortunately there is a lot more to dosing equipment than appears in those glossy catalogues. Knowing the problems associated with the dosing equipment and supply of reagents in the water treatment plants which are continuously manned, it was felt that the installation of such equipment in the 'automatic' pumping stations which receive relatively unskilled attention would be a complete waste of money. This left dilution and aeration as alternatives. As there is a shortage of water for domestic purposes, dilution had to be ruled out leaving aeration as the only possible practical answer.

The next question was, how much air? Most of the literature quotes 1 cfm per inch of diameter as a guide, although Boon and Lister(6) have described a more scientific method for determining the amount of oxygen to be injected under UK conditions. It was decided to use various small compressors (the type used with paint sprayers) of known delivery at the service pressure and increase their number until desired results were obtained.

In the case of Villa Rosa considerable difficulties were experienced with the blocking of the pumps and inadequacy of the electricity supply with the result that only three compressors of 2.5 cfm each could be used, equivalent to 0.75 cfm per inch diameter. Samples were taken three days a week for three weeks at 8 a.m. in the pump well and 9.15 a.m. at the discharge end of the rising main. These are the approximate times that sewage with peak BOD passes these two points and the most crucial test for aeration. It was found that the aeration reduced the sulphide production from 6 mg/l to 1.5 mg/l i.e. the concentration of total sulphide leaving the main was still higher than that entering by 1.50 mg/l.

In the case of Pampatar it was possible to inject more air and the results were much more encouraging as figure 2 shows. The BOD peak in this case is not so definite and so sampling was carried out every hour. Figure 2 shows the results of one compressor (2.5 cfm) in operation continuously. Figure 3 shows the results of starting the compressor at 9 a.m.; figure 4 shows what happens when two compressors were started at 9 a.m. Control was established within an hour and an actual reduction of total sulphides occurred.

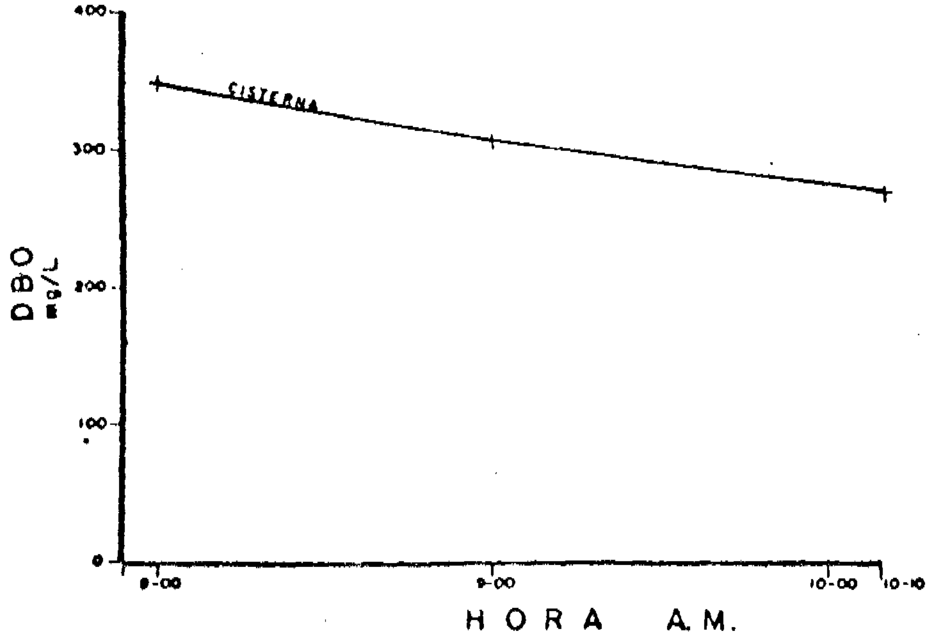
On March 1 a dissolved oxygen meter was available and figure 5 shows the result of three compressors (7.5 cfm) started at 9 a.m. on the dissolved oxygen in the discharge from the rising main and figure 6 shows the effect of one compressor started at 9 a.m. All these should be compared with figure 1 which shows average conditions without aeration.

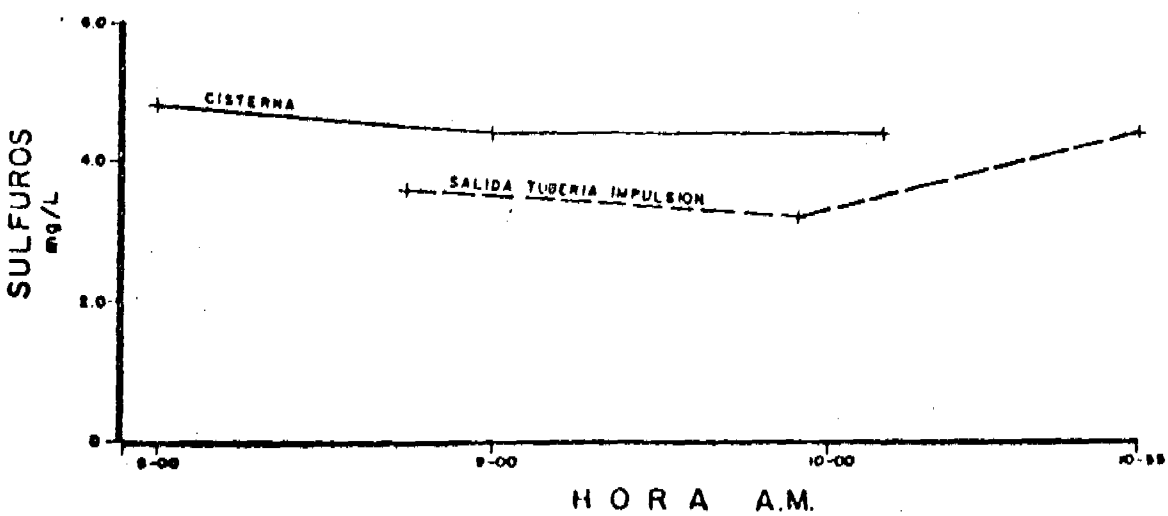
Boon and Lister indicate the need to consider oxygen requirements as related not only to diameter of the main but to its wall (i.e. slime) area and volume as well. These parameters are presented in Table 2 and explain the lack of success in the case of Villa Rosa when the amount of air injected is related to volume and internal surface area of the mains.

TABLE 2: Comparison of aeration intensities used in sulphide control studies

Number of compressors	Volume of air cfm	cfm/inch diam.	m^3 air/m^2 surface per day	m^3 air/m^3 per day
		Villa Rosa		
3	7.5	0.75	0.8	2.7
		Pampatar		
1	2.5	0.42	0.25	6.7
2	5.0	0.83	0.49	13.3
3	7.5	1.22	0.74	20.0

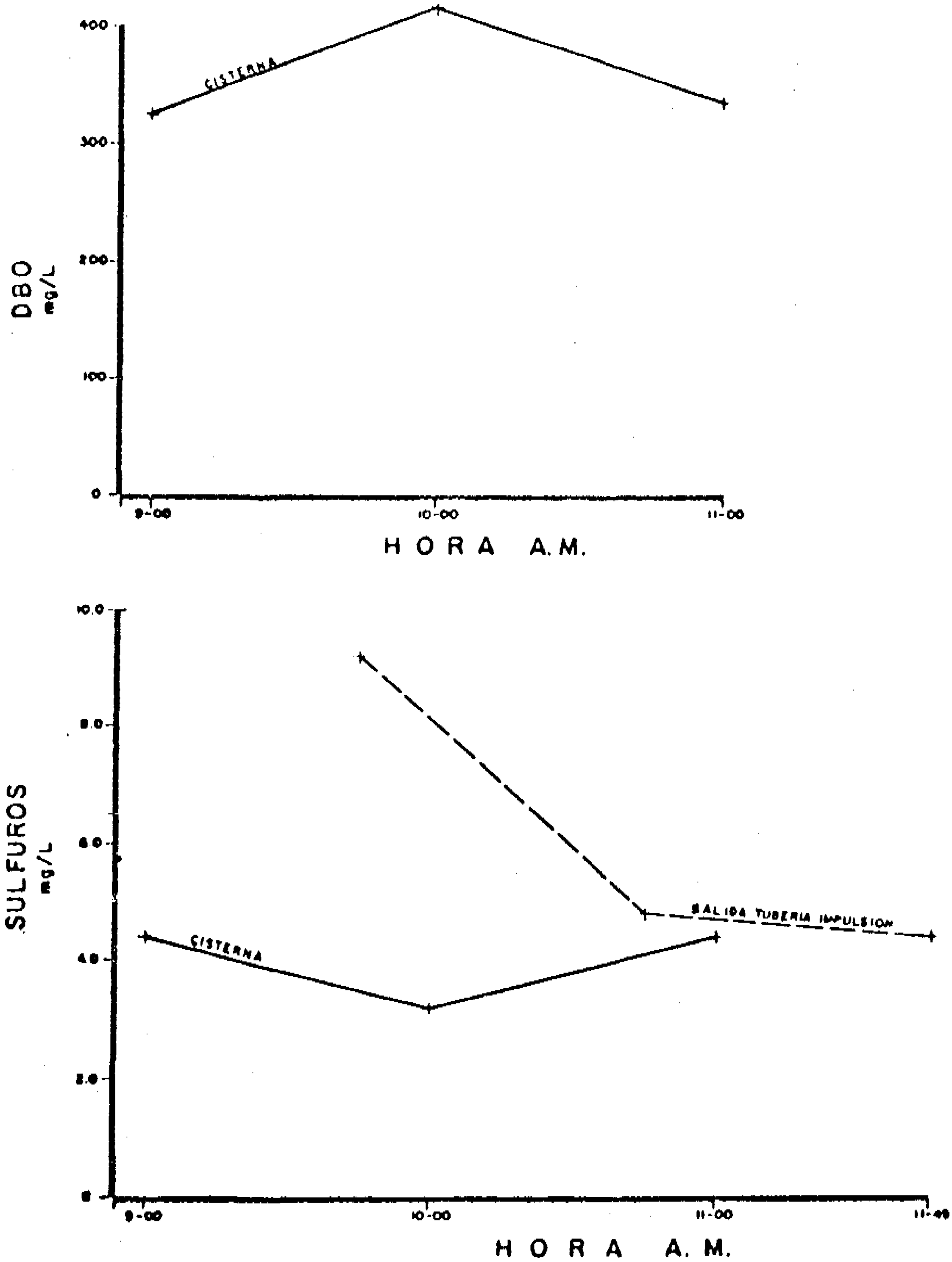
FIGURE 2:





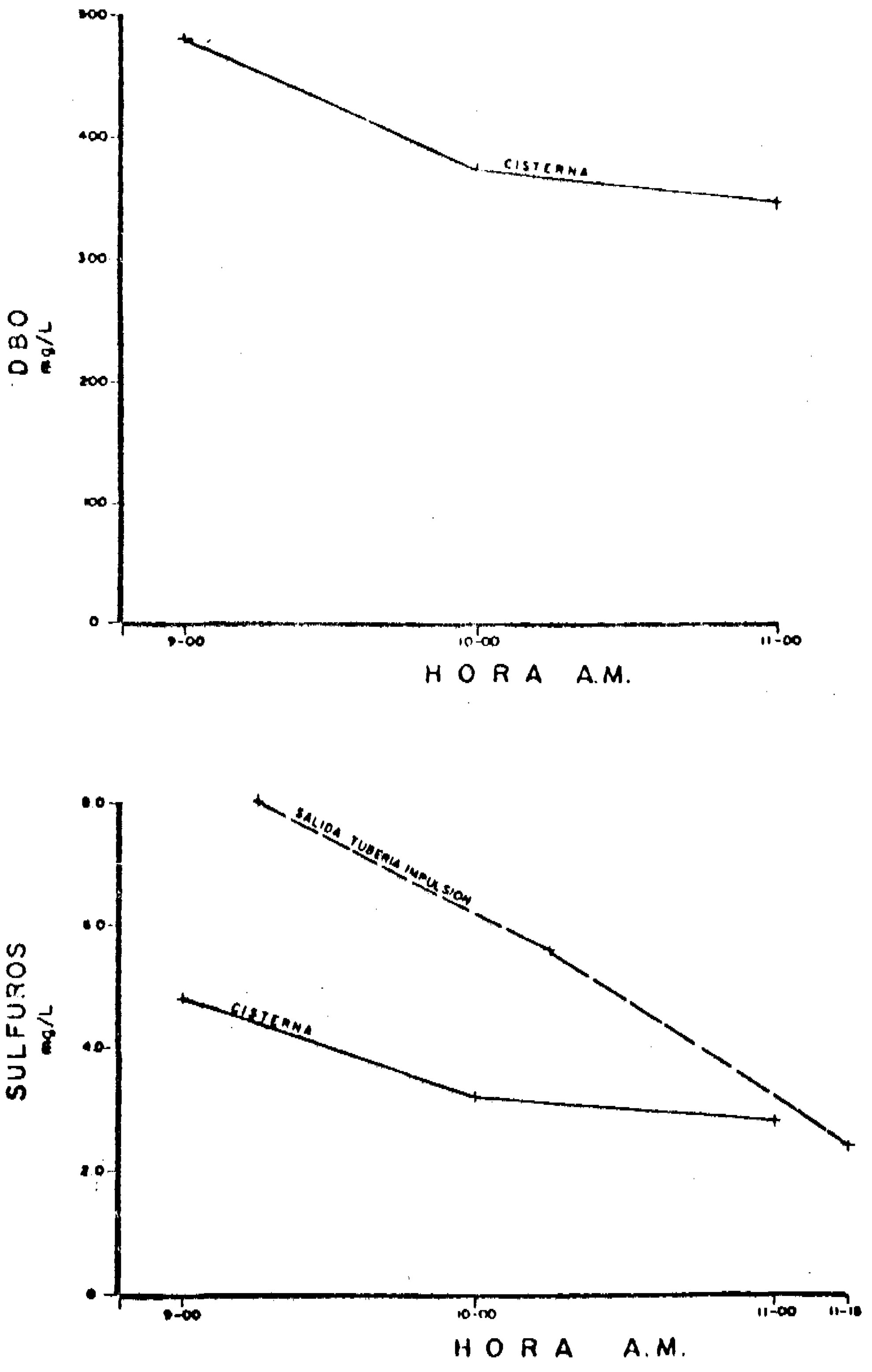
MUFSTREO CONTINUO ESTACION DE BOMBEO 'PAMPATAR'
FEBRERO 18/77 (CON AEREACION CONTINUA)

FIGURE 3:



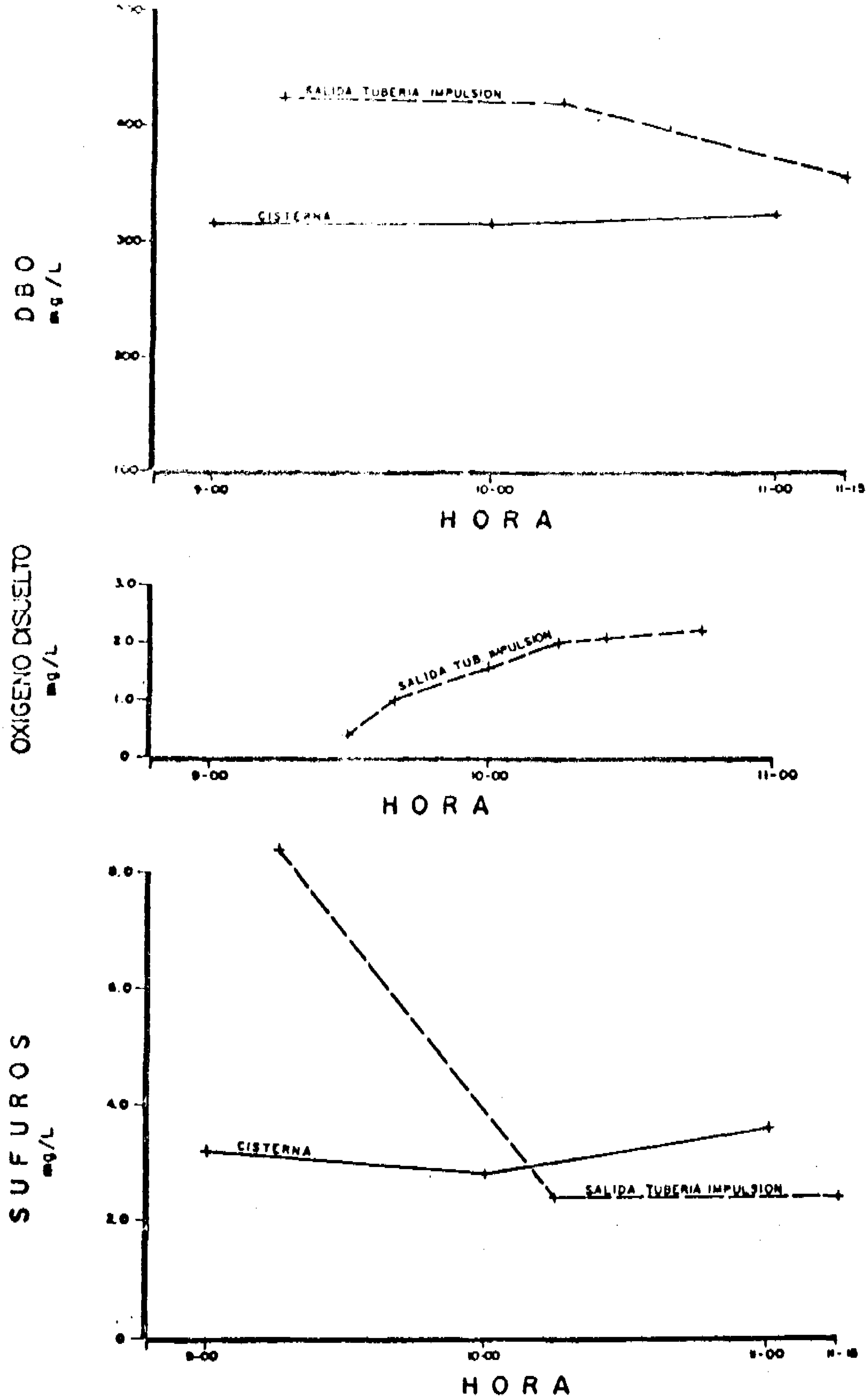
MUESTREO CONTINUO ESTACION DE BOMBEO 'PAMPATAR'
FEBRERO 21/77 (CON AEREACION A PARTIR DE LAS 9-00 A.M.)

FIGURE 4:



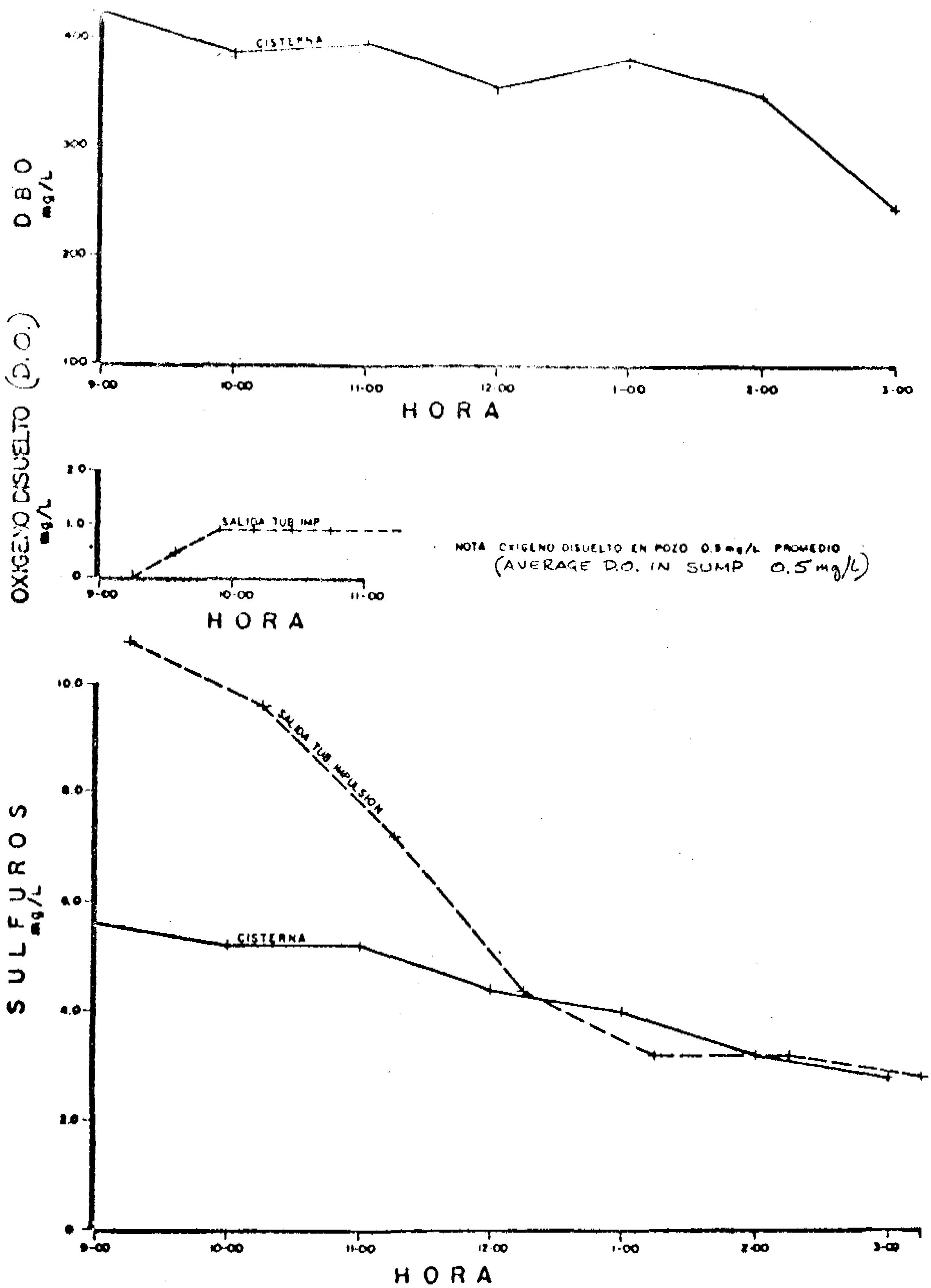
MUESTREO CONTINUO ESTACION DE BOMBEO 'PAMPATAR'
FEBRERO 23/77 (CON AEREACION A PARTIR DE LAS 9-00 A.M.)

FIGURE 5:



MUESTREO CONTINUO ESTACION DE BOMBEO 'PAMPATAR'
MARZO 1/77 (CON AEREACION A PARTIR DE LAS 9-00 A.M.)

FIGURE 6:



MUESTREO CONTINUO ESTACION DE BOMBEO 'PAMPATAR'
MARZO 7/77 (CON AEREACION A PARTIR DE LAS 9-00 A.M.)

Although one compressor in Pampatar gave about half the intensity of Villa Rosa based on diameter, the superficial and volumetric intensities were about double. With injection of 13 m^3/m^3 of volume per day, a D.O. of 1 mg/l could be maintained. It should be stressed that the total oxygen demand of a rising main is the sum of that due to the respiration of organisms in the sewage plus that of the organism in the wall slimes. Unfortunately the relative contributions of these are very difficult to determine, hence the need to take the worst case.

It is interesting to note that if the sewage respiration rate is taken at 10 mg/l per hour (found respirometrically) and the slime respiration taken at 2.1 g/m^2 per hour (using the figure of 700 mg/m^2 per hour given in reference 6 for 15°C and allowing 7% increase per 1° rise in the temperature), the theoretical air demand is 2.2 cfm.

CONCLUSIONS

Recommendations to INOS included the following:

a) The majority of the cases of corrosion and odours are due to sulphide production in rising mains.

b) Rising mains should be kept as short as possible, preferably no longer than 200 m.

c) Where long rising mains are unavoidable, continuous injection of air at the pump end of the main should be contemplated.

d) The amount of air required in such cases may be estimated from the following:

   1 cfm per inch diameter

   OR

   0.5 m^3/m^2 internal surface per day

   OR

   10 m^3/m^3 volume per day

   The maximum figure given by the dimensions of the main is that to be used. These parameters should be updated with experience of their use in practice.

e) Great care should be taken in the design of the manhole at the discharge of rising mains to avoid splashing and minimise turbulence.

f) A vent shaft at least 10" diameter and 10 m high should be provided for manholes receiving rising mains. Care should be taken in its location to avoid odour nuisance.

g) Sewers receiving rising mains should be designed with the utmost care to avoid turbulence. If this is not possible then acid resisting materials should be used with adequate ventilation.

h) INOS should discuss with the Ministry of Health the possibility of raising the minimum vent pipe diameter specified in the Building Code to 4 inches.

i) Main sewers should have minimum gradients to afford an average boundary shear force of 0.2 kg/m^2 at average flow conditions and the use of the minimum velocity criterion of 0.6 m/s should be discontinued. (This recommendation was in the light of research by the U.S. Environmental Protection Agency(7) and the work of Yao(8), and takes into account the necessity not only for self-cleansing velocities but also 'self-aerating' velocities).

k) The feasibility of diluting the sewage flow during the early years of a new sewerage system should be investigated in order to secure better flow conditions.

These recommendations were intended to draw to the attention of INOS the necessity for preventing sulphide problems at design stage rather than having to cure them later at a greater cost.

The study described has no great scientific merit, but the findings have some practical value and it is to be hoped that this paper will serve to spark off interest and, hopefully, more detailed research into sulphide problems in other 'hot' countries where funds are available. The knowledge gained may then be applied in poorer countries in order that such funds that are available for sewerage may be more securely invested.

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discussion

CHAIRMAN: J M G van DAMME
Manager
WHO International Reference Centre
for Community Water Supply

Mr JOHN PICKFORD said that at the first session of the first Conference in 1973 a paper from Hans van Damme set the tone of subsequent Conferences and it was therefore a special delight to have him take the chair. He was the Manager of the WHO International Reference Centre in the Hague and has recently taken an increasing interest in sanitation as well as community water supply.

Mr J M G van DAMME introduced Mr Mark Lansdell who had worked for eight years with local authorities in the U.K. before going to Venezuela in 1973 to study water pollution control alternatives for the River Tuy. This study ended in 1974 but Mr Lansdell decided to stay in Venezuela and work for a Venezuelan Consulting Engineer.

2. Mr M LANSDELL illustrated his paper with slides. The island of Margarita, where much of his work has been carried out, was a great tourist attraction situated off the north coast of Venezuela. Table 1 showed the tremendous growth in the cities in Venezuela. The capital of the Republic, Caracas, grew from 350 000 in 1941 to over two million in 1971 and the sewerage and water supply services had been severely taxed by the inflow of people due to improvement of health, prosperity and better conditions in the cities.

3. The outfalls from the urban areas of Margarita discharged into the sea and under certain wind conditions solids were blown back and affected parts of the shore. His firm had looked at the collection of the outfalls by gravitating sewers and pumping the combined flow to a treatment works and using the effluent for golf courses, public parks and agriculture. For gravitating sewerage the 54" concrete pipes were laid with a fall of 1 in 1500 which gave reasonable velocity to stop sulphide production. Pipes were lined in the factory with three layers of coal tar epoxy as an added safety measure. For the design of the 3 kilometres long rising main, two existing systems were studied in order to find some means of stopping sulphide generation.

4. One system served a government housing estate with a population of 10 000 people. Sewage is pumped through 2 kilometres of 10" rising main. Two Flygt pumps were protected by a basket mounted on rails in the sump which could be raised for cleaning, but it became blocked and sewage backed up in the pipeline for 300 metres. The incoming sewage had very high sulphide content due to stagnation. Also the pumps stopped about once a week so an electrician had to come out and lift out the pumps. To overcome this problem they had erected a fixed screen outside the sump so that personnel of lower training could clean the screen with a rake. From this pumping station the septic sewage was pumped through 2 kilometres of 10" main causing damage to the wall of the receiving manhole. The 18" pipe downstream with a gradient of 1 in 500 was eaten away and became swollen due to sulphide attack. A free fall down a drop of 1.2 metres caused 5 - 10 centimetres of the manhole wall to disappear. The products of the corrosion on the benching edges were yellowish and purple. A little further downstream, the pipe improved because the wind blew against the flow and gas was carried back upstream.

5. The other pumping system served a typical Old Latin American town with

single-storey buildings. In these old areas the overflow from the septic tanks was discharged into the sewers, with the result that the sulphide concentrations were quite high although solids were on the low side. Generally, the sewage from the old town was much stronger than that from the public sector housing estate. The BOD was 400-500 mg/l. The end of the rising main which served the old town was badly affected by black anaerobic slime. A lot of gas was liberated but the sewer leaving the manhole was clay-ware and was in good condition. The sulphide content in the rising main was 12mg/l, causing complaints from the people when the manholes were opened up. Consequently, many of the manholes were sealed with putty because the residents at night could not stand the stench. Mr LANSDELL had considered dilution and adding all sorts of chemicals but these were not suitable as there was no adequate water supply on that part of the island so aeration was tried. At night the BOD was about 40mg/l and there was no sulphide production between 2 a.m. and 7 a.m. Air compressors, as used for paint spraying, were connected through non-return valves to the rising main. It was then found that when the pump stopped, the pressure became sub-atmospheric for about fifteen seconds. A sophisticated piece of plumbing was connected up to the rising main with a snifter valve so that when the pressure in the main was negative, air was sucked into the main. However, on testing at the far end of the pipeline, there was no reduction in sulphides because once the rising main was full of air, there was no water hammer. So air was injected into the main and 75% reduction of sulphides was achieved. There were problems with voltage and pump blockage.

6. In the second smaller main, it was possible to inject relatively more air into the main and a reduction in sulphide was achieved between the inlet of the pumping station and the discharge end of the main. It was decided to switch off the compressors at night. The situation was under control within an hour of starting the compressors at 8 a.m. When injecting air, bubbles formed quite large air pockets scouring the slime which resembled tea leaves.

7. Mr LANSDELL said that a manhole at the end of the first rising main had been covered with cement mortar by the residents. The cement was chipped away when the manhole was opened up to take samples. People complained of the smell so a PVC ventilating column, 250mm diameter and 10 metres high, was erected reducing sulphides from 40mg/l to about 5mg/l. The ventilating column took advantage of the north east trade wind to induce a draught which was quite effective. Whilst air was being injected, there were no complaints from the residents near this manhole, but as soon as there was a power cut, the residents complained once again.

8. Three conventional sewage treatment plants had been constructed in Venezuela in 1973. Other treatment plants were oxidation ponds. In one of the conventional treatment plants only 50% of the equipment was working. The sludge pump had not worked for four months and one of the screw pumps had broken down. Mechanics give priority to water supplies and consequently faults to sewage plants did not get much attention. Rising sludge was blown to the inlet end of the sedimentation tank but effluent was quite reasonable.

9. Mr LANSDELL then described sulphide generation in sewers. Under aerobic conditions the micro-organisms in sewage take in oxygen and give off carbon dioxide. In a steep sewer where the exchange prohibition is very high, oxygen is transferred across the surface of the sewage but in a flat sewer there may not be sufficient turbulence for oxygen to dissolve in the body of the sewage and maintain aerobic conditions. Then the slimes which form in this part of the sewer become anaerobic. The lower layers of slime against the wall are anaerobic and sulphides are formed. Where the sewage is fairly fresh there is an aerobic layer of slime which oxidises the sulphides formed in the slimes near the wall, but where the velocity is low, the velocity may not be sufficient for oxygen exchange and the whole of the slime becomes anaerobic. Sulphides then pass into the sewage and are released into the sewer atmosphere. Then, subject to several factors mentioned in the paper, they are absorbed into the moisture on the wall of the sewer and converted into sulphuric acid which in turn eats the concrete. Attack was worse at the springing between air and water. It was necessary to consider the exchange of oxygen into the sewage. It was recommended by Yao that 0.6m/s as a minimum sewage velocity was too low according to research in other countries. The average shear force on the submerged part

of the sewer should be at least 0.2 kg/m^2. This could be arranged by adjusting the hydraulic radius and the slope.

10. Mr S PRAKASH said that in India they had the same problem with the formation of sulphides in sewers as Mr Lansdell had in Venezuela. They found that they were able to solve the problem by putting up a number of ventilating shafts all along the system so that the gases formed escaped into the atmosphere. The ventilating shafts were placed every 15 metres or so. The system had been inadequate, with manholes collapsing. Sewers were only laid with collar joints and he wondered whether these would be good enough in heavy sub-soil. In his experience where the depth of the sewer was unusually large and where heavy sub-soil was encountered, settlement of the sewer sometimes took place so SNS rubber jointed concrete pipes were now being introduced. Mr PRAKASH asked whether Mr LANSDELL had tried using rubber jointed pipes.

11. Mr LANSDELL said that the question of ventilation of sewers has been raised and discussed since the 1840's and no-one has really come up with any scientific means of predicting what would happen in the sewers. It was a complex situation with wind, flow, differences of relative humidity and changes of temperature between ground and sewer and air. Mr LANSDELL said that the team put up a ventilating shaft to see if they could reduce its height and take advantage of the wind. The Venezuelan standard 2" diameter house ventilating stacks were much too small and that they should be changed to 4 inches. Pinson on the Cairo sewer system mentioned a huge ventilating fan and shaft, but the sewer still kept on corroding.

12. In Venezuela, air was injected just downstream of the reflux valve in the pumping station into the bottom end of the rising main maintaining sufficient oxygen through the main. The pipes had ogee joints with a rubber insertion, were about Class 7 on the American scale and could withstand most overloads.

13. Mr W A GILLINGHAM thought that ventilation through domestic properties was an essential part of the system. Sometimes on economic grounds, a client insisted that no further properties were to be ventilated in order to save stacks, where sulphides are not released in the normal system. Mr GILLINGHAM asked whether Mr LANSDELL agreed with the necessity.

14. Mr LANSDELL thought that it was more effective to have a spread of ventilation so it can take into account any changes in the wind, or climatic situation. He also thought that the ventilation system in U.K. is much better than it was before the abolition of traps which were a dreadful waste of money and which kept getting blocked up. L.C.C. used to have ventilating manhole covers which were tried in Venezuela but children put sticks down them and water and sand got in, so were not a good idea.

15. Mr A W SHILSTON asked whether Mr LANSDELL could contrast the style of working in Venezuela with an indigenous consultant, with his experience in the U.K. Mr SHILSTON thought this would be interesting and helpful since it was the order of the day for U.K. people to enter into joint ventures with overseas firms. An understanding of the method of working and the language difficulties would prove interesting. Mr SHILSTON thought that admission of air into rising mains was traditionally discouraged and most people spent a lot of time trying to exclude air from rising mains. Introducing air into a rising main might mitigate some problems but introduce others.

16. On the point of clay-ware pipes, the author mentioned that these appeared to be particularly resistant to the ravaging effects of corrosion. What maximum size of clay-ware pipes were obtainable in Venezuela from the U.S.A.?

17. Mr SHILSTON said that Flygt pumps were now much used for U.K. rural pumping schemes and he wondered if this type of pump was in widespread use in Venezuela.

18. Mr LANSDELL said that working in Venezuela as an individual provided quite a lot of freedom. His partner was an irrigation expert. Engineering in Venezuela was still a cottage industry, and it was easy for expatriates to get work, especially in the oil fields.

19. If a rising main dipped, rose and dipped again, the air had to be let out and pumped in again at a low spot or

else in the case of long rising mains, the air could be injected at the outlet end. Depending on circumstances, enough air might be introduced to reduce any sulphides formed during the first anaerobic length. The paper included a practical guide to required air volumes. Three different figures may be arrived at and what was wanted was the upper bound for the volume of air required. A number of compressors should be installed with a little to spare, but the cost of installation was not very high compared with the pumping plant.

20. Commenting on clay-ware pipes, Mr LANSDELL said that the maximum size produced in Venezuela was 16 inches diameter. The factories there could not meet the demand, so pipes were obtained from the United States. These pipes were up to 42 inches diameter, but above about 20 inches diameter, rubber joints were not available. If rubber joints were not available, then either a bitumen joint had to be made or clay-ware pipes are not used. The sockets of clay-ware pipes used with sand and cement joints burst if there was sulphide present due to expansion of the mortar.

21. Mr LANSDELL thought that Flygt pumps were good but needed very good protection; fixed screens, cleaned at least every two days, were recommended. This cleaning was essential in Venezuela due to the abuse of the sewage system. The pumps will soon block up if they are not cleaned out properly.

22. Mr SHILSTON added that it was normal to keep air out of the rising mains to prevent bursting. He thought that a clean water engineer would be horrified at the thought of intentionally injecting air into a rising main because it was a fundamental aspect of design to keep air out.

23. Mr PRAKASH supported what Mr SHILSTON had said and thought that introducing air into a rising main did not solve anything. The formation of sulphides was due to septic conditions in the sewer. Usually there were low velocities in the sewer system.

24. Mr LANSDELL said that his experience with corrosion has been confined to Venezuela. Generally, corrosion was associated with pumping systems. He had seen one gravity sewer with sewage eight hours old and sulphides had only risen 1 mg/l because there was reasonable velocity.

25. Mr D R YOUNG suggested that high velocities alone could not prevent septic conditions because very few sewer systems had times of concentration of less than half an hour. In hot countries, septic conditions prevailed within half an hour. He thought Mr LANSDELL's point about adequate velocities preventing the build up of slime to be more valuable.

26. Air or oxygen in a pumping main was a paradox but it had to be done to give air to the organisms.

27. Mr PRAKASH was not convinced about introducing air into the rising main. He would prefer fresh air to enter the system through the manholes and the gases to escape through ventilating shafts.

28. Mr LANSDELL said that the gases coming out of the main when injecting air did not affect the surrounding inhabitants but as soon as injection stopped, they would receive complaints again. Mr LANSDELL wondered whether there would be an extra friction head when air was injected as the density of the water became less. He had seen no evidence of a rise in the friction loss provided the main did rise all the way to the outlet.

29. Mr C E BASHAM said that ventilation, to a certain extent, prevented moisture from forming on the upper part of the pipe and therefore, presumably, prevented the generation of sulphuric acid. In work being done in some countries, it was found that hydrogen sulphide was released where there was turbulence, such as where pressure mains discharged to break-pressure tanks or at backdrops.

30. Mr BASHAM's firm was currently taking over a large pipe company in America. Pipes with flexible joints up to 900mm diameter were available in South America. In the old days, firms like Doultons produced pipes up to 72 inches diameter but then concrete came in and engineers decided that the cost of clay was too much and concrete pipes were much cheaper. Architects argued that they did not know how engineers got

away with this, pointing out that if they built a house for a hundred years and the walls fell in twenty five, they would not be allowed to build another. Mr BASHAM thought that too much attention was given to the initial cost and not enough on the life of the installation. GRP pipes up to 1200mm diameter were not being produced.

31. The CHAIRMAN said that we would never solve the problems of sewerage in the developing countries if we had to change the sewers every thirty years.

32. Mr R J HOLLAND suggested to Mr PRAKASH that 45 feet was an exceptional height for a ventilating column. Mr HOLLAND said that he had used 15 feet columns and found that they had no beneficial effect.

33. Mr HOLLAND said that in Kenya sewers are normally of poor quality concrete pipes. Kenya is short of foreign exchange and could not afford to import clay pipes. Kenya does not appear to have suitable natural clay. He asked if there are any means of avoiding hydrogen sulphide corrosion in a new scheme using concrete sewers? Could designers, for example, ensure the sewers surcharged once a day to wash out any sulphuric acid forming?

34. A typical scheme in a small town in a developing country took a long time to reach its design flows. Inevitably during the early years, there would be long retention in the rising mains and low flows in the sewers, and concrete sewers could disintegrate during this period. What success had been achieved by lining concrete sewers? He had seen epoxy paints applied, but they came off in sheets as corrosion proceeded behind the coating.

35. Mr HOLLAND asked what safety precautions should be taken when entering sewers containing hydrogen sulphide.

36. Mr LANSDELL said that on the question of concrete pipes, one answer was to keep the outfalls as deep and as short as possible. Sometimes surface water could be passed through a new sewerage system to raise the flow, so improving velocity and reducing the BOD by dilution.

With BOD of less than 70-80 mg/l there was little sulphide production. In Cairo canal water was used to flush sewers. The most important precaution was to purge a system with fresh air before men entered.

37. Mr A I BHATT suggested that to combat corrosion, concrete pipes should not be used but instead high density polythene should be used. These were slightly more expensive than concrete pipes, but their ability to resist corrosion was excellent. They were less brittle than clay pipes, easy to handle and the jointing very easy.

38. Mr J H KOP advised against allowing spare capacity in a new combined sewerage system (in view of the then allongated retention time of the dry weather flow in the system). The second generation would cope with the overloading by dry weather flow and run-off (e.g. run-off might be partly uncoupled from the system in the future.)

39. Mr LANSDELL said that in certain lengths of very flat gradient top-end pipes, flushing was a real benefit.

40. Mr KOP said the Dutch had the advantage of living below the surrounding canals which could be used to flush the system when required. Because of low temperatures, there was not much sulphide production, so canal water was only used to flush detritus out. Maybe in certain areas of the Far East such as Thailand or Bangladesh, it might be useful to flush the system from the canals, but it would require extra provisions and thus entail extra costs, capital as well as operational.

41. In reply to a question from Mr J B HENDERSON, Mr LANSDELL said that perhaps the W.R.C. could suggest what should be the lowest influent for satisfactory treatment. During his tests at night, there was no production of sulphides even in the rising main and injection could be stopped for five hours at least and started up again between 6.30 - 7 o'clock. The BOD increased from 40 to 350 mg/l in half an hour especially in the government housing estates. It was found that the BOD produced per person was about 49 grammes, which was fairly low.

42. Mr H MANN agreed that septicity was

unlikely with a BOD below 80 mg/l. However, there was no control over the amount of waste going into the sewer and therefore no control over the dilution. Sewage was by no means a standard substance. He had come across BOD in sewers exceeding 2000 mg/l. Stronger sewages always produced septic conditions. Oxygen could be used for the consumption of oxidisable carbonatious matter so a sewage system could be designed with oxygen or air injection at a sufficient number of points to maintain a BOD lower than 80 mg/l. Otherwise H_2S would be produced and measures must be taken to prevent corrosion. This could be done by ventilation or the use of materials that would not be seriously corroded.

43. Mr GILLINGHAM said that on a small project, he immersed concrete pipes in bitumen to give them a lining but was not sure how far this was effective in preventing corrosion.

44. Mr LANSDELL had applied three coats of coal tar epoxy sprayed on to the inside of the pipes but he questioned its effectiveness. It only needs a hole the size of a molecule for the rot to set in. He gathered that some success had been obtained with PVC keyed-in liners. The Australians using these liners had found that sprayed-on coatings were a waste of time. It was also found that calcarious aggregate had doubled the life of concrete.

45. Mr HOLLAND's firm carried out many experiments a few years ago and found that dipping asbestos cement sewer pipes in bitumen did not protect the pipes. The experiments demonstrated that if a coating was not taken around the face of the joints to the outside of the pipes, it rapidly came off in sheets. At the time of these experiments, the experts in U.K. on coating concrete structures against hydrogen sulphide corrosion were at Burton-on-Trent where they dealt with very hot brewery wastes. He understood that this Authority eventually gave up coating concrete pipes and changed over to glass fibre and plastic sewers.

46. In Kenya, when water supplies and sewerage programmes were provided for smaller towns, it was found that people would not use enough water, presumably as previously they had been used to carrying water for miles and thus appreciated its true value. A minimum of 70 l/pd was allowed in the designs, but consumption was only 10 - 15 l/pd. As a result, sewers tended to block solid. Under the Kenya water tariff consumers pay minimum charges for each water connection to cover a specific amount of water per day, but in practice often do not use even 20% of thier allowance.

47. Mr E J FELTS said sewers were being introduced into Katmandu and Katmanlay. To reduce blocking a water jetting vehicle had been obtained. The question of finance in developing countries was rather frightening and Mr FELTS had noted that the tariff for water supply covered the cost of sewerage in Venezuela.

48. Mr LANSDELL said that up to now the major cost in water services had been for the water supply. He did not know what percentage of the annual budget of the Water Authority was for sewerage but it was not very high. Sewerage systems generally discharged to the nearest stream without treatment cost. Operation and maintenance of the sewerage system was very poor so there was not a great cost there.

49. The CHAIRMAN, with regard to the finance item, asked whether anyone else had experience of a sewerage levy being paid by those who have had a water supply whether they had sewerage or not.

50. Mr PRAKASH said that in India, water and sewerage were financed together. The total income and expenditure for water and sewage were taken as one. The sewage expenditure was roughly 40% of the total.

51. Mr A W TURNER had recently returned from Bangladesh. In Dacca, a sewerage system is now 70% installed and the authorities were having difficulty in getting people to convert to the sewers because the rate for water was 7½% of the net annual rental over ten months and those with sewage connections paid another 7½%. It seemed standard practice now for the Regional Water Authorities to charge equally for sewerage and water because what goes in must come out.

52. Mr HOLLAND said that in his experience, it usually cost more to put in sewerage than a piped water supply. But higher sewerage charges were not usually acceptable to the ppopulation so it was customary to increase the water

charges so as to subsidise sewerage.

52. The CHAIRMAN asked if anyone had experience on precautions in hot countries.

53. Mr PRAKASH said that in India workers wore gas masks for going down manholes and also ensured that there was enough fresh air in the system. The manholes on either side were kept open. Before workers were allowed to go down they tested for freshness by putting down a piece of burning paper. Sometimes fresh air had to be pumped into the system before allowing workers to go in. Workers were provided with safety belts.

54. Mr E H BIRD asked Mr LANSDELL to demonstrate the application of the 0.2 kg/m^2 shear force rule.

55. Mr LANSDELL said that the average shear force around the wetted perimeter of a submerged hydraulic surface was equal to pg mi. The hydraulic gradient and the diameter could be modified to make sure that the shear force was not less than 0.2 kg/m^2. It was possible to produce a family of curves for discharge against slope and proportional depth. The latter was a problem; if the sewers were more than two-thirds full, the water surface was reduced and there was insufficient oxygen transfer into the volume of the liquid.

56. Mr LANSDELL then referred to the APA Manual which gave curves of flow against slope. With the aid of a diagram used by Yao, Mr LANSDELL explained that at 1400 l/s the slope was 1/2000 and at 105 l/s it was 1/670. To give virtually sulphide-free conditions at an effective BOD of 1.4% (Curve A). The Manual was well worth reading. Curve B conditions would produce a few tenths of a mg/l of sulphide and there might be some corrosion in the 30 years life of a sewer. The slope should be adjusted according to the expected BOD and temperature of the sewage. Yao had found that 0.2 kg/m^2 shear force roughly corresponded with Curve A and 0.1 kg/m^2 followed Curve B.

57. Mr KOP had carried out tests behind to check the shear of 2 N/m^2. Even with PVC pipes it was observed that sometimes sewage was at a standstill. Even when again the flow became high, little sills or areas of egg shell etc. had formed pools, which created sulphide conditions especially in temperatures over 25°C. The pipes varied between 150mm and 400mm diameter.

The CHAIRMAN concluded by thanking everyone who had taken part in the discussion.

C.T. MYERSCOUGH

problems of conflicting demands for water in el salvador

1. INTRODUCTION

The firm of Wallace Evans & Partners were commissioned by the Overseas Development Administration of the Foreign and Commonwealth Office of the British Government at the request of the Government of El Salvador under the Technical Assistance Agreement between Great Britain and El Salvador to carry out a Technical and Economic Feasibility Study with the following aims:

a) To establish for the period up to 1995 proposals for the provision of additional water supplies to the city of San Salvador.

b) To prepare proposals for the development of the sewerage system and treatment of sewage from the city.

c) To investigate the general problem of pollution in rivers and lakes throughout the country with a view to recommending a programme for future control and abatement.

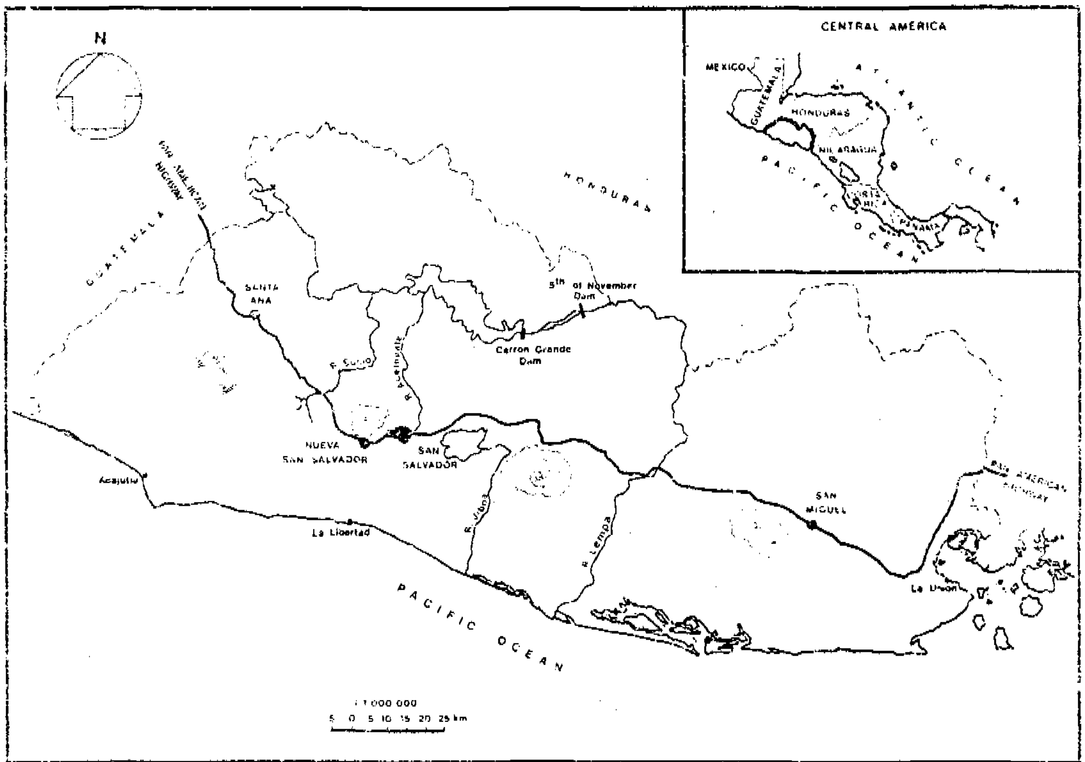
The study was undertaken for the Administracion Nacional de Acueductos Y Alcantarillados (ANDA) the authority responsible for the provision of water supply and sewerage services throughout El Salvador. It followed a United Nations Development Project investigation into possible sources of water for the City of San Salvador (1967-1972)(1) and a study of the city's water distribution system by Messrs. Black and Veatch Consulting Engineers carried out in 1967(2).

This discussion sets out to describe the conflicts of water demand which arose due to the requirement to provide additional water supplies for the city of San Salvador and emphasises the need for an overall control of water resources in a small crowded country.

2. BACKGROUND

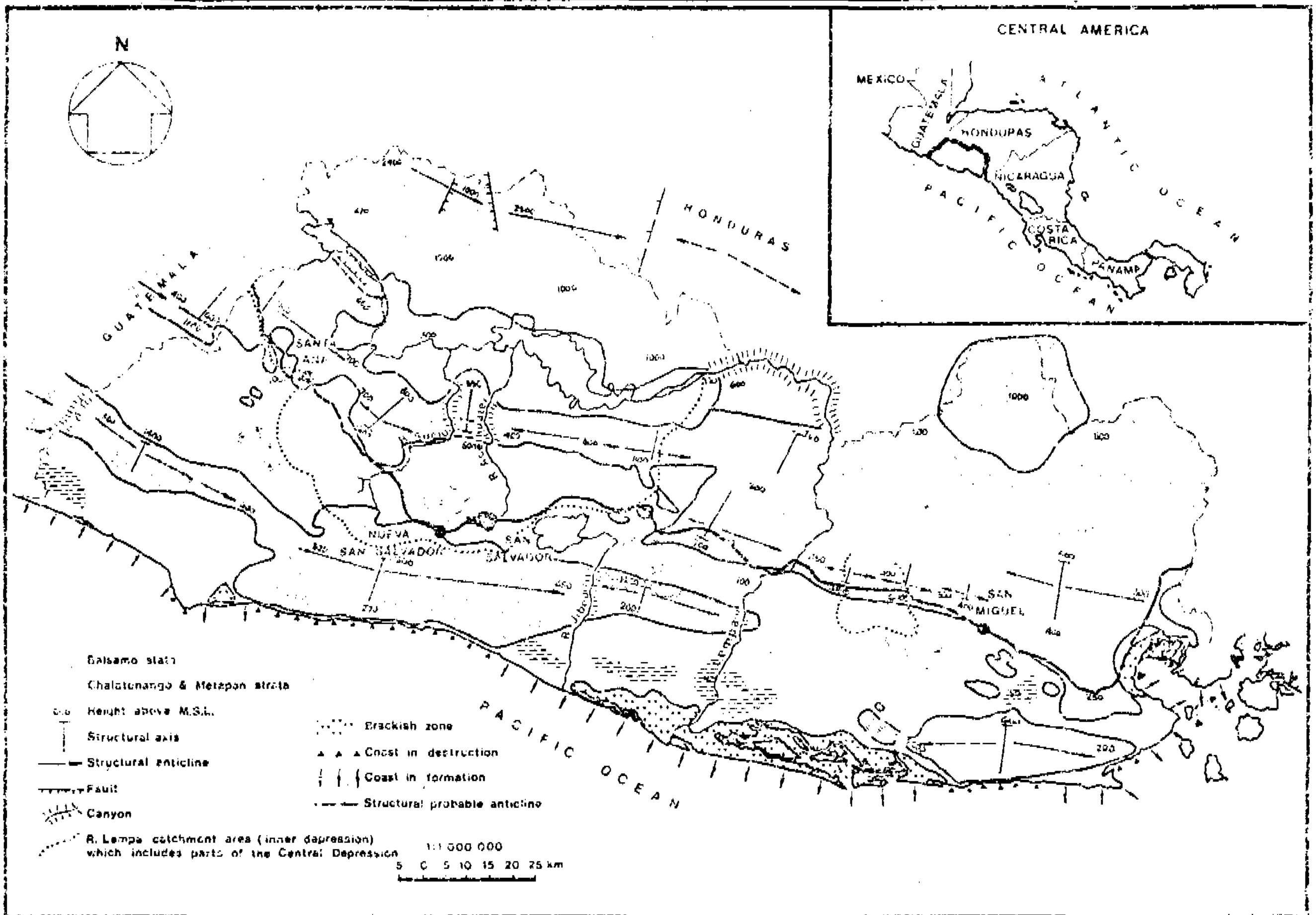
El Salvador is a small Central American Republic, bounded to the North by Guatemala and Honduras, and has the Pacific Ocean as its southern seaboard. The country is long and narrow in shape being some 270 km in length with a total area of 21 000 km^2. The present population is some 3.5 million. Of this 60% can be classified as rural and 40% urban though there is an increasing trend towards urbanisation. There are three main urban areas: San Salvador (570 000 population), Santa Ana (96 000) and San Miguel (60 000). Figure 1 shows the location of El Salvador and the locations of these principal urban areas.

FIGURE 1: <u>El Salvador</u>



The country is dominated by volcanoes and crater lakes and shows the characteristics of recent geological activity with very rugged terrain and steep, young rivers which carry large amounts of sediment from recent volcanic deposits. (An estimated 7 million cubic metres of sediment annually is transported by the River Lempa to Cerron Grande Dam Site[3], where the average annual river flow is 5300 million cubic metres.) The main geographical feature of the area is the trough or "graben" sometimes known as the Nicaraguan depression which passes through Costa Rica, Nicaragua, El Salvador and Guatemala running roughly parallel to the coast. This "graben" zone is one of intense and continuing tectonic activity which has resulted in complex and disordered geological formations. The country has a chain of volcanoes stretching along its full length parallel with the coastline but some 25-30 km inland. A range of hills (El Balsamo) also lies parallel between the volcanic chain and the seaboard. These hills are geologically "older" and have a great influence on the groundwater drainage of the country (figure 2).

FIGURE 2: Pliocene rocks and their influence on groundwater flow



The river systems draining the country can be considered as consisting of two main elements. An internal drainage basin running roughly from west to east which is drained by the River Lempa and a series of short, steep rivers rising in the southerly slopes of the El Balsamo hills which flow due south to the sea. The River Lempa is the most important river in the country and accounts for 72% of the country's hydraulic resources. It has an international river basin of some 18 000 km^2 rising in Guatemala and flowing through part of Honduras. 10 000 km^2 of the river basin are in El Salvador. (This represents 48% of the national territory). The river has great hydro-electric potential and is being developed for this purpose(4).

3. RAINFALL AND THE HYDROLOGICAL CYCLE

El Salvador has two distinct seasons; wet (May to October) and dry (November to April). The rainfall generally occurs in the form of local short duration high-density electric storms which are more intensive over the higher terrain. The volcanoes and hills in the country therefore have great influence on the hydrological resources of the country. This is particularly so of the volcanoes which, due to the nature of the quaternary volcanic material of which they are formed, allow much of the precipitation to infiltrate below ground (in some favourable areas up to 60% of the total rainfall). This in turn recharges the aquiferous volcanic and alluvial sediments in the country's valleys and plains. This groundwater storage mechanism has the effect of maintaining flows in the rivers throughout the dry season.

The average annual rainfall in El Salvador is high - some 1865 mm, but so are the losses due to evapo-transpiration(5). The annual hydrological balance for the period 1968-1972 is given in Table 1.

TABLE 1: Hydrological balance for the period 1968-1972

	Annual volume $m^3 \times 10^6$	Percentage	
Rainfall	39 488.7	100	
Run off	14 507.7	37	
Evapo-transpiration (real)	24 365.0	62	
Change in storage	616.0	1	(1)

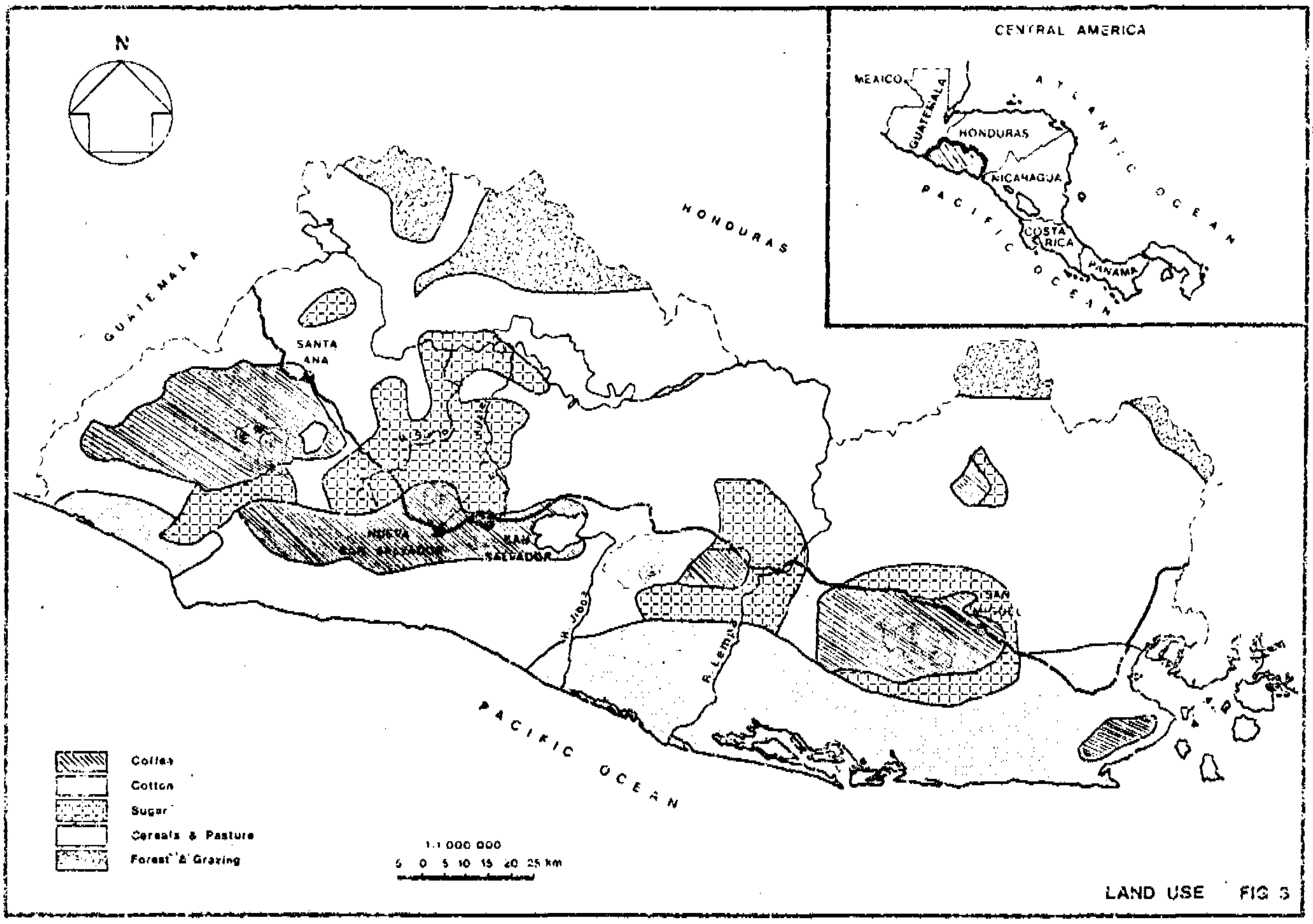
4. POPULATION AND LAND USE

The main centres of population, San Salvador, Santa Ana and San Miguel, were established during Spanish colonial rule, and were trading centres for the production of indigo dye and the cultivation of cocoa beans. These crops are no longer grown, and coffee is now the prime crop on the volcanic slopes near these urban centres. The presence of plentiful water resources obviously has had a considerable influence in the location and growth of these centres. During a slump in world coffee prices some twenty years ago cotton growing was successfully introduced in El Salvador on the coastal plains where it was found that the high ambient temperatures suit the plant. The main cotton growing area is on the coastal plain stretching between the ports of La Libertad and La Union but a smaller cotton growing region also exists on the plain surrounding the port of Acajutla. Sugar is grown in the central plains of the country. Figure 3 shows the present main agricultural divisions of the land and the present land uses are tabulated in Table 2. Sisal growing is mainly confined to the eastern area of the country centred around San Miguel. In addition to these crops which are exported, maize and other crops are grown for internal consumption. Also cattle ranching takes place in a number of small areas and there are a number of intensive chicken and pig production units utilising home grown agricultural foodstuffs.

TABLE 2: Present land uses

Use	Hectares	Total Hectares	Percentage	
Permanent cultivation		163 881	8.19	
Coffee	141 606			
Others	22 275			
Semi-permanent cultivation		33 584	1.68	
Sugar cane	14 885			
Others	18 699			
Annual crops		429 846	21.49	
Cotton	55 860			
Cereals	227 663			
Others	146 323			
Pastures		619 181	30.96	
Natural	514 205			
Seeded	104 976			
Forest		50 000	2.50	
Mountains		189 955	9.50	
Areas without agriculture		513 553	25.68	
	TOTAL	2 000 000	100.00	(3)

FIGURE 3: Land use



El Salvador is a small and crowded country, having a population density of 170 persons per km^2, with a current population growth rate of about 3.5% per annum. It is anticipated that the country's population will reach 7.2 million by the year 2000. There is obviously a great need to develop the agricultural resources of the country as far as possible in order to support this high population density.

The gross national product for 1970 was colon/2500 m (= US$ 1000 m).

TABLE 3: Division of gross national product

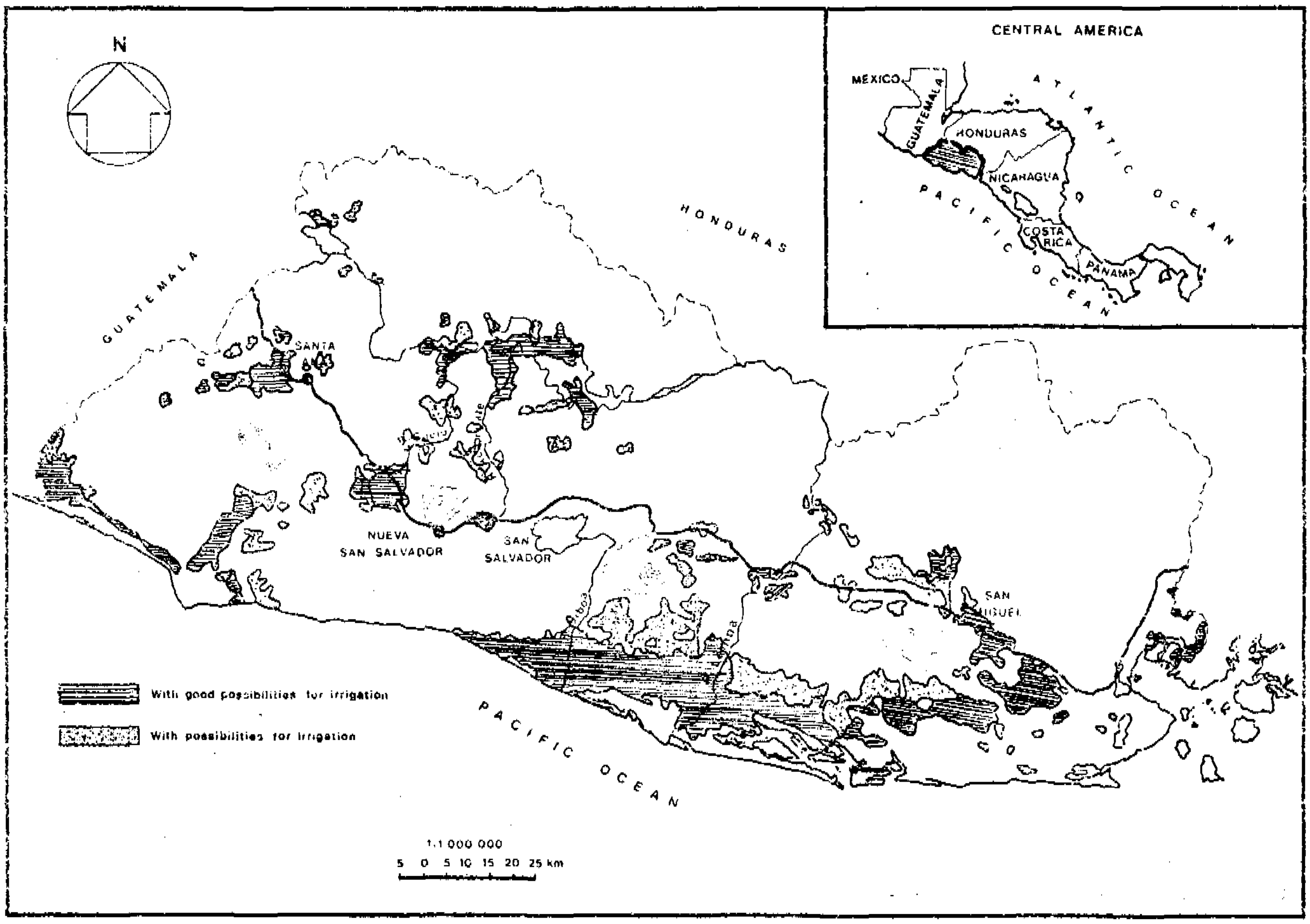
Activity	Percentage
Agriculture	27.2
Commerce	21.8
Industry	19.4
Others	31.6

(6)

These figures indicate the important role which agriculture plays in El Salvador.

It has been estimated by the Ministry of Agriculture that some 327 110 hectares of the terrain in El Salvador would be suitable for intensive cultivation using irrigation. The areas which have been designated as being suitable for irrigation are shown in figure 4. These areas form the main plains of the country. At present only about 23 750 hectares are irrigated (an area in the Zapotitan valley near San Salvador and the San Miguel Plain) so that there is a large potential for agricultural development if the country's water resources can be developed for irrigation purposes(3). Irrigation of land will allow two harvests a year.

FIGURE 4: Land suitable for irrigation

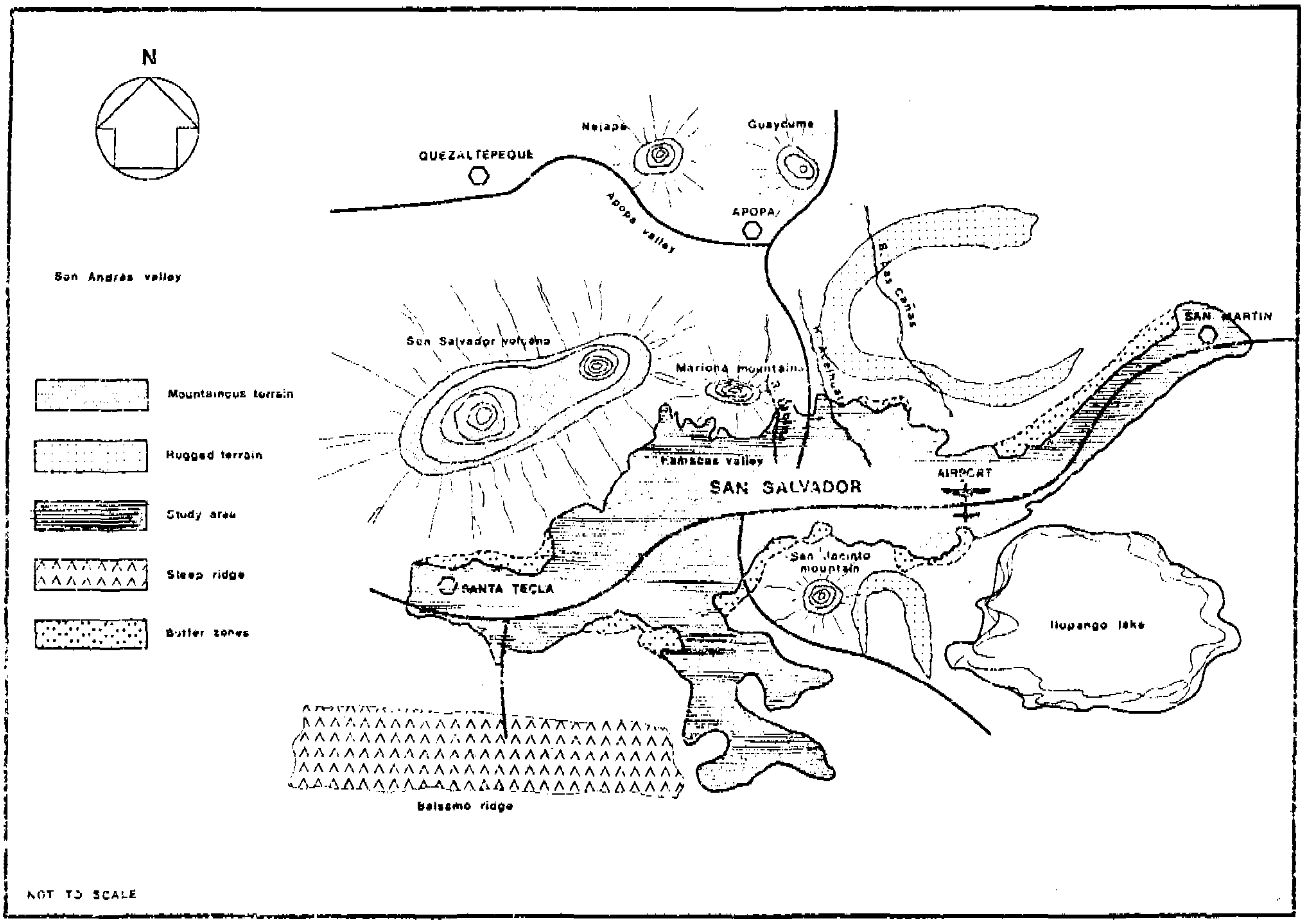


The mineral resources of the country are minimal, and at the present time there are only two small mining operations in existence, one being for silver and one for gold. Cement is also manufactured near Metapan.

5. THE CITY OF SAN SALVADOR

San Salvador lies between 600 metres and 900 metres above sea level and is some 40 km from the coast (see figure 5). It is situated on the eastern slope of the El Boqueron Volcano. There is a volcanic crater lake to the east of the city. The Balsamo range of hills rise immediately to the south of San Salvador and forms a physical barrier between the city and the coast. Immediately to the north of San Salvador a ridge of hills, the Cerros de Mariona, forms the northern limit of the city. To the west of the city there is a narrow gorge some 10 km long. Thus the city has

FIGURE 5: Diagram of natural barriers to urban development



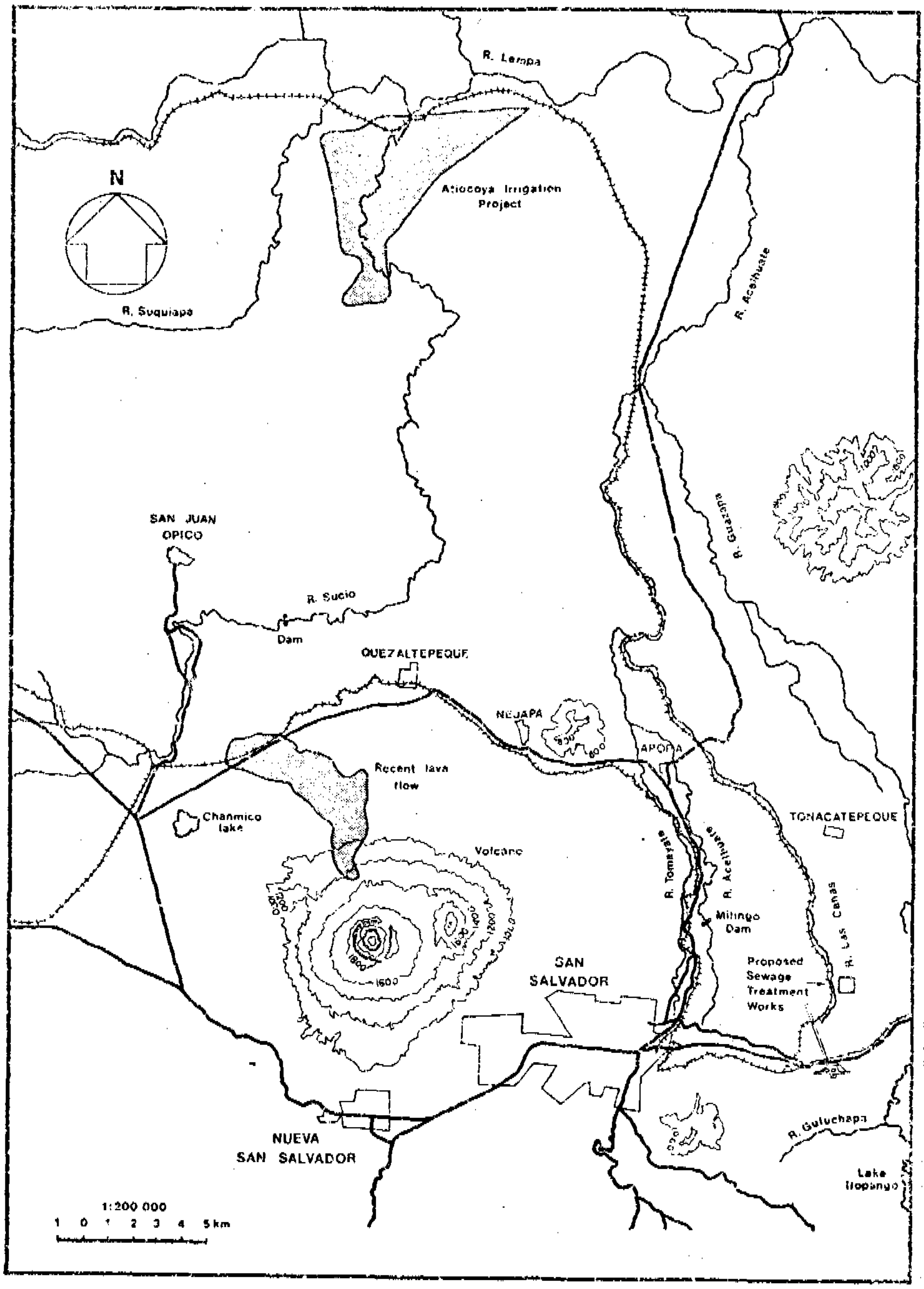
geographical features surrounding it which will constrain its ultimate development. Two river systems, the River Sucio and the River Acelhuate, originate on the west and east sides of the El Boqueron and flow northwards to the River Lempa (see figure 6).

The city lies on the Nicaraguan depression and is in an area of severe seismic activity and earthquakes of greater than force 8 in the Mercalli-Sieberg scale can be expected. Earthquakes of this magnitude have occurred frequently in the past. It was completely destroyed by an earthquake in 1854 and was extensively damaged in the 1917 and 1919 earthquakes. The 1917 earthquake was accompanied by a major eruption of lava from El Boqueron volcano but fortunately the lava flows were emitted down the north-west slope of the volcano on the opposite side to the city. Faulting is predominantly in an east-west direction parallel to the direction of the "graben". A secondary direction of faulting is north-north-west - south-south-east, being roughly in the direction of the northward flowing rivers. The valley of the River Las Cañas to the east of the city is aligned along one of these faults.

The climate in the region of San Salvador can be described as salubrious although the seasonal rains from May to September may induce very humid conditions. Figure 7 shows the meteorological data from the San Salvador Meteorological Station.

Most of the rainfall in San Salvador (approximately 70%) occurs between 18.00 and 0.600 hours in the form of short squalls which appear to be influenced by local breezes. The mass of the San Salvador volcano has a

FIGURE 6: River Sucio and River Acelhuate

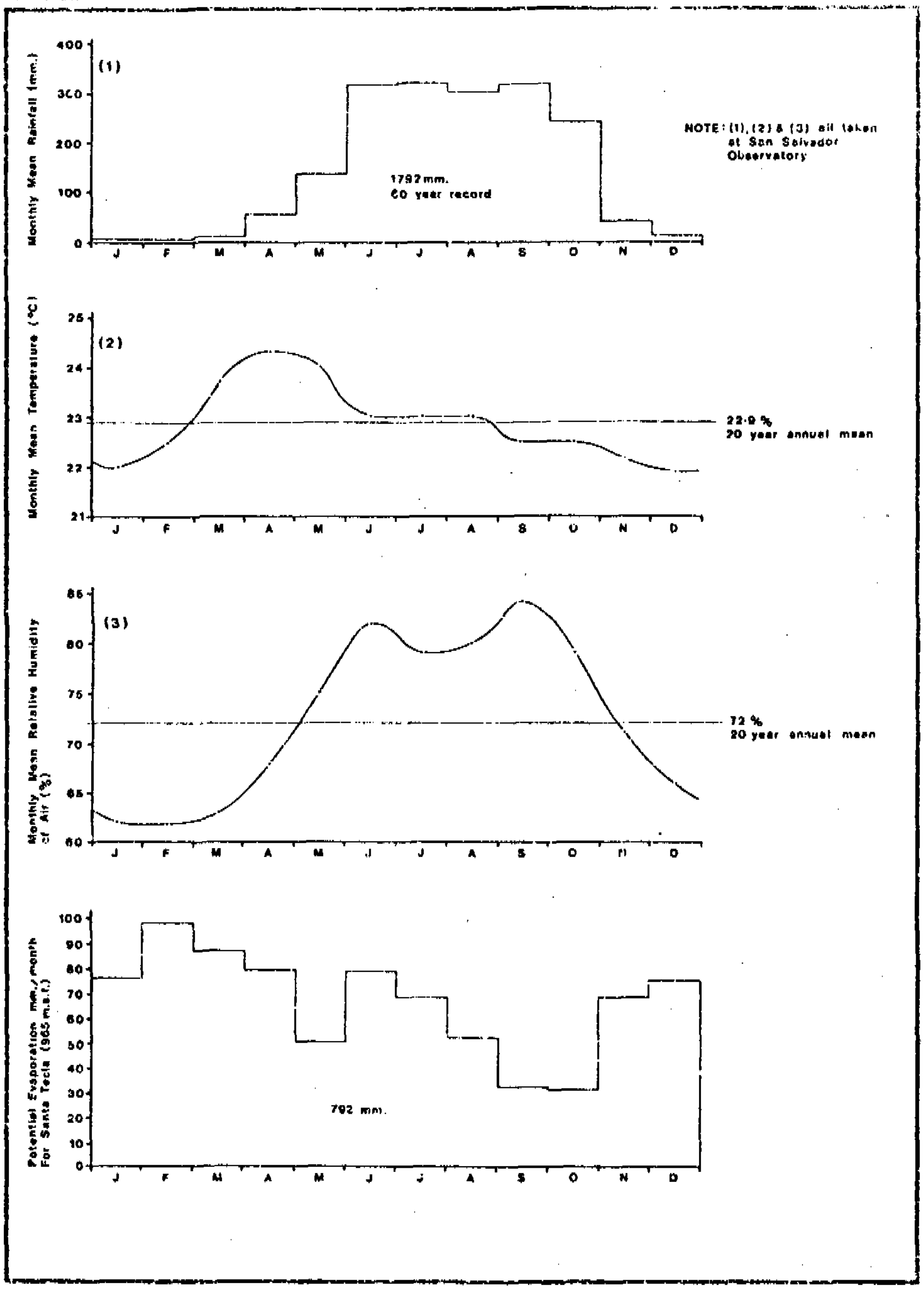


marked effect on the local climatic conditions and is the major factor in determining the magnitude of precipitation to the head of the Rivers Sucio and Acelhuate. These river basins were studied in detail during the UNDP investigation and Table 4 shows the flows for these rivers averaged over the four years. (Records were taken 1967-1971). The measurements were made at El Jocote on the Sucio and at the confluence with the Lempa on the Acelhuate.

TABLE 4: Mean monthly flows in m^3/sec.

River	Maximum (September)	Minimum (March)	Mean
River Sucio at El Jocote (Catchment area 724 km^2)	23.34	4.96	11.02
River Acelhuate at Guayapa (Catchment area 713 km^2)	27.53	4.10	11.26

FIGURE 7: Meteorological data: San Salvador



It should be mentioned that the flows given in Table 4 for the River Acelhuate include sewage flows from the city estimated at 1.3 m^3/sec. In the upper reaches of the river within the city limits, the river flow can be considered as undiluted sewage as natural water flows are virtually non-existent.

At present the city obtains its industrial and domestic water supplies from an aquifer underneath the city. The aquifer extends over 126 km^2 and is located on the south-east slopes of the San Salvador volcano. The surface slope of volcanic ash, tuffs and lava which form the aquifer material varies from 1 in 3 at 1500 m above sea level to 1 in 25 at 600 m. The isofreatic levels vary across the city from about 150 m depth at 900 m contour level to emerge as springs at the Acelhuate River around 600 m. Extensive logging of existing boreholes in San Salvador has established a decrease in ground-water levels of something like 1 m a year. Allowing for some future building development and consequent reduction in the recharge area available, it has been estimated that the reliable yield of the aquifer is 1.3 m^3/sec but the present abstraction rate is nearer 2 m^3/sec.

6. FUTURE WATER DEMANDS

A department of the Ministry of Public Works, Dirección General de Urbanismo y Arquitectura, are responsible for planning within the city. This department recognised the geographical constraints and have produced a planning map with population densities at saturation level when the whole of the area which can be built on has been developed. These are reproduced in Table 5 and show a population density at saturation of 1 830 000.

TABLE 5: City area - land use and population densities at saturation

Land use	Area (ha)	Population density (persons/ha)	Population
Low density housing	1726.63	125	215 829
Medium density housing	2370.45	250	592 613
High/medium density housing	1141.08	375	427 905
High density housing	278.08	500	139 040
*I.V.U. housing	519.88	375	194 955
Institutional	567.89	100	56 789
Institutional	308.81	NA but allow:	2000
Institutional	36.91	nil	nil
Industry	914.13	nil	nil
Light industry	353.41	50	17 670
Possible development zone	2245.01	50	112 250
Commercial	280.98	50	14 049
Commercial	138.43	nil	nil
"Buffer zone"	1076.97	50	53 849
Green zone	203.42	nil	nil
TOTALS:	12 162.08		1 826 949

* Instituto de Vivienda Urbana (Government Department responsible for low-cost housing).

The anticipated population densities for the various zones given in the above Table are very high by American standards. However El Salvador is a densely populated country and standards of housing tend to be lower than in a developed country. The forecast of population for the study area in the city is given in Table 6.

TABLE 6: Population forecast for study area

Year	Population
1975	700 000
1980	900 000
1985	1 100 000
1990	1 450 000
1995	1 700 000
Saturation	1 830 000

Table 7 shows typical population densities for other countries for comparison.

TABLE 7: Typical population densities

Country	Area (km^2)	Present population (m)	Density (p.p. km^2)	City	Density of city (pp.Ha)
Guatemala	108 889	5.2	48	Guatemala	80
Dominican Republic	48 734	4.0	82	Santo Domingo	96*
Costa Rica	50 900	1.8	35	San Jose	25
El Salvador	21 350	3.6	170	San Salvador	47

*Forecast for 1975

Metering carried out on all sources during the study indicated that the gross mean production rate was about 2 m^3/sec. This represents a gross consumption (including waste) of some 300 litres per person per day based on a population of 570 000. In the report prepared by Black and Veatch Consulting Engineers in 1967 they arrived at a gross consumption of 267 litres per person per day based on an estimated population of 480 000. These estimates were made on metred water consumption in periods when there was no short-fall of water in the metropolitan area of San Salvador and can therefore be considered reasonably realistic. For comparison water production statistics for other countries in Latin America and the West Indies are given in Table 8.

The Black and Veatch Report suggested that the unaccounted for water amounted to something like 39% of the water produced. During this later study efforts were made to corroborate this figure by leak detection methods but the results were inconclusive, though a figure of around 30% was considered the right order.

From the figures of unit production given in Table 8 it appears that the gross demand is increasing by some 5 litres per head per day every year. It was assumed during the study that some improvement in the wastage will be achieved and the following unit water production figures were taken as shown in Table 9.

TABLE 8: Water production characteristics in 1969

Country	City	Water production l/p/d	Population	GNP/ person US$	Average revenue m^3/US$	Percentage unaccountable water
Brazil	Sao Paula	310	5 900 000	250	0.05	36
Colombia	Bogota	315	2 520 000	310	0.07	25
Colombia	Cali	295	920 000	310	0.04	22
Colombia	Palmira	295	140 000	310	0.02	30
Jamaica	Kingston	235	600 000	460	0.08	23
Nicaragua	Managua	250	340 000	360	0.09	18
Venezuela	Caracas	280	2 000 000	950	0.13	32

TABLE 9: Future water production (litres/person/day)

Year	Production
1972	300
1975	282*
1980	310
1985	337
1990	365
1995	392

*Assumed some improvement in wastage figure

The design water production figures necessary to meet the future water demands for the City of San Salvador are shown below.

TABLE 10: Projected mean water production (m^3/sec.)

1975	2.3
1980	3.2
1985	4.3
1990	6.1
1995	7.7
Saturation	10.0

7. SOURCES IDENTIFIED

Figure 8 shows the locations of sources which were identified during the study to meet the water demand for the City of San Salvador up to the year 1995. The staging of the development of these sources is shown in Figure 9. A short description of each source follows.

FIGURE 8: Location of water sources for the city of San Salvador

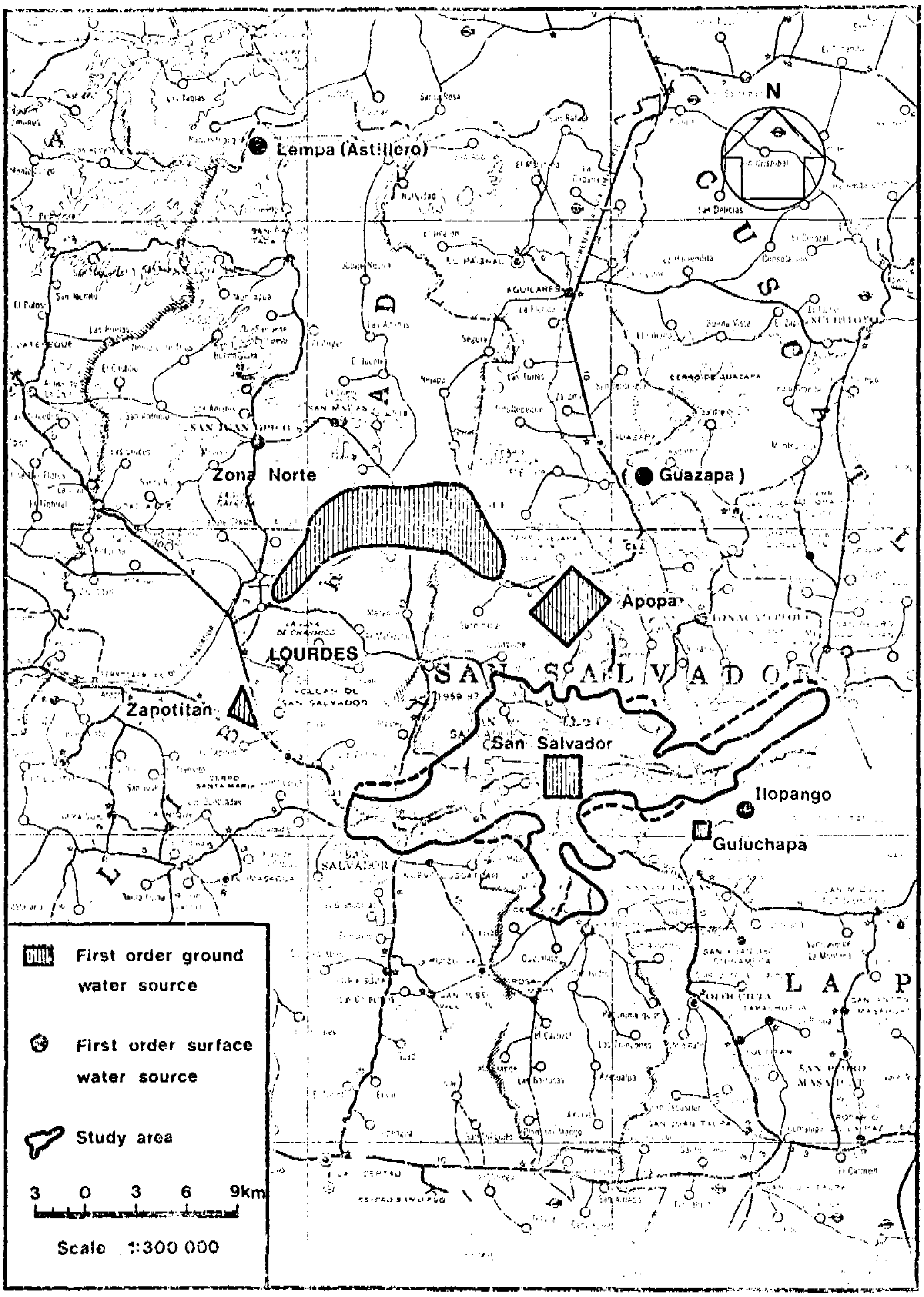
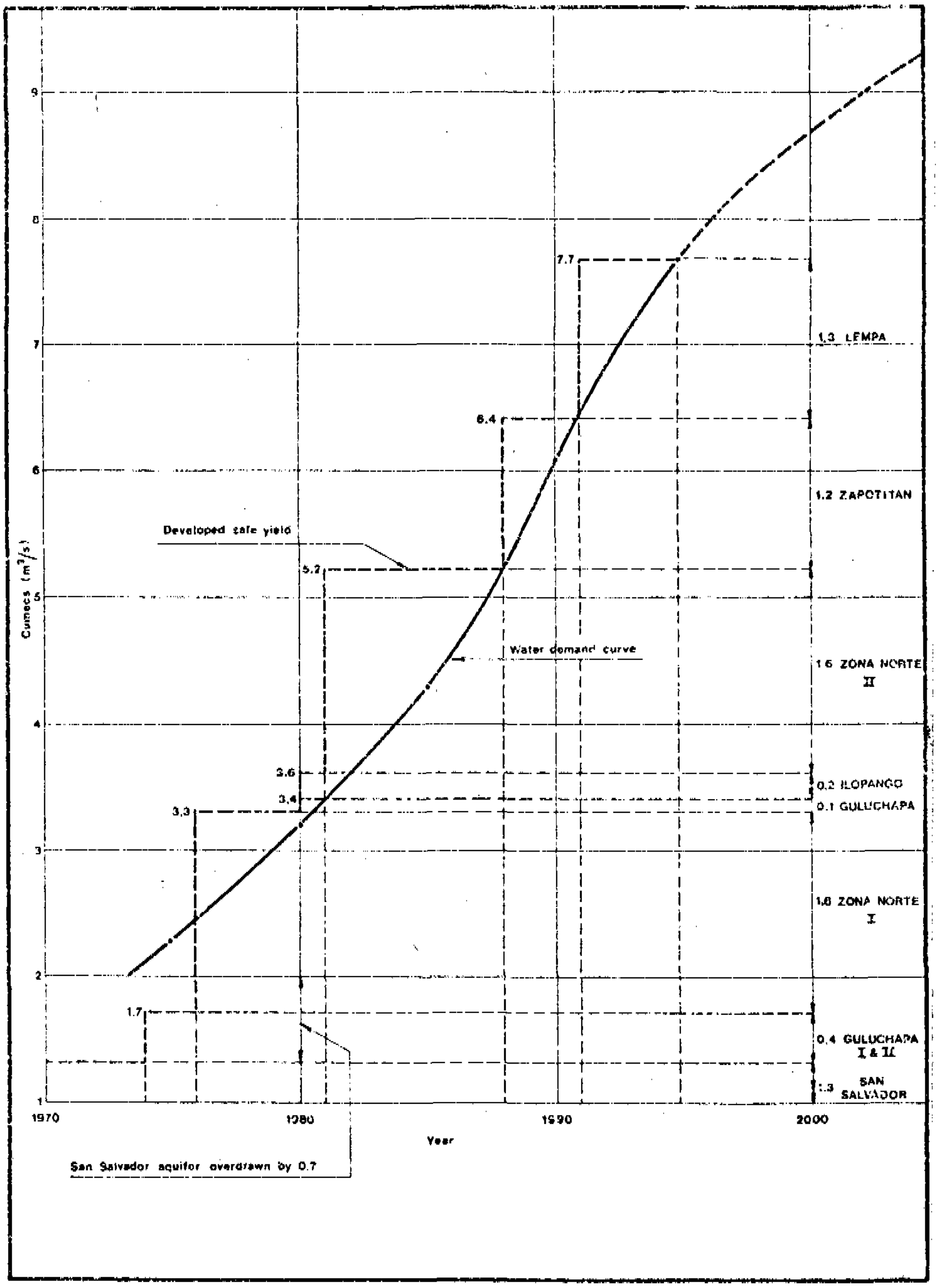


FIGURE 9: Phasing of proposed water supply schemes



Guluchapa has a catchment area of 38 km² and is a sub-basin of Lake Ilopango. The basin is formed of re-deposited materials, principally sands, tuffs and clays and generally exhibits good hydrological properties. The water table at the valley floor of this basin is at ground level and there is every possibility that when the valley is developed by borewells and the table lowered, further recharge water will enter.

Zona Norte Groundwater. The area lies to the north and north-west of the San Salvador volcano and the following possible sources were identified by the UNDP project team which they estimated could provide 3.2 m^3/sec for the city of San Salvador. These are summarised in Table 11.

TABLE 11: Zone Norte potential sources

Locations	Springs m^3/sec	Wells m^3/sec	Total m^3/sec
Recent lava flows in Quezaltepeque and Sitio del Nino	1.10	1.20	2.30
El Angel, Los Luceros, Nejapa	0.45	0.25	0.70
La Junta, north of Apopa	-	0.20	0.20
TOTAL			3.20

The UNDP report states that these estimates are conservative and their recommendations were accepted and work commenced early in 1973 on the detailed design of works for the Zona Norte Stage I scheme which will provide 1.6 m^3/sec for the City of San Salvador.

Zapotitan groundwater. The Zapotitan groundwater basin is part of a large flat fertile plain in the headwaters of the River Sucio to the west of the San Salvador volcano. This basin is extensively used for agriculture. The mean annual basin yield as assessed by the UNDP team is estimated at 4.3 m^3/sec. The Zapotitan basin is largely made up of pyroclastic deposits much of which are secondarily deposited by the rivers and have very variable distribution creating within a short distance aquifers, aquitards and aquicludes. The central portion of the valley has low transmissibility values. However, the UNDP team did identify an area in the south-east corner of the basin where good transmissibility values were obtained and they recommended that this should be developed for the City of San Salvador with an average annual yield of 1.2 m^3/sec.

Lake Ilopango. Lake Ilopango is a collapsed volcano crater lake of 72 km^2 in area and is only 10 km from San Salvador. In places it is 240 m deep and has a total catchment to the lake outlet of 200 km^2. The large available storage per unit depth so close to the city makes the lake a very attractive potential source. However the presence of 10 mg/l of boron salts (measured as boron) in the lake water means that the water is toxic to certain plants and is not very suitable as a source for the City except in admix with other water. It is suggested that when the Guluchapa source has been developed to its full potential of 0.5 m^3/sec that 0.2 m^3/sec should be extracted from Lake Ilopango and mixed with groundwater from Guluchapa.

River Lempa. The River Lempa is located 50 km north of San Salvador at its nearest point to the city. The Rivers Acelhuate, Sucio and Suquiapa all drain high polluting loads into the Lempa so that abstraction from the river for water supply should take place upstream of the highest polluted tributary, namely the Suquiapa. Initial estimates of the reliable run of river yield at Astillero upstream of the Suquiapa suggest a figure 10 m^3/sec so that in the long term the water supplies for the City of San Salvador are reasonably assured (see figure 8).

7. CONFLICT OF WATER DEMAND

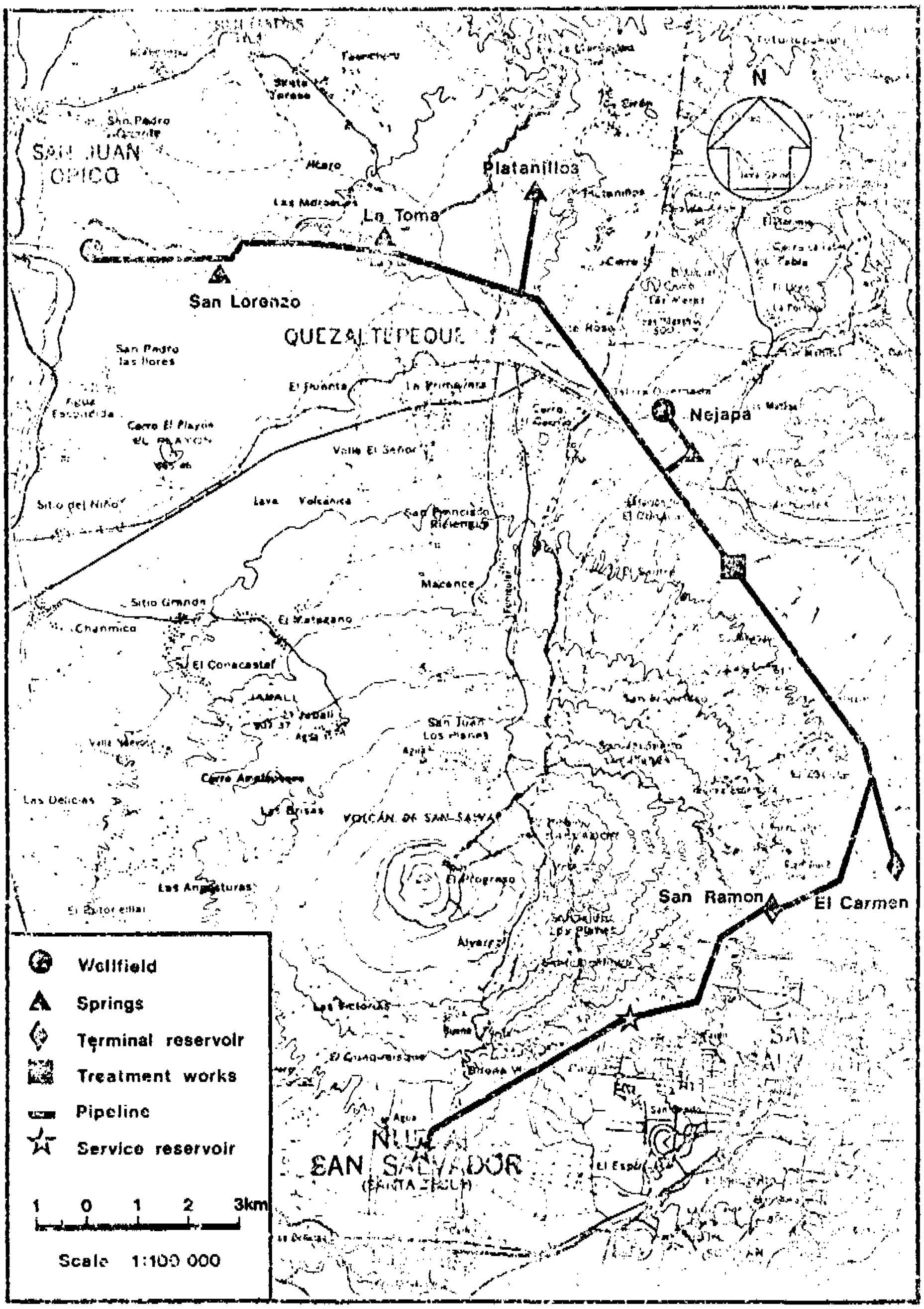
When considering new water sources for a city it is inevitable that the requirements of the city will conflict with other present and future uses. The United Nations project team report adopted the theme that the water supplies for the City of San Salvador should have priority over other considerations. This philosophy would seem logical in the light of the current rapid increase in the population of the city (4.6% per annum). The rate of growth of the city is very much greater than that of the country as a whole (3.5%) due to migration of rural population. This migration is creating an ever increasing problem for the city authorities and is being tackled by a rapidly expanding programme of low-cost housing. Also the World Bank is financing schemes to provide sites with services so that self-build schemes can be implemented. Obviously it would be a better solution if alternative foci of urban development could be established, but at present all the new industrial development in the country is centred at San Salvador. It will need strong government action/interference to reverse the present trends.

The first major scheme to be implemented will be the Zona Norte Water Supply Scheme which will supply an extra 138 million litres/day to the city. This scheme has now been designed and construction is about to commence, financed by Inter-American Development Bank funds. The scheme is shown diagrammatically on Figure 10 and involves the pumping of spring and borehole supplies into a common trunk main varying in size from 450 mm to 1200 mm diameter discharging to a water treatment plant. After treatment water is raised to the city by means of a high lift pumping station via a 1200 mm diameter steel main 15 km long against a head of some 300 mm. This station delivers to two separate control reservoirs. Distribution works in the city will include the construction of two major re-lift pumping stations, 40 km of ductile iron water mains varying from 1200 mm to 300 mm diameter and eleven service reservoirs varying in capacity from 20 000 to 4000 m^3.

In the River Sucio basin there are many conflicting requirements for water which will suffer when the Zona Norte Scheme is constructed. The Ministry of Agriculture are implementing a scheme to abstract irrigation water from the Rivers Sucio and Suquiapa to irrigate an area of some 4200 hectares in the Atiocoya region near the confluence of the Sucio and the River Lempa. During the most critical months this irrigation project will require irrigation water at the rate of 2.9 m^3/sec and it is proposed to extract 2.0 m^3/sec from the River Sucio and the balance of 0.9 m^3/sec from the Suquiapa. The minimum stream flows in the River Sucio once both stages of the Zona Norte Scheme have been implemented wil be very low and this scheme will not be feasible, and no special allowance was made to ensure a minimum flow in the River Sucio as it is considered a logical step to reserve the better quality water sources near to San Salvador to satisfy the future water demands of the city. The irrigation scheme could anyway be served directly from the River Lempa. It should be noted that one of the conclusions reached in the Sewerage and Sewage Treatment section of our study was that all sewage flows from the city should be transferred to the valley of the River Las Canas so that the Zona Norte water will not be returned to the River Sucio if this proposal is implemented. Figure 6 also shows the location of a small hydro-electric station on the Sucio (2500 kw, owned and operated by Caess). Its use will have to be discontinued when the Zona Norte Scheme is implemented.

The spring source at San Lorenzo has a small dam and diversion channel to take water over the River Sucio to a sugar-growing area. This irrigation facility will be lost to the local land owner when the Zona Norte Scheme is implemented.

FIGURE 10: Zona Norte supply scheme



At La Toma the spring water has been dammed to form a large swimming pool (1500 m^3). The area surrounding the swimming pool is at present being developed as a major tourist attraction by the Ministry of Tourism without recognising the fact that the considerable flows of spring water through the pool will be diminished when the supplies are requisitioned for the city and inevitably the water quality in the pool will suffer. It was felt that the risk would be too great to collect water downstream from the pool and the proposal is for capture works upstream with a provision of a small pump flow to the pool (50 l/sec). Proposals for providing a filtration plant for a pool of this size would obviously be very expensive.

Spring waters in the Apopa/Nejapa areas are used for power generation and cooling at sugar cane processing plants and for village clothes washing and these facilities will be lost when the Zona Norte Scheme is implemented.

The Guluchapa valley scheme which is being developed by ANDA at present will deplete flows in the Guluchapa River which is currently being used to irrigate vegetable crops.

When the Zapotitan source is developed this will have an inhibiting effect on the Ministry of Agriculture's long term plans for the development of irrigation schemes. The proximity of the valley to the metropolitan area and good possibilities of irrigation of the fertile soil have led to its development to supply agricultural produce, mainly root vegetables, corn and sugar cane. An area of 7000 hectares has been quoted in a report by the Ministry of Agriculture as being suitable for irrigation and a project is currently being developed to irrigate 4000 hectares[(7)]. The irrigation demand for the 4000 hectares at present under development has been assessed as follows: surface water demand - 1.8 m^3/sec; maximum groundwater demand - 1.0 m^3/sec. Of this up to 45% would be non-consumptive use and the excess would drain back to the River Sucio. There are plans for a new town to be developed at Lourdes (see figure 6) in the Zapotitan basin which ultimately will accommodate a population of some 180 000 and the utilisation of the mean annual yield of the basin could be as shown below but future irrigation projects would have to be curtailed unless treated sewage effluent from Lourdes new town were used.

TABLE 12: Proposed utilisation of mean annual yield in Zapotitan Basin

Irrigation of 4000 hectares	2.1 m^3/sec
Future water requirement Lourdes New Town	1.0 m^3/sec
Available for San Salvador	1.2 m^3/sec
Total	4.3 m^3/sec

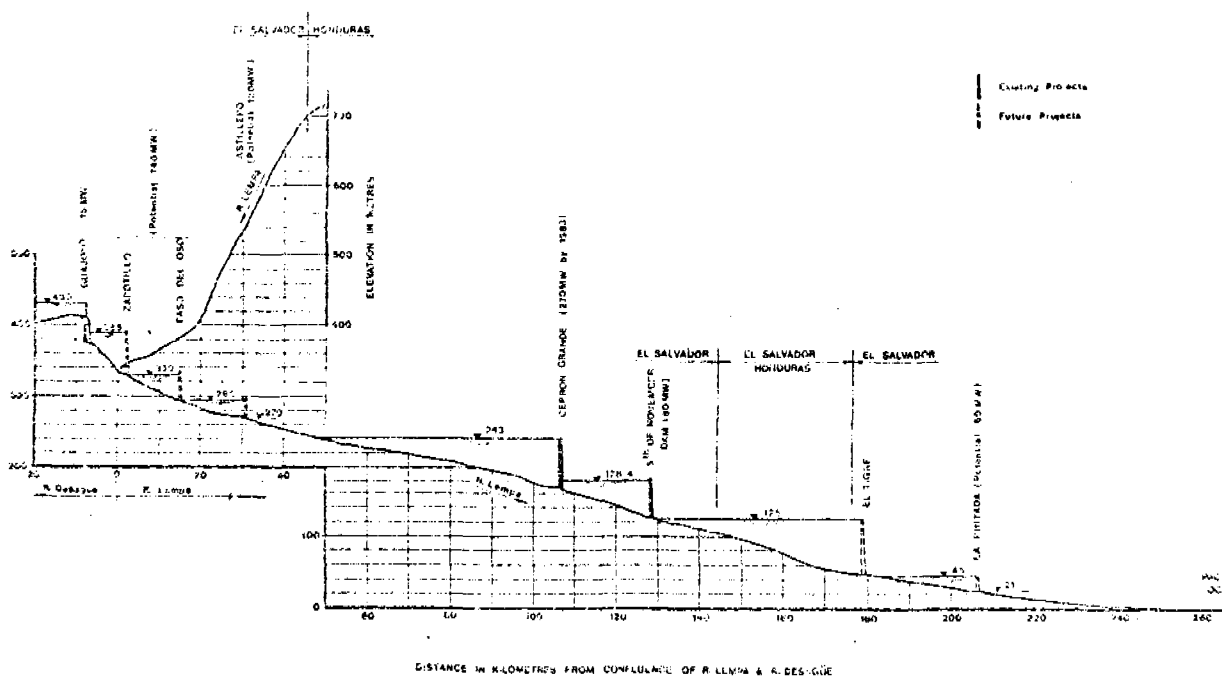
9. NEED FOR CONTROL OF WATER RESOURCES IN EL SALVADOR

The Government of El Salvador have been active in a policy of trying to provide job opportunities in San Salvador and have attracted many light industrial concerns to the city. The conditions are made particularly favourable for industrial investment in the city due to tax concessions and cheap and good labour resources. Industrialists have also been allowed to develop their own borewell water sources within the San Salvador aquifer without any control on abstraction. This has contributed to the over drawing taking place in the aquifer and has led to some of the existing wells supplying the city drying up at certain times of the year.

Again there has been no control on industrial discharges to sewers or watercourses and there are very great pollution problems in the country. For instance five-day BOD values as high as 400 ppm were obtained for river water samples taken from the River Suquiapa during December when coffee cherries are being processed to extract the coffee beans. Generally, coffee, sugar and sisal processing plants are sited adjacent to rivers and water is used and water is polluted indiscriminately without any effective control.

The River Lempa is the country's most important river and has already been developed at three sites for hydro-electric power generation[3], (see figure 11). The river passes through fertile valleys which could be irrigated but at the price of reducing flows available for power generation. This river has a portion of its catchment in Honduras so that flows available to El Salvador now cannot be guaranteed in perpetuity.

FIGURE 11: Development of hydro-electric power on River Lempa



An additional problem for the water resources of the country is the rate at which de-afforestation has taken place and due to the nature of the volcanic ash the natural terrain erodes creating even greater silt loads in rivers and producing infertile conditions on hillsides.

The need for control of the country's water resources was recognised in the United Nations project's report and reiterated in the Wallace Evans and Partners study[8] in which a National Council of Water Resources is suggested. The main task will be to establish a legal framework to allow such a council to be effective in deciding priorities for water use and control of pollution.

The above sounds very like the arguments used to bring about the Water Reorganisation in the U.K. One justification for this reorganisation was that the estimated consumption of 14.1 x 10^6 m^3 of water a day in England and Wales will increase to 2¾ x 10^6 m^3 of water a day[9]. These estimates assumed an increasing population and continued growth of industrial consumption. Already it looks as though our population is stabilising and in the last few years the growth in industry has not lived up to expectations due to the economic climate.

In the City of San Salvador the dangers of predicting future demands are far greater. One of the main causes of high per capita water consumption in the dry season is garden watering. It is arguable that as the city develops land which at present has properties with large gardens will be redeveloped to a higher housing density and the per capita water consumption could decrease. Also it is difficult to believe that the extremely rapid rate of expansion of the city will be maintained. Already a "low key" birth control programme is being implemented and a change in Government policy could well divert future industrial development to an alternative area. It is therefore likely that the development programme outlined in figure 9 will be considerably stretched. Leak detection is difficult in San Salvador as leaks do not show on the surface due to the porous nature of the subsoil. Due to low pressures in water mains domestic properties tend to have low level water storage tanks which fill over 24 hours so that night detection methods would not give a true picture. However, as new mains are laid and the distribution system improved waste should be reduced which again could affect the timing of implementation of future schemes.

The development of water schemes is also influenced by the cost of borrowing money. The Zona Norte Scheme is to be financed by a "soft" loan from the IADB and there may be some justification in buying as much water (and time) as the opportunity arises.

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discussion

CHAIRMAN: J M G van DAMME
Manager
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THE CHAIRMAN announced the start of the 2nd Session on the Latin America subject, saying that Mr Myerscough of Wallace Evans & Partners had worked in El Salvador for $1\frac{1}{2}$ years, and more recently in Saudi Arabia. He was much concerned with the planning element of the work mentioned in his paper.

2. Mr C T MYERSCOUGH said that rather than engineering, the main problems in carrying out a feasibility study had been connected with communication and politics. When he first went to El Salvador, armed with a crash course in Spanish, and tried using the telephone, the standard answer "A parte de quien" (i.e. "Who's speaking?") sounded so like "He's departed from here", he'd replied "Gracias", and put the phone down, mystified why so many people were always out! Mr MYERSCOUGH showed slides to illustrate various aspects of his paper and the following comments were by way of explanation of these slides:-

3. A.N.D.A. (Administracion de Aqueductos y Alcantarillados), the National Water and Sewerage Authority, was formed in 1961. Before that, the water and sewerage functions were carried out by the municipalities within the metropolitan area of the city of San Salvador, and all these had their own tariff system and their own way of implementing community schemes. A.N.D.A.'s responsibilities are for planning, finance, execution, operation and maintenance. It was set up to be an autonomous and self-financing institution, but unfortunately had never become self-financing and had to be subsidised by the Government. This subsidy currently amounts to some U.S. 1,000,000 dollars a year. A.N.D.A. is run by a board of directors which has a voting president and representatives from the Ministry of Health, the Ministry of Public Works, the Ministry of the Interior and the National Council of Economic Planning. They meet once a week to discuss Water Authority affairs. The Water Authority is divided into three divisions:- an engineering division looking after feasibility studies and the design of new work; an operations and maintenance division to look after the construction of new schemes and the maintenance of new equipment; and thirdly an administration division.

4. The dominant feature of this part of Central America is the Nicaraguan depression, along which there is a volcano every 30 kilometres or so. The area is subject to serious seismic activity, and therefore has its own design problems. El Salvador is lagging behind in the trend towards urbanisation taking place in most of the countries of the world, but is near to take-off point. The rainfall is high in El Salvador and is greatly influenced by the high ground formed by volcanoes. The drainage pattern of the country is influenced by the older rocks. Short rivers drain due south but the rivers from the Central Plain drain north to the main river of the country, the River Lempa. The areas where a cooler climate is available, on the slopes of the volcanoes, is used for coffee, sugar is grown in the central plains, and cotton on the hot coastal plains.

5. El Salvador's population of $3\frac{1}{2}$ million is growing at $3\frac{1}{2}\%$ per annum and will reach 7 million by the year 2000; the main preoccupation of the Salvadorean Government is how to feed an ever increasing population. The Ministry of Agriculture is therefore extremely keen to irrigate as much land as possible.

6. Erosion is a serious problem and the white volcanic ash washes down rivers, the process accelerated by extensive deforestation. The terrain is dry and burnt up from December until May. It is a pleasant climate for living as, in the capital of San Salvador, it tends to rain at dusk with the days being fine. Rain is associated with hurricane activity in the Caribbean and it is the fear of the Salvador Government that possible future artificial control of hurricane activity in the Caribbean could upset the climate of El Salvador and decrease the annual rainfall.

7. Lower-class type of housing in the city of San Salvador had timber walls and roofs of locally made clay tiles. Concrete pipes were used for sewers in San Salvador and there was no corrosion due to sulphides because the city was so steep that velocities were high. The city was set out in a typcially Spanish fashion with east-west and north-south streets on a grid system. These are generally very narrow and make the siting of new sewers difficult. There were a number of ravines running through the city down the slopes of the volcano. The volcanic ash provides good trench support, and generally does not require timbering - it is just like cutting cheese. During the study, it was found possible to safely maintain an excavation six metres deep without support.

8. On the slopes of the volcano water is extracted from bore wells. Lower down it emerges as springs and there are spring capture chambers. The city's main collector sewer follows the upper reaches of the River Acelhuate. This sewer was constructed in the years 1963-64, collecting the majority outfalls discharging into the River Acelhuate. However, there are still a lot of discharges going straight into higher reaches of the river - one example is a distillery effluent with a BOD of up to 25,000 mg/l. The sewer eventually discharges into the river on the east side of the city.

9. The river is used for a variety of purposes:- clothes washing, bathing and power generation. Power for a sugar mill is obtained from the city of San Salvador's sewage! One of the problems of the country is that the sugar mills need to be located near a water supply (for cooling purposes). One sugar mill on the bank of a river discharges effluent with a BOD of something like 500 mg/l plus a lot of waste sugar cane. There are at present no attempts to control or treat wastes from sugar mills. In coffee processing, the effluent from plants extracting beans from coffee cherries has a BOD of the order of 5000 mg/l. On the River Suquiapa there are ten coffee processing plants and their combined discharges have a polluting effect equivalent to a town with a population of 350 000. In El Salvador factories for decortication of sisal gave a very strong effluent with a BOD of something like 4000 mg/l.

10. The River Acelhuate receives raw sewage from the city of San Salvador, which itself has a population of 600 000 people. Children could be found playing in the river, and not surprisingly the figures for deaths from gastro-enteritis are very high - 60 per 100 000. Also, infant mortality for children under a year old is high - 60 per 1000. On the Acelhuate the river water, which is mainly sewage, is used to irrigate vegetables. Gauging stations had been installed on the River Sucio by the United Nations Development Project, whose study the Wallace Evans & Partners work followed, and readings were continued throughout the water study. For pollution studies, Mr MYERSCOUGH and his team used submersible temperature and dissolved oxygen recording equipment. They found that they were very unsuitable for the application because sediment in the rivers soon choked the sensors. Portable hand-held instruments were finally utilised.

11. Arkon depth recorders were used on the sewer system for flow measurement, the depths being calibrated by dilution techniques. Flows were measured at the outfalls of the main collector sewers.

12. The spring source at San Lorenso emerged from a bank of 1565 lava flow. A dam that had been built by a local farmer and water diverted to an irrigation channel and used to irrigate terrain on the other side of the River Sucio crossing the river by means of an aqueduct. This facility will be lost when this water is taken for the city of San Salvador.

13. At La Toma a swimming pool had been built, fed by a spring which only emerged after the 1917 earthquake. One of the local landowners decided that this was a golden opportunity to produce a swimming pool with a constant flow of sparkling water through it. The scheme proposed by Wallace Evans would capture the spring at the top end of the pool and pump spring water to the proposed water treatment plant. Only a very small flow through the swimming pool will then be left. This will represent a sad loss of a facility which is already supported by the Ministry of Tourism who have so far ignored the Water Authority's intentions.

14. Lake Ilopango, close to the capital, is very beautiful and is used for sailing. Unfortunately it cannot at present be utilised as a source of water for the city since its water contains 10 mg/l of Boron salts. Boron is not harmful to humans, even up to concentrations of 30 mg/l, but over 3 mg/l, Boron is potentially harmful to plants. Consequently, it could not be used for irrigating gardens.

15. A.N.D.A. have installed standpipes and handpumps as local water supply facilities. Mr MYERSCOUGH said that his team had recommended that all the sewage from the city should be picked up by a main collector sewer and transferred by means of a tunnel outfall sewer to the next valley to the east. In this way the sewage would be taken away from the immediate area of the city. The River Canas Valley is not very fertile and not developed, the terrain being too rugged. Eventually a treatment plant would be built there. Initially only primary settlement would be provided. The Acelhuate is a very steep river, and although it has a BOD of approximately 200 mg/l in the dry season, immediately downstream of the city of San Salvador, by the time it reaches the River Lempa some 60 kilometres away, the BOD is around 12 mg/l, so the natural purification in the river is very effective. There are no sewage treatment plants in El Salvador. The Wallace Evans & Partners study recommended that centres of urban population should be provided with sewage treatment facilities, and that there should be a system established for charging the industrialists for polluting the water courses on a basis similar to that adopted in Holland.

16. Mr MYERSCOUGH expressed his doubts about planning decisions in particular when forecasting populations and water demand. He also speculated whether it was right to transfer flow from one river basin to another. In the development of water sources for the city of San Salvador, water would be extracted from the River Sucio basin and would return as sewage to the River Acelhuate, reducing the available water for the Atiocoyo irrigation project further downstream on the River Sucio.

17. The CHAIRMAN thanked Mr MYERSCOUGH and said that El Salvador was an example of a fairly advanced country in that part of the world which represented many of the problems in planning of the water and sewerage.

18. Dr S M ROMAYA said that the speaker's doubts with regard to the forecasts of population, the degree of use etc., were by no means peculiar to sewerage schemes, indeed they are a problem for planners in general. He wondered whether it was possible to incorporate a degree of flexibility within the design to allow for a degree of variation from the forecasts.

19. Mr MYERSCOUGH had suggested in the study that the programme for the sources was very tentative and the whole field of water demand, water use and so on should be reviewed in detail every five years. Their demand figures for the city were based on the dry season when gardens were watered. With six months dry weather each year it was assumed that people would water their gardens and the design was based on the demand at the peak of the dry season. In Salvador, the whole scheme was to provide on average 1.6 m^3/s, but considerably less in the wet season and up to 1.9 m^3/s in the dry season.

20. Mr C PEEL asked whether there was a possibility of doubling the supply of water and also raising the quality if the trend continued, i.e. a 3.5% annual increase in population, doubling up in a matter of 25 years.

21. Mr MYERSCOUGH replied that whilst they were there it appeared possible to implement the water source development programme that they visualised. However the country was improving from an industrial point of view at a very rapid rate, because there was very good cheap labour. Industry might bring more money into the country and therefore finance

water supply schemes. But it was a "chicken and egg" situation. They were now very short of water so that industrialists would fight shy of going there. They therefore had to overcome this by putting in a major water supply scheme.

22. The CHAIRMAN wondered, in the light of what was just said, what were the difficulties.

23. Mr MYERSCOUGH thought that the difficulties were communication and politics. In El Salvador there were presidential elections every four years. Following elections the heads of all the ministries and water authorities change so that there was a problem of lack of continuity of staff. This inevitably resulted in series of short advances followed by static periods when the staff did not want to make decisions because an election was imminent.

24. Mr PEEL said that Mr Nehru when Prime Minister of India talked about water and food and said that India was running hard in order to stand still. It seemed to Mr PEEL that as fast as you had a scheme to provide water, there were more people needing it and the per capita amount could not be increased.

25. Mr M W CRABB said that Mr MYERSCOUGH mentioned that there could be a restriction on industrial and other economic expansion, but that people should not be restricted from watering their gardens. Did Mr MYERSCOUGH think that there should be some restriction possibly by cost?

26. Mr MYERSCOUGH said that A.N.D.A. had come up with an interesting solution. Those with high incomes in San Salvador tended to live higher up the volcano because the climate was better. A.N.D.A. had tried to introduce a system where the tariff depended on how high the water was pumped. However those with the political power also lived high on the hill and this tariff system was not implemented.

27. Mr CRABB asked if there was a problem of people refusing to pay their water bills and Mr MYERSCOUGH said that water was cut off if the bi-monthly bills were not paid within fourteen days. This was a matter that the Water Authority handled extremely well. Unfortunately only some 60% of the water meters were functioning and the remaining households were billed for a nominal amount. There is also a lot of scope in a rapidly developing city for clandestine connections which are very hard to trace.

28. The CHAIRMAN wondered why there were so many poor people in the city of San Salvador.

29. Mr MYERSCOUGH said that the population living in shanty town conditions was about 60 - 70 000. The people came from the country to the city to try to get work. Standpipes around the city provided water for these shanty town dwellers.

30. Mr A J H WINDER, referring to the swimming bath at La Toma, said that in a developing country these sort of facilities would be more and more valuable as land was used up and as the standard of living increased, and it seemed a pity to cut them out. Surely, Mr WINDER argued, the water undertaking would treat the water in any case and elsewhere would probably take supplies from rivers which might be infected anyway.

31. Mr MYERSCOUGH replied that they did not want to take this risk. For a long time they planned to have the proposed water pumping station downstream of the swimming pool and then decided that one pollution disaster would put the whole system at risk. In the eastern wellfield the study team did some pump tests close to the village of Nejapa and quickly dried up wells in the village and caused a local furore.

32. Mr A W SHILSTON noted that the author had said:- "despite cleaning and preparation, we still thought people were going to be pretty ill after eating sewage-irrigated vegetables". Mr SHILSTON wondered whether there was any evidence of the ill medical effects of irrigating vegetables with sewage.

33. Mr MYERSCOUGH said that it was dangerous to irrigate salad vegetables with sewage. Other crops could be irrigated with sewage as long as it was stopped a while before they were harvested. Based on what had been done in Israel, fruit trees could be irrigated provided sewage did not come into contact with the fruit. An American not issued to their Embassy staff in El Salvador suggested that salad ingredients should be washed in iodine.

34. The CHAIRMAN said that there seemed to be two reasons for this problem, one technical the other probably a psychological one.

35. Mr S PRAKASH wondered whether there was a survey carried out for unaccounted water, that is the difference between the quantity of water produced and the quantity of water supplied.

36. Mr MYERSCOUGH said this was a major preoccupation of his during their study. There were some thirty A.N.D.A. sources of water in the city. The study team installed flow recorders and measured the pressures over 24 hours on each of these. After several attempts, they thought that they established what the dry season water production was. But only 60% of the domestic meters were actually functioning, so they looked at areas from where more meters were functioning, and came to an estimate of about 30% unaccounted water in San Salvador. They also did work on waste detection which was abortive. Using a portable waste detection meter, they studied night flow in isolated areas, but had a difficult task trying to cut off house connections because most of the houses had night storage tanks which were filled by pumps when the mains pressures were higher.

37. Mr PRAKASH had noticed on one of the slides a standpipe where the water was all going down the drain. He wondered who was paying for this water, or whether it was a free standpipe?

38. Mr MYERSCOUGH said that there were a hundred free standpipes located near shanty-town dwellings.

39. Mr PRAKASH asked whether the 30% unaccounted water was included in these standpipes. Mr MYERSCOUGH said they had tried by observation to establish the amount of water taken from the standpipes and the 30% excluded what came out of the standpipes.

40. Mr C C KERR said that he would be interested to know if any steps were taken on the uses to which water was put e.g. gardening and other domestic uses. Was it possible to give any figures on this. Mr MYERSCOUGH said they initiated surveys of selected areas and found it was too difficult to establish the use-pattern.

41. Mr KERR then asked if the problem in the supply of water was due to urban drift. Could Mr MYERSCOUGH give any indication of water charges?

42. Mr MYERSCOUGH said that he thought El Salvador desperately needed to establish other centres of industry, but San Salvador was the only major city in the country and its bright lights attracted people from the country areas. There seemed no way of reversing this trend other than setting up similar foci elsewhere in the country.

43. A.N.D.A.'s water tariff had been drawn up in 1961. Since then they had several attempts at revising the tariff but each time it was met with so much opposition that the Government decided that they would rather support A.N.D.A. than approve a higher tariff. In 1973 the tariff was increased but it was nothing like the economical cost of water.

44. The CHAIRMAN said that somehow, on this particular problem, there were too many answers and not enough questions.

45. Dr ROMAYA suggested that there should be a minimum charge for small quantities and increased rates for greater quantities used. This would be better than current practice in some countries in the Middle East where the charges per unit decrease for larger quantities.

46. Mr MYERSCOUGH said that in El Salvador the squatters had free standpipes. Upper class houses would be charged more for water pumped up the hill and would also be charged up to 200% more for greater use of water but this tariff had not been implemented yet.

47. Mr M LANSDELL said that in Venezuela water charges were about 10p per cubic metre with increased charges over about 100 cubic metres. There was a very stiff connection charge of £15 000 per litre per second for estate developments. This covered sewerage as well as water supply.

48. The CHAIRMAN asked what was the reasoning behind this. Mr LANSDELL said that they reckoned that this covered the investment they had to make to increase the water supply.

49. Mr KERR said that in Malawi the charges were 40 - 50p per 1000 gallons and there were standpipes for those who did not want to buy. There was a feeling that if water was needed for gardens, then

much more should be charged.

50. Mr CRABB said that in the U.A.E. charges were about £2 per 1000 gallons, but two-thirds of the population did not pay their water bills! Those who did pay were largely in the higher income bracket.

51. Mr A W TURNER said that in Dacca, Bangladesh, 20% of the population were well below the bread line, and were on a ration card system. Water was obviously a necessity and a prevention against disease etc. so the Council suggested that everyone who had a ration card should be entitled to water. Most of the poor people are supplied by water from the 1400 standpipes in Dacca alone. If users were charged a certain sum, e.g. one day's pay per year for water against their ration card, it might prevent abuse.

52. Mr D R YOUNG said that a two-stage scheme had been recommended for El Ain. Above 350 litres per day the rate would be doubled. It was unlikely that the Government would accept this.

53. Mr H MANN returned to the irrigation of vegetables with sewage and thought there was a danger of trying to over-simplify the situation. It was always possible to irrigate plants with crude sewage but only with danger to health, which was much more serious in tropical than in temperate countries. Nevertheless crude sewage could be used for primary stages of crop growth and under reasonable control for the irrigation of such crops as fodder and timber. Partially treated sewage, even with primary treatment only, considerably reduced the health risks, and a number of cash crops such as coffee, sugar cane, cotton and oil seed could be irrigated. Provided irrigation with sewage was stopped for some time before harvesting, there was no reason why sewage should not be used to a greater extent in developing countries.

54. Mr LANSDELL was attacked by amoebic dysentry twice a year. This was largely transmitted by tomatoes and lettuce. Unless these were very well washed, amoebic cysts were often present. Even chlorination of effluent did not kill off the cysts.

55. Mr E H BIRD suggested that lettuce should be boiled for ten minutes! He then asked Mr MYERSCOUGH about the damage to sewers particularly those in turmoil caused by earthquakes.

56. Mr MYERSCOUGH had looked for evidence of damage to pipes during the 1965 earthquake which virtually destroyed the airport, and found that the sewer system had no recorded damage. They came to the conclusion that pipes flexed with the ground. Mr MYERSCOUGH went to Managua, in Nicaragua, immediately after the earthquake there, and looked at the water supply system and the damage done to it. At a valve chamber, the pipe on either side had sheared so that obviously the pipe was not vibrating in sympathy with the valve chamber. So for San Salvador they decided that flexible connections on either side of chambers were needed. They would investigate danger to the tunnel sewer outfall in detail once the go-ahead was given to build it. Obviously, they would want to know details of any faulting along the route of the tunnel.

57. Mr J G WILSON asked Mr MYERSCOUGH if any particular investigations were made into the possibility of earthquake effect on sources as some springs had been resited after earthquakes.

58. Mr MYERSCOUGH said that it was expected that larva flow might go down the north west side of the volcano again and could wipe out their western well field. It was hoped that the sources were so well spread out that the city would still have water. A.N.D.A. was more concerned with the possibility that the trunk main would be severed during an earthquake and suitable emergency arrangements would be set up to provide temporary piping. Fortunately, the source works are off the main earthquake zone which runs through the city centre.

59. The CHAIRMAN thanked the speakers for most interesting points brought forward.

R.J. HOLLAND

the improvement of domestic sanitation in unsewered areas of kenya

1. INTRODUCTION

The intention of this paper is to describe the problems which arise when providing domestic sanitation in unsewered areas and to show how one country, Kenya, is attempting to overcome these difficulties.

The selection of Kenya as an example is solely because the author has recent experience of this country's problems and their solution. Similar situations - indeed often much worse situations - may in the author's experience be found in virtually every country of the world.

Kenya is, in fact, to be congratulated because its Government realises the advantages of proper sanitation and is actively taking steps to overcome its present problems. The initial step was to take advice from the World Health Organization.

The benefits of proper sanitation are well known and are here summarised only to set the following technical discussion into perspective:

- The reduction of hazards to human health
- The prevention of unacceptable or uneconomic pollution of water resources
- The elimination of aesthetic nuisance
- Improved convenience.

Kenya has the common problems of a rapidly increasing population, especially in urban communities, rapidly advancing industralisation and rising living standards.

The Kenya Government is attempting to keep pace with these changes and in the sanitation field has the objective of ensuring that every dwelling and every business and factory in the country will have adequate sewage disposal arrangements by the end of this century.

TABLE 1: Summary of domestic sewage disposal methods anticipated in Kenya, outside Nairobi, by the year 2000

Type of Community or area	Anticipated Sewage Disposal Method (thousands of persons)								Projected population for year 2000 (thousands)
	Sewerage	Septic tanks	Large (1) cesspools	Small * cesspools	Aqua-privies	Pit latrines	Bucket lavatories	None	
Nomadic	-	-	-	-	-	300	-	700	1000
Low potential rural	-	60	-	-	60	2010	60	110	2300
Medium & high potential rural	20	730	40	350	-	12 560	-	-	13 700
Low density urban	350	360	30	150	170	440	-	-	1500
High density urban	5700	180	60	-	60	-	-	-	6000
Totals	6070	1330	130	500	290	15 310	60	810	24 500

(1) That is, dealing with water-borne sanitation

* That is, not dealing with water-borne sanitation

The sub-objectives of this programme are:

- The provision of sewerage in more intensely populated urban areas (including all those with more than 124 persons per hectare).
- Every sewage disposal installation constructed in the future shall be appropriate to the circumstances and properly designed and constructed.
- Every sewage disposal installation in Kenya shall be effectively used, operated, maintained and serviced.

It may appear that the first of these sub-objectives will eliminate Kenya's domestic sanitation problems, but this is not the case. Table 1 shows that even with the intensive sewerage capital development programme - estimated to cost Kenyan £212 million (approximately £300 million sterling) at 1972 prices - needed to achieve this sub-objective by the year 2000, the overwhelming majority of Kenya's citizens will still be served by individual-type domestic sanitary installations.

This is the justification for paying increasing attention to the choosing, design, construction and servicing of such facilities, and for this Paper.

2. BACKGROUND TO MY INVOLVEMENT

An agreement for the development of rural water supplies in Kenya, signed in 1970 by the Swedish and Kenya Governments, contained the requirement that the Kenya Government should establish long-term national plans for water supply development.

Discussions concerning this plan demonstrated the need for a national study into the Kenya Water Sector; the World Health Organisation (WHO) was chosen as the executing agency. The review and national planning of sewage disposal, plus the preparation of national guidelines and design criteria, were included in the study.

Field operations commenced in 1971. The study was essentially a co-operative effort between WHO and the Water Department of the Kenya Government. WHO provided a team of nine experts, who worked in Kenya for varying periods. The Kenya Government provided experts and support staff, to bring the total input to 500 man-months of which the WHO input was one-third.

A total of seventeen reports were issued by the study team. I had the honour of being the WHO Sanitary Engineer responsible for the sewage disposal reports.

The study ended in 1973. I had the privilege of being invited back to Kenya as Project Manager on the second or implementation phase. Specifically, my task was to implement the recommendations in the sewage disposal reports which included establishing the first Kenyan national sewerage agency. This became a division within the Water Department of the newly-formed Ministry of Water Development.

I spent the next two and a half years as a WHO staff member heading the Sewerage Division in the Kenya Government. During this time the Sewerage Division grew in numbers and prestige and was able to initiate a national sewerage development programme, sewerage training courses for sub-professional Government personnel, plus several more of the report recommendations.

It was an interesting and exciting period of my career. The material in this Paper is in part abstracted from the WHO sewage disposal reports, and is partly based upon my subsequent experience.

3. METHODS CURRENTLY USED IN KENYA

It is not intended in this section to give comprehensive descriptions or design details of the various methods of domestic sanitation. To do this would obscure the primary purpose of this Paper. The brief descriptions which are given should be regarded rather as definitions abstracted from a glossary.

Also, with the aim of simplicity, no attempt has been made to discuss the relative merits of the variety of improvements and inventions now available which go to improve the efficiencies of the various methods. For example, in recent years excellent techniques for improving the water seal on aqua-privies have been developed.

This paper instead deals with the basic form of each, on the assumption that the most suitable variations will be taken into account and adopted when preparing standard designs (see section 5).

Summary of the situation

In 1972 the total population of Kenya was approximately 12 millions, of whom perhaps five percent lived in Nairobi. Of those living outside Nairobi, only 0.9 millions lived under urban conditions, leaving a balance of 10.5 million rural dwellers.

The types of villages which occur in Europe are unusual in Kenya; here the rural population tends to live on scattered smallholdings or farms, grouped generally around market and local centres, and the towns and cities.

The WHO study carried out during that year revealed that, outside Nairobi, the types of domestic sewage disposal facilities were divided approximately as follows:

- Primitive sanitation - 51% of the population
- Conservancy systems (bucket latrines or cesspools) - 3%
- Pit latrines - 40%
- Septic tanks or aqua-privies - 4%
- Sewerage - 2%

This tends to give an optimistic picture of the situation, as many of the installations were found to be inefficient and were health hazards. This was often because they had been poorly designed or in the case of septic tanks, aqua-privies and pit latrines, because they had been constructed in unsuitable ground. However, the great majority of troubles and difficulties resulted from bad maintenance and poor servicing.

Primitive methods

This term is here used to cover the variety of simple waste disposal methods ranging from indiscriminate urination, defaecation and sullage disposal to hygienic waste burial.

Direct excretion on to the ground surface is inexcusable in any type of community. It is perhaps acceptable for persons travelling or living alone in remote areas, provided some discretion is exercised.

Indiscriminate excretion on the ground surface or, even worse, into watercourses, is no doubt the reason for the prevalence in Kenya of disease, including bilharzia (schistosomiasis) which is present in most streams and rivers. Particularly dangerous is the nomads' habit of excreting close to the unprotected wells found in the arid regions.

Burying excreta, if carried out quickly and conscientiously, is satisfactory for communities in sparsely-populated areas. Either a shallow trench latrine, into which a layer of soil is added after defaecation, or a soil box, the contents of which are regularly emptied, are satisfactory.

Unhappily, the regular burial of wastes requires a measure of discipline and so unless there are servants to do this work, or there is an overall discipline as in a military camp, burial systems cannot normally be relied upon to continue.

The indiscriminate disposal of sullage, which is water dirtied as a result of domestic washing or food preparation, is normally not so dangerous to health, provided that the population density is not high, the ground on which the sullage discharges is permeable and there is no danger of it polluting water supply sources.

Where quantities of sullage are small, and buildings not too close to each other, throwing a bucket of dirty water on to the ground causes little trouble; a combination of soakage and evaporation soon eliminates the pool.

If rather more sullage is discharged from a sink drain then where plots are large, a simple system of shallow ditches will often suffice and will help irrigate crops. However, this method often provides conditions suitable for insects and vermin, and can be a health risk and cause nuisance. It should be remembered that sullage can contain a wide range of unpleasant suspended matter which can decompose anaerobically, in addition to grease which clogs the ground.

It is never satisfactory to discharge sullage on areas where it will pond, or into shallow open drains which often merely transport the resulting health hazard to another location. However, this rule is rarely obeyed with the result that pools of water or patches of damp ground are always apparent in populated areas in Kenya, even during the dry seasons of the year.

Conservancy - bucket latrines

Bucket latrines should comprise leak-proof containers which are frequently emptied before they become full. The buckets are usually small, and normally deal with excreta only.

Even at their best bucket latrines have very few merits unless expensive sterilising chemicals are regularly added to their contents; this is rarely the case in a country such as Kenya.

The more usual picture of a bucket latrine is of an unhygienic and offensive facility, nearly always leaking or overflowing and usually surrounded by vermin and insects, many being of the types which help spread human diseases. Sometimes a degree of cleanliness is achieved in Kenya by keeping poultry which devour insects. The need to install bucket latrines in a simple shed, from which they may be quickly removed, frequently means that they are at all times visible to the passers-by.

At the very least, each time they are emptied the buckets should be properly washed and disinfected, unhappily a rare occurrence as the servicing then changes in degree from simple bucket-emptying to carting away full buckets to a central cleaning depot.

The operation of collecting and disposing of nightsoil from bucket latrines is usually nauseating. In some Kenyan towns the buckets are manually carried long distances to the disposal ground. Except in the cities and large towns, a common method is to empty the buckets into handcarts, each comprising an empty drum supported horizontally across two wheels; when full the handcarts are dragged away to be tipped and emptied into a sewer, septic tank or local depression. Only rarely are the buckets and handcarts washed after use; spillage of nightsoil is frequent and health hazards are alarmingly obvious.

The installation of a bucket latrine does not solve the problem of disposing of sullage and where the ground is unsuitable this normally adds to the unhygienic conditions.

Pit latrines

Pit latrines are intended to deal only with excreta and should not receive sullage. If they do, rapid clogging of the wall surfaces and surrounding ground is liable to occur; flooding during wet weather can have similar effects.

Pit latrines are by far the most common type of constructed domestic sewage disposal facility in Kenya. Although there are communal pit latrines, most are private, serving only one family.

Where the ground is permeable and the water table low, pit latrines can operate well; however, care must be taken to ensure that seepage from a latrine cannot pollute underground water extracted from adjacent shallow wells. This danger is often overlooked.

When a pit latrine becomes full it should be covered by soil and replaced by a newly-dug pit. This requirement alone normally rules out a pit latrine as a method suitable for an urban environment where undeveloped land is scarce. This unsuitability is reinforced by the desirability of locating a pit latrine, which must always be regarded as a potential danger to health, at least ten metres from any dwelling or food storage and preparation area. This requirement is not always appreciated and a great number of pit latrines are improperly located too close to and even occasionally inside dwellings.

Pit latrines are frequently excavated in poor ground without sufficient internal support so that ground collapses become a constant nuisance and threat. Pit latrines are not suitable where the ground is impermeable or waterlogged. In such circumstances they fill rapidly. Although theoretically this problem could be overcome by frequent replacement by new pits, in practice pit latrines in such circumstances almost invariably overflow and spread diseases, especially hookworm.

Emptying of pit latrines should never be sanctioned, although this is a far from uncommon practice. The need to empty a pit latrine is a clear indication that this method of sanitation is unsuited to the circumstances. A generous description of such pits is that they are sub-standard open cesspools with difficult access for emptying.

Emptying of pit latrines does occur, usually manually - a dreadful task. This produces the problem of disposing of the pit contents, which in practice is frequently on to the nearest undeveloped site.

In hot districts pit latrines tend to smell and attract insects. These two problems can be controlled if the latrine slab is regularly cleaned and disinfected - a difficult task if the slab is not of concrete. In the past some local authorities in Kenya have very commendably supplied concrete pit latrine slabs to private individuals at nominal prices. However, the majority of pit latrine covers in this country are still of timber.

Where pit latrines are used there is normally the additional problem of how to dispose of sullage. The better method in permeable ground is to construct, as it were, a second pit latrine but filled with rubble and then covered to act as a soakage pit for the sullage. In particularly good ground rubble-filled covered trenches are equally suitable. Both these methods of sullage disposal are rare in Kenya today.

Aqua-privies

An aqua-privy can be considered to be a cross between a pit latrine and a septic tank, the tank being substituted for the pit. The watertight septic tank has a high outlet which allows the more liquid contents of the tank to overflow into a sub-surface ground soakage system. The normal arrangement on the relatively few aqua-privies found in Kenya is for the cover slab to have a simple squatting hole formed around a vertical pipe which extends below the surface of the liquid in the tank.

An aqua-privy is hygienically preferable to a pit latrine, provided that the ground is sufficiently permeable to absorb the overflow and the water seal is maintained by the frequent addition of water. For this latter reason aqua-privies have generally proved more satisfactory in Moslem areas as it is the admirable custom of these peoples to wash their bodies after using the toilet; the water thus used is sufficient to maintain the water seal.

Aqua-privies need de-sludging but only at infrequent intervals. However, as they are normally provided for low cost housing in smaller towns, the relatively limited servicing they require is usually ignored. The result is that in time most aqua-privy installations provided in Kenya have become entirely clogged by semi-dried sludge, which can only be removed by manual excavation.

Conservancy cesspools

Cesspools essentially are watertight sewage storage tanks; for hygienic operation they must be sufficiently large to hold all the sewage produced between emptyings, with sufficient spare capacity to allow for additional inflows due to visitors or arising from breakdowns in emptying arrangements. Provided that cesspools are carefully and inoffensively emptied at frequent regular intervals they are both sanitary and satisfactory.

However, cesspools are expensive, especially where the water supply is piped so that water usage is high and the cesspools must therefore be large.

Cesspools are used where ground soakage is not possible. This could be because the ground is impermeable or waterlogged, or because a high density of development allows no spare ground for soakage systems. If these conditions do not exist then the much cheaper septic tank, with its considerably reduced servicing requirements, is a more suitable facility.

There are very few properly designed and constructed cesspools in Kenya. There are many sub-standard installations, however, plus a large number of pit latrines and septic tanks provided in unsuitable circumstances which inadvertently act as cesspools. The most common fault is that the cesspools provided are too small so that they overflow instead of storing all the sewage they receive. Often the overflow is through a pipe or hole deliberately left in the side of the cesspool by the builder. The overflowing sewage pollutes ground surfaces and water resources and this defeats the initial object of attempting to provide a sanitary installation.

The frequent and regular servicing of cesspools is a major problem in Kenya at the present time except in a few larger towns and cities. Because of the relatively large volumes of sewage involved, emptying is a task which can feasibly be carried out only by the use of cesspool-emptying vehicles, the operation of which demands a relatively high level of organisation and sophistication, and funds. Also there must be suitable discharge and disposal arrangements for the collected contents, preferably at a sewage treatment works designed for this task. In many districts in Kenya cesspools are emptied by means of hand buckets, a most distasteful and dangerously unhygienic method; transport of the contents is often by offensive open ox-carts; spillage is inevitable.

The cesspool will always have applications in Kenya. However, sewerage is an alternative which is so very much better and normally cheaper than a series of cesspools for urban areas.

Septic tanks

The septic tank is a watertight container with a high outlet which discharges sewage after settlement into a sub-surface soakage system, or occasionally to a further treatment unit. Treatment of septic tank effluent is only feasible on a communal scale and as this arrangement is thus more correctly classified under 'sewerage', it will not be discussed further in this Paper.

Where ground soakage is possible and permissible a septic tank can be an excellent method of disposing of all the sewage from a household. However, in congested areas or under impermeable,waterlogged or other ground conditions where soakage is impossible, a septic tank becomes merely an overflowing undersized cesspool. Septic tanks in Kenya have in many cases been constructed where the ground is unsuitable. Most of these have either natural or purpose-made, but nevertheless illegal, overflows into a convenient ditch or low-lying area.

For correct functioning the capacity of a septic tank is proportional to the daily sewage inflow and so capital costs can be reduced by disposing of sullage elsewhere; however, where the sullage has a high solids or grease content, as from high class housing, this is very often a false economy because the sullage will quickly block any ground soakage arrangement if it does not first pass through a septic tank.

In Kenya septic tanks provided are often poorly designed or too small. A properly designed tank is relatively large and intricate and there is a great temptation for builders to cut costs. If a septic tank is too small then solids are carried over in the effluent to block the ground soakage arrangements. In the extreme the tank may be relatively so small that scour prevents the settlement of any sludge, and the installation does not function.

Occasionally, but regularly, accumulated sludge needs to be removed from a septic tank. A septic tank is thus dependent upon proper servicing which is often lacking in Kenya. It is common practice to delay emptying a septic tank until sludge accumulation causes blockages. If sludge is not emptied from a septic tank it will accumulate until it is carried over in the effluent. This sludge will quickly block any ground soakage arrangements, thus converting the septic tank plus its soakage system effectively into a cesspool. Ground soakage systems for septic tanks in Kenya are of two general types. Although the usual arrangement is to have open-jointed pipes laid along a rubble-filled trench, soakage pits are also common. These resemble pit latrines; they are usually hollow and covered by a slab containing a manhole cover for access.

When sludge carried over from a septic tank blocks a soakage trench the usual remedy is to extend the trench or to build more trenches in parallel. When the walls of a soakage pit become blocked, either more pits are constructed in series or frequently the walls of the blocked soakage pit are manually scraped to remove the deposited sludge which is causing the trouble. Sadly it is thus usually the symptom resulting from poor servicing which is dealt with rather than the lack of servicing which is the cause of the trouble. The extension of soakage trenches and the scraping of soakage pits has in Kenya tended to become the accepted method of servicing a septic tank.

By far the best method of de-sludging a septic tank is by means of a cesspool-emptying vehicle, but in Kenya these are owned by only the largest towns and cities. In other districts small wheeled tanks fitted with handpumps for raising the sludge into the tank are used. Poorer communities empty septic tanks by means of buckets. This means often that the sludge is merely dumped on the ground surrounding the tank. At the best, when emptying is manual, the sludge is taken away in open ox-carts.

The supervision and servicing of sanitary installations

The reasons why so many installations in Kenya produce disappointing sanitary results may be summarised as being because a high proportion are inappropriate to the circumstances, a large number of those which are properly chosen and planned are badly sized, designed and/or constructed, and few are properly serviced and maintained. Supervision by competent trained personnel is the only solution to the incorrect choice, design and construction of facilities.

Bucket latrines, aqua-privies, cesspools and septic tanks all need regular and efficient servicing. The organisation of such servicing is beyond the scope of individuals and in an advanced society must be considered the responsibility of the local public authority.

There appears to be an almost universal opinion amongst lay persons that once funds have been allocated and spent to provide an installation then financially that is the end of the matter. This opinion is not confined to domestic sanitation or even to community sewerage. As a result, time and again public authorities controlled by lay persons completely underestimate the manpower and financial requirements of servicing and maintenance. The smaller town, urban and rural councils of Kenya have in the past fallen into this trap, with the result that most have found they are unable to service regularly and properly the domestic sanitary installations they have correctly insisted upon and approved.

4. COMPARISONS BETWEEN DOMESTIC SANITARY ARRANGEMENTS

An immediate difficulty is that the different methods do not all perform the same function, as the following examples show:

i) Septic tanks followed by efficient ground soakage can effectively dispose of all the sewage - that is excreta plus sullage - from a household, producing only a relatively small volume of sludge in the process.

ii) The two conservancy systems, i.e. bucket latrines and cesspools, merely store sewage pending its periodic removal and disposal collectively with the sewage of others in the community. Thus these are not truly methods of domestic sewage disposal.

iii) Bucket latrines and pit latrines deal only with excreta and not with sullage.

iv) Cesspools and septic tanks are the only individual-type arrangements which can deal with waterborne sanitation i.e. the drainage from water closets.

For this reason the following comparisons are not strictly valid. However, they are considered to be sufficiently accurate to produce meaningful conclusions.

Technical comparisons

Regardless of the sanitary arrangement adopted, the owner usually has a choice, unless the local authority dictates otherwise, as to how he disposes of sullage. For example, if the installation is a septic tank he could discharge his sullage directly on to the ground, into a sub-surface soakage system or through the septic tank. The total capital cost of the septic tank installation obviously varies with his choice.

Taking into account these alternatives, the various possible methods are listed and described in Table 2 'Sewerage', which in this Paper implies a sewer system plus all plant for pumping and treating sewage before disposal, is included for purposes of comparison.

TABLE 2: Various methods of domestic sanitation

(note: This table also serves as a key to Tables 3, 5 and 6)

ABBREVIATION	DESCRIPTION
LAND	Excretion directly on to the land surface.
BURY	Excreta buried; sullage discharged on ground.
BUCKET-G	Conservancy-bucket latrines; sullage discharged on ground.
BUCKET-S	Conservance-bucket latrines; sullage disposal through sub-surface drains or soakage pits.
PIT-G	Pit latrine; sullage discharged on ground.
PIT-S	Pit latrine; sullage disposal through sub-surface soakage system.

AQUA PRIVY-G	Aqua-privy; sullage discharged on ground.
AQUA PRIVY-S	Aqua-privy; sullage disposal through sub-surface soakage system.
AQUA PRIVY	Aqua-privy; sullage discharged into privy.
CESSPOOL-G	Conservancy-cesspool; sullage discharged on ground.
CESSPOOL-S	Conservancy-cesspool; sullage disposal through sub-surface soakage system.
CESSPOOL	Conservancy-cesspool; sullage discharged into cesspool.
SEPTIC TANK-G	Septic tank; sullage discharged on ground.
SEPTIC TANK-S	Septic tank; sullage disposal through sub-surface soakage system.
SEPTIC TANK	Septic tank; sullage discharged to septic tank.
SEWERAGE	Public sewers connected to sewage treatment works; sullage discharged into sewers.

TABLE 3: Advantages and disadvantages of various methods of domestic sanitation.

SEWAGE DISPOSAL SYSTEM	Hygienic to use	Convenient to use	Public health hazard	Aesthetically satisfactory	Public nuisance	Suitable in impermeable ground	Unlikely to contaminate ground surface	Unlikely to contaminate underground drinking water	Unlikely to pollute surface water resources	Low capital cost	Cheap and easy to maintain	Maintenance is inoffensive	Public health risk if unit is not emptied regularly
LAND	+++	+++++	+	+	+	+++	+	++	+++				
BURY	+++	++	+++++	++++	++++	+++	++++	++++	++++	+++++	++++	++++	
BUCKET-G	+	++++	+	+	+	+++	+++	++++	++++	+++++	+++	+	+
BUCKET-S	+	++++	+	++	++	+++	+++	++++	+++++	++++	+++	+	+
PIT-G	+++	++++	+++	++	++	++	+++	++	++++	+++++	++++	++++	++
PIT-S	+++	++++	++++	+++	+++	++	++++	++	+++++	++++	++++	++++	++
AQUA PRIVY-G	+++	+++	++++	+++	+++	++	+++	++	++++	++++	++++	++++	+++
AQUA PRIVY-S	+++	+++	+++++	++++	++++	+	+++++	++	+++++	+++	++++	++++	+++
AQUA PRIVY	+++	++++	+++++	++++	++++	+	+++++	++	+++++	++	++++	++++	++++
*CESSPOOL -G	+++++	+++++	++++	++++	+++	++	+++	++++	++++	++	++	+++	+
*CESSPOOL -S	+++++	+++++	+++++	+++++	++++	++	+++++	++++	+++++	+	++	+++	+
*CESSPOOL	+++++	+++++	+++++	+++++	++++	+++++	+++++	+++++	+++++	+	+	+++	+
*SEPTIC TANK-G	+++++	+++++	++++	++++	++++	++	++++	+++	++++	+++	++++	++++	+++
*SEPTIC TANK-S	+++++	+++++	+++++	+++++	+++++	++	+++++	+++	+++++	+++	++++	++++	+++
*SEPTIC TANK	+++++	+++++	+++++	+++++	+++++	+	+++++	+++	+++++	++	++++	++++	++++
*SEWERAGE	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	++	++++	+++++	

NOTES: The more plus signs the better.

*It is assumed that water closets are connected to these units.

The technical advantages and disadvantages of the various methods are summarised on Table 3.

Cost estimates

Records of unit costs for domestic sanitary facilities are not systematically recorded in Kenya. Appendix B gives the bases for the estimates given in this section. The calculations leading to these cost estimates are detailed in Appendix A. Even where records do exist it is difficult to determine typical unit costs for any method; costs vary, for example, with the location, with the ease of excavation of the ground and with the sophistication of the building provided over a pit latrine or aqua-privy. Sewerage costs have even more variables. Inter alia, they depend upon ground conditions, topography and population density. For these reasons the estimated average unit costs which follow, although they are considered to be generally applicable throughout Kenya outside Nairobi, do not necessarily apply to any particular project in any particular location.

The estimated capital and running unit costs together with the anticipated working lives of the various sewage disposal installations listed are summarised on Table 4. This table has been based on an assumed average number of five persons per household or per latrine unit, except in the case of pit latrines where a figure of eight persons has been used.

TABLE 4: Approximate unit capital and running costs of various methods of domestic sewage disposal

Method		Capital cost	Life of unit in years	Annual running costs
BUCKET LATRINE		16	0.5	114
PIT LATRINE		60	8	24
AQUA PRIVY	Tank	320	15)	
	Soakage		)	64
	arrangement	120	5)	
CESSPOOL		4800	20	268
SEPTIC TANK	Tank	1600	20)	
	Soakage		)	16
	arrangement	300	5)	
SEWERAGE with conventional treatment				
(i) Sewers		800	40	16
(ii) Treatment		800	25	60
SEWERAGE with oxidation ponds				
(i) Sewers		800	40	16
(ii) Treatment		240	30	12

Notes: (next page)

Notes:

(i) All costs are based upon 1977 values.

(ii) All costs are given in Kenyan shillings (£1 sterling currently equals approximately 14 Kenyan shillings).

(iii) All costs given are per capita.

(iv) The costs for cesspools assume water-borne sanitation.

(v) The individual owner pays the running costs for pit latrines; all other running costs are paid from public funds.

(vi) Except for pit latrines where eight users have been assumed, the costs are based upon an average of five persons using each facility.

(vii) In this context 'conventional treatment' of sewage implies a treatment works constructed using permanent materials and providing preliminary, primary and secondary treatment. The oxidation ponds will provide the same degree of treatment as 'conventional treatment' works.

Cost comparisons

Table 4 does not allow simple economic comparison between the various methods. Direct comparison becomes possible when the unit capital costs are converted into annual costs. Figures 1 and 2 have been prepared in this way from the information presented in Table 4. Interest rates of 6% and 10% respectively have been used to compile these two figures.

Conclusions drawn from cost comparisons

The more important conclusions arising from figures 1 and 2 include the following. It should be noted that they are not sensitive to the rate of interest:

(i) Pit latrines are undoubtedly the cheapest method.

(ii) Cesspools are relatively very costly.

(iii) Bucket latrines are more expensive than sewerage, where treatment is by oxidation ponds.

(iv) Aqua-privies are comparable in cost to sewerage.

(v) Septic tanks are more expensive than sewerage.

However, as explained earlier, the costs of sewerage are dependent upon a variety of circumstances including ground conditions and population density, so there will be many particular instances where sewerage is more costly than bucket latrines, aqua-privies or septic tanks. Also, as previously noted, the various method are not strictly comparable and therefore decisions as to which disposal method to choose cannot be based solely upon financial reasoning. Other factors are also important.

FIGURE 1: Comparison between annual costs per capita of various methods of sewage disposal (based upon annual interest rate of 6% and 1977 values)

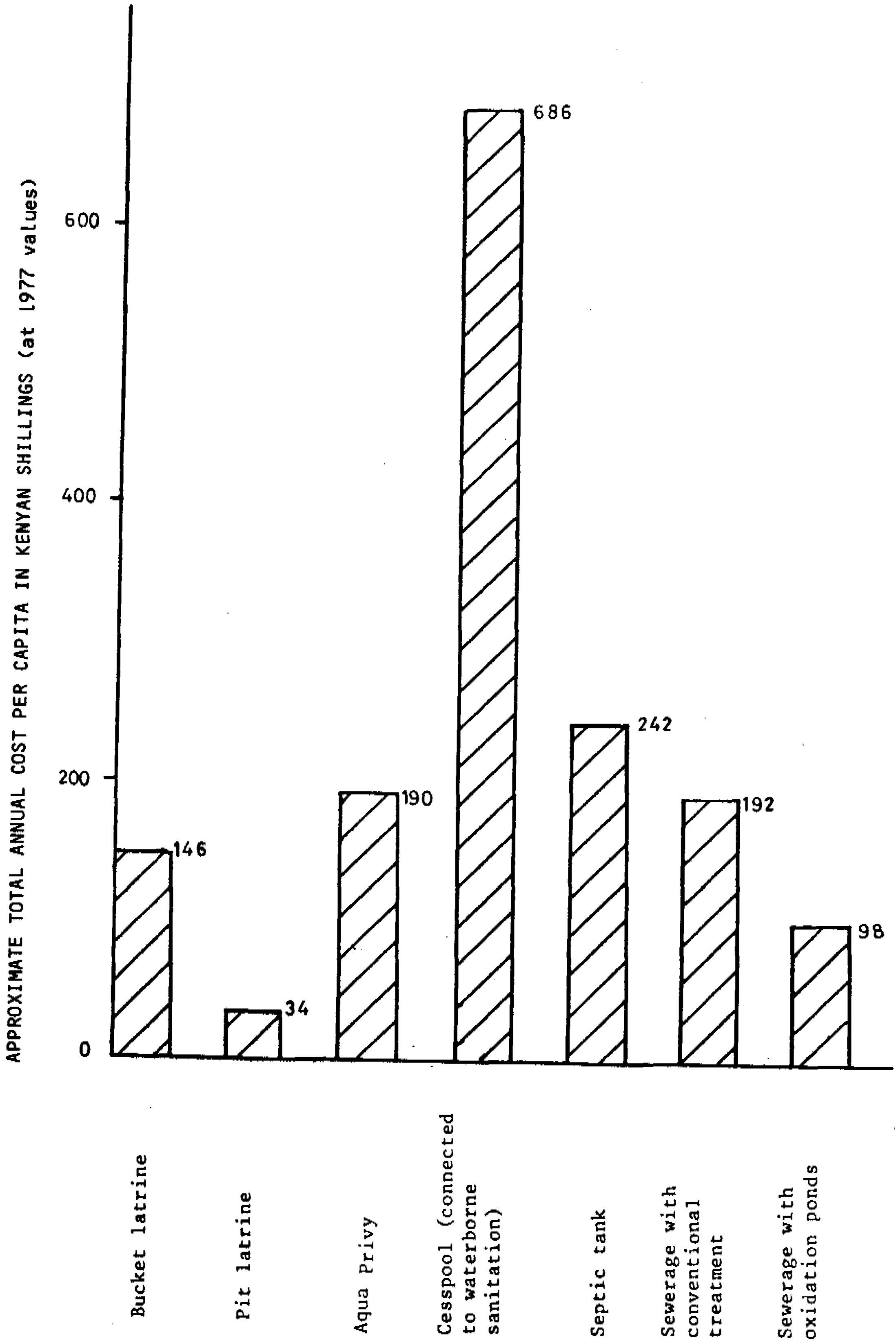
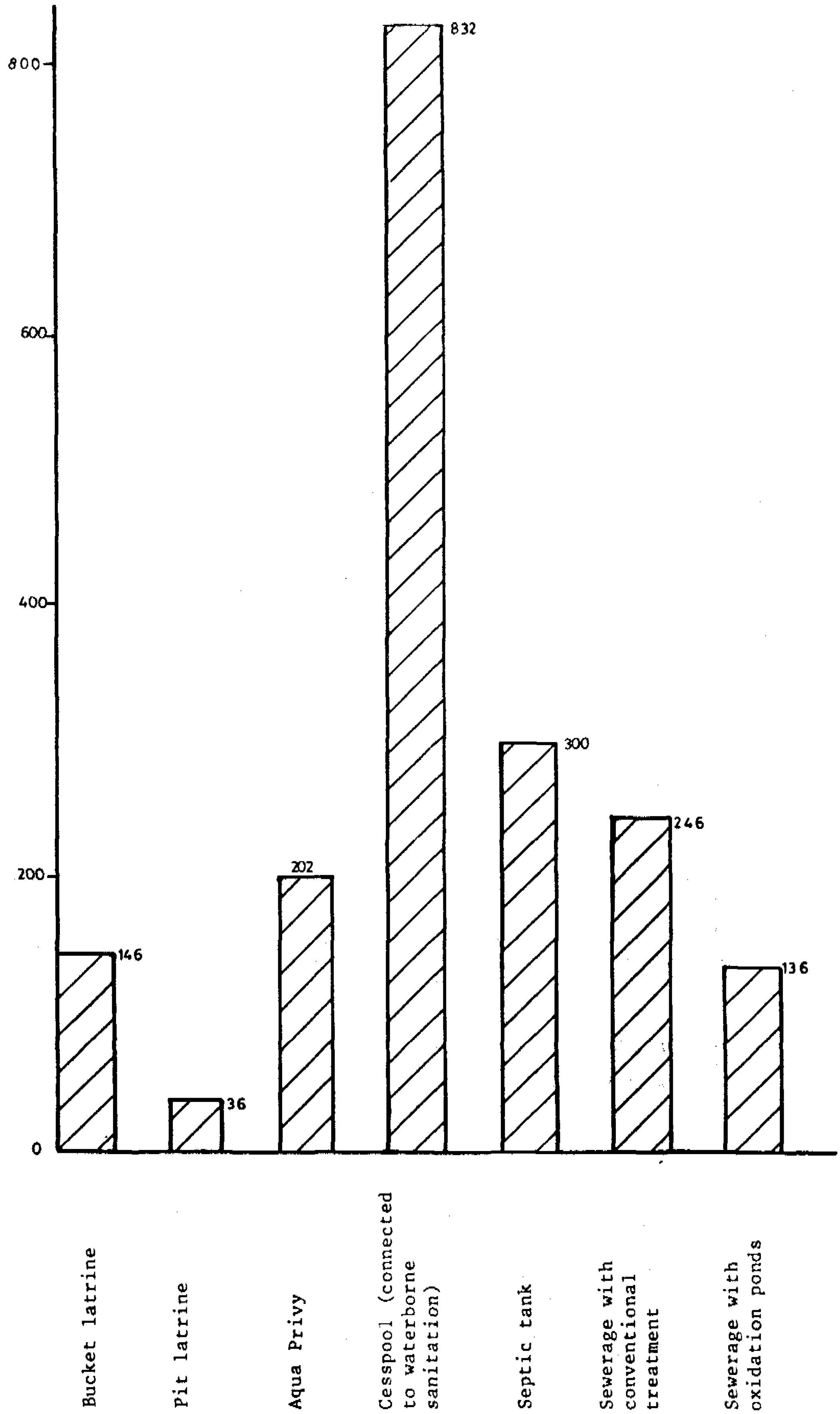


FIGURE 2: Comparison between annual costs per capita of various methods of sewage disposal (based upon annual interest rate of 10% and 1977 values)



5. RECOMMENDATIONS MADE TO THE KENYA GOVERNMENT

The WHO sewage disposal reports included the following recommendations. Implementation commenced during the second phase of the WHO project, with the Sewerage Division within the Water Department of the Ministry of Water Development acting as the national technical agency and advisor.

The term 'sewerage' implies a system of sewers followed by treatment of the collected sewage before disposal. Where there is a piped water supply with individual connections to properties, sewerage is certainly the most convenient, inoffensive and sanitary method of dealing with domestic sewage provided that the system has been properly designed, is well constructed and diligently maintained. This is as true for the individuals served as for the community.

However desirable it is not feasible to provide sewerage for every property in Kenya. It is considered realistic to provide sewerage generally in:

(i) all urban residential areas where the population density is 50 persons per acre (124 persons per hectare) or more, and also in the business and shopping centres enclosed by these residential areas;

(ii) the higher density town suburbs located on impermeable ground;

(iii) the more developed parts of local and market centres located on impermeable ground;

(iv) all communities of market centre status and above where the water supplies come from local shallow wells.

There will always be a need to install individual-type domestic sewage disposal facilities. Where these are provided, for economic reasons it will not always be possible to provide the best possible of these in every case. The target at which to aim is to ensure that a certain minimum standard and type of facility appropriate to each particular set of circumstances is provided.

Sanitary facilities should be properly selected

The selection of the sanitary method to suit particular circumstances is a fundamental exercise. The selection process was for convenience condensed to the guidelines illustrated on Tables 5 and 6. These relate methods of domestic sewage disposal to the community to the local permeability of the ground and to the type of water supply. In these tables the titles of the methods have been abbreviated as on Table 2.

The types of communities have been summarised into five categories:

Nomadic, with a pastoral population moving with the seasons and therefore living in temporary dwellings.

Low potential rural, which implies a scattered but settled population.

Medium and high potential rural. In this context 'potential' is based generally upon the availability of water and thus covers most areas of higher rainfall.

Low density urban (less than 50 persons per acre, or 123 persons per hectare).

High density urban

TABLE 5: Relationship between the types of water supply, ground conditions and methods of domestic sewage disposal

TYPE OF COMMUNITY	IMPERMEABLE GROUND								
	INDIVIDUAL PIPED SUPPLIES			PIPED COMMUNAL SUPPLIES			OTHER SOURCES OF WATER SUPPLY		
	Minimum acceptable	Other suitable methods	Realistic maximum	Minimum acceptable	Other suitable methods	Realistic maximum	Minimum acceptable	Other suitable methods	Realistic maximum
NOMADIC	-	-	-	-	-	-	Land [1] Bury [1]	Bucket-G Bucket-S	Pit-G
LOW POTENTIAL RURAL (excluding market and local centres)	Pit-G	Pit-S Aqua-privy-G Aqua-privy-S Aqua-privy Septic tank-G Septic tank-S	Septic tank	Bury	Bucket-G Bucket-S Pit-G	Pit-S	Bury	Bucket-G Bucket-S	Pit-S
MEDIUM AND HIGH POTENTIAL RURAL [2]	Cesspool-S [4] Septic tank-S [5]	Cesspool	Sewerage	Cesspool-S [4] Pit-S [5]	None	Cesspool	Cesspool-S [4] Pit-S [5]	None	Cesspool
LOW DENSITY URBAN (less than 50 persons per acre) [3]	Cesspool-S [4] Septic tank-S [5]	Cesspool	Sewerage	Cesspool-S [4] Pit-S [5]	None	Cesspool	Cesspool-S [4] Pit-S [5]	None	Cesspool
HIGH DENSITY URBAN (50 or more persons per acre and including town centres) [3]	Cesspool	None	Sewerage	Cesspool	None	Sewerage [6]	-	-	-

Notes:
[1] Burial is the minimum acceptable method for any nomadic community; land disposal is only acceptable on a journey.
[2] Including market and local centres in low potential rural areas, but excluding rural centres.
[3] Including rural centres.
[4] For individual plots less than 1/5 acre.
[5] For individual plots 1/5 acre or greater.
[6] Preferably with communal water closets provided by the local authority.

TABLE 6: Relationship between the types of water supply, ground conditions and methods of domestic sewage disposal

TYPE OF COMMUNITY	PERMEABLE GROUND											
	INDIVIDUAL PIPED SUPPLIES			PIPED COMMUNAL SUPPLIES			WATER SUPPLY FROM SHALLOW WELLS			OTHER SOURCES OF WATER SUPPLY		
	Minimum acceptable	Other suitable methods	Realistic maximum	Minimum acceptable	Other suitable methods	Realistic maximum	Minimum acceptable	Other suitable methods	Realistic maximum	Minimum acceptable	Other suitable methods	Realistic maximum
NOMADIC	-	-	-	-	-	-	Bucket-G	Bucket-S[4] Pit-G[4]	Pit-S[4]	Land[1] Bury[1]	Bucket-G Bucket-S	Pit-G
LOW POTENTIAL RURAL (excluding market and local centres)	Pit-G	Pit-S Aqua-privy-G Aqua-privy-S Aqua-privy Septic tank-G Septic tank-S	Septic tank	Bury	Pit-G	Pit-S	Bucket-G[4]	Bucket-S[4] Pit-G[4]	Pit-S[4]	Bury	Pit-G	Pit-S
MEDIUM AND HIGH POTENTIAL RURAL[2]	Pit-G	Pit-S Septic tank-G Septic tank-S	Septic tank	Pit-G	None	Pit-S	Cesspool	None	Sewerage	Pit-G	None	Pit-S
LOW DENSITY URBAN (less than 50 persons per acre)[3]	Septic tank-G	Septic tank-S Septic tank	Sewerage	Pit-G	Pit-S Aqua-privy-G[5] Aqua-privy-S[5]	Aqua-privy[5]	Cesspool	None	Sewerage	Pit-G	None	Pit-S
HIGH DENSITY URBAN (50 or more persons per acre & including town centres)[3]	Septic tank-S[6]	Septic tank[6]	Sewerage	Aqua-privy-S[5]	Aqua-privy[5] Septic tank-S[7] Septic tank[7]	Sewerage[7]	-	-	-	-	-	-

Notes:
[1] Burial is the minimum acceptable method for any nomadic community; land disposal is only acceptable on a journey
[2] Including market and local centres in low potential rural areas, but excluding rural centres.
[3] including rural centres.
[4] These pit latrines and soakage arrangements must be located with extreme care.
[5] In Moslem communities only, except where the privy also has a shower with piped water.
[6] Septic tanks are communal, *not individual*
[7] Preferably with communal water closets provided by local authority.

The Physical Planning Department of the Ministry of Lands and Settlement has classified communities on the basis of a points system. Points are awarded for certain facilities which the community has (for example, hospitals earn three points the same as a fire station, and two points are given for a library). In this way each community is placed in one of the following categories:

Local centres	(8 to 12 points)
Market centres	(13 to 18 points)
Rural centres	(19 to 36 points)
Urban centres	(37 points or more)

Conditions in market and local centres are considered to be more similar to conditions in medium and high potential rural areas, and these communities are therefore included in this category on Tables 5 and 6. Similarly, rural and urban centres are considered as low density urban communities and are therefore excluded from the medium and high potential rural category.

The distinction between 'permeable' and 'impermeable' ground is obviously imprecise. It is intended to establish in Kenya a standard test, probably based upon the rate of soakage of clean water out of a pit of specified size in order to standardise these descriptions.

The volume of water used domestically and consequently the volume of sewage produced, normally depends upon the type of water supply; thus the type of water supply often determines the optimum method of domestic sewage disposal. Tables 5 and 6 distinguish between different types of water supply:

(i) Individual piped means a supply connected to sanitary fittings, including a water closet, within a building.

(ii) Piped communal includes water taps located in private plots surrounding houses in addition to communal water points.

(iii) Water supply from shallow wells implies that water has to be carried a reasonable distance from, for example a village well, to each property.

(iv) Other sources of water supply include water sources such as springs and watercourses which are far away from the community.

The selection of the most suitable method of domestic sewage disposal depends upon the type and wealth of the community to be served. The two tables give a choice of installation for each set of circumstances, ranging from the minimum acceptable facility to the realistic maximum which is the best it is reasonable to provide. The aim should of course be to encourage people to install in their homes the best appropriate sewage disposal arrangements which they can afford. In particular where there is sewerage and the property is permanent every effort should be made to persuade property owners to have waterborne sanitation, draining into the public sewer.

Sanitary facilities provided should be properly designed and constructed

If they are to operate correctly sanitary installations need to be properly designed and constructed and to be of a size appropriate to the loadings they will receive. The policy recommended to the Government of Kenya was to replace the many and varied 'standard' designs for sewage disposal facilities then current in Kenya by national standard designs backed by law. These designs should specify the appropriate standards of building materials and should be linked to treatment and/or disposal capacity to ensure that units are never in the future overloaded.

The preparation of standards designs is currently in hand. Once completed these designs should not be regarded as fixed. Continuous research and development should take place with the aim of constantly improving details and efficiencies.

Records should be kept of all installations

The foundations for any effective organisation are records and statistics which show the extent of the problem to be tackled. In the present context, records should at the least give the numbers of the different types of domestic sewage disposal arrangement in each community or rural area, plus details of their needs, arrangements and frequency of servicing. Records are slowly being assembled in Kenya.

The supervision and servicing of sanitary facilities should be properly organised and supported by legislation

The WHO reports suggested to the Government of Kenya that it should be the responsibilities of the Government and local sewage disposal authorities to ensure that all sanitary facilities when constructed are appropriate to the circumstances and properly designed and built.

It was recommended that the responsibility of servicing sanitary units rests solely with the appropriate local sewerage authority which, however, should have power to recover the costs of its service from each property owner who benefits. In this context servicing includes emptying bucket latrines, aqua-privies, cesspools and septic tanks at appropriate intervals, and disposing of their contents. The proper maintenance of the units should rest with the owners who should be obliged to ensure their constant hygienic operation. Supervision and servicing require careful planning and organisation both on a national and local level. Also, if they are to be effective the powers and roles of the various sewage disposal authorities need to be backed by appropriate legislation with realistic penalties for non-compliance.

The control and supervision of the selection and construction of domestic sanitary installations can become a relatively simple and routine task once the selection guidelines (Tables 5 and 6) become nationally accepted and standard designs for the various sanitary units have been prepared.

The servicing of large numbers of sanitary installations is not an easy task. It requires not only proper equipment but also considerable planning and control if it is to be effective and economical. Once a successful system has been achieved in a particular community, however, the servicing operations become routine and therefore more easily controlled.

Adequate trained staff should be provided nationally and to the local sewage disposal authorities

The proposed national and local sewage disposal authorities require staff at every level of competence. There is, however, a severe shortage in Kenya of suitably trained and experienced personnel, both professional and sub-professional. As a stop-gap measure professional expatriates fill most of the senior positions. It was recommended to the Government that as a matter of urgency training programmes should be commenced for sub-professionals. The Training School of the Ministry of Water Development with the assistance of Sewerage Division personnel undertook this task on a national scale.

Recruits selected direct from school are given a twelve-month general training in water supply and sewage disposal theory and techniques and allied subjects, followed by a specialist four-month course in sewage disposal. Local authorities may second their own staff to these specialist courses, provided they have the appropriate education to qualify for entry. The total intake is approximately fifteen each year. The better students (approximately one-third of the total) are then sent to the Nairobi Polytechnic on a diploma sandwich course in sanitary engineering. Plans are in hand to send the very best students overseas to study for first degrees. All Ministry of Water Development students when they leave the Training School receive practical training followed by formal refresher courses, also at the Training School. For a student who does not attend the Nairobi Polytechnic, his theoretical plus practical training lasts three years.

In parallel with these efforts by the Ministry of Water Development, the Nairobi University with the assistance of the World Health Organisation now runs higher degree courses in sanitary engineering for graduates, normally sponsored by the Ministry of Water Development or by local authorities.

Adequate funds should be provided for the sewage disposal authorities

If they are to be implemented, the above recommendations require finance. The successes achieved during the past four years have happily convinced the Government of Kenya of the wisdom of spending funds in this way and at both national and local levels the necessary finance is now starting to be allocated.

Adequate refuse and stormwater drainage collection and disposal arrangements should be provided

It may seem that these problems have little to do with the subject of this paper. However, in fact they are closely allied and if not dealt with in parallel to sanitary sewage disposal, then the potential benefits of sanitation can to a great extent be cancelled. Refuse, or garbage, has many of the undesirable characteristics of sewage and its collection and disposal should similarly be carefully organised and controlled otherwise hazards to public health and the pollution of water resources will continue.

If there is no adequate stormwater drainage flooding will occur. There is no domestic sanitary arrangement which can withstand flooding. Facilities cease to function, giving rise to all the dangers and nuisances to which insanitary installations are prone.

The public should be educated into good sanitary practices

To be successful any programme aimed at improving sewage disposal can only succeed if it has the backing of the majority of the local people. The spread of disease can only be reduced in Kenya if people realise the importance of hygienic habits. Even the best sewage disposal arrangements will not function if they are used incorrectly. If the facilities provided are not utilised or are misused, then their installation was to some extent a waste of money.

The WHO reports urged that every medium for communication should be used to educate and persuade citizens into wanting and using correctly sanitary sewage disposal facilities; public statements by Kenya's leaders, posters, films and demonstrations in remote areas were all suggested as ways of achieving these objectives.

Education by persuasion usually achieves the best, long-lasting results. The recommendations included pilot projects in busy centres during which 'model' latrines are constructed by the local sewage disposal authority in order to show the public what is required. Another positive recommendation was to provide the best possible sanitation in schools so that the younger generation will become familiar with modern facilities and eventually want them in their homes; guiding school children in this way should help stamp out many social taboos which today hamper the spread of good sanitation.

What is required for success is a national campaign which provides drive and knowledge and also encourages the participation of each family in the form of labour or materials or both. Happily a growing public awareness of the benefits of good sanitary practice is becoming obvious in Kenya's cities and larger towns.

APPENDIX A

CALCULATIONS OF UNIT COSTS FOR PROVIDING, MAINTAINING AND SERVICING DOMESTIC SEWAGE DISPOSAL FACILITIES

The reasoning and calculations which follow are subject to the qualifications described in section 4. The basic costs used and the life expectancies suggested for the various installations are necessarily very approximate, but are considered sufficiently accurate for present purposes. All costs given are in Kenyan Shillings (K Shs) and are based upon 1977 values.

Miscellaneous costs

Ground soakage is common to several methods of domestic sanitation; the problem of periodically collecting and disposing of night-soil (from bucket latrines) or sludge similarly often features. It is therefore a convenient first step to establish unit costs for these processes before considering the various methods in detail.

a) Ground soakage

Ground soakage here implies a sub-surface arrangement which may be either a soakage pit or a shallow piped drainage system dealing perhaps with sullage or with the effluent overflowing from an aqua-privy or septic tank. The size and therefore the costs of an installation will vary with its duty. Typical costs for a soakage unit suitable for a single dwelling range from K Shs.600/= to 1200/=. Five years is an average life before replacement or major extension are required. Untreated sullage would normally clog the ground before this, but a unit dealing with septic tank effluent should last longer.

b) The collection and disposal of night-soil and sewage sludges

Night-soil and sewage sludges should preferably be collected and conveyed by a purpose-made vehicle; pumps rather than hand buckets should be used to empty sewage tanks. For costing purposes it is assumed that night-soil and sludges will be transported to a collection depot and then dumped into trenches and rapidly buried. This is usually the cheapest method, the annual costs per capita varying from approximately K Shs.4/= for septic tank sludges to K Shs.14/= for night-soil from bucket latrines, and to K Shs.28/= for the contents of cesspools.

Bucket latrines should be emptied, washed and disinfected daily; the better method is to have two buckets for each household, one bucket being in use whilst the other is being cleaned, preferably at a central depot. Although ox-carts can be used to convey full buckets to the disposal/washing depots, purpose-made motor vehicles are more sanitary and much less offensive. For a small town the costs of servicing bucket latrines are approximately the same whether conveyance is by vehicle or by ox-cart: an ox-cart becomes cheaper in larger towns. It has been found that a vehicle costing K Shs.192/= with a total labour force of five men can deal with 300 bucket latrine installations; the cost of servicing one bucket latrine is then approximately K Shs.570/= per year including emptying, conveyance, cleaning and night-soil disposal.

The size of a cesspool is related to the planned period between emptyings. When calculating unit costs the assumption has been made that each cesspool will have a capacity equivalent to 6½ weeks' inflow but will be emptied monthly. A purpose-made tank lorry complete with pump and suitable for cesspool-emptying costs approximately K Shs.240 000/=. Such a vehicle manned by a team of three should be able to deal in rotation with one hundred cesspools; the cost of servicing a cesspool serving a single household is then approximately K Shs.1340/= per year, including disposal of the cesspool contents.

A correctly-sized septic tank requires desludging about once in two years; an aqua-privy, which can be much smaller than a septic tank, should be emptied about twice each year. The better servicing method is to use a cesspool-emptying vehicle. However, a small town in a remote area may not have sufficient work to make economic use of such a vehicle and in such circumstances a simple tank with a handpump and fitted to an ox-cart is an acceptable alternative. A cesspool-emptying vehicle with a gang of four men should be able to deal in rotation with either 5000 septic tanks or 1250 aqua-privies; a simple ox-cart tanker plus five men should be able to service 3000 tanks or 750 privies. The costs of emptying and disposing of the contents of a single domestic tank using a vehicle have been found to be approximately double those when an ox-cart tanker is used. If it is assumed that 20% of all septic tanks and 40% of all aqua-privies are emptied by means of handpumps fitted to ox-cart tankers, then the average total annual costs of servicing a septic tank approximately equal K Shs.80/=; comparative costs for an aqua-privy are approximately K Shs.320/=.

Unit costs for various arrangements

As discussed in section 4, the various methods of domestic sanitation listed in Table 2 do not all perform the same function. An important distinction should also be made between systems such as bucket latrines, pit latrines and aqua-privies, all of which are household excreta disposal units essentially complete in themselves, and cesspools, septic tanks and sewerage which are incomplete units and must normally be supplemented by water closets. Therefore, for true comparison the related necessary costs of supplying piped water and constructing water closets should perhaps be added to the costs of providing cesspools, septic tanks and sewerage.

However, in the following unit cost estimates for cesspools, septic tanks and sewerage, although waterborne sanitation is assumed:

(i) the costs of water supply and of water closets and other installations within a dwelling are ignored, and

(ii) The costs of drains connecting the dwellings' conveniences to either a sewage tank or a public sewer are ignored.

It is assumed that the disposal of excreta by simple burial incurs neither capital nor running expenditure.

a) Bucket latrines

Buckets cost about K Shs.80/= each, and two buckets used alternatively may be expected to last one year each before replacement.

b) Pit latrines

Pit latrines are usually constructed by the family who will use them and so the only cash expenditure is normally on materials. However, in order to compare this system with others it will be assumed that labour is employed during construction. A pit latrine with a simple building made using local materials will cost approximately K Shs.500/=. Eight years is a typical life for a correctly-sized pit in appropriate ground. Servicing costs for a typical pit latrine serving one dwelling, including repairs to the building and regular cleaning of the squatting slab using water and disinfectant, are assumed to be approximately K Shs.200/= per year.

c) Aqua-privies

The construction costs of an aqua-privy, including a building made of durable material but excluding soakage arrangements, are approximately K Shs.1600/=. Such a unit should last for fifteen years before major repairs are required.

d) Cesspools

Cesspools are expensive as they are necessarily large and must be made of good materials to ensure water-tightness. However, being of simpler design, volume for volume they are relatively cheaper to construct than septic tanks. Assuming monthly emptying, (viz a capacity equivalent to 6½ weeks' inflow) a cesspool tanking all liquid wastes from a dwelling with waterborne sanitation and other modern water-using arrangements would cost approximately K Shs.24 000/= to construct; its life should be about twenty years.

e) Septic tanks

Septic tanks must similarly be made of sound materials. Excluding ground soakage arrangements, the construction costs of a septic tank to deal with sewage from a dwelling served by a piped water supply and with waterborne sanitation vary from approximately K Shs.6000/= to 10 000/= depending upon whether the sullage is discharged on to the ground surface or into the tank; an average value of K Shs.8000/= is assumed for costing purposes. A septic tank may be expected to have a life of twenty years.

f) Sewerage

Unit costs for sewerage may conveniently be divided into the costs of the sewerage system and those for sewage treatment and disposal. Sewerage system unit costs are very variable depending upon local circumstances including population density, ground conditions and topography, but they are generally independent of the type of sewage treatment or disposal. Based upon persons served, the unit per capita costs of an urban sewerage system for Kenya outside Nairobi may vary from as little as K Shs.240/= in an overcrowded locality to K Shs.1800/= for a spacious suburb; K Shs.800/= is assumed as an average per capita unit cost. Given proper attention, sewers and their appurtenances can be expected to last for forty years without any major repairs.

For maximum efficiency sewers must be regularly flushed and repaired; there may also be pumping stations with equipment consuming electricity and requiring more frequent maintenance. It is assumed that maintenance costs, including labour and transport, are equivalent to 1% of the capital costs of the sewers and buildings, plus 2% of the costs of the mechanical and electrical equipment. With an additional allowance to cover power consumption, the annual running costs for a typical sewerage system in Kenya are approximately K Shs.16/= per head of population served.

Sewage may be treated in many ways before disposal. The most expensive method applicable to Kenya is 'conventional' treatment; the least is treatment in oxidation ponds. In this context conventional treatment comprises screening, grit removal and primary settlement, followed by secondary treatment in filter beds and humus tanks; sludges are digested before running on to drying beds.

The unit costs for conventional treatment are roughly constant for towns with population ranging from about 5000 to 30 000 persons; costs are generally higher for smaller towns and decrease as the population served increases. Unit costs for oxidation ponds are approximately constant, regardless of the population served.

Typical capital costs for conventional treatment in Kenya are K Shs.800/= per head; annual running costs including sludge disposal, repairs, labour and electricity, can be taken as 7.5% of this figure. Although the lives of buildings and concrete units are normally greater than those of equipment, an average life of twenty-five years for all components of a sewage treatment works is assumed.

Comparative unit costs for oxidation ponds are approximately K Shs.240/= per head with annual running costs of K Shs.12/= per capita. These costs are based upon land costing K Shs.30 000/= per acre. Oxidation ponds are large in area and their costs are therefore very sensitive to land values.

APPENDIX B

SOURCES OF UNIT COSTS GIVEN IN APPENDIX A

Kenyan costs for sanitary installations and their servicing were discussed with many persons with local knowledge - Ministry and local authority officers, consulting engineers and contractors. The costs so obtained were checked with the World Health Organisation and also with those given in publications usually concerning other countries. Specific publications consulted include the following:

1. Several publications of the Central Public Health Engineering Research Institute of Nagpur, India.

2. Rural sanitation in the tropics (1968). The Ross Institute, the London School of Hygiene and Tropical Medicine.

3. Aspects of water pollution control (1961). World Health Organisation. Public Health Paper no.13

4. Excreta disposal for rural areas and small communities (1958). World Health Organisation, Monograph Series no.39

5. Waste stabilisation ponds (1971). World Health Organisation, Monograph Series no.60

6. The design and construction of the pit latrine. World Health Organisation local publication, Kenya-2/PL/69

7. The economics of wastewater treatment. Townend (1962). Journal of the Institute of Sewage Purification, vol.62, part 3.

8. The cost of sewage treatment. Bradley & Isaac (1969). Journal of the Institute of Water Pollution Control, vol.68, no.4

9. Government of Kenya sectorial study and national programming for community and rural water supply, sewerage and water pollution control. WHO, 1972. Report nos 3,8 and 13

discussion

CHAIRMAN: C L LANGSHAW, OBE ARICS FRSH FIPHE
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Mr R J HOLLAND said that his paper was about a very important aspect of sanitation which he considered was very much neglected, and that was, "What do you do about sanitation when you haven't, or can't afford, sewerage?" There were numerous text books on sewerage, sewage treatment and sewage disposal but, in the developing countries, most people will never have sewerage. It was of vital importance to realize and remember this and to decide what could be done about these less fortunate people.

2. Although the paper was tied to the particular circumstances of Kenya, it really dealt with domestic sanitation in circumstances which were common throughout Africa and probably throughout the developing World. Kenya would like to provide the best possible amenities for its citizens but it had very limited funds and tremendous demands on those funds.

3. Kenya being a stable country could get loans from international and bilateral agencies, but limited the amount it borrowed each year. Kenya had very limited natural resources and depended on tourism which is the major money earning industry, and rural farming industries, particularly coffee, tea and sisal.

4. Kenya was mainly an arid semi-desert country. Apart from the coastal strip, which averaged 15 miles wide, only those parts of Kenya at high altitude had reasonable rainfall; these areas contained most of the population. In most of the country the only occupants were nomadic tribes and small communities of primitive peoples.

5. Kenya had several towns, but most people live in the rural areas on scattered smallholdings with their families. There were few villages. Kenya's population was increasing rapidly. Over 50% of Kenyans were under the age of 14. There was three years free primary education for all. The population of Kenya was now probably 13 000 000 people of which less than 10% lived in urban communities; out of those probably 700 were in Nairobi. It was thought that by the end of the century the population could reach 30 million of which 12 million might live in urban communities. Kenya was trying hard to industrialise. Unemployment is a large problem. Landless people tended to drift into the towns but there was often no work for them to do.

6. Kenya had a high rainfall but most of its population lived in the highlands where streams were narrow and steep and therefore water resources were relatively scarce. The run-off was rapid and before long the water was well away from the population centres. So Kenya had a water resources problem and could not afford to pollute its water resources and lose them. Kenya, being a hot country, also has endemic diseases. In recent years transportation systems had improved, so diseases could quickly spread from one end of the country to the other.

7. Tourists who came to Kenya usually

had never been acclimatised to tropical diseases. Proper national sanitation was essential for the tourist industry because even if the tourists themselves lived in hotels with all sanitary conveniences, the hotel servants probably lived in low cost houses or shacks. If these are insanitary, then diseases will be passed on to the tourists by the servants.

8. Text books, Mr HOLLAND said, tell us that in unsewered areas we should have septic tanks or pit latrines or aqua privies; the books show neat typical drawings of the various units and make their use sound very simple. But when these units are seen in fact, the great majority of septic tanks, pit latrines and the like just do not work. When he went to Kenya for the World Health Organisation with the task of improving domestic sanitation, he saw the need was to improve the systems that the people had been brought up with rather than to introduce radically new ideas. Each system worked in particular circumstances, but what was good for one set of circumstances, was not necessarily adequate for another. The first problem was to choose the best system for each different set of circumstances. The next problem was to ensure that the chosen system was properly constructed and operated.

9. Mr HOLLAND next referred to the statistics which could be found in the paper. He said that the statistics gave a rather optimistic picture of the situation in Kenya because, in practice, even simple tanks and pit latrines were not working properly.

10. He felt that primitive sanitation had no place in a developing country, except very remote areas. Also, bucket latrines did not provide a sanitary system for disposing of domestic sewage from any community.

11. Pit latrines were by far the most common type of domestic sanitary installation, not only in Kenya but also in most other countries in the developing World. If they were built correctly in the correct circumstances, they could be sanitary and effective, until the household had piped water supplies and needed a more sophisticated method of sanitation. A common misunderstanding concerning pit latrines was that provision should be made for emptying them. Soon after he first arrived in Kenya, he was taken to see a house in the middle of Mombasa where the emptying of a pit latrine was in progress. The latrine was in a room occupied by a family and the method of emptying the pit was for a naked man to go down a rope with a bucket. A hole was knocked through the wall of the house and the pit contents were poured through the hole on to the ground outside. Pit latrines should be used, filled, covered with soil, forgotten and replaced by a new installation; they should not be emptied.

12. Aqua privies had not really caught on in Kenya because they needed regular emptying and maintenance. Generally, such servicing of installations in Kenya was inadequate, and aqua privies had consequently acquired an undeserved bad reputation.

13. By Mr HOLLAND's definition, cess pools were water-tight containers that did not leak. Virtually every cess pool he had seen in a developing country leaked, or overflowed continuously because they were not regularly emptied. He thus concluded that, in developing countries, where servicing is primitive, cess pools were very rarely satisfactory in practice.

14. Septic tanks were excellent if properly serviced and if built under the right circumstances. In Kenya, instead of emptying septic tanks, it had become the practice to extend ad infinitum the ground soakaway system on which the tank depends, as the existing system becomes blocked by sludge carried over from the tank. Mr HOLLAND suggested that this was attacking the symptoms rather than the cause.

15. Sewerage was not always perfect but it was the ideal at which to aim. In his paper Mr HOLLAND had discussed what to do when sewerage could not be provided. Virtually all these alternative methods of domestic sanitation depended upon good operation and regular servicing and this needed organisation and funds. Many lay people seemed to think that once an installation is built, then that was the end of the matter. One of Mr HOLLAND's major battles in Kenya when he worked for WHO and the Government was to convince local authorities and the Government that they must allocate funds for servicing, including the provision of a proper organisation, equipment and vehicles. In his paper, Mr HOLLAND had prepared Table 3 in which he had tried to show the relative merits of different methods of domestic sanitation. Having calculated the relative costs of the different methods, in Tables 5 and 6 he had tried to link the various circumstances with

feasible methods of sanitation. These Tables were issued as the standard guidelines for Kenya, so that in any circumstances likely to occur reference to these tables would indicate which sanitation method was acceptable, which was the best that could realistically be expected, and which other methods would be reasonably suitable. The difficulty was in making people abide by these guidelines. His paper listed recommendations made to the Kenya Government as to how to achieve compliance.

16. In rder to ensure that sanitary facilities provided are in practice properly designed and constructed, Mr HOLLAND considered it was necessary to build up a national supervisory organisation and set up training schools. This had been done in Kenya so that now there was a small army of sub-professionals, guided by professional engineers who toured the country helping to select sanitary installations and ensuring that they are properly designed and constructed.

17. A major victory had been that generally the citizens of Kenya are now convinced that they should have good sanitation. (Indeed people were coming forward and asking for these facilities). Any programme of sanitation must have the backing of the people of the country and Mr HOLLAND and his colleagues have expended considerable effort in persuading the Government, local authorities and people of the advantages of good sanitation. Many older people could see nothing wrong with existing insanitary conditions. Therefore propaganda was directed mainly at school children and younger people; attempts had to be made to install the best possible facilities in schools. Perhaps in a generation's time, proper sanitation would be taken for granted in Kenya instead of being just a word used by health officers and Government officials.

18. The CHAIRMAN thought Mr HOLLAND had summed up the situation in Kenya about overcoming the difficulties in his last few remarks about persistent propaganda and tackling the next generation. With 50% of the population under the age of 14, it would be possible to have a population that had a greater awareness of sanitation. Mr HOLLAND had not mentioned bore hole latrines and The CHAIRMAN asked if Mr HOLLAND had experience of them and if so whether he would add them to his list of possibilities in one position or another.

19. Mr A J H WINDER referred to two statements in the paper. The first was that "the Government tried to keep pace with the changes etc. as the objective of ensuring that every dwelling and every business and factory in the country will have adequate sewage disposal arrangements by the end of this century", and the second that "51% of the population have absolutely no form of sewage disposal at all at the moment and the rest are pretty inadequate". Mr WINDER suggested that no country could possibly have the resources to deal with this problem.

20. Mr HOLLAND replied that the first quotation was a stated objective by the Kenyan Government. At first the Government aimed to provide everyone with a guaranteed adequate water supply by the end of the century, and later added the aim of providing also proper sanitation. The statement referred to "adequate sewage disposal" arrangements. A pit latrine properly constructed in appropriate circumstances was an adequate sewage disposal arrangement. At the end of the century it is anticipated that only 25% of the total population would have sewerage; the Government's policy is to ensure that everyone has a sanitary installation appropriate to his peculiar circumstances.

21. The CHAIRMAN said that this was an aim in the West Indies some years ago and it was achieved by employing ten technicians rather than engineers. They were taught a comparatively limited coverage of the subject, sufficient for them to be able to construct satisfactory installations. The end of the century was not far away, but with a determined Government policy and a growing awareness of the population itself, a good deal of progress could be made.

22. Mr HOLLAND said that four years ago, the training of sub-professional technicians in sewerage started in Kenya. Now, the Government was training about 15 per year so at the present time there were about sixty trained men mainly working for local authorities throughout the country. When the first batch went out they found there were often no funds allocated for the servicing and supervision of sanitary facilities but more and more local authorities were now providing funds. Generally speaking, major Kenyan towns have municipal engineers who comprehend the problems which arise from insanitary conditions. There is also a nucleus of aware engineers in the Government.

23. Dr S M ROMAYA asked whether the latrines would be provided for individual houses or on a community

basis. Payment for the construction would ultimately make or break the system quite apart from the technological problems.

24. Mr HOLLAND said that the systems that he had discussed in the paper were applicable to single houses or very small groups of houses. He would expect the householder to pay for the installation. A householder (or his family) would almost certainly dig his own pit latrine and build his own building over it. He would probably provide the labour element for a septic tank installation, bringing in a builder to construct the tank proper. Kenya was well organised for loans for most purposes and if a householder needed a septic tank but could not afford it, he could probably obtain a loan from his local authority and repay it along with his rates over a few years. Generally speaking, people were anxious to provide themselves with sanitation, but it was very disheartening to see pit latrines and septic tanks still being built into solid rock so that they cannot possibly operate.

25. Mr C PEEL said that Mr HOLLAND had not mentioned pour-flush slabs with a very shallow trap cast underneath and wondered if he had had any experience of this type of latrine. This slab could fit over aqua-privies, pit latrines and bore-hole latrines. In Nigeria these were used very successfully with a very small quantity of water discharged through the trap. For public latrines 44 gallon oil drums and dippers for approximately 2 - 3 pints of water were provided.

26. Mr HOLLAND said that aqua-privies were not currently being built in Kenya; they had a bad name because most of those which existed were blocked as a result of bad servicing. One local authority in Kenya had once made sealed slabs and had sold them at nominal prices to the citizens, but sadly this practice had now lapsed. Apart from in this particular area, he had never seen sealed slabs in Kenya. In Mr HOLLAND's experience, water seals worked in Moslem areas but rarely elsewhere.

27. Mr B M U BENNELL said that the introduction of water supplies was usually the first step followed by sanitation. It was disappointingly evident that water supplies of themselves did not produce a marked increase in the health of the community. Mr BENNELL asked if any case studies had been done in Kenya to demonstrate that the health of the community improved when sanitation of the type that had been described was installed. He found the cost very daunting and wondered if it was justified in terms of benefit of the health of the local community.

28. Mr HOLLAND replied that he was part of a WHO study team in Kenya during 1972/73 which looked into these aspects, but in particular into the effects of improved water supplies on public health. Graphs included with the reports showed that as more water was used by a family at a particular usage, suddenly their health increased. It was demonstrated that good sanitation improved the health of the community and also prevented pollution of water resources. Cholera, dysentry, bilharzia and diarrhoel diseases were very common in Kenya and were water-borne in some way or another. The very high prevalence of these diseases would undoubtedly decrease as a result of improved sanitation.

29. Mr BENNELL said that the deep philosophical question he had posed was whether improving health alone was justified in a country with limited cash at its disposal, if, for example, you could not feed the population when the health was improved. Should they not strike a balance between improvement of health, and improved agriculture which would enable more food to be produced?

30. Mr HOLLAND was at one time team leader preparing a Master Sewerage Plan for Bombay. Bombay had tremendous problems of housing, disease and poverty, Possibly, saving lives by improving the water supply in such a community could mean more people would die as a result of starvation and undernourishment. He felt that social problems such as the best way of spending limited funds was the task of the politicians. In the case of Bombay, the engineers' brief was to improve sanitation and that is what they did.

31. Mr W A GILLINGHAM noted that a large part of Mr HOLLAND's paper dealt with the abuse of the system. Mr GILLINGHAM asked what was the possibility of improving that situation rather than extending the system across the country. Would a system be set up where inspectors could demand that sanitation worked correctly?

32. Mr HOLLAND had made recommendations and tried to enforce them by helping re-draft Kenyan laws and by training inspectors and supervisors in the

Ministry of Water Development. The local authorities were reluctant to accept guidance because they felt that any involvement of the Central Government tended to undermine their authority. In many of the towns in Kenya the position was almost desperate, with diseases endemic in the poorer quarters. Something needed to be done quickly so trained persons were concentrated in the larger communities, and had not been able to move into the rural areas.

33. Kenya's policy was to sewer the centres of all towns and other designated "growth centres".

34. Mr S PRAKASH said that they have a similar situation in New Delhi. In the old walled city, there were many poor people needing a sewerage system and so the government decided to give them a grant for providing a WC and connecting sewerage. There was some hesitancy on the part of the householders to take to this system. Probably this was because the systems were not well maintained and well designed.

35. Mr S C DUTTA GUPTA said a programme had been prepared for the unsewered areas of Calcutta. Pre-fabricated latrines manufactured by the Calcutta Municipal Development Authority were installed in two ways. In the bustee areas one latrine seat with a septic tank for every 25 persons was provided free of cost and about 5 000 of this type had been installed. In other unsewered areas of Calcutta household latrines were provided at a subsidised rate, applicants paying 25% of the cost of construction. About 4 000 premises had been served in this way.

36. Mr PEEL said hookworm anaemia was one of the most debilitating diseases in Africa today affecting half the rural population in some places. If hookworm ova were passed out in the faeces on to the ground, they hatched into larvae and then passed through the feet of people walking barefoot. Wherever there was indiscriminate defeacation, hookworm anaemia was found and the only way of controlling it was by installing latrines. It did not matter which type of latrines so long as the excreta was underground or in a tank or somewhere away from people's feet. In a country like Kenya, the economic return would be enormous because hookworm anaemia was a debilitating disease which prevented people achieving full productivity. They reached a stage when they could not cultivate because they were too weak.

37. Mr HOLLAND said that in western Kenya bordering Lake Victoria the ground is water-logged during the rainy seasons. In this area, pit latrines flood and overflow and hookworm infestation was endemic.

38. The CHAIRMAN added that engineers and other people had to face the question of how far money should be spent on preventative measures for the health of the community. During the last few weeks, two medical men had stated that there has been more progress made on controlling disease by engineers than by doctors. When he was concerned with malaria control in areas which were very seriously affected, the main problem was that when it had been cleared from a particular area, the people did not isolate themselves.

39. Mr PEEL said there was no problem in tropical Africa which was not part of some other problem. Ridding an area of one particular malaria-carrying mosquito because conditions were made unsuitable for it may create the right conditions for another malaria-carrying species.

40. Mr J H KOP said that in order to save on investment and on operational maintenance for septic tanks, only the water from WCs was sent through the septic tank and all other waste water from bathrooms and kitchens was sent to the soakage pit behind the septic tank. This system worked well and Mr KOP wondered if this was done in Kenya.

41. Mr HOLLAND recommended that liquid kitchen wastes should go through a septic tank; however, bathroom wastes could be used to irrigate gardens and vegetable plots. Even in Nairobi there were unsewered areas and there it was usual to dispose of domestic waste waters on the land.

42. Another speaker asked if there was a demand for reclaimed effluent for irrigation. Would that be a further factor in deciding what sort of treatment to choose.

43. Mr HOLLAND replied that generally the population of Kenya lived where there was sufficient rainfall. Irrigation was seen as a method of sewage treatment but generally in Kenya treated sewage was required in the rivers to maintain flows downstream.

44. Mr R A REED asked what system of sanitation was recommended for western Kenya where existing systems flooded.

45. Mr HOLLAND replied that they had not solved that problem apart from providing cess-pools or sewerage, which were too expensive for widespread use in rural areas. Septic tanks should have an additional capacity to cater for floods in areas where they occur.

46. Mr REED had just returned from Bangladesh where almost the whole of the country was flooded and most people lived in rural areas.

47. Mr KOP said that he had worked in Bangladesh and in small villages they tried to solve the problem by providing elevated public latrines. In some market places this worked alright but in other places the people were not willing to go to the high ground.

48. Mr BENNELL asked whether Mr HOLLAND had any experience of what they are doing in China, where it seemed they were doing well in public health practice.

49. Mr HOLLAND replied that traditionally China had always deposited domestic sewage on the land and this arrangement had probably helped considerably in keeping China's rural population alive and nourished!

50. Mr E J FELTS agreed that the Chinese used excreta on their pepper gardens.

51. The CHAIRMAN remembered that the Chinese used nightsoil to feed pigs and Mr PEEL said that Mao Tse Tung in his early days made the remark that he regarded every human being as a source of fertilizer.

52. Mr PRAKASH said that it would take a very long time to organise the use of waste from the cities in the country. He suggested that the standard drawings of the septic tank latrines that Mr HOLLAND had used in Kenya would be useful.

53. Mr HOLLAND said that these were still being prepared and added that WHO Monograph 39 was still the best book on excreta disposal in unsewered areas.

54. Mr J M G van DAMME had heard with great interest about what had been done in Kenya to develop a pool of sub-professionals who had been trained and were going around the country. Work on sanitation was no use at all unless a lot of time and energy was also spent on education.

55. Mr HOLLAND said that while he was in Kenya with WHO, discussions were held to decide on an integrated attack by medical and technical personnel and it was agreed that the best method was to try and teach good sanitary practices and other health matters to one person in each community. The right person might have some connection with health such as the midwife; alternatively, he might well be the village gossip. Probably, the best contributions engineers could make was to build typical units in different villages so everyone could, for example, see what a septic tank should look like in an area where septic tanks were suitable.

56. The CHAIRMAN said that he had heard of the village policeman being used to pass on information to the villagers and then carrying out supervision and Mr HOLLAND said it had to be someone who was locally respected; his background was probably not so important.

57. Mr A W SHILSTON asked whether religious customs and taboos were a problem.

58. Mr HOLLAND replied that in the Moslem coastal areas of Kenya there were difficulties. For example, some fathers were reluctant to use the same toilet as their wives and daughters. There were some religious taboos which were obvious potential problems, but it was anticipated that these will disappear in time if children were given some sanitary education.

59. Mr van DAMME argued that where people are used to separate facilities for men and women, it might be right to let them keep it that way. If an engineer suggested that they should change their habits so that sanitation was easier to develop, perhaps the engineer was wrong and perhaps that was the reason why some schemes fail.

60. Mr HOLLAND thought that sadly modern living often required old ideas to be forgotten. If this trend continues in years to come different races and different religions would presumably become indistinguishable from each other.

61. Dr ROMAYA felt that it was impossible to provide a technological solution in isolation. There was a tendancy to use the politician as a scapegoat, but if any such scheme was to succeed the technological solution should give due consideration to financial, agricultural, educational and sociological aspects all considered together. An example was earlier discussion about whether a project would last twenty or thirty years but in

the same area it had failed because a bolt or a nut could not be found and the work had stopped after two years.

62. The CHAIRMAN asked whether any work has been done to try to ascertain the effect of pollution of the sub-soil and the distance pollution travelled from its source.

63. Mr HOLLAND said that they had not carried out any studies in Kenya but work had been done elsewhere on pit latrines. In his experience, it seemed that people did not realise the danger of pollution which could result and a shallow well was frequently dug alongside a pit latrine. In reply to a further question from the CHAIRMAN, Mr HOLLAND said he had not seen any medical evidence demonstrating the effects of diseases being transmitted in this way.

64. Another delegate said that an artificial recharger of sewage effluent for irrigation had been carried out in Arizona, U.S., where the effluent passed through about 300 feet of sandy gravel and toxic substances were transmitted.

65. Mr KOP said that in Indonesia tests had been made on latrines and it seemed that a safe distance between a well and a latrine would be about a travelling time of seventy days to ensure that viruses were not transmitted.

66. Mr E H BIRD said that in Barbados pure water was taken from a depth of less than a hundred feet of limestone beneath a discharge of farm sewage.

67. Mr K G STRATFORD said that numerous experiments had been carried out in the U.K. to determine the rate at which pollution travelled in aquifers. One such experiment carried out during the Croydon typhoid outbreak in 1936 indicated that a common salt solution, used as a pollution indicator, travelled a mile towards a well in fissured chalk in 24 to 36 hours.

68. The CHAIRMAN said that it was some consolation that nobody had mentioned the difficulty of maintenance of the cess-pits. In his experience these often released sewage through a hole at the bottom, which was the opposite of what they were designed to do.

M.F.G. ARCHER

water pollution control works in libya

1. INTRODUCTION

This paper sets out to describe some aspects of the major water pollution control works which have been and are being provided in various towns in the Socialist People's Libyan Arab Jumahereya (formerly known as the Libyan Arab Republic and subsequently in this paper referred to as Libya).

It is not intended to describe every detail of the work done at each town, but certain aspects have been selected for discussion and reference made to specific cases where appropriate. The paper is based on projects undertaken at the six largest towns of Tripoli (Capital), Benghazi (Second City), Derna, Misurata, Tobruk and Sebha. All these places are situated on the coast except Sebha which lies in the Sahara Desert some 600 kilometres south of Tripoli. Projects are also proceeding in other centres, but the Author's knowledge principally covers those mentioned above. In the case of Sebha, Misurata and Derna this knowledge is limited to Phase 1 only.

The works concerned cover the era 1961 to the present and in some instances include projected future works which are anticipated to be carried out over the next fifteen to twenty years.

It is hoped that the paper, in addition to being informative, will form a basis for discussion and also elicit from delegates comparative information and data related to similar projects in other countries or, indeed in Libya itself.

2. LIBYA

General

Libya (figure 1) covers an area of approximately 210 million hectares along the north coast of Africa. It borders Egypt and the Sudan on the east, Chad and Niger on the south and Algeria and Tunisia on the west. It consists of the three former provinces Tripolitania, Cyrenaica and the Fezzan, and the main commercial cities are Tripoli and Benghazi. Libya

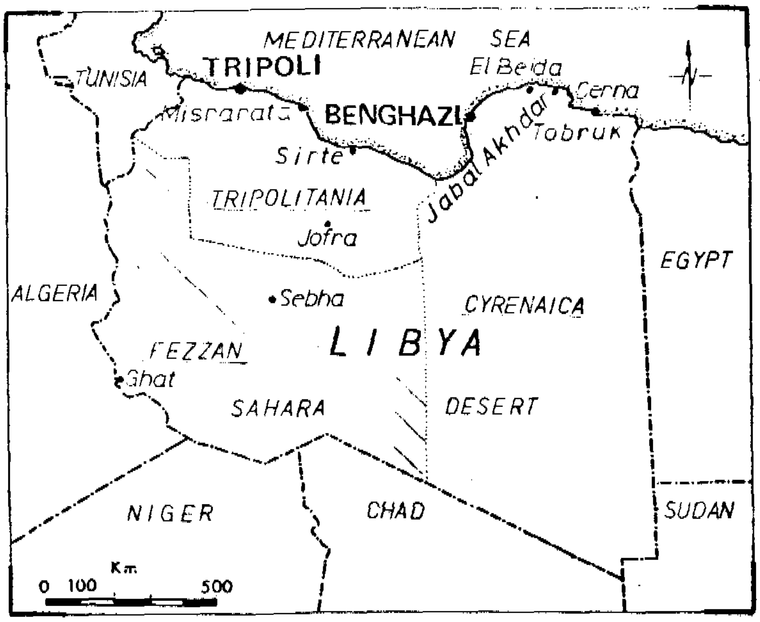


Fig.1 — LIBYA

became a Republic on the 1st September 1969 but is now the Socialist People's Arab Jumahereya.

Vast sand and rock deserts are the predominating features of much of the country, the southern part of which lies within the Sahara Desert. The coastal region of much of Tripolitania and part of Cyrenaica is comparatively fertile, the wide and desolate expanse of the Sirte Desert separating the two provinces. The eastern part of Cyrenaica between Barce and Derna is mountainous and the Jebel Akhdar or Green Mountain rises to a height of 800 metres. The Fezzan is mostly desert with a few scattered oases, the most important being those at Jofra, Sebha and Ghat.

There are few rivers and rainfall is sporadic. The greater part of the country has a hot and arid desert climate. Along the Mediterranean coast, however, where all the main towns are located, the climate is more temperate. Rain occurs mostly between October and March and no rain falls in June, July and August. The maximum temperature in summer is about 44°C and in winter the temperature may change from near freezing at night to quite warm in the afternoon. Humidity is often 80% or above. Temperatures soar when the wind (known locally as the ghibli) blows from the south.

Population

The present population of Libya is about 2.6 million, Tripolitania being the most heavily populated area. 85% of the population live in the more temperate coastal regions. Libya is an almost exclusively Muslim country and its people observe most of the traditional customs of Islam.

Economy and finance

Oil accounts for about 99.5% of the total value of Libyan exports, the main oil producing region being in Cyrenaica. Oil revenue in 1976 was of the order of LD 2000 million equivalent to £4000 million.

In common with many other Arab countries, revenue from oil sales has enabled the Libyan Government to embark on large development programmes which require infrastructure engineering, including drainage facilities which had previously hardly existed. Funds are provided from central Government sources to local municipalities on a direct grant basis to the full amounts required, there being no borrowing and repayment arrangements and no system of revenue collection. In spite of the high level of oil revenue the flow of funds is often slower than required to match the necessary rate of progress on projects.

3. THE PROJECTS

General

In 1961 when the Government decided to proceed with drainage schemes in certain towns, the only sewerage system of any significance was that in Tripoli, an old combined system. Benghazi boasted an old inadequate network of overloaded sewers in part of the central area whilst Tobruk had only a limited foul system serving an army barracks. Derna, Misurata and Sebha had no system of main sewers and drainage was to cesspits and septic tanks.

The systems of Tripoli and Benghazi, such as they were, discharged to the sea or partly enclosed bodies of water through various short outfalls, most of which were situated close to built-up areas. The Tobruk system discharged to a small treatment plant.

Although not considered in this paper, a basic system of sewers and a sewage treatment plant had been installed at Beida in 1959. The treatment plant was of the traditional biological filter type.

Apart from a desire to deal urgently with the amenity aspect, the Government concluded that the discharge to the sea of such large volumes of water in a country where its conservation is so important was wrong. Their terms of reference, therefore, provided for the treatment of sewage to a standard which would permit the use of the effluent for irrigation purposes.

Work on the initial phases of sewerage projects for each town commenced in the year 1961 to 1973, each project having its own chequered history and reaching completion during the period 1963 to 1977. The second phase of each project commenced with Benghazi in 1973 followed by Tripoli and Tobruk. Work on Phase 2 of Sebha, Derna and Misurata has also started but, as previously stated, the Author is not in a position to know details of progress on these schemes.

Phase 1 projects

The basic details of the Phase 1 projects are given in Table 1. The Phase 1 projects were all affected to a greater or lesser degree by labour problems, unsettled political conditions in the Middle East, financial failure of some contractors, and general administrative difficulties, resulting in delays; in the case of Benghazi some seven years beyond the original contract completion time of four years.

TABLE 1: Details of Phase 1 projects

	Benghazi	Tripoli	Tobruk	Misurata	Sebha	Derna	Total
Total length of sewer (kilometres)	162	267	15	41	15	49	549
Number of foul sewage pumping stations	10	4	3	18	5	3	43
Number of S.W. pumping stations	4	-	-	1	1	-	6
Capacity sewage treatment works (m^3/day). (All to tertiary standard, biological filter plant with sludge digestion and drying beds)	27 300	27 300	1360	1360	1360	4550	-

Phase 2 projects

Benghazi

In 1973 the Municipality of Benghazi commissioned the Author's firm to prepare a comprehensive Master Plan to cover sewerage and sewage treatment requirements for the town to the year 2014, to be followed by project reports and a vast programme of design and construction. The Master Plan and all project reports have been accepted, a large amount of design work executed, certain contract work under construction and contracts out to tender. Tables 2 and 3 have been prepared to indicate progress to date on design and letting to contract and the programme for the future.

TABLE 2: Benghazi - details of Phase 2 projects (sewerage)

Contract	Total length main sewers($) (km)	No. of P.S's	Contract start date	Contract time (months)
101S	60	-	Sept. 1974	30
102A	12 *	-	Aug. 1974	39
102B	11 *	-	Aug. 1974	39
101N	60	2(F)	Dec. 1975	30
104	25	1(F)1(S)	Nov. 1975	30
105	31	-	Mar. 1977	24
108A	36	2(F)	Out to tender	36
106A	61		Out to tender	30
111	Replacement & modifications to P stations		Out to tender	30
106C	20 (pumping main)	1(F)	After 1977	36
108B	30	1(F)	After 1977	30

....Table 2 (Cont)

Contract	Total length main sewers($) (km)		No. of P.S's	Contract start date	Contract time (months)
108C	30		1(F)	After 1977	30
102C	5	*	2(S)	After 1977	36
106B	50		2(F)	After 1977	36
109A	35			After 1977	30
113A	50		1(F)	After 1977	36
110A	40			After 1977	30
102D	5	*		After 1977	30
102E & F	13	*	1(S)	After 1977	36
109B	45			After 1977	36
115A	70			After 1977	36
115B	72			After 1977	36
102G & H	9	*	2(S)	After 1977	36
Total:	770				

(F) = Foul sewage
(S) = Stormwater
* = R.C. Box culverts
$ = Excluding laterals

TABLE 3: Benghazi - details of Phase 2 project (sewage treatment)

Contract	Dry weather flow (m^3/day)	Extension (E) or New (N)	Contract start date	Contract time (months)
103A	54 500 (stage 2&3)	E	June 1977	
107A	65 000 (1 & 2)	N	Out to tender	
Further extensions to be carried out as required in the future.				

As will be seen from Table 2 the second phase commenced on site in late 1974 when three contracts were let for the construction of sewers and stormwater culverts. Two more contracts were signed in 1975 for sewer and pumping station construction followed very recently by a further sewer contract and one for the extension of the existing sewage treatment works on the south side of the town (Guarchia). Further sewer contracts will be let soon together with a contract for a new sewage treatment works to the north of the town.

The total value of current contracts is some £340 million, peak monthly value of work executed having been £5 million with a new peak of £8 million likely in 1978.

A notable feature has been the operation for two years of the sewage treatment works by a contractor. Further details are given in Section 10 in this paper.

Tripoli

Progress on the development of the sewerage system at Tripoli has proceeded at a slower rate than that at Benghazi, one reason being that the original system is more extensive at Tripoli. Some work has preceeded piecemeal, part of which has been undertaken by the Author's firm. There has so far been no townwide concerted action, apart from the recent preparation of a Master Plan for the year 2000, to provide for the rapidly expanding city.

In respect of the treatment works the Author's firm were engaged in 1974 to prepare designs for an extension by 110 000 m^3 per day to the existing 27 500 m^3 per day works and tenders received in June 1976 are still being considered.

Tobruk

The Author's firm was engaged in 1974 to prepare a sewerage Master Plan for the town followed by project reports, detailed design and supervision of construction. The position to date is that the Master Plan has been accepted. Project Reports have been prepared for Contract Areas 1 and 2 and for Contract 11. A draft report has been submitted for Contract 3 - extensions to the sewage treatment works. The drainage work to connect a Government housing project, Contract 11, is at present under construction. Tenders have recently been received for Contract 1. Instructions to prepare contract documents for Contract 2 have also been received. A site investigation contract to cover the proposed development area was let in December 1976 and completed in March 1977.

TABLE 4: Tobruk projects

Contract	Total length+ Main foul sewer (km)	Number of P stations	Capacity of works m^3/day	Type of works
1	30 ø	4 *	-	-
2	10	-	-	-
3	-	-	30 000	Filters
Future sewer contracts	60	2	-	-
Future works extensions	-	-	10 000	Filters
11	30	1	-	-

* 1 No. new pumping station and refurbishing 3 No. existing stations.

\+ Does not include lateral connections

ø Foul and stormwater sewers

4. FOUL SEWERAGE

Type of system

The practice of providing separate foul and stormwater systems, now widely accepted in countries where total annual rainfall is low and confined to relatively short periods during the year, has been adopted, except in the case of Tripoli West where instructions by the employing authority required a combined system. The existing system at Tripoli, apart from a satellite development to the West, has been designed on the combined system with overflows of storm sewage to the sea.

Design criteria

One of the most difficult aspects of the engineer's work is in deciding basic design criteria and achieving confident acceptance of them by the authorities because of some or all of the following reasons:

a) The absence of established sewerage systems and therefore of experience of practice resulting therefrom.

b) Feedback of experience from established systems for which he or others have been responsible.

c) The absence of the professional bodies in the country concerned which, for example in Great Britain, provide a forum for the exchange of experience and opinions.

d) The uncertainty of planning policy both at national and regional levels.

e) The confusion in the minds of officials arising from the differences in approach and criteria proposed by different consultants.

f) The difficulty of employing authorities in realising that, at least in some cases, exact science cannot be applied.

In the case of current schemes for Tripoli, Benghazi and Tobruk, the design criteria and parameters adopted are as shown in Table 5.

TABLE 5: Design criteria and parameters for foul sewers

Minimum diameter of sewer	200 mm
Pipe size for properties connections ..	150 mm
Minimum velocity normal	1.00 m/sec
absolute	0.75 m/sec
Friction formula	Colebrook-White
K value	0.6 mm
Pipe capacity	6 x dwf
Flow/capita (future)	
Benghazi	270 litres/day
Tripoli	270 litres/day
Tobruk	150 litres/day
Population densities	
Benghazi	100 - 600 persons/ha
Tripoli	100 - 600 persons/ha
Tobruk	100 - 600 persons/ha
Pumping mains	
Maximum velocity	2.0 m/s
Minimum velocity	0.75 m/s
Pumping rate (generally where overflow possible)	3 dwf

The need to reduce the possibility of septic conditions in the sewage and the resulting corrosive effects was taken seriously and one of the precautions enlisted was to adopt a minimum normal design velocity in the sewers of 1.00 metres per second to ensure self-cleansing. It was necessary in places to relax this criterion to reduce for instance depth of excavation, but in all cases sewers have an absolute minimum self-cleansing velocity of 0.75 m/s at full bore.

The value of K selected in the Colebrook-White formula seems to vary among consultants and this variation causes employing authorities some concern since with such large schemes overall costs will be affected as well as anticipated velocities. A value of 0.6 mm appropriate to matured sewers was accepted and used in the design of the foul sewers in the present cases.

The dry weather flows (dwf) were calculated from the projected ultimate per capita water consumption figures. Sewers were sized by multiplying the dwf by a factor of 6 to be sufficient to provide a margin for possible groundwater infiltration and incidental surface water ingress. With rubber ring joint pipes infiltration is not expected to be large. The minimum size of main sewer adopted was 200 mm in the light of the following factors:

a) The need to minimise sewer blockages and to facilitate maintenance

b) To allow some margin against possible higher population densities than foreseen by the planning authorities, this factor being influenced by the many changes taking place between planned and actual development.

Property connections

Experience has shown that the sewerage system is considered by the users to be available for the reception of not only normal human waste but for the disposal of all kinds of objects of varying sizes and shapes. This has resulted in frequent blockages and generally heavy maintenance problems and at the request of the authorities special precautions have been taken in the designs. The two main steps taken were to limit the distance between manholes to 50 metres and to arrange where possible for property connections to enter the main system only by way of manholes and not through pipe junctions. A chamber is provided outside each property for the connection of the internal system and the chambers are linked through a lateral system which in turn is connected to a main sewer manhole. This arrangement is not always possible, such as in narrow streets or where existing services prevent it, but is the rule rather than the exception.

MATERIALS

Gravity sewers

For the original Phase 1 works design the choice of pipe material lay between concrete, glazed vitrified clay and asbestos cement. The concrete pipe manufacturers at that time showed considerable problems in transporting their product economically and the locally manufactured material was inferior and very sub-specification. The GVC pipes, of course, unquestionably provided a material with good anti-corrosive properties, but this advantage was offset by the high transportation costs, the limit on diameter and the short lengths entailing higher laying costs. In addition, early experience produced very high breakage costs. The problems associated with sewer fabric attack by sulphuric acid are each day more manifest and the current expansion in works in the Middle East have accentuated these problems. The prevention of this corrosion is uppermost now in the design engineer's mind.

The general experience from early examination of the existing sewer fabrics, mainly concrete pipes and culverts, showed no visible sign of fabric attack by sulphuric acid. At the Phase 1 stage this situation was acknowledged, but the lack of firm evidence demonstrated that conditions were obviously not conducive to the formation of sulphuric acid. It is felt that the very high per capita water consumption provides a weak sewage well below the strength of an average U.K. sewage. This, coupled with the low average temperatures (18 - 25°C) and the high velocities achieved and designed for in the sewer network, reduce the likelihood of the formation of sulphuric acid.

The asbestos cement pipes, the material eventually chosen, were readily available from local Mediterranean sources. The AC pipe suffers a small breakage loss owing to the ability to remove the fractured element and to provide a pipe of reduced length by turning the end. Similar argument was put forward for the choice of gravity sewer material for the second phase of the works for Tripoli, Benghazi and Tobruk.

The operating experience of the AC pipes constructed under the Phase 1 works showed no attack; similarly the manholes appeared sound. During recent construction of Phase 2 work it was necessary to 'exhume' a length of 900 mm diameter AC pipe after six years of service. It was in 'mint' condition and was relaid and put back into use. Consideration was given to the introduction of lining materials, especially in regions known to provide ideal conditions for generation of sulphuric acid, but the previous and current operating experience coupled with the continued practice of minimum velocity criteria excluded any revision to the original choices.

Due to the rapid programme of sewer construction it was necessary to ensure that there would be adequate pipe supplies to permit the speedy construction. For this reason it was decided that stormwater networks could be of concrete. The tendering procedures permitted the use of GVC pipes in the lower diameters and also the use of glass reinforced plastic pipe. However, the use of the latter was excluded from those areas where adequate protection to external damage by construction and development works was the overriding factor.

Pumping mains

A similar approach was undertaken in the choice of pumping main material. This lay in Phase 1 between steel and asbestos cement. The steep pumping mains were designed with an internal bituminous lining and externally sheathed and provided with cathodic protection. Mains of both these materials were used in the Phase 1 works. For Phase 2 the choice was extended to include GRP and ductile iron, the choice being left generally to the tenderer on pricing grounds. An exception to this was where development was likely to take place and GRP were excluded as having insufficient external structural strength against accidental damage caused by adjacent construction works.

Manholes

The original designs were similar to the standard practice in U.K., a precast ring with concrete surround. This proposal involved the contractors in providing fabrication facilities for the precast element and recent designs have included circular or rectangular in-situ castings, following a preference by the contractors for this construction system. The covers were specified to exclude sand ingress as far as possible. This was best achieved by correct seating arrangements and most suppliers of this item have achieved this requirement.

There is a tendency by the local authorities to use for their own work a very sub-standard form of circular cover which frequently seats inadequately and provides a traffic hazard.

Pipe protection

The pipe bedding and protection details were designed for rigid pipes using the method set out in Special Report No. 37 published by the Building Research Station. The design for flexible pipes varies but principally adopts the approach set out by Mr N W B Clarke in his paper "Buried pipelines".

Bedding materials are usually sand gravel or concrete depending on the design conditions, but sand is specifically excluded for lengths where formation level is below groundwater table. The design has generally been carried out for varying trench conditions. Generally sand and gravel bedding with medium strength pipes have been used in preference to a lower strength pipe on a higher bedding factor support.

Testing

Small diameter gravity sewers are tested using water with a permitted loss under a minimum head of 1.0 m at the upstream end. Larger sewers are tested using air against a permitted loss on a pressure equivalent to 100 mm of water. The test requirements for pumping mains using a water test is the greatest of 2 x working or $1\frac{1}{2}$ x closed valve, or 3.5 kg/cm^2 whichever is the greater.

Ventilation

Originally all house connections lateral chambers were provided with ventilation pipes, but subsequently the local authority have enacted legislation to ensure that house drainage is vented similar to normal U.K. practice, and thus lateral chambers are not now provided with separate ventilation pipes. Ventilation pipes on the sewerage network are provided on all branch sewers greater than 100m in length and at the head runs of all main lines.

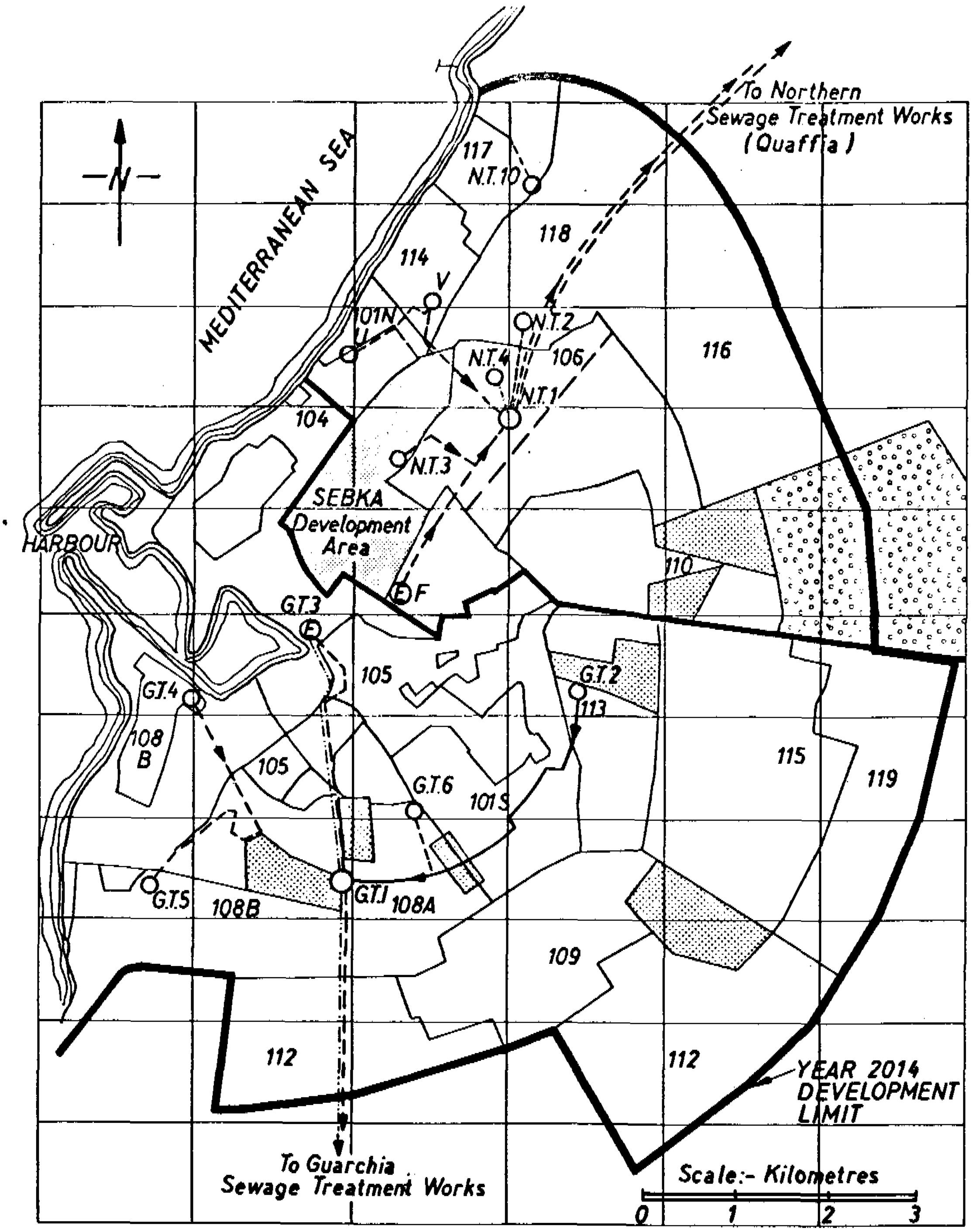
Benghazi sewerage system

Benghazi is generally flat, being a sebka area. The land generally falls seaward from the East, but the central and northern areas require pumping stations to lift the sewage from the low lying areas. The overall plan provides for development up to the year 2014 (see figure 2).

An extensive study resulted in the decision to provide two separate treatment works, one on the North side and one on the South side, their location being if possible close to the agricultural areas that will be using the treated effluent. The existing sewage treatment works at Guarchia, located South of the city, at present drains the central zone of Benghazi. This arrangement conveniently divided the city into a North and South drainage zone.

Pumping stations

The major sewage pumping stations have flow measurement equipment and overflow facilities. At certain of the smaller pumping stations where it is not convenient to separate flows greater than 3 dwf because of overflow problems, outlet pumps have been installed for rates of up to 6 dwf.



LEGEND:-

Boundary between areas served by GUARCHIA and NORTHERN Treatment Works

Housing Sites

Pumping Mains

Foul Pumping Station

Industrial Housing Site

Existing

Existing Foul Pumping Station

Sewers

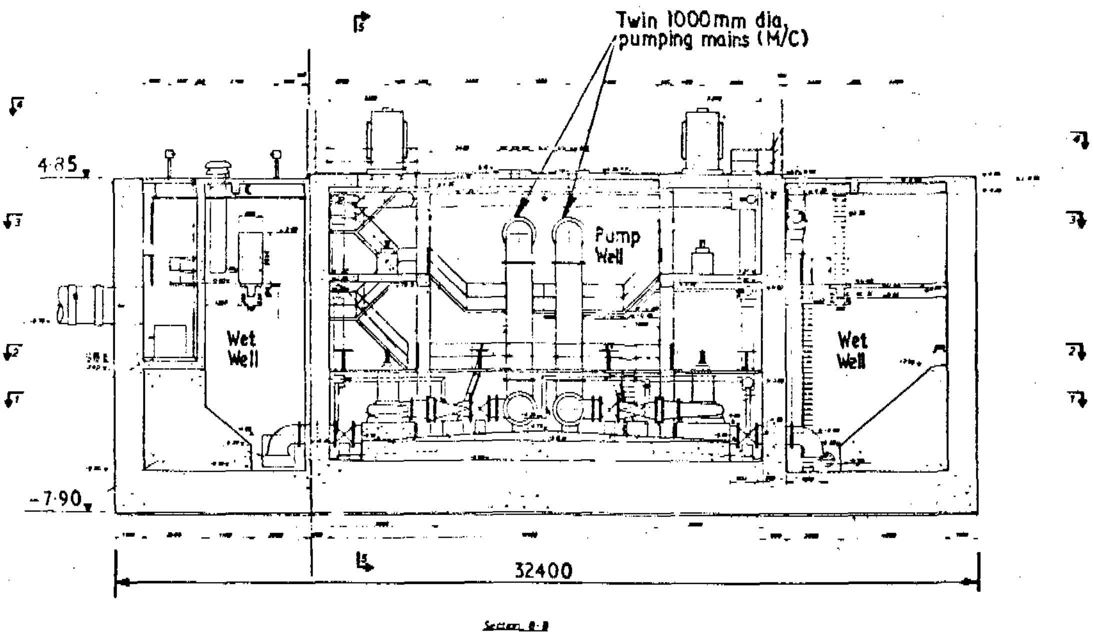
FIG. 2 BENGHAZI FOUL SEWERAGE SYSTEM

The pump arrangements are conventional using centrifugal sewage pumps. In the main pumping stations in addition to the duty pumps, one standby and one maintenance pump have been provided.

The majority of pumping stations are provided with coarse screens which are hand raked. The main town pumping stations are provided with semi-rotary mechanically raked screens, flow measurement and overflow facilities. Flow measurement readings are used to transmit signals to control motorised penstocks which restrict the flow to the wet wells to 3 dwf capacity of the treatment works. Overflowed quantities are allowed to pass to the stormwater culverts after passing through vertical raked fine screens.

One of the larger pumping stations pumps to the Northern Treatment Works. A plan and section (figures 3 and 4) show the general layout of the station.

FIGURE 3: Typical foul sewage pumping station (section)
(all diameters in millimetres)



The station is arranged with a central pumping hall with two wet wells on either side. The pump casings have been sized as to be suitable for the initial, intermediate and ultimate stages of the design. Each of the last two stages will be achieved by a change of impeller and change of speed achieved by the use of two speed double wound motors. Table 6 summarises the initial foul pumping station capacities. The pumping mains to the new sewage treatment works will be twin 1200 mm with cross-over connections at suitable distances.

Experience so far

Clearly the mere provision of physical structures and systems is not the end of the story and much needs to be done in educating the public in the proper use of them and in providing efficient maintenance facilities. The sewerage system is often looked upon as the repository for all manner and size of objects.

FIGURE 4: Typical foul sewage pumping station (plan) (all dimensions in millimetres)

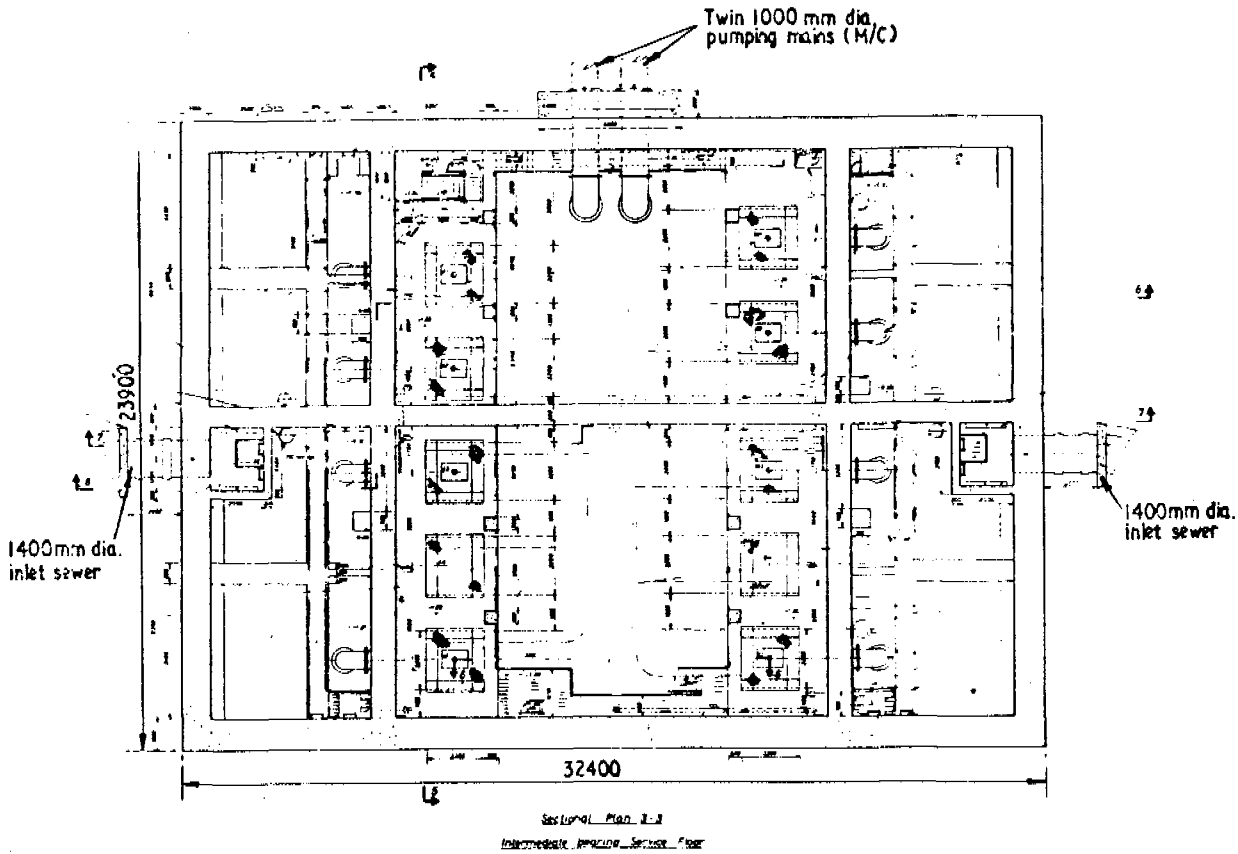


TABLE 6: Benghazi - Phase 2 sewage pumping stations (initial) summary of pumping rates

Pumping station	No of pumps	Maximum capacity m^3/hr	Pumps		Max. total head m
			Type	Size (mm)	
U	2 + 1	670 (ultimate)	Sewage	250	11.0
V	2 + 1	2024 (ultimate)	Sewage	350	10.12
	2 + 1	2024 (storm)	Sewage	350	10.00
F	2 + 1	1644 (ultimate)	Sewage	350	26.00
GT1 'A' pumps	2 + 2	5800	Sewage	600	40.00
'B' pumps	5 + 2	17 680 (ultimate)	Sewage	600	37.00
GT6	3 + 2	3125 (ultimate)	Sewage	300	9.00
NT1	3 + 2 and 3 + 2	16 250 (ultimate)	Sewage	600	21.00

In some countries the rate of property connection can be very slow, resulting in low rates of flow in the sewers and ensuing problems of solids settlement and septicity. In Libya there is generally a keenness to connect and indeed many difficulties have been suffered by contractors who have found sewage flowing in systems still being constructed by them due to illegal connections being made.

On the whole sewers laid so far have worked well and there has been no reason to drastically change the design approach other than the spacing of manholes and providing rider lateral systems. The corrosion problem with asbestos cement pipes has not arisen as has been the unfortunate experience elsewhere.

The old sewer network in Tripoli constructed before the Author's firm's involvement with the sanitation of the city, was principally constructed of minimally reinforced concrete. These sewers, having a variety of shapes and in places very flat gradients, have so far shown no deterioration from sulphuric acid attack.

Manhole covers have generally worked satisfactorily, especially considering the extreme traffic loadings that are more than occasionally encountered and incorrect reseating and repositioning resulting in unbalanced loadings and thereby fracture of cover frame or both. This latter problem being a direct cause of inadequate understanding and of inexperience in proper maintenance of the sewerage network.

5. STORMWATER DRAINAGE

General

The approach to the provision of stormwater systems in the various towns in Libya is basically the same. The broad differences between the projects stem from differences in topography, i.e. essentially the need to pump as opposed to disposal by gravity. In the cases of Tobruk and Derna the topography and available falls are such that little pumping is necessary and long trunk sewers are rare. Misurata is generally "dish shaped" and run-off has to be collected and pumped away from the town centre. The Phase 1 arrangements here were to pump to the sewage treatment works for partial treatment before either ground soakage disposal or pumping to the irrigation areas. Sebha is flat and similar to those at Misurata were provided. The Tripoli Phase 1 provision did not involve pumping but will probably be necessary in future developments. The extent of systems to be provided vary depending on the topography of the particular town. It is proposed to discuss the Benghazi system since it is the largest and most advanced and includes most of the features of the other projects.

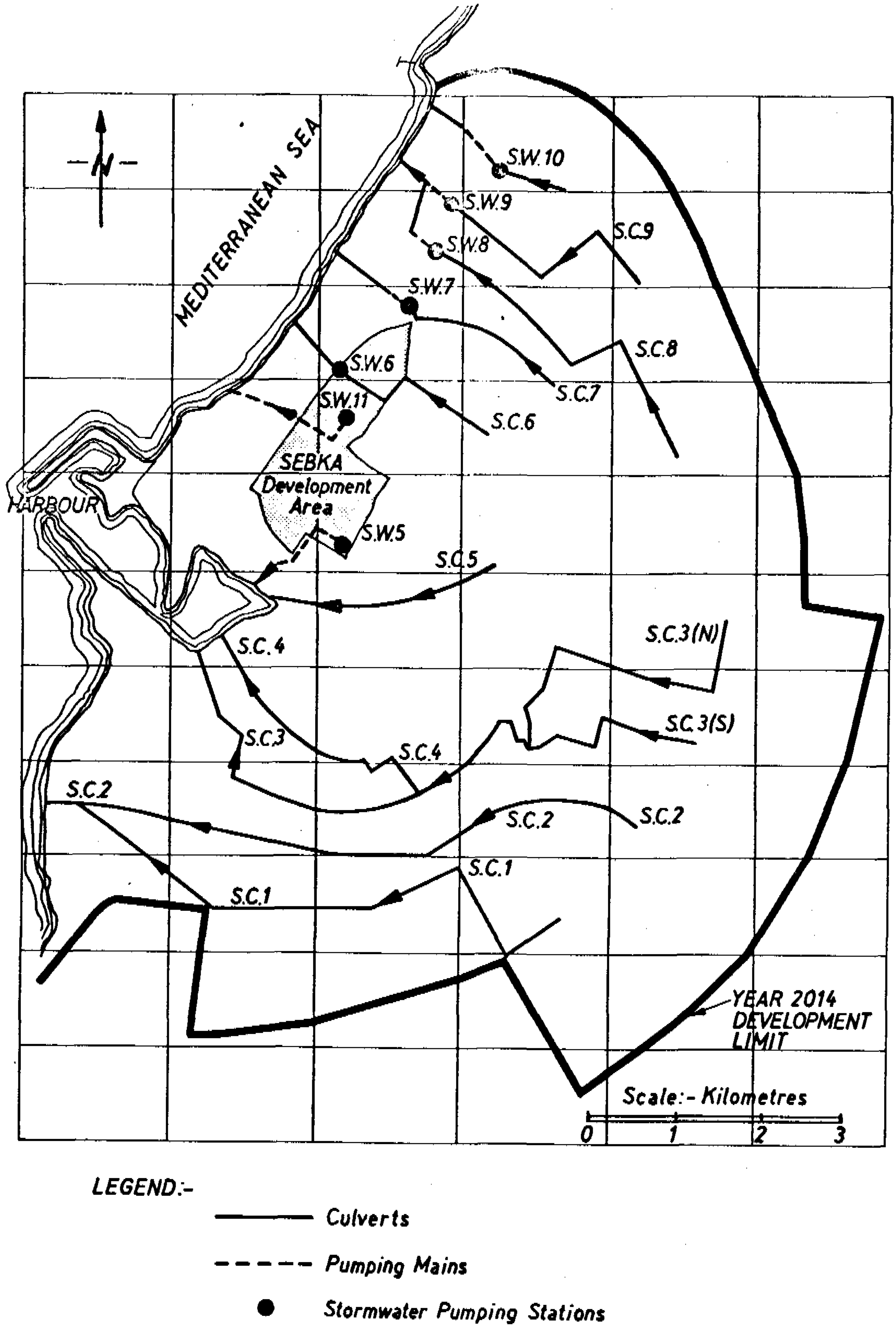
BENGHAZI STORMWATER SYSTEM

General

Benghazi is probably the most difficult of all the six towns for which to provide stormwater disposal facilities since surface water from itself and the hinterland flows across it and there are no defined natural water-courses or wadis available for the orderly collection and transport of run-off to the sea. Also the fall of the ground is generally very slack and the way to the sea is inhibited by fast-growing development which is already extensive and which has already sterilised the few natural routes which did exist at one time. The situation is further aggravated by the fact that the ground surface in some cases rises before finally sloping down to sea level. Again, the Selmani Sebka, a large inland lagoon near the town centre, which at one time served to receive run-off from certain areas, has been filled in and is now itself a flat area which is rapidly developing.

It is thus necessary to provide long artificial waterways across the town and at some points to finally pump to the sea. The type of waterway chosen is the box culvert which at their low reaches becomes considerable in size. The pumping stations are also substantial. Figure 5 illustrates the main culvert collectors and pumping stations.

FIGURE 5: Benghazi stormwater drainage system



Rainfall

Benghazi is situated in a semi-arid climatic zone and rainfall is concentrated into the winter months and is practically non-existent in the summer months. The following are monthly average precipitations in millimetres.

Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual total
67	40	19	5	2	-	-	-	3	17	46	66	265 mm

From records available from 1921 to 1972 the average highest rainfall in one day is:

In 1 year - 29.6 mm
In 2 years - 34.5 mm
In 5 years - 41.0 mm

At the time of the design of the Phase 1 project in 1962/63 the only available information on rainfall intensity for Libya was that compiled by the United States Weather Bureau in a paper published in 1975 entitled 'Rainfall intensities for local drainage design in coastal regions of North Africa'(1). The data therein covered the region in the vicinity of Tripoli only. A storm curve was selected for Benghazi with the aid of this data based on a two-year return, one-hour intensity storm.

For the Phase 2 designs, rainfall data from the Meteorological Office at Benghazi was used in conjunction with data compiled by the British Meteorological Office to formulate rainfall statistics used for design purposes. These were for a two-year, two-hour storm intensity curve and a one-year, two-hour storm hydrograph respectively. The former was used in the Lloyd-Davies method for some stormwater sewers and the latter modified for use as a two-year, two-hour storm used in a computer program for the design of majority of stormwater sewers and the stormwater culverts. For hydrograph purposes the storm profile was assessed as being similar to a fifty percentile British summer storm and for Lloyd-Davies purposes the maximum intensity was limited to 37 mm/hr at a minimum of five minutes time of concentration.

Impermeability factors

Unpaved areas of Benghazi act in many cases as though they are paved due to the hard impermeable rock at the ground surface. Also where soil is present it is often of a fine cohesive nature when wet. These conditions produce high overall impermeability factors and actual experience during storms does indicate a high percentage run-off. The overall impermeability factors adopted after site investigation and due consideration are as follows:

Residential	0.6 to 0.8
Industrial	0.9
Open areas	0.2
Agricultural	Nil
Community facilities	0.9
Military	0.9
Educational	0.9

In general properties are not connected directly to stormwater drains but entry is by way of the road gullies.

Culverts

The pipe reticulation system is conventional and reasonably straightforward, the maximum size of pipe being 2000 mm diameter. The hydraulic and structural design of the culverts was also relatively straightforward, but due to their size a great deal of thought had to be put into the choice of route. In the case of one culvert it was necessary to split the culvert to take two routes since there was no route wide enough for a single structure large enough to take the total flow. The sizes, total lengths and capacities of the culvert system are given in Table 7.

TABLE 7: Culvert details

Culvert	Maximum size (metres)	Total length (km)
SC1	4.0 x 2.5*	7.50
SC2	4.0 x 2.0*	7.80
SC3	4.0 x 2.0*	12.8
SC4	4.0 x 2.5*	3.5
SC5	2.5 x 2.0	2.8
SC6	4.0 x 2.5	3.5
SC7	4.0 x 2.5	3.5
SC8	3.5 x 2.0	5.5
SC9	4.5 x 2.5	3.5
SC10	4.0 x 2.5	2.5

*Twin culverts

In order to try to reduce the size of culverts, consideration was given to the provision of balancing reservoirs, perhaps by using old disused quarries, but the proposal was rejected by the authorities as a possible health and environmental hazard as well as presenting a maintenance problem.

All culverts for some part of their length are either partly or totally below sea level and during the dry season when no stormwater is entering the system, there will be static water remaining. In order to allow for cleaning and to reduce the possibility of odours issuing from road gullies arrangements have been provided so that the sea may be excluded and the culverts pumped out. Each culvert is provided with a specially designed outfall chamber structure containing penstocks in addition to the normal tide flaps. At the end of the rainy season the penstocks can be closed and mobile pumps used to empty the culverts.

Each culvert is provided with a low flow channel to reduce deposition of solids so far as possible. However in such a sandy area there is expected to be deposition of heavy particles and access for cleaning gangs with skips and other tackle has been provided by large multiple-cover shafts.

Stormwater pumping stations

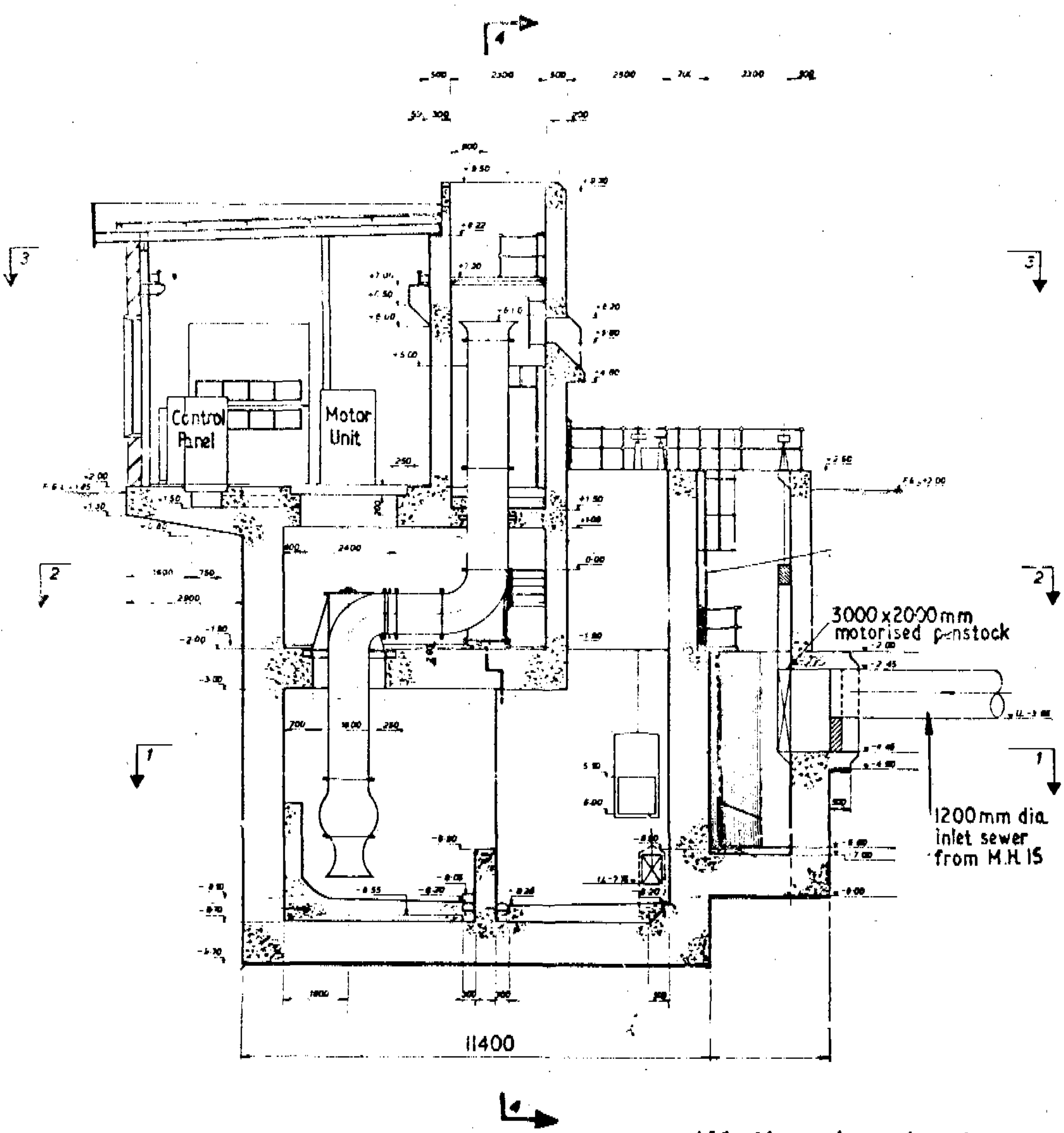
Included in the Phase 1 project were two pumping stations, SW1 and SW2 consisting of suspended mixed flow pumps, SW1 lifting into a header chamber built on to the upper end of an R.C. pressure box culvert and SW2 pumping into an asbestos cement pumping main. SW1 pumps to the inner harbour and SW2 to the sea.

The earlier stations in the Phase 2 works contained conventional mixed flow suspended pumps. A typical example of this type is pumping station SW5 where four duty and one standby unit have been provided. All pumping stations have model tests before approval is given and considerable changes were required in the baffle arrangements of Station SW5 to improve flow pattern to the pump sections.

When four pumps are operating the total discharge is 36 000 m^3/hr. Each 1000 mm pump discharge is fitted with a single door non-return valve and sluice valve. The general configuration of the station dictated the rather oblique angle of entry of the sewer to the wet well.

All future stormwater pumping stations will be of a different design. They will pump direct to a header chamber and discharge above the maximum TWL, therefore making the use of valves unnecessary. This arrangement reduces the size of the pumping station and also incorporates the header chamber as part of the pumping station structure. The cost of the mechanical equipment is also reduced with the omission of the reflux and sluice valves (see figure 6).

FIGURE 6: Typical stormwater pumping station



All dimensions in millimetres

The new stormwater pumping stations will be provided with grit-retaining walls in the wet wells designed such that the major quantity of grit is contained in an area remote from the pump suctions. At the end of the rainy season the remaining water in the wells will be pumped into the nearest foul sewers by submersible pumps located in their own suction chambers isolated from the main wet wells. Weir penstocks have been provided so that top water only from the main wells is allowed to enter the drainage pump sump leaving the grit to be removed by use of skips lowered into the wet wells by mobile cranes. Table 8 shows the basic data for stormwater pump stations, either designed or to be designed.

TABLE 8: Stormwater pumping stations

Pumping station	Maximum capacity m^3/hour	No of pumps	Pumps		Maximum total head (m)
			Type	Size (mm)	
SW1	19 500	3 + 1	Mixed flow	600	7.50
SW2	10 220	4 + 1	"	600	11.00
SW5	36 000	4 + 1	Mixed flow	1000	14.00
SW6	55 900	5 + 1	"	1000	12.50
SW7	55 300	5 + 1	"	1000	14.00
SW8	43 388	5 + 1	"	1000	7.00
SW9	64 580	6 + 1	"	1000	6.80
SW10	66 960	6 + 1	"	1000	7.00
SW11	37 800	5 + 1	"	1000	11.20

Standby generation

Standby generation has been provided at all pumping stations to ensure operation of the pumping equipment in the event of a failure of the main electrical supply. The large stations have separate structures housing the generator sets and high voltage switching systems to control the load to the pump motor demand.

In the interests of economy and to maintain a standby electrical supply in some of the smaller stations in Phase 1 a 200 amp 5 pin connecting socket and plug system has been introduced. To this plug a mobile generator can be connected to reinstate the power supply until the network mains is restored.

The type of generator installed is diesel engine driven. Each generator has its own day tank for oil and the generator station has a bulk oil tank for supplying the day tanks. Thus once called for during a power failure the standby generator can keep the station supplied with electricity for as long as is necessary.

6. SEWAGE TREATMENT

Phase 1

The six Phase 1 towns, Tripoli, Benghazi, Tobruk, Sebha, Misurata and Derna, are all provided with central sewage treatment facilities to which the town's sewage is pumped from one main pumping station in each case through pumping mains from three to eight kilometres long. Conventional biological filter plants are provided in each case with sludge digestion (heated at Tripoli and Benghazi and cold at the other towns) and drying on beds. Treatment is to the tertiary stage in each case. The biological filter process was chosen on grounds of simplicity and reliability, there being ample land available at the time.

The conventional stages of treatment adopted were:

Preliminary treatment	- comminution - detritus tanks
Primary treatment	- sedimentation tanks
Secondary treatment	- biological filters - recirculation - humus tanks
Tertiary treatment	- rapid gravity sand filters - prior chemical dosing - chlorination of filtrate (pre and post-chlorination at Benghazi)
Sludge digestion	- heated at Tripoli and Benghazi - cold at Derna, Tobruk, Misurata and Sebha
Sludge drying	- open with underdraining except at Sebha where underdrainage was omitted.

All plants have been successful in so far as design is concerned, but operational achievements are in proportion to the availability of sufficient and suitable staff, the larger works being the most successful. As with all progress, experience has suggested improvements for future designs, but mainly in terms of detail, except in the case of the tertiary plants where rapid gravity sand filters have proved too complex and sensitive to mal-operation. In the Phase 2 designs, microstrainers have been adopted for the two Benghazi Works.

Phase 2 - Benghazi

In the extensions to the existing Southern sewage works and the provision of new sewage treatment works to serve the northern half of the city, various sewage treatment processes were considered. The concept of stabilisation oxidation ponds was rejected on the grounds of environmental nuisance, land area required and the need to provide an impermeable lining to all agoons to prevent infiltration into the limestone aquifer was a major cost factor especially as the lining was required to be absolutely watertight to satisfy the stringent requirements of the Water Authority. This left the principal choice between percolating filters and an activated sludge plant for secondary processes. The other unit designs were based on conventional practice. It was felt that owing to the very limited operational experience on the existing works at Benghazi it would not be prudent to propose a change from the existing percolating filter system to the early stages of the extension.

The initial stages of the works include for percolating filters whilst for future stages it is proposed that the activated sludge process be adopted. In fact, due to the limited space available at the Southern Sewage Treatment Works, it will be essential in the future to adopt a less land-hungry process than percolating filters for the final extensions.

Southern treatment works - Guarchia

The proposed extensions to the treatment works at Guarchia are summarised in Table 9, together with the corresponding features of the proposed extensions of the works at Tripoli. It is not intended to expand on the description of the treatment units for each extension except where the units proposed provide a special interest.

TABLE 9: Units for proposed extensions to new and existing treatment works at Tripoli and Benghazi

	TRIPOLI Stage 2 (110 000 m^3/d) dwf	GUARCHIA, BENGHAZI (Southern works) Stages 2 and 3 (54 000 m^3/d) dwf	QUAFFIA, BENGHAZI (Northern works) Stages 1 and 2 (65 000 m^3/d) dwf
INITIAL TREATMENT			
Screening	6 no. 900 mm dia, comminutor 3 no. fine screens with disintegrator	3 no. fine screens (also serve Stage 1) with disintegrator	2 no. fine screens with disintegrator
Grit removal	2 no. 11.0 m dia. detritors	1 no. 10.0 m dia. detritor	1 no. 11.0 m dia. detritor
Grease removal	4 no. tanks 17.4m x 7.1m x 4.4m	-	-
PRIMARY TREATMENT			
Sedimentation tanks	8 no. tanks 42.7m dia x 2.0m deep	6 no. tanks 28.0m dia x 2.2m deep AND 4 no. tanks 18.3m dia x 2.4m deep (linked with Ph.1 sizing)	8 no. tanks 28.0m dia x 2.5m deep
SECONDARY TREATMENT			
Biological treatment	32 no. aeration pockets 17.0 x 17.0 x 5.0m deep with 50 hp motors	8 no. filter beds 205.0 x 34.0 x 2.0m with 3 no. distributor	12 no. filter beds 162.0 x 32.0 x 2.0m
Settling tanks	8 no. tanks 42.7m dia x 2.7m deep	6 no. tanks 28.0m dia x 2.2m deep AND 4 no. tanks 18.3m dia x 2.4m deep (linked to Ph.1 sizing)	8 no. tanks 28.0m dia x 2.5m deep
TERTIARY TREATMENT			
Microstrainers	-	11 no. 5.0m x 3.0m dia	13 no. 5.0m x 3.0m dia
Chlorination	Max. 12 mg/l	Max. 12 mg/l	Max. 12 mg/l
IRRIGATION			
Pumping	3 x dwf	3 x dwf	3 x dwf
Storage	3 days	3 days	3 days

/cont.....

Table 9 (cont...)

	TRIPOLI	GUARCHIA, BENGHAZI	QUAFFIA, BENGHAZI
SLUDGE TREATMENT			
Consolidation	2 no. tanks 15.8m dia x 4.5m deep	-	-
Storage	2 no. tanks 14.5m dia x 2.5m deep	-	-
Thickening	5 no.electroflotes 36m^2	-	-
Primary digestion	6 no. heated tanks 21.5m dia x 11.1m deep	4 no. heated tanks 18.0m dia x 10.8m deep	4 no. heated tanks 21.5m dia x 9.5m deep
Secondary digestion	3 no. unheated tanks 21.5m dia x 11.1m deep	2 no. unheated tanks 18.0m dia x 10.8m deep	2 no. unheated tanks 21.5m dia x 9.5m deep
Drying beds	54 bays each 20.0m x 40.0m	24 bays each 14.0m x 40.0m AND 20 bays each 17.5m x 40.0m	40 bays each 20.0m x 40.0m

The primary sedimentation tanks were of two sizes to permit the most economic use of available space left on the existing site following the Phase 1 works. Rectangular percolating filters were adopted to maximise the limited space available when all stages of the work were laid out. Experience with the Phase 1 rectangular filters was successful and encouraged their adoption again.

It has already been stated that the performance of the rapid gravity sand filters with the low level of operational/maintenance skills had resulted in continued mal-functioning of the tertiary treatment process. Micro-strainers will therefore be adopted for the polishing stage for these extensions.

Recirculation facilities are included to firstly ensure biological film activity during periods of low flow and further to overcome septic conditions in the primary sedimentation tank resulting from lengthy detention periods.

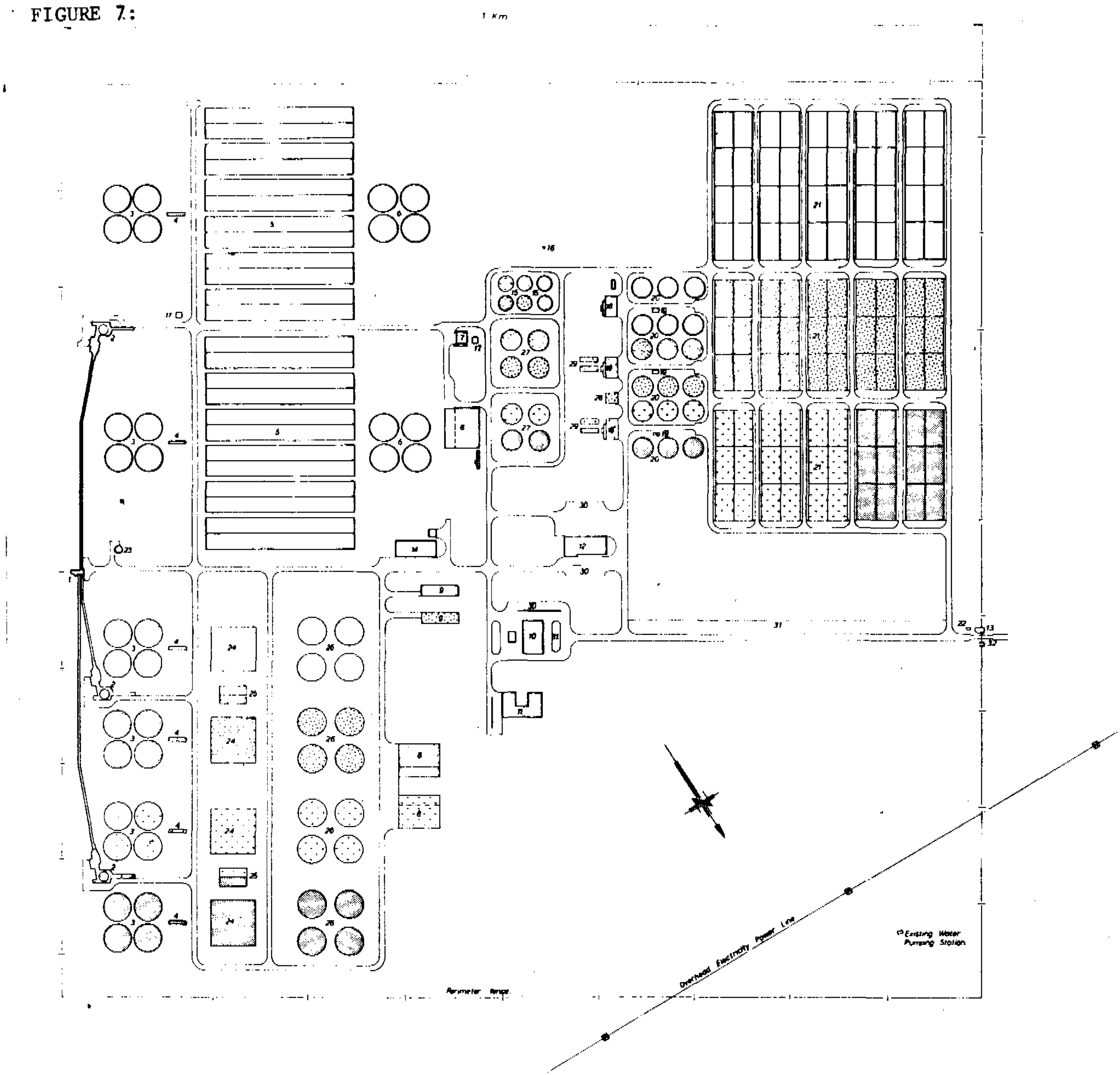
Northern sewage treatment works - Quaffia

Figure 7 shows the staged development of this sewage treatment works. The site chosen to the north east of the city is presently remote from development and on unused land.

The layout involves the distribution to each extreme of the works via long open channels where velocities are such as to ensure that grit is carried to the settlement basins. Future extensions to the works will employ the activated sludge process following the gaining of general works operation experience from the operation of the percolating filter plant. As for the Southern sewage treatment works, this works has a conventional heated sludge digestion system. For part of the summer months with high ambient temperatures, heating is not required.

Sludge for these early stages is dried on open sludge drying beds. The sludge drying beds design omits conventional media and underdrainage. The designed drying times for the Phase 1 works were considerably improved upon and following tests on paved areas it was found that evaporation drying was adequate with a minimum of floor run-off to achieve a spadeable sludge within a sludge drying cycle of 28 days. The absence of media and floor drainage permits mechanical lifting with a wheeled front loading bucket tractor.

FIGURE 7:



WORKS UNITS & BUILDINGS

1 Flow Splitting Chamber
2 Inlet Works
3 Sedimentation Tanks
4 Filter Distribution Flumes
5 Filter Beds
6 Humus Tanks
7 Works Pumping Station
8 Microstrainer Building and Chlorine Store
9 Irrigation Pumping Station
10 Administration Building
11 Welfare Building
12 Workshop and Stores Building
13 Gatehouse
14 Generator Building
15 Gasholders
16 Waste Gas Burner
17 Electrical Switchgear Houses
18 Sludge Pump and Boiler House
19 Control House
20 Sludge Digestion Tanks
21 Sludge Drying Beds
22 Water Pumping Station
23 Water Tower
24 Aeration Tanks
25 Returned Activated Sludge Pumping Station
26 Final Settlement Tanks
27 Secondary Sludge Storage Tanks
28 Sludge Liquor and Washout Pumping Station
29 Secondary Sludge Thickeners
30 Parking Areas
31 Planted Areas
32 Shelter

WORKS STAGE DETAILS

Stage
1 and 2
3
4
5
6

BLOCK PLAN

NORTHERN SEWAGE TREATMENT WORKS (QUAFFIA) BENGHAZI

Phase 2 - Tripoli

The operational experience of the Phase 1 works at Tripoli is more comprehensive although not available at the time of writing. However, at the design stage in 1973 of the Benghazi and Tripoli works, a senior member of the staff of the Water Research Centre was retained to take samples and analyse raw sewage, and for information the results of the investigation are given in Table 10. A typical effluent analysis is given in section 7 - Re-use of treated sewage (Table 11).

TABLE 10: Analysis of raw sewage at main inlet to sewage works (Tripoli)

Time	pH value	4-h PV	Temp (°C)	Flow (mgd) sewage	Flow (mgd) recirc.	SS	OrgC	COD	Amm N	KjN	BOD_3	BOD_5
10/7 Wednesday												
1715	7.0	48	27.6	11.5	3.1							
1815		No flow		5.7	3.0							
1915	6.9	39	26.6	12.0	3.0							
2015		No flow		3.3	3.9							
2115	6.8	42	25.4	12.4	1.7							
2215	6.8	38.5	25.6	13.2	2.0							
11/7 Thursday												
0715	6.8	40	25.2	8.5	3.5							
0815	6.7	43	26.2	14.5	3.7							
0915	6.6	31.5	27.2	13.0	2.5							
1015	7.0	41	27.6	12.5	4.0							
1115	6.8	41	27.6	16.7	2.2							
1215	6.8	36.5	28.0	14.8	3.5							
1315	6.8	32.5	28.0	8.0	2.4							
1415		No sample taken										
1515	6.8	40	28.6	16.3	0.4							
1615	7.1	25	28.0	14.0	0.8							
15/7 Monday												
0800}	7.1	53		12.4	3.7}	228	112	415	20	28		150
1000}				4.8	2.6}							
1200}	6.8	56		9.6	2.1}	228						
1400}				11.0	3.8}							
1600}	7.3	52		7.4	3.8}	184	117	385	23	35		170
1800}				7.0	4.0}							
2000	7.5	56		11.0	3.0	132						
2400		No flow			3.5							
0400		No sample taken										
17/7 Wednesday												
0800	7.1	57		9.5	3.9	192}						
1000	7.1	55		2.1	3.9	164}	127	385	23	28		140
1200	7.1	47		10.3	3.9	112}						
1400	7.1	32		10.1	4.0	196}						
1600	7.1	58		9.5	3.9	60}						
1800	7.2}	52		13.7	3.9	108}	141	385	30	37		129
2000	7.2}			10.2	3.2	240}						
2400	7.2	32		3.4	4.0	196}						
0400		No main flow		1.0	4.0							
19/7 Friday												
0800	7.2	60		9.6	4.1	390}					324	
1000	7.1	39		7.0	4.0	205}	160	505	23	33	254	90
1200	7.6	31		6.9	4.1	220}					234	
1400				1.9	3.9							
1600				0.9	4.0							
1800				2.8	4.0							
2000				1.2	4.0							
2400				0.8	4.0							
0400	7.0	54		3.1	4.0	180	68	285	24	33	215	143

Notes to table 10

All results are given in mg/l except where otherwise stated.
Flow from El Medina pumping station and pumping station B only.
Composites made according to sewage flow at works.

The crude sewage is much weaker than normal UK domestic sewage and is comparatively low in nitrogen. The strength of the sewage is probably due to a lower BOD/capita, a high water usage and in the old network groundwater infiltration.

The works have been designed on the basis of sewage strengths of 300 mg/l BOD with SS content of 350 mg/l which it is anticipated will eventually occur in Tripoli. Although Tripoli is a large works it will be served by numerous small pumping stations draining areas with low times of concentration. A figure of 3 dwf for peak flows was adopted for the hydraulic design of the sewage treatment works, together with an allowance of ½ dwf for returned operational flows.

The layout of the works is shown on figure 8 together with a flow diagram (figure 9). The proposals include grease removal tanks to overcome the grease/oil problems occuring on the existing Phase 1 works. The sedimentation tanks, eight in number with a diameter of 42.7 m, have triple arm scraper blades to ensure rapid evacuation of the sludge.

The secondary treatment uses the activated sludge process with air applied by electrically driven vertical axis surface rotors. Control and performance is automatic using dissolved oxygen probles actuating weir draw-offs. The final settling tanks are similar to the primary sedimentation tanks but are flat bottomed. The sludge evacuation is by vacuum lift. The surplus activated sludge is gravity thickened before flotation thickening to increase the d.s. content to 4%. The thickened sludge is then mixed with the primary sludge before conventional heated digestion.

As for the Benghazi works, Tripoli will have concrete bottomed sludge drying beds with no underdrainage system. Initially, design for the works included tertiary treatment using microstrainers, but following discussions with the Agricultural Project Authorities and their consultants, the Client instructed the omission of these units. The designed effluent standards from the final tank with chlorination, 15 mg/l BOD 20 mg/l SS was felt to be adequate for the irrigation requirements for the particular arrangements planned. Standby generation has been provided at this works and the two in Benghazi.

Comparison

From the very brief description of the sewage treatment works in the previous paragraphs it will be obvious that there are certain differences between the provisions made at the various works. Differences of approach depend on local circumstances as is well known, although there needs to be a common aim within one country where possible. It may be useful here to explain the reasons behind some of the major decisions and the reasons for variation in process design between the two major cities.

Screening

The contents of the sewage at Tripoli occasionally contain excess of particular screening matter and maceration of this excess has not always been complete. There has been a tendency for stringing of the screenings to build up downstream. It was felt that a second stage screening and disintegration would overcome this problem.

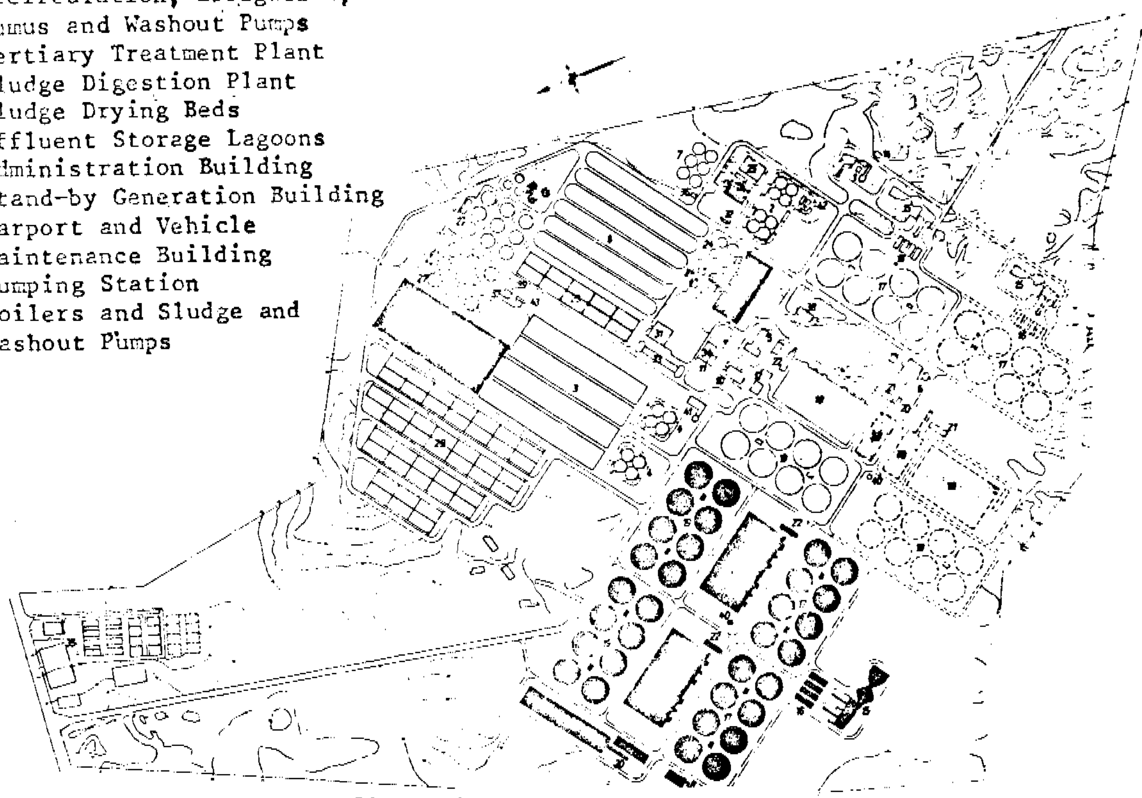
However, at Benghazi a single stage screening and maceration unit was proposed as being adequate. A further stage could be introduced if the same problem occurs here.

Existing Treatment Works

1 Inlet Works
2 Primary Sedimentation Tanks
3 Filter Beds
4 Humus Tanks
5 Pumping Station Recirculation, Irrigation, Humus and Washout Pumps
6 Tertiary Treatment Plant
7 Sludge Digestion Plant
8 Sludge Drying Beds
9 Effluent Storage Lagoons
10 Administration Building
11 Stand-by Generation Building
12 Carport and Vehicle Maintenance Building
13 Pumping Station Boilers and Sludge and Washout Pumps

Key

- Existing Phase 1 Treatment Units
- Proposed Phase 1 Treatment Units
- Stage 1
- Stage 2
- Stage 3 & 4

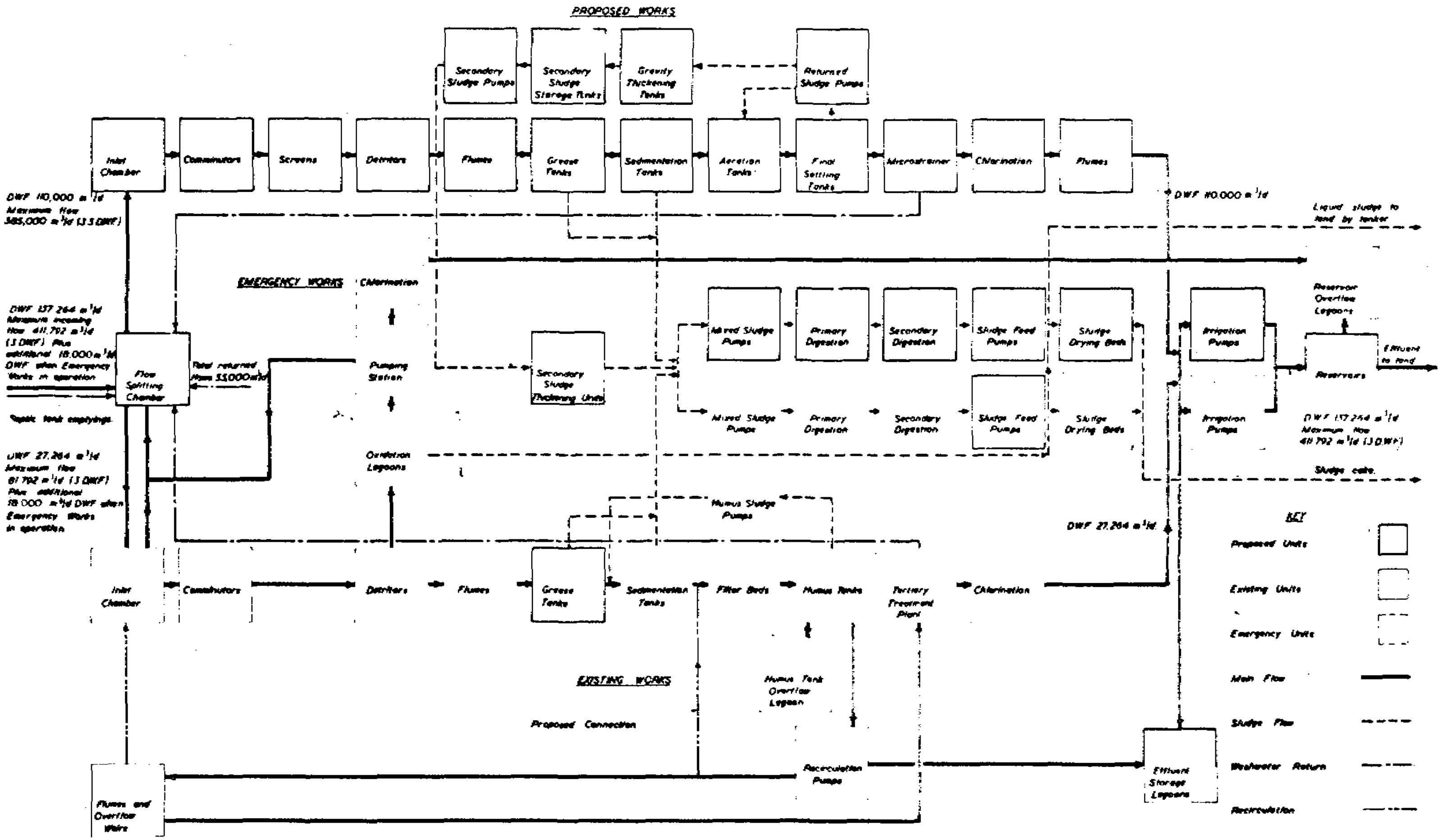


Proposed Treatment Units

14 Flow Splitting Chamber
15 Inlet Works
16 Grease Tanks
17 Primary Sedimentation Tanks
18 Aeration Tanks
19 Final Settling Tanks
20 Measuring Flumes
21 Chlorination House
22 Pumping Station Returned Activated Sludge Pumps
23 Secondary Sludge Gravity Thickening Tanks
24 Secondary Sludge Storage Tanks
25 Secondary Sludge Thickening Units
26 Pumping Station Mixed Sludge Pumps
27 Sludge Digestion Plant
28 Gasholders
29 Sludge Drying Beds
30 Microstrainer House
31 Main Workshop and Stores Building
32 Pumping Station Secondary Sludge Feed Liquor Pumps
33 Carport
34 Stand-by Generation Building
35 Site Houses
36 Pumping Station Digestion D
36 Pumping Station Digestion Sludge Pumps
37 Pumping Station Digestion Sludge Pumps
38 Pumping Station Irrigation Pumps
39 Pumping Station No.9 Digestion Plant Washout Pumps
40 Pumping Station Washout Pumps
41 Instrumentation Centre
42 Grease Tanks
43 Sludge Tanker Filling Bay
44 Area for Future Sludge Dewatering

Figure No. 8

BLOCK PLAN
SEWAGE TREATMENT WORKS-TRIPOLI



FLOW DIAGRAM

SEWAGE TREATMENT WORKS - TRIPOLI

Figure No. 9

Grease removal tanks

Tripoli has experienced large build up of oils and grease at the sedimentation tank. To reduce this nuisance grease removal tanks have been incorporated in the design.

Secondary treatment

The comparison of advantages and disadvantages of percolating filter bed and activated sludge plants are well documented. The dominant factor that prompted the adoption of percolating filters for Benghazi works was the lack of specialist skills necessary for the successful operation of the A.S. treatment plant, especially in view of the need to maintain the necessary standards for irrigation water.

The reverse of this argument applied for Tripoli where it was felt that the operational expertise established over the year permitted the use of the activated sludge process. A process more suitable and economic for an extension of this size. Space problems were also pressing at Tripoli.

Effluent standards tertiary treatment

One could spend much time on arguing the virtues of providing various standards of water for irrigation. Many parts of the world use crude sewage for soil improvement and it is not many years since this was practised in the UK. However, the argument has always lain in making the effluent as safe as possible, especially if there is any likelihood of misuse and mistaken identity.

The reasons for the lower standard at Tripoli is that the sewage effluent will be used for the production of fodder crops under Municipal control as a managed system and not, as is present practice in Tripoli and projected for Benghazi, to provide irrigation water to farms.

Sea disposal

The opponents of sewage treatment for seaboard towns will ask why long sea outfalls were not considered. The overall policy of the Government has been one of re-use to supplement the dwindling supplies of potable water at present used in vast quantities for irrigation. In addition those familiar with the Mediterranean sea coast of Southern Europe will be only too aware of the problems of sea disposal within an almost land locked sea.

7. RE-USE OF TREATED SEWAGE

General

In Libya water is at a premium there being low rainfall, few rivers and limited groundwater resources in most areas. In spite of this agriculture was important in times past. With the advent of oil the drift from agriculture accelerated, but Government policy is reversing this trend and agricultural development is a very high priority. In the current five-year plan a high percentage of funds is earmarked for such development.

Policy is, therefore, to conserve water resources and the question of re-use is important. Part of this policy is to use treated sewage for irrigation purposes and where possible farms are being established near to sewage treatment works as part of the general countrywide farm development programme. The six Phase 1 works were therefore all designed with this in view, but so far effluent has only been used at Sebha and Tripoli due to the fact that farms have yet to be established in those areas. Of these two, the Author has knowledge only of the Tripoli scheme and even then not extensive as he has not been involved in the project beyond the stage of the effluent storage reservoirs. The policy of re-use for irrigation purposes has continued on the Phase 2 schemes.

Quality of treated effluent

The two most important aspects of quality of water for irrigation use are those relating to health risk and suitability for crop production. The former, although the more serious in relation to human life than the latter, is the most difficult of the two to deal with since much research work still needs to be done in this field and generally acceptable standards have not been settled. Some authorities, such as in India and America, have set their own standards, but these are few and in view of the increasing need to re-use treated sewage, there is an urgent requirement for research resulting in the fixing of standards in respect of health risk.

In the case of Libya the use of sewage effluent will be under controlled conditions at Government farms where piped potable water supplies will be available so that risk to health will be at a minimum; but still a risk.

The plans for irrigation projects were not very advanced at the Phase 1 treatment work design stage and the type of crop to be grown, irrigation techniques etc were not known, but decisions on treatment standards had to be taken. It was decided to design for treatment to a standard of effluent of 10 mg/l for both BOD and SS followed by chlorination to give an initial residual of 1.5 mg/l. These arrangements have apparently proved satisfactory at Tripoli since the initial proposals for a continuation of this standard for Phase 2 were accepted. A subsequent decision by the irrigation authorities to switch to fodder crops only led them to reduce their requirements to 15:20 standard.

Effluent quality in terms of the parameters which affect its usability for irrigation is largely predetermined by the raw sewage constituents. The one causing most concern in Libya is salinity which affects the majority of crops in varying degrees. Crops will be injured if there is an accumulation of salt in the root zone as a result of poor drainage, inadequate irrigation or use of water which is too salty. Other constituents and parameters such as sodium have to be taken into account, of course. It is difficult to predict what may take place in the complex mineral constituents of most soils, five factors being important:

- The ease with which the soil will take water.
- The drainage characteristics of the soil.
- The rate of application of irrigation water sufficient to prevent salt accumulation in the crop root zone.
- Crop tolerance to constituents of the water.
- The need for skilled agricultural management.

Because of the variability and uncertain inter-relation of the above factors, any standards set are merely guidelines and experimentation is necessary to establish what can be achieved with any particular water. The following guide given by the Salinity Laboratory of the United States Department of Agriculture was used in considering the potential of treated sewage effluent for irrigation purposes in Libya. Salinity is measured here in terms of electrical conductivity (micromhos per centimetre at 25^{o}C).

	Electrical conductivity (mmhos/cm 25°C)
Low salinity water - Can be used for irrigation with most crops on most soils	0 to 250
Medium salinity water - Plants with moderate salt tolerance can be grown	250 to 750
High salinity water - Permissible but only plants with high salt tolerance can be grown. Unsatisfactory where soil drainage is restricted.	750 to 2250
Very high salinity water - Not usually suitable for irrigation unless drainage is adequate, irrigation water is applied in quantities adequate to provide considerable leaching and very salt tolerant crops are grown.	2250 to 5000

The predicted salinity levels for treated effluents in the six towns were:

	Electrical conductivity mmhos/cm
Benghazi	3000
Tripoli	1500
Tobruk	1500
Derna	750
Misurata	1500
Sebha	1000

The figures for Benghazi are marginally acceptable, but with good management techniques and appropriately selected crops success could be reasonably expected.

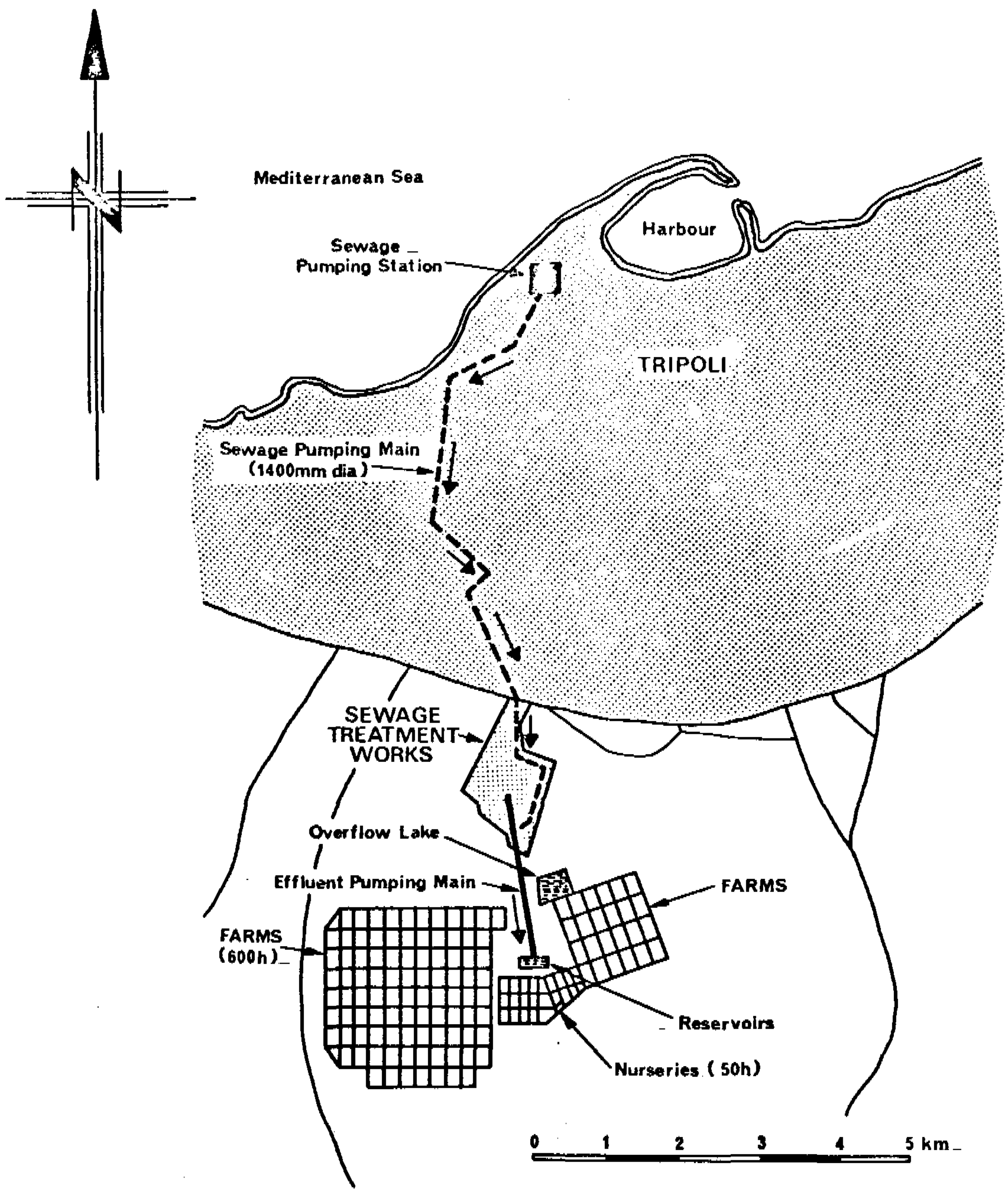
Data on actual daily salinities being experienced at Tripoli are not available, but an average appears to be 1000 mmhos/cm.

At Benghazi the current circumstances are unusual and temporary, various factors contributing to produce a very high salinity level. Due to overpumping of groundwater the water supply is at present of the order of 4000 mmhos/cm. In addition, groundwater of very high salinity from contractors excavations is being disposed of to the sewers because of the difficulty of using other methods of disposal. This has been acceptable since water has not been required for irrigation. Figures of up to 5000 mmhos/cm have been reported for the treated effluent. However, there is now a need to reduce the salinity levels to permit the use of the effluent for irrigation.

Use of treated sewage at Tripoli

Only at Tripoli has re-use progressed to any significant extent, where farms have been set up, each six hectares and where a family lives and works. In addition to the farms (total area 600 hectares) there are 65 hectares of fodder crops and 50 hectares of nurseries. The area is continuing to expand but the supply of effluent is at the moment limited to 27 400 m^3 per day, the output of the Phase 1 works. The proposed extensions to the treatment works will add a further 110 000 m^3/day, but will not be available for at least 3 years. The layout of the present project is shown in figure 10. The crops which have been successfully produced are vegetables, citrus and other fruits, wheat, barley and alfalfa grass for cattle fodder.

FIGURE 10: Irrigation area - Tripoli



Typical analysis of the effluent is shown on Table 11. Data obtained on 18th July 1974 for chlorinated effluent gave free chlorine as varying between 0.2 and 1.2 mg/l during the day.

TABLE 11: Typical treated sewage analysis (Tripoli 1969)

	Final effluent (lagoons)		
(Results in milligrammes/litre)			
Alkalinity as calcium carbonate	225		
Hardness	310		
Carbonate	225		
Non-carbonate	85		
Dissolved solids dried @ 180°C	980		
Suspended solids	8		
Suspended solids volatile	-		
Oxygen absorbed (permanganate)	5.0		
BOD	7.0		
Ammoniacal nitrogen	6.6		
Albuminoid nitrogen	0.25		
Nitrite nitrogen	0.6		
Nitrate nitrogen	16.0		
pH	8.6		
Chloride	295		
Anionic synthetic detergent (manoxol O.T.)	5		
Iron	0.06		
Zinc	0.10		
Copper	Nil		
Lead	Nil		
Manganese	Nil		
Boron	0.5		
Electrical conductivity (micromhos/cm @ 25°C)	1450	1389	1600
(Results in milliequivalents/litre)			
Cations			
Calcium (Ca)	3.5	3.65	4.1
Magnesium (Mg)	3.2	3.45	3.8
Sodium (Na)	6.1	7.2	8.7
Potassium (K)	0.51	0.49	0.62
Anions			
*Carbonates (CO_3)	5.4	4.7	4.3
Sulphates (SO_4)	1.8	2.0	2.5
Chloride (Cl)	6.3	6.6	9.9
Nitrates (NO_3)	0.66	0.69	0.93

*Bicarbonate expressed as carbonate.

In general the irrigation has been a success and as already mentioned the effluent from the Phase 2 extensions will be used to provide irrigation water for a new area of some 2000 hectares. This area will use production farming to supply fodder crops only.

It has been argued that with a stricter control on the use of this effluent that a marginal reduction in effluent quality could be tolerated at the expense of a lessening of the certainty of adequate bacterial kill. This approach has been adopted and the effluent to be used for irrigation will be chlorinated final tank effluent.

8. CONTRACT DOCUMENTS

The subject of contract documents could form a paper on its own there being many problems which can arise during the course of a contract due to shortcomings in them. It is proposed here only to include some specific items which may be of particular interest in the total content of public health engineering.

All contracts on the Libyan projects so far have been on a fixed price and re-measure basis, the document comprising

- drawings
- conditions of tender
- form of tender
- conditions of contract
- specification
- bills of quantities

The conditions of contract have been based on the "Conditions of Contract (International) for Works of Civil Engineering Construction" prepared by the Federation Internationale du Ingenieurs - Conseils jointly with the Federation Internationale du Batiment et des Travaux Publics (FIDIC). These have been amended in certain respects and extended to suit local conditions and the requirements of the authorities.

All documents are required to be in Arabic which is the ruling language of the contract, but corresponding documents in the English language are issued to facilitate use by foreign contractors and indeed to assist generally in the understanding of technical terms which are difficult to translate into Arabic. Great care is necessary in translations as inaccuracies can be costly as well as confusing. In respect of drawings both Arabic and English were used together. Sewer sections involved hundreds of sheets of drawings which included a small number of repetitive words and notes such as "gradient", "pipe size", "concrete bedding" etc. which lent itself to a system of symbols which avoided translation except the key which described them. The sets of drawings were reduced in size and bound into books for tendering purposes and for general use.

Every contract allows for a mobilisation period of 2 or 3 months prior to the execution period which is made up of the construction period and the preliminary take-over period. The latter is a period during which the employer has an obligation to inspect the work and take it over and the contractor has an obligation to complete the work and to a standard acceptable for take-over. The provision has been included in the Phase 2 contracts to ensure rapid conclusion by all parties to a contract programme. Prior to such provisions take-over took place after the contract completion date and often continued for very extended periods.

Also based on previous experience and with the object of "pacing" the contractors" progress and also to keep the contractors' activities within reasonable physical bounds, the contracts are divided in sections each with a different completion time from the contract commencement date. Liquidated damages are payable for delay in the completion of any section.

"Simplicity" is a key word in the engineering of projects in developing countries and this applies not only to design but to other matters including contract documents. The application of this principle to the bills of quantities has been found to be advantageous to the expedition of the project as a whole and the total number of items has been reduced by aggregrating them. For instance the concrete items include in one item for the concrete, steel, shuttering, mortices, splays, small buxouts etc. This principle has been successful but the preliminary notes to the bills of quantities need to be very full and carefully written to ensure that the tenderer knows exactly what he has to be included in his rates.

It has been found that contractors often do not appreciate the need for special techniques and in some instances the contract documents have included a description of the method which the contractor would be required to use. An example of this is the construction of the twin 4 metre by 2 metre deep culvert across Sebca (lagoon deposits) areas at Benghazi where difficult dewatering and ground stability problems exist. The details included the specification of sheet piling and the minimum depth they were to be driven.

A feature of the Benghazi project is the very extensive site investigation and report mentioned elsewhere. This report was available to tenderers and gave invaluable assistance to them in tendering. In addition the contract documents themselves included borehole details relevant to the contract area as well as a geotechnical appreciation.

Regarding the conditions of contract, a few points of special interest may be mentioned. Clause 10 of the FIDIC Conditions has been modified to exclude the reference to the tender being based on data on hydrological climatic and physical conditions supplied by the employer. This was considered inappropriate to the present schemes where the contractor is able to ascertain reasonably closely the conditions under which he would have to work. No extension of time is allowed except for reasons of additional work, any extension to be based pro rata on the value of the additional work. The international arbitration clause is deleted and disputes are to be settled by reference to arbitration in Libya.

Experience has shown that local conditions make strong management essential for success. This has not always been realised by contractors and many have failed to achieve good results as a consequence. All Phase 2 contract documents therefore include a requirement for the contractor to provide a separate contract management team of appropriately experienced men to monitor progress and activities and advise the contractor's project manager.

In Phase 1 the principle of separate civil engineering and machinery contracts was adopted and on some projects the machinery was broken down into separate contracts for each type of plant. The problems of co-ordination were enormous. The Phase 2 contracts are therefore generally in the form of omnibus contracts to include everything.

9. CONSTRUCTION

General

The construction methods used and the problems experienced cover a field too large to be dealt with here to any significant extent, but certain features will be brought out which it is hoped will be of interest. It is perhaps important first to get the perspective right by realising the enormity of the task of installing drainage systems in fast growing towns where the need is not only to provide facilities for currently developing areas but to catch up on providing them in the older areas where streets are impossibly narrow and general congestion is the norm. Even if the funds for such expensive utilities are available, the physical disruption to the towns as a whole can set a limit on the rate at which construction can be accepted without serious breakdown. Where all the other utilities are also being renewed or installed at the same time, the effects on the life of the community can be imagined.

A major problem has been the control of dust raised during the moving of excavated soil and from temporary diversion roads in built up areas. This may seem strange in a land of natural dust storms but these are not as frequent as sometimes imagined. The re-routing of heavy traffic volumes for long periods through areas not planned for it also causes great inconvenience to the public and tests its patience to the limit. The limits are sometimes over-reached and the contractors with others concerned come in for some heavy criticism; some justified and some not.

Added to this are the effects of the difficulty of supplies of plant, materials, labour and skills generally, possibly further aggravated by unstable international political conditions. For good measure, climatic conditions may be thrown in. To continue in the pessimistic vein before going on to show that the impossible is possible if a determined approach is adopted, one could add to the list the problems of communications, acquisition and temporary occupation of land, ultimate taking over of projects, road closures and traffic diversions, lack of approved planning layouts, drying up of funds, hesitancy in decision-making, and delays in delivery of materials through port and other delays. Most of these factors are to be expected in any country where rapid development is taking place as they are a consequence of the "mushrooming" situation.

Many a tale may be told of unusual problems met during construction such as the dump of hundreds of all mustard gas bombs, buried in the sand, accidentally scooped up by the digger and the D8 which ran over a land mine and had its tracks blown off. The bombs held progress of a large culvert up for 12 months. Fortunately such warlike incidents are now very infrequent and it is more likely that a thrilling archeological find may be made revealing a Roman or Greek artefact to add to the wealth of the historic interest which exists in Libya. One way or another, in order to achieve objectives there is a need for constant alertness and application of effort and skill by the engineer.

The question of communications, or lack of them, causes great difficulty both on the site and between towns and countries, and much thought and planning is necessary in overcoming the resulting problems. On site it has been necessary to set up VHF radio and messenger systems to cover the work which can be extended over a very wide area. The international communications problem is improving with the increasing availability of the telex system. Communication by cable has been surprisingly good but telephone links are not.

In general, once a contract is signed the process of mobilising to full production is fairly slow. As the largest and most recent project, Benghazi again provides the most fruitful field for illustrative examples.

Contractors

The work is of a size which should interest international contractors but this has not been the case to a great extent. So far the nationality of contractors who have been involved in drainage work are, Libyan, Tunisian, Egyptian, Bulgarian, Yugoslav, Italian, Greek, Turkish, French, German, Lebanese and British. British contractors have been mainly concerned with machinery contracts, only one having carried out a civil engineering contract in Tobruk between 1963 and 1965. Local contractors have come more to the fore in recent years and have given creditable performance, being prepared to listen to advice and learn from experience. All contractors seem under local conditions to require a great deal of supervision and strong guidance. No doubt they take the brunt of the site problems particularly in built-up areas where their personnel are in the "front line" facing the public and police.

With a few exceptions the standards achieved are very good and sometimes outstanding in view of all the circumstances. This is a result of not only their own efforts but of the supervising engineers. Their methods of working in narrow streets can often be rather haphazard in respect of excavation work and it is here that maximum inconvenience to the public can be caused and evoke complaints.

The problem of manpower has been previously mentioned. This problem extends throughout all levels and even local contractors are staffed with mainly expatriate personnel which may consist of half a dozen nationalities. Management is often not of the highest calibre and advanced techniques such as critical path planning are not used although the sewage works contracts will require such control.

Construction plant employed is generally of good quality and is often new. The problem of keeping it in good running order is ever-present as conditions are arduous and maintenance difficult due to lack of spares and quality of mechanics. Drivers can also be heavy-handed and brutal with their machines.

Sewerage

Ground conditions are very variable being in hard limestone rock, rock with fissures carrying large quantities of water, firm dry clayey sand, silty ground with high water table and dry loose sand with boulders which hinder the driving of trench sheeting. Locations range from old narrow streets with ancient buildings with poor foundations to open areas, where sometimes even the road layout has not been settled!

The limestone rock is very variable in hardness and in certain areas where blasting was not permitted the normal rate of progress was reduced to a quarter and breacher points were being consumed by the hundred. The problem was so extreme that the contractor claimed a considerable amount for unforseeable physical conditions. The same contractor was also unfortunate enough to have to work in an area where there were a number of fissures in the limestone rock and had to deal with considerable quantities of water requiring many pumps.

In the areas lying close to the sea where the ground was silty sand with groundwater not far below ground level, sewer construction is difficult and only in some places is it possible to dewater by well point due to the fineness of the silt. Close sheet piling (or trench sheeting) with internal pumping has been the usual method adopted. Care not to draw down the groundwater table over a wide area is necessary so as to reduce the chance of the subsidence of buildings. Thus it is necessary to restrict the length of trench opened. Cases have occurred of subsidence and in one or two cases buildings have had to be evacuated. Many spurious claims by property owners have been made and cracks are pointed to which obviously originated many years ago.

Trench excavation is usually carried out by machine with final bottoming manually executed. Where necessary the trench sides are supported by timber or metal sheeting. In narrow streets and alleys excavation is by hand and all excavated material is removed. Extreme problems arise when a narrow alley contains septic tanks which have to be emptied, sterilized and broken out to permit the sewer to be laid. Meanwhile the flow from the property must be dealt with.

Where bitumen macadam road surfaces have to be broken out the specifications require that the metal be cut on the lines of proposed trench sides. This provides a neat edge to receive the final reinstatement.

Trench backfilling is an important part of the operation and good compaction is insisted upon in order to avoid subsidences which can cause danger to traffic, particularly during the rainy season. The road authorities and the police take a serious view of the condition of trench reinstatement.

Pipes have been laid on concrete, sand or granular beds. The sand is dune sand and being fine care in its case is necessary. Granular fill is crushed limestone being a 50/50 mix of 20 mm and 40 mm stone. This had proved successful particularly in excessive groundwater conditions and can be compacted by the labour with a rammer. Sand is not used below groundwater level.

Pipelaying with asbestos cement pipes has now been proceeding in Libya almost continuously for 12 years and has proved to be an easy pipe to lay and pass watertightness tests successfully. All sizes up to 2000 man diameter have been used, the larger sizes being initially developed for the Benghazi project some years ago by the Lebanese factory. On the larger pipes junctions are made by cutting holes in the pipe with a special machine and joining the saddle to the main pipe with epozy resin adhesive. This has proved a neat and successful method, the original method being to bolt the saddle on to the main pipe.

Supplies of asbestos cement pipes are currently coming from the Lebanon, Germany, Italy, Austria and Belgium. Asbestos cement pipes are made in Libya but with ordinary partland cement and are not lined. Damage to pipes in transit varies, but on the whole only a small percentage are affected. The larger pipes suffer most and great care in lifting them is necessary.

One of the contractor's biggest headaches is the illicit connection of properties by their owners before construction is complete. Not only does this practice create a danger and interfere with progress but it creates problems of inspection and take-over. At peak production a total rate of laying by three contractors of some seven kilometres in a month has been reached.

Plastic pipes are sometimes used for property and road gully connections.

The main pumping station at Benghazi was constructed in Phase 1 by driving a ring of sheet piles into the rock, supported by reinforced concrete ring beams. Although the water table was high, little pumping was necessary. The rectangular station was built inside the piles. No leaks have appeared in the station so far.

The two large stormwater pumping stations SW1 and SW2 in Sebka deposits were built by the diaphragm wall method using bentonite. This speeded up their construction considerably although there were many snags. Other smaller, circular stations were also built in this way.

Culvert construction

Two three-year contracts have recently been completed in Benghazi comprising a total of 23 kilometres of reinforced concrete culvert of sizes ranging from twin 4m x 2½m to 2m square. The work was carried out by Greek and Turkish Cypriot contractors respectively. The work had basically two aspects; major excavation and major structural work. Depths of excavation reached 10 metres and in parts the whole carriageway was removed. Much of the work was fortunately in dry sandy clay which presented no particular problem except when existing water mains followed the edges of the excavation which caused subsidences in parts resulting in fractures and discharge into the excavation. A substantial length was in hard rock and initially blasting was envisaged. Test blasts were carried out and the effects checked by vibrograph readings which were negligible. However, the granting of permission to blast as a routine was protracted and the contractor elected to use compressors.

It was important with such deep and wide excavation in important highways to ensure that backfilling was carried out carefully to obtain good compaction to provide a stable road base. The specification which detailed the methods to be used included for density testing to achieve a result of 95% of the B.S. standard test result.

Dewatering was generally by pumping with 6"/8" electric or 4"/6" diesel pumps from sumps within the excavation fed by side drains. The Hudig well point system was tried in one place but was unsuccessful because the tubes could not penetrate the rock layer and therefore could not be placed deep enough to draw down the water table.

Across the Sebka areas in the highly sensitive clay interlocking sheet steel piling was used and driven into the porous rock (calcarenite). Wells were sunk into the rock at intervals outside the sheeting and pumps dewatered through the rock. The disposal of excavation water was a constant problem and where available existing sewers were used after the settlement of sediment in tanks. On occasions a pipe system had to be laid to carry the water sometimes up to 500 metres.

The quantities of concrete to be placed in floors, walls and roofs (separate operations) were considerable and good planning and control was necessary. The length of section was 30 metres and the floor or roof of a twin 4 metre wide by 2½ metre deep culvert contained 165 m^3. Both contractors used central batching plants of $50m^3$/hour and $70m^3$/hour in conjunction with five transit mixers serving each hour. One contractor used concrete pumps in conjunction with skip placing only. The maximum quantity placed by one contractor in a day was $300m^3$.

Specially designed shuttering was imported by both contractors, both systems using a track on which the shuttering could be rolled on to the next section. This facility was rarely used in practice and lifting by crane was employed.

Sewage treatment works

There has been no experience of treatment works construction for some years since the main work on the Phase 1 project at the Guarchia site was completed, but it may be of interest to recall a few aspects although the work was carried out in a mainly conventional manner.

The experience of having seven machinery contractors and a civil engineering contractor involved on one site has led to the conclusion that one composite contract is to be preferred or at the most one civil engineering and one machinery contract.

The circular dry stone wall filters at Tobruk, Sebkah, Misurata and Derna proved successful in that they employed local materials and avoided the potential cracking problem of the reinforced concrete walled filter.

The filter media available in Libya is a limestone and careful selection is necessary to ensure the achievement of test results called for by the British Standard. Wadistone is often the most suitable if in large enough quantities. This was not so in Benghazi and quarried stone was used. Tests on media stone were initially carried out in the UK and it was necessary to send heavy bulky samples by air freight. Also at the peak of production the quantity to be tested was more than the UK laboratories could cope with in a reasonable time. Arrangements were therefore made on site for testing facilities using the rapid method developed by the Water Research Centre. After some experimentation to overcome technical problems such as control of both temperature, a successful routine was achieved.

Fine stone and dust are a problem and careful sieving and probably washing is necessary. Placing methods must be carefully planned and an arrangement for further dust removal at the bed immediately prior to placing was found necessary at Benghazi.

The curing of concrete in the hot season is important and membrane curing has been used with success. The very hot conditions at Sebka created particularly difficult problems of shrinkage and cracking.

Floor screeds on the conical floor of tanks have given problems in terms of accuracy of profile and crazing. It is probably best to wait for the scraper bridges and arms to be erected so that they can be used to help set the finished screed levels.

Site investigations

A proposal that an extensive site investigation should be carried out at Benghazi was accepted, and great credit is due to the authorities for being prepared to proceed with a necessary, but not always seen as such, basic investigation.

At a cost of £580 000 a contract for 18 months was let in 1974 to carry out 5000 metres of drilling in 500 boreholes. At peak production 600 metres were drilled in a day. Detailed logging, core analysis, an appreciation and a detailed report in English and Arabic was also required. The contract was let to a Yugoslav firm and difficulties arose over language and differences between Yugoslav and British terminology and practices. Conversion to Arabic can be imagined. After much effort by the consulting engineer's staff things were straightened out. The information was required to permit design work and to assist contractors tendering. The work also supplies useful data for other projects and provides information on the geology of Benghazi. Even this contract had its problems with rigs being ejected from private land, bogged down in mud and even catching fire.

10. OPERATION AND MAINTENANCE

General

From the inception of all the Phase 1 projects it was obvious that a large problem would present itself when the time came for the authorities to take over the installations and operate them. With no tradition of skills in the water pollution control field, coupled with an overall situation in which the supply of skilled men and indeed unskilled men was almost non-existent, the prospect of operating and maintaining such extensive systems was daunting. Also, no professionally qualified men experienced in water pollution engineering of local origin existed. The need for training was obvious, but even if training was instituted it was clear that a comparatively large proportion of the operating staff would have to be imported from outside Libya. Also, the organisation and resources required to manage and support operating staff required to be built since even where an embryo organisation existed it was not sufficiently strong to form a basis of the larger structure required for the new project.

At an early stage a report on requirements was made to the authorities, but serious difficulties always seemed to present themselves and obstruct positive action. In the case of one of the smaller projects, two men were sent to Britain for training on sewage treatment works. The exercise was basically successful and the two men returned to produce results which were good, having regard to the fact that they were hampered by being the only two with any "feel" for running a works among many who, understandably, were without it.

In the case of Tripoli, eighteen skilled men were sent to Britain for training at various sewage treatment works, but within a few months of their return had turned to fields other than that of water pollution control. Most of the men were basically good material, but the case illustrates the lack of attraction that exists in this discipline.

At professional level the smaller works have been managed over short initial periods by expatriates who have since handed over to local managers. The latter have done well in the face of great odds, such as lack of spares, consumable stores and good skilled operators. The vital importance of water pollution control systems has taken a long time to establish in the industrial nations and it is not surprising that the younger nations are going through the same sequences of development. It is hoped that frequent mention of the difficulties experienced is perhaps of use in making progress towards a solution.

At the larger Tripoli treatment works the initial professional management was provided by an expatriate official assisted by a works manager and an electrical/mechanical engineer seconded from the Consulting Engineer's staff. Currantly the works is managed by a Libyan engineer who leads a mixed local and expatriate staff. Operation has settled down to a fairly successful level but the perennial problems of skilled labour, spares and consumables persist. The level of achievement gives cause for congratulation under the circumstances.

Benghazi is an interesting divergence from the other projects in that on the advice of the author's firm the authorities opted to contract the operation and maintenance of the treatment works and the ten town pumping stations for a period of two years.

Benghazi operation and maintenance contract

In early 1973 the Consultants were instructed to prepare a tender document for a two year operation and maintenance contract for the 27 400 m^3/day biological filter sewage treatment works and 14 pumping stations (10 foul water and 4 stormwater) to include for the training of staff. Such contracts are not common and the documents need to be carefully written. The situation was complicated by the following circumstances:

a) Civil engineering construction works had still to be completed at some of the pumping stations.

b) Properties had been connected to sewers for some years and due to the relative levels of the lagoon into which the pumping station overflow discharged and the sewers, the latter had operated under surcharge conditions at low velocity permitting the settlement of solids.

c) Maintenance work not carried out by a contractor in liquidation at the treatment works.

d) Machinery was still being erected, tested and commissioned, including the generators, the only source of power at the treatment works.

e) Certain machinery only partly erected (years beforehand) and some erected but not tested or commissioned.

f) Painting contract not let.

All the above problems had their roots in the delays and complications which resulted from the non-completion of the original construction contract by the first contractor. Apart from the obvious difficulty of overlap of responsibility between the construction and operating contractor, there was no certainty as to when the various parts would be complete for take-over by the latter. Also the effects on the pumping stations of the movement of rubbish in the sewers on draw-down when the pumps were started could be serious.

The essence of the contract is probably contained in one of the clauses which reads:

> "During the Contract Period it shall be a prime duty of the contractor to develop the operation, maintenance and management of the installations from their initial putting into use to a full working condition with proved system and procedures ready for handing back to the Employer. Such development shall be carried out with particular reference to local conditions and to suit the eventual objective of operation by the Employer's staff".

The following are some of the obligations of the operating contractor:

a) Subject to any remaining obligations of other contractors, to take the installations as he found them, bring them into operation and develop them and the processes for which they were designed to an acceptable level.

b) To bring the works to a maturity and optimum operational standard in accordance with normal accepted practice.

c) Plant gardens and carry out landscaping work.

d) Train staff to a level to permit them to assume the operation and maintenance of the works at the end of the Contract. A Training Officer to be appointed to supervise.

e) To pay damages for non-operation or improper operation of units or plant.

f) To compile instruction manuals for all grades of staff covering operation and maintenance procedures.

g) To supply all consumables and spares and leave a supply of the former sufficient for six months operation and replace all used of the latter.

h) To operate the works on a shift system, covering 24 hours per day.

i) To maintain operating logs, records and data schedule and diaries.

j) To make detailed weekly, monthly, quarterly and annual reports.

k) To establish systems and routines.

l) To develop and maintain safety systems.

m) To provide and maintain a suitable technical library.

n) To provide staff in accordance with the minimum requirements set out in the Contract documents.

o) To carry out regular sampling and testing and maintain full laboratory service. Special tests which could not be performed in Libya to be carried out in another country if necessary.

p) To provide a service for sampling and testing trade wastes at industrial premises.

Pricing of the Contract was based on an all-in rate per month of operation set against each pumping station and the sewage treatment works.

The Contractor selected was a Libyan firm who brought in trained expatriate personnel. The combination of the various factors involved in this unusual contract could have justified the occurrence of great difficulties and below average achievement. However, in the event although there were some problems the Contract was carried out successfully founded on the basis of a carefully prepared Contract Document. The least satisfactory part was the training element which did not succeed due to the lack of good material.

The question of spares presented a constant problem due to unobtainability or long delivery periods.

Works performance

At the time of writing it has been difficult to obtain data on performance but average values for 1976 at Benghazi for four categories of data are:

	Raw sewage	Humus tank effluent
BOD_5	120	19
COD	382	70
SS	225	26
Amm^l.N.	25.3	2.5

Average values for Tripoli are:

BOD_5	140	19
COD	291	52
SS	277	29
Amm^l. N.	19	2.7

(All in mg/l)

The above are indicative only. Further data is given in sections 6 and 7.

11. CONCLUSION

It is hoped that the foregoing gives a very broad view of what comprises nearly the sum total of the first steps in providing the main towns of Libya with modern sanitary facilities. The work is a challenge in its size and associated problems particularly in the absence of results from established and tried systems and practices.

There is a great need for discussion amongst engineers of their experience of problems and their solution in the Arab countries.

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discussion

CHAIRMAN: C L LANGSHAW, OBE ARICS FRSH FIPHE
Former President
Institution of Public Health Engineers

Mr M F G ARCHER went through the paper briefly pointing out certain points of interest.

2. The work had been in two phases, the first phase covered six towns and the current phase was concerned with three of those six, Tripoli, Benghazi and Tobruk. The whole of the work covered an era of 1961 to the present. All the Phase 2 towns were on the coast, but in Phase 1 one of the towns, Sebba was in the Sahara, some 600 kms from the coast. Libya was a sandy, rocky desert with the coastal region which was comparatively fertile. The rainfall was very sporadic and there were very few rivers in the country. The population was about 2.6 million, almost totally Moslem. There were about 300 000 ex-patriots working in the country and it was expected that this figure would rise over the next few years to some 400 000 due to the lack of skilled labour and technical and professional people.

3. The standard of living in Libya was now reasonably high and there was very little poverty. The oil wealth was being distributed through most of the population and shanties were almost non-existent. The economy was based mainly on oil revenue, accounting for some 99.5% of the total value of Libyan exports. This had enabled the Government to proceed with important development projects including sewerage.

4. Before the present work Benghazi had a very small overloaded sewerage system in the central old part of the town. Tripoli had a more extensive system, mostly on a combined basis. Derna Misurata had nothing nor did Sebba, and Tobruk had a very small scheme which served a military barracks.

5. The policy of the Libyan Government was to use sewage effluent for irrigation. The schemes as shown in Tables 1 and 2 involved a very large amount of work. The total value of the current contracts was £340 million and the execution of the rate had been £5 million per month and in 1978 it was likely to rise to £8 million per month.

6. The practice of providing separate foul systems was now accepted in countries where the total annual rainfall was low. This system has been adopted in Libya in most cases, although there was a small development west of Tripoli where the design had been on the combined system. To avoid septicity the design velocity was 1 metre per second but in some cases this had been reduced to 0.75 metres per second.

7. Experience of the operation of sewerage systems had led the client to request that the distance between manholes be reduced and in Phase 2 the maximum distance between manholes was set at 50 metres. For various reasons the pipes were made of asbestos cement. These were attractive from the point of view of cost, speed of laying and availability. In Phase 2 the contract documents provided scope for contractors to propose alternative types of pipe, but in fact the client instructed that they should continue to use asbestos cement.

7. As shown in figure 2, Benghazi sheds in two directions. The northern part drained to pumping station NT1, the southern part to pumping station ST1. The main pumping stations were quite large structures. Figure 3 showed the main

foul sewage pumping station NT1 which had twin wet wells either side of the central dry well. The dry well and the two wet wells were force ventilated.

9. For storm water drainage there were no natural water courses or wadis available for discharge to the sea. The gradient was generally very slack towards the sea and often good routes were sterilised by development. Consequently main carriers were built across the town from east to west. All these main carriers were reinforced concrete block culverts. The largest was 4 metres across x 2.5 metres deep. This involved fairly difficult construction in a busy town. Attempts were made to reduce the size of these culverts by incorporating storage reservoirs but the client thought that these would cause health hazards and would need to be maintained so they were eventually ruled out.

10. In the storm pumping stations the discharge entered a chamber which overflowed. This maintained a constant head and did away with quite a bit of valve work.

11. In all cases the foul sewage was pumped to a treatment works some distance from the town and treatment was in conventional biological filters. Biological filters were adopted for Phase 1 as the most appropriate form of treatment plant consistent with a shortage of skilled labour was in very short supply. In Phase 2 filters were provided for Benghazi and Tobruk, but Tripoli had been running for a longer time and staff were trained for the more sophisticated activated sludge process.

12. The policy was to use treated sewage for irrigation. So far it had only been used in Tripoli and Sebha. For various reasons, the tertiary treatment plant at Tobruk was never completed. In Benghazi and Derna there were no farms ready. In Tripoli on Phase 1 they had irrigated for 4 - 5 years and they had grown a number of crops for human consumption. The intention was to switch to cattle fodder crops, and the Irrigation Department now required a 15/20 effluent as against the 10/10 originally proposed.

13. On construction one of the problems was the total amount of work required in such a short time. It was sometimes totally disruptive of the community life, traffic and so on, and sometimes local reaction was very strong. Operation was difficult because of the lack of skilled labour and professionals. There was a need to evolve some sort of professional body such as the I.W.P.C. which would generate interest in education in this field and might prompt the Government to formulate a training scheme. In Benghazi the client decided to hand over the plant to a contractor for two years to operate and carry out training. The operation part worked out very well with a local contractor who took on mostly Polish ex-patriots trained in the field. Training of local staff continued to be a problem.

14. Mr ARCHER then showed some slides. Some illustrated the problems of maintaining access to property. Sometimes, when a contractor was racing against time, this got out of hand. One slide showed a low pressure testing machine which had been built by the contractor who had been unable to supply test certificates for some pipes because the Lebanese factory where they had been made was bombed and the records were lost.

15. One slide showed an AC pipe which had been in use for about five years with sewage flowing through it rather sluggishly. It was taken up and cleaned, amd as it was in mint condition, was put back on a new route. Another slide showed an Italian culvert combined sewer built 30 - 40 years ago. The concrete wall was still in pretty good shape. At one point the contractor wanted to do some blasting, The police insisted on a small structure being built and the contractor had to cause an explosion near the construction to see if it fell down. It did not and so they were allowed to go on!

16. The last slides showed potatoes and a citrus fruit tree grown in the irrigation area at Tripoli.

17. Mr C T MYERSCOUGH complimented the author on a most comprehensive and interesting paper and asked a number of questions. Why was the capacity for the separate sewer six times the dry weather flow as this seemed rather large? What type of joints were intended for asbestos cement pipes and what problems were encountered with the joints? Why were two wet wells used at the pumping stations? Finally, were the FIDIC conditions of contract chosen by Howard Humphrey or by the client?

18. Mr ARCHER replied that 6 DWF was adopted to give some scope to the uncertainty of planning. Mr G A MILL said that the decision to design for 6 DWF was also because roof drainage frequently discharged into a central courtyard and drainage from the central courtyard tended to go into the foul sewer.

19. Mr ARCHER then said the joints on the AC pipes were the Rika type joints and there were no particular problems. Two wet wells had been used in the foul pumping stations to try to neaten the layout. Rather than having a long station they provided a square layout. The design would prevent deposition of solids in a long wet well. FIDIC conditions had been proposed by the firm and accepted by the client.

20. Mr C N FREER said that the works described by Mr ARCHER were quite sophisticated. Knowing the problems of maintenance in the Middle East, would he still go for sophisticated works or for a lower cost simple type of works such as waste stabilization ponds? Micro-strainers had been proposed for future use. Had Mr ARCHER any experience of them in the Middle East? Mr FREER's experience in this country was that they were very troublesome units.

21. Providing sludge drying beds without media obviously made sense but Mr FREER was interested to know what depth of sludge would be put on the beds. Under the contract arrangements, what method of measurement was incorporated; was it one of the British methods or their own standard measurements?

22. Lastly, on the question of irrigation, was bilharzia endemic in Libya? If so were any special precautions taken in the treatment of the effluent prior to irrigation?

23. Mr ARCHER said that with works of this size, he would still proceed with the so-called sophisticated designs because they were relatively simple and although there was a problem of skilled labour, this had to be overcome. The educational and professional system needed impetus by the Government to create the necessary skills rather than demanding something much simpler all the time. There would be no advance towards acquisition of skill.

24. To Mr ARCHER's knowledge there were no waste stabilization ponds in Libya. He thought that experimental work should be started as ponds were suitable for the smaller towns. On the design of ponds, Mr ARCHER had the impression that design by one method would give a pond twice the size of another designed by a different method. There is therefore need for local experimentation.

25. Mr ARCHER had no detailed experience with micro-strainers himself, but his firm went into this very carefully and decided that they would be better than rapid gravity filters. Gravity sand filters had been included on the Phase 1 works and had proved difficult to operate.

26. Mr MILL said that sludge was applied to drying beds in 100 milimetre layers. One layer would be dried and another layer applied. The beds were designed for ease of emptying using wheeled loaders.

27. Mr ARCHER said that the method of measurement had been simplified in Phase 2. Associated items had been grouped together to shorten the Bill of Quantities. For instance, whereas manholes were broken down into concrete, steel, shuttering etc. for base walls and roof slab, they were now billed as a whole manhole unit varying only by depth and type. The method had worked very well and all parties were happy. As far as Mr ARCHER knew bilharzia was not extensive in Libya.

28. Mr TSAI-HONG LO said that unlimited fresh water was not available in some parts of the world. For example Hong Kong used sea water for flushing purposes. Did anyone have any experience in dealing with this kind of sewage where 10% was sea water?

29. Mr D R YOUNG said Abu Dhabi had terrible trouble using sewage effluent for irrigation in the city of Abu Dhabi. When he arrived there three years ago central reservations had virtually no plants growing because salts in the raw sewage were so high it was causing problems with treatment, and likewise salts in the effluent were not allowing the plants to grow. This was due to pumping of groundwater into the sewers. That might be akin to the situation in Hong Kong. Drastic measures were taken including pump confiscation, heavy fines etc. Consequently there were now beautiful gardens due to the improved effluent.

30. Mr J H KOP said that in Tunisia there was leakage of sea water into the sewage system and effluent was used for the irrigation of cypress plants which were very sensitive to salt. They had either to stop the leakage or use another means of irrigation.

31. Mr LO said he did not think effluent was needed for irrigation in Hong Kong.

32. Mr H MANN said that sewage containing a high proportion of sea water could be treated satisfactorily by most aerobic processes. It was a question of acclimatising either the activated sludge or the film to the salinity of the water and maintaining the loading. Difficulty would arise in using effluent for irrigation because the effluent would have the same salinity as the iffluent. If the effluent were not required for irrigation the treatment of sewage would not seem to be affected.

33. Mr A W SHILSTON noted that manhole spacing had been reduced to 50 metres and asked what was the original spacing which proved to be too much.

34. The author had stated that because of a more sophisticated level of artisan skill in Tripoli activated sludge was used for Stage 2 in preference to filters which had been the system elsewhere. Mr SHILSTON recollected that Mr Lovatt - formerly the senior partner of Howard Humphreys - in the discussion of his 1970 paper to the I.P.H.E. on Sewerage and Sewage Purification in Libya had said that up to that time biological filter flies had caused no problems in Libya or in other schemes his firm had been associated with in Kenya, Uganda and Sudan. Was there now a fly problem which led to a choice of activated sludge in Tripoli?

35. An earlier paper on the works reported chlorination of the final effluent used for irrigation because it was thought that the locals might be tempted to drink it. Mr SHILSTON wondered whether there had been any experience of this. Was chlorination still to be adopted as a design criteria?

36. Lastly, although Libya was a socialist state, the author had commended the private contractors who were making a very useful contribution. Were private contractors compatible with the socialist state of Libya?

37. Mr ARCHER said the original spacing of manholes was 75 - 100 metres. Whilst there had been outbreaks of fly infestations at Benghazi and Tripoli, the problem was transient and short-lived and was coped with. The decision to go for activated sludge was only because Tripoli was ready to handle its operation but Benghazi apparently was not.

38. In reply to further questions from Mr SHILSTON, Mr ARCHER said that activated sludge was the preferred design assuming there was a proper level of maintenance skill. Mr ARCHER also agreed that chlorination of final effluent was originally in part-protection against accidental drinking of the water. Mr ARCHER said that private contractors had to be joint stock companies.

39. Mr SHILSTON suggested that manhole spacing had to be reduced because rubbish was getting into the sewers. Had Mr ARCHER's firm discussed this abuse of the system with the client?

40. Mr ARCHER said this was one of the many things that the client raised during general discussions of the project. Another proposal was that a proper maintenance organisation should be put together.

41. Most of the manholes had tight-fitting square covers which had to be lifted with special ring keys and spanners.

42. Dr S M ROMAYA thought there was contradiction in some of the comments about training of local personnel. Mr ARCHER had said that something could not be implemented due to lack of suitable material. On the other hand, in reply to a question about the high skills required, the answer was "that people must be trained for higher skills".

43. Mr ARCHER said that there was a difference between the short-term situation with what should be the long-term situation. It was wrong to take the simple way out and say "there will never be any trained personnel, let's go for something simple but perhaps not appropriate". The governments should and will no doubt, set up training programmes and get the salaries right. Pay in many countries had been very low for people involved in sewerage and should be much higher to encourage the right type of person. Dr ROMAYA said that the success of schemes depended very much on the first years.

44. Mr J M G van DAMME suggested that the Engineer should stress as hard as possible that training was indispensable for any scheme.

45. Mr B M U BENNELL wondered whether

consultants considered the problem of maintenance of the plant at the design stages with the object of achieving a fully-automated maintenance-free plant.

46. Mr ARCHER said that thought was given to this aspect but thought that, robust simplicity, not automation should be the objective. However, he repeated the question "Should we continue accepting that for evermore there would never be any possibility of the local people operating their own equipment?".

47. Mr BENNELL suggested that labour to do this would be imported. Mr ARCHER said that the objective was cutting down the total amount of labour consts on site, consistent with simplicity.

48. The CHAIRMAN remembered the GLC giving thought to this some years ago and had decided on the automation of vital equipment and recording rather than trying to achieve automation of the whole plant.

49. Mr A J H WINDER said that from his experience, equipment should not be made complicated. The more semi-skilled workers employed the better. It was better to keep equipment basic and capable of being maintained by semi-skilled people than to bring in complicated equipment which would be liable to go wrong and there would be no-one to mend it. There was no shortage of semi-skilled workers.

50. Mr W A GILLINGHAM said his experience in developing countries was that one could not get individuals to screw up nuts. Maintenance of equipment came down to organisation and getting technicians capable of understanding the nuts, bolts and washers of equipment.

51. Mr MANN said that courses were necessary to encourage confidence. In developing countries people could be trained to operate relatively sophisticated machinery like a sewage works but would be promoted to some other job and the sewage works would again be in the hands of semi-skilled people! He asked how many staff were currently employed at Tripoli sewage works. Mr ARCHER thought it was about two hundred, but only half were effective, and most were 'general hands'.

52. Mr van DAMME thought that it was a question of phasing and putting first things first. First you have to train people and educate them. Only then can you have complicated technologies. It was very difficult to tell Banks and Governments that installing complicated equipment was the wrong thing to do.

53. Mr BENNELL had not referred to under-developed countries with little money and resources. He was talking about oil-rich countries with all the money in the world for expensive pieces of equipment, but lacking the will to maintain the skills that maintain them. Was the right equipment being provided in a situation like this?

54. Another speaker said these countries had the technology to process oil, compared with which sewage treatment was a comparatively simple process. He suggested that developing countries wanted high technology but consultants designed simple schemes wherever possible.

55. Mr M W CRABB said since sophisticated equipment was being installed in sewage treatment, was it intended at some future date to treat the effluent to drinking water standards?

56. Mr ARCHER said that this was not planned. He thought it likely that water would be obtained from the desalination of sea water rather than from sewage effluent.

57. Mr J D ROBSON asked Mr ARCHER to explain the decision to provide tertiary treatment before irrigation.

58. Mr ARCHER said that because chlorination was necessary, reduction of BOD and SS meant that less chlorine was used and reduction of suspended solids reduced blockage in the irrigation distribution system.

D. R. YOUNG

some aspects of public health engineering in the middle east

INTRODUCTION

General

This paper outlines problems encountered in public health engineering projects due to the prevailing conditions in the United Arab Emirates and the solutions adopted to overcome the problems.

In 1974 D Balfour & Sons were appointed by the Government of Abu Dhabi as Consulting Engineers for projects to provide facilities for water distribution, sewerage, sewage treatment and reuse of treated effluent for irrigation for the City of Al Ain. The terms of reference for the projects comprised the preparation of Master Plan reports followed by detailed designs, tender documents and supervision of construction of the necessary works recommended in the Master Plans.

Climate

Al Ain, the second city of the Emirate of Abu Dhabi, is situated some 160 kilometres inland from Abu Dhabi city near the border with the Sultanate of Oman. It is also close to the foothills of the Oman mountains with the centre of the city approximately 280 metres above sea level. Al Ain and the surrounding area being situated close to the Tropic of Cancer experience warm winters and hot summers. The mountains of Oman generally shield the area from the moist winds of the Indian Ocean and consequently rainfall is spasmodic and infrequent. These effects combine to create the desert conditions that prevail.

The mean monthly air temperature varies from 17°C in January to 36°C in August, but it is fairly common in the months of July and August for the temperature to reach 50°C. Since Al Ain is inland the humidity is lower than that of the coastal areas, being generally below 50% for most of the year, and can be as low as 15%.

PLANNING

The wealth of the state of Abu Dhabi has allowed rapid expansion of the economy and has enabled the Government to carry out an ambitious programme of development including new roads, harbours, airports, new towns and villages and all the necessary infra-structure of a modern state.

The large number of immigrants entering Abu Dhabi has imposed a pressing need for more development and the supply of essential services. A vicious spiral is caused in that much of the new development now being constructed is to house and serve people from the construction industry.

It is essential to incorporate into any design flexibility to accommodate unexpected changes in population growth rates, location or density within the limit of good engineering design. This can add to the cost of a Scheme, but having experienced problems of under-design due to unforeseen population growth the Government is prepared to meet the additional burden of cost. For example it has been fairly common for extensions to public utilities facilities such as sewage treatment works or power stations to be commenced before even the previous phases of construction were complete. Resulting from these experiences the Government now require Consultants and Planners to ensure that adequate provision is made in all projects for the maximum foreseeable populations.

WATER DISTRIBUTION

Water Consumption and Conservation

It was not possible to assess with any degree of accuracy the present water consumption and it was necessary to predict the likely future consumption on the basis of experience in other parts of the Middle East where similar conditions obtain.

The conservation aspect was considered of paramount importance in view of the limited sources of water supply. The initial source of water is well-fields tapping the aquifers fed by rainfall on the Oman mountains. No long term tests had been carried out on aquifer recharge and the safe yield of the well-fields had not yet been established. It was considered prudent to take steps to avoid unnecessary wastage and limit demand in some way, since the future alternative source or supplementary source was desalinated water from a plant on the coast. This water would be extremely expensive since to the already high cost of producing the water would have to be added the cost of pumping to Al Ain, a distance of some 140 km against a static head of the order of 280m.

Considering the above, it was decided to provide water meters to all domestic connections, as well as those for industrial and agricultural use, to promote a responsible attitude to the use of water and thereby curb excessive use and wastage. It was further decided that the pressure available to each consumer would be regulated by means of a stop tap adjacent to the meter. The Master Plan outlined methods by which the tariffs could be adjusted to encourage water conservation.

The increase in the availability of water will give encouragement to the expansion of the local agricultural activity and it was Government Policy that this should be encouraged. The allowable extent of agricultural expansion was however dependent on the safe yields of the well-fields and it was therefore difficult to assess any realisitic water demand for possible future agricultural areas. This uncertainty was another factor requiring the design to be extremely flexible.

Many of the roads had, or were to have, trees planted by the sides and in the central reservations. It was considered that in future sewage effluent would be used for irrigation of the trees but, until adequate supplies of treated sewage effluent are available, provision should be made for water to be taken either from local wells or from the potable water supply.

Distribution System

The city was divided up into a suitable number of distribution zones taking into account the topography. Each zone will be fed by a pumping station situated adjacent to a ground level service reservoir, with approximately 2 days storage, and a network of water mains. The service reservoirs will be generally inter-connected and provision was made to receive water from either the well-field source or from the future desalinated water source. The ground water is of high quality and it is only necessary to incorporate chlorination equipment for the water treatment.

Due to the construction activity in the city, it was considered prudent to adopt cement lined ductile iron water mains as the most resilient pipe material.

The service pipe was polythene and the connection from the main was terminated at a meter chamber adjacent to the property.

The reinforced concrete service reservoirs were designed to be partially buried with an embankment over the roof as a means of thermal insulation. The materials and workmanship necessary to produce high quality concrete for the reservoir construction are dealt with in a subsequent section.

In designing the pumps for pressurizing the pipe system care was taken to limit the range of capacities to be provided such that interchangeability of pumps could easily be achieved. It was also considered prudent to provide a full range of spare pumps and spares for pumps in the Contract. Additionally sufficient standby capacity was provided to ensure the continued full operation of the system in the event of pump or motor failure. This is important since the spares will inevitably need to be imported and this can involve delays.

At least 3 months storage capacity for chlorine has been provided since this material will also need to be imported and adequate stocks should always be maintained. The pumping station sub-structure and buildings were designed to provide adequate space for any future pumps required to cover increased demand due to changes in population, density, etc., as outlined previously. There will therefore be space for any future pumps required to cover increased demand or to service an additional pressure zone.

SEWERAGE AND SEWAGE TREATMENT

Special Problems in a Desert Climate

In hot desert areas movement of fine sand, usually known as dune sand, presents many problems and could cause difficulties with the operation of the sewerage and sewage treatment system. Sand may find its way into the system from the washing of clothes, through manhole and chamber covers where these are not properly sealed and many other ways. Sand can cause filtration problems, excessive wear in pumps and mechanical equipment and difficulties with sludge withdrawal from treatment processes.

Sand entering via the domestic connection could not be prevented, but the main sewerage system was designed to be sealed as far as possible against the ingress of wind-blown sand. In the sewers good cleansing velocities are important to maintain the fine sand in suspension or at least to move any deposition at high rates of flow. Grit extraction equipment at the sewage treatment works is essential, and the regular cleansing of wet wells at pumping stations is very necessary.

In hot climates sewage will rapidly become septic if it is devoid of oxygen for even a short period, and under such conditions strong odours and a corrosive atmosphere in the sewers and manholes will occur. The formation of sulphides can be minimised by reducing the retention period in the sewerage system as far as possible. It was therefore imperative to ensure high velocities in the sewers and it was decided that, normally, a minimum velocity of 1 metre per second at ultimate maximum rates of flow should be achieved. In addition checks were made to ensure that the minimum velocity in the early stages of the development would be of the order of 0.7 metres per second. Where sewers are to be laid with only minor development connected in the early stages, sewer flushing will be carried out at regular intervals.

Good ventilation of the sewer system is essential, but the use of ventilated manhole covers was ruled out due to the possible ingress of fine sand. It was not considered wise to adopt ventilating columns at regular intervals on the main sewers since odour problems are often experienced when temperature inversion conditions prevail. The only means of ventilation acceptable was via the stack pipe at the domestic connection.

It could not be expected that the above measures would be completely effective and therefore there would still be a build-up of hydrogen sulphide in the wet wells of the pumping stations. It was considered that the above proposals would keep the sulphides generated in the gravity sewers feeding the pumping stations to a reasonably low level. Nevertheless it is necessary to maintain an acceptable working environment in the pumping stations and it was decided to adopt a forced ventilation system with ozone treatment of the air discharged to the atmosphere to control odours. Small scale ozone production units, which have a low power consumption, are relatively inexpensive and will be provided at each pumping station for the treatment of the air discharged to the atmosphere via the ventilation system.

The potential for sulphide formation is greatest in rising mains as natural aeration of the sewage cannot occur. The addition of chemicals to the sewage to prevent sulphide formation is feasible but would need to be continous resulting in high chemical costs. It was considered essential to adopt some method to reduce the sulphide in the pumping main especially in an effort to reduce the offensive odours that would occur at the discharge point of the pumping main discharging to the sewage treatment works. Facilities for the injection of oxygen downstream of the pumping station and at intermediate points along the pumping main are to be provided.

Sewage Treatment System

Bearing in mind that the pumped sewage has had some pre-treatment, by virtue of injected oxygen, it was considered that problems of corrosion and odours would be minimal at the inlet to the works. Thus no special treatment at the inlet works was provided and this consists of screens, macerators, detritors and flow measurement.

As the sewage should be well oxygenated on reaching the works it was considered unwise to provide primary sedimentation tanks since this could result in septic conditions reoccuring. It was therefore decided to adopt the extended aeration system of treatment. Concrete tanks with surface aerators are to be used with an approximate retention period of 20 hours at dry weather flow. Final settlement is provided in circular concrete tanks, from which the activated sludge will be removed and returned to the inlet to the aeration tanks. In order to produce an effluent of suitable quality for re-use for irrigation, tertiary treatment in the form of rapid gravity sand filters has been provided. After sand filtration the effluent will be chlorinated prior to reuse.

The surplus sludge will be treated by aerobic digestion in simple rectangular tanks with floating aerators. Odours from this process should be minimal since the surplus sludge should be relatively stable by virtue of the long sludge age (ca. 20 days) in the aeration tanks. A period of consolidation will be allowed in the digestion tanks and after removal of the top water the sludge will be delivered to open lagoons where final reduction of the moisture content will be achieved by natural drying.

With the effluent being used for irrigation and the dried sludge for the conditioning of sandy soils it can be seen that treated sewage represents a valuable contribution to water and agricultural resources.

Sewerage System

Due to the topography of Al Ain it is possible to drain the central area of the city (with a few exceptions) into a trunk sewer gravitating to within a short distance of the sewage treatment works. At this point a major pumping station is to be constructed from which the sewage will be discharged into a 3 km long pumping main. Oxygen will be injected into the main as described previously.

The outlying areas of the city were sub-divided into smaller drainage areas, in which sewage pumping stations of various capacities are located. From these pumping stations, sewage will be pumped into a pumping main system which ultimately discharges to the trunk sewer.

In addition to the ozone equipment mentioned earlier, which is to be installed to reduce odour, it is necessary also to protect the stations from corrosion. In the wet well all surfaces are to be lined with PVC sheeting bonded to the walls and any remaining exposed concrete surfaces will be protected by acid-resistant mortar.

The manholes on the sewerage system have been designed such that the concrete walls will be constructed with a glass reinforced plastic (GRP) liner which is left in after completion. Further, the underside of the top slab will be lined with GRP and a GRP plate placed beneath the lid of the manhole cover. Again acid resistant mortars will be used where surfaces are unavoidably exposed to the corrosive atmosphere i.e. at the roof slab joint and the benching.

The sewer pipe material generally adopted will be vitrified clay for all diameters up to 600mm. Above this diameter GRP pipes will be used. In the past, in the Middle East, vitrified clay has been used somewhat cautiously due to excessive breakages in shipment which caused their cost to be prohibitive. However, the exporters of these pipes have recently managed to reduce this loss to something less than 1% by using single cargo ships, by palleting pipes and giving careful supervision to the unloading operations. The corrosion resistance of vitrified clay makes this material ideal for use in the Middle East. The cost of vitrified clay, however, above 600mm diameter becomes prohibitive and GRP would at present seem to represent the best solution, taking into account its corrosion resistant qualities and its cost. It does, however, need special care during pipe-laying as its strength, as a pipeline, depends on the backfill material and the way in which it is placed. The material adopted for the pumping mains will be ductile iron because of its known durability and strength.

The minimum size of pipe will be 150mm (including the house connections) to minimise the risk of blockages. House connections will generally not be made to the main sewer by angle branch connections, but through a manhole. The gradients required to achieve the minimum velocities mentioned previously mean that the drainage areas in relatively low density housing developments are quite small, but it is desirable that the number of pumping stations should be kept to a minimum. However, it was considered that in this situation the higher sewage velocities in the pipes were the more important factor.

Effluent re-use

The re-use of the dewage effluent for irrigation purposes is of great importance in Al Ain since there is a major tree planting programme in progress. It is highly desirable to use sewage effluent for irrigation to avoid, where possible the use of more valuable potable water sources. Although the system necessary to distribute the sewage effluent throughout the city is an expensive one it represents a case where the wealth of the country can be used to achieve a considerable long term benefit. It was considered necessary to chlorinate the effluent from the sewage works, since, however many precautions are taken, it is possible that irrigation workers and members of the public may inadvertently dring irrigation water.

CONCRETE

In the Middle East salt-laden aggregates can be one of the most likely causes of the problems in concrete manufacture but with fresh water being at a premium, the washing of aggregate is an extremely expensive item. The use of saline water in the concrete mix could be another cause of poor concrete, and it was considered that the specification for concrete should, whilst limiting the overall chloride and sulphate levels, take into account the problems of the salt content of both aggregates and water. A limit was therefore placed on each individual component as regards chloride and sulphate levels as well as an overall limitation.

The dust content of the aggregates in the Middle East is frequently high and its variability from one batch to another is often a cause for widely varying test cube results. Good sieving of aggregate should avoid this problem, but in an area where dust storms are frequent it was considered that aggregates should be stored in hoppers, bins or closed sheds. There would therefore also be some control over the temperature of the materials which when standing in the direct sun could reach a temperature as high as 80^{o}C. The use of aggregates at high temperature causes a 'flash set', and to help to avoid this in the mixer it has also been specified that the concrete mixing plant should be painted white, since it has been established that a temperature reduction of the metalwork of the order of 10 deg.C can be achieved. Provisions were made in the specification for the addition of ice where necessary to cool materials and in addition, a strict limitation regarding the time from mixing to placing has been imposed.

CONCLUSION

It is important to remember that problems arising with and the solutions adopted for the Al Ain water distribution and sewerage systems are particular ones and applicable to one part of the Middle East. In some cases they may also apply to other areas in the Middle East, but it should be remembered that there are often many solutions to an engineering problem. In this instance, it is indeed fortunate that the relative wealth of Abu Dhabi permits the adoption of the optimum engineering and environmental solutions to the problems arising from geographical location.

discussion

CHAIRMAN: B M U BENNELL, BSc FICE
Principal Engineering Adviser
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THE CHAIRMAN introduced Mr YOUNG who is a Senior Engineer with Balfours, Consulting Engineers. He has been with them for ten years and for the last 2½ years had been resident in Al Ain, Abu Dhabi as Project Manager.

2. Mr D R YOUNG said the work in Abu Dhabi was certainly "Engineering for Health" in hot countries. The provision of a distribution system for potable water and provision of sewerage, sewage treatment and systems for effluent re-use had a valuable part to play in the "health" of a country in the Arabian Gulf area which is reputed to be the "hottest" part of the World. Al Ain has always been an important centre for the Bedouin tribe; it is near the mountains and due to the date plantations, is very green. Al Ain translates as "the springs" although most of the springs were tapped in the mountains, mostly inside the new border with Oman. Water was channelled along ancient aqueducts feeding the plantations, sometimes supplemented by groundwater.

3. The Bedou used to come to their houses in Al Ain to escape the humid heat of the coast during the summer months. After harvesting the dates in the autumn, they returned to the coast, with enough dates to last for the whole year, to engage in fishing and pearl diving during the winter. At Al Ain the maximum summer temperatures were always much higher than on the coast, but the relative humidity determines toleration of the temperature. The village of Al Ain was very important to the Bedou and the President of the UAE, Sheik Zayed, was born in the locality. He was keen to develop the area to become the second city of the Emirate of Aub Dhabi. Until relatively recently, the villages were a collection of houses and huts made from woven palm fronds and mud. Development started when a dual-carriageway road was built from Abu Dhabi to Al Ain in 1968, when the early wealth from the oil riches first began to be used. Development was slow at first and only progressed at a rapid pace after 1974.

4. Mr YOUNG envied the relatively low rates of growth pertaining in the poorer, under-developed communities, since one of the main problems of design in Abu Dhabi is to cater for the rapid increase in population.

5. Population projections of 185 000 for Al Ain in about 20 years time gave an explosive increase - 9,4% per year. A similar growth rate had occurred in Abu Dhabi city. Actually comprehending the rate of change was in itself a big problem. In 1975 the population in Al Ain was considered to be about 30 000 inlcuding the outlying villages. Two years later at a census, it was considered to be 60 000, much more than the 9.4% annual increase.

6. When Mr YOUNG arrived there early in 1975, water was supplied from many wells indiscriminately drilled around the town. Some were in private ownership and some in Government ownership. The water from

the wells was distributed by a few minor pipe distribution networks from overhead tanks, or distributed by water tankers. Some people collected their water from the ancient "aflaj", the culverts bringing water from the Oman mountains. There was evidence of the water table being dramatically drawn down due to the over-pumping of the aquifer.

7. Domestic wastes were either discharged into septic tanks (which were usually inadequately designed, rarely emptied and often overflowing) or directly through a hole in the wall to soak-away in the surrounding sand. Structural designs of the septic tanks were generally poor and more often than not the roofs were cracked or completely broken causing danger to health and limb. Many of the septic tanks were located near the wells and there was some evidence that these sources of water supplies were being polluted. At one location the presumptive coliform count was over 10 000 per 100ml but there was no evidence of any increase of infectious diseases due to the pollution of wells. During 1972, however, there was an unusually high rainfall and the incidences of dysentry and gastro-entiritis increased five-fold. This was presumbaly due to the overflowing septic tanks, whose contents were washed around the town. It was clear that the provision of water and sewerage facilities in the expanding town was urgently needed.

8. The client indicated that there would be planning objections to the use of high water towers from the aesthetic point of view and that an underground reservoir with associated booster pumps offered a lesser security risk. With the rather low standards of maintenance applied to mechanical equipment in this part of the World the adoption of elevated water towers would have been preferred. The pump design and control would have been easier using water towers but distribution systems would have been less flexible. A pumping station to boost the supply with plenty of space for future pumps offered this flexibility.

9. When it came to sewage treatment, probably the most arguable item was the Engineer's reasons for adopting extended aeration rather than biological filters used elsewhere in the Middle East. Certainly, the filter could cope with shock loading and was able to receive flows in excess of the designed ones and still produce an acceptable effluent. However, it was considered that the fly nuisance with biological filters would be a problem and their efficiency would be severely affected by wind-blown sands. Waste stabilization ponds were rejected as wind-blown sands would gradually fill the ponds decreasing the effectiveness of the treatment and increasing the frequency of de-sludging. Also large quantities of water would be lost through evaporation which from a water conservancy point of view would be unacceptable.

10. Having opted for the activated sludge process for biological treatment it was considered that surface aerators were the most appropriate as there would be the possibility that air diffusers would be blinded by sand. Furthermore, when the capital and running costs were considered, extended aeration came out cheaper.

11. The high evaporation rate would be useful for dewatering the sludge and when dewatered, the sludge would be used for conditioning agricultural land. As there would be no primary sludge from the works, and the surplus activated sludge would be well oxidised, anaerobic digestion was considered unsuitable. Furthermore, the collection of gases from an anaerobic digestion system was of no great advantage in an energy-rich country. With aerobic digestion the organic matter would be largely destroyed, the sludge could be readily dewatered, the process would not be susceptible to inhibitory substances in the sewage, there was less likelihood of odour problems and used in conjunction with extended aeration of the sewage the digestion capacity would be considered reduced.

12. In connection with engineering for health in hot countries, new problems were often arising. Perhaps the old problems were not wholly solved and new processes would certainly be devised in the future. An open mind should be kept as regards the future methods by which water is distributed, sewage collected and treated. As an example, when Balfours arrived in Al Ain they had expected to use epoxy-lined asbestos cement pipes for sewers since these were readily available, but ended up adopting vitreous clay pipes. GRP was most suitable for large sewers and for manhole linings and it was thought wise to adopt GRP ladders for access to the manholes. However, commercially produced GRP ladders which were tested failed to meet corrosion-resistance requirement. Engineers should warn clients that the best solutions to the various problems posed in hot climates may be difficult to achieve due to the lack of ideal products, materials, etc., and allowance must be made for changes, as new knowledge becomes available.

13. Finally, Mr YOUNG said that the

solutions to engineering problems in the Middle East might be complex and expensive and were certainly different from those adopted for temperate climates. It was fortunate that the rich developing countries could afford to pay for the solutions to the engineering problems arising out of their geopgraphical location.

14. Mr MARK LANSDELL said that when he worked for local government in Britain, they always carried a ladder around with them. Where a fixed step ladder went into the wall there was sometimes considerable corrosion. Mr LANSDELL was interested that when the rains in Al Ain came, the gastro-enteric diseases increased five times. In Venezuela in the rainy season the figure doubled.

15. Mr YOUNG said that in 1972 when these rains occurred, it was coincidental with the opening of the new government hospital and there was a possibility that before 1972 many people who had sickness and diarrhoea did not go for treatment.

16. Many types of ladders were seriously considered for Al Ain and they were still looking for a suitable type. With plastic coated step irons the weakness was at the wall. Portable ladders would have to be telescopic for different depths of manholes and the fixing of the bottom of the ladder on the benching could be quite hazardous. GRP ladders probably offered the best alternative providing acid resistant resins were used. One inch plastic sheathed iron bars across the manhole were finally adopted.

17. Mr C PEEL wondered whether Mr YOUNG had any idea of the production costs of desalinated water.

18. Mr YOUNG replied that about a year ago, it was about £4 per 1000 gallons. With earlier plants, there was no means of putting some salts back into the treated water, which was therefore highly corrosive. In Abu Dhabi pressures were low, so people tended to fill baths to have a reserve of water and this was most foul-looking due to the corrosion of the water mains.

19. For the Al Ain/Abu Dhabi proposal the desalinated water would be chemically treated to protect the distribution system.

20. Mr C N FREER asked about the methods of distributing for irrigation water and digested sludge.

21. Mr YOUNG said that the distribution of the digested sludge had not been organised but it would be air-dried, stored and distributed. Farmers would welcome it because the soil in the area needed humus. The final effluent which should be 10:10:10 standard would be chlorinated before distribution. Three PVC pipes would be laid down each dual carriageway, and standpipes with hoses attached would be provided or drip feed systems installed to regularly water the trees. Initially, trees would be irrigated by well water and possible potable water would be used while the supply exceeds the demand. Ultimately, sewage effluent would be used with a large effluent reservoir and pumping station, delivering to water towers located at various points in the town. The irrigation main materials were quite different from those for the water supply in an effort to stop improper connections.

22. Mr A J H WINDER commented on the very unique situation where money was pouring into a country which thirty years before had no income. Did this money reach the inhabitants - the average man?

23. Mr YOUNG replied that money could get into the average man's hands if he wanted to take it. There were 100 000 UAE nationals who had the benefits of the surplus wealth. They were given land which they could develop, for example by building flats on it. Another way the local people could benefit was to become a local partner in an international company. There was hardly any poverty, although there were some very mean huts on the fringes of the town, but the inhabitants, like the landowners, had colour televisions.

24. Mr A W SHILSTON asked what problems arose from the metering of water supply, and whether sea water had been considered for flushing WC's, cleaning the streets or other secondary purposes.

25. Mr YOUNG said his firm thought metering essential to stop excessive use. In Dubai the consumption of water was considerably less than in Abu Dhabi where there was no metering. The suggestion for Al Ain was that a dual tariff system could apply, the first 350 litres per head being charged for at a standard rate and any excess charged at an enhanced rate.

26. Mr C C KERR saw reference in the paper to the use of stop-taps for controlling supplies. Perhaps this was better than metering.

27. Mr YOUNG replied that stop-taps were provided to reduce the pressure and were additional to meters which are, of course, necessary to measure water consumed.

28. Mr J G WILSON said that GRP pipes had a great future in the Middle East, especially since they were manufactured locally. Did Mr YOUNG foresee any problems in obtaining the right synthetic material and in making sure contractors used the right techniques for bedding the pipes. Were the contractors being trained?

29. Mr YOUNG stressed that the bedding around the pipe was important. Under John Taylor's direction GRP pipes had been successfully installed in Abu Dhabi, for pumping mains, although some pipes had split through bad handling. The GRP pipes had not yet been laid in Al Ain but Mr YOUNG had been impressed by the competence of the men laying the pipes in Abu Dhabi.

30. Mr WILSON asked what bedding material would be used, and Mr YOUNG said it was the "as dug" sand. Mr WILSON said that his firm had considered using local 10mm sand at Dubai but foresaw problems with the intrusion of sulphates into the bedding.

31. Mr YOUNG said that Dubai had groundwater problems. When installing GRP pipes with high groundwater, one had to be very careful because of flotation.

32. Mr S PRAKASH asked whether the local engineers were sufficiently trained to deal with the soil?

33. Mr YOUNG tended to take the same view as Mr ARCHER - that the client wanted to advance technically. That entailed more than sewage treatment. There were power stations, desalination plants, water pumping stations and a whole galaxy of things involved with modern living. We could not single out sewage treatment and make that alone simple and foolproof.

34. A British national ran the sewage treatment works at Abu Dhabi successfully. He had 100 staff mostly Pakastanis, for a population of 30 000. The works included a pressure filtration tertiary treatment plant. Although the country has a small indigenous population there are many foreigners such as Pakistanis, Indians, Egyptians, Sudanese, Palestinians, Jordanians, Bahranians, Iranis and so on. The foreigners include professional people down to unskilled workers.

35. Because their reputation would stand to some extent on the success of the sewage works, Balfours would be suggesting that they be responsible for the management of the works in the early years. They would employ a sewage works manager and the necessary skilled staff, and at the same time promise to train local people to run the plant. In a similar way Swiss Consultants were running a cement works in Al Ain.

36. Mr SHILSTON requested a discussion on the point he had raised earlier on sea water.

37. Mr YOUNG did not see any reason for not using saline water for street washing in Al Ain, but in Abu Dhabi gully connections (with sand traps) had been made into the foul sewers because the groundwater table is high. Therefore, the use of saline water would not be preferred, as the salt in the sewage did adversely affect the sewage works effluent and may preclude its use for irrigation. All water from the sewage works should as far as possible be used for irrigation and this applies particularly to Al Ain where there was a massive programme of tree planting. It seemed ludicrous that during the hot summer in Britain in 1976 people were not allowed to water their gardens and yet with the temperature at 52°C watering is carried out in a country that has limited water resources. Consideration should be given to agriculture and tree planting being controlled so that they matched the available water.

38. Mr SHILSTON said that presumably once the trees were established, they would be sustained by the groundwater.

39. Mr YOUNG said that at Al Ain groundwater was deep, but that in his garden, he had eucalyptus trees 30 - 40 feet high. Mr SHILSTON suggested that there was a great capillary pull. Mr YOUNG agreed; when a well was drilled outside his house, water was 70 or 80 feet down, which the eucalyptus trees would probably have reached as they have very deep root systems.

40. Mr W A GILLINGHAM wondered if anyone had experience of the effect of salt water on building materials.

41. Mr SHILSTON asked if they cleaned streets with sea water in Hong Kong and if so were there any problems. Mr TSAI HONG LO replied that they did use it but

it depended on the areas.

42. Mr YOUNG said that when devising the concrete specification it was accepted that there would be some salt in the aggregate and possibly there would be some salt in the water. So limits were set on the salt content in aggregate, in water and overall. There was also the possibility of staining if saline water was used for curing concrete.

43. Mr GILLINGHAM said that in some areas external rendering was washed down with saline water, which resulted in malfunctioning of the rendering.

44. Mr D A COOKE asked how far the concentration of sulphate in the aggregate and water for concrete should be limited.

45. Mr YOUNG replied that there were limitations to each constituent part in the mix and to the overall mix (not more than 2.5% by weight of the cement in the mix). It was just a matter of finding the right source.

46. Mr COOKE asked what quality of concrete could be obtained.

47. Mr YOUNG said that variability of concrete was frequently caused by change in the dust content from sand storms and bad sieving. Aggregates were the main problem in Abu Dhabi. Al Ain had reasonable aggregates by comparison.

48. Mr PEEL referred to the population increase in Al Ain and asked if any ceiling was to be placed on the population. Mr YOUNG said that it might be wise if a ceiling could be tied to the water supply.

49. Mr PEEL said that if population was pinned at 100 000 and allow no more migration, natural reproduction will steadily increase from there.

50. Mr YOUNG said that when Gibbs carried out the water resources survey for Al Ain, they proposed that the population should be limited to 30 000 people. The present population was about 60 000. There were about 250 Europeans.

51. In reply to questions from Mr FREER about the quality control of concrete with particular reference to temperature, Mr YOUNG said all aggregates should be stored in sealed sheds or bins to stop dust and pollution. They allowed for the addition of ice to the water as metal and stone in the open sun could reach 80°C. Painting the batching plant white reduced the temperature of the metal by 10°C or even 15° compared with other colours, and thus reduced the chance of a "flash set". (The maximum temperature of a fresh concrete mix is specified at 30°C).

52. For curing concrete Mr YOUNG sprayed membranes. Hessian could cause problems unless it was absolutely saturated all the time, and in a water-short country this was asking too much. Also, if it did dry at all, wind was funnelled between the hessian and the concrete surface.

53. One of the greatest problems was to avoid a temperature gradient through the concrete whilst curing. This could be achieved by means of shading.

54. Mr J H KOP asked whether Balfours has tried using polyester concrete pipes which could be made on site by mixing sand with polyester in the same way as unreinforced concrete pipes were made.

55. Mr YOUNG said that they did not consider it because of the likelihood of sulphide attack.

56. Mr YOUNG and Mr KOP proceeded to discuss GRP and polyester pipes. Mr YOUNG said they only used GRP pipes for larger diameters in desert areas. Within the urban area, GRP could not be used because a future trench dug alongside the pipe would take away the side support and cause the pipe to collapse.

57. Mr KOP said he had used the material on a big sewage treatment plant with 300 000 inhabitants in Holland because they wanted a lightweight concrete for the channel around sanitation tanks. Mr KOP wondered if it could be used as a pipe material in desert areas because it was rigid, lightweight and could withstand any attack.

58. Mr W STUART suggested that although diffused aeration might become blocked by sand getting into the tanks, a course bubble aeration system might minimise blockage problems. With surface aerators the motors would have to be very carefully protected from dust.

59. Mr YOUNG said they had an inbuilt flexibility in the design.

60. Mr STUART added that dust storms could increase the volume of sludge and incapacitate the digestion system.

61. The CHAIRMAN concluded by saying that clearly the problems of excess were greater if not more complicated than those of poverty. He sometimes wondered whether there was sufficient basic research to back up this tremendous surge of civil engineering in the oil rich states. There seemed to be so many questions to which the answers were not yet known, that he suggested that there could be much more done to support the efforts of our contractors and consultants in these countries.

I.C. CAMP

interceptor study for laguna lake development authority, philippines

The views expressed in this paper are those of the author alone and do not necessarily reflect the official views of the Laguna Lake Development Authority nor the Government of the Republic of the Philippines.

INTRODUCTION

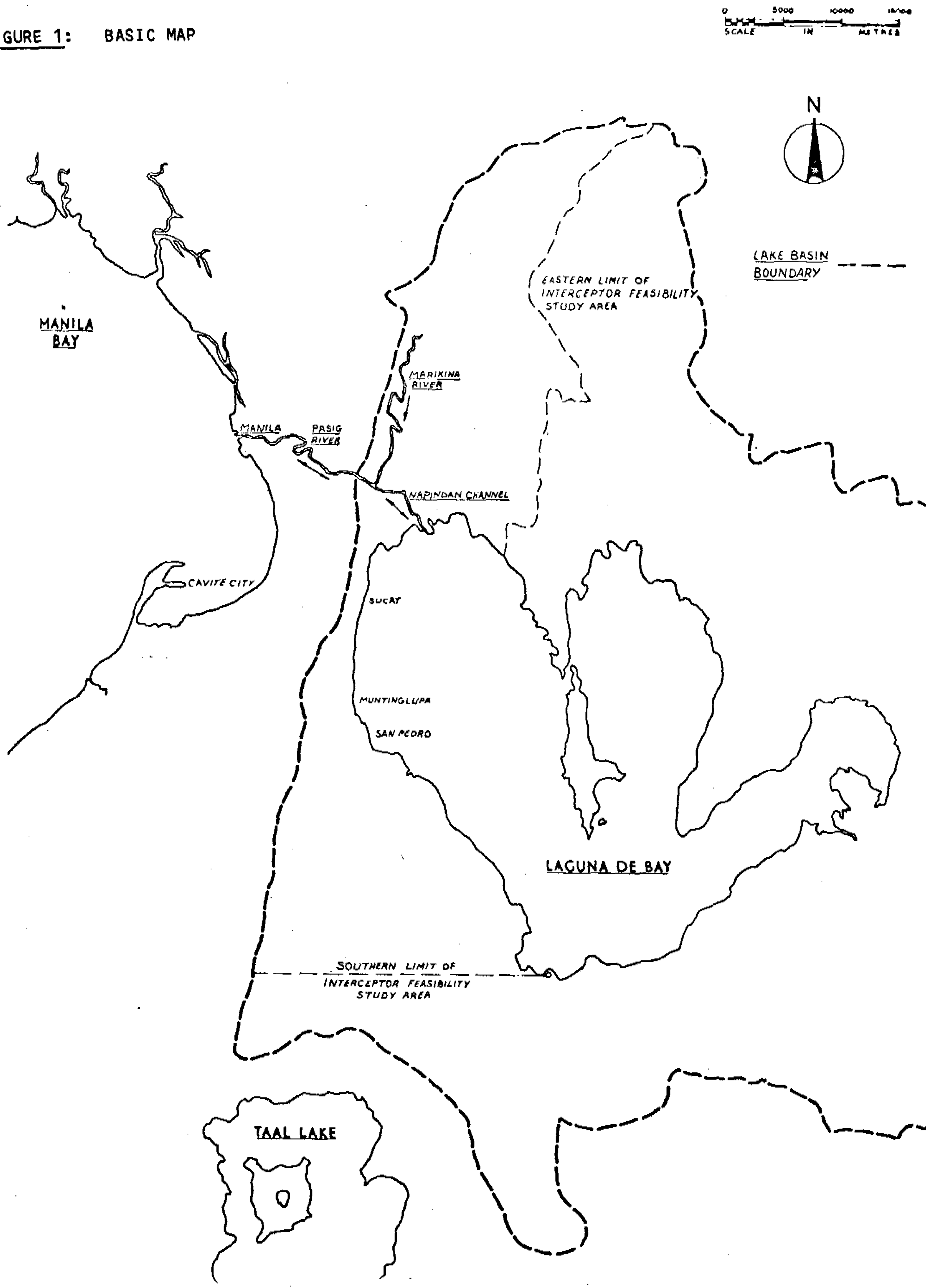
Manila, the capital city of the Republic of the Philippines, is one of the many fast growing areas of Asia. The present population is about 6 m and by the year 2000 is expected to have reached 16 m.

The central area is already densely populated and development is spreading along the coast of the very fine and extensive Manila Bay; also development has spilled over the inland ridge into the catchment of Laguna de Bay which is situated about 15 km east of the centre of Manila. Figure 1 shows the relationship between Manila, the Bay and the Lake. Important features of the area are the Pasig River, the Marikina River and Napindan Channel which are also shown in the figure. Their influence will be referred to later.

The supply of potable water for Manila has always been a major problem owing to expansion of the supply system lagging behind the increasing domestic and industrial consumption; previous studies by others have identified supply sources which might be developed as part of a long-term on-going expansion programme.

One of the sources so identified is Laguna de Bay. Aware of the potential benefit of this natural resource to the country, the Philippine Government created the Laguna Lake Development Authority (LLDA) in 1966 to conserve and develop the resources of the Laguna de Bay Region. The LLDA's powers were further strengthened by the Government in 1975 so that they could better control development within the catchment of the lake basin and minimise pollution of the lake consistent with the requirement for its use for fisheries, irrigation water (for lake-side agricultural areas) and for potable supplies.

FIGURE 1: BASIC MAP



LAGUNA DE BAY - PRELIMINARY STUDIES

Laguna de Bay, the largest lake in the Philippines, is a shallow body of water with a surface area of 900 sq km. Its average depth can vary from about 2.8 m at the end of the dry season (in April/May) to 4.8 m or more towards the end of the wet season (November/December). Owing to its shallow depth, particularly in the dry season, wind-induced water movement stirs up the light bed sediment such that the lake water is always turbid, frequently looking like weak milk-coffee.

In 1968 it was concluded in a report(1) to the NWSA that pollution existed at isolated parts of the lake but at that time it was said not to be widespread and did not constitute a problem. With industrial development of the lake-shore and expected population growth, it was considered that pollution could become a problem in the future.

One major source of pollution comes from the Pasig River which, at certain unfavourable conditions of tide in Manila Bay and lake water level near the end of the dry season, can reverse its direction of flow and discharge saline water, itself containing a very heavy pollution load from Manila, into the lake. It was suggested in the report that some form of hydraulic control might be feasible, not only to prevent back flow of the River Pasig into the lake, but also to eliminate the frequent and prolonged flooding in central Manila; the latter is due to the inadequacy of the River Pasig to pass peak floods from the Marikina River and the lake catchment whose only outlet to the sea is via the Napidan Channel and River Pasig.

As a result of those studies the Government is about to embark upon the construction of the Hydraulic Control Structure across the Napindan Channel - to prevent back flow of Pasig River water into the lake, the Mangahan Floodway - which would take the Marikina floodwaters into the lake thereby minimising flooding in the centre of Manila, and the Paranaque Spillway - which will serve as an emergency outlet for the lake to Manila Bay so that lake-shore properties and agricultural areas would not be flooded in the wet season. These projects are shown in figure 2.

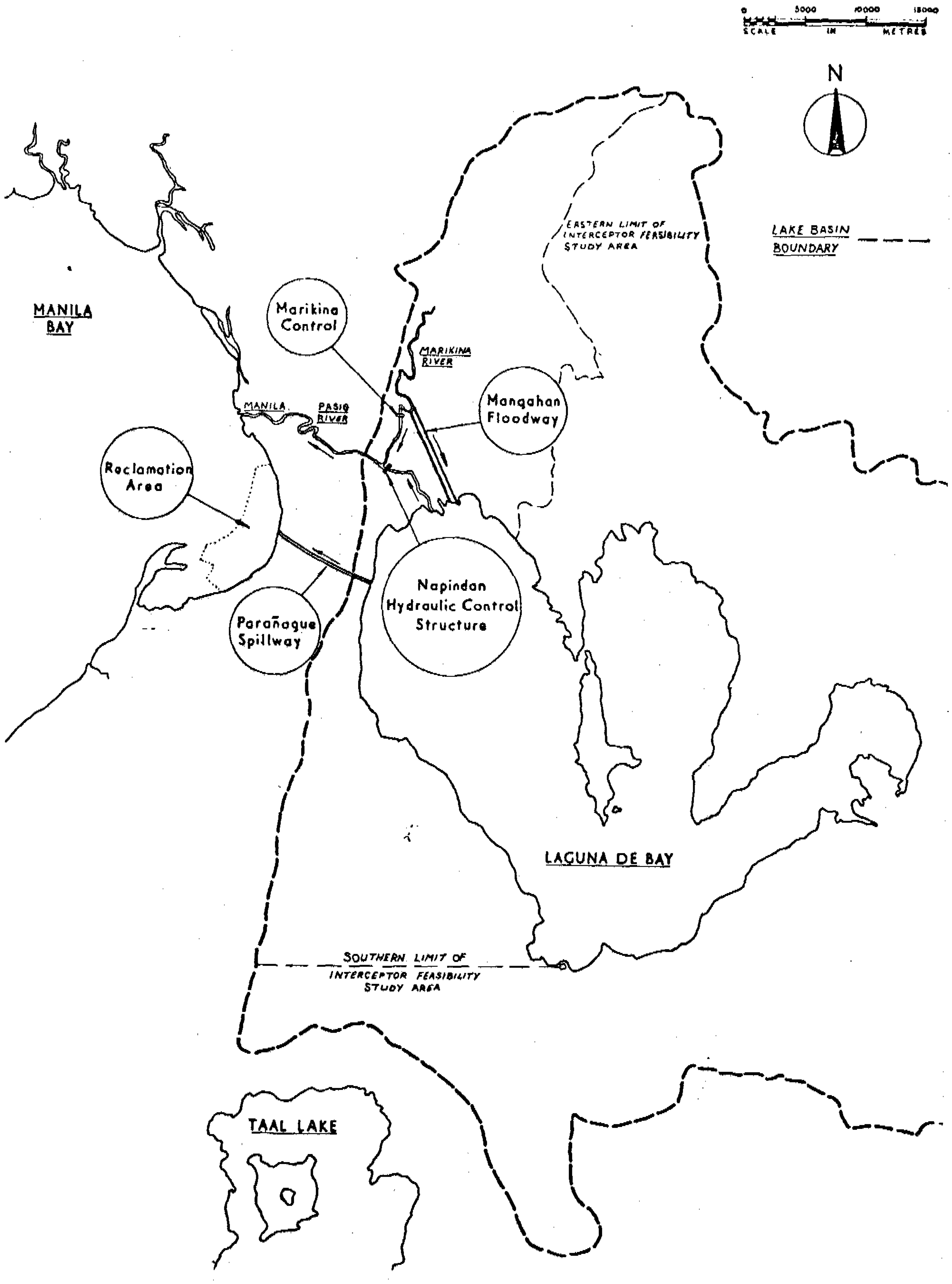
At the conclusion of these works and if no other action is taken, the lake could be receiving the untreated wastes from about 2.5 m population, and from an extensive and mixed industry. Owing to overspill development gaining momentum particularly along the western and northern shores of the lake, it is predicted that by the year 2025 the lake catchment population could have risen to 5.3 m.

Between 1967-1969 a Master Plan study(2) of the Manila Metropolitan area for the WHO embraced part of the Laguna de Bay catchment; the study report set out proposals for sewerage and temporary sewage disposal facilities, the phased construction programme leading to the establishment of a trunk Pasig sewer and outfall to Manila Bay.

Within the area studied, many of the properties had individual, or were connected to, communal septic tanks but as emptying was seldom undertaken the effluent overflow to adjacent surface water drains, channels or ditches was as strong, if not stronger, than crude sewage, a situation which still pertains.

Relative to the more pressing needs of the Manila Central Area, the lake shore and Marikina valley sewerage were considered low priority. However, as a result of the subsequent lake water study(3) the need to control pollution of the lake, in association with the Mangahan Floodway and the Napindan Hydraulic Control Structure, was re-emphasised. The Laguna Lake Development Authority therefore commissioned JD & DM Watson to make a more detailed Interceptor Feasibility Study comprising an evaluation of the pollution problem and its solution; a final report in draft has now been submitted to the Authority by the consultants.

FIGURE 2: HYDRAULIC CONTROL PROPOSALS



INTERCEPTOR FEASIBILITY STUDY

Objectives

An interceptor is usually thought of as a sewer laid to take flows from existing lateral sewers and to convey them collectively to some other point for disposal. For the purposes of this study the term relates to the interception of liquid wastes however conveyed so that they could be discharged either into Manila Bay or to the Lake, with or without treatment as might be found necessary.

Much of the previous study material formed a useful starting point in the collection of basic data but with such a rapid increase of population and industrial development within the study area (shown in figure 3), updating was an unavoidable task. Because of the changed circumstances and the possibility of future changes in the type and location of development, it became abundantly clear that the interceptor system would have to be designed with maximum flexibility in mind.

In the special case of waste discharged to Laguna de Bay, it was necessary to consider nutrients, organic load (BOD), suspended solids, toxins and bacterial contamination.

a) Nutrients pose a special problem; further studies are in progress in an endeavour to more positively establish the limiting factors in lake eutrophication.

b) Calculations show that, so far as BOD is concerned, if dispersed uniformly over the lake there is adequate oxidation capacity to deal with the sewage in the crude state. However, dispersion in this manner is not feasible.

c) Toxic substances in industrial effluents must be strictly limited by partial or complete removal before the effluent is discharged to the lake so as to protect fisheries and man.

d) Percentage reduction of bacterial organisms in conventional treatment works is very high although the remaining numbers are significant; exposure to sunlight effects a further reduction in numbers.

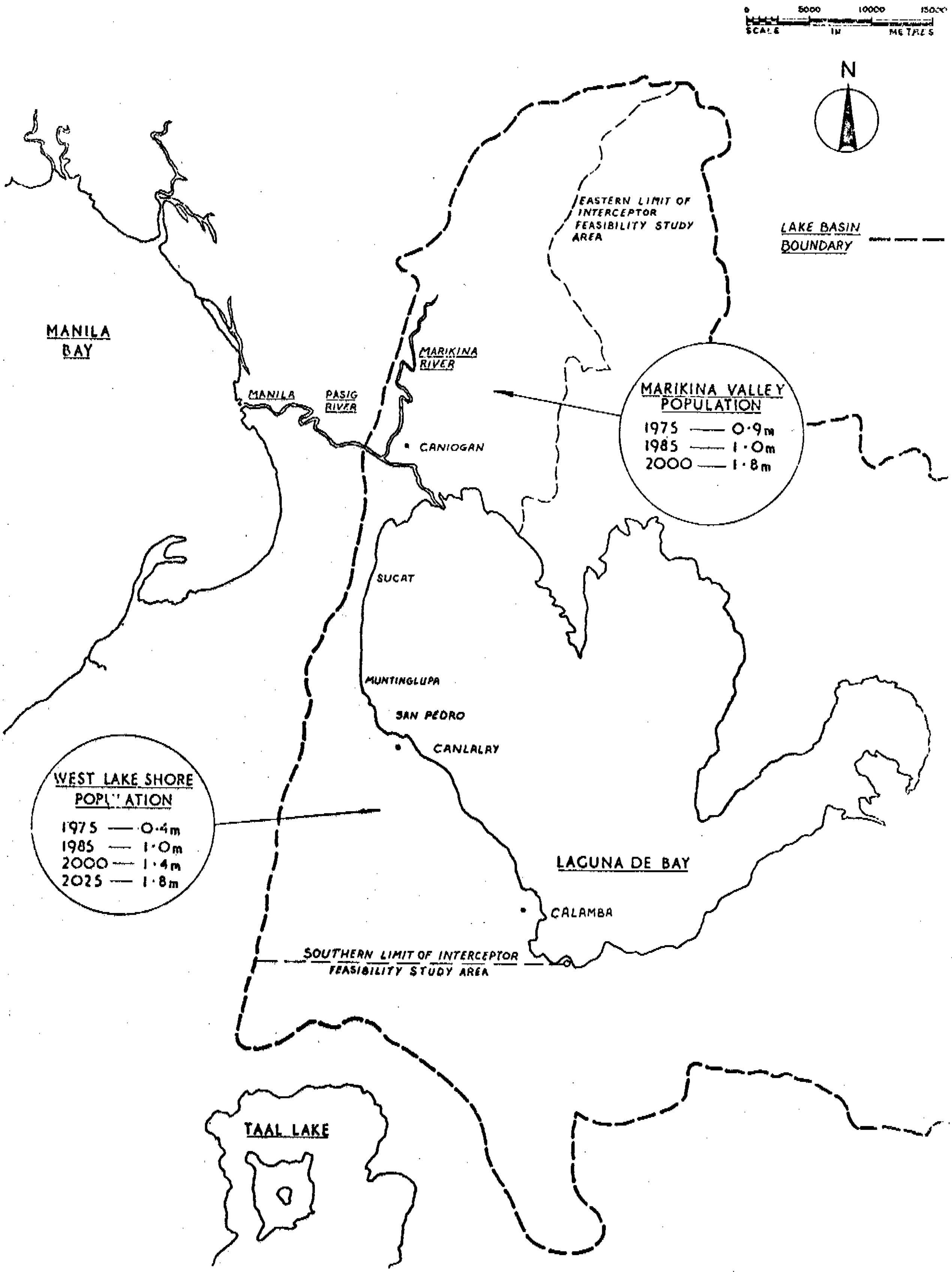
Water quality standards

The Philippine National Pollution Control Commission in 1966 promulgated classification and water quality standards for fresh water; the regulations are now under review and careful consideration is being given to sensitive waters, such as Laguna de Bay, the Marikina and Pasig Rivers.

Even in their 'natural state' rivers, lakes and seas are subject to contamination from vegetable and animal debris, soil particles, chemicals dissolved in ground and other waters, and other 'pollutants'. All natural waters have a capacity for self-purification which results in oxidation, assimilation or stabilisation of polluting substances by chemical and biological means; this capacity may be diminished if the polluting load is excessive or if toxic conditions occur. The disposal of domestic sewage and industrial liquid waste normally and economically takes place to natural water courses contributing to the water cycle, eventually reaching the sea, but it is necessary to control the volume and nature of polluting discharges to ensure that the loads applied are within the capacity of the receiving water.

It may be convenient and economic to reduce the pollution load in a treatment works or alternatively to convey the flows to a point where more

FIGURE 3: DEVELOPMENT GROWTH PREDICTIONS



dilution is available, and in consequence the capacity for self-purification is enhanced. The use made of the water downstream of the discharges is also relevant, and special care needs to be taken of water used as a source of potable supply or for recreation. For fresh water streams and rivers, the available dilution can be ascertained and the effect of the diluted waste on the biological system and the rate of self-purification assessed. For marine discharge conditions, the available dilution is potentially very large and the main concern is with conditions near the discharge point, necessitating measurements and prediction of water movement and waste dispersion.

Natural waters normally contain significant amounts of oxygen in solution; the equilibrium or 'saturation' value depends on temperature and salinity. Chemical or biological oxidation is an important means of purifying or stabilising many pollutants and depletes the oxygen level, but this is offset by replenishment, mainly from the atmosphere and, depending on the rate of oxygen demand, a dynamic balance may be struck at a level less than saturation.

In previous studies of the lake attention has been drawn to nitrogen - and its role in eutrophication - and to the harmful effects of toxic substances. It was suggested(4) that, from the studies carried out in 1973, the total nitrogen input to the lake should be limited to 5000 tonnes a year and that, so far as domestic sewage was concerned, this objective could be achieved by the provision of an interceptor along the west shore of the lake from San Pedro to Sucat to collect and export to Manila Bay the industrial wastes of the most industrialised area along the lake shore, and the municipal waste from San Pedro to Muntinglupa. It was also assumed that the Marikina Interceptor would discharge the northern area to the Pasig River. It was further said that sewers and lagooning facilities must be progressively built between 1990 and 2000 to serve the predicted 1 m total future inhabitants in the cities around the lake shore. It was stated that the population projection for the year 2000 was 2.8 m; thus the wastes from about 1.8 m were to be diverted to the Pasig River.

Events have significantly overtaken the projections made in 1973. At the present rate of growth, the 2000 year population will be reached by 1985, if not earlier, continuing to rise to about 5.3 million by 2025.

Thus the scale of the task has dramatically altered, not only in the volume of sewage to be collected, but a greater degree of treatment would have to be given to all of the flows to achieve the same lake water quality objectives. Pending the formulation of a comprehensive set of standards applicable to the whole country, the Interceptor Feasibility Study Consultant has suggested that any effluent discharged to the lake should contain not more than 30 mg/l SS and 20 mg/l BOD. A process would also need to be chosen to give good denitrification.

It was envisaged that as the initial stage of construction would comprise approximately 25% of the foreseeable future requirements there should be scope for subsequent effluent improvement (biologically and bacteriologically) so as to minimise initial capital expenditure. So far as discharge to the Pasig River is concerned - for long known as 'the dead river' - maximum benefit would be derived by first improving the upper reaches of the river so that, by having a reserve of dissolved oxygen, lower reaches of the river could more readily assimilate some of the wastes aided by the natural processes of self purification. Thus if the initial phase of construction is to have a discharge to the head of the Pasig River, it should also be well nitrified and to a 30 mg/l SS - 20 mg/l BOD standard.

Alternative solutions

From a consideration of the topography of the Marikina Valley, the logical development of the valley sewerage system would be to bring all sewage to the southern end near Caniogan and to discharge treated effluent into the Pasig River for dilution and conveyance to the sea via Manila Bay. Owing to the congested development near the confluence of the Marikina River, Pasig River and Napindan Channel, direct discharge to the Pasig River would be expensive. Thus the initial phase of construction would allow effluent discharge into the Napindan Channel, the hydraulic control being so arranged that it is taken with a small flow into the Pasig River from the lake most of the time.

The west lake shore with its present concentration of industry and residential property being expanded southward presents the option of treatment to a high quality and discharge to the lake or treatment to a lesser standard and discharge to the Manila Bay. As the concentration of population and industry in the southern portion of the study area increases, determination of the best location for an outfall, or outfalls, is governed by land availability for construction, effluent re-use in such a manner as results in further purification, and evaluation of the engineering aspects of alternative schemes of sewerage and sewage treatment.

Consideration of these factors has led to the selection of the Canlalay and Calamba areas as possible works sites, a single aerated lagoon/oxidation pond unit being provided at each and a twin module aerated lagoon/oxidation pond unit at Caniogan, each module to have a dry weather flow capacity of 100 000 m^3/d. Thereafter, development in the respective catchment would dictate the type and location of facilities additional to those provided in the first phase of construction.

Stream and river intakes

In the absence of a conventional sewerage system, all liquid wastes generated in the catchment which do not evaporate or become absorbed in the soil (extensive use being made of the polluted streams and rivers for land irrigation) eventually find their way into the lake and the Marikina River via the many streams and rivers.

Thus to intercept pollution at minimum of expense the lake shore interceptors and other trunk sewers must be arranged to accept as much of the stream and river flow in the dry season as may be feasible, acknowledging that during the wet season a much diluted pollution load will have to pass forward to the lake until such time as a full sewerage system is available. The stream and river intakes thus become a vital part of the first phase of construction.

Any structure placed in a river system alters its regime and smooth transition into and out of the structure is essential; over-topping must also be controlled. If any of these features disturb the regime, the river may quickly take a new course around the structure.

Regarding the intakes, the major operational problem to be overcome is the prevention of large objects entering the sewers. A conventional bar screen, if not frequently raked, would rapidly clog and prevent interception. Raking could be undertaken manually or mechanically but the former would require almost continuous manual attendance. Mechanically raked screens would require no more than perhaps two visits each day to remove the screenings to the disposal point and to generally check the equipment.

It is considered feasible to devise a non-conventional manually raked screen which would require no more visits than for a mechanically raked screen, but attendance time for raking and disposal of the screenings would be greater. However, as transport of debris in rivers is influenced by the characteristics of the regime and wind conditions, there is no guarantee that identical intake screen arrangements in different locations will operate with equal efficiency.

The draft proposals allow for collapsible gates to be provided where the weir level has to be located below the lake's top water level of 12.5 m above LLDA datum. This feature keeps the lake water out of the river but in times of floodflow allows the river to discharge without over-topping its banks. The added advantage of this system is its capacity to hold a small 'first flush' storm flow within the river basin and for it to be drained into the interceptor as required.

Sewerage

Route selection was based upon many visual inspections on the ground, check line and levels surveys over the majority of the selected routes, supplemented by two visual reconnaissances (at three month intervals) by helicopter and recorded in 210 photographs. Very detailed 1/10 000 scale maps had been prepared some years previously by the Bureau of Coast and Geodetic Surveys, but the rapid growth of development meant that every detail had to be checked.

The long term proposals provide for wasteflows from the population, industry and livestock expected by the year 2000. Such a system could be achieved through a programme of expansion both of the trunk sewers and the reticulation of small sewers conveying wasteflows from individual properties to the trunk sewers. However, the major problem facing the LLDA is the one of ensuring that routes now selected for trunk sewers are still available at the future construction dates.

For reasons of economy in capital and running costs, it is desirable that future drainage should be on the 'separate' system, i.e. where a two-pipe system is provided, one exclusively for all liquid wastes and the other for surface water run-off from roads and paved areas.

Except at considerable and unnecessary expense to prevent it, infiltration will occur in the sewer system. By infiltration, we mean the entry of ground water through defective joints and leaks in damaged pipes forming the whole system comprising interceptors, laterals, reticulation system and house drains. The act of constructing sewers and drains opens the ground and unless exceptional backfilling methods are carried out, ground water usually finds its way into the backfill material. Thus, assuming the water table is high enough, the degree of infiltration is a function of the care and skill with which the pipes are made and laid.

There is no doubt that the art of pipe manufacture and pipe laying in the Philippines is improving. As major projects come forward for implementation it will be necessary for the improvements to continue so that locally manufactured pipes are available with flexible joints and, where necessary, surfaces resistant to corrosion arising from liberation of hydrogen sulphide from septic sewage.

So far as concrete pipes are concerned, specialised manufacturing techniques are required for pipes of more than 2 m diameter. Consideration of various alternative solutions of sewerage and sewage disposal indicated that some schemes might require pipe diameters of 4.5 m. However, the early years of operation with large sewers and relatively low flows - hence low velocities - would lead to unacceptable deposition of solids and increase in septicity. In the review of all the factors it was concluded that the maximum size of the initial phase sewers should be limited to 2 m internal diameter.

Concurrently consideration of sewage treatment requirements and phased development led to the conclusions that which ever form of treatment was to be adopted, the module size should be based upon a dry weather flow rate of 100 000 m^3/d. Assuming a separate sewer system and from an analysis of the probable distribution of domestic and industrial wastes, infiltration and flow balancing effects in a large sewerage network, it was concluded that the peak flow rate into a standard size module would be about 270 000 m^3/d.

Quite fortuitously, this is also the carrying capacity of a 2 m diameter pipe laid at a gradient to give satisfactory velocity flowing full of 1.0 m per second, the hydraulic design based upon the Colebrook-White equation and 'K' factor of 1.5 mm.

Sewage treatment

In the initial period of operation when the majority of the inflow to the treatment works will be from polluted streams and rivers, the sewage strength will be weaker than that from a conventional sewerage system owing to dilution from the natural stream and river flow but clearly the latter will be at a minimum during the dry season.

In the long term liquid wastes must be taken into the system direct so that the volume to be treated and pollution of surface waters are minimised. It is suggested that priority should be given to the connection of major industrial wastes because, as large point sources, collection is more easily and economically achieved than the same volume of domestic wastes. However, whilst the objective is to collect all wastes, those that are not biodegradable may have to be pretreated at the manufacturers premises before discharge into the communal system.

From 1970 to 1976 the number of industrial premises appear to have more than trebled; the recent assessment gave the probable number at 460 of which 16 have pretreatment plants. The LLDA has now to decide upon its future course of action; insistence upon construction of more pretreatment plants which might become abortive in perhaps five years time may no doubt appear to the industrialists concerned as unnecessary expenditure and cause for annoyance but some measure of control has to be effected to protect the lake (which is already in use for fisheries and agriculture) pending commissioning of the interceptor system. Thus there is some latitude for accepting a compromise solution in the interim giving maximum overall benefit in the future. This ideal solution should be the objective but it may be hard to achieve in practise; every case has to be judged upon its own merits.

The tropical conditions in the Philippines favours low-cost treatment processes by oxidation ponds, but for the population involved, a very large land area would be required. Draft layouts suggest that land areas of about 1.0 ha would be required for a dry weather flow of 1000 m^3/day.

The major operational problems with natural oxidation pond are: unreliable performance in terms of effluent quality, smell and control of mosquitoes. For these reasons the pond system was discarded in favour of a more controllable system comprising surface aeration in a 5 m deep lagoon having 4 days retention followed by two 1.5 m deep oxidation ponds in series, each having 3 days retention (at 1 dwf). The lagoons would be preceded by mechanically raked screens and spiral flow grit channels. Land area requirements reduce to about 0.6 ha for a dwf of 1000 m^3/day.

It is envisaged that if development continues at the predicted rate additional treatment facilities would be required either in the form of aerated lagoons/oxidation ponds or, where space limitations preclude their use, conventional activated sludge units with the facility for significant nitrogen removal. An alternative solution but requiring greater capital resources would be to provide screening and settlement followed by a long land line and outfall to Manila Bay.

For economy of construction and compatibility, discharge to Manila Bay should be considered in conjunction with disposal of sewage from the seaward side of Manila. Previous marine studies indicated areas of feasibility but the proposals will have to be reviewed taking account of the very significant reclamation work which is presently taking place in Manila Bay.

For the subsequent phases of construction the design data will require revision based upon experience gained in the operation of the previous phases and prediction of future conditions. So far as domestic wastes are concerned, the load discharged to the sewers will depend upon the extent to which the reticulation system is developed and nature of the residential development served. It is estimated that in the unsewered areas only about 25% of the domestic pollution load reaches water courses; some of this load may be subsequently absorbed in land irrigation schemes before the flow reaches the interceptors via streams and river intakes.

Livestock in the study area includes pigs, poultry, ducks, quail, cattle, caraboas, horses and some goats. The principal animals of concern are pigs and to a lesser extent poultry. In commercial establishments it is envisaged that animal wastes removed from pens during daily wash-down procedures would be passed to pretreatment units to halve the pollution load discharged to sewers. Livestock wastes account for about 0.5% of the flow but about 25% of the pollution load, but reducing to about 12.5% by the end of the century.

Agricultural wastes will remain a source of pollution on the lake as their collection and treatment would be prohibitively expensive. Thus very close control over the use of fertilizers and pesticides is required.

MANAGEMENT AND FINANCE

The successful implementation of the project will be heavily dependant upon the adequate manning of the system and in the raising of finance for capital and running costs.

Management aspects include the control of all types of development within the lake catchment, supervision of sewerage and house connections to ensure that surface water is kept out and that infiltration is minimised, control over agricultural wastes and the use of fertilisers and pesticides, establishment of a procedure for rapid clearing of oil spills and harmful chemicals, operation of the system and staff training.

Policy decisions have yet to be taken by the LLDA regarding financial aspects of the proposals. If the scheme is considered as a social project it might be argued that its cost should be recovered within the country's general taxation arrangement. At the other extreme, a charge might be levied on every user. However, it seems that the correct solution may be somewhere between the extremes.

It would be misleading to quote the estimated costs of the project as the initial phase of construction does not include lateral sewers nor house connections, but in the long term the capital expenditure could be within the range 100-120 US dollars per person served by the system (at present day prices).

ACKNOWLEDGEMENTS

The Author is most grateful to the Laguna Lake Development Authority for permission to present this contribution to the conference and acknowledge the great help and encouragement received from the Authority's officers and staff during the Interceptor Feasibility Study. Acknowledgement is also made for the assistance given by the Philippine Government and Asian Development Bank.

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discussion

CHAIRMAN: B M U BENNELL, BSc FICE
Principal Engineering Adviser
Ministry of Overseas Development

THE CHAIRMAN introduced Mr I C CAMP who would describe a feasibility study which his firm had recently carried out for the Laguna Lake Development Authority in the Philippines. This paper gave a very interesting description of problems associated with avoiding the mistakes made by the developed world in respect of pollution at possibly a more modest cost and at the same time continuing the development. There were awful examples of pollution in the Great Lakes of North America and the increasing pace of deterioration of the Mediterranean.

2. Mr CAMP was an Associate of Watson Hawksley (formerly J D & D M Watson) and has been with the firm for twenty years. This assignment was his first experience overseas, and he had since worked mainly in the U K.

3. Mr I C CAMP said that the Philippines had no oil of its own and the financial situation there was vastly different from that of Al Ain. By the end of the century if not before, Lake Laguna might be required as a water supply source for Manila and by this time the population within the Lake catchment might number four to five million. Thus, domestic and industrial wastes generated within the Basin must be dealt with, although it was not necessary to treat effluents to drinking water standards because advantage could be taken of natural purification within the Lake. As had been said many times before, the solution to any problem had to be tailored to suit the local situation. Account must be taken of the country's material and financial resources, its technical and managerial competence to participate in the design and subsequent operation of a project, and the present and future needs of the community. The Philippines was a fast developing country and what was an appropriate solution today might be inappropriate five years hence.

4. The Laguna Lake Development Authority had many projects in hand to preserve and indeed to improve the Laguna Lake and its environs, part of which was within the metropolitan area of Manila, the capital city. Mr CAMP's involvement in their scheme was confined to the interceptor feasibility study, a project to minimise the pollution of the Lake. Whilst engineering aspects were the focus of Mr CAMP's firm's attention, they nevertheless had to select a sewerage system which could maximise the use of local materials and commodities. Sewage treatment facilities must be within the operational capabilities and financial resources of the native population although it was recognised that foreign technical and financial assistance would be required.

5. Mr CAMP then showed some slides, commenting that Manila was full of charming contrasts. An increasing awareness of the need to minimise pollution in the interests of public health was seen in a horse-drawn carriage; underneath the horse's tail was a canvass bag!

6. A helicopter, where up-to-date maps were not available, was not a luxury when it came to finding feasible routes from large diameter sewers through congested development which seemed to

become more densely packed with each succeeding day.

7. Verticle growth was a more economic form of development in terms of sewerage. Manila's multi-storeyed blocks of hotels, offices and residential units were generally located on seaward facing slopes i.e. facing Manila Bay extending inland and southwards from the mouth of the Pasig River.

8. Within the older parts of the city, the banks of the Pasig River were congested with a variety of commercial buildings overlooking the heavily polluted and mild coffee coloured river water decorated most of the year with floating clumps of water hyacinths which came down from the Laguna Lake. Upstream of the city centre, particularly alongside the Marikina River, a more rural scene existed between industrial premises.

9. The upper reaches of the Napinda Channel were flanked by ricelands and were regularly flooded during the wet season to a depth of as much as two metres.

10. One of the early projects by the L.L.D.A. was the encouragement of fish farming within the Lake but its continued success would depend upon the maintenance of acceptable lake water quality and, in this respect, they were undertaking at that time a continuing monitoring programme particularly looking at nitrogen and phosphorous levels. There was no doubt that water hyacinths could do a useful purification job, but according to laboratory studies by the National Space Technical Laboratory retention times of three or four weeks were required for the hyacinths to take up pollutants from first-stage aerated lagoon effluent. The plants must then be harvested before they can complete their life cycle otherwise absorbed pollutants would be returned to the water from the decaying plant, also causing depletion of oxygen.

11. For a population of several million, the concept of treatment solely by hyacinths with the tremendous task of continuous harvesting and disposal of the harvested material did not seem to be a feasible proposition. Also the growth was seasonal diminishing during the winter thus reducing the treatment potential. Action had been commenced to provide trade waste treatment plants whose effluents discharge either directly or indirectly into the Lake pending development of a comprehensive scheme.

12. Soon after the interceptor feasibility study commenced it became apparent that in the absence of a community sewerage system, and with a present population of approximately 1.8 million without any sewers, the only way to limit pollution going into the Lake would be to pass stream water through treatment works. It was considered that this would be the quickest compromise solution to the problem. During the dry season the whole of the river discharge could be accepted as the flow almost wholly derived from man's activity. In addition this scheme would provide a safeguard in the event of a mishap with one or more of the several private trade waste treatment plants. For example when dealing with an industrial effluent, one of the walls in the aeration tank collapsed and put the whole plant out of operation so that the whole of the effluent having a very high BOD went into the river untreated.

13. In the absence of sewerage septic tanks had to be constructed for all new development; as a result of their population explosion, about forty new dwellings each able to accommodate about eight people were being built every day within the Laguna Lake region.

14. Septic tank effluent sometimes had a higher BOD than fresh sewage, but with reduced floating solids septic tanks seem to provide a marginal aesthetic benefit. Attention must be given to solid waste disposal. Indiscriminate private dumping into waterways nullifies improvements achieved by sewerage and sewage treatment.

15. There was no doubt that if a conventional sewerage system could be afforded, the maximum benefit would be achieved by giving priority to its provision with all subsequent development and, according to the availability of financial resources, gradual sewerage of existing areas might then be undertaken. However there were many lakeside dwellings which could not be served by a conventional sewerage system and in due course the Authority might have to consider their phased reconstruction possibly elsewhere and provided with basic sanitation connected to the sewerage system. Meanwhile the Laguna Lake Authority had a tremendous and formidable task ahead of them controlling private development programmes. At Canlubarng sugar cane and coconut plantations were being cleared for a new city being designed for a population of one million people building up over the next fifty years. On the other hand,

agricultural areas should be preserved for the production of much needed food.

16. The engineering solution suggested in the feasibility report could achieve improvement in the lake water quality but they had to be complemented by control of solid waste disposal and the use of fertilizers and pesticides in agricultural areas. For good measure and perhaps added interest, the engineer had to take account of the fact that the Philippines was an active seizmic zone; a constant reminder could be seen in the nearby Taal volcano which simmered gently between dramatic eruptions. There were well established designs for earthquake engineering and as far as the Philippines were concerned, flexibility of pipe joints was of great importance. In fact, the key note of projects of this type was flexibility in all aspects of design and construction and management thus allowing for changing conditions in the years ahead.

17. Mr R J HOLLAND said Mr CAMP had mentioned in his paper about the Black and Veatch Report. Was this another example of a problem about which report after report was written, and then shelved and superseded. Would Mr CAMP's recommendations be implemented?

18. Mr CAMP said the Black and Veatch Report was a master-plan study in 1969 and was a major attempt to decide what was to be done within Manila and the surrounding area. At that time the Laguna Lake Authority was being set up. Black and Veatch's proposals had given the Lake catchment low priority because they were not then thinking of the Lake as a water source. Also, in the six or seven years since Black and Veatch, developments had drastically changed the situation - for example building had been constructed over the lines of proposed sewers.

19. Mr HOLLAND said that he had been concerned with Bombay sewerage master-plan studies. They had a problem there, which must be repeated in many places, in that they prepared the master-plan without knowing how much money Bombay was prepared to spend on implementing it. World Bank, who were supervising the study, said that they must forget money and get out the best master-plan. So they ended up with a master-plan which Bombay could not afford. If they had known how much money was available their master-plan would have been quite different. One could not do a master-plan in sections over thirty years when it was intended to be implemented over the next five. Priorities were all wrong and he wondered whether Manila was a similar case to that.

20. Mr CAMP said that if plans of any description were not acted on in five years, they would be out of date, particularly in developing countries. Therefore a master-plan must define stages accepting that at the tail-end, conditions will have changed. Similarly with the feasibility study, one needed to leave all options open. For Lake Laguna three sites were selected for treatment works. Approximately 25% of the ultimate capacity would be provided in the first phase, but their options were such that if the Lake nitrogen level rose in years to come, sewage could pass to Manila Bay instead of developing more treatment modules on existing sites.

21. Mr A W TURNER was interested in the water hyacinth proliferation and wondered if there was some prospect of using it as a sort of fuel or manure.

22. Mr CAMP said that hyacinths were harvested in the Lake region on a very small scale by private individuals. It could be used as manure or as cattle fodder but large quantities had to be harvested and they had a very high moisture content. As far as Mr CAMP knew, nobody had made a great effort on a large commercial scale but this was something that the Lake Laguna Authority intend to look at.

23. Mr A J H WINDER thought that these plants could be used as a source of methane gas which could then be used as fuel.

24. Mr CAMP said that in Manila a bio-gas plant had been started on a pig farm where there were about a thousand pigs. This had received quite a lot of publicity and many people had become interested in its wider application.

25. Mr P HAWKINS asked if Mr CAMP gave any consideration to unsewered methods for excreta disposal which might work out considerably cheaper than conventional sewers.

26. Mr CAMP said that it would require a capital investment programme of about £8 million per year until the year 2025 to get a complete sewerage system. Meanwhile a combination of ancient and modern methods would have to operate in parallel

but there was a special situation when discharging into what was to be used as a source of water.

27. Mr HOLLAND thought that water hyacinths were a suitable substance for composting along with sewage and felt composting was a neglected field.

28. Mr A COWAN said that ITDG had a panel studying alternative power sources including bio-gas, which required a lot of development work. In India and China this had been subsidised by government in recent years. Mr COWAN wondered whether a number of systems could be tried as proto-type projects in the Philippines, and then future projects would have some solid ground to move on.

29. Mr CAMP said that the feasibility report had made these sort of points. They needed to carry out pilot scale trials for a number of things and also to be free to decide the sort of things to look at in the future.

30. Mr H MANN said that the amount of solid and other materials removed from sewage by conventional treatment plants was known. Had any work been done to calculate the amount of water hyacinths which would be produced on the basis of BOD consumed?

31. Mr CAMP said he was unable to comment but thought that several other factors would affect growth; he wondered if anyone else could answer the question.

32. Mr COWAN said that there had been a whole series of studies on the water hyacinth in the New Scientist.

33. Mr B M U BENNELL said that he had read one of these reports. If water hyacinths were used, the result would be a lot more solid matter to be dealt with.

34. Mr MANN said the capital cost of waste treatment might be less but the capital cost of removing the water hyacinth itself might be a lot more.

35. Mr CAMP said that after removal of the water hyacinth, there would be a liquor which might be put on agricultural land after digestion as it should be rich in readily available nutrients.

36. Mr MANN said that in that sort of climate it was possible that sludge could be easily dewatered on a drying bed.

37. Mr W A GILLINGHAM suggested that the water hyacinths provided only partial treatment through part of the year. Water treatment needed to be effective all the year round.

38. Mr MANN said in North Africa hyacinths function all the year round but there was still the removal problem.

39. Mr BENNELL said it seemed that we were aiming for some natural method of purification. Had this been studied to a great extent?

40. Mr MANN did not think it was impossible for parts of the Lake to be developed as stabilization ponds by building bunds. If these were loaded at reasonably well regulated rates, the effluent could be satisfactory.

41. Mr CAMP said that they had not looked at that particular possibility. However in future when the new hydraulic control structures were in operation, the Lake level would vary by two metres annually. This presented a problem in terms of impounding part of the Lake. It might be better to use the foreshore and form lagoons on those areas so that even in the high water season, a constant level could be maintained inside the lagoon. Lagoons would have to be taken out of operation sequentially about once in five years to remove accumulated sludge.

42. Mr W STUART suggested that the Lake could deal with BOD reduction by oxidation. If solids could be separated, it might be feasible to reduce the concentration of phosphates by chemical means as a relatively low-cost solution.

43. Mr CAMP said that they did look at the possibility of other methods of treatment but the scheme proposed for the first stage was a straight forward aerated lagoon followed by an oxidation pond. This involved the minimum amount of materials for construction and the only major power requirement was for the aerators. Having looked at all the various possibilities, this still came out the cheapest. While that stage of construction was in operation, the Authority would obtain experience in running the plant and bring the development of the catchment area under control. Different methods of treatment could then be selected for later stages to suit conditions and financial resources.

44. Mr M L HEMMING believed that a vast amount of work was being done on water

hyacinths and algae by the Hungarians for the Russians in the Black Sea area which has been published in "Water Research". Some work had also been done in Ireland but they had had some operational problems.

45. Mr CAMP said that there was a great difference between experimental work and using hyacinths for the treatment of wastes from millions of people. If things went wrong, then there would be a terrible mess.

46. Mr A J H WINDER asked if Mr CAMP had considered improving the quality of water before treatment by some sort of aerator and turnover system for the whole Lake in the form of air guns.

47. Mr CAMP commented that the Lake had an area of 900 square kilometres and was two metres or so deep. Wind effects on the surface resulted in a big oxygen uptake. Mr WINDER commented that he had not realised that the Lake was so shallow.

48. Mr CAMP said that the shallow depth was the problem - turbulence quickly stirring up the bottom so all one could see was mud.

49. Mr C PEEL asked had any thought been given to floating surface aerators in the lagoons as opposed to fixing them.

50. Mr CAMP said they had proposed to use floating aerators in the aerated lagoon system with a four day retention period. This would be followed by two oxidation ponds each of three days retention, so there would be ten days retention in all. There would be eight 200 horse power aerators for each treatment module having a DWF capacity of $0.1M^3d$.

51. Mr J H KOP asked what would be the percentage of pollution caused by the industries around the Marikina River going towards the Lake. If it was a high percentage, would it be possible to catch the effluents from the industries first. If so, a charge could be made to the industries along the river.

52. Mr CAMP said pollution from industries is significant and the first objective is to intercept industrial effluents and treat those wastes before discharge. Trade waste charges would be levied on all industry in the catchment including those with pretreatment facilities to cover the Authority's cost in monitoring the discharge and exercising control.

53. In reply to a further question from Mr KOP, Mr CAMP said that pollutors were not confined to a single area. The interceptor sewer system was designed to collect the industrial effluents and domestic wastes and all would be charged for that service. The effluent from the various treatment works could be taken either into the Lake or later into Manila Bay as may be dictated by circumstances.

54. Mr M LANSDELL asked what cooperation was there between the planning authorities and the water services. To get an interceptor through an urban area required very good cooperation between the departments.

55. Mr CAMP said the LLDA was now vested with the responsibility of coordinating activities but until such time as they had a sewerage plan their powers had not been put to the test. The number of agencies and private arrangements for water supply and multiplicity of municipalities able to act unilaterally presented quite a problem in relation to control where it affected sewerage and sewage disposal.

56. Mr LANSDELL asked whether the planning authorities reserved land required for the water services.

57. Mr CAMP said that there was not an authority who undertook that function; in his firm's report to the Authority (LLDA) guidelines were given for the reservation of land for sewerage and purchase of land for treatment works.

58. Mr STUART asked if Mr CAMP had any idea of the balance of the nutrients flow coming from natural run-off of the area and that coming from industry. He had read that the Ministry of Agriculture and Forestry Commission had investigated the use of natural ground to utilise phosphates.

59. Mr CAMP said that nutrient discharge from agriculture was about five or six times that from industry. Recent research in Manila by the International Rice Research Institute found that under certain conditions rice plants take up to 90% of the nitrates in the effluent. However, an intensive monitoring and control programme may be required in the future to ensure that excessive use of fertilisers is eliminated and to maximise water re-use.

60. The CHAIRMAN thanked Mr CAMP for his dissertation on the Philippines which once more seemed to revolve around the lack of planning and the problems caused thereby.

A.W.TURNER

water supply in bangladesh

CHAIRMAN: B M U BENNELL, BSc FICE
Principal Engineering Adviser
Ministry of Overseas Development

THE CHAIRMAN introduced Mr TURNER who was formerly Chief Engineer with the Metropolitan Water Board and had recently been employed by WHO as Consultant concerned with the water supply problems in Bangladesh, particularly Dacca and Chittagong.

2. Mr A W TURNER said he was a "pure water man" who had just paid his first visit to Asia, accompanied by the former Chief Accountant of the Lee Conservancy.

3. Dacca was the capital of Bangladesh with a population of one and a half million which was increasing rapidly. Chittagong was a sea port with a population which was probably 500 000. Both cities were almost entirely dependent for their water supply on tube wells which had to be over 100 feet deep to get through clay into the aquifer. There had been an IDA tube-well programme since 1964 and they had now got to the stage where they needed to develop surface supplies. Dacca had a water works which must be one of the oldest in S E Asia; it was just over a hundred years old and had sand filters and sedimentation tanks and so on, but only provided three million gallons per day.

4. In Bangladesh there were a lot of consultants including Russians, Americans and Germans. It was important to provide facilities which the local people could operate. At Dacca and Chittagong the equipment being installed was not as sophisticated as the oil-rich countries.

5. Mr TURNER then showed slides of the Himalayas where he had spent a few days. Katmandu had great poverty and in need of development. Bangladesh was about the same area as Britain, half of it being not more than twenty or thirty feet above sea level. Every bit of land was taken up in the delta which is very fertile, but the paddy fields were far too small for economic development of crops.

6. Demra on the river Lakha outside Dacca had been suggested as a site for a new source treatment works. IDA-funded sewers and water mains were being built all over the city to cope with the increasing demand. Inevitably population increase had overtaken them and certain parts of the city only had a few hours' supply per day. Water towers with a capacity up to about a quarter million gallons were dotted around the city but unfortunately there was not enough water to fill them. Tube-well water went straight into the system.

7. Chittagong was hillier than Dacca and the land rose to about 200 feet above sea level. A booster station was being built on the site of the old waterworks. Water was pumped from about sixteen bore-holes supplying a city of 300 000 and a typical production was about fourteen million gallons per day. In both cities, waste amounted to 35-40% of the supply. Ground water was running short because the pieometric level of the water was getting lower and there was an increasing content of iron in the water from certain wells in the Chittagong area. IDA had funded an iron removal plant, which included teak racks over which the water dripped before

going into two lagoons. The water was also chlorinated and there were some small gravity filters.

8. The main troubles on the engineering side were financial. Expenditure and income did not balance. In Chittagong some of the water rates had not been collected since the War of Independence in 1971.

9. In Dacca there were 200 000 water bills to get out twice a year. They had asked for a few simple calculating machines to ease the problem.

10. The waste of water was very high. They had 1400 street hydrants which wasted a lot of water and there were many illegal connections. They had a crash programme of replacing the hydrants with a new type of pressure-reducing valve which operated when the person leant on it. It was made out of ferrous material rather than brass, so was less suitable for the scrap market. They were concentrating on publicity and had a travelling waste prevention unit.

11. There was a lot of argument about metering. In Dacca there were 40 000 meters to put in. 20 000 were installed but meters were going out of action more quickly than they were being put in. A meter repair shop had been built from IDA funds. Mr TURNER was not in favour of meters particularly in developing countries.

12. There was lack of staff to maintain plant and at pumping stations in Dacca, 40% of the meters were out of action at one time.

13. Mr S C DUTTA GUPTA said that in Calcutta 30 000 gallons per hour was obtained from a 6 inch tube well, 100 feet deep with a strainer. What was the figure for Bangladesh?

14. Mr TURNER replied that some of the tube wells in Chittagong gave over a million gallons per day.

15. In the IDA programme linings of wells were being extended from about 90 feet to 100-120 feet to restrict pollution.

16. Mr E J FELTS had been faced with the problem of 20 000 services, some of them laid in electricity conduit and a wastage of 60% to 70%. Metering each connection was the only satisfactory method of control because of the large number of unauthorised connections in the urban areas. Mr FELTS had faced the same problems in Malaysia, and from the point of view of management of water supply in developing countries, metering was essential in order to establish the percentage of unaccounted water. Any financial institution approached for loan funds always asked what was the position with regard to unaccounted water.

17. The CHAIRMAN said that the subject of metering or reading meters and even the mechanical design of meters seems to be something which might be the topic of another seminar. The IRC might do something on these lines. He felt metering had been accepted rather readily and had produced many problems which ought to be aired.

18. Mr TURNER suggested that measurement of unaccounted water did not require a meter on every supply. Measurement of night flows, when the mains were full of water, was useful.

19. Mr S PRAKASH said that in Delhi they had 200 000 meters, of which 30 - 32% were out of order. Reading meters and sending the bills every two months was more expensive than a flat-rate system where the bill was sent every year on the basis of property values.

20. Mr TURNER said that the practical business of collecting water rates was the trouble. Water was a public service and perhaps the poor should get it free, but that was a political decision. Whatever system of charging was adopted somebody had to pay for the whole of the cost and there was always grumbling and arguments about individual water rate bills by the consumer.

21. Mr A W SHILSTON asked whether it was desirable to chlorinate bore-hole water before it went into supply and what was the difference between a tube-well and a bore-hole.

22. Mr TURNER said there was no difference between a tube-well and a bore-hole. The only chlorination in Dacca was to the hospital supply and the river-water supply. Only about 15% of water was chlorinated. None of the Chittagong supply was chlorinated at present but sterilisation was planned for the future.

23. The CHAIRMAN said that we had seen a very wide spectrum of engineering problems associated with water supply and sewage disposal ranging from the astronomically luxurious to the pitifully poor.

W. STUART

simplified concrete tank construction and associated equipment

INTRODUCTION

The tank construction methods and equipment outlined in this paper relate to the INKA concrete tank technology system and the associated equipment developed for use with such concrete tank constructions.

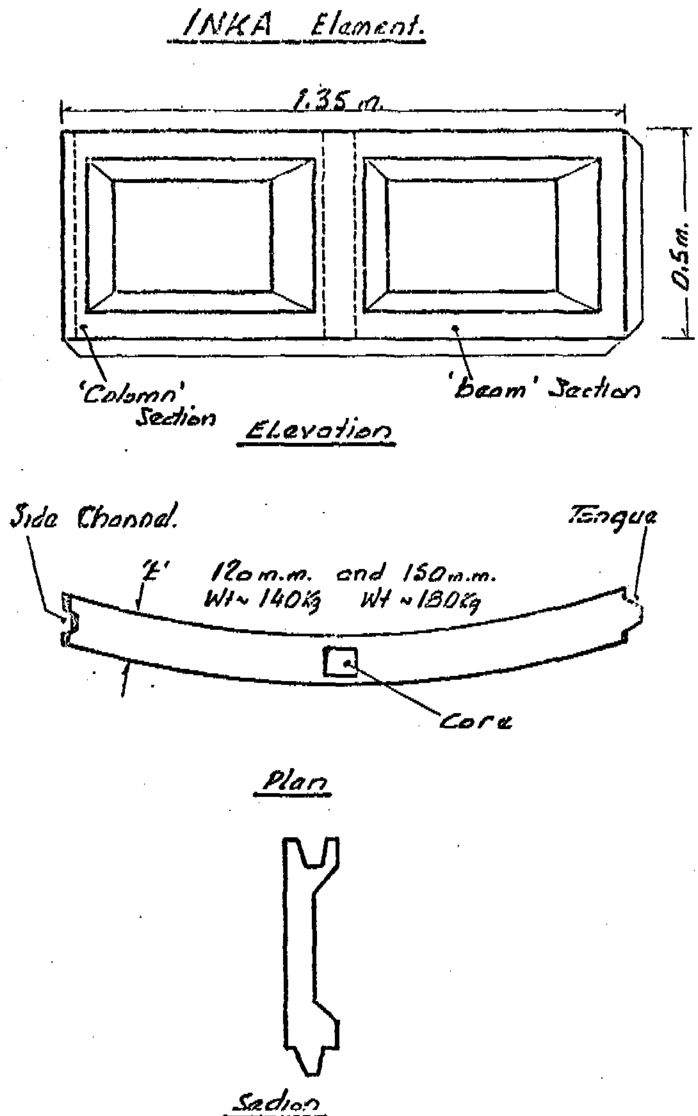
Such systems are normally applicable for construction in developing countries in a flow range between 900 and 800 m^3 per day although the concrete tank system has been utilised in flow ranges as low as 100 m^3 per day in the UK. The flow range of 900/1000 m^3 per day generally equates to a population range of 4000/35 000 population equivalents (p.e's). Also later in this Paper I have described a method of steel tank construction for use in developing countries for population ranges of 200 to 4000 persons, the tanks being designed for construction into the ground under full earth backfill conditions, or earth embankment as required.

CONCRETE TANK CONSTRUCTION

Design

INKA tanks are circular reinforced concrete tanks constructed from a series of prefabricated precast concrete panels which we describe as 'elements' produced essentially under factory controlled conditions. Such an element is described in figure 1, and the individual element measures approximately 1.35 metres in length, being 0.5 metres high with a gross thickness, dependent upon the diameter of the tank to be constructed, between 120 mm and 150 mm, corresponding to an element weight of some 140/180 kg.

FIGURE 1:

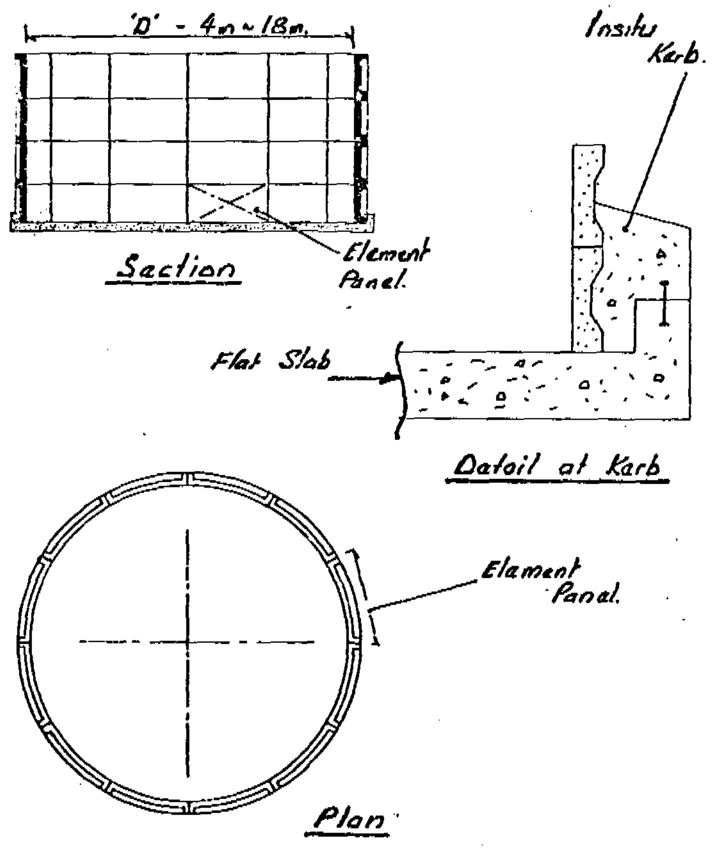


The elements are cast in steel moulds which have been manufactured to accurate radii, each mould having a detachable timber base upon which the element is cast and initially cured. A combination of aggregates are used in the element manufacture to give a high strength dense concrete mix with a low water:cement ratio to ensure minimal cracking during curing. As outlined on figure 1, each element has a 'tongue and groove formation' such that the element top has a channel groove running throughout its length. At the casting stage, frame bar reinforcement is placed within each element to provide inherent structural rigidity.

INKA tanks are designed as circular reinforced concrete tanks subject to hoop tension conditions and capable of withstanding passive earth pressure, either as backfill or embankment, with the tanks empty. The tank wall tension reinforcement is placed in the preformed element grooves and grouted into position on site as normal reinforced concrete. No form of prestressing or post-tensioning is used, thus avoiding the consequential problems of end block stresses and anchorage sheer cracks associated with prestress works. The tension stresses in the reinforcement and the concrete are designed within the relevant code limits equivalent to the tank diameters and heights required. The tanks are constructed on a simple flat slab foundation and following the tank construction, a cast insitu concrete kerb beam is placed around the elements at the base level, as described in figure 2.

FIGURE 2:

Single Tank Construction



When compared to insitu concrete tank construction, INKA tanks show considerable cost savings on an equivalent diameter basis, as the use of the precast concrete element system dispenses with the need for complicated site shuttering, special bar reinforcement and involved insitu concrete pours. Each individual element may be considered as containing its own framing mechanism in the form of a concrete column and beam construction, with a flat slab spanning between the beams and columns of the element. Such a construction ensures that load transfer takes place into the specially formed element grooves and cores, which contain the horizontal tension reinforcement and the vertical dowel bar tie reinforcement.

Casting/manufacture

As stated, the elements are cast in specially developed moulds to the required tank diameters. This operation takes place within factory controlled conditions in a specially developed factory unit within our casting facilities here in the UK. In developing countries, the elements may be manufactured locally on site on a simple flat slab foundation under a sunshade roof shelter. Curing would then take place utilising a dished slab with water recirculation from curing sprays. Due to the use of the low water:cement ratio and special high-frequency vibrators attached to the moulds, the mould units may be stripped from the elements immediately after removal to the curing bay. We have found that virtually no deformation of element shape occurs due to the dense highly compacted concrete mix. The element normally spends about 24 hours on the timber base before removal and further curing. A range of special handling equipment has been developed to facilitate element handling and dispersal at the manufacture/casting stage, and transport to site.

Construction

Following the requisite curing, the elements are delivered to site essentially as pre-shrunk units. This means that the shrinkage of the structure as a whole at the final construction stage is considerably reduced - a factor which can have considerable benefit in hot countries where the control of regulated curing of relatively thin concrete wall structures can be both difficult and expensive. In the UK we have found that comparison of equivalent tank diameters between INKA tanks and insitu concrete tanks can show cost savings in the range of 30/40% of the tank construction where INKA tank units are used. Additionally, in the UK the availability of skilled and semi-skilled labour is readily available at a reasonable cost, although the differential that exists between skilled / unskilled labour in the construction industry is vague. In developing countries the cost of indigenous skilled labour, where available, is high, and the cost of importing such labour extremely so. Generally, construction work involving concrete tank constructions has been estimated to require a ratio of skilled to completely unskilled labour in the order of 1:3.5, and in certain instances dropping to 1:2. This therefore means that the vast majority of skilled labour required on construction projects in developing countries has to be imported at high cost. Figure 3 shows some relative figures relating to the cost of labour and materials in the construction industry, comparing UK and Middle East costs, although it must be pointed out these are given as indicative measurements only, local conditions readily determining the market value appropriate to the project in question. I have also outlined within this table relative geographical distances between regional centres of population in Saudi as a demonstration of the physical difficulties encountered in obtaining labour from local centres. Even in the UK we have some experience of regional cost differences when we consider the relevant costs for construction workers on oil rig sites compared to 'normal' construction sites, in spite of the fact that such undertakings may be geographically close.

Figure 2 shows the general construction of an INKA tank built as a single wall applicable in the diameter range of 4 metres to 18 metres. Figure 4 describes the layout and location of the reinforcement which is applied on site in the form of horizontal circular tension reinforcement and vertical dowel location reinforcement. As described, each element has a top level groove to allow the placing and location of the hoop tension reinforcement as a continuous spiral in one plane around the tank, grouted into position on site as each element lift occurs. The vertical groove in the element end corresponds to a central core hole in the centre of each element, as described in figure 1, such that the vertical dowel reinforcement may be passed continuously through each element lift, tying the horizontal rings together. Normally, 6 mm indented steel reinforcement is used as the horizontal tension reinforcement, the number of loops being determined to suit the structural requirements of the tank under consideration relating to tank depth and diameter. Successive elements are grouted in position using a mix consistency similar to that of the original casting mix of the fine aggregate grading range, a paint-on bond being applied to the element surfaces before the grout, with bond additive, is placed. Where pipes are required to pass through walls, the typical construction is as outlined in figure 8.

FIGURE 3: Relative cost ratios - labour costs

	U.K. Rate 44 Hour Week	M.E. Rate* 60 Hour Week
Labourer/Helper	1.05	0.60
Welder	1.60	3.40
Carpenter	1.30	2.90
Electrician	1.50	3.10
Erector	1.25	3.20

* Excludes leave allowances, accommodation allowances and travel

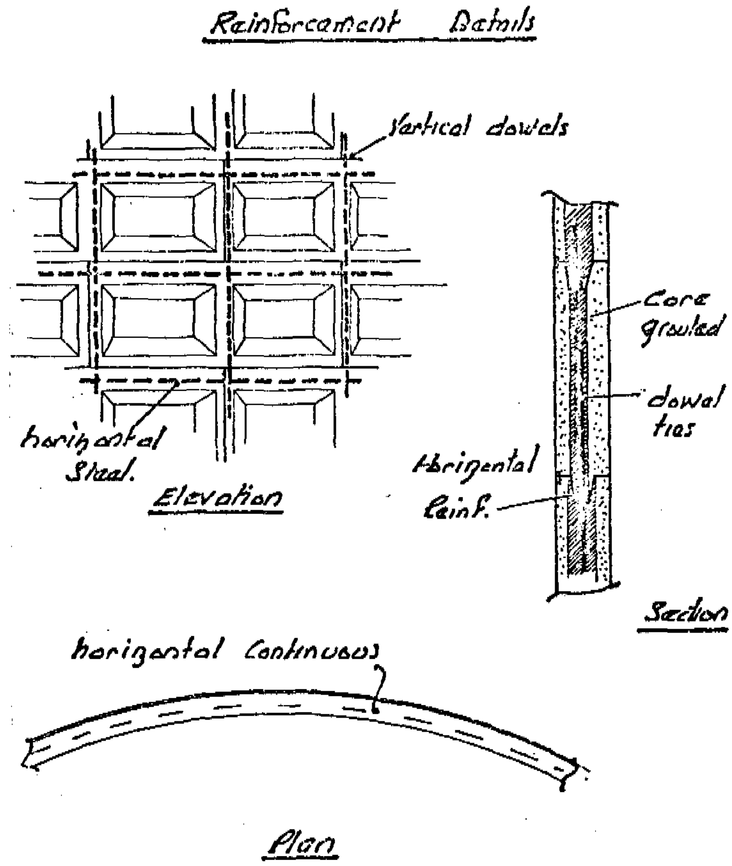
Plant Costs (Top Line Equipment)

	U.K. Rate Per Week	M.E. Rate Per Week
Crane (15 Tonne)	480	750
Crane (25 Tonne)	600	950
Welding M/C (400 amp)	50	68
Compressor (600 c.f.m.)	60	90
Mixer (5/7) Portable	20	31
½ Tonne Pickup	150	220

Approx. Distances Between Population Centres - Kilometres

	Damman	Hofuf	Mecca	Riyadh	Jeddah	Dhahran
Damman	0	170	500	460	1550	15
Hofuf	170	0	1300	330	1400	150
Mecca	1500	1300	0	1000	70	1450
Riyadh	460	330	1000	0	1050	450
Jeddah	1500	1400	70	1050	0	1500
Dhahran	15	150	1450	450	1500	0

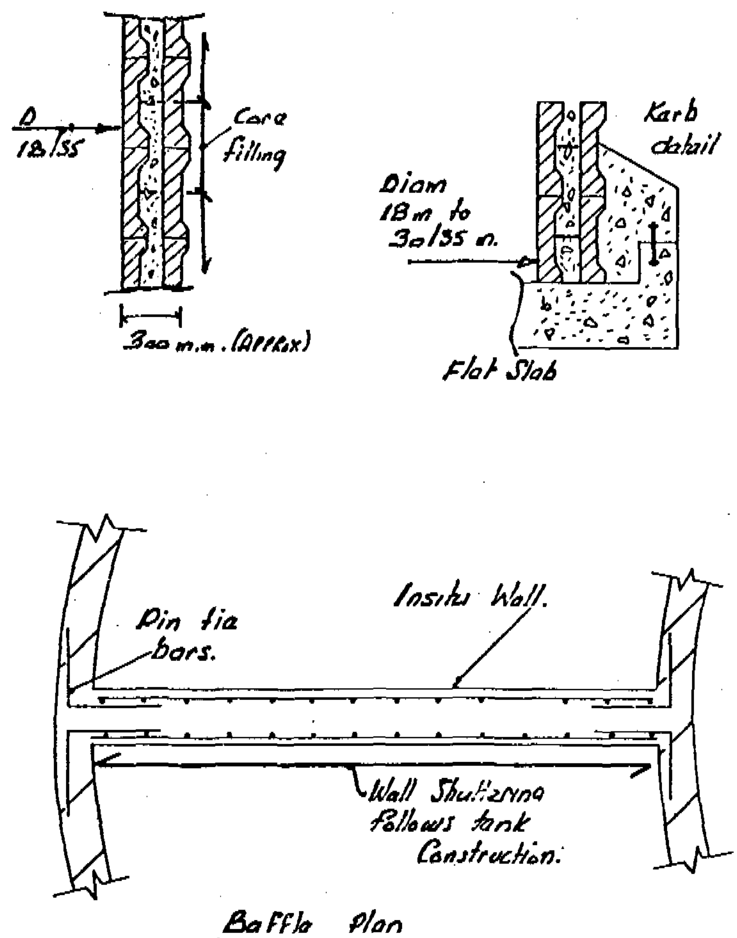
FIGURE 4:



INKA tanks are normally constructed on a flat base, although where required tank construction can take place on sloping bases.

Figure 5 describes the construction requirements where a double tank wall is required for larger diameters, between 18 metres and 30 metres diameter. Under such circumstances each wall leaf is 120 mm thick, with an overall wall construction of some 300 mm. Consideration could be given to larger tank diameters by increasing the distance between the wall elements, thus increasing the overall wall thickness. The construction of a double wall tank would be carried out in alternate lifts, and the core grout being placed to a half-element depth as each lift proceeds. The location of the external kerb arrangement for the double tank wall is also indicated in figure 5, as is the arrangement of the insitu baffle wall, which may be required between inner and outer tank wall constructions. Such an arrangement is necessary where INKA Bioreactor Systems are constructed, as the outer ring is used as the external wall to the aeration and sludge treatment zones, the inner tank providing the settling system. For such systems, which are suitable up to population loads of some 4000 persons, it is necessary to divide the outer ring into zones for aeration, sludge treatment, grit removal etc. The same requirement is also necessary where

FIGURE 5:



we construct an INKA Spiral 'S'. System where a series of concentric rings are constructed as part of the aeration, sludge treatment etc requirements. Generally speaking, such plants are suitable up to population loads in the range of 4000/35 000 p.e. The general construction details of a division wall are as indicated in figure 5 where, at the construction of the INKA tank walls, 90^{o} 'pin bars' are built in to the horizontal element joints with a pin length projecting from the wall face for location within the division wall. Normally such division walls, designed as vertical cantilevers, are cast into position following the construction of the tank, thus only requiring relatively simple straight shuttering to effect the division wall construction.

A range of special erection equipment in the form of lifting hooks, grabs, and special crane units have been developed for use as part of the INKA tank system. With respect to the crane units, these have been designed for essentially manual operation, thus minimising maintenance and 'down time' due to failure of mechanical/electrical plant.

Application

We consider that the application and use of INKA tank systems in developing countries would result in considerable cost savings compared to insitu or prefabricated steel tank constructions. We have developed a TECHNOLOGY PACKAGE whereby we undertake to supply supervisory personnel to work with local unskilled labour for the production of the concrete tank elements and subsequent construction of tank units on site. As part of this package we supply, on a contract rental basis, the necessary special mould units, special vibration equipment, base mould equipment, handling and erection equipment etc, in order to produce, cure and construct a tank system complete. This includes the supply of a special low order mechanical/electrical cranage unit for the construction phase.

The application of INKA tanks has already in the UK demonstrated a wide range of application, and apart from their use in our own INKA aeration systems have been utilised in projects for filter tank units, balancing and settling tanks as part of ICI high rate filter schemes, bulk storage and industrial waste water use. At the present time we have under construction two major projects utilising the Spiral 'S' System with INKA tanks, where a total of some 70 tank units are under construction. We are also about to commence a further project involving the construction of some 35 tanks as part of a scheme for a trout farming project.

With the development of the INKA Spiral 'S' generally described in figure 6, the application and range of use of the tank units for waste water treatment has been considerably expanded. We are already at an advanced stage of discussion for the use of the Spiral 'S' system, utilising the tank units, for projects in the Middle East and Africa. INKA tanks are essentially a self-help operation, the tanks being manufactured locally to site with local labour, although we do not consider at this time that the method is applicable for projects having flows lower than 1000 m^3/day. The system has not yet been used as part of water supply treatment, although we have already constructed tank units complete with roofs as part of an industrial treatment process, and such an application could be readily adopted for water storage.

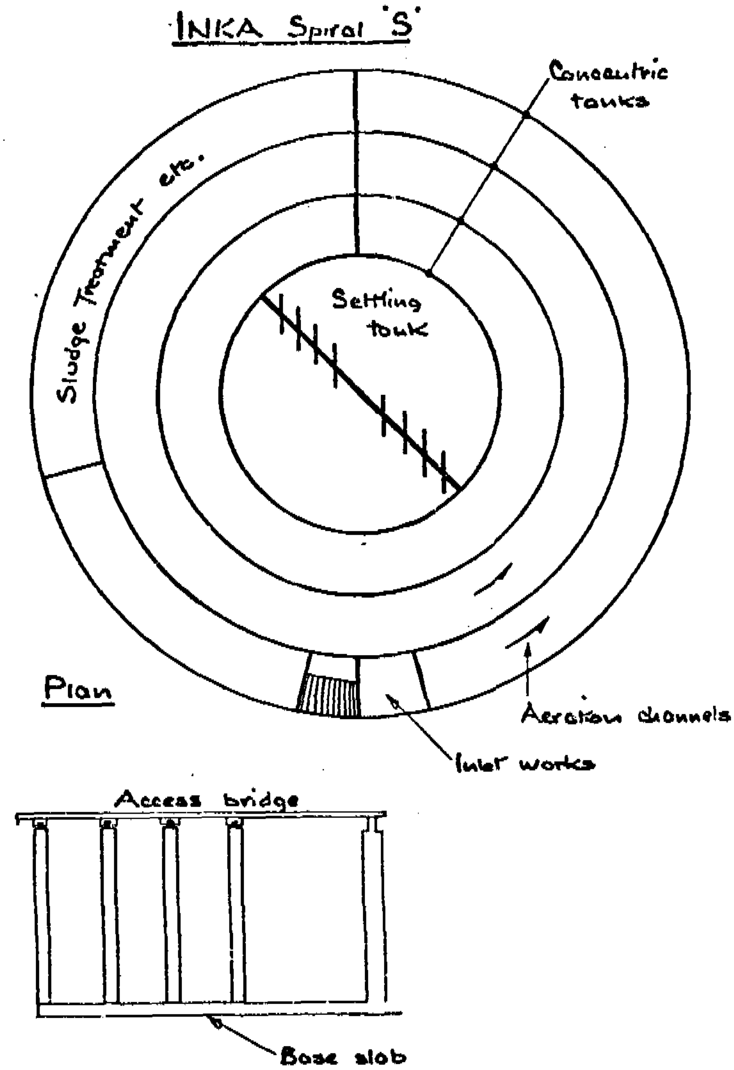
STEEL TANKS

We have been, and are involved, in the supply of small range package sewage treatment plants to developing countries, utilising steel tanks. One of the many problems associated with steel tanks is the lack of structural rigidity of tanks constructed into the ground under earth backfill pressure with the tanks empty. Such conditions usually result in tank buckling with consequential plant failure.

Figure 7 shows a system of steel tank design/construction we have developed utilising a close bolting technique for construction on site, and incorporating horizontal and vertical tank stiffening to provide structural rigidity. Such a construction, which is designed as a shell unit, subject to vertical compressive loading and end thrust, has been found to withstand full earth backfill conditions to a diameter of some 15 metres, constructed 3 metres into the ground.

As described in figure 7, horizontal stiffening is provided to counteract the ring compression due to the earth backfill, and the vertical break bank stiffeners are provided to reduce the l/r ratio of the horizontal stiffening to accord with design requirements. Such tanks are usually produced in a height range of 2.5 to 4.5 metres depending upon requirements and diameter. The circumference panel lengths are normally about 5.5 metres, the individual panels being joined together using a close bolting technique, the jointing flanges being rolled steel angles. Such

FIGURE 6:



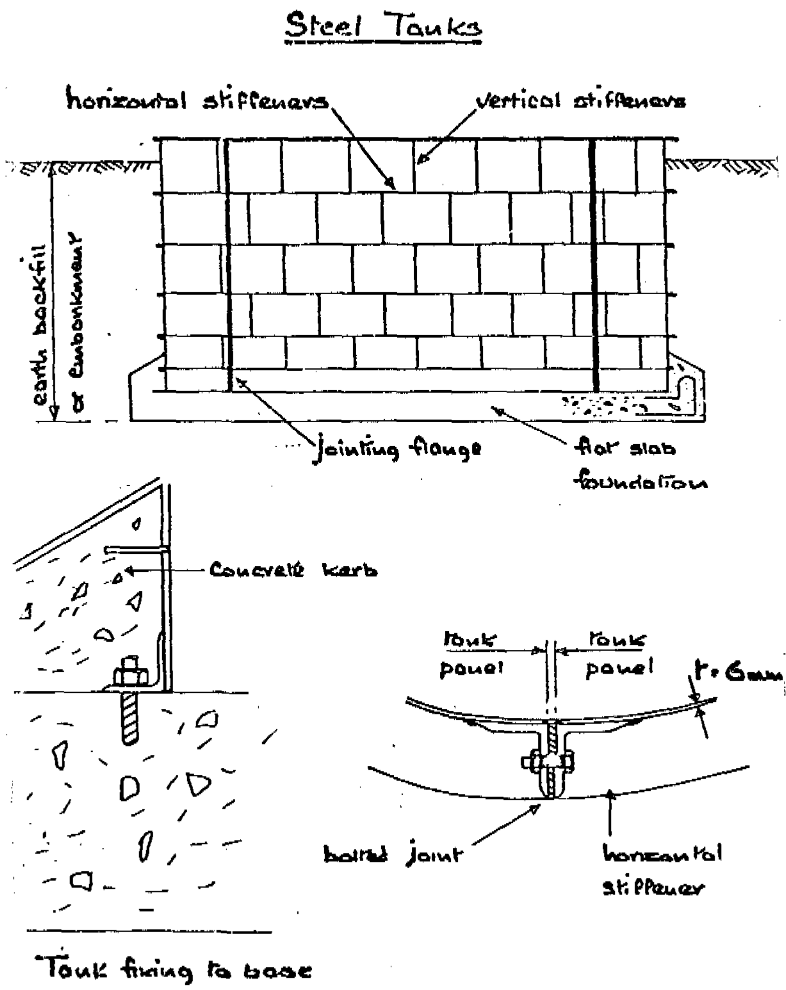
tank units when constructed on site have a very high inherent strength, and due to the construction techniques employed have the added bonus that they resist even the most adverse handling and shipping conditions!

Under most circumstances we have found that such steel tanks incorporating stiffening are cheaper than insitu concrete tanks of equivalent diameters, as essentially only unskilled labour is required on site in order to erect the tanks under our supervision. Such tanks have been utilised as part of wastewater treatment projects both in the UK and in developing countries. We have, however, found that the overall costs of such steel tanks are greater than equivalent concrete INKA tanks.

Equipment

Where we are responsible for the supply of a small package type unit or 'turn-key' contract we have developed a range of equipment which is equally

FIGURE 7:

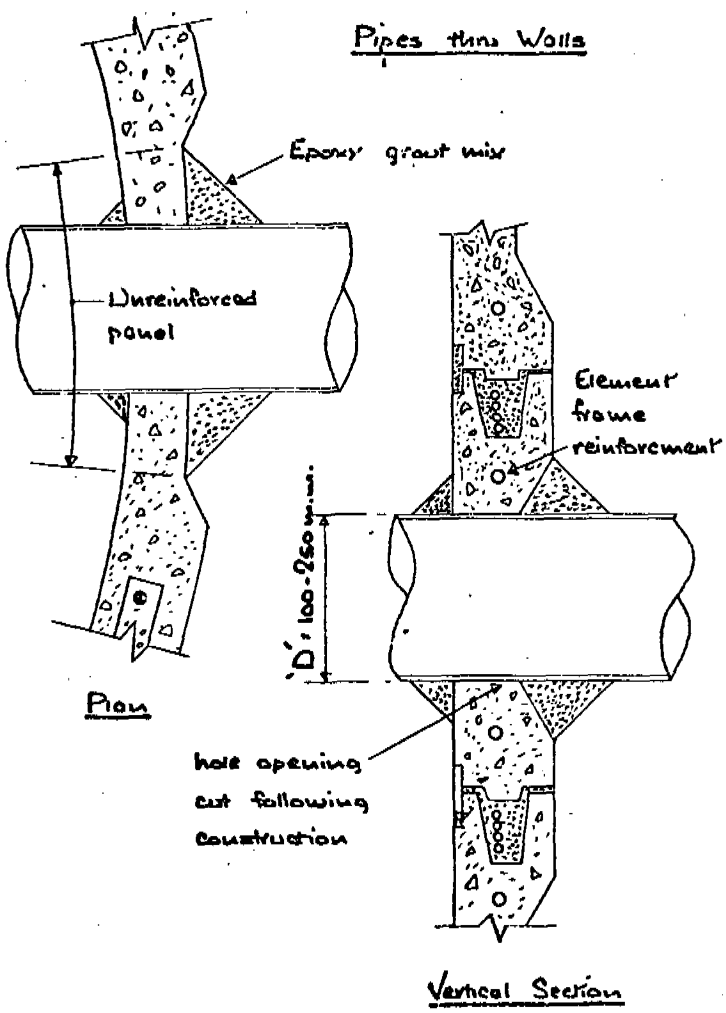


applicable to both the concrete INKA tank or prefabricated steel tank systems. The range of equipment operation is similar to that of established practice - what we try to ensure is that the location and fixing of the same has a higher degree of flexibility in relation to overseas works as opposed to UK installation, where access to the site during tank construction is not readily available.

Flexibility can be achieved by utilising such items as stainless steel/ mild steel suspended weirs with adjustable wall brackets as opposed to cast insitu units, and the inclusion of floating joints on scraper assemblies etc.

Where possible pre-assembly of equipment should be carried out in the UK before dispatch, and where steel tank units are employed we carry out complete trial erection. In spite of such precautions it will, however, be found necesaary to increase the structural dimension of equipment being sent to developing countries in order to prevent damage occurring during transit. Where possible containerisation is worth consideration. Some 'flexible' support systems are shown in figure 9.

FIGURE 8:

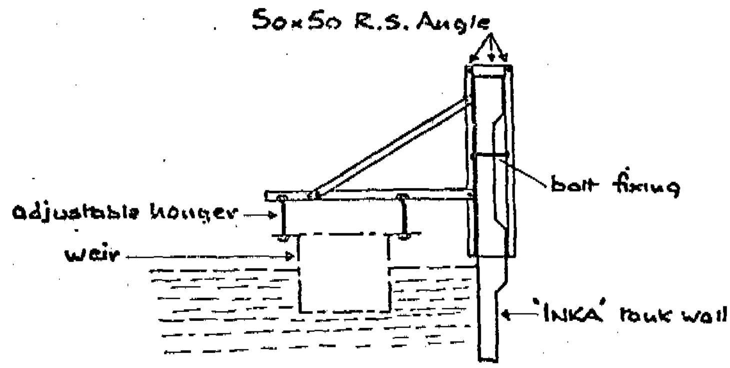


Normally the type of system we supply to developing countries involves a diffused aeration system utilising air blowers for medium pressure, high volume air production. We have found that if the blower speed does not exceed 1200 rpm, taking due account of temperature rise across the machine, the blower life will be extended due to the low wear on bearings and blower vanes etc. Consideration should always be given to providing as much protection as possible against dust intrusion, especially in the case of mechanical plant and electric motors. Whilst such protection may seem obvious, a further stage of protection is to provide a greater depth between top water level and the top of the tank wall. We have found that a distance of 500 mm gives a reasonable degree of protection against dust intrusion into the plant.

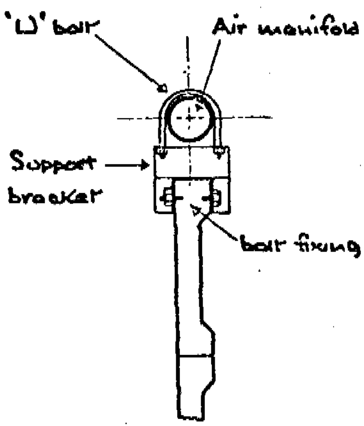
Whenever considering equipment for construction/installation for projects abroad, there are four essential points we consider:

a) Consideration of total prefabrication/partial fabrication to size of unit and structural rigidity of same. At all costs avoid site welding unless on very large projects.

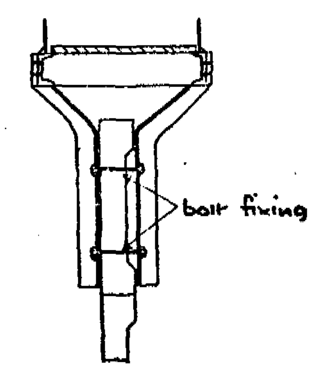
FIGURE 9:



Weir fixing detail



Air manifold fixing detail



Access walkway fixing detail

b) Availability and quality of labour and erection plant locally to site.

c) Costs of shipping and transportation of items, as very often shipping is a 'Catch 22' situation - if you don't pay for low bulk high dead weight, then you pay for low weight high cubic capacity. At the equipment design stage a break down of items of plant such as scraper shafts/scraper arms, screen units etc, to simply assembled site units can often considerably reduce bulk shipping charges. In spite of additional cost, the use of containers can prove worthwhile.

d) The overall maintenance of the plant in terms of spares required, plant finish and general running considerations. It will often be found much more convenient to supply spare fractional horse power motors for units such as scrapers and screens, as opposed to supplying motor internals. Consideration of simple automation in terms of plant running experience is always worthwhile for simple operations such as intermittent descumming, sludge transfers, sludge thickening, aerobic digestion etc.

When specifying a paint finish it must be remembered that the high quality temperature controlled pitch epoxy paint applied at works cannot readily be repeated in overseas countries, nor indeed in the UK. I would suggest that following shot blasting, primer painting and undercoating is sufficient for most equipment, with supply of adequate touch-up paint, the finishing coats of paint to be applied on site. We have found that chlorinated rubber provides a satisfactory paint finish and protection, and one that can be readily maintained in the years ahead.

Finally, whenever designing, supplying or constructing equipment for treatment plants in developing countries, the greatest requirement I feel is to equate all such considerations to common sense.

ACKNOWLEDGEMENTS

My thanks are due to the British Steel Corporation and their Consultants, Messrs Edwards, Jackson & Luxton; Messrs Hugh Baird & Sons (Pencaitland Maltings) and their Consultants, Messrs Cowan & Linn C.C.E., and A. Johnson Construction Co. Ltd. for permission to describe information and slides of related projects.

discussion

CHAIRMAN: J A PICKFORD, MSc ACGI MICE FIPHE
Senior Lecturer
Loughborough University of Technology

THE CHAIRMAN introduced Mr W STUART who was Manager of the INKA Division of the Johnson Construction Company and had considerable experience of the installation of sewage treatment plants in the Middle East.

2. Mr W STUART said his firm was part of the Axle Johnson Group of companies with a head office in Stockport and a turnover of £2000 million. His paper was essentially concerned with direct contractual hardware public health engineering. The first section dealt with a system of concrete tank construction developed within the group and used with some success in the U K. The tank construction process was essentially a self-help operation and could well be adapted for developing countries. His firm had also been concerned with the supply of package plants for up to four or five thousand population in different parts of the world. These involved the use of steel tanks which could suffer some deterioration especially by connection failure. Johnson's had developed a process to overcome this using stiffening which had been very successful.

3. Mr STUART then showed some slides of this concrete tank with panels 1.35 metres long, 0.5 metres deep and a thickness between 120 and 150 millimetres. These were made upside down on a vibrating table. The simple ground slab foundation was cast in-sitic concrete following the construction of the tank wall. The tanks were between 4 metres and 18 metres in diameter in virtually any incremental size.

4. The pre-cast panels were fairly light so local labour could easily be trained. On one site the conractor used a crane which could be broken down and assembled by two men.

5. Mr STUART showed slides of the construction and use of the tanks for fish farms, water storage and sewage treatment works, and pointed out the advantages of this method of construction.

6. Mr C N FREER spoke of the dangers of flotation with such a light tank in areas with a high water-table. He noted that the bottom of the walls were treated as pin joints with no movement.

7. Mr S PRAKASH suggested that a thicker base should be used where the water-table was high, and that the tanks should be submitted to an hydraulic test. He asked if 18 metres was the maximum diameter and Mr STUART said that tanks up to 35 metres diameter had been used.

M.L. HEMMING

the use of high rate biofiltration in hot and humid climatic conditions

INTRODUCTION

The introduction to a watercourse of biodegradable organic matter which consumes dissolved oxygen and promotes the growth of micro-organisms leads to water pollution. If oxygen is re-introduced as with naturally flowing water by diffusion from the atmosphere, the organic matter and deleterious micro-organisms will be destroyed and oxygen in the water will again be available for beneficial marine growth.

The trickling or percolating filter is a recognised device for rapid aeration of domestic or industrial wastes containing biodegradable organics. The heart of the filter is the media or packing. The media serves as the support system on which a slime of micro-organisms grows. The waste flows or trickles by gravity over the slime covered packing. Air rises through the packing by natural draft counter current to the down flowing waste and the aerobic micro-organisms in the slime digest the organic matter in the presence of the oxygen diffusing into the slime.

Trickling filters are used extensively for wastewater treatment because of the following major advantages:

1. Simplicity of construction.
2. Ease of operation.
3. Low operating costs.
4. Minimum maintenance requirements.

Over 66% of the municipal treatment plants in Western Europe and the USA use this type of oxidation system. The system was first used on a large scale in 1893 at the Salford Sewage Works.

However, conventional media in the form of clinker, slag, stone, gravel, coke and in some cases coal, is limited in its ability to provide high surface area per unit volume due to its geometric configuration. As the purpose of the media in a biological filter is to provide a large surface area for the aerobic growth of attacked micro-organisms, it can be said that there is a relationship between surface area and numbers of organisms and the greater the number of organisms, in general terms, the greater the weight of BOD removed per unit volume of media. With mineral media there is not only insufficient area for the formulation of beneficial thin-film slime, but oxygenation is poor due to the limited natural draft. In addition, uneven build-up and sloughing-off of sludge contribute to the plugging of the irregular and varied crevices between the rocks.

THE DEVELOPMENT OF PLASTIC MEDIA

The physical deficiencies of mineral media plus low hydraulic and organic loading capabilities has led to a considerable effort being expended in the search for a superior packing media, with a concentration of effort on synthetic materials exhibiting the desirable properties.

The ideal media was defined by Chipperfield as follows:

1. It should be capable of removing high weights of BOD per unit packed volume.
2. It should be capable of operating at high hydraulic loadings per unit volume and unit area.
3. It should possess a significantly open structure to avoid blockage by the accretion of solids and to ensure an adequate supply of oxygen without recourse to forced aeration.
4. It should be sufficiently strong structurally to bear its own weight and the weight of overlying layers of medium, together with the attached growths of bios.
5. It should be sufficiently light in weight (even when loaded with bios) to enable a significant reduction to be made in the civil engineering costs of plant construction.
6. It should be biologically inert, neither attacked by nor inhibiting growth of the treatment bios.
7. It should be chemically stable, not degrading with use or in the presence of small quantities of solvents, organic chemicals etc.
8. It should have as low as or cheaper cost per kg of BOD removed when packed as conventional biological purification processes.

These characteristics have become the standard by which all media are assessed, and it is clear from these characteristics that plastics offer the best chance of developing an ideal media.

However, biological filtration systems may be broadly categorised as either:

- low rate
- intermediate rate
- high rate

depending on the hydraulic or organic loading applied to the medium. It is generally agreed that sharp demarcations do not exist between the successive categories and that to some extent the descriptions are interpreted differently according to local practice. It is however becoming universally accepted that high rate biofiltration starts at approximately 3.0 m^3/m^3 day hydraulic loads or with organic loads in excess of 0.6 kg BOD/m^3 day.

Common experience has shown that a high rate filter will not produce economically a high quality effluent and high rate filters are not normally used to produce well purified effluents.

The development of high rate plastics media originated both in the UK and in the USA, the earliest experiments being carried out in the USA by Dow Chemical Co (Dowpac and Surfpac), B F Goodrich (Koroseal) and the Fluor Corporation (Polygrid). Although initially polystyrene was used in manufacturing plastics media, PVC (polyvinyl chloride) is now generally preferred, as it has better chemical resistance and is self-extinguishing.

In the UK most of the work carried out on plastics media was initiated by Imperial Chemical Industries Ltd with a view to developing an ideal biological filter medium. This resulted in the design of a PVC packing known as Flocor, which has been commercially available for fifteen years. During this time considerable operational experience has been gained on large and small installations.

Since the early work some 1000 plants employing plastics media have been built on a world wide basis on all five continents including the countries of Iran, South Africa, Caribbean, Singapore, Malaysia, Hong Kong, Japan, Australia and New Zealand.

HIGH RATE MEDIA (ORDERED)

Flocor E, the most widely used high rate roughing ordered media, consists of alternating plane and vacuum formed corrugated sheets of PVC foil bonded together with a PVC based adhesive. Flocor E is built up to form standard modules 1200 mm x 600 mm x 600 mm. The top and bottom of the modules are then flanged by a heating process. These modules in their turn can be fitted into any regular shaped containing structure, with cutting if required.

However, when the material is exported from the UK to areas other than Europe it is usually in the unassembled form i.e. flats and formings and assembled on site. Under these conditions flanging equipment may not be available locally.

The corrugations are arranged so that there can be no free fall through the vertical channels and the applied liquid over a wide range of application rates flows in a thin film over the corrugated surfaces without collecting into drops at the angles of the corrugations. Exhaustive physical and biological test work has been carried out to determine the present form of the product.

The packing should be stacked in tower-like structures, but by virtue of the low bulk density of the media the 'towers' need only be of lightweight construction e.g. a comparatively lightweight mild steel frame or even wood framework clad with say PVC sheets. The cladding serves to contain the liquid rather than support the packing in this case.

The effluent to be treated is fed to the top of the 'towers' continuously and distributed evenly over the cross-sectional area of the tower at a minimum irrigation rate of 1.5 $m^3/hr\,m^2$ cross-section of packing. The advent of plastics roughing media has made it a practical proposition to pack the media to depths of 7.8 m for flanged modules and 3.0 m for unflanged modules.

Because of the high compressive strength of the packing it is possible to pack to these depths without an intermediate support for the packing. This when necessary need only be simple in design, e.g. narrow parallel beams 40 mm wide, spaced ideally as the module is placed with its 1.2 m length horizontal: at 200 mm centres.

As well as the module having its 1.2 m length horizontal, the module would be arranged so that the flat sheets would be vertical. The second layer of packing up the tower would be placed again, so that the 1.2 m length is horizontal, but at right angles to the layer below and above.

Ideally within the limits of 1.8 to 7.8 m packed depth (the volume of packing being fixed for a given applied load), the cross-sectional area of the packing is usually arranged so that the volume of effluent to be treated is at least as close to the minimum irrigation rate for the maximum period of time, since if the volume is less than the minimum irrigation rate, re-circulation must normally be employed.

As a design principle with high-rate plastics media re-circulation should be kept to a minimum for economic reasons. It is comparatively easy, however, by the arrangement of levels and baffles in sumps, to arrange for automatic recycling, should the crude supply of effluent fail or drop to a low level, without employing expensive electrical switchgear.

Effluent flows down the packing and bios in a thin film, and because of the uniform void structure a supply of air is allowed to rise through the filter and a supply of oxygen is transferred through the falling film to the bios. This enables the process of BOD reduction to take place with high efficiency.

Similarly, as with conventional percolating filters, where the following humus settlement tanks are an integral part of the treatment process, a settlement process is required after high rate treatment on plastics packing. Here the settlement process is also an integral part of the treatment.

The effluent is collected from the base of the tower and then passed to a settlement system, ideally under gravity flow. Experience has shown that the upward flow type with a 60° included angle in a conical base and tanks of the radial flow type, are equally successful. Experience has also shown that the previously considered normal design parameters for settlement tanks do not apply when treating effluent from high rate systems, as the solids voided from these systems settle very readily. As a result upward flow velocities of 2.4 m/hr have now become standard parameters to be considered.

Experimental evidence and experience on full scale plants have shown that with an intelligent approach to the desludging of these settlement tanks, a sludge of 3-4 per cent w/w solids can normally be removed and that the sludges produced by this process are certainly no more difficult to dewater than the sludges produced by the more conventional biological treatment. Evaluations of the specific resistance filtration of sludges of biological origin arising from Flocor systems have been made and show a normal specific resistance of 10-20 x $10^9/sec^2/g$.

The sludges are also typically amenable and reduction of specific resistance to filtration by chemical treatment (e.g. flocculation) and have no greater, if any, adverse effect upon the dewaterability of primary sludges with which it is common practice to treat in admixture, than do conventional filter humus solids.

Conventional primary sedimentation can be eliminated when feeding Flocor systems with macerated or screened wastewaters, and solids that would normally settle in the primary settlement tanks do not undergo any significant biological degradation on passage through the system, since their passage through the regularly ordered medium is unimpeded.

In addition, fine particles resulting from maceration effectively act as nuclei for flocculation when absorbed at bios surfaces, with the result that many colloidal materials, previously non-separable by sedimentation, become settleable after biophysical flocculation and desorption.

Thus one effect of the Flocor treatment in this form, as distinct from bio-oxidation effects, is to make it possible to separate by sedimentation a greater proportion of the suspended materials present than is possible without such treatment, and to employ higher flow rates in sedimentation vessels.

Depending on the strength of the effluent being treated and on the discharge standard required, the settled effluent from the settlement tank would be discharged partially treated to a coastal discharge. Alternatively, it could be passed to a polishing filter type using either stone or plastics media or to a 'fining' activated sludge plant.

TYPICAL APPLICATION

One area where high rate plastics media is beginning to play a significant part in the protection of the environment is Malaysia. The Malaysian Government under its 1974 Environmental Quality Act has taken the initial steps for the future protection of the environment. This act is shortly to be enforced and the standards proposed under this legislation are shown in Table 1.

TABLE 1: Four-generation sets of effluent standards

Parameter	Standard A 1.7.78	Standard B 1.7.79	Standard C 1.7.80	Standard D 1.7.81
Biochemical oxygen demand (BOD), 3-day, 30°C; mg/l	5000	2000	1000	500
Chemical oxygen demand (COD), mg/l	10 000	4000	2000	1000
Total solids, mg/l	4000	2500	2000	1500
Suspended solids, mg/l	1200	800	600	400
Oil and grease, mg/l	150	100	75	50
Ammoniacal nitrogen, mg/l	25	15	15	10
Organic nitrogen, mg/l	200	100	75	50
pH	5.0 - 9.0	5.0 - 9.0	5.0 - 9.0	5.0 - 9.0
Temperature, °C	45	45	45	45

It is claimed that there are approximately 150 Palm Oil Mills in Malaysia of which some 100 are in Peninsular Malaya. These mills produced some 1 000 000 tonnes of crude oil with a parallel effluent production of 3 000 000 tonnes containing some 57 000 tonnes of BOD. This BOD load is equivalent to the BOD load of a population of 70 000 000. When it is realised that the real population of Malaya is of the order of 10 000 000 the magnitude of the effluent problem facing the Palm Oil Industry in Malaysia is appreciated.

Production methods do vary from mill to mill but in general terms a typical effluent from a mill would have the following composition:

TABLE 2

	Crude	After flotation
pH	3.5	3.6
COD	64 000	6400
BOD	42 000	3500
PV	12 000	1250
Suspended solids	27 000	400
Total solids	52 000	
Oil	4000	20
NH_3	20	7
Organic N	800	

After flocculation, using say 100 ppm Ferric Chloride and 10 ppm of a cationic polyelectrolyte and flotation the polluting strength of mill effluent is substantially reduced to values shown in Table 2.

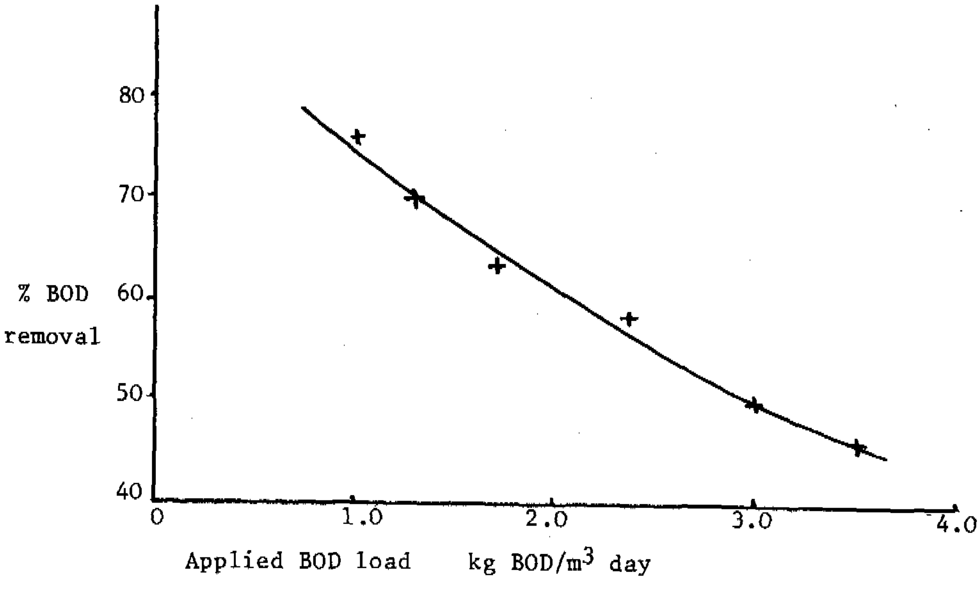
A float of the order of 15-20% solids being removed from the flotation stage.

Although flotation substantially reduces the polluting load it can be seen that the effluent is still significantly stronger than the ultimate standard required by Government.

Following flotation the effluent is deficient in nutrients and extremely acidic. However, following adjustment of these deficiencies the effluent is in an ideal condition for the optimum use of high rate biofiltration to meet the ultimate discharge standard. To achieve this standard, two stages of high-rate biofiltration are required operating in series.

Following laboratory and pilot-plant studies the treatability curve shown in figure 1 was obtained for Flocor E plastics medium.

FIGURE 1: High-rate biofiltration using plastic filter media (Flocor E) for the treatment of effluents from palm oil mills following 'microflotation'



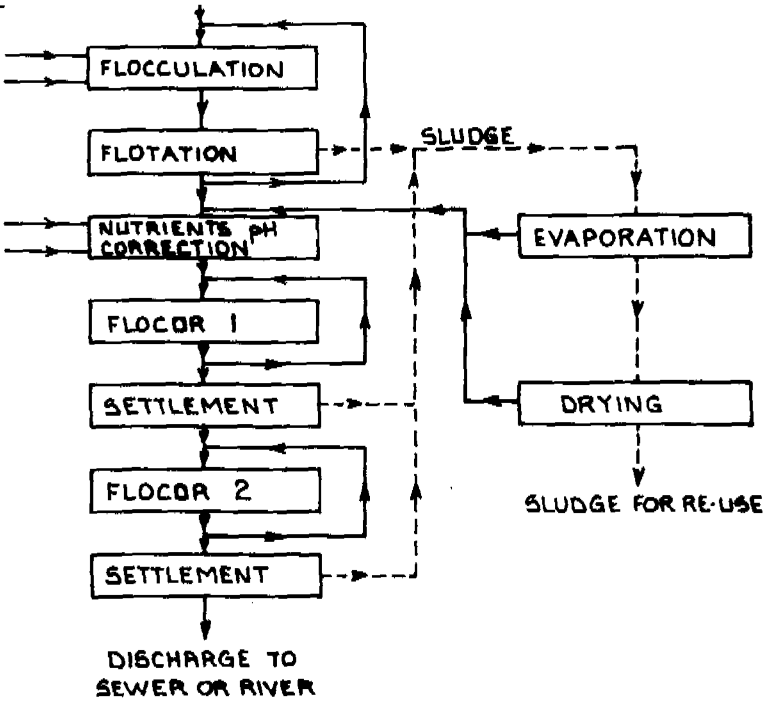
A typical plant design (biological data) is shown in Table 3 and a typical flow sheet in figure 2.

TABLE 3:	Type of effluent:	Palm oil mill effluent
	Volume:	30 m^3/hr = 720 m^3/day
	BOD concentration:	3500 mg/litre (after flotation)
	Daily BOD load:	2520 kg BOD/day
	Special features:	Screening, Chemical flocculation, Flotation, pH adjustment, Nutrient additions
	Treated effluent standard required:	500 mg/litre BOD 400 mg/litre S solids

Design Proposals						
Stage	Stage Load kg BOD/DAY	Stage Load kg BOD/m^3/DAY	'Flocor' Volume m^3	Anticipated efficiency %	BOD mg/litre	
					Inlet	Outlet
1	2520	2.0	1260	60	5500	1400
2	1008	1.8	557	65	1400	500
Stage	Tower Details			Minimum Irrigation Rate m^3/hour	*Hydraulic Load m^3/m^2/day	*Surface Load m^3/m^2/day
	Packed depth m	Plan dimensions mxm	Plan area m^2			
1	5.4	21.6 x 10.8	233.28	343	0.6	3.1
2	5.4	9.6 x 10.8	103.08	153	1.3	7.0

*based on crude flow

FIGURE 2:



CONCLUSION

The experiences gained in the Western World using high-rate plastics media can be applied in hot and humid climatic conditions providing adequate attention is paid to the engineering design of equipment and the treatability of the various wastewaters are considered under local conditions.

discussion

CHAIRMAN: J A PICKFORD, MSc ACGI MICE FIPHE
Senior Lecturer
Loughborough University of Technology

Mr M L HEMMING said that in biological purification the use of percolating or trickling filters was well known and well understood. They had been in use since the 1890's and their advantages and disadvantages compared with other biological treatment systems, such as activated sludge, were also well known. The disadvantages detailed in the paper had led to the development of plastics media, especially for roughing treatment or high rate biofiltration. It was mainly in the form of ordered media, although there were forms of random media now commercially available for high rate applications. Flocor was one version of ordered media type.

2. Mr HEMMING showed slides of flocor blocks which were stacked in tower-like structures, which could be made of local materials such as timber. A more sophisticated structure had a concrete base and steel framework with plastic sheeting as a lagging material.

3. Mr HEMMING explained the effect of local conditions such as temperature and altitude on the volume of media needed in a particular application to solve a particular problem. The volume was proportional to temperature to the power 0.15. In simple terms, the volume of media required decreased by 15% - 20% for an effluent temperature of 30°C compared with the same effluent at 10°C. The design should take into account the rate of bio-degradability of the substrate whether it be domestic sewage or, say, palm-oil effluents, as described in the paper. Generally data from one type of waste could not be transferred to another type of waste or from one system to another.

4. In terms of high rate filtration a treatability curve was required for the particular waste being treated. An example quoted in the paper was the curve from palm-oil effluents, actually produced at the mill in Malaysia. To obtain the curve it was usually necessary to know precisely the manufacturing processes. Data could be obtained by simulating the conditions in a laboratory under controlled conditions, or on site. However in remote areas it was difficult to provide the attention necessary to obtain the data. The design of the biological filtration plant also depended on the hydraulic loading and the surface area of the media.

5. A typical palm-oil effluent had a BOD in the order of 42000 mg/l. By comparison, the population of Malaysia was approximately 11 000 000, and the 150 palm oil mills in Malaysia produced a population equivalent of 70-80 million people. It was not surprising that when the Malaysian Government introduced the Environmental Act the first problem they tackled was palm-oil effluents. They recognised that no treatment plant could be installed overnight and no effluent treatment system was cheap. The objective was to achieve a BOD of 500 mg/l, and suspended solids 1500 mg/l by 1981.

6. The palm-oil effluents contained fairly high concentrations of both dissolved solids and suspended matter and had a high degree of mineral content. Unfortunately, these solids did not settle, but the flotation system enabled the palm-oil mills to meet Standard A.

7. The date for the first stage had been extended to 1979. Having got the effluent to meet Standard A, a conventional high rate filtration system could be designed to meet the discharge consent conditions. High rate filtration systems lent themselves to stage-wize development.

8. Problems of odour, difficult sludge made it essential to give particular attention in high rate filters to air access, pH of the feed substate, nutrient balance, irrigation rates, hydraulic and organic problems. If attention was given to these factors and there was a will to operate the effluent treatment plant correctly, the effluent could be satisfactory and by-product utilisation could be achieved.

9. Mr H MANN asked at what temperature the experiments were carried out at, whether the BOD removal was in terms of settled effluent, and what was the specific surface of Flocor E. He had noted that the BOD test had been over three days at 30^{o}C and wondered how this compared with the usual five days at 20^{o}C or three days at 27^{o}C.

10. Mr HEMMING replied that the specific surface area of Flocor E was 90 metres per cubic metre. The difference between 3-day BOD at 30^{o}C and 5 days at 27^{o}C was of the order of 10% but as the accuracy of the BOD test was only plus or minus 10%, the difference was insignificant. The ambient temperature in Malaysia was 30^{o}C. The anticipated temperature of the palm-oil effluent was 35^{o}C, and this has been borne out in practise by subsequent filter operations.

11. The BOD removal curve was in relation to soluble BOD which in effect was equivalent to settled BOD.

12. Mr C PEEL asked if Mr HEMMING had any information on the random-packed Flocor and Mr HEMMING replied that this was called "Flocor R" for "Flocor Random". It consists of small pieces of corrugated tube and the specific surface area was 330 square metres per cubic metre compared with 90 for Flocor E. In a low-rate bio-filtration system, the BOD removal was almost proportional to surface area. However the palm-oil mill effluent could not be applied to a low-rate system.

13. Mr A I BHATT asked whether treatment plants were to be designed in stages for the 1981 standard?

14. Mr HEMMING said that the Palm Oil Producers Association claimed that palm-oil was economically unsound when they went through difficult times. Yet there is significant increase year by year in the number of palm-oil mills in Malaysia. The ultimate standard the Government wanted was the one quoted for 1981. The palm-oil producers claimed that they could not afford to meet these standards. Producers wanted to phase investments over a period of years, depending on the rate of inflation. It might pay the producer to construct all the civil works immediately.

15. In reply to a further question from Mr BHATT, Mr HEMMING explained that there were four standards - for BOD figures they were 5000, 2000, 1000 and 500 mg/l. Flotation would give a BOD of 3500 mg/l which satisfied the first standard. The first stage of biological treatment would reduce the BOD to 1400 mg/l which was below the second standard, and the second stage of biological treatment would give a BOD of 500 mg/l which was the ultimate standard.

16. Mr C N FREER asked whether ICI had constructed plastic media filtration plants in hot climates for effluents from abbatoirs, and if so, were there any smell and fly problems?

17. Mr HEMMING replied that an abbatoir effluent plant in Johannesburg had been commissioned recently and there was one in Perth, which had a hot climate, and was trouble-free. There were a number of food packaging firms in Singapore and Hong Kong using Flocor and to the best of his knowledge these were also trouble-free.

18. Mr D R YOUNG enquired about the success of ICI's research programme into intermittent dosing of plastic media. Mr HEMMING said most waste plants with high rate filters had used a constant rate, but rotary distributors were being installed particularly for larger installations which had 1500 - 2000 cubic metres filters. Most were circular rotary distributors and had been designed for the average uniform rate with the distributors rotating at a constant speed. A minimum irrigation rate of 1.5 cubic metres per square metre per hour

was recommended. With a static distributor this was the overall irrigation rate of the system but with rotary distribution it was the instantaneous rate.

20. Mr BHATT asked if there had been any study of the comparative cost of operation and maintenance using plastic media. Mr HEMMING said that a plastic media could not compete with gravel or broken stone on a volume cubic metre media basis. However the capital cost per gram of BOD removed depended on the type of feed. In the majority of cases plastic media was competitive with activated sludge or conventional filters.

21. Mr R VIGURS asked on what basis the support system should be designed, and what was the life expectancy of Flocor.

22. Mr HEMMING said that 320 kilograms per cubic metre was the minimum weight which a support system should take.

23. The life expectancy depended on the type of material from which the plastic media was manufactured, but thirty years was a reasonable expectancy.

24. Mr M LANSDELL asked for more information about sludge processing.

25. Mr HEMMING said it consisted of evaporation with recovery of condensate to produce a syrup. In some cases the husks and some of the kernels from the palms were used as fillers.

26. The CHAIRMAN thanked Mr STUART and Mr HEMMING. He thought it had been an interesting and enjoyable two days and the interest had been because of the large number of contributions to the discussion as well as the quality of all the Papers, and the way in which they had been presented. He hoped everyone would come again and bring some of their clients with them to the 5th WEDC Conference in April 1979.