WATER CRISIS IN COLOMBO

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The water crisis in Colombo has provoked many people to come forth not only to question the cause of it but also to suggest numerous alternatives to solve the problem. This paper is to attempt to clarify the situation both in respect of the cause of it as well as in the solutions sought as permanent and emergency measures adopted, along with the problems that occurred in carrying out the emergency measures.

Prior to the clarifications, solutions and problems, it may be best briefly to outline the background history of water supplies to the city of Colombo and its suburbs.

Colombo derived its pipe-borne water on implementation of the Labugama Impounding Reservoir in 1887 followed by further improvements in 1924. The Reservoir had been designed to be capable of supplying a safe yield of 12.0 million gallons per day (m.g.d.). The full storage capacity of the Reservoir was estimated to be 1960 million gallons capable of sustaining a supply of 12 m.g.d. for approx. 150 days or so, i.e. to say from January to May. It appears to have considered evaporation losses, seepage losses to be compensated by intermittent odd rainfall recharging the reservoir. The catchment area feeding the reservoir was about 2,385 acres fed by an average rainfall of about 150 in. varying from a low 120 in. to a high of about 180 in. per year. As the city developed the source was unable to cope with the demand that sometimes it had to be supplemented from the river intake at Ambatale until the Kalatuwawa Reservoir project was implemented in 1954 (please note it is over 20 years old now). The Kalatuwawa Reservoir was designed to cater for a safe supply of approx. 20 m.g.d. Its catchment area is about 3,320 acres with a full storage capacity of about 3,580 million gallons. This too seems to have been designed on a 150-day duration of supply without replenishment. Its rainfall pattern is similar to the Labugama catchment being adjacent. The sum total of the two reservoirs is regarded as being capable of a safe supply of about 32 m.g.d. even in the worst drought, extending over 4 to 5 months. Since siltation and other factors may have affected the capacity, we may regard its today's safe yield as 30 m.g.d.

Now, on examination of the present day demands in 1976, over 20 years after Kalatuwawa, Colombo has grown into a major city with a resident population of approx. 600,000 and a floating population of about 150,000 to 200,000 whose demands of water have to be met. In addition industries too have developed and it is estimated that Colombo's consumption of water is around 40 m.g.d., inclusive of losses, wastage etc. This averages to about 50 gallons/person/day inclusive of other users, losses etc. This figure is considered high as direct users are low without proper sewer facilities and internal plumbing. However, assuming 40 m.g.d. as the present requirement, how is it met? The two sources restricted to a safe yield of 30 m.g.d. or even 28 m.g.d. leaves a balance of 8 to 10 m.g.d. to be accounted for. There are two ways that this could be met, (i) from the sources, (ii) outside sources. When I refer to from the sources, it means Labugama and Kalatuwawa supplying beyond its safe capacities as designed and (ii) outside sources meant such as the Kelani river source at Ambatale. From way back in 1972, Colombo has been augmented from the pumping scheme at Ambatale from an initial 2 m.g.d. to about 7 m.g.d. per day in 1974-1975. Did this still overcome the deficit? This means the two reservoirs were possibly overdrawn to meet the balance. This was highlighted in 1973 to some extent when after the monsoon in June-July period, a water cut had to be imposed in September-October. Similarly, at the end of November 1975 the reservoirs were full or nearly so, but by May-June a water cut had to be imposed. In turn let us examine the pumping scheme established initially to supply five towns called Towns South of Colombo, namely Kolonnawa, Kotte, Dehiwala-Mt. Lavinia, Moratuwa and Panadura, from the Kelani river at Ambatale. This was implemented in 1966 and is 10 years old. In its 2nd stage, independent of Colombo, it was to be augmented to meet their demand by laying additional duplicate lines and to increase its capacity to meet the growing demands of these towns. These five towns have progressively developed whose demands have now reached the initial max. of 20 m.g.d. that the 1st stage could cater, at which stage the next augmentation should have been in force. However, due to the shortage in Colombo the pumping scheme released more and more water from the pumping scheme at a slight detriment to the five towns where some pockets of areas in high zones suffered. But this release to Colombo was effected largely by overloading the existing plant from its rated capacity of 20 to about 25 m.g.d. approx. taking a risk in the plant performance and equipment. The safety factor provided was utilised for this purpose. To provide more at that stage of over 5 m.g.d. to Colombo was at the expense of the other five towns. Before getting into the 1976 crisis proper, I wish to mention what action was taken after the 1973 crisis n Colombo. The emphasis on the impending water shortage was brought to the notice way back in 1971. On these representations and on the Master Plan that had been prepared, it was with difficulty due to the foreign exchange crisis, a 20 m.g.d. pump was ordered prior to the 1973 crisis but failed to avert by the non-arrival of the pump in time. Following the crisis. uprating the supply at Ambatale from 20 m.g.d. to 40 m.g.d. was undertaken in 1974 on a French line of Credit,

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But this still left work to be undertaken to utilise the increased supply to Colombo for want of foreign assistance. World Bank was approached and have taken an active interest in financing the rest of the work, but on the Master Plan an integrated system had been proposed as the least cost solution. The World Bank now requires the institution to manage it and government's decision on it. This is being actively pursued for immediate solution to enable implementation of the rest of the work needed with foreign assistance. The implementation and extension of the purification plant etc. at Ambatale from 20 m.g.d. to 40 m.g.d. answered the immediate need of the availability of water but the next stage of delivery to Colombo was left unsolved, where it called for improvements to the pipeline, service reservoirs and more the necessity for pumps, without which Colombo nor the other towns would reap the benefit of the increased supply available. The integrated system envisaged in the Master Plan called for the Labugama and Kalatuwawa Reservoirs, the pumping scheme at Ambatale and the various service reservoirs feeding the various towns along the trunk mains to be controlled as one unit capable of dispensing the water available in a manner to cater for all on the least cost possible both in establishment and in operation. This meant that Kalatuwawa water that came to Dehiwala could best be used to feed that area and further south while Colombo could draw from Ambatale. The World Bank hopes to finance through IDA funds on a soft loan the balance work in this stage and possibly the consequent stages as well.

Regarding the augmentation, it was proposed in the Master Plan to undertake the following improvements in respect of Colombo and its suburbs, (a) 1st stage improvement of 20 m.g.d. to 40 m.g.d. at the Ambatale Purification Plant, (b) Re-lining one of the mains at least to carry more water upto about 29 m.g.d. for Colombo through its combined battery of mains, (c) Providing an additional 3 m.g. reservoir at Maligakanda to enable to cater for a better equitable distribution in Colombo, (d) Improvements to the Distribution Network to overcome deficiencies in supply.

In respect of (a), it was imperative to develop this stage to make available purified water whether it be to Colombo, towns South of Colombo or any other area. Even in the 2nd stage of the five towns South of Colombo this was provided for to the extent of the establishment of the intake structure and components of the Purification Plant. But to cover the additional supply to Colombo, (b) had to be accomplished, i.e. the capability of transmitting additional water to Colombo. The C value of the existing pipes was determined and was considered low. By re-lining the mains it was estimated that the C value could be increased through which means the capital expenditure of new mains could be avoided. In this instance, the re-lining considered was only in the section lying between Ambatale and the Service Reservoir at Maligakanda and Elie House through which the additional water could be boosted. It must be remembered that the mains from Labugama and Kalatuwawa are an approx. length of about 30 to 32 miles. To re-line the whole length would entail a tremendous cost unless justified on the necessity for it against other alternative proposals. Considering that 40 m.g.d. is Colombo's present requirement and by 1985 (say) 45 m.g.d. if 24 m.g.d. is supplied from the river supply, then only 16 m.g.d. increasing to 21 m.g.d. need be met from the two Impounding Reservoirs of Labugama and Kalatuwawa leaving a surplus of 14 m.g.d. to 9 m.g.d. diminishing with the expansion of Colombo. This surplus could be left as storage for emergency or better utilised to supply areas already lacking water, such as the Towns North of Colombo or Maharagama area (Towns East of Colombo). Water availability means money either in prevention of health hazards or in industrial development and human welfare. (c) the provision of a 3 m.g. reservoir at Maligakanda was technically found necessary to alleviate the peak flow demands covered by it where expansion had taken place without due precaution and proper zoning system planned out to enable the Service Reservoir established way back in 1900s to function in the manner it was designed to serve. This brings up the question of a water cut and its effects on the consumers and the system as a whole. Imposing a water cut acts in a number of ways: (a) Consumer resistance to the cut, (b) effect on the distribution network, (c) inability to cater even a very (restricted) supply to some areas. Analysing each in turn, taking consumer resistance— the moment a water cut is imposed, the consumer tends to arm himself with whatever water he can store whether he intends to use it or not. The consequences are that some will derive the full benefit of the restricted supply as against some totally denied of any supply. On a 4 hour supply by the time the pipelines could get charged to sufficient pressure to all the areas, the draw-off being excessive does not build up and the lucky few benefit. To overcome this one possible answer is to give on a zonal supply, area by area, but Colombo's distribution system appeared unable to carry out such a distribution under its present network. When a 4 to 6 hour supply was given some areas did receive water over this period while others did not receive at all though the supply was given. In turn the question of the best hours of supply that could benefit the maximum had to be examined.

Taking peak demand factors into consideration and losses due to faulty system, it was difficult to decide the best period. At the height of the water cut, i.e. when the supply had to be limited to 15 to 17 m.g.d. comprised about 9 m.g.d. from Ambatale and 6 to 8 m.g.d. from the two Reservoirs (6 to 8 m.g.d. was based on allowing only maximum release of about 2 in. drop in Kalatuwawa and 4 in. in Labugama), it was estimated that only a 4-hour supply could be maintained at sufficient pressure to feed the available water. The next question was during what time was this issue to be given. By releasing at a time in the morning it was expected to prevent undue losses and wastage. Another question that arises is why couldn't it be given 2 hours in the morning and two hours in the evening. The Service Reservoirs so situated could have fed only surrounding areas close to it and only a few areas would have benefitted both in the morning and evening. This arises through the long lengths of distribution network from the service reservoirs and the pressure build-up being dissipated in a short length whereas one conti-

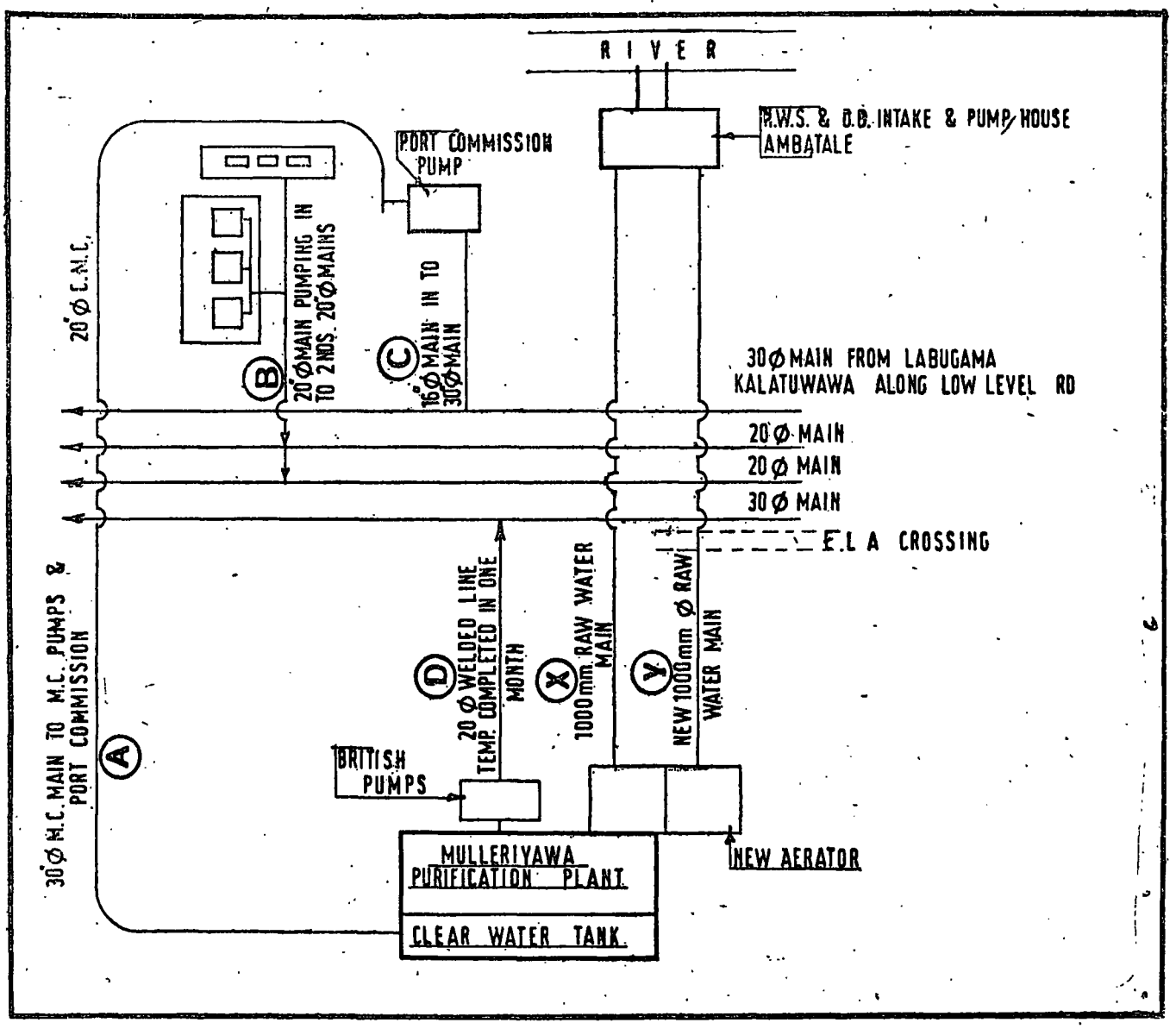

Fig 1. Proposal put up to augment water supply to Colombo

nuous pressurised spell has better chances to reach a larger area. Possibly on a zonal basis more equitable distribution could have been possible. But due to the limited period of supply and concentrated draw-off during the time of release, the higher zones in Colombo as well as the overhead tanks in houses never received a supply through lack of pressure. In some areas the level was so low that some sank wells or hume pipes to receive water below ground level.

There are three Service Reservoirs that feed the distribution network of the city of Colombo. They are located at Maligakanda (8.0 m.g.) more or less central in the network, Elie House (8.0 m.g.) in the Northern area and Dehiwala Reservoir (4.0 m.g.) in the South. The Labugama and partly Kalatuwawa fed Maligakanda and Elie House Reservoirs, in normal times, while Kalatuwawa alone fed Dehiwala Reservoir. The Dehiwala Reservoir normally received about 12 m.g.d. from Kalatuwawa. With the draw-off limited to about 4 m.g.d. or less from Kalatuwawa, during the crisis, the South area like Wellawatta hardly received any water while Maligakanda Reservoir with the limited resources of about 7 m.g.d. could not pressurise the lines to reach these areas. Thus the extremity of supply appeared to reach only upto a point in Havelock Road and in low-lying areas. Even areas of Elibank Road etc. were denied any supply. In some cases the distribution pipes were small in diameter and heavily encrusted, allowing a very limited flow that was snapped up by consumers closest to the bigger network distribution. There are numerous such distributional difficulties while in some very low-lying areas the taps continued to flow for many more hours beyond the 4-hr. supply draining out the distribution pipes.

The total withdrawal of water from the distribution pipes creates another problem. Iron bacteria is allowed to form within the pipe through exposure through the vacuum in the line and on release of flow into it on resumption of supply the iron bacteria breaks to float to make the water appear rusty. Further, chlorine dosage reacts with these particles and the effect of chlorination could be nullified in reacting with this bacteria tending to make the water to be unsafe bacteriologically if sufficient dosage is not administered to combat the formation as well as other harmful bacteria. But there is a difficulty in administering such dosages particularly a very high dosage may be unpalatable to those who receive it close to the source of application. But under the available restricted supply this problem has to be accepted and adequate precautions taken. It is always desirable to retain the lines filled with water as far as possible but in no distribution network could it be possible to do that without incurring very heavy expenditure unwarranted when there is no water-cut to contend with.

Now, turning to the crisis, numerous proposals and causes have been attributed to the crisis. I do hope you will pardon me, if I appear to have evaded some issues. As mentioned, if the Labugama and Kalatuwawa reservoirs were virtually on the verge of overflowing at the end of November 1975, then for it to have depleted by May-June 1976 is possible only if there was no replenishment at all during the 5-month period or it was overdrawn to some extent. Assuming an increased draw-off of about 3 m.g.d. over its safe yield it amounts to about 150 million gallons in that period and in addition to unprecedented drought conditions and heavy evaporation could result in finding the reservoirs at its lowest level at the end of the period. When the anticipated monsoon rains failed by the end of May, the cut was imposed. Some argue, why wasn't it imposed earlier. In turn some will argue, if the monsoon broke why was it imposed when the reservoirs were ripe to receive the monsoon. It is a matter of judgement. But whatever it is, crises such as these are common when the limit of the resources are critical as pointed out Kalatuwawa is 20 years old and an augmentation to its was necessary to avert such a crisis.

I would like to get on to the emergency operations that were attempted to improve the water situation, particularly in the city. With the two reservoirs, namely Labugama and Kalatuwawa able to survive only a few days on normal supply and may be a month or a little more on a limited supply, action was taken as a first step to introduce a cut to the Five Towns supplied from the Kelani river and supplement as far as possible Colombo. The possible draw-off from Labugama and Kalatuwawa was limited to about 6 to 8 m.g.d. and the Colombo Municipality with the pumps available appeared to be able to draw only 8 to 9 m.g.d. Thus Colombo could receive only 15 to 17 m.g.d. against their requirements of about 40.0 m.g.d. normally. This is where it necessitated a maximum water cut of nearly 16-18 hrs/day in Colombo. The next move was to expedite added supplies to Colombo. To do this two basic items had to be implemented. (i) produce the 40 m.g.d. at Ambatale and (ii) pumps and connecting pipelines necessary to deliver more water to Colombo. (i) Already the National Water Supply and Drainage Board had taken steps to lay the raw water main of 1000 mm. to push 40 m.g.d. to the plant and this was expedited working round the clock. (ii) Frantic search for suitable pumps to boost water to Colombo was embarked along with the necessary pipelines and other equipment. To achieve the above, I now propose to go into the detailed problems and activities involved. Under (1), a 1000 mm. pipeline had to be laid from the River Intake point to the Purification Plant, the pipes had been obtained on the French Line of Credit as Stage I improvements on the Master Plan along with the plant and equipment. The length of main to be laid was approximately 2,300 ft. These pipes were of the ductile iron type with Simplex Rubber Joints. It had to be laid in a low-lying terrain along a dry weather road crossing an ela and under the low level road. In addition, civil engineering structures had to be constructed to let in the water into the plant through the existing aerator. It was decided to undertake this through direct labour by the Board. The initial difficulty encountered was in trying to align the pipe joints that required cranes and suitable equipment to be able to move a pipe weighing about 2 to 3 tons into position, to be connected through the Simplex Rubber joint. Since cranes could not be moved into position, with the aid of jacks suitably arranged and manual labour each joint was achieved. Extreme care had to be taken to see that the positioning of the pipes for connection was such that the Rubber Seal was not twisted in anyway and fitted into the joint to prevent any leaks. In addition a number of other items such as air valves and scour valves had to be connected on the line with sufficient supports out of concrete buttresses where necessary. The line laying encountered three major difficulties (a) across the ela crossing, (b) road crossing, and (c) connection to the existing pumping main system. Regarding (a) Two mass concrete abutments had to be constructed. (b) At the road crossing at the low level road there was the battery of maine carrying the Labugama and Kalatuwawa water to ths city. The excavation had to be as deep as 14 to 18 ft in this area to be able to cross them underneath. In addition the existing 1000 mm. line already supplying the 20 m.g.d. from the River Intake had taken a deviated form and that too had to be avoided. In respect of (c), the major difficulty arose that the flanged end of the existing 1000 mm. main left for future connection had been anchored against a heavy R.C. concrete support. To avoid the least interruption to the existing supply and also to support temporarily the new connection, another anchor block was constructed till the new line was connected and the permanent anchor was constructed. When the connection was done and since the time that could be allowed for the concrete to settle, was limited due to the emergency on the next day of the connection when the power supply failed and both intake pumps pumping approximately 30 m.g.d. automatically stopped the water hammer or back thrust by head of water in the pipeline acted against the temporary supports and sheared it at the base by shifting the block by about an inch but still withstood. It was quite a decision to make whether on resumption of pumping whether the thrust would be too great to be taken up by the weakened block

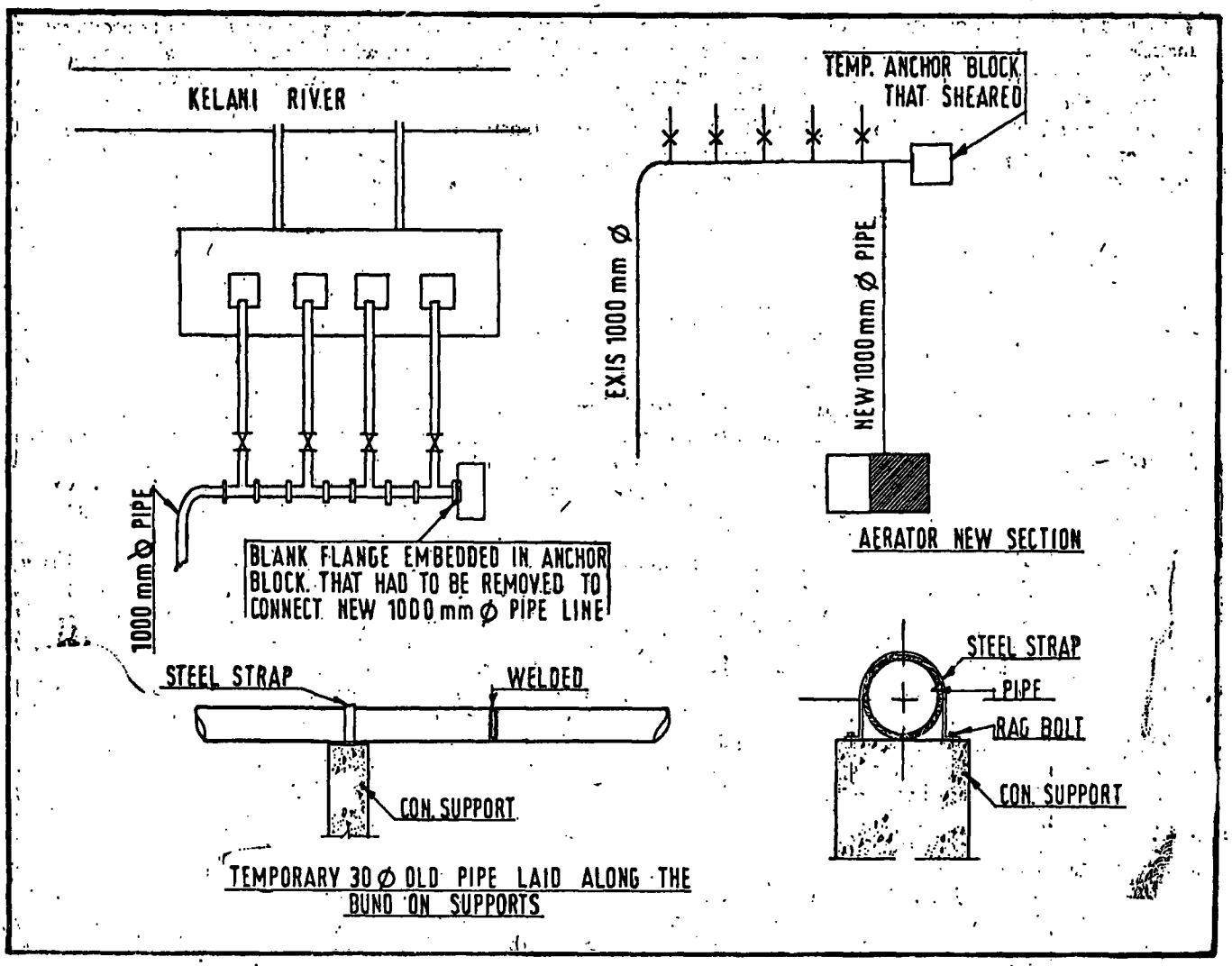

Fig a. Some construction details

or not and what suitable strengthening could be done. As time was so precious it was decided to take the risk and resume pumping in the hope that any sudden power failure the surge could travel along the two lines instead of a direct impact on the anchor. The water head that acted directly on the anchor block could have been in the range of about 80 tons due to the water in the 1000 mm. line that was being pumped under a pressure of about 100 ft. head that was cut off. However, no further mishap occurred and the permanent anchor was constructed after which the danger of this type was not considered possible.

Under (2), pumps to boost an added supply to Colombo and necessary connecting pipelines etc. was actively pursued. As mentioned earlier, the Colombo Municipality had already laid a 30 in. main with a short length of 20 in. main as a positive suction line to boost water into the battery of mains at Ambatale. They had 3 No. 4 m.g.d. pumps and 3 old pumps operating at a head of about 250 - 300 ft. to boost into two 20 in. mains that were supplying Maligakanda and Elie House Reservoirs. It was through this means that they were pumping about 7 m.g.d. prior to the crisis from about 1973-1974. The Colombo M.C. had ordered for a 4th pump of capacity 4 m.g.d. but on inquiry it was expected only in about October. The positive suction line that was from the Clear Water Tank at Mulleriyawa plant was checked to determine its maximum carrying capacity. The level difference between the Clear Water Tank and the pumping station was approximately 80 ft. Allowing for friction losses and other losses it was estimated that from this line around 15 m.g.d. could be extracted. Similarly in the Master Plan for future supplies to Colombo from the integrated scheme at Ambatale, pumps of 8 m.g.d. with a total head of 300 ft. was found necessary to boost 16-20 m.g.d. into the battery of mains to supply Maligakanda and Elie House Reservoirs. Thus a frantic search to obtain off the rack as it were, any high capacity pumps but with a head of at least 250-300 ft. preferably 8 m.g.d. or any pumps close to this range was initiated. All embassies and every possible source were intimated of our urgent need for pumps and other pipe connections necessary. At the same time in the latter part of June, Mr. A. N. S. Kulasinghe, who had arrived in the island, on hearing of the crisis promptly came to the rescue with a suggestion that he is aware that Colombo Port Commission had dredger pumps that might be suitable to supply about

5 to 6 m.g.d. to Colombo in addition to the pumps installed. The one objection was they were diesel operated and very expensive to run as well as being very bulky. At about the same time the British High Commission informed the Ministry and Government that there are some ex-stock 30 years old unused pumps that could be made available but the capacity was 2 m.g.d. each.

In July a high level Government and Ministerial decision was taken to install the Colombo Port Commission pump as well as obtain at least 3 No. British pumps of 2 m.g.d. to augment the Colombo supply as early as possible. It was decided to install the Port Commission pump at the Municipal Pumping Station to be fed by the existing positive suction line that was supplying the Municipal pumps as that line was capable of being tapped up to about 15 m.g.d. The Port Commission pump was to deliver into one of the 30 in. mains that was traversing near the pumping station while the existing C.M.C. pumps fed into the two 20 in. mains. When the British pumps arrived they were to be installed at the Purification Plant from where a delivery line of approximately 2300 ft. was to be laid to connect the supply to another 30 in. main at the low level road. (See fig. 1) Implementation of these proposals at such short notice and to be completed as quickly as possible was a task of such magnitude that called for a concentrated effort.

Firstly, on examination of the Port Commission Pump it was found to weigh about 14-15 tons and needed a suitable base to be prepared to take the load. The dimensions of the pump base was approximately 20 ft. by 5 ft. If a concrete base was prepared to take the load allowing time to settle the pump could have been placed only after about 10 days at least. In place of which to cut short the time, concrete Kentledge blocks used by the Bridges Organisation for loading their cylinders were used as the base with a concrete mat reducing the time necessary to install the pump. Without installing the pump and aligning it, the pipe connections could not be figured out, for the suction end of the pump was 16 in. diameter and delivery 14 in. diameter in a rising form of outlet. The suction end of 16 in. diameter meant that to connect it to the positive suction line of 20 in. diameter, fabrication of special pipes was necessary. This was overcome on the suction side by using an available 20 in. steel pipe onto which a 16 in. diameter fabricated steel pipe was welded to form a Tee reducing from the 20 in. to 16 in. diameter. Then since the 20 in. diameter line was at ground level and the suction inlet was about 4 ft. above ground a 16 in. diameter 90 degree bend had to be fabricated to fit in the suction side such that the line was connected to the suction end perfectly fitting to prevent air leaks that might create air locks and causing ineffective suction on the pump. Another problem that was encountered on the suction side was when the existing suction line was exposed it was found to be a cast iron pipe of an irregular size and not 20 in. diameter internal as normally expected. Using makeshift arrangements of plugging and collars to create an effective joint between the steel and the cast iron, the connection was carried out and tested to the effectiveness of the joint established. Next came the problem on the delivery side. The rising outlet was at an angle of about 60 degrees to the horizontal and had to be connected to the 30 in. main from 14 in. diameter outlet. In addition it was necessary to provide controlling valves on this line as well as the pipes available to lay a distance of about 250 ft. to reach the 30 in. main. After an intensive search, a 12 in. diameter reflux valve and sluice valve were found available along with 16 in. diameter steel pipes. Thus it was decided to fabricate a 14 in. to 12 in. steel tapered pipe to fit into the valve connection and another from 12 in. to 16 in. diameter to connect to the available pipes with a radial type of 16 in. bend to be welded into the 30 in. main. In addition, the pump required a cooling tank and oil storage tank to feed the pump. All this was achieved through the excellent co-operation and erstwhile effort put in by the Port Commission officials who gave top priority to this job and were responsible for the quick installation, fabrication of pipes and throwing in their best equipment and staff into this job. The reward was in supplying additional water so urgently needed within one month of commencing work on it. This alone indicates the effort put in by them. Secondly, on the installation of the British Pumps that were expected the following works became necessary, (a) Location and installation of the pumps, (b) Pipe connections to and out of the pumps, (c) Power supply to operate the pumps. Taking each one in turn, (a) Location and installation of pumps—with regard to location two positions where the pumps could be installed were possible, (i) at the new clear water tank if it could be completed in time and (ii) site close to the existing plant from which water could be drawn into the pumps for delivery. Both were pursued. In respect of (i) it was necessary to get the clear water tank completed in time to place the pumps as well as to be in a position to receive water into it, and priority was given to do so. At the same time a base was prepared under (ii) to receive the pumps near the flume of the Purification Plant. (b) A length of nearly 2300 L.ft. of pipes had to be laid to be able to supply from one of the above location to the 30 in. mains that was supplying Maligakanda and Elie House Reservoirs in Colombo. To do this as an emergency measure discarded and retrieved 30 in. diameter pipes lying at Ambatale was considered the quickest and easiest solution. Though they were old they appeared to be still serviceable for such a purpose as an interim measure. To expedite the work and ensure quickest results it was decided to throw it to a contractor capable of handling such a job in an emergency. M/s. Walker & Greig undertook to meet this emergency and the following operational venture was undertaken. Since time to lay would cause delay, the pipes were to be welded along the length anchored sufficiently along its length and any weak spots in the pipes to be attended and deliver the completed works in a specified time including installation of the British pumps taking delivery at the Bandaranaike International Airport. (c) to operate all the pumps and equipment the power requirement was essential. The C.E.B. was roped in to meet these requirements. They threw in their share to see that adequate power was available to meet the demand. They established additional transformers and necessary electrical facilities to cope with the operation in hand. They as much as the C.P.C. and M/s. Walker & Greig were throwing their maximum effort on highest priority to achieve the quickest result in this operation.

The problems that were encountered were numerous and I hope to touch only on a few. Regarding the location of pumps it was observed that even if the clear water tank was completed there was still problems of installation and added pipelines involved that decided to fix the pumps at the location near the flume. This served the same purpose. The other was on the arrival of the British pumps, the time limit for unloading was limited to a 10-hour turnover time for the special chartered plane. Even when loading with all the sophisticated equipment there was a delay in departure due to loading problems in U.K. This was achieved within the prescribed time or earlier. I do not wish to elaborate on the techniques adopted but wish to illustrate how a job can be performed without all the cry for sophisticated equipment that has and is being developed to ease a job, but in an emergency what is handy and your ingenuity is the answer.

Coming to what all this has achieved is, to put in a nutshell, Colombo was receiving over 20 m.g.d. from the Ambatale integrated supply and able to cater to the needs during the Non-Aligned Conference and also succeeded in alleviating the long suffering consumers from a severe cut to a near normal supply, the advantage of which is that it could avert a severe crisis as experienced in June-July, in the future.

Lastly, this brings up the question of the future and what could be done and is being done to avoid situations of this nature. To cover this, I propose to be brief and indicate what the future is, the works here to be carried out and achieved in time to meet any future crisis. The first question to be solved is the present shortage even with all these emergency measures. To do so we have to look into the levels of the water in the Labugama and Kalatuwawa Reservoirs. These two sources were expected to safely yield 30 m.g.d. at least. There have been a number of suggestions to supplement these sources such as pumping into them from Kelani or Kaluganga etc. Supplementing in this manner it is intended to increase its capacity from 30 m.g.d. or merely to regulate the extraction against monsoon failure. As you are aware with 30 m.g.d. Colombo is still short of its needs by about 10 m.g.d. at present and may reach 15 m.g.d. by 1985 or so. In order to increase the capacity at Labugama and Kalatuwawa, additional improvements of storage, purification and pipelines are necessary. The basic problem is that the two reservoirs are limited in these respects and this is where the least cost solution in the Master Plan solved the problem for both Colombo and Greater Colombo dispensing with unwarranted expenditure on additional pipelines, purification plants, utilising to the maximum the existing facilities to satisfy the requirements. The least cost solution attempted to do with one purification plant for Greater Colombo as a unit, as well as, did away with any new trunk mains but only expected to re-line one of the 20 in. mains for the present. In addition with a pumping system from the Kelani river at Ambatale, future stages could be developed as and when required, with a final withdrawal of about 100 m.g.d. in the year 2000 or so. The present position is that with 20 m.g.d. already being supplied from Ambatale to Colombo, the two reservoirs could only safely give say another 10 m.g.d: till sufficient levels are built up to be able to overcome the next drought period in early next year. If sufficient rains occur in Oct.-Nov. then it may be possible to remove the cut totally. But this alone does not totally help Colombo in the future. The following works too have to be done. They are in brief: (i) Pumps, (ii) Re-lining of the 20 in. main, (iii) another 3 m.g. service reservoir at Maligakanda and (iv) improvements to the distribution system. All these have been included in the World Bank request and should be implemented as early as possible to avoid future crises.

Finally, I have to place on record the magnificent co-operation between all organisations involved in the emergency work. It showed that in a crisis everybody was prepared to throw in their share of maximum effort to achieve the quickest result possible. My sincere thanks go out to the Secretary, Ministry of Local Government, the British High Commission, the Colombo Port Commission, the State Development and Construction Corporation, M/s. Walker & Greig, Ceylon Electricity Board, the Colombo Municipal Waterworks Dept. Officials and staff and last but not least all the officials and staff of the National Water Supply and Drainage Board, for their unstinted co-operation and assistance without which this achievement could not have been possible.

ERRATA

Please note the following type-setting errors in the first part of Dr. J. B. X. Devotta's paper which appeared in the Sept. 1976 issue of 'ENGINEER'.

1. Equation (1) should read:

$$f(S) \equiv N_1(S) \cdot N_2(S) + D_1(S) \cdot D_2(S) = \sum_{k=0}^{n} a_k s^k = 0$$

2. In equations (5), (6), (10) and (13) the symbol ϕ should be read as ϕ