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WATER MALAYSIA '92

8TH ASPAC - IWSA REGIONAL WATER SUPPLY CONFERENCE & EXHIBITION

PUTRA WORLD TRADE CENTRE
KUALA LUMPUR, MALAYSIA
26 - 30 OCTOBER 1992

TECHNICAL PAPERS

VOLUME 1

CONTAINING PAPERS TO BE PRESENTED ON
27 OCTOBER 1992

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THE MALAYSIAN
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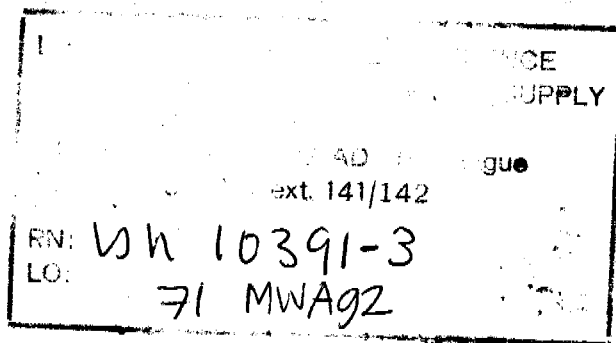
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FOR SESSIONS

1A	1B	1C
2A	2B	2C



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CONTENTS

TECHNICAL SESSION 1A PRETREATMENT, EVALUATION AND TRENDS IN WATER TREATMENT

- Pretreatment of Contaminated Raw Water of Public Water Supplies by
Fixed-film Biological Processes - RBC and BCA 1A1-1
Chao-Fuei Ouyang & Cheng-Shang Ying
- Evaluation of Water Purification System Referring to Mutagenicity 1A2-1
Yoshinori Kurosawa, Yasumoto Magara & Yoshiharu Hisamatsu
- Trends in Water Treatment - Application in Malaysia 1A3-1
F. W. Crowley

TECHNICAL SESSION 2A WATER TREATMENT - FILTRATION

- Slow Sand Filter for Groundwater Recharge.
Ten Times Longer Filter Run Than was Usual Up to Now 2A1-1
Dr. h. c. sc. tech, ETH Maarten Schalekamp
- Assessing Membrane Filtration for Particulate Removal 2A2-1
Takasi Kohno, Yashikazu Itoh & Yoshhide Kaiya
- Filtration of Horizontal Flow Filter 2A3-1
K. S. L. Lo & C. S. Lay

TECHNICAL SESSION 1B RIVER WATER QUALITY MANAGEMENT

- Water Quality Computer Simulation Modelling of Sg. Linggi 1B1-1
Mohd. Akbar Johari
- Classification of Rivers in Malaysia According to Various Beneficial Uses
and Water Quality 1B2-1
Dr. Fauzi Abd. Samad & Dr. Abu Bakar Jaafar
- The Use of Database Management Systems in Water Quality Management 1B3-1
I. Chanthiran

TECHNICAL SESSION 2B ASPECTS OF WATER SUPPLY - GLOBAL CHANGE, STRATEGY AND CRITERIA

- Impacts of Global Change on Water Supply, and Response Measures 2B1-1
Shinichiro Ohgaki, Tomoyasu Matsuda, Sombo Yamamura & Hiroyasu Yoda
- The Strategic Aspects of Water Supply 2B2-1
M. J. Rouse
- Recent Water Resources Criteria for the Production of Drinking Water 2B3-1
M. Rapinat

TECHNICAL SESSION 1C
PRIVATISATION

Privatisation of the Water Industry	1C1-1
<i>Brian R. Thorpe</i>	
Privatisation of Water Supplies - Malaysian Experience	1C2-1
<i>Ir. V. Subramaniam</i>	
Privatisation of Water and Wastewater Services	1C3-1
<i>T. A. Rogers</i>	

TECHNICAL SESSION 2C
PRIVATISATION

Privatised Water - Organisation, Regulation and Funding	2C1-1
<i>J. Jeffery</i>	
Involvement of the Private Company in Water Supply, The New Development Era in Indonesia	2C2-1
<i>Priyono Salm</i>	
The Impact of The Private Development of Water Systems in Urban Areas of Mindanao	2C3-1
<i>Ernesto B. San Juan</i>	

TECHNICAL SESSION 1A
PRETREATMENT, EVALUATION AND
TRENDS IN WATER TREATMENT

Pretreatment of Contaminated Raw Water of Public Water Supplies by
Fixed-film Biological Processes - RBC and BCA

Evaluation of Water Purification System Referring to Mutagenicity

Trends in Water Treatment - Application in Malaysia

PRETREATMENT OF CONTAMINATED RAW WATER OF PUBLIC WATER SUPPLIES BY MIXED-FILM BIOLOGICAL PROCESSES - RBC AND BCA

Chao-Fuei Ouyang
Civil Engineering Department
National Central University
Chung-Li, Chinese Taiwan

Cheng-Shang Ying
China Engineering Consultants, Inc
Chinese Taiwan

Abstract: This study is to carry out experiments and studies on the contaminated raw water of public water supplies pretreatment by Rotating Biological Contactors (RBCs) and Biological Contactor Aeration processes (such as Honey Cone-processes) in order to determine its effectiveness in treatment and the feasibility of its used as an alternative to prechlorination. According to the results of this study, it showed that the two biological pretreatment processes exhibited high treatment efficiencies and had significant effectiveness in the removal of ammonia nitrogen (NH_3 -N). The capital costs, operating and maintenance costs, land requirement, the stability and reliability of operation, etc were compared and evaluated in the pretreatment of contaminated raw water of public water supplies by the two biological pretreatment processes.

key words: Rotating Biological Contactor, Biological Contactor Aeration, contaminated raw water, pretreatment, prechlorination

1. Introduction

Even though the raw water of a public water supply are badly polluted nowadays, the treatment of public water has always been processed by adding chemical agent which can not remove odor. In order to remove NH_3 -N, Pre-chlorination is to be used but the massive organic compounds of raw water, which react with chlorine, would produced trihalo-methane, a hazardous carcinogenic substance.

The water treatment technique of bio-film process is very effectively to remove BOD, COD, anion surface active agent, particularly NH_3 -N removal (Nitrification). A plus is to reduce the pre-chlorine dosage. It is considered a powerful way to suppress the generation of trihalo-methane.

This study is to explore the characteristics of bio-film process in the raw water treatment, consisting of the rotating biological contactor process (RBC) and the biological contactor and aeration process (BCA). The sampling

water for this experimentation is picked up directly from Keelung river, the most poorly contaminated water source. This achievement gained from the experimentation is very solid, and its results, after carefully reviewing its applicability, could be substantialized and used as the optimal design parameters on the economic, operational and land requirement basis.

2. Experimental Method and Criteria

This study applied two methods, RBC and BCA for experiment of pilot plant in association with the following laboratory equipment:

2.1 Biological contactor Aeration processes (BCA)

The experimental installation as shown in Fig. 1, consists of reaction tank, contact filter media, diffuser pipes and etc. Its specification is described as follows:

Reaction tank:

Dimension: 1200m/m L × 600m/m W × 3500m/m H

Contact filter media:

Dimension: 600m/m × 600m/m × 100m/m;

Specific surface area $326.16\text{m}^2/\text{m}^3$

Porous diameter 13mm, 9 unit (3 unit per set), 1.08 m^3 per set of honey cone.

Diffuser pipe:

Type: SD 100 of Tsutsunaka plastic industrial Co., Japan.

Material: PVC & Neoprene

Dimension: 88 mm ϕ × 65 mm H

Diameter air rate: 10 l/min per piece

Number : 6 pieces (2 pieces of per set)

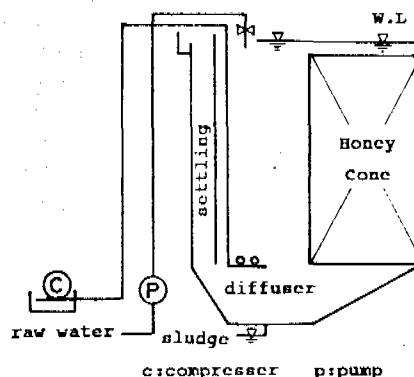


Fig.1. Flow Diagram of
BAC PILOT PLANT

In the initial experimental stage, three pilot plants were set up with the hydraulic loading at 5, 12 and 20 $\text{m}^3/\text{m}^3 \cdot \text{d}$, equivalent to 3.75, 9 and 15 l/min in flow rate, respectively. The last stage changed the operational criteria to 12, 20, and 30 $\text{m}^3/\text{m}^3 \cdot \text{d}$, equivalent to 9, 15 and 22.5 l/min.

2.2 Rotating Biological Contactors Processes (RBC)

The specification of 3 four stage RBC pilot plant is shown in Table 1, the primary installation as shown in Fig. 2.

Table 1 The equipment specification of RBC pilot plant

Item	Specification
Disc Type	plate type
Disc material	acrylic board
Disc diameter	300 m/m
Disc thickness	2 m/m
Disc interval	15 m/m
Disc number	15 pieces × 4 = 60 pieces
Total surface area of Discs	8.48m^2
The ratio of Disc submergence	40%
Volume per stage	9.8 l
Volume of settling tank	11.3 l
Liquid Volume/Disc surface area	$4.62\text{ l}/\text{m}^2$

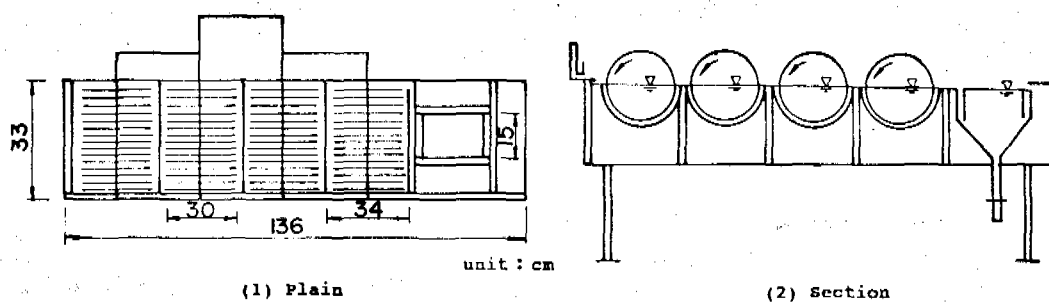


Fig.2. Schematic Diagram of RBC Pilot Plant

The hydraulic loading of the three pilot plants were 200, 500 and 800 $\text{l/m}^2 \cdot \text{d}$, equivalent to 1.178, 2.945 and 4.712 l/min in flowrate, respectively.

2.3 Item and Method of Analysis

The study was carried out under continuous conditions and the items of daily analysis included temperature, PH, turbidity, alkalinity, dissolve oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonium nitrogen ($\text{NH}_3\text{-N}$), nitrite nitrogen ($\text{NO}_2^-\text{-N}$), nitrate nitrogen ($\text{NO}_3^-\text{-N}$) and chlorine demand, in accordance with the 16-th edition of the Standard Methods.

3. Results and Discussions

The study took a whole year, starting in the mid-August, 1986 and continued to the end of August, 1987. The influent water was tamed for half month to get it matured, then for a variety of testing.

The water quality of the raw water during the experiments are $\text{pH}=6.0 \sim 7.2$, turbidity: $5.6 \sim 81 \text{NTU}$, $\text{DO}=0.8 \sim 8.6 \text{ mg/l}$, $\text{BOD}=0.3 \sim 5.6 \text{ mg/l}$, $\text{COD}=3.14 \sim 18.6 \text{ mg/l}$, $\text{NH}_3\text{-N}=2.4 \sim 9.4 \text{ mg/l}$, $\text{NO}_2^-\text{-N}=2.1 \sim 442.2 \mu\text{g/l}$, $\text{NO}_3^-\text{-N}=0.55 \sim 2.06 \text{ mg/l}$, water temperature= $15 \sim 31^\circ\text{C}$. The water treatment system used on Taiwan normal includes coagulation, flocculation, settling, rapid filtration and disinfection, provides that the raw water quality conforms to the standards of the second class for public water supply. This will serve as the basis in the discussion and comparison of the study results with the performance of other water treatment systems.

3.1 Experimental Results of BAC

3.1.1 Treatment Characteristics under Different Hydraulic Loading

According to the experimental results, it can be seen that as the hydraulic loading increases, the quality of the treated water expressed in turbidity, BOD, COD and $\text{NH}_3\text{-N}$ removal deteriorates. This is caused by the shorter detention time as the hydraulic loading increases. If insufficient time is provided for full reaction, there would be lower removal rates, as illustrated in Fig 3. In Fig 3, it can be found that the removal rate of $\text{NH}_3\text{-N}$ decreases from the highest of 92.0% to 71% when the hydraulic loading increases from $5 \text{ m}^3 / \text{m}^3 \cdot \text{d}$ to $30 \text{ m}^3 / \text{m}^3 \cdot \text{d}$. Thus the removal mechanism of this method was basically nitrification. It was noted from the figure that at the low hydraulic loading, the removal rate of the organic material was not so prominent. While the hydraulic loading was at $5 \text{ m}^3 / \text{m}^3 \cdot \text{d}$, and the retention

time maintained at 4.8 hours, most reation notable was nitrification. A small amount of heterogenic bacteria had sufficient time to oxidize the tiny quantity of organic material. The removal rate of NH_3 -N and the organic material began to become prominent as the hydraulic loading increased.

3.1.2 The Treatment Characteristics Under Different NH_3 -N Loading

Divide the NH_3 -N concentrations of raw water in the experiments into six groups base on their magnitudes. Convert the average of NH_3 -N concentrations into corresponding NH_3 -N loading under different hydraulic loadings. Compute the average of corresponding NH_3 -N removal efficiency and NH_3 -N concentrations of treated water. Also compute the denitrification efficiency V_r (the NH_3 -N removal per unit area) of each group.

A.Relationship between NH_3 -N loading and NH_3 -N removal efficiency

The relationship between the hydraulic loading and NH_3 -N removal efficiency under different NH_3 -N concentration of raw water is as shown in Fig. 4. In figure, it can be seen that the range of NH_3 -N loading is narrower ($1.4 \sim 24.1 \text{ g/m}^3 \cdot \text{d}$, $3.79 \sim 57.7 \text{ g/m}^2 \cdot \text{d}$) at lower hydraulic loading conditions ($5, 12 \text{ m}^3/\text{m}^3 \cdot \text{d}$). In this range, the higher the NH_3 -N loading is, the higher will be the NH_3 -N removal efficiency. The removal efficiency is always above 82%, and reaches a maximum of 96%. However, at higher hydraulic loading conditions ($20 \text{ m}^3/\text{m}^3 \cdot \text{d}$, $30 \text{ m}^3/\text{m}^3 \cdot \text{d}$), the range of NH_3 -N loading is wider ($6.2 \sim 96 \text{ g/m}^3 \cdot \text{d}$, $12.6 \sim 65.13 \text{ g/m}^3 \cdot \text{d}$). When NH_3 -N loading increases to $50 \text{ g/m}^3 \cdot \text{d}$, NH_3 -N removal efficiency decreases gradually, and only reaches a maximum of 74%. Hence when treat by this method and if the NH_3 -N loading is more than $50 \text{ g/m}^3 \cdot \text{d}$, nitrification bacteria can not adapt adequately.

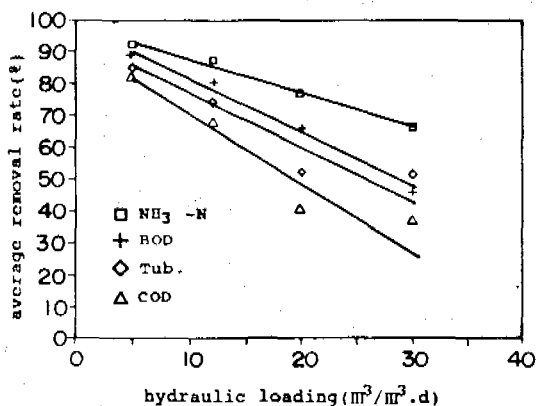


Fig.3. The relationship between hydraulic loading and removal efficiency for BAC process

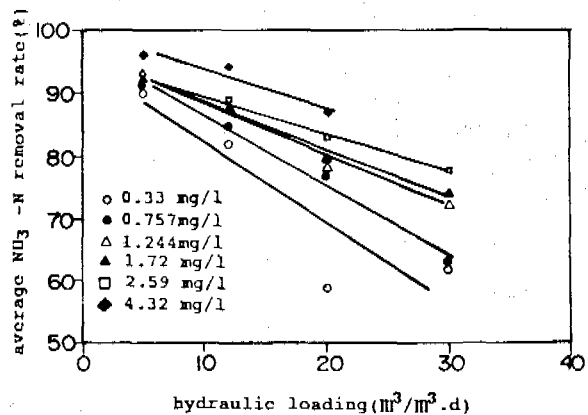


Fig.4. The relationship between NH_3 -N loading and NH_3 -N removal efficiency under different concentrations for BAC process

B.Relationship among the NH_3 -N concentration, of treated water hydraulic loading and unit areal NH_3 -N removal

The nitrification rate, V_r , can be expressed in follwing equation:

$$V_r = Q/A_w(C_0 - C_e)$$

Eqn(1)

where A_w =contacted biofilm area= $326.16 \text{ m}^2/\text{m}^3$

C_0, C_e = the NH_3 -N concentration of raw water and treated water (mg/l)

Q = flow rate (m^3 /day)

V_r = Nitrification rate ($\text{g}/\text{m}^2 \cdot \text{d}$)

From the foregoing discussion, it is apparent that, when the treated water NH_3 -N concentration C_e is relatively high and the raw water NH_3 -N concentration C_0 is also high, the unit areal NH_3 -N removal efficiency will increase. The above discussion shows that the hydraulic loading and raw water NH_3 -N concentration have a significant effect on unit areal NH_3 -N removal. Using the various raw water NH_3 -N concentration, hydraulic loadings and the correspondings NH_3 -N removal obtained in the experiments, it leads to the relation formula as the relationship between the relevant parameters was found as follows:

$$L_r = 3.903 \times 10^{-3} H_L^{0.852} C_0^{1.076} \quad R^2 = 0.9948 \quad \text{Eqn(2)}$$

where: L_r : unit areal NH_3 -N removal ($\text{g}/\text{m}^2 \cdot \text{d}$)

H_L : hydraulic loading ($\text{m}^3 / \text{m}^3 \cdot \text{d}$)

C_0 : raw water NH_3 -N concentration (mg/l)

3.1.3 Consumption of Alkalinity

According to the nitrification theory, with 1 mg/l of NH_3 -N transformed into NO_3^- , 7.14 mg/l of alkalinity will be consumed. Using the experimental results, the varies of alkalinity (ie, the difference of alkalinity between the raw and treated water) divide by the NH_3 -N removal efficiency (ie, the difference of NH_3 -N concentration between the raw and treated water), resulted in the alkalinity consumption for each unit of NH_3 -N nitrified.

In the BAC Process, at four different hydraulic loadings of $30 \text{m}^3 / \text{m}^3 \cdot \text{d}$, $20 \text{m}^3 / \text{m}^3 \cdot \text{d}$, $12 \text{m}^3 / \text{m}^3 \cdot \text{d}$ and $5 \text{m}^3 / \text{m}^3 \cdot \text{d}$, alkalinity consumed for each unit of NH_3 -N nitrified was found to be, respectively, 8.96, 7.66, 7.77 and 7.66, very close to the theoritical value. Hence the theoritical value can be used as the basis of alkalinity consumption. During the experiments, the treated water pH always remains about 7, indicating that there was sufficient alkalinity in the raw water to complete NH_3 -N nitrification.

3.1.4 Comparison of chemical dosages required for raw water and treated water

The comparison of chlorine demand between raw water and treated water is based on the amount of chlorine needed for break point chlorination. The curves of break point of raw water and treated water are shown in Fig.5. The NH_3 -N concentrations of raw and treated water (at hydraulic loading 20, 12 and $5 \text{m}^3 / \text{m}^3 \cdot \text{d}$) are respectively, 1.318, 0.481, 0.214 and 0.158 mg/l. As shown in fig. 5, the amount of chlorine need for break-point chlorination of raw and treated water are, respectively, 13, 4.5, 2 and 1.5 mg/l. The corresponding ratios of $\text{Cl}_2 / \text{NH}_3$ -N are 9.86, 9.36, 9.34 and 9.49. All these value are greater than the theoritical value of 7.6. The reason is that both raw and treated water contain some organic compounds that will consume some chlorine.

Using the experimental results divide the reduction in quantity of chlorine (ie, the difference of chlorine needed for break-point chlorination between the raw and treated water) by the quantity of NH_3 -N removed (ie, the difference of NH_3 -N concentration between the raw and treated water). It can

be seen that, at various hydraulic loading ($30, 20, 12$ and $5 \text{ m}^3 / \text{m}^2 \cdot \text{d}$), the corresponding reduced quantities of chlorine are about $10.60, 10.52$ and 10.45 times of the removed quantities of $\text{NH}_3 - \text{N}$. The average is 10.20 . Hence the removed quantity of $\text{NH}_3 - \text{N}$ increases when the reduced quantity of chlorine is increased. This will also reduce the magnitude of Trihalo-methane produced.

3.2 Experimental Results of RBC

3.2.1 Treatment Characteristics under Different Hydraulic Loading

According to the experimental results, it can be seen that, as the hydraulic loading increases, the quality of the treated water expressed in turbidity, BOD, COD and $\text{NH}_3 - \text{N}$ removal deteriorates. This is caused by the shorter detention time as the hydraulic loading increases. If insufficient detention time is provided for full reaction, there would be lower removal rates, as illustrated in Fig. 6. In Fig. 6, it can be found that the removal rate of $\text{NH}_3 - \text{N}$ decreases from the highest of 89% to 65.3% when the hydraulic loading increases from $200 \text{ l} / \text{m}^2 \cdot \text{d}$ to $800 \text{ l} / \text{m}^2 \cdot \text{d}$. To a lesser extent this is also true with BOD, COD and turbidity. Thus the removal mechanism of this method was basically nitrification.

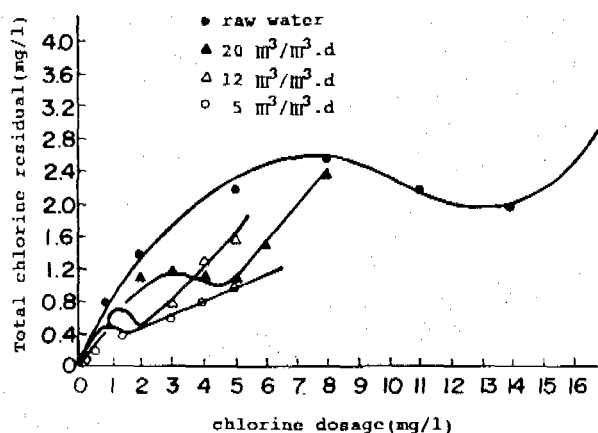


Fig. 5. The relationship between chlorine dosage and chlorine residual of raw and treated water for BAC process

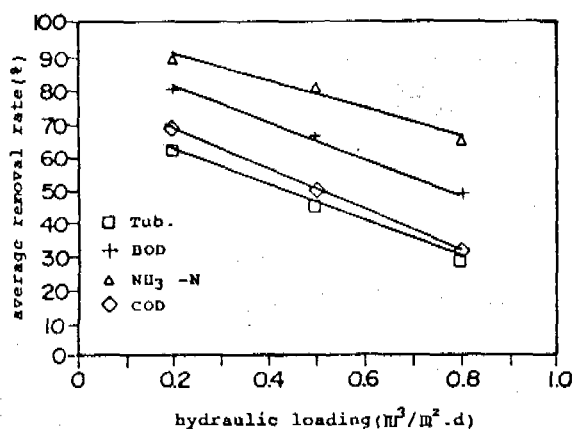


Fig. 6. The relationship between hydraulic loading and removal efficiency for RBC process

3.2.2 The Treatment Characteristics under Different $\text{NH}_3 - \text{N}$ Loading

Divide the $\text{NH}_3 - \text{N}$ concentration of raw water in the experiments into six groups base on their magnitudes. Convert the average of $\text{NH}_3 - \text{N}$ concentrations into corresponding $\text{NH}_3 - \text{N}$ loading under different hydraulic loadings. Compute the average of corresponding $\text{NH}_3 - \text{N}$ removal efficiency and $\text{NH}_3 - \text{N}$ concentration of treated water. Also compute the denitrification efficiency V_r (the $\text{NH}_3 - \text{N}$ removal per unit area) of each group.

A. Relationship between $\text{NH}_3 - \text{N}$ loading and $\text{NH}_3 - \text{N}$ removal efficiency

The relationship between the hydraulic loading and $\text{NH}_3 - \text{N}$ removal efficiency under different $\text{NH}_3 - \text{N}$ concentration of raw water is as show in Fig. 7. It can be seen that, under the same hydraulic loading, the higher the $\text{NH}_3 - \text{N}$ concentration of raw water is, the higher will be the $\text{NH}_3 - \text{N}$ removal

efficiency. However, at lower hydraulic loading ($200 \text{ l/m}^2 \cdot \text{d}$), when the NH_3 -N concentration of raw water increases ($0.33 \sim 4.32 \text{ mg/l}$) the NH_3 -N removal efficiency has not significant effect, and the removal efficiency is always above 90%. But the hydraulic loading increases to $800 \text{ l/m}^2 \cdot \text{d}$, the NH_3 -N removal efficiency decreases. The NH_3 -N removal efficiency increasing is obvious as the NH_3 -N concentration of raw water increases.

B. Relationship among the NH_3 -N concentration of treated water, hydraulic loading and unit areal NH_3 -N removal

$$V_r = Q/A_w (C_0 - C_e) \quad \text{Eqn(3)}$$

where A_w = biofilm area of disks = 3.396 m^2
the other parameters similar to Eqn(1)

It shows that, under the same hydraulic loading, the higher the treated water NH_3 -N concentration is, the faster the nitrification rate will be. Because the treated water NH_3 -N concentration C_e is relatively high, the NH_3 -N loading is relatively heavy and the raw water NH_3 -N concentration C_0 is also high, the unit areal NH_3 -N removal efficiency will increase. The above discussion shows that the hydraulic loading and raw water NH_3 -N concentration have a significant effect on unit areal NH_3 -N removal. Using the various raw water NH_3 -N concentration, hydraulic loadings and the corresponding NH_3 -N removal obtained in the experiments, it leads to the relation formula as the relationship between the relevant parameters was found as follows:

$$L_r = 2.388 \times 10^{-3} H_L^{0.817} \times C_0^{1.056} \quad R^2 = 0.9956 \quad \text{Eqn(4)}$$

where : L_r : unit areal NH_3 -N removal ($\text{g/m}^2 \cdot \text{d}$)

H_L : hydraulic loading ($\text{l/m}^2 \cdot \text{d}$)

C_0 : raw water NH_3 -N concentration (mg/l)

3.2.3 Consumption of alkalinity

In RBC process, at three different hydraulic loadings of 800, 500 and $200 \text{ l/m}^2 \cdot \text{d}$ alkalinity consumed for each unit of NH_3 -N nitrified was found to be, respectively, 7.52, 7.61 and 7.50, very close to the theoretical value.

3.2.4 Comparison of chlorine dosages required for raw water and treated water

The curves of break point of raw water and treated water are shown in Fig. 8. The NH_3 -N concentrations of raw and treated water are respectively, 0.915, 0.413, 0.254 and 0.099 mg/l (at hydraulic loading: 800, 500 and $200 \text{ l/m}^2 \cdot \text{d}$ respectively, for the latter three value). As shown in Fig. 8, the amount of chlorine need for break-point chlorination of raw and treated water are, respectively, 11, 5, 3 and 0.8 mg/l . The corresponding ratios of $\text{Cl}_2 / \text{NH}_3$ -N are 12.02, 12.1, 11.8 and 8.08. All these value are greater than the theoretical value of 7.6. The reason is that both raw and treated water contain some organic compounds that will consume some chlorine.

Using the experimental results divide the reduction in quantity of chlorine (ie, the difference of chlorine needed for break-point chlorination between the raw and treated water), by the quantity of NH_3 -N removed. The results show that, at various hydraulic loading (800, 500 and $200 \text{ l/m}^2 \cdot \text{d}$), the corresponding reduced quantities of chlorine are about 10.12, 10.54 and 10.55 times of the removed quantities of NH_3 -N. The average is 10.20.

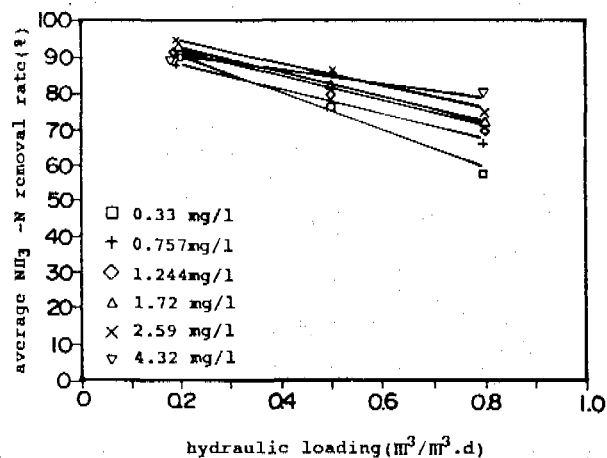


Fig.7. The relationship between NH_3 -N loading and NH_3 -N removal efficiency under different concentrations for RBC process

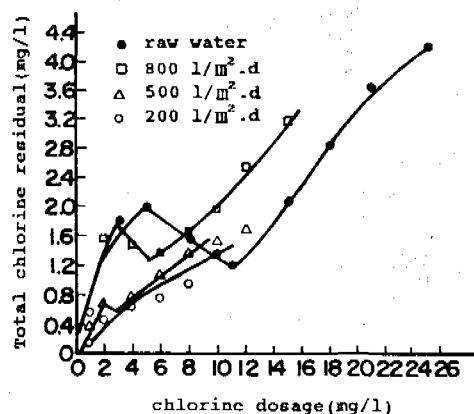


Fig.8. The relationship between chlorine dosage and chlorine residual of raw and treated water for RBC process

4. Comparison of Pre-treatment

Comparatively, these two bio-film processes show higher removal rate than the conventional processes in the pre-treatment of the contaminated raw water, apparently the removal of NH_3 -N. In the meantime, they benefit the reduction of chlorine dosage as well the generation of trihalo-methane. Then the next important question is how these two effective-proven processes be applicable to the public water treatment plant. Per the provision set forth in the Articles 2 to 6 of Taiwan Water Body classification and Water Quality Standards, the water quality of the public supply is classified as shown in Table 2.

Table 2 Water Quality Standards of Public Water Supplies

Grade	Water Use	Water Quality Standards	Remark
Grade A	Public water Supply(Class I)	pH=6.5~8.5, $\text{DO} \geq 6.5\text{mg/l}$ E.Coli, MPN $\leq 50/100\text{ml}$	Raw water is used by disinfection treatment.
Grade B	Public water Supply(Class II)	pH=6.0~9.0, $\text{DO} \geq 5.5\text{mg/l}$ E.Coli, MPN $\leq 5000/100\text{ml}$, $\text{BOD}_5 \leq 2\text{mg/l}$, $\text{SS} \leq 25\text{mg/l}$ NH_3 -N $\leq 0.3\text{mg/l}$, $\text{H}_2\text{S} \leq 0.05\text{mg/l}$	Raw water is used by ordinary water treatment
Grade C	Public water Supply(Class III)	pH=6.0~9.0, $\text{DO} \geq 4.5\text{mg/l}$ E.Coli, MPN $\leq 10000/100\text{ml}$, $\text{BOD}_5 \leq 4\text{mg/l}$, $\text{SS} \leq 40\text{mg/l}$ NH_3 -N $\leq 0.3\text{mg/l}$, $\text{H}_2\text{S} \leq 0.05\text{mg/l}$	Raw water is used by special or higher water treatment.

In view of the water treatment procedures adopted by the public water treatment plant are mostly the conventional method in Taiwan. After the treatment of the surface water, the water quality for the public use is expected to reach grade B as shown in Table 2 .

In the conventional treatment of raw water, the most important step is to removal of NH_3 -N. In order to lift the treatment efficiency and the elimination of odor, the pre-chlorination is the common practice. Doing this the NH_3 -N might consume tiny chlorine, but offer the opportunity for the generation of trihalo-methane. In the biological water treatment , the more

the NH_3 -N is removed, the less the chlorine will be added, and the less chance for generating trihalo-methane, then the water becomes safer for service.

In the raw water pre-treatment, it is strongly recommended that the biological processes shall be so designed as to remove the NH_3 -N as its principal criteria. To achieve the grade B water quality, the NH_3 -N concentration shall be reduced as low as below 0.3 mg/l. As the results shown in the above mentioned two experimentation, while the NH_3 -N reach the grade B standard, the other items of water quality also reach the standards of class II for public water supplies. That is why it is recommended to use the removal of the NH_3 -N as the basic design parameter.

An investigation of all rivers in Taiwan has reported that the NH_3 -N content in river water, the most is at 0.5 mg/l, some as high as 4 mg/l with annual average at 2 mg/l and BOD at 4 mg/l.

In order to precisely understand the benefit of RBC and BCA, three different flow rate with the NH_3 -N concentration at 2 mg/l have been treated by these two methods, namely, 10,000 m^3/d , 30,000 m^3/d and 50,000 m^3/d where 85% of the NH_3 -N shall be removed to the target of 0.3 mg/l. Their individual erection investment, site area requirement, operation cost and other factors are tabulated in the Table 3 for comparison.

Table 3 Comparative Performance Efficiency Between RBC and BCA

Treatment Method	BCA	RBC
Construction Cost	high	low
Loading Variety	Two stages, each stage mixes completely, therefore the loading variety is low	Multi-stages (4 stages) less loading variety
Site Area	Need larger site area	Less site area
Operation cost	high	low
Operation Technique	The blower system requires good care	Driving motor only, less skill required
Sludge Production	high	low
Temperature Influence	low	High. However, the annual average temperature in Taiwan is high which provides positive influence
Proven Record	Japan has one factory	Japan has one factory
Maintenance	Complicated due to blower system	Easy, Unless the shaft breaks. since the organic content is low, the loading is low, no possibility to break the shaft.

5. Conclusions and Recommendations :

This study has set up six pilot plant in the field, three each for experimenting the efficiency of RBC and BCA (fixed-film biological process). The sampling water is the poorly contaminated river water. This study has continued for one whole year, its results are significant and achievement is solid. All values gained from the experimentation are applicable to the public water treatment plant. Our valuable conclusions and recommendations

are listed as follows :

- A. After the pre-treatment of contaminated water by means of RBC or BCA, the treated water quality is greatly lift. It further alleviates the subsequent treatment operating loading and pre-chlorination dosage.
- B. These two methods are very effective to remove the NH_3 -N and organic, particularly the high removal rate for the NH_3 -N. It is obvious that the pretreatment of raw water by the fixed-film biological process is dominated by the nitrification reaction.
- C. In these water pretreatment, the reaction of in nitrification will consume a plenty of alkalinity in the raw water. One unit of the NH_3 -N will require an average of 7.3 ~ 7.6 mg/mg alkalinity which is very close the theoretical requirement of 7.14 mg/l. It shows the fact that the alkalinity content of raw water is sufficient enough to produce a complete nitrification with the NH_3 -N.
- D. The greater the NH_3 -N removal rate is, the less the chlorine dosage will be used. As calculated, the chlorine reduction ratio is 10.17 ~ 10.53 times the NH_3 -N removal ratio. It is apparent that these two methods are excellent substitute in the water pre-treatment.
- E. While the NH_3 -N concentration in the contaminated water is below 2 mg/l, in the RBC process, the hydraulic loading shall be designed at $15 \text{ m}^2/\text{m}^3 \cdot \text{d}$; and in the BCA process, the hydraulic loading designed at $320 \text{ l}/\text{m}^3 \cdot \text{d}$. both method can make the treated water quality to grade B standard (Class II of public water supplies) where the NH_3 -N concentration is below 0.3 mg/l. Other factors such as pH value, BOD, COD and turbidity also can meet grade B water quality.
- F. Comparing the RBC process with the BCA process, the former requires less construction cost, site area and operation cost with high operation stability and reliability. It might be affected by the climate, but shows minor influence. In addition, the former process encounters less trouble, easy for maintenance. This is probably the cause for low trouble because low organic contents in the raw water.
- G. To gain the maximum performance efficiency in raw water pre-treatment in Taiwan, it is strongly recommended to adopt the RBC process for the raw water pre-treatment.

6. Acknowledgement

We are here to extend out hearty appreciation for Taiwan water company with whose full financial support this study can be completed within the schedule.

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EVALUATION OF WATER PURIFICATION SYSTEM REFERRING TO MUTAGENICITY

Yoshinori Kurosawa
Dept. of Water Supply Eng.
The Inst. of Public Health
Tokyo, Japan

Yasumoto Magara
Dept. of Water Supply Eng.
The Inst. of Public Health
Tokyo, Japan

Yoshiharu Hisamatsu
Dept. of Community Env. Sciences
The Inst. of Public Health
Tokyo, Japan

ABSTRACT: We have been studied the biological activated carbon (BAC) processes for water supply from polluted surces. In this report, we studied mutagenicity of treated water in each process, such as coagulation/sedimentation, rapid sand filtration, granular activated carbon (GAC) filtration, and ozonation.

The results obtained from an experimental plant showed that the combination of the coagulation/sedimentation and GAC filtration decreases the mutagenicity, but those of the ozonation and BAC filtration increases it in the certain conditions. The mutagenicity of samples were higher in TA 100 strain tests that means the substitutional mutations in nucleotides.

1. INTRODUCTION

The performance of biological activated carbon, as a method of organic pollutants in raw water for public water supply, was studied in an experimental plant. In a previous paper, the authors reported the results of a study on the removal of various contaminants in a system equipped with either a coagulation and sedimentation process or an ozonation process.¹⁾ In this paper, the performances of water purification processes are evaluated, referring to the behavior of mutagenicity as a new index.

For evaluating organic matter in drinking water, such overall indexes as potassium permanganate consumption value, TOC and THMFP are conventionally referred. However, the use of conventionally indexes seems to be insufficient for evaluation an advanced purification process are installed to treat heavily polluted raw water. For example, ozonation changes the characteristics of organisms in water by degradation although it does not substantially decrease the quantity of organisms. Where aldehyde or other byproducts are produced by ozonation or biological synthetic products are produced by biological treatment, the conventional index can not satisfactorily evaluate the performance of the processes.

The authors examined the performance of coagulation and sedimentation, ozonation, and filtration processes with the use of mutagenicity as well as referring conventional surrogated parameters.

2. METHOD OF EXPERIMENT

An experimental coagulation and sedimentation plant of $4 \text{ m}^3\text{-day}^{-1}$ was used for the experiment. (For the detail of the experimental plant, refer to the previous report¹⁾). The effluent from a collective night soil treatment plant which consists of anaerobic digestion and activated sludge process is applied to city tap water dechlorinated with activated carbon adsorption, this synthetic water adjust to $2 \text{ mg}\cdot\text{l}^{-1}$ TOC was used as experimental water.

Aluminum sulfate was selected as the coagulant and Al/T ratio of coagulation was adjusted to 0.05. Ozonated oxygen was applied so that the ozone concentration became $1 \text{ mg}\cdot\text{l}^{-1}$ in ozonation process.

The effluent from coagulation and sedimentation process was supplied to filters under conditions shown by the flow chart in Fig. 1.

A study was made on five processes, which were: (1) coagulation/sedimentation and biological activated carbon filtration (F-1), (2) coagulation/sedimentation and granular activated carbon filtration (F-2), (3) coagulation/sedimentation and rapid sand filtration (F-3), (4) coagulation/sedimentation, ozonation and biological activated carbon filtration (F-4), and (5) coagulation/sedimentation, ozonation and granular activated carbon filtration (F-5). Filter media filling conditions are shown in Table 1.

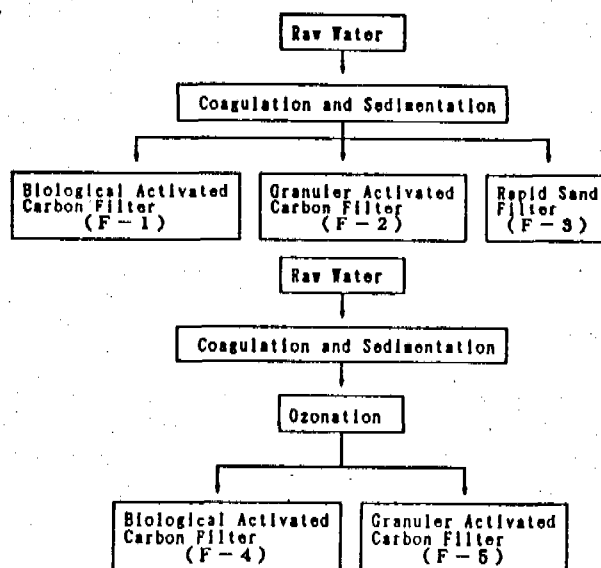


Figure-1 Experimental Flowsheet

For the ozonation and biological activated carbon process, biological film on the surface of activated carbon was developed through a 1107 days filtration

of ozonated water. Consequently, this carbon was considered to be "biological activated carbon".

Filters were washed for 3 minutes so that the expansion ratio

Table-1 Experimental Condition of Each Filters

Filter No.	F-1	F-2	F-3	F-4	F-5
Filter Media	G A C	G A C	S and	G A C	G A C
Filter Size (mm)	0.50~0.59	0.50~0.59	0.50~0.59	0.50~0.59	0.50~0.59
Void Volume (%) *	*82.5	*82.5	46.1	*82.5	*82.5
Bed Volume (g)	761	761	2,300	761	761
Velocity (m·d ⁻¹)	120	120	120	120	120
Filter Area (m ²)	3.0×10^{-3}	3.0×10^{-3}	3.0×10^{-3}	3.0×10^{-3}	3.0×10^{-3}
Retention Time(min)	3.1	3.1	3.1	3.1	3.1

$$* \frac{\text{Total Volume} - \text{Volume of Media}}{\text{Total Volume (50} \times 60 \times 600 \text{ mm)}} \times 100$$

became 200% of filter bed depth. Samples were taken every other week, except those for mutagenicity testing which were taken every season. Sample was analyzed by conventional method for each evaluation item in accordance with conventional employed methods.

Chlorination of samples for the mutagenicity test was performed so as to attain Cl_2/TOC ratio = 5. Samples were treated by XAD-2 resin filter at the filtration rate was 2.5 l per hour. The extracted samples dissolved in dimethyl sulfoxide, and then applied to the mutagenicity test. The bacterial strains used were *Salmonella typhimurium* His⁻ strains TA 98 and TA 100. Assay was carried out according to the method of Ames et al²⁾, with slight modifications including a preincubation step²⁾. Each dose level was tested using duplicate plates.

3. RESULTS AND DISCUSSION

3.1 Pollutant Removal Characteristics Viewed from General Water Quality Items

3.1.1 Removal of TOC

Fig. 2 and Fig. 3 shows changes in TOC removal rate with the time of filtration and cumulative volume of filtrate.

In each filter, TOC removal rate was fluctuated seasonally, that is when the water temperature increased from low temperate conditions the removal rate was increased about 50% in maximum of mean removal rate. then the removal rate was decreased gradually and unstably at end of September when the water temperature began to get lower.

In both cases of ozonation and without ozonation, the GAC filtration systems showed 30-50% of TOC removal, which was higher than all the other cases, and the BAC systems showed 20-40%, while the conventional sand filter system showed 0-50% of TOC removal, which was lower than all the

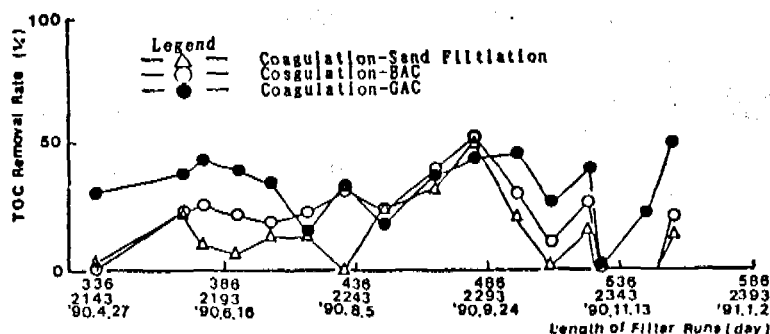


Figure-2 Daily Variation of TOC Removal

X direction shows Length of Filter Runs.

at various condition:
first line, GAC filter process
middle line, BAC Filter process
bottom line, exact date of testing of TOC removal rate

The Removal Rate:

$$\frac{[TOC \text{ in Influent (Coagulation and Sedimentation)} - \text{Effluent}] / \text{Influent}}{TOC \text{ in Influent (Coagulation and Sedimentation)}} \times 100$$

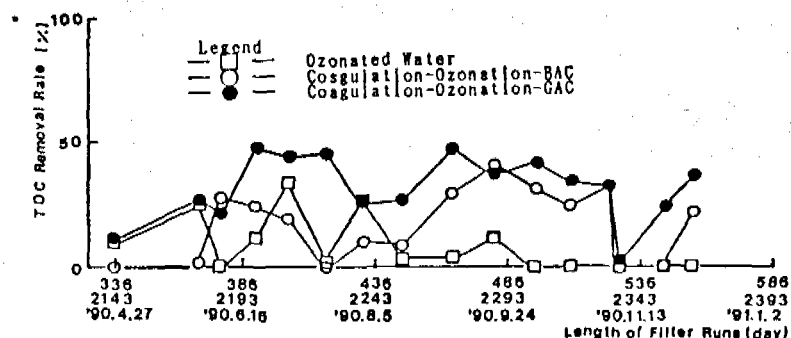


Figure-3 Daily Variation of TOC Removal

X direction shows Length of Filter Runs.

at various condition:
first line, GAC filter process
middle line, BAC Filter process
bottom line, exact date of testing of TOC removal rate

The Removal Rate:

$$\frac{[TOC \text{ in Influent (Ozonated Water)} - \text{Effluent}] / \text{Influent}}{TOC \text{ in Influent (Ozonated Water)}} \times 100$$

systems. This indicates that the GAC systems, although operating for more than one year and having reached the theoretical breakthrough point, still had physical adsorbability. However, TOC removal by the GAC systems in summer, when the running period reached around 450 days, was 25-30 %, which was close to the removal rate by the BAC systems. In spring and autumn, when the water temperature fluctuated, the GAC systems always showed higher performance than the BAC systems. Both GAC and BAC systems did not particularly depend on ozonation. The BAC filter systems showed about 50% TOC removal in summer under a TOC load of $2 \text{ mg} \cdot \text{l}^{-1}$, while the BAC filtration systems showed, as described in the previous report, about 30% TOC removal lower $1 \text{ mg} \cdot \text{l}^{-1}$ load. This implies that the higher TOC load, the higher its removal rate.

3.1.2 Removal of Total Organic Halide Precursors

Fig. 4 shows changes in removal rate of total organic halide precursors (TOXFP) with the time of filtration and cumulative volume of filtrate. The BAC filter and GAC filter, both without ozonation, removed -5 to +50% of TOXFP and -10 to +70% of TOXFP, respectively. The BAC filter and GAC filter, both with ozonation, removed 0-60% of TOXFP and 20-95% of TOXFP, respectively. In short, in terms of TOXFP removal, filtration with ozonation was superior to filtration without ozonation, and GAC filtration was superior to BAC filtration.

Ozonation generally showed low TOXFP removal rates, as low as 0-10%. Nevertheless, ozonation assists further filtration to remove TOXFP; ozonation itself does not reduce TOXFP, which is produced by dosage of chloride.

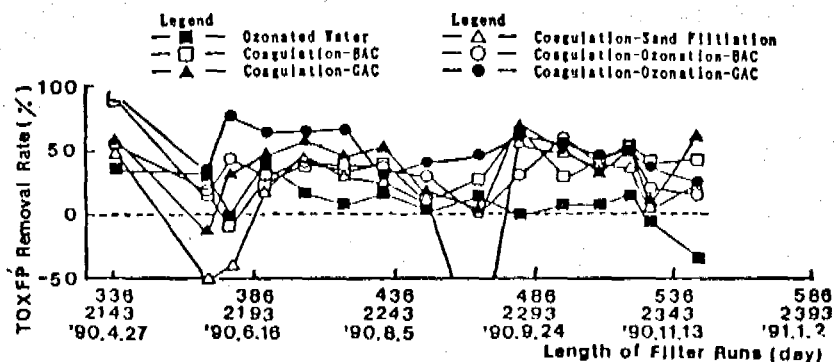


Figure-4 Daily Change of Total Organic-Halide Precursor Removal Rate

Removal of TOXFP tended to decrease in summer when the water temperature increased and in spring and autumn when the water temperature fluctuated, some filter systems showed even minus removal rate. This phenomenon could be explained by that same of TOX precursor as THM precursors shown in above was the metabolite of organisms in filters. In summer, biological activity was stimulated by water temperature rise.

3.2 Characteristics of Pollutant Removal Viewed from Behavior of Mutagenic Substances

Removal of micropollutants in an advanced water purification process was evaluated in accordance to changes of the quantity of mutagenic substances and seasonal changes. The mutagenicity test was carried out using TA98 strain and TA100 strain, and the mutagenicity of dichloromethane extract and methanol extract was studied. Fig. 5 shows an example of the methanol fraction as a result of Ames test carried out on September 4, 1990 (water temperature was high) using TA98 strain (-S-9mix).

The number of revertants in the case of Ames test of the effluent of collective night soil treatment plant, which was used as the seed of experimental water, was 55 per plate when the sample was 0.17 l per plate, and 118 per plate when the sample was 0.33 l per plate. In other words there was the dose and response relationship. Experimental raw water showed 65 revertants/plate when the sample was 16.6 l per plate, also indicating mutagenicity. In the raw water, killing occurred when the sample was 33.3 l per plate.

After the coagulation and sedimentation of raw water, mutagenicity was not observed: the number of revertants was 15 per plate when the sample was 16.6 l per plate, and 12 per plate when the sample was 33.3 l per plate. In contrast, ozonation of the raw water increased mutagenicity: the number of revertants was 80 per plate when the sample was 16.6 l per plate, and 136 per plate when the sample was 33.3 l per plate. As a result of filtration of the raw water, GAC filtration without ozonation reduced mutagenicity: the number of revertants at 16.6 l of sample per plate decreased to 10 per plate. On the other hand, BAC filtration without ozonation increased mutagenicity: the number of revertants was as high as 54 per plate at 16.6 l of sample per plate. BAC filtration with ozonation resulted in 28 revertants/plate at 16.6 l of sample per plate, while GAC filtration with ozonation showed 20 revertants/plate at 16.6 l of sample per plate. In both BAC filtration and GAC filtration with ozonation, mutagenicity decreased in comparison with 80 revertants/plate in ozonated raw water. In this case BAC filtration was inferior to GAC filtration in reducing mutagenicity: the number of revertants was reduced by about 50%.

Based on the results of the experiment, the following questions should be studied: (1) whether ozonation or biological treatment produces mutagen, or; (2) whether ozonation is the cause of precursors of mutagen, which should be mutagen by subsequent reaction with chlorine; (3) how produced mutagenic substances (or their precursors) can be removed in the subsequent processes; (4) how mutagenicity in each processed water.

Concerning (1) and (2) above, biological treatment and ozonation does not produce mutagen because a sample did not show mutagenicity until the sample was increased to 20 l per plate. But if same sample was chlorinated, the mutagenicity of chlorinated sample was increased. Therefore, biological processes and ozonation produced mutagenicity precursors similarly to the case of trihalomethane.

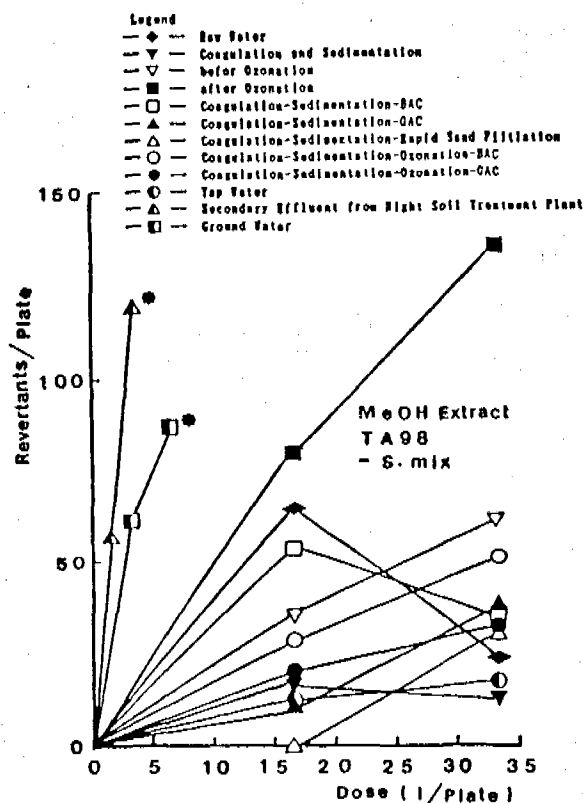


Figure-5
Mutagenicity of
Processed Waters
in summer

•: Scale for these two cases
is 0 to 3.5 (l/Plate)

In order to clarify (3) and (4) above, we attempted to determine the ratio between the number of revertants in the objective samples and the number of revertants in samples at individual process, specific mutagenicity.

Table 2 shows seasonal variation of specific mutagenicity as an example of methanol extract using TA98 strain. Mutagenicity in raw water was 1.4 revertants/plate at a sample quantity of 33.3 l per plate in spring, 1.7 revertants/plate in summer, and 4.9 revertants in autumn. Mutagenicity in winter is assumed from existing data to be 3.2 revertants/plate because data on the same sample quantity is not available. In conclusion, specific of raw water is in the descending order of seasons: autumn, winter, summer, and spring.

Seasonal changes of mutagenicity depend on water purification processes. For example, in the coagulation and sedimentation process, mutagenicity decreased in all the seasons; however the decrease in summer and autumn, when the mutagenicity was higher, was about 50% of the decrease in the other seasons. Ozonation increased mutagenicity strength up to 1.1-2.1 times (1.8 times on average) of mutagenicity in the coagulation and sedimentation effluent.

Table-2 Seasonal Effects Against Mutagenic Activity
(MeOH Extract TA98 -S-9mix)

Season Processes	Spring		Summer		Autumn			Winter	
Dose (l/Plate)	8.3	33.3	16.6	33.3	8.3	16.6	33.3	16.6	33.3
Raw Water	—	—	3.0	—	3.2	5.2	4.9	2.0	2.8
Coagulation	—	2.4	—	—	—	2.4	2.4	—	2.3
before Ozonat	—	2.1	2.1	2.9	2.1	2.8	3.7	—	2.4
after Ozonat	—	3.7	3.5	5.3	3.8	4.4	7.9	2.9	4.0
Sand Filtrat	—	3.1	—	—	—	2.2	3.1	—	—
Coagulat-BAC	—	3.1	2.7	2.1	2.1	3.0	2.1	—	3.3
Coagulat-GAC	—	2.1	—	2.2	—	2.4	2.5	—	—
Ozonat-BAC	—	4.2	—	2.6	2.4	2.4	3.3	—	2.1
Ozonat-GAC	—	—	—	2.0	—	2.5	4.8	—	—
Tap Water	—	2.3	—	—	—	2.9	2.9	2.6	3.8

Date of Testing. Spring Season: 1990. 6. 7. Water Temperature: 22.0°C

Summer Season: 1990. 9. 4. Water Temperature: 28.0°C

Autumn Season: 1990.11. 5. Water Temperature: 17.5°C

Winter Season: 1991. 2. 4. Water Temperature: 9.7°C

—: Tested but less than two-fold of control

In case of filtration without ozonation, specific mutagenicity after GAC filtration remained 0.7-1.6 (average

1.0) of that before the process; the GAC filter neither decreased nor increased specific mutagenicity. Specific mutagenicity after BAC filtration became 0.9-2.2; BAC filtration increased specific mutagenicity by about 50% on an average, increased particularly in spring and summer. Rapid sand filtration, which is a conventional water purification process, may also increase mutagenicity, but no so much as ozonation or BAC filtration.

In case of filtration with ozonation, specific mutagenicity after the BAC process was 0.4-1.1 (average 0.6), while specific mutagenicity after GAC process was also 0.4-1.1 (average 0.6). This means that BAC filtration and GAC filtration can reduce mutagenicity precursors by 40-60%, and particularly significantly in summer, autumn and winter. However, GAC and BAC processes are sometimes not able to reduce specific mutagenicity to the level before chlorination. However, ozonation accelerates production of mutagenicity precursors that can be generated by the subsequent chlorination, but the precursors are easily removed by activated carbon adsorption and biological treatment. Dichloromethane extract using TA98 strain, although details are not shown here, indicated results similar to the results on methanol extract.

A study on the effect of low temperature in winter was made using TA100 strain. In methanol extract, almost no mutagenicity was observed on any sample when the sample quantity was 13.3 l per plate, while positive mutagenicity was observed on many samples when the sample quantity was 26.6 l per plate. Similarly to the case of TA98 strain in summer and other seasons, rapid sand filtration and BAC filtration accelerated mutagenicity of TA100 strain. Ozonation also temporarily increased mutagenicity. However, BAC filtration and GAC filtration decreased the mutagenicity again, similarly to the case of TA100 strain in summer and other seasons. Compared with TA98 strain, TA100 strain showed relatively lower mutagenicity. For dichloromethane extract of TA100 strain, the number of revertants could not be counted because killing occurred.

It has been clarified that, in general, rapid sand filtration and BAC filtration increase mutagenicity and, particularly, BAC filtration throughout seasons increases specifically mutagenicity. In contrast, GAC filtration, with and without ozonation, decreased mutagenicity. GAC filtration without ozonation decreased mutagenicity under given conditions; however, it may increase mutagenicity higher than in coagulation and sedimentation treated water in case of a high dose.

The above results indicate that mutagenicity of raw water is higher in autumn than in spring and summer and decreases in winter. This phenomenon was due to the character of night soil treatment secondary effluent which was used as polluted raw water on the experimental plant. Because the water temperature was high in summer and autumn 1990, the biological activity of activated sludge at the night soil treatment plant was high, and therefore the raw water from the plant contained a lot of biological metabolic waste. Consequently, mutagenicity decreased in winter when biological activity decreased due to decreased water temperature, and was lowest in spring when organisms delayed in adaptation to water temperature increase. Mutagenicity in coagulation and sedimentation treated water decreased in autumn and spring when the water temperature was low and unstable. This relates to the quality of coagulation which depends on water temperature. In contrast, ozonation, mutagenicity did not decrease substantially in winter because the decrease in water temperature increased the efficiency of reaction between ozone and organisms.

BAC filtration significantly increased mutagenicity not only in summer but also in winter than the coagulation and sedimentation process. However, rapid sand filtration, which has also same biological activity, decreased mutagenicity in winter. It is considered to be the cause of this difference that, although the activity of organisms attached to the filtering material begins to decrease when the water temperature decreases 10°C or lower, activated carbon whose complicated porous construction reduces the effect of water temperature and allows metabolite, which becomes mutagenic substances, to grow continuously. In the case of BAC filtration with ozonation, however, the mutagenicity of ozonated water decreased in winter by more than in summer. In contrast, GAC filtration decreased mutagenicity not only in summer but also in winter in both cases of ozonation and without ozonation.

Samples used for mutagenicity in summer were immediately filtered with a 0.45 μ m membrane filter, then tested for general water quality testing items. The results are shown in Table 3. The results of general water quality analysis shown in Table 3 do not fully agree with the results of mutagenicity test shown in Fig. 5. For example, when water after the coagulation and sedimentation process was ozonated, its quality represented by TOC, potassium permanganate consumption value and fluorescent substances decreased, while the mutagenicity in ozonated water was higher than that in coagulation and

sedimentation treated water, as shown in Fig. 5. This phenomenon have been induced by a known characteristic of ozonation, since: ozonation degrades large molecular substances and converts hydrophobic substances into hydrophilic substances, although it does not much decrease the absolute quantity of organic substances.

Table-3 Qualities of Water
After Treatment Processes

Treatment Processes	Raw Water	Coagulation	Ozonation	F-1 Coag. BAC	F-2 Coag. GAC	F-3 Coag. Sand	F-4 Ozon. BAC	F-5 Ozon. GAC
TOC ($\text{mg}\cdot\text{l}^{-1}$)	3.0	2.8	1.9	1.1	1.0	2.3	2.7	1.2
E_{254}	0.067	0.020	0.022	0.018	0.010	0.024	0.017	0.007
PV ($\text{mg}\cdot\text{l}^{-1}$)	9.0	3.3	2.7	2.8	2.0	4.7	2.3	1.1
Fluorescen Sub	79.8	77.7	45.8	45.8	18.6	89.2	27.9	8.1
THM ($\mu\text{g}\cdot\text{l}^{-1}$)	6.2	0.9	0.7	2.8	2.6	4.9	1.0	2.1
THMFP ($\mu\text{g}\cdot\text{l}^{-1}$)	29.9	14.3	11.9	11.6	10.3	13.9	10.1	6.9
TOX ($\mu\text{g}\cdot\text{l}^{-1}$)	57.4	50.4	52.7	99.1	43.5	35.8	18.5	36.1
TOX FP ($\mu\text{g}\cdot\text{l}^{-1}$)	323.3	117.5	105.5	54.1	71.6	148.0	125.8	57.5
Cl_2/TOC Ratio	4.4	5.7	5.0	5.1	5.3	6.0	6.4	5.7

For Steps of Treatment, see Fig. 1

Date of Testing. 1991. 9. 4, Water Temperature: 28.0°C

4. CONCLUSION

The results of the experiments on advanced water purification plants lead to the following conclusion.

It has been clarified that coagulation and activated carbon adsorption decrease mutagenicity while ozonation and biological treatment such as BAC filtration increase mutagenicity under certain conditions. It may be concluded that, to secure water safety viewed from mutagenicity, long-term use of activated carbon as BAC is not desirable. In this case, since TA100 strain showed strong mutagenicity in samples from various water purification system, mutagenicity of substitutional nucleotides is considered to be induced from mutagenicity of flame shift type.

The results of experiments revealed that conventional indexes of water quality do not always agree with the indexes of mutagenicity test. Consequently, when raw water polluted to such an extent that advanced water purification must be employed for a water treatment plant, mutagenicity testing should be performed in addition to testing for conventional water quality items.

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Figure-1 Experimental Flowsheet

Figure-2 Daily Variation of TOC Removal

Figure-3 Daily Variation of TOC Removal

Figure-4 Daily Change of Total Organic Halid
Precursor Removal Rate

Figure-5 Mutagenicity of
Processed Waters
in Summer

Table-1 Experimental Condition of Each Filter

Table-2 Seasonal Effects Against Mutagenic Activity

Table-3 Qualities of Water After Treatment Processes

TRENDS IN WATER TREATMENT - APPLICATION IN MALAYSIA

F.W. Crowley
OBE BSc FICE FIWE
Binnie & Partners
Surrey, Great Britain

INTRODUCTION

Consideration of every conceivable treatment process in current use for drinking water supplies is well beyond the scope of this paper and would not assist readers in Malaysia to understand the reasons for the development of new processes elsewhere in the world and especially in the United Kingdom. Attention is therefore focused on those processes new and traditional which would have application in Malaysia.

In many countries there has been a progressive development of detailed regulations governing drinking water quality with a fundamental objective of securing reliable drinking water at a time when natural supplies are becoming increasingly contaminated as a result of urban and industrial development. The extent to which advanced treatment processes are used depends on a number of factors including the actual detection of contaminants, the cost and benefits of removing them and the sensitivity and demands of consumers. As water quality standards become more stringent then additional treatment stages are necessary some of which have to be advanced and sophisticated processes which are not always suitable for developing countries.

WATER QUALITY

During the last decade tremendous attention has been focused on improving the quality of drinking water particularly so in western Europe and in the United States of America. The motivation for this probably stems from a greater appreciation by all that water is an extremely valuable commodity and that natural supplies are becoming increasingly contaminated as a result of urban and industrial development. A logical development of this has been the introduction of new water quality regulations to ensure continuing improvement to the purity of drinking water.

The development of regulations in the United States and in Europe¹ have been quite different. The USA have had drinking water standards as far back as 1914 with the periodic tightening of standards and regulations are now being developed to meet a phased programme of setting new standards up to 1995. By contrast, until the passage of the Water Supply (Water Quality) Regulations 1989, water undertakings in England and Wales were required to supply "wholesome" water but there was no definition as to what this actually meant. The 1989 regulation closely followed the EC drinking water directive² which was first published in 1980 and the combination of these has prompted new approaches to water treatment in order to achieve compliance. Examples of more stringent standards for compliance are lead, nitrate, colour, iron and manganese. Of great significance has been the importance attached to the reduction of trihalomethanes (THMs) in drinking water because of the association

with carcinogens. The THMs are formed along with other disinfection byproducts when water containing natural organic compounds is chlorinated. As a result great efforts have been made both to try alternative methods of disinfection and to reduce organic material in the raw water.

A great deal of research and technological development has taken place over the last few years in processes for the removal of trace organic compounds in water. Pesticides and insecticides are within this group of chemicals to be removed from drinking water and this poses very difficult problems in agricultural areas which are used as sources of water supply.

The processes used for the removal of organics from water can have important side benefits in relation to taste and odour control. Removal of taste and odour are looked upon by water undertakers as important to satisfy their customers by improving the attractiveness and acceptability of drinking water.

The subject of drinking water quality and compliance with EC standards continues to receive intensive media coverage in England and Wales suggesting to some that quality is inferior and may pose health risks. This is strenuously refuted by the water undertakers who claim the water quality supplied is already of an exceptionally high standard and will improve even more with the completion of development programmes.

CONVENTIONAL TREATMENT

Historically, conventional treatment of drinking water supplies has been built up in stages each stage representing an additional safety barrier to the passage of contaminants in the raw water. The simplest form of treatment in a single stage is some form of disinfection usually chlorine and this is still appropriate for clean ground water free from organic or some other form of contamination. The addition of sand filtration to disinfection provides the second stage of treatment and many waters are still treated in this way usually with the addition of a small dose of coagulant and with pH adjustment. Sand filtration may be slow, rapid gravity or pressure with variations on each such as the substitution of sand by anthracite or carbon as the filtration media. Typically the third stage of treatment is a clarification stage which may take many and varied forms of design from a non chemical settlement basin to an advanced high flow rate design of clarifier.

The three stages of treatment described are found throughout the world and whatever justifications are found for more advanced treatment techniques the clarification, filtration and disinfection stage will continue to be the workhorses of the treatment cycle for drinking water. There is always the danger that the inclusion of advanced processes such as ozone and granular activated carbon for the removal of micro quantities of contaminants will be done at the expense of optimising coagulation, clarification and filtration which usually remove in excess of 98% of the contaminants present in most raw waters when they are operated efficiently.

IMPACT OF QUALITY REGULATIONS

From the early 1970s it was known that the use of chlorine for disinfection could lead to the formation of potentially hazardous compounds such as trihalomethanes. The limit of 100 $\mu\text{g/l}$ which was first set in the USA and then adopted by the UK has had a major impact on water treatment. Many water undertakings set a much lower limit than 100 $\mu\text{g/l}$ for water leaving the treatment works. The lower figure is set on the basis that many supply systems have secondary chlorine dosing in the reticulation systems and if there is organic debris in the pipes the THMs will undoubtedly rise with the addition of more chlorine.

A number of treatment strategies can be used to limit the formation of THMs. An obvious one is to make a significant reduction to the natural organic content of the raw water. This is especially so where the bacteriological quality of the raw water is poor and there is a need to prechlorinate the water for that reason alone. In the UK the official advice³ has been that any health hazard associated with disinfection byproducts will be extremely small and that efficient disinfection should on no account be compromised by efforts to minimise them. It seems more than likely that future treatment cycles will include a dedicated organic removal stage which will then permit high chlorine doses to be applied when necessary without excessive THM formation.

Many water undertakings have successfully controlled THM formation by reducing the intensity of chlorination or eliminating prechlorination altogether. At some works inter-stage chlorine addition has been successfully used to combat THM formation even though the total chlorine dose applied may amount to the same. It is usually worth trying.

Apart from THMs a large number of chlorination byproducts have been identified in recent years and many are known to be potentially hazardous⁴. As a result there was initially a marked swing towards the use of alternative disinfectants such as ozone and chlorine dioxide; more recently however a more cautious approach is being taken to change from chlorine due in part to the lack of information on the nature and toxicology of byproducts arising from the alternative disinfectants.

The regulations impose low limits for inorganic metals and compounds such as lead and nitrate. Lead has posed particular problems for many European countries because lead plumbing was used over many decades in houses and buildings. The evidence of lead in drinking water is especially prevalent in areas where the water is acidic and there is little or no natural alkalinity to give a protective lining to the pipes. To replace all the lead pipes over a short period is enormously expensive and the usual immediate solution is to provide chemical dosing such as orthophosphoric acid for protection against lead dissolution.

Wherever intensive agricultural practises are used the nitrate levels are liable to be a problem and likely to exceed permitted regulation limits especially when water is derived from groundwater; surface waters in such areas usually have seasonal incidence of high nitrates. Many areas are like this in Europe and as a consequence there has been accelerated development of nitrate removal processes. Where blending

with a low nitrate water is impossible then the two main nitrate reduction processes in use are ion exchange and biological denitrification. Membrane processes such as electrodialysis reversal (EDR) and reverse osmosis have also been used. Nitrate reduction is generally costly in capital and costly to operate and it is specific to nitrate reduction unlike some other processes which have important side benefits.

Many emotive words have been written and spoken in the last few years about the health hazards associated with synthetic organic compounds. A wide range of these compounds have been detected at low concentrations in drinking water and limits have been set for some of these on the basis of possible effects on health. Pesticides and insecticides are an important and diverse group of chemicals some of which are commonly found in agricultural areas at trace levels in both ground waters and surface waters. These substances are practically unaffected by conventional water treatment and their removal will usually require the inclusion of additional treatment processes. The two processes which are most commonly used are oxidation with ozone and adsorption on to granular activated carbon (GAC) in filter beds. Extremely low limits have been set for pesticides in the regulations and their removal present water undertakings with a considerable challenge. Expensive treatment by the addition of GAC plus an extended contact time for disinfection plus advanced oxidation processes such as ozone and hydrogen peroxide may be commonplace in the future.

It has been found that some ground waters and particularly those in built up areas are contaminated with trace concentrations of volatile organic compounds (VOCs) which are used as solvents in industry. The regulations impose stringent values and as VOCs are not removed by conventional water treatment processes then special treatment has to be applied. Unfortunately the substances are not biodegradable and resist breakdown by most oxidants including ozone. Packed tower aeration is generally effective with adsorption by GAC as an alternative or in conjunction with a powerful oxidant.

DEVELOPMENT OF TRADITIONAL PROCESSES

The preceding section described some of the ways in which water undertakings in the UK and continental Europe are having to provide process design changes in order to meet the challenges of stringent new water quality regulations. Most of the processes can be accommodated as extra stages of treatment to existing works and only occasionally is a complete re-build necessary. It is probably true to say that in the stimulating and challenging climate of discovering and applying new processes so as to improve drinking water quality further and further little attention has been paid to the improvement of clarification and filtration technology and the optimising of chemical treatment. Current strategy is of course one of diminishing return as the greater the purity achieved the more expensive it becomes for each successive contaminant removal stage.

This diversion from the traditional processes of clarification and filtration over the last decade is in many ways unfortunate as most countries throughout the world still depend on a basic three stage process for purification. Many countries continue to follow World Health Organisation guidance and in 1984 the Organisation published 'Guidelines for Drinking Water Quality (GDWQ)'. The object of this publication was to provide guidance to national organisations wishing to set their own drinking water standards. In fact like its predecessors of 1958 and 1971 GDWQ commanded great support and the Guideline Values (GVs) have been adopted as national standards in many countries. The background to this is that instead of setting Maximum Admissible Concentrations (MACs) as did the EC Directive, GDWQ set GV's with the intention that in setting a national standard, the GV's should be adopted to suit local dietary and socio-economic circumstances. GV's were based on an assumed lifelong consumption and subject to medical advice can be exceeded for a long time.

This approach to standards means that for many countries a more pragmatic approach is taken where the priority is very often a plentiful supply of 'wholesome' water rather than the elimination of every micropollutant for questionable medical reasons. Thus the improvement of the traditional processes of disinfection clarification and filtration remains of great significance and importance to such countries and will continue to be so.

Prechlorination

The deliberate reduction of prechlorination levels generally replaced by the use of inter-stage chlorine addition was referred to earlier the objective being to reduce the risk of THM formation. Another change in disinfection practice has been stimulated not by drinking water standards but by tighter health and safety regulations relating to the storage of chemicals and in particular to liquified chlorine gas. In the UK for instance there is a growing number of treatment works where plant for the electrolytic production of sodium hypochlorite has replaced the use of gaseous chlorine, thereby avoiding large, potentially hazardous liquid chlorine stores. A secondary benefit is the avoidance of transporting liquid chlorine and so eliminating potential road and rail accidents. Nowadays chlorine addition to final water is almost universally done using automatic control to a preset residual using sulphur dioxide to trim the chlorine to the required level.

Clarification processes

The development of clarification processes has been very slow over the past decade and this is probably because researchers contractors and consulting engineers have concentrated on the development of the more exotic processes for the reasons stated earlier in the paper. In Europe there was a major increase in chemical clarification technology in the 1960s and 1970s at a time when more water was urgently required to meet the needs of a reviving industry and a growing population. Floc blanket and solids recirculation clarifiers were very popular for the treatment of raw waters with colour and suspended material and of course chemical

softening was then still in vogue. The geometry of these tanks and the overflow rates used (up to about 3.5 m/h) meant that the tank volume usually contained the equivalent of 1½ to 2 hours throughput at the design flow. In some tank designs chemical mixing tended to be neglected the theory being that the mixing achieved in the tank itself and within the sludge blanket was sufficient to provide adequate velocity gradient for efficient mixing and flocculation.

It is of interest to contrast this with the situation in the USA. As far back as 1942⁵ a US Public Health Service Manual of Recommended Water Sanitation Practice suggests that an ideal combination of flash mixing and flocculation would provide about 1-2 minutes of violent agitation followed by 20-30 minutes of slow mixing to promote flocculation. The whole sedimentation basin to be designed to provide a total retention period of at least 5-6 hours. At the same time chemical mixing theory had advanced a great deal in the USA but there has always seemed a strong reluctance to apply this understanding of chemical mixing theory and design other than to the fine tuning of horizontal flow and solids recirculation tanks. This still seems to be the case through the 80s and into the 90s.

Some advances to liquid solids separation techniques have occurred in the UK despite the preoccupation with the more exotic processes for the removal of micropollutants. Progressive development has occurred in the UK and in France to sludge blanket tanks to reduce construction costs and to achieve higher flow rates. In the UK the geometry of the tank has been changed from a conical shape to a flat bottom and in France the design of the Pulsator tank was modified to include inclined plates. A sand seeded sedimentation tank design has been resurrected which was first known in the UK in the late 60s and was built before then in Hungary.

The most significant development in clarification technology over the last few years in the UK is the use of dissolved air flotation (DAF) for the treatment of coloured waters and those with algae. The process is very suitable for stored waters which have low suspended solids and there are also a few examples where it has been used for the treatment of river waters without any intermediate treatment. The DAF process has been widely used for drinking water and with great success in countries in western Europe particularly in Scandinavia and with technology initially borrowed from industries such as mining, paper and paint. To meet the stringent water quality standards which most water undertakers now set for the effluent from a clarification stage it has been necessary to reappraise the systems for chemical flocculation, air bubble distribution, the water flow path and sludge float removal to optimise performance and this work is ongoing.

The Sirofloc process is relatively new originally patented in Australia and makes use of magnetite to adsorb principally colour and colloidal material from raw water. Magnetite has a charged surface in an aqueous suspension being positive at low pH and negative at high pH. Low pH conditions (by acid addition) are used at initial contact of the magnetite with the raw water and then passed through a magnet before entering the clarifier where settlement occurs.

Magnetite is recovered from the sludge by raising the pH with caustic soda and after washing in rotating magnetic separators is returned to the inlet of the works. The waste material so obtained is minimal and can be treated and disposed of like any other clarifier sludge.

There are a number of other processes which have been used for drinking water but application is limited to particular circumstances or the nature of the raw water. Examples include ion exchange, biological removal of iron and manganese, ammonia reduction by biological nitrification and membrane processes. They are not in widespread use and it is thought unlikely to have any major impact in the immediate future in Malaysia for drinking water treatment.

Filtration

Before the 1980s when granular activated carbon (GAC) became a popular filtration media, there was a strong trend in many European countries towards dual media filters such as anthracite overlying sand. This arrangement required a wash system of water only or water and air separately applied. Dual or multilayered filters then lost popularity in favour of single sized sand media and the use of combined air and water wash. There was a noticeable trend towards such a wash system which had been used for many years in France and Germany and a number of specialist contractors produced their own designs of false floors and nozzles with a plenum chamber below.

More recently the use of GAC as a single media in filters has reversed this trend in backwashing technique and separate air and water wash is used as it is less liable to carbon loss. Surface sweeping during the final stages of washing is still used in some designs, but there is less emphasis placed on its importance. There are still many different designs in common use from shallow media (0.5 m depth) to deep (>2 m) beds, from the use of single sized to mixed size media and from wholly sand to mixtures of sand, anthracite, carbon, garnet and so on. Filtration velocities vary from 4 m/h to 15 m/h at the upper end. A common trend throughout is the use of air for backwashing either in conjunction with water or applied separately.

Like clarification there has been a reluctance in the USA to change from traditional practice of using a high velocity water wash only with elevated troughs for washwater removal. Gradually it appears a more flexible approach is occurring to the provision of backwash facilities and although there is still a preponderance of high velocity water wash systems, there are now a number of new plants using either separate air and water washing or a combination of the two.

Few changes have occurred in the way filters are hydraulically designed and controlled except that modern electronic control systems are almost universal with electrically powered actuators for valves in preference to water hydraulics oil hydraulics or pneumatic systems. Declining rate systems have come to stay especially in large works. For water quality control through filters it is now quite common to have individual turbidity meters installed on each filter outlet although expensive to install.

Slow sand filtration continues to be recognised in Europe as an efficient form of treatment, especially for polishing following some other form of treatment which does not involve chemical coagulation. Few dispute the attributes of slow sand filters for bacteriological improvement and virus removal, but its application is limited to relatively low turbidity waters free from filter blocking algae. The biggest constraint to more widespread use is land area, but in appropriate circumstances slow sand filters are installed with pre-roughing rapid gravity filters or pre-ozonation.

In the last ten years considerable progress has been made with sand cleaning methods. These include travelling bridge cleaning without external sand removal similar to the methods employed in some designs of continuously operating rapid gravity filters.

Sludge treatment

Water undertakings are no different to major industrial concerns and no-one relishes having to install expensive waste treatment and disposal facilities when there is no return on capital investment. Attitudes are changing quite rapidly however due to legislation which prohibits indiscriminate dumping of wastes on land or discharge to watercourses. There is therefore an acceptance nowadays that an efficient form of sludge treatment is both desirable and necessary to meet the new legislation and in the UK land shortage usually points the way towards a system of mechanical dewatering by plate pressing or by centrifuge. As a pretreatment stage before mechanical dewatering WRC⁶ developed a continuous sludge thickener in the 1980s which is designed for desludging underwater and allows a continuous cycle to proceed of filling, decanting and desludging.

Plate pressing has been used for several decades for both drinking water treatment and for sewage treatment but a recent development of the recessed plate design is the membrane plate press which has been installed on a number of works. A horizontal stack of plates and cloths is firmly clamped together between a heavy fixed end plate and a similar moving end plate with sludge pumped through the centre. The dewatered sludge cake is held between adjoining cloths and when pressure is released drops below with the filtrate passing through the cloth to the end of the stack.

APPLICATION TO MALAYSIA

What benefits can Malaysia derive from the developments which have occurred elsewhere in water treatment technology?

Should Malaysia stick to proven practices of water treatment which have served them so well over the years or should the water authorities opt for new and usually more complicated forms of treatment to achieve the same objective of high quality water?

These are not easy questions to answer, more so when financial resources are readily available to pay for more expensive treatment processes if they are indeed needed.

For many parts of the country Malaysia is blessed with a plentiful supply of water and there is a mixture of reservoir stored water sources and direct abstraction from rivers and it is believed the latter predominate by a big margin. Unlike the UK which obtains about 40% of its drinking water supplies from ground water, Malaysia has few examples.

Treatment of the majority of river waters in Malaysia is generally straightforward responding well to pH conditioning (lime or sodium aluminate) followed by chemical coagulation usually with aluminium sulphate. Disinfection is nearly always with chlorine and the use of ammonia for chloramination is not uncommon. Floc formation generally tends to be on the fluffy side when suspended solids are low and pH control becomes sensitive for the best settlement results. As with many tropical countries the phenomenon of rising floc or sludge blanket is a common feature during the hottest part of the day.

In recent years the design of new treatment works has tended towards well proven conservative designs. A rapid survey⁷ of Rural Water Supply Schemes constructed since the 1960s showed that 85% had horizontal flow designs (63% of which were lovo) and two of the horizontal tanks had been uprated with tube settlers. For the whole of peninsula Malaysia it is understood the design of clarification tanks included in water supply schemes follow the same pattern there being about 70% horizontal flow (of which 52% are lovo) and only 8% using sludge blanket designs. There are a few radial flow designs (4%) and then the balance are where a clarification stage is unnecessary and treatment is a mixture of slow sand and pressure filtration. Rapid gravity filtration practice is conventional with a mixture of separate air and water pipe lateral systems and combined air and water washing.

For Malaysia it seems eminently sensible to make use of clarification designs which are familiar to operators and which operate with the minimum of trouble. Rivers are usually subject to rapid changes of solids loading and for direct river abstraction schemes there is a need to absorb these changes without affecting performance. A horizontal flow tank meets this criteria and there is then merit in research effort to optimise all the features of the design. Amongst these would be mixing (hydraulic or mechanical), entry and distribution condition at inlet, the adoption or otherwise of a single inclined tray (lovo design) or possibly a multi-tray design, outlet collection (for example single or multiple launders), vee notch or submerged orifice overflow, sludge discharge arrangements and so on.

For stored waters which are usually more consistent in quality than a direct river source then the opportunity could be taken to try out alternative or new treatment processes. The DAF process seems to be an obvious choice for coloured or algae laden water and where the water undertaking itself is confident the operating staff can manage the greater range of mechanical/electrical equipment included in a DAF design. There is no other newly developed clarification process which springs to mind which might have significant benefits to Malaysian water treatment practice.

In waters with high organic content and where the potential for THM formation exists with prechlorination then the practice of inter-stage chlorination is worth trying.

Rapid gravity filtration in Malaysia is generally based on sound practice built up over many years and there seems no obvious reason to change other than to provide for combined air and water washing whenever possible.

So far this section has looked at the appropriateness of departing from what has become conventional water treatment designs in Malaysia. One step further is to try and anticipate what will be needed in the future in the face of changing water quality regulations. Elsewhere in the world urban and industrial development has resulted in a deterioration of the environment including rivers and water sources. The type of contamination resulting is likely to cover the whole range of microbiological chemical and synthetic organic compounds including all those which are non biodegradable. Although active steps are being taken by the authorities to try and contain the extent of contamination it would be foolhardy to suppose that prevention will be complete and therefore water supplies dependent on these sources will have to provide additional treatment. This need will very likely be reinforced by the publication of new WHO Guidelines in 1993 or 1994 which are expected to contain a much extended range of chemical standards. The effluent resulting from industries such as palm oil factories, latex factories and from timber preservatives contain very high levels for Chemical Oxygen Demand (COD). If not already in hand it would seem very appropriate for Malaysia to devote resources to research programmes to identify the nature of the compounds constituting the high CODs and to test advanced processes such as ozone, GAC, hydrogen peroxide and other unit processes for their removal.

As industrialisation and urbanisation continues to proceed at a rapid pace it would seem almost inevitable that Malaysian water undertakings will be forced to plan to incorporate these advanced treatment processes for the treatment of water derived from rivers subject to such contamination.

CONCLUSIONS

It is reasonable to suggest there is a common objective throughout the world to provide people with safe drinking water of the highest possible purity consistent with the financial resources available.

In many European countries and in the United States of America new water quality regulations which are mandatory in their application have forced water undertakings to research and develop new treatment process to meet these standards. The work is ongoing as scientists detect more substances in micro quantities with potential health hazards.

Advanced treatment processes which are now becoming increasingly common in order to meet new drinking water quality regulations include alternative disinfectants (ozone, chlorine dioxide and change to electrochlorination), nitrate removal, treatment against lead

dissolution, oxidation with ozone (sometimes combined with hydrogen peroxide) and GAC filtration.

This attention to new and exotic processes has tended to deflect attention from conventional treatment stages (disinfection, clarification and filtration) which will usually account for over 99% removal of contaminants in a raw water. This is probably unfortunate for those less developed countries which are never likely to have the financial resources to provide for enhanced treatment processes such as ozone, GAC or hydrogen peroxide.

The paper suggests that water undertakings in Malaysia should continue to concentrate on optimising the conventional treatment processes which are well proven over the years. Additionally to be very much aware of the likelihood that in future the more advanced processes will be necessary as industrialisation increases and drinking water standards become more stringent. A research programme is recommended for the identification of contaminants which already exist in some polluted rivers and which may be a common feature in the future and to determine the best processes for their removal.

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TECHNICAL SESSION 2A
WATER TREATMENT - FILTRATION

**Slow Sand Filter for Groundwater Recharge - Ten Times Longer Filter Run
Than was Usual Up to Now**

Assessing Membrane Filtration for Particulate Removal

Filtration of Horizontal Flow Filter

SLOW SAND FILTER FOR GROUNDWATER RECHARGE TEN TIMES LONGER FILTER RUN THAN WAS USUAL UP TO NOW

Dr. h.c.sc.techn. ETH Maarten Schalekamp
Water Supply Zurich
Zurich, Switzerland

1. Summary

In 1971 it was discovered that the slow sand filters of the Lakewater Plant Lengg, Zurich, which were charged with a 10 cm thick layer of activated carbon PKST 0.5 - 2.5 mm showed a 6-times longer filter run than those without an activated carbon filtering layer. This discovery was then used for the construction of the groundwater recharge basins Hardhof. All recharge basins, each with an area of about 4000 m², were charged with a 10 cm activated carbon filtering layer PKST 0.5 - 2.5 mm and covered by a 1.2 mm thick fleece. After 10 years filter basin # 3 was cleaned. The fleece as well as the activated carbon layer and 7.5 cm sand were removed. Instead of the expensive activated carbon an easily-washable gravel of 3 - 6 mm grain was charged and the whole covered again by a fleece. The pressure losses after this cleaning process are as low as they were ten years ago.

2. General

The Water Supply Authority Zurich meets the water consumption of the city and region by 5% spring-water, 75% lake-water and 20% ground-water. The Lakewater Plant Moos on the left shore of the lake treats, besides the lake-water, also the spring water, and has a capacity of 150'000 m³ per day. The Lakewater Plant Lengg on the right lake shore, treats only lake-water and produces in maximum 250'000 m³ per day. The Groundwater Plant Hardhof is able to supply on sporadic days in maximum 150'000 m³ (Fig. 1).

The Lakewater Plants Moos and Lengg operate an 8-stage treatment facility. One stage of it is the covered slow sand filter. Four stages are used in the Groundwater Plant Hardhof to clean the bank filtrate for recharging the ground-water. One of the stages consists of three open slow sand filters in the recharge basins.

3. The Groundwater Plant Hardhof

In order to provide sufficient water for the population, and to counter the immisions in the old ground-water plant, the ground-water plant was completely renewed in the years 1973 - 1980. The increase in capacity amounted to 80'000 m³/d, so that on some days, sporadically, about 150'000 m³ water can be produced. At a low ground-water level this peak performance is, however, only possible during a few days. The mean capacity amounts from 60'000 up to a maximum of 80'000 m³/d. To utilise the total productive capacity of the plant during dry periods, a

project for the construction of a river water plant with a maximum capacity of 80'000 m³/d for additional recharge, was given the go-ahead by the voters.

Each of the four large water collectors consists of a 25 m deep vertical shaft which has a diameter of 4 meters. By means of radially arranged and horizontally driven filter pipes with an inside diameter of 300 mm and a total length of 300 m, at two different levels, the ground-water is collected and passed into the shaft. The catchments are each equipped with three submersible motor pumps of 200 l/s capacity. The well tops are covered with earth and planted with shrubbery. For the artificial recharge of the ground-water three recharge basins were constructed each with an area of about 4000 m² giving a total of 11'730 m². The required infiltrate for the ground-water recharge is collected in 19 vertical filter wells situated along the banks of the River Limmat from the Zonal Pumping Station Hardhof to the Werdhölzli and delivered by means of pumps to the recharge basins. The capacity of the recharge facilities amounts to at least 40'000 and in maximum 80'000 m³/d. Together with the river water plant it will become possible in future, during low water in the river, to recharge up to a maximum of 120'000 m³/d. In order to prevent water from the Grünau-Settlement, situated to the west of the Europa-Bridge, entering the ground-water aquifer of the plant, six drainage wells with a maximum capacity of 200 l/s and a water distribution centre - i.e. "Surge Chamber Hardhof" - were constructed along the Europa-Bridge (Fig. 2).

The three open filter basins were placed along the Motorway N1 in such a way, that, on the one hand as large an amount as possible of infiltration water could again be collected in the horizontal filter wells and, on the other hand enable the infiltrating water diverting the polluted ground-water influent from the city area away from the drinking-water catchment zone.

Each recharge basin consists of an exterior wall with cascade spillway, filter body and in the neighbourhood facilities for the basin management. The filter body consists of 100 cm gravel filter, a 100 cm thick lake-sand layer having a grain size of 0.2 - 2 mm and a thick activated carbon layer PKST 0.5 - 2.5 mm. The entire filter is covered by a fleece, 1.2 mm thick (Type R 70/30 150 B), made of polypropylen and acryl (Fig. 3).

4. Experiences with the Double Layer Rapid Filtration

During the years 1965 to 1969 the author carried out many tests concerning the filtration with single and dual media filters with respect to efficiency as well as filtration rate. At that time it was discovered that a dual media filter with the same efficiency showed a 5 times longer filtration time than that of a single media filter. At the beginning of the 1970's similar experiments were carried out by the Water Supply Authority Zurich (WSZ). The single media filter had a filter bed of 90 cm in thickness, consisting of quartz sand with a grain size of 0.4 - 1.0 mm (Fig. 4). The dual media filter was charged with 70 cm quartz sand and 20 cm activated carbon PKST 0.5 - 2.5 mm, Norit 07 or Lurgi LW Extra Hydrarffin 0.25 - 1.4 mm. The results of these experiments were similarly satisfactory as those obtained by the tests in St. Gall. Furthermore, experiments were made with anthracite 0.5 - 2.5 mm and with pumice 1.0 - 2.5 mm. The results of these trials too, were very positive. Subsequently, the activated carbon filters in the Waterworks Moos and Lengg were designed as double layer filters. For the first layer 50 cm quartz sand 0.4 - 1.0 mm was taken and, depending on the filter run, an activated carbon layer of 100 - 150 cm. For the double layer rapid filters a pumice layer was used and not one of anthracite. The reason for this being that the anthracite requires a backwashing velocity of at least 75 m/h/m² for layer separation, where as pumice only needs 45 m/h/m². The grain sizes can be gleaned from Figs. 5, 6 & 7. During the experiment on large facilities the dual media filtration was twenty-one times longer than for the single media filtration, however, no

flocculation agents were used for this large-scale experiment. The loss of pressure amounted to a total of 125 cm and the filtration velocity was the same for both filters, i.e. in minimum 2.8 and in maximum 5.6 m/h/m² (Fig. 8). The Lakewater Plants are, however, being operated with a microflocculation stage and the filter run of the dual media filters is five times longer than for the single media filters. The filtration rate and pressure losses were the same as were found in the experiment without micro-flocculation (Fig. 9).

5. Experiences with Dual Media Slow Sand Filtration

Slow sand filters were utilised in Switzerland from the middle of the last century onwards for cleaning surface water. Today they are, above all, of very great importance for the ground-water recharge. Experiments carried out by the author during the 1970's in St. Gall and during the 1980's in Zurich have clearly shown that the slow sand filter, with respect to the filtering of the phytoplankton as well as also for the bacteriological cleaning, is not a surface filter but a volume filter. The cleaning effect is equally satisfactory whether the filter is being operated with a filtering rate of 7.5 m or 15 m per day. Higher filtering rates yield a somewhat less satisfactory result. The experiments were carried out with covered slow sand filters. They consist of a concrete floor with hollow bricks and collecting channels, a layer of 20 - 30 cm gravel having a grain size of 5 - 25 mm and a further layer of about 90 cm lake sand, grain size being 0.2 - 2 mm (Figs. 10, 11 & 12). During the experiments the loss of pressure losses in the various layers of the slow sand filter. From this the fact emerges very clearly that the accretion, even at those unusually high filtering rates, takes place in the uppermost 5 cm. After the cleaning process, whereby a layer of 5 cm was removed, the pressure loss was only 40 cm. This value is about 10 cm lower than the one before the tests.

The sudden appearance of the Zebra Mussels *Dreissena Polymorpha Pallas* (DPP) caused the introduction of chlorine (Cl₂) as preoxidation in the Lakewater Plants of Zurich. To remove the excess chlorine the slow sand filters were charged with a 10 cm thick layer of activated carbon PKST 0.5 - 2.5 mm (Fig. 14). What already had been observed in the dual media filters, namely at least the five-fold increase of the filter run, also appeared in the dual media slow sand filters, even though the filtering velocity was here 5 - 8 times slower than in the dual media fast filters (Fig. 15). After one year of operation the pressure loss of the dual media slow sand filter amounted to about 60 cm at a filtering velocity of 15 m per day. This means that at a total pressure loss of 2 m this filter would show a run of up to three years. Subsequently this really happened. Filters with a filtering velocity of only 5 m instead of 15 m per day, would have a run of 9 years. This discovery was an important guide for the design of the slow sand filters of the groundwater recharge.

6. Experiences with the Dual Media Slow Sand Filtration of the Groundwater Recharge Basins

The dual media slow sand filters of the groundwater recharge basins are composed in the same manner as has been described in Paragraph 3. In Fig. 16 the screening curve of the special sand 0.2 - 2 mm is illustrated. This layer of sand is 1 m high and is placed on a 1m thick gravel layer. The special sand (lake sand) is covered by a 10 cm layer of activated carbon PKST 0.5 - 2.5 mm. This cheap "Throw away carbon" was chosen on account of two reasons: on the one hand to obtain by this second layer of coarse granulation a longer filter run and, on the other hand, to eliminate the products of the preoxidation, namely the mixture of

chlorine and chlorine dioxide, to prevent them from reaching the underground. It was foreseen to use an oxidising mixture of up to 1.5 mg/l. In time, however, this amount could and had to be reduced to 0.5 mg/l. Experience has shown that, if the oxidising mixture contained an equal amount of chlorine and chlorine dioxide, no chlorinated hydrocarbons were formed. According to the new quality aims in Switzerland, drinking-water must not contain more than 0.3 mg/l chlorite. Therefore, the dosage for groundwater recharge amounts to 0.5 mg/l oxidising agent or 2.5 mg/l chlorine and 2.5 mg/l chlorine dioxide. Thus the quality targets, with respect to chloroform as well as with respect to chlorite content, are guaranteed. This amount of oxidising agent is also sufficient for the foreseen purpose of countering the excessive formation of algae. Figs. 17 & 18 illustrate the filter material, the special sand and the PKST activated carbon. It was discovered by tests that, if the filters were not impounded with water, the oxidising mixture is completely decomposed by the cascade aeration. If the filter basins are impounded, the oxidant mixture is totally decomposed by the biomass on the fleece (Fig. 21). From this knowledge the fact emerged that no activated carbon is necessary anymore for the elimination of the oxidising mixture. In order to obtain longer filter runs for the dual media slow sand filters, a layer of grit, for instance, having a granulation of 1 - 3 mm can be used in place of activated carbon. When the recharge basins were taken into operation in 1981, the slow sand filters could not be impounded, as they were of course not yet polluted. The uppermost layer of activated carbon PKST dried out and could be blown away by the wind. In order to prevent this, the Water Supply Authority Zurich installed a fleece (Fig. 19). This fleece (Fig. 22) consists of coarse fibres and felt harder to the touch than the 1.23 mm fleece (Type R 70/30 1250 B) in use of today (Fig. 23). In time a biomass was formed on this fleece, which normally would have formed itself on the activated carbon, when the filters were impounded with water. After five years of operation the fleece alone showed a pressure loss of 1.2 m. The fleece was removed. Before the removal it must dry for a few days, otherwise it would break under the weight of the wet biomass, thus polluting the filter bed unnecessarily. Subsequently a new fleece was placed on top of the activated carbon, whereby the pressure loss dropped back by 1.2 m (Fig. 24). This fleece costs Sfr. 2.60 per square meter. The replacement of this fleece came to only c. Sfr. 10'000 for the material. Costs for the installation of the fleece amounted to c. Sfr. 5'000. The total renewal costs, therefore, came to c. Sfr. 15'000. It was only thanks to pure chance that such favourable cover was found. Without this fleece the filter run would only last 3 years at most instead of the present 10 years. From Figs. 24, 25 and 26 can be gleaned the filter run as well as the pressure loss in the individual basins and the size of the charged layers. According to the experiments with the dual media slow sand filters in Lengg the filter run could even have been 18 years if the capacity of the filters were taken into account. However, this was not possible because, on the one hand, no covered slow sand filters were being operated and, on the other hand, the fleece, which in time takes on the effect of a cover, lets too much light pass at the beginning. Furthermore it was discovered that the activated carbon granulation was broken down and became very fine grained during the years of operation. This is most probably the result of being long exposed to the wind and weather (moisture, heat, cold and frost). It can clearly be seen from Figs. 27 & 28 what granulation the new PKST possessed 10 years ago and what it is today. The granulation is now very fine. Tests between the new and the exhausted PKST activated carbon showed that the loss of pressure had increased sevenfold (Fig. 29). This phenomena took the works management completely by surprise, so that the filters silted up in the shortest time, which was really not expected. A 10-year filter run is of course in itself a small miracle in comparison to all other water supplies which normally must skim-off their recharge basins once to twice per year at velocities of 2.5 to 6 m/d. When it was time for basin No. 3 to receive a new fleece, and the phenomena of the fine granulation

SLOW SAND FILTER FOR GROUNDWATER RECHARGE TEN TIMES LONGER FILTER RUN THAN WAS USUAL UP TO NOW

Dr. h.c.sc.techn. ETH Maarten Schalekamp
Water Supply Zurich
Zurich, Switzerland

1. Summary

In 1971 it was discovered that the slow sand filters of the Lakewater Plant Lengg, Zurich, which were charged with a 10 cm thick layer of activated carbon PKST 0.5 - 2.5 mm showed a 6-times longer filter run than those without an activated carbon filtering layer. This discovery was then used for the construction of the groundwater recharge basins Hardhof. All recharge basins, each with an area of about 4000 m², were charged with a 10 cm activated carbon filtering layer PKST 0.5 - 2.5 mm and covered by a 1.2 mm thick fleece. After 10 years filter basin # 3 was cleaned. The fleece as well as the activated carbon layer and 7.5 cm sand were removed. Instead of the expensive activated carbon an easily-washable gravel of 3 - 6 mm grain was charged and the whole covered again by a fleece. The pressure losses after this cleaning process are as low as they were ten years ago.

2. General

The Water Supply Authority Zurich meets the water consumption of the city and region by 5% spring-water, 75% lake-water and 20% ground-water. The Lakewater Plant Moos on the left shore of the lake treats, besides the lake-water, also the spring water, and has a capacity of 150'000 m³ per day. The Lakewater Plant Lengg on the right lake shore, treats only lake-water and produces in maximum 250'000 m³ per day. The Groundwater Plant Hardhof is able to supply on sporadic days in maximum 150'000 m³ (Fig. 1).

The Lakewater Plants Moos and Lengg operate an 8-stage treatment facility. One stage of it is the covered slow sand filter. Four stages are used in the Groundwater Plant Hardhof to clean the bank filtrate for recharging the ground-water. One of the stages consists of three open slow sand filters in the recharge basins.

3. The Groundwater Plant Hardhof

In order to provide sufficient water for the population, and to counter the immissions in the old ground-water plant, the ground-water plant was completely renewed in the years 1973 - 1980. The increase in capacity amounted to 80'000 m³/d, so that on some days, sporadically, about 150'000 m³ water can be produced. At a low ground-water level this peak performance is, however, only possible during a few days. The mean capacity amounts from 60'000 up to a maximum of 80'000 m³/d. To utilise the total productive capacity of the plant during dry periods, a

project for the construction of a river water plant with a maximum capacity of 80'000 m³/d for additional recharge, was given the go-ahead by the voters.

Each of the four large water collectors consists of a 25 m deep vertical shaft which has a diameter of 4 meters. By means of radially arranged and horizontally driven filter pipes with an inside diameter of 300 mm and a total length of 300 m, at two different levels, the ground-water is collected and passed into the shaft. The catchments are each equipped with three submersible motor pumps of 200 l/s capacity. The well tops are covered with earth and planted with shrubbery. For the artificial recharge of the ground-water three recharge basins were constructed each with an area of about 4000 m² giving a total of 11'730 m². The required infiltrate for the ground-water recharge is collected in 19 vertical filter wells situated along the banks of the River Limmat from the Zonal Pumping Station Hardhof to the Werdhölzli and delivered by means of pumps to the recharge basins. The capacity of the recharge facilities amounts to at least 40'000 and in maximum 80'000 m³/d. Together with the river water plant it will become possible in future, during low water in the river, to recharge up to a maximum of 120'000 m³/d. In order to prevent water from the Grünau-Settlement, situated to the west of the Europa-Bridge, entering the ground-water aquifer of the plant, six drainage wells with a maximum capacity of 200 l/s and a water distribution centre - i.e. "Surge Chamber Hardhof" - were constructed along the Europa-Bridge (Fig. 2).

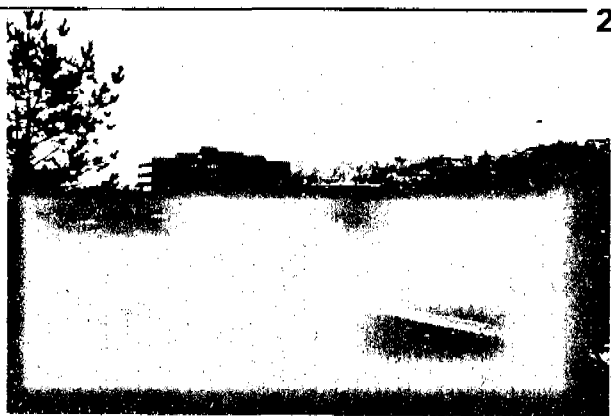
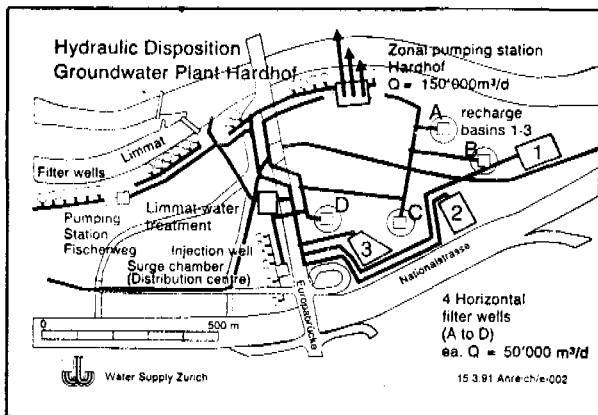
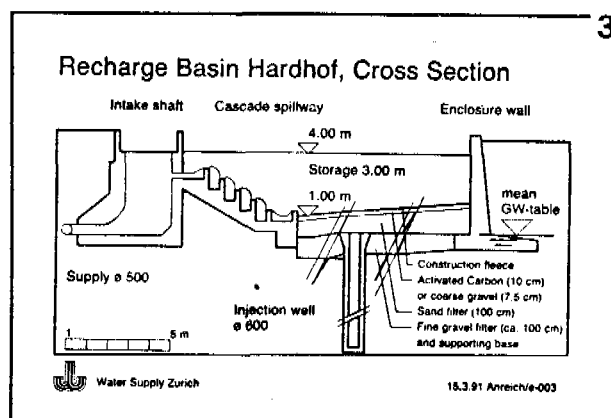
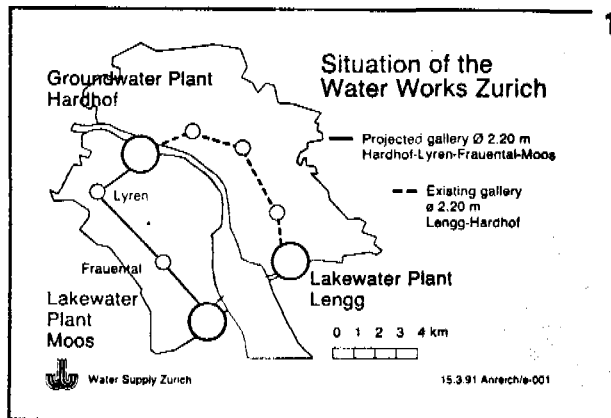
The three open filter basins were placed along the Motorway N1 in such a way, that, on the one hand as large an amount as possible of infiltration water could again be collected in the horizontal filter wells and, on the other hand enable the infiltrating water diverting the polluted ground-water influent from the city area away from the drinking-water catchment zone.

Each recharge basin consists of an exterior wall with cascade spillway, filter body and in the neighbourhood facilities for the basin management. The filter body consists of 100 cm gravel filter, a 100 cm thick lake-sand layer having a grain size of 0.2 - 2 mm and a thick activated carbon layer PKST 0.5 - 2.5 mm. The entire filter is covered by a fleece, 1.2 mm thick (Type R 70/30 150 B), made of polypropylen and acryl (Fig. 3).

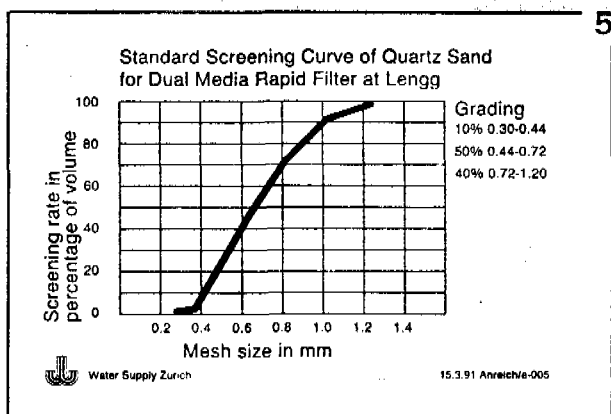
4. Experiences with the Double Layer Rapid Filtration

During the years 1965 to 1969 the author carried out many tests concerning the filtration with single and dual media filters with respect to efficiency as well as filtration rate. At that time it was discovered that a dual media filter with the same efficiency showed a 5 times longer filtration time than that of a single media filter. At the beginning of the 1970's similar experiments were carried out by the Water Supply Authority Zurich (WSZ). The single media filter had a filter bed of 90 cm in thickness, consisting of quartz sand with a grain size of 0.4 - 1.0 mm (Fig. 4). The dual media filter was charged with 70 cm quartz sand and 20 cm activated carbon PKST 0.5 - 2.5 mm, Norit 07 or Lurgi LW Extra Hydriffin 0.25 - 1.4 mm. The results of these experiments were similarly satisfactory as those obtained by the tests in St. Gall. Furthermore, experiments were made with anthracite 0.5 - 2.5 mm and with pumice 1.0 - 2.5 mm. The results of these trials too, were very positive. Subsequently, the activated carbon filters in the Waterworks Moos and Lengg were designed as double layer filters. For the first layer 50 cm quartz sand 0.4 - 1.0 mm was taken and, depending on the filter run, an activated carbon layer of 100 - 150 cm. For the double layer rapid filters a pumice layer was used and not one of anthracite. The reason for this being that the anthracite requires a backwashing velocity of at least 75 m/h/m² for layer separation, where as pumice only needs 45 m/h/m². The grain sizes can be gleaned from Figs. 5, 6 & 7. During the experiment on large facilities the dual media filtration was twenty-one times longer than for the single media filtration, however, no

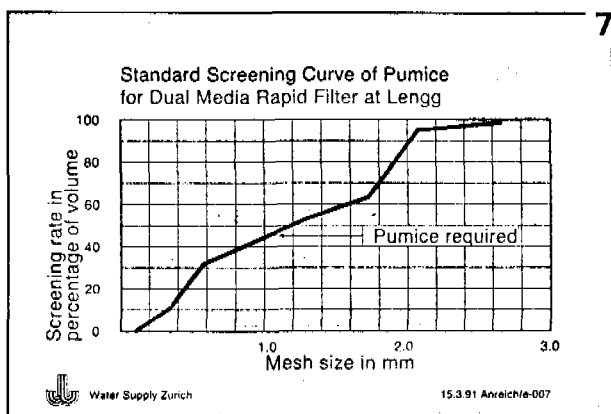
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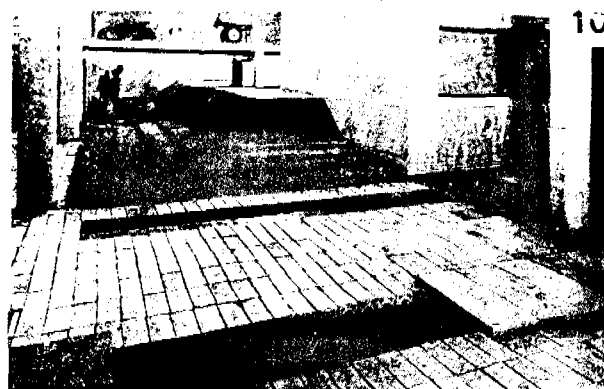
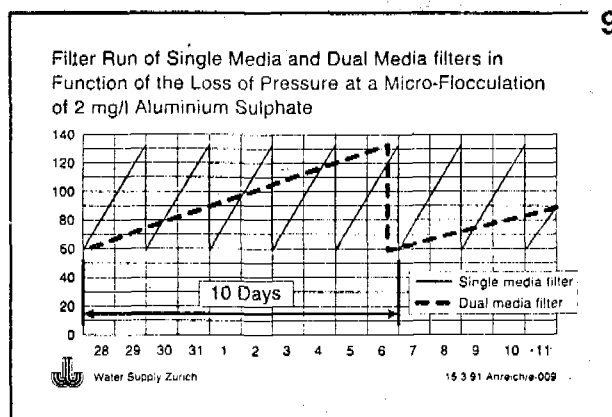
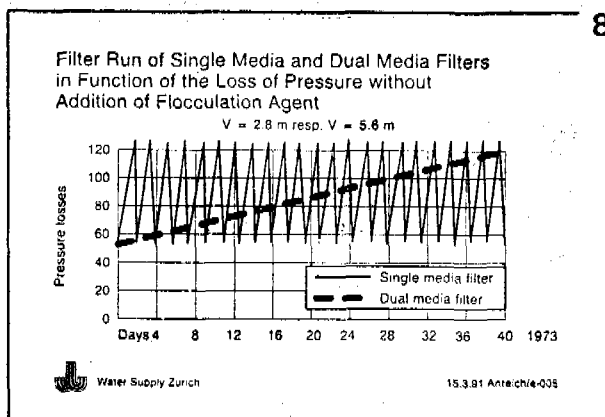


Single media rapid filter Lengg
90 cm quartz sand 0.4 - 1.0 mm.

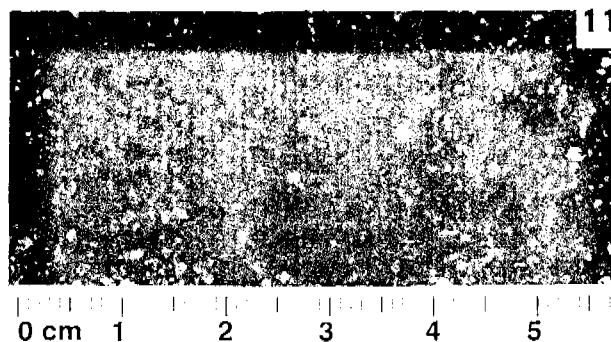


Dual media rapid filter Lengg with 90 cm quartz sand
0.4 - 1.0 mm and 50 cm pumice 1.0 - 2.5 mm.

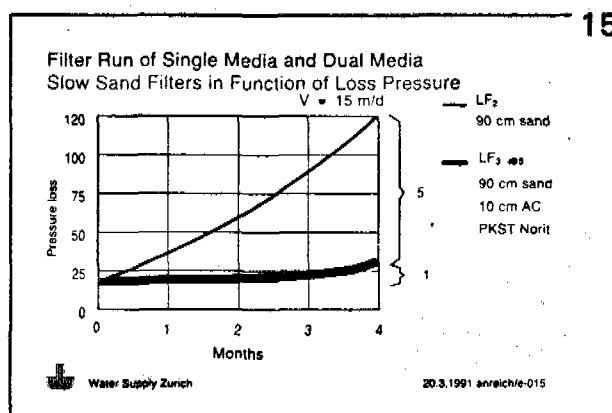
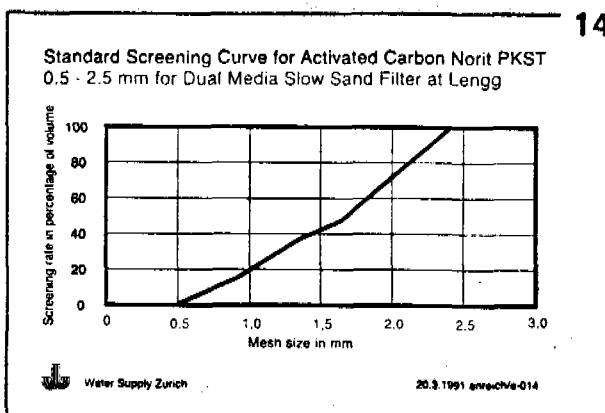
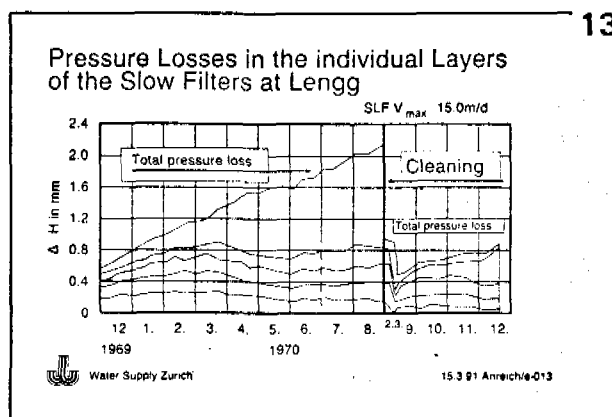
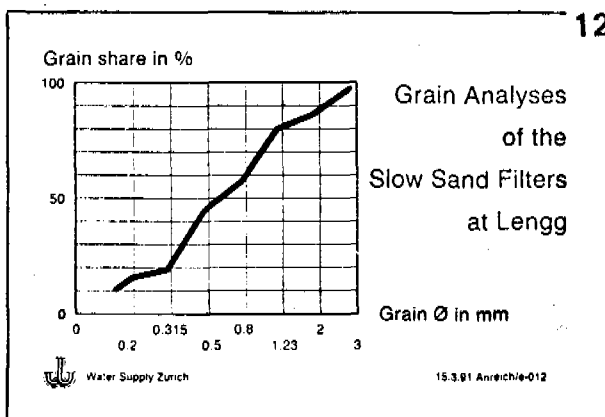


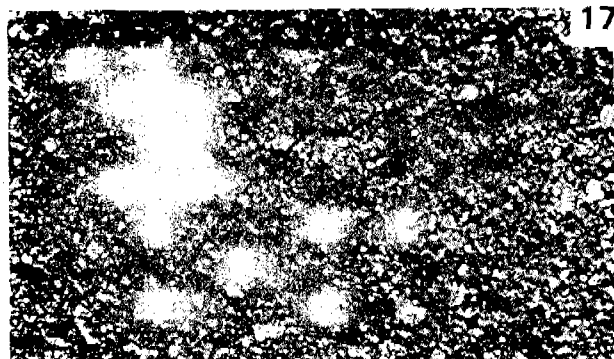
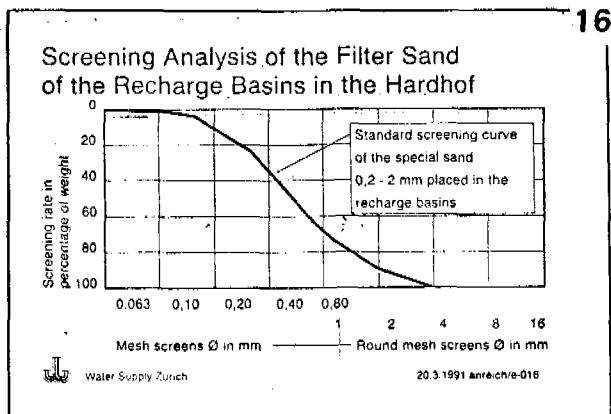


Construction of a covered slow sand filter Zurich.

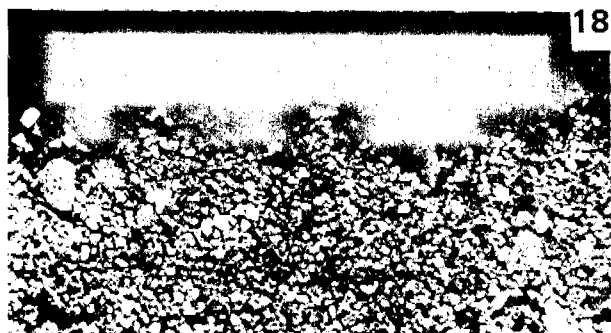


Detail of the 90 cm thick lake sand layer of the slow sand filter Leng. (Granulation = 0.2 - 2 mm)





Detail of special sand 0.2 - 2.0 mm of the recharge basins Hardhof.



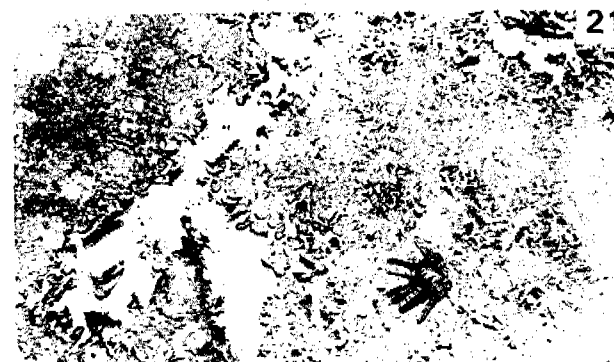
Detail of special sand 0.2 - 2.0 mm and of activated carbon PKST 0.5 - 2.5 mm of the recharge basins Hardhof.



Installation of the 1.2 mm thick fleece onto the recharge basin No. 2.



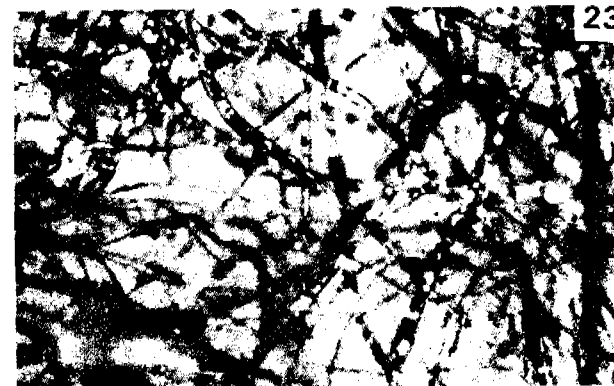
Water impoundage c. 1.0 m in the basin No. 2.



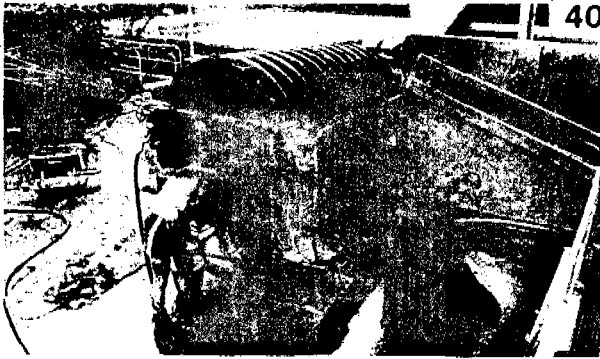
Dry bio material on the fleece with a bunch of keys after drainage of basin No. 2.



Fleece installed in 1981. 12.5-times enlarged.



Fleece installed in 1990. 12.5-times enlarged.



Wasching of the gravel with the mobile washing machine rented from the Municipal Works St. Gall.



Charging of the gravel by means of hydraulic transport, basin No. 3.



Basin No. 3. Installation of the gravel. At the left new measuring shaft.



Basin No. 3. Installation of the 1.2 mm thick fleece. Fastening by iron shackles.



Cyclone for gravel washing. Inner construction.



Cyclone for gravel washing. Trial operation in the Lakewater Plant Moos.

ASSESSING MEMBRANE FILTRATION FOR PARTICULATE REMOVAL

Takasi Kohno
Ebar-Infilco Co. Ltd
6-27 Kohnan 1-chome
Minato-ku
Tokyo, Japan

Yoshikazu Itoh
Ebara-Infilco Co. Ltd
6-27 Kohnan 1-chome
Minato-ku
Tokyo, Japan

Yoshihide Kaiya
Ebara-Research Co. Ltd
4-2-1, Motofujisawa
Fujisawasi
Kanagawa, Japan

Abstract:

In a pilot study of the hollow-fiber microfiltration (MF) of an untreated lake water, the efficiency of membrane filtration for the removal of particulate material were evaluated in terms of the permeate flux (transmembrane pressure) and the membrane material.

Key Word: Membrane Filtration, Microfiltration (MF), Hollow fibers, Turbidity removal, Coagulation, Waterworks,

1. Introduction

Membrane filtration technology has been drastically developed in recent years, based on improvement of membrane materials, and has been applied to the fields such as ultrapure water treatment, water recovery from waste water, night-soil treatment, food industries, and so on.

But membrane technology has not been utilized in the field of waterworks in Japan, except some small scale facilities for desalination of sea water.

There are many potential advantages to treatment of drinking water by Membrane Filtration for liquid-solid separation compared with conventional treatment, such as

- 1) stable operation against variation of raw water quality.
- 2) reduction of construction area.

Membrane technology will be increasingly popular as an alternative process in the drinking water treatment in Japan.

Figure 1 presents various separation processes that are employed in water treatment and the typical size ranges of materials found in raw waters.

This Figure shows Microfiltration (MF) is available to remove suspended solid instead of conventional sedimentation, filtration system.

However, little information is available in the literature on the use of MF for particulate removal from untreated drinking water source.

The primary problem with application of MF in water treatment is fouling. There is widespread belief that small particles and organic molecules in natural water will result in irreversible fouling of MF membranes, leading to decreasing permeate flux and the need for frequent membrane replacement.

It is necessary to establish optimum operation condition and cleaning method of membrane for actual applications.

	Dissolved solid			Suspended solid			
	Ionic	Molecular	Macro-molecular	Micro-particle	Macro-particle		
	Range	Range	Range	Range	Range		
Size μ m	0.001 (1nm)	0.01	0.1	1	10	100	1000 (1mm)
Matters to be removed	Ion	Viruses		Coliform			
	Aqueous salts		Bacteria				
		T H M		Algae		Protozoa	
		M F P		Silt			
			Clay			Sand	
Separa- tion Process			M F				
			U F				
		RO			Sedimentation		
		N F			Filtration		

MF: Micro-Filtration UF: Ultra-Filtration RO: Reverse Osmosis

NF: Nano-Filtration

THM: Trihalomethane THMFP Trihalomethane formation potential

Fig - 1 SEPARATION PROSECESES AND MATERIALS IN RAW WATER

A pilot study was undertaken to evaluate the efficiency of membrane filtration for the removal of particulate material from untreated lake water. As a strategy for avoiding pore fouling, it is proposed that the foulants capable of entering the membrane's pores be aggregated to produce particles that are rejected at the membrane surface.

Microfiltration experiments with and without coagulation were conducted to test the feasibility of manipulating coagulation conditions to reduce fouling.

2. Materials and Methods

Experiments conducted with Kasumigaura Lake water were performed using a pilot unit configured for constant flow and dead end filtration in 2 trains. A schematic diagram of pilot unit is shown in Fig 2.

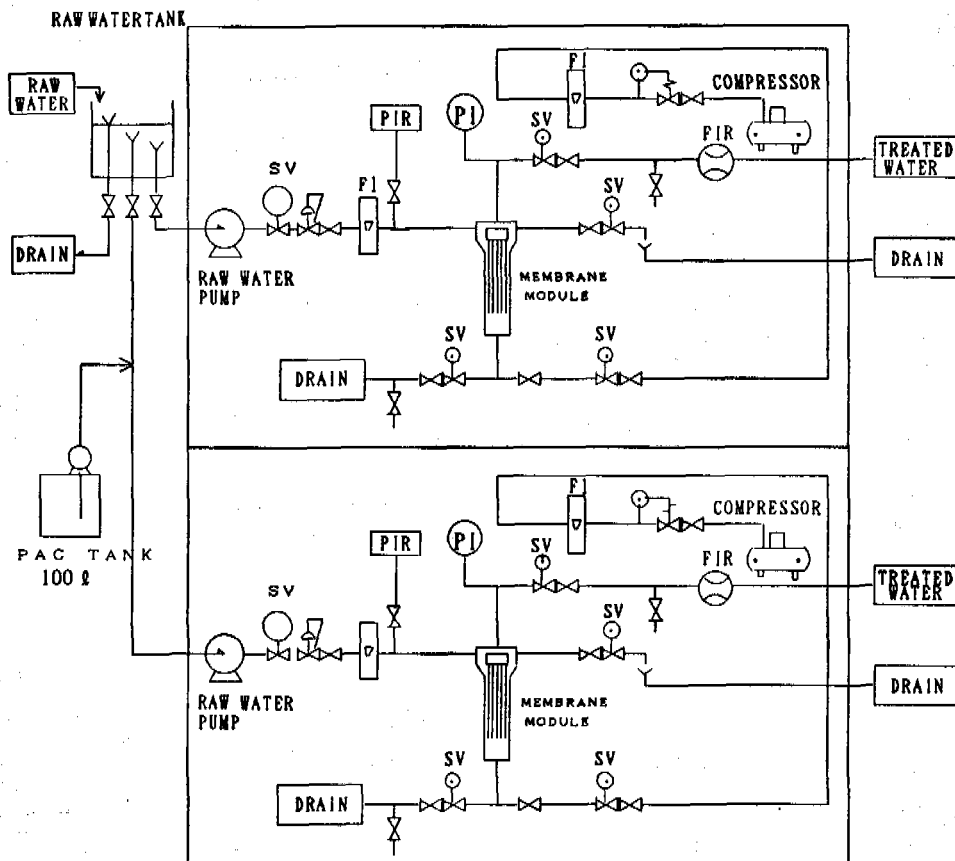


Fig- 1 FLOW DIAGRAM

FI :FLOW INDICATOR
SV :SOLENOID VALVE
PI :PRESSURE INDICATOR
PIR:PRESSURE INDICATOR RECORDER
FIR:FLOW INDICATOR RECORDER

The unit utilized a single external pressure type MF module containing hollow fibers. Membrane Module Specifications are as follows.

Membrane Module Specification	
Material	Polyethylene
Pore size	0.1 μm
Hollow fiber diameter	Inner 270/Outer 410 μm
Effective filtration area	10 m^2
Module dimension	ϕ 110x800 L

Operation conditions are as follows.

Operation conditions	
Operation Process	Filtration → Airbubbling wash → drainage
Flow rate	7.2 m ³ /day (0.03m ³ /m ² /h :constant)
Filtration	60 min
Airbubbling wash	2 min 40Nl/min
Drainage	2 min
Coagulant	Polyaluminum chloride
Dosing rate	40 mg/l

1 Train : without pretreatment

1 Train : with coagulation pretreatment

The feed and treated water lines were monitored with turbidity meter, pressure sensors at the module inlet and magnet flowmeter at the module outlet. Raw water turbidity and transmembrane pressure were recorded.

3. Results and discussion

3.1 Water quality

The quality of treated water is the almost same for both train, regardless of the pretreatment applied. Table 1 summarizes the quality of raw water and treated water. The table shows that turbidity, suspended solid, Fe, Mn in the raw water were removed, except dissolved matter. Microfiltration was very effective in removing particulates without pretreatment.

Param.	Raw War		Dissolved Matter (1μm Filterd Water)		Treated Water	
	Range	Ave.	Range	Ave.	Range	Ave.
PH	7.4-8.3	7.6			7.4-8.4	7.7
Turbid.	4-15	8.0			<0.5	
SS (mg/l)	3-13.6	7.3			<1	
Color	15-40	29.7	7-15	11.5	6-12	10.3
Fe (mg/l)	0.03-0.14	0.07	<0.02		<0.02	
Mn (mg/l)	0.03-0.14	0.07	<0.02		<0.02	
TOC (mg/l)	3.6-12.6	7.7	2.9-9.8	5.1	3.1-8.3	4.6
KMnO ₄ Consump. (mg/l)	10-17	12.9	7.2-10.7	9.1	6.6-10.4	8.8

TABLE - 1 WATER QUALITY PARAMETERS

3.2 Transmembrane pressure

The transmembrane pressure profile for the 800h of operation of the MF pilot unit is shown in Figure 5. A similar pattern was observed for the transmembrane pressure irrespective of pretreatment.

Rapid and irreversible fouling occurred within the first 100 houring. After rapid increase, transmembrane pressure became stable.

In comparison with the uncoagulated train, the increase in transmembrane pressure in the pretreatment train was a little slowed. However after 800 h of operation, transmembrane pressure had increased to approximately the same level. Coagulation pretreatment of this raw water produced smaller improvements in membrane flux.

During operation, abnormal high transmembrane pressure because of an interfiber clogging by coagulant was observed in the pretreatment train. This may have been due to accidental blockade in the air feed line for air bubbling wash. This phenomenon shows possibility that insufficient air bubbling cause an interfiber clogging.

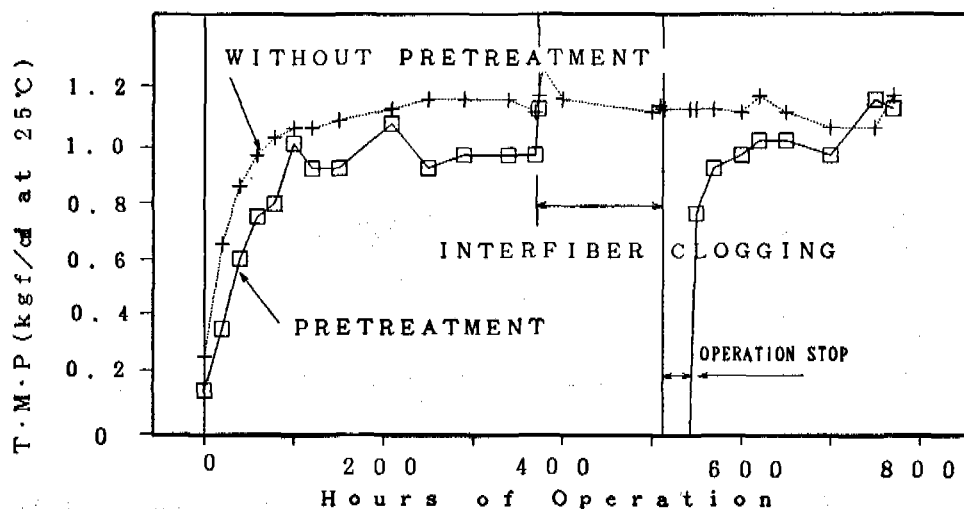


Fig-4 TRANSMEMBRANE PRESSURE

3.3 Recovery of flux

Fig-5 shows flux recovery rate of the membrane after 800 h operation against initial flux. Each flux was measured after wash with tap water at 0.5 kg/cm², 25°C. The total flux available after surface and chemical wash was approximately equal for the both membrane.

Surface washing increased flux by only 1 percent (pretreatment), 13 percent (without pretreatment). This indicates that most of the loss in flux is associated with materials bound to the membrane surface or within the membrane matrix.

A 4-h chemical wash using 1 N NaOH resulted in an additional recovery of 30 percent of the initial flux, thought to be due to the solubility of organic materials adsorbed to membrane. Followed chemical wash using 1N-HCL, 1%-H₂O₂ increased flux by only 5-9 percent.

A chemical wash using NaOH was most effective for flux recovery.

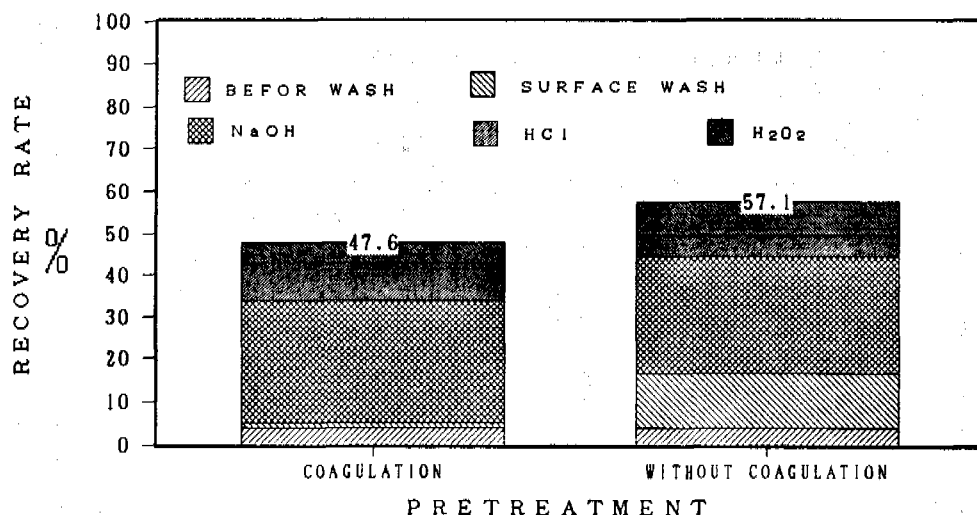


Fig. 5 RECOVERY OF THE INITIAL FLUX

3.4 Membrane material

One of the primary technical considerations in using these membranes should be selection of membrane material.

The extent and irreversibility of adsorptive fouling may be less for hydrophilic membranes than hydrophobic membranes.

Experiment was carried out to compare the two type membrane (hydrophobic polyethylene membrane and polyethylene membrane applied hydrophilic treatment) using same pilot unit without pretreatment. Operation conditions were same as before.

The transmembrane pressure profile for the 50days of operation of the hydrophilic and hydrophobic membrane is shown in Figure 6.

As shown in Fig 6 the transmembrane pressure of hydrophobic membrane was higher than one of hydrophilic membrane.

This confirms that hydrophilic membrane are much susceptible to irreversible fouling than hydrophobic membrane.

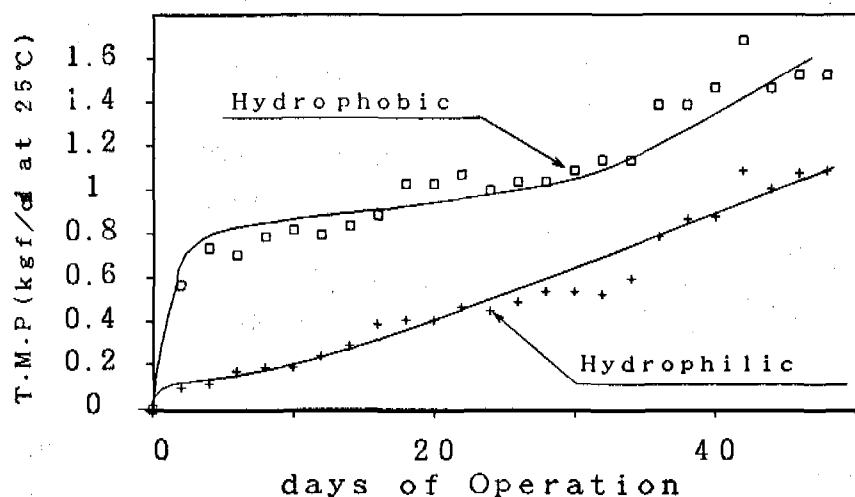


Fig-6 TRANSMEMBRANE PRESSURE

Conclusions

The results obtained from this study are summarized as follows.

- (1) Microfiltration was effective in removing particulates without pretreatment.
- (2) Coagulation pretreatment of this raw water produced smaller improvements in membrane flux.
- (3) Transmembrane pressure of hydrophilic membrane was lower than one of hydrophobic membrane for short-term experiment.
- (4) More research needs to be directed toward assessing the effect of long-term operation of membrane on treated water quality against variation of raw water and operation and maintenance requirements including durability of membrane.

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FILTRATION OF HORIZONTAL FLOW FILTER

K.S.L. Lo
Graduate Institute of Environmental Eng.
National Taiwan University
Taipei, Chinese Taiwan

C.S. Lay
Graduate Institute of Environmental Eng.
National Taiwan University
Taipei, Chinese Taiwan

ABSTRACT: A pilot plant was used to investigate the filtration efficiency of the horizontal flow filter. Experimental parameters included the turbidity of raw water, grain size of filter medium, depth of filter bed and filtration time. The particle size distributions of suspended particles in the filtrate and raw water were analyzed by the laser granulometer.

INTRODUCTION

Traditionally, tap water purification plant uses vertical flow for the filtration process. The major function of filter is to remove small suspended particles from water. The removal mechanisms include interception, sedimentation and diffusion (Yao et al., 1971; Amirtharajah, 1988). The suspended particles with diameter less than $1\mu\text{m}$ are removed by diffusion mechanism, while the particles larger than $10\mu\text{m}$ are removed by interception and sedimentation mechanisms. This study used the theory of traditional filtration process to design a horizontal flow pilot filter. The filtration efficiency of the horizontal flow filter was investigated according to the parameters such as kind and grain size of filter medium, depth of filter bed and raw water quality. Laser granulometer was used to analyze the particle size distributions of suspended particles in the filtrate and raw water.

EXPERIMENTAL MATERIALS AND METHODS

Experimental apparatus is shown in Figure 1. The horizontal flow filter is made of acrylic plastics, its dimension is $180\text{cm} \times 30\text{cm} \times 70\text{cm}$. There are four zones (1) water inlet zone, (2) filtration zone with sampling pore and water level meter, (3) water outlet zone, (4) chassis zone. For the length dimension, filtration zone is 150cm , water inlet and outlet zones are 15cm ,

respectively. For the height dimension, chasis zone is 10cm, filtration zone is 60cm. Due to the limitation of laboratory and water quantity, the height of filter medium was only 12cm during the experiment and 10cm of it was used for filtration. The actual cross-sectional area for filtration is 30cm x 10cm which is shown in Figure 2.

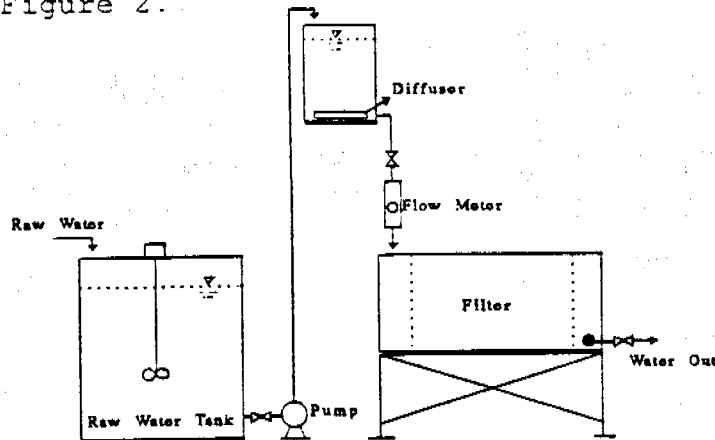


Fig.1 Diagram of experimental apparatus

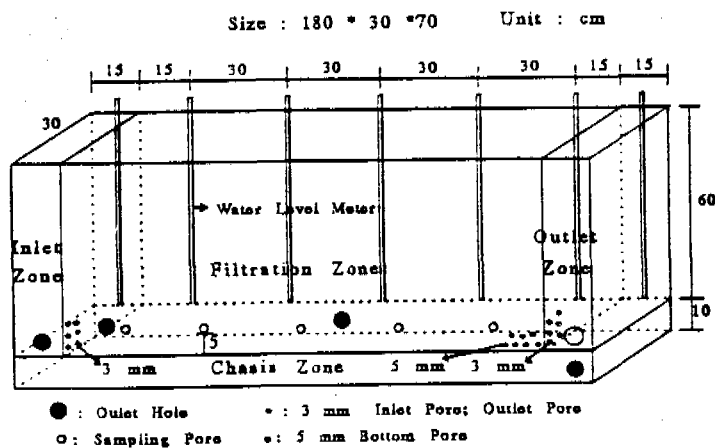


Fig.2 Diagram of horizontal flow filter

There are 3mm ϕ holes drilled on the acrylic plate between water inlet zone and filtration zone, as well as filtration zone and water outlet zone. There are 5mm ϕ holes drilled between filtration zone and chasis zone for backwashing. The chasis zone was fulfilled with tap water during the experiment. It is assumed that the water in the chasis zone will not affect the filtration process.

Filter media are small gravel (E.S. is 4.83mm, U.C. is 1.0) and quartz sand (E.S. is 0.53mm, U.C. is 1.5). The raw water was from the reservoir of Graduate Institute of Environmental Engineering, National Taiwan University. Suitable agitation was applied to control the turbidity of raw water during testing (Lo

et al., 1990). Water quality of raw water is shown in Table I. The filtration speed was 120 m/day during the experiment. The laser granulometer (Model 715, Cilas Alcatel Compangnie, Germany) can measure 1 to 192 μm , various ranges are 1-1.5-2-3-4-6-8-12-16-24-32-48-64-96-128-192 μm . It can measure the weight percent of various particle diameter ranges. The particle size distribution of suspended particles is a relative value. Blank sample can be used to create the background value which is standard value for measuring water sample. The blank sample used is the pure water produced from water purifier (Milli-Q SP System).

Table.I Water quality of raw water and filter run

Medium	Turbidity(NTU)	Turbidity Removal Eff.(%)	Filter Run(hr)
Gravel (4.83 mm)	33-35	75-90	15
	17-20	45-90	44
	2.8-3.8	55-80	71.5
Quartz (0.53 mm)	16-23	87-95	21.5
	11-13	86-90	37.5
	4.5-6.5	62-75	48

RESULTS AND DISCUSSIONS

Turbidity Removal Efficiency

Figures 3 and 4 show the turbidity removal efficiency versus filtration time at 75 cm depth of filter bed for small gravel and quartz sand, respectively. The turbidity removal efficiency is increased as filtration time is increased for small gravel. It is not significant for quartz sand, the increasing trend is slow. Figures 5 and 6 show the turbidity removal efficiency versus different depth of filter bed. It shows the suitable depth of filter bed is 75 cm. From the results of Table I, the raw water turbidity is higher, the removal efficiency is better.

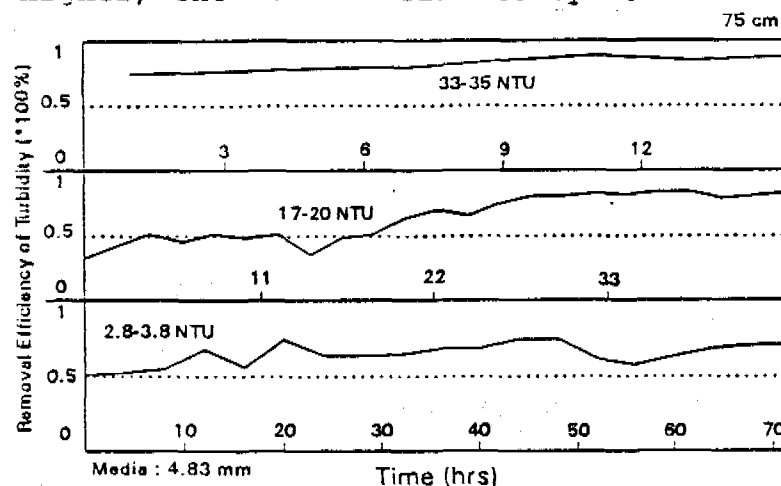


Fig.3 Variation of turbidity efficiency versus filtration time at 75 cm depth of filter bed for gravel

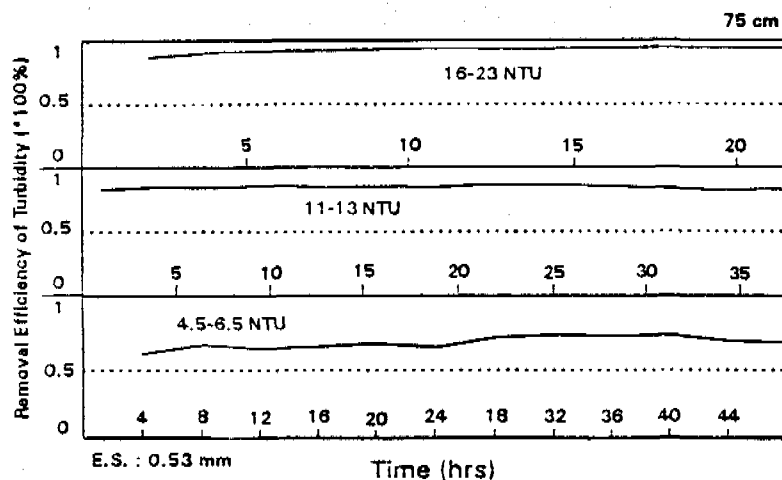


Fig.4 Variation of turbidity efficiency versus filtration time at 75 cm depth of filter bed for quartz sand

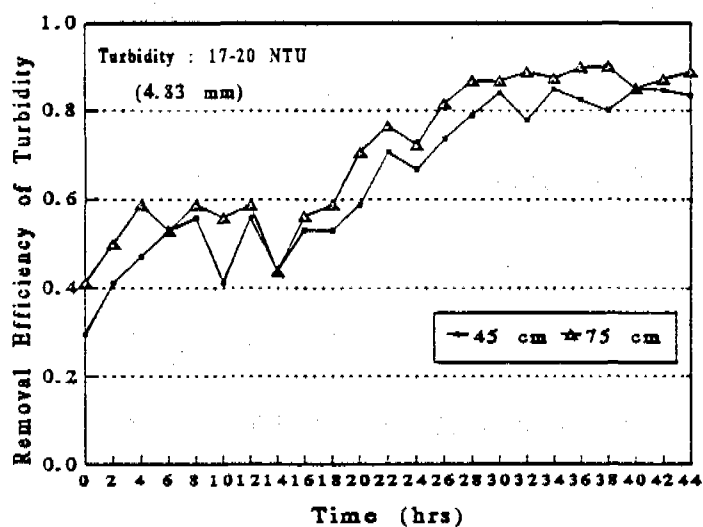


Fig.5 Variation of turbidity efficiency versus different depth of filter bed for gravel and raw water is 17-20 NTU

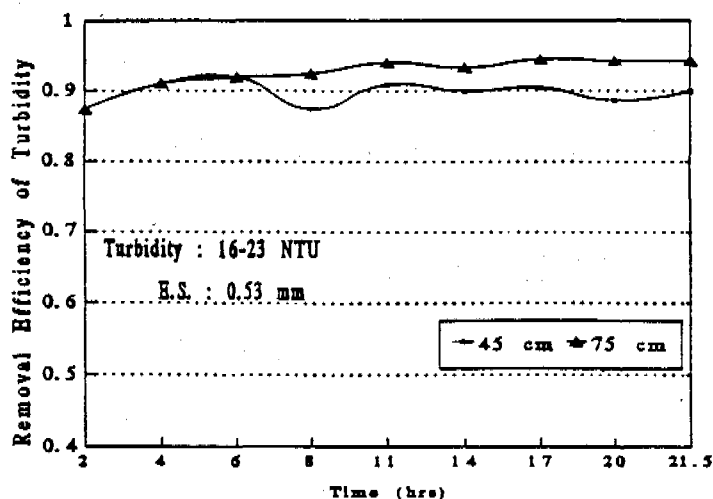


Fig.6 Variation of turbidity efficiency versus different depth of filter bed for quartz sand and raw water is 16-23 NTU

Because the void is larger among gravel particles, the suspended particles will penetrate into the filter bed. For horizontal flow filter, voids among filter medium are like many sedimentation tanks in it. Many suspended particles will sediment in the void to get filtration effect. The void of filter medium at the front portion will fulfill of suspended particles, especially a large quantity of them are collected at the bottom of filter medium during the experiment. It indicates that the sedimentation and interception mechanisms are significant for gravel medium. While the void is smaller among quartz sand, so the suspended particles do not penetrate deeply into filter bed. The suspended particles are collected at several cm filter medium of front portion. Thus, the interception mechanism is significant for quartz sand medium.

Figure 7 shows the variation curves of turbidity removal efficiency. After 30 hours, there is no removal function at 15 cm location for gravel. It shows the penetration capability of suspended particles is over 15 cm for 4.83 mm gravel medium. While the quartz sand medium has filtration function during all of the filtration experiment at 15 cm location. It seems the penetration capability of suspended particles is less than 15 cm for 0.53 mm quartz sand medium.

Filter Run

The judgement for the end of filtration process is different between vertical flow filter and horizontal flow filter (Hsieh, 1980; Vichian, 1984; Oscar, 1987). Vertical flow filter uses water quality of filtrate and head loss as the parameters. This experiment maintained the constant effluent rate. When the voids of filter medium fulfill of suspended particles and surface overflow occurs, then the filtration process is ended. Table I shows the filter run of different experiments.

Particle Size Analysis

For the gravel filter medium, Figure 8 shows the results for the turbidity of 17-20 NTU. The weight percent of particles larger than 32 μm was reduced significantly, while that of smaller than 24 μm was increased. It shows the removal efficiency is better for above 32 μm particles than below 24 μm particles in raw water. Figure 9 shows the results for the turbidity of 2.8-3.8 NTU. There are two sets of data for 8 hrs and 64 hrs filtration. After 64 hrs, the weight percent of particles above 32 μm in the filtrate was reduced significantly.

For the quartz sand filter medium, Figure 10 shows the results for the turbidity of 11-13 NTU. The weight percent for various particles did not deviate a lot. The weight percent of particles larger than 48 μm was slightly reduced, while that of smaller, than 32 μm was slightly increased. Figure 11 shows the results for the turbidity of 4.5-6.5 NTU. The weight percent of particles between 32 to 96 μm was slightly reduced, and that of larger than 128 μm was increased, while no significant deviation was found for smaller particles.

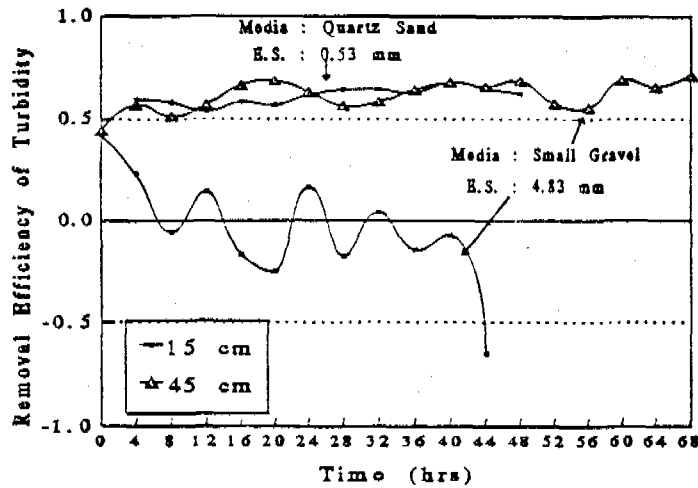


Fig.7 Variation of turbidity efficiency versus filtration time at 15 cm depth of filter bed for gravel and quartz sand

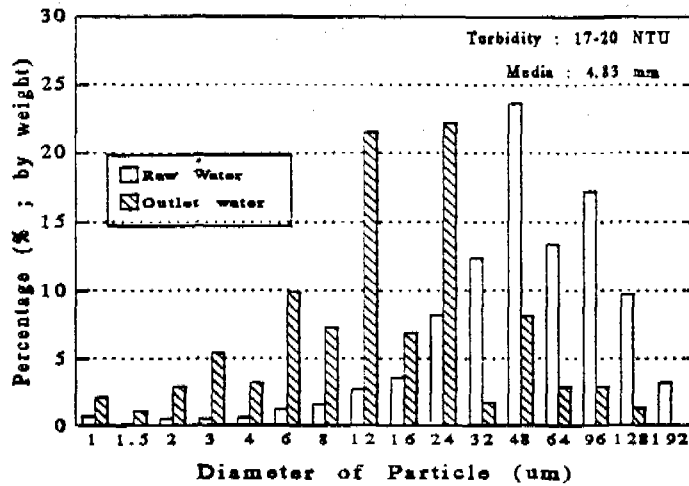


Fig.8 Particle size distributions in the filtrate and raw water for gravel filter medium which raw water is 17-20 NTU

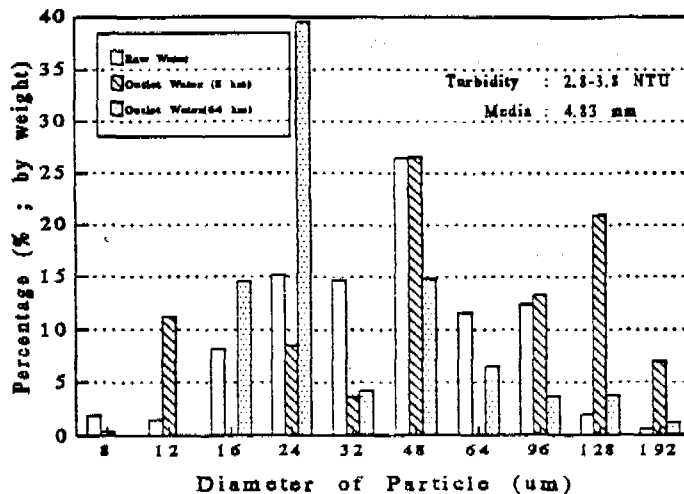


Fig.9 Particle size distributions in the filtrate and raw water for gravel medium which raw water is 2.8-3.8 NTU

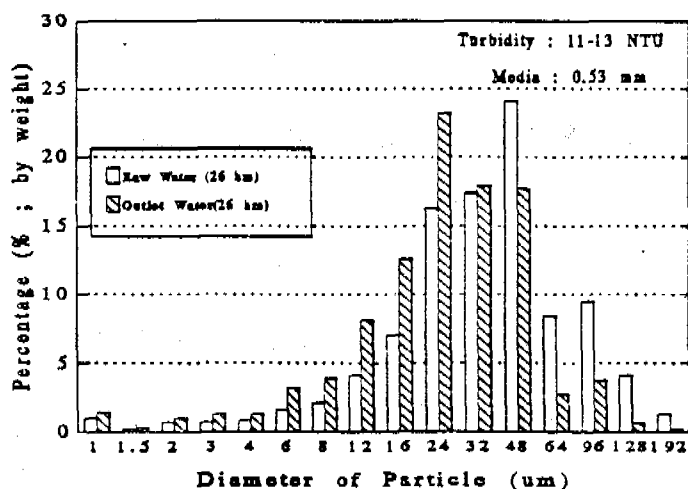


Fig.10 Particle size distributions in the filtrate and raw water for quartz sand medium which raw water is 11-13 NTU

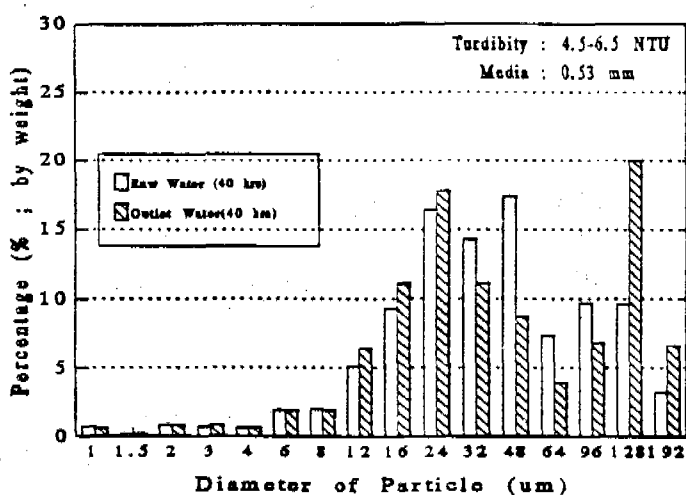


Fig.11 Particle size distributions in the filtrate and raw water for quartz sand medium which raw water is 4.5-6.5 NTU

Figures 12 and 13 show the particle size distributions in the filtrate at different filtration time for gravel and quartz sand, respectively. It indicates that the removal proportion of particles above 48 μm is better than the particles below 48 μm as the filtration time is increased for gravel medium. While the influence of filtration time for quartz sand medium is not significant. Figures 14 and 15 show the results for different depth of filter bed. For gravel, the differences of particle size distribution from 45 to 105 cm are not significant except 15 cm. In other words, it will be influenced by removing a proportion of suspended particles which is located at the front portion less than 45 cm. For quartz sand, the weight percent of different particle diameter is resembled from 15 to 105 cm.

Removal Efficiency of Suspended Particles

Laser granulometer was used to measure the weight percent distribution of various particles in water. At the same time, SS

content was measured. Both values were multiplied to get the weights of various particles, then the removal efficiency can be calculated. Under the operating conditions of this research, the suitable length of filter bed is 75 cm, so the removal efficiency is discussed only at 75 cm.

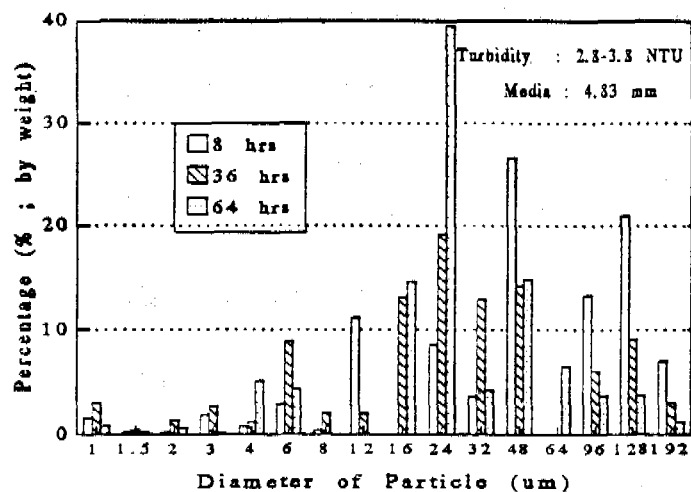


Fig.12 Particle size distributions in the filtrate at different filtration time for gravel medium which raw water is 2.8-3.8 NTU

For the gravel filter medium, when raw water turbidity is 33-35 NTU, the removal efficiency is about 70-90% for particles smaller than 24 μm, and it is increased to 85-100% for particles larger than 32 μm. When raw water turbidity is 2.8-3.8 NTU, the removal efficiency is about 40-90% for particles smaller than 24 μm, and it is increased to 75-100% for particles larger than 32 μm.

For the quartz sand filter medium, when raw water turbidity is 11-13 NTU, the removal efficiency is more than 90% for particles smaller than 96 μm, and it is 85-90% for particles larger than 128 μm. When raw water turbidity is 11-13 NTU, the removal efficiency is about 70-90% for particles smaller than 96 μm, and it is 85-90% for particles larger than 128 μm. When raw water turbidity is 4.5-6.5 NTU, the removal efficiency is about 85-100% for particles smaller than 64 μm, and it is 75-90% for particles larger than 96 μm.

For gravel medium, the removal efficiency of different particles is increased while filtration time is increased. It is due to the void of filter medium is occupied by suspended particles and the pore size is reduced gradually to remove many more suspended particles. So the removal efficiency is increased with filtration time. For quartz sand medium, the removal efficiency is only slightly affected by filtration time.

Figures 16 and 17 show the removal efficiency of suspended particles at different depth of filter bed for gravel and quartz sand, respectively. For gravel medium, the variation of removal efficiency for suspended particles is occurred at the front portion which is from 15 cm to 45 cm. For quartz sand medium, the

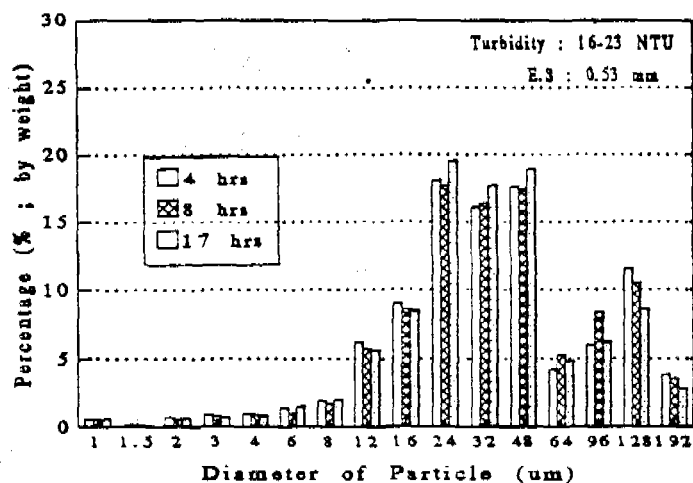


Fig.13 Particle size distributions in the filtrate at different filtration time for quartz sand medium which raw water is 16-23 NTU

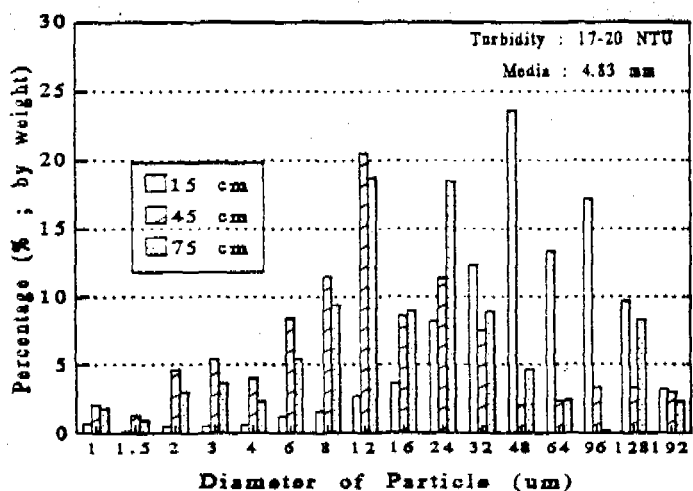


Fig.14 Particle size distributions in the filtrate at different depth of filter bed for gravel medium which raw water is 17-20 NTU

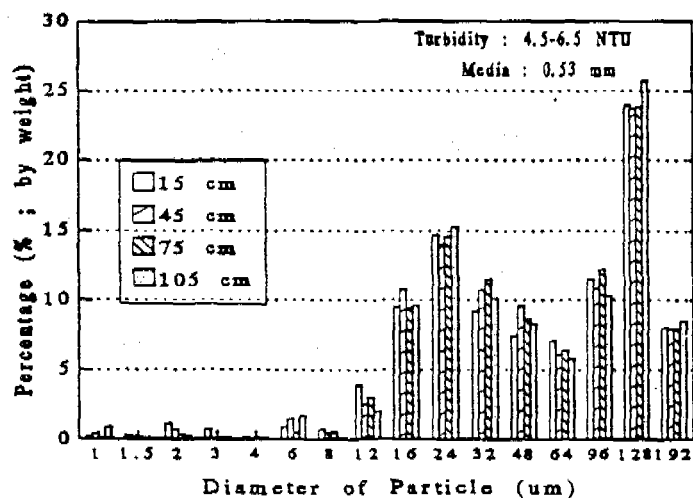


Fig.15 Particle size distributions in the filtrate at different depth of filter bed for quartz sand medium which raw water is 4.5-6.5 NTU

removal efficiency of suspended particles for 15 cm to 75 cm is quite close. It shows the influence is located at very front portion and less than 15 cm.

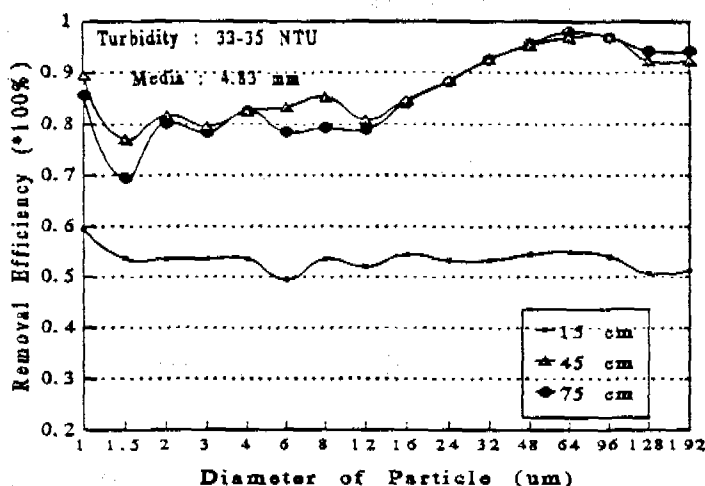


Fig.16 Removal efficiency of particles at different depth of filter bed for gravel filter medium which raw water is 33-35 NTU

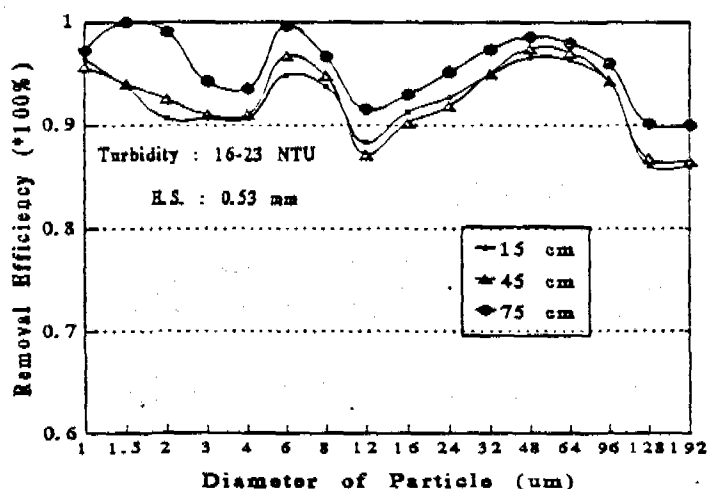


Fig.17 Removal efficiency of particles at different depth of filter bed for quartz sand medium which raw water is 16-23 NTU

CONCLUSIONS

The turbidity removal efficiency increases with the increasing filtration time, from 45-75% to 80-90% for the gravel medium. But for the quartz sand medium the removal efficiency increases from 62-87% to 75-95%. The depth of suspended particles which penetrate into filter bed ranged from 15 to 45 cm when using gravel as filter medium. On the other hand, it would be less than 15 cm for quartz sand. The turbidity removal efficiency increases with the increasing the depth of filter bed. Under the operating conditions of this study, the suitable depth of filter bed is about 75 cm. The interception and sedimentation mechanisms are significant for the gravel filter medium, while the interception

mechanism is significant for the quartz sand filter medium. From the analysis results of laser granulometer, it shows better removal efficiency is obtained for the size of suspended particles larger than 32 μm by using the gravel medium. This operating type could be more suitable for the coarse filtration in treating the highly turbid raw water or could replace the coagulation sedimentation process as the pretreatment of filtration. While the removal efficiency of different size of suspended particles is quite good for the quartz sand medium, it is recommended to do feasibility study for the replace of filtration unit.

ACKNOWLEDGEMENTS

This research work was supported by funds provided by the Taiwan Water Supply Corporation, R.O.C.

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TECHNICAL SESSION 1B
RIVER WATER QUALITY MANAGEMENT

Water Quality Computer Simulation Modelling of Sg. Linggi

**Classification of Rivers in Malaysia According to Various Beneficial Uses and
Water Quality**

The Use of Database Management Systems in Water Quality Management

WATER QUALITY COMPUTER SIMULATION MODELLING OF SG. LINGGI

Mohd. Akbar Johari

Ph.D., P.E.

Jabatan Bekalan Air Negeri Sembilan

Negeri Sembilan, Malaysia

ABSTRACT : The Sg. Linggi watershed is among the most urbanised drinking water catchment in the country. It however remains the principal source of water supply for the state of Negeri Sembilan. Due to the deteriorating quality of the raw water and the need to maintain its intended use, concerted efforts were made to study, evaluate, monitor, and recommend various strategic actions for remedial purposes (Johari, 1989; Linggi Taskforce, 1989).

The objective of this paper is to present efforts made in the water quality simulation modeling of the Sg. Linggi using the QUAL2E-UNCAS United States EPA (Environmental Protection Agency) model, and projecting modeled predictive scenarios relating causes and effects within the system. This serves as a basis in evaluating and assessing possible alternatives in the final decision-making process on mitigative measures to be implemented by the State Government.

INTRODUCTION

The Sg. Linggi Watershed

The Sg. Linggi watershed spreads over an area of 326 km² at the point of the abstraction of the Sg. Linggi Water Treatment Plant. As shown in Fig. 1, the watershed is highly urbanised and densely populated, which is accounted for by the state capital - Seremban, and by its neighbouring conurbations. In addition there are 2 major industrial zones within the watershed south-east of the town nucleus. The Sg. Linggi provides the source of raw water for the treatment plant which is capable of producing a maximum operating capacity of 20.0 MGD (Million Gallons per Day) of treated water. This is sufficient to meet 50 percent and a 100 percent of the water demands of Seremban and Port Dickson, respectively (Johari, 1990).

Pollutional Sources and Impacts.

Studies have shown that Sg. Linggi is in a state of serious pollution with a significant degradation of its raw water source observed since 1961 (Binnie & Partners, 1979). Various point and non-point sources

of pollution had been identified, which are attributable to raw sewage, industrial discharges, agricultural runoffs, and pig waste effluents. Based on an extensive analysis of water quality parameters performed by the Linggi Taskforce (Linggi Taskforce, 1989), the Sg. Linggi is regarded as not suitable to be utilised as a source of drinking water as measured by the standards set by the National Surveillance Programme (MOH, 1984). Figure 2 depicts the direct impact of the pollutional sources upon the dissolved oxygen profiles of the Sg. Linggi (Binnie & Partners, 1979; Johari, 1990).

It is envisaged that socio-economic developments within the watershed will continue in the foreseeable future. Parallely, however, the Government is equally concerned and committed to introduce mitigative environmental control programmes in the quest to improve the water quality conditions of the Sg. Linggi. Based on the dual objective, a predictive computer simulation modeling study of the Sg. Linggi was undertaken to evaluate possible solutions to the masterplan beginning September, 1991. Parts of the modeling efforts are presented in this paper.

WATER QUALITY COMPUTER SIMULATION MODELING

Simulation Modeling Technique

Simulation entails a mathematical abstraction of real world systems, and, hence, a simulation model is a set of equations and algorithms that describe the real system and imitate the behaviour of the system (Johari, 1988).

A fundamental first step in organizing a simulation model involves a detailed analysis of all existing and proposed components of the system and the collection of pertinent data. This step is called the system identification or inventory phase.

The second phase is model conceptualization, which often provides feedback to the first phase by defining actual data requirements for the planner and identifying system components that are important to the behaviour of the system.

Model calibration, the third phase involves testing or tuning of a model to a set of field data, preferably a set of field data not used in the original model construction. The calibration or tuning should include a consistent set of theoretically defensible parameters and inputs, i.e. parameters should not vary outside of the range reported in the literature nor should the parameters vary in an "unstable" fashion outside the range of accuracy (Thomann, 1982).

The final phase, model validation requires testing of a calibrated model to additional field data, preferably under different external conditions to further examine model validity.

Water Quality Modeling

A water quality model is a mathematical statement or set of statements that equate water quality at a point of interest to

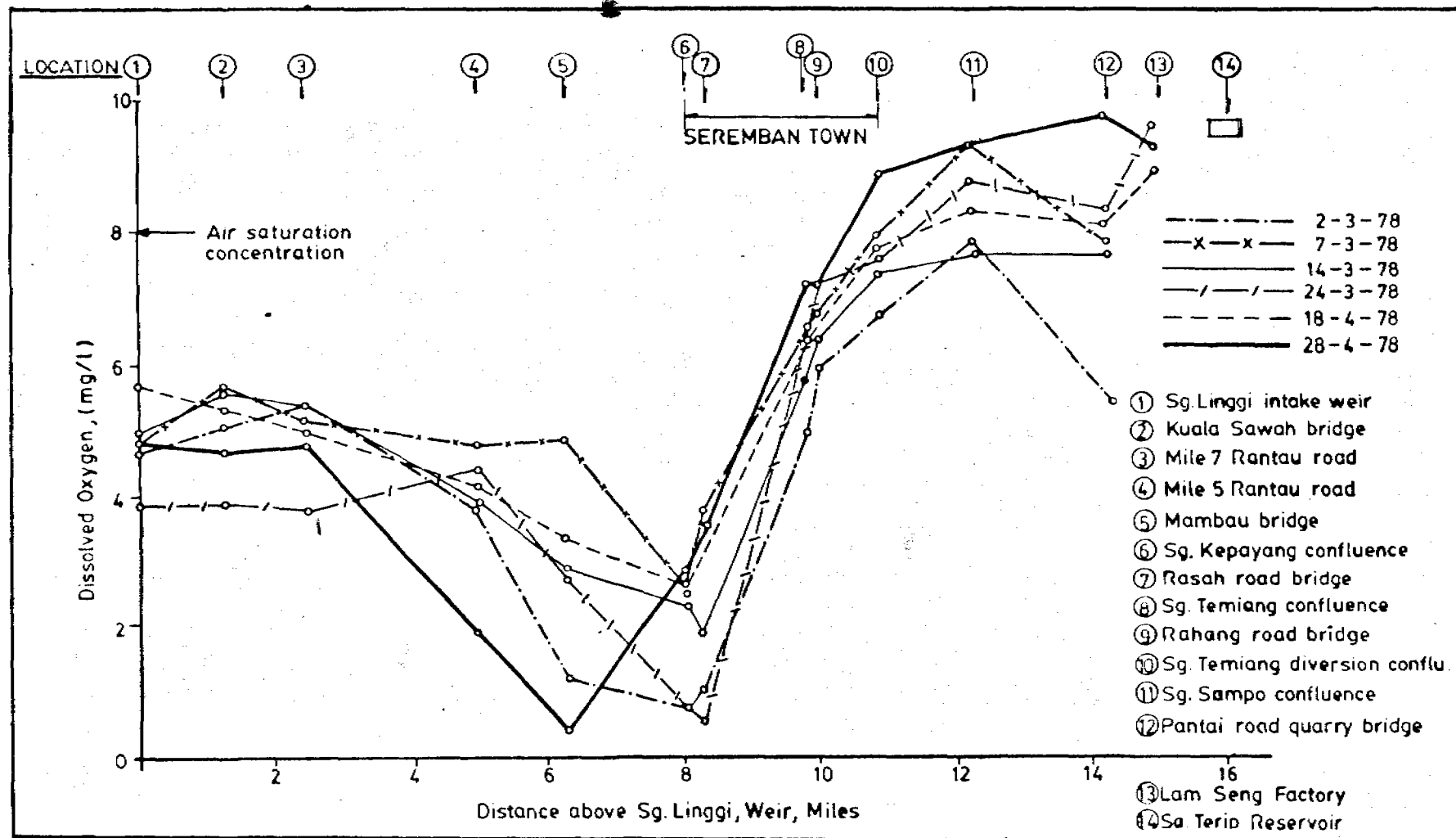


Fig. 2 Sg. Linggi Dissolved Oxygen Profile

causative factors. In general, water quality models are designed to (i) accept as input, constituent concentration versus time at points of entry to the system; (ii) simulate the mixing and reaction kinetics of the system; and (iii) synthesize a time-distributed output at the system outlet.

Since hydrophysical and ecological equations are invariably coupled, water quality models are usually characterized by high degrees of complexity and very difficult mathematical solutions. Selecting the appropriate degree of complexity is a challenging task. Usually, models are generated in accordance with preset objectives of the modeling effort and with predetermined amounts and quality of field observations (Krenkel and Novotny, 1979).

The concepts of water quality modeling is being promoted increasingly by hydrologists and engineers in the scientific community for application on a wide range of "real-world" problems. Models have been used under a variety of conditions, including physical setting, data availability, and other factors affecting potential benefits of such assessment techniques. Numerous models have been applied to simulate water quality conditions in streams, surface-water impoundments, urban areas, aquifers, and estuaries (Steele, 1984).

Stream Water quality Model QUAL2E-UNCAS

The Enhanced Stream Water Quality Model QUAL2E and QUAL2E-UNCAS (Brown, L. C., and T. O. Barnwell, 1987) permits simulation of several water quality constituents in a branching stream system using a finite difference solution to the one-dimensional advective-dispersive mass transport and reaction equation. The conceptual representation of a stream used in the QUAL2E formulation is a stream reach that has been divided into a number of subreaches or computational elements equivalent to finite differences. For each computational element, a hydrologic balance in terms of flow (Q), a heat balance in terms of temperature (T), and a materials balance in terms of concentration (C) is written. Both advective and dispersive transport are considered in the materials balance. Mass can be gained or lost from the element by transport processes, external sources and sinks (e.g., waste discharges or withdrawals) or by internal sources and sinks (e.g., benthic sources or biological transformations). The equation is solved for the steady-flow, steady state condition in a classical implicit backward difference method. The specific equations and solution technique are described in detail in the QUAL2E computer program documentation (USEPA, 1987).

Prototype Representation

Prototype representation in QUAL2E consists of dividing a stream in a network of "Headwaters", "Reaches", and "Junctions". The fundamental reason for subdividing sections of stream into "Reaches" is that QUAL2E assumes that some 26 physical, chemical and biological properties (model input parameters or coefficients) are constant along a "Reach". The question that must be addressed in order to define a "Reach" is what constitutes "significant" change in these model inputs - "significant" in the sense of their impact on simulation results, not necessarily in the sense of change in the

inputs themselves.

Mass transport in the QUAL2E computer program is handled in a relatively simple manner. There seems to be some confusion about QUAL2E's transport capabilities as it is sometimes called a "dynamic" model. However, in all of the computer programs in the QUAL series, there is an explicit assumption of steady flow; the only time-varying forcing functions are the climatologic variables that primarily affect temperature and algal growth. A more proper term for this capability is "diel," indicating variation over a 24-hour period. The forcing function used for estimating transport is the streamflow rate, which, as mentioned above, is assumed to be constant. Stream velocity, cross-sectional area, and depth are computed from streamflow.

One of the most important considerations in determining the assimilative capacity of a stream is its ability to maintain an adequate dissolved oxygen concentration. The QUAL2E computer program includes the major interactions of the nutrient cycles, algal production, benthic and carbonaceous oxygen demand, atmospheric reaeration, and their effect on the dissolved oxygen balance as shown in Fig. 3. In addition, the computer program includes a heat balance for the computation of temperature and mass balances for conservative minerals, coliform bacteria, and non-conservative constituents such as radioactive substances. Chlorophyll a is modeled as the indicator of planktonic algae biomass in QUAL2E.

User Requirements

In its present state, QUAL2E requires some degree of modeling sophistication and expertise on the part of a user. The user must supply more than 100 individual inputs, some of which require considerable judgment to estimate. The uncertainty analysis procedures incorporated in the computer program serve both to guide the user in the calibration process as well as to provide information about the uncertainty associated with calibrated model.

THE SG. LINGGI PROJECT FORMULATION AND MODEL REPRESENTATION

Stream Network Representation

Figure 4 presents the Sg. Linggi prototype system representation suitable for simulation by the QUAL2E model. The Sg. Linggi is modeled from its headwaters, the Pantai headworks to the SLWTP intake, a total distance of 28.0 miles, along its main stem. Valid simplifications were made to the system for the purpose of reducing undue complexity of the system, hence computational needs, while maintaining its intended analytical objective.

Sixteen major point loads of significant importance were identified in the system as shown in Fig. 4. They comprised of 3 direct discharge outfalls (PL1, PL5, and, PL11) and 13 tributaries of the Sg. Linggi. In addition, municipal discharges originating from open drains and sewers serving the town of Seremban were simulated as dispersed loads along river reach R3 from RM 12 to RM 8.

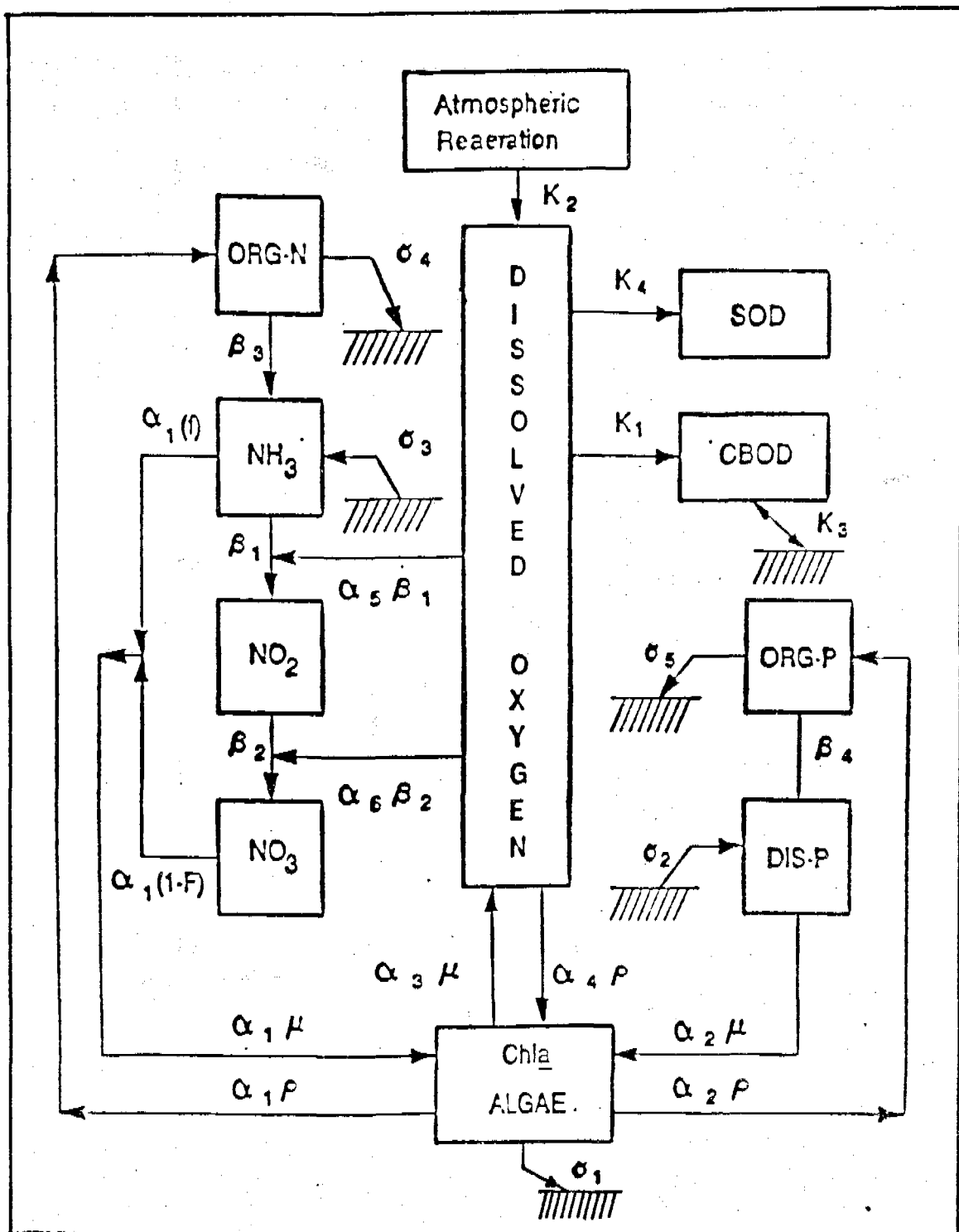


Fig. 3 QUAL2E Schematic of Dissolved Oxygen Balance

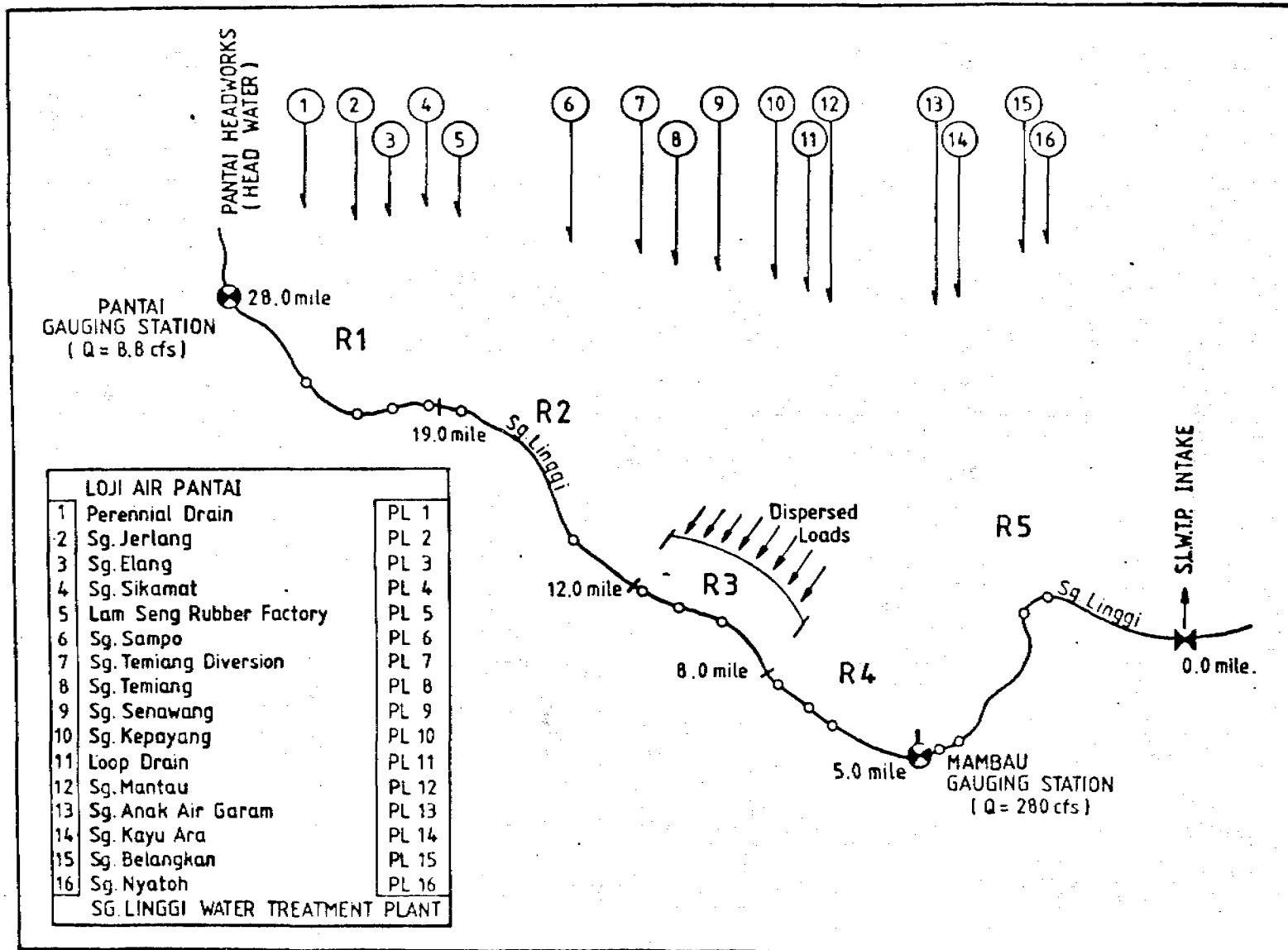


Fig.4 Prototype River System Representation In QUAL2E Model Simulation

Data Collection Programme

A 6 months field investigation and data collection programme was conducted by the project team to measure and determine various groups of parametric values used as inputs to the model. Basically, the parameters are grouped either as hydraulic inputs or water quality inputs as listed in Table 1.

The hydraulic parameters includes flow datas (headwaters, incremental flows, point and dispersed flows), velocities, and stream depths. Two hydraulic stage-discharge control stations were used to provide datas utilised in the calibration and validation process of the model as well as in the computation of the incremental flows, i.e., the Pantai and the Mambau Gauging Stations.

Water quality parameters includes BOD and DO concentration values of the forcing functions to the model. Sixteen water quality monitoring stations were established along the Sg. Linggi for the purpose of sampling and analysis. The frequency of sampling and analysis was on a biweekly basis. Basic environmental parameters, i.e., pH, temperature, conductivity as well as dissolved oxygen were measured on site, while samples for BOD were collected and transported to the Sg. Linggi Research Laboratory for analysis. The techniques used in the sampling, transportation, sample preparation and preservation, and analysis were in strict conformance to the Standard Methods of Examination of Water and Wastes (APHA, 1976). The dissolved oxygen values measured (observation points) were used in the calibration and validation stages of the modeling effort.

The hydraulic coefficients and the water quality reaction coefficients were determined both in the field (insitu) as well as in the Laboratory. The coefficient values were checked against the typical range of established parametric values as part of the testing and screening process. A certain degree of judgement was made where necessary and appropriate in the screening process.

Model Representation

Figure 5 depicts the model prototype representation of the Sg. Linggi system used in the computation. As observed, the Sg. Linggi is divided into 5 stream reaches of various lengths. The division of the stream reaches among others was based on the degree of detail (objective) required, the amount of worth of available data, stream geometry, number and location of wasteloads, hydraulic and biochemical characteristics. An element length of 0.5 miles was selected for the system which is sufficient for the degree of resolution required. This resulted in a total of 56 computational elements for the Sg. Linggi.

RESULTS AND DISCUSSION

Model Calibration and Validation

The hydraulic (depth, velocity, and flow) and water quality (dissolved oxygen) parametric values acquired in the data collection

Table I : QUAL2E Input File

```

TITLE01          WASTELOAD ALLOCATION AND ASSIMILATIVE CAPACITY MODELING
TITLE02          BG.LINGOI WATERSHED ABOVE SLWTF
TITLE03 NO       CONSERVATIVE MINERAL I           IN
TITLE04 NO       CONSERVATIVE MINERAL II          IN
TITLE05 NO       CONSERVATIVE MINERAL III         IN
TITLE06 YES      TEMPERATURE
TITLE07 YES      BIOCHEMICAL OXYGEN DEMAND
TITLE08 NO       ALGAE AS CHL-A IN UG/L
TITLE09 NO       PHOSPHORUS CYCLE AS P IN MG/L
TITLE10          (ORGANIC-P, DISSOLVED-P)
TITLE11 NO       NITROGEN CYCLE AS N IN MG/L
TITLE12          (ORGANIC-N, AMMONIA-N, NITRITE-N, NITRITE-N)
TITLE13 YES      DISSOLVED OXYGEN IN MG/L
TITLE14 NO       FECAL COLIFORMS IN NO./100 ML
TITLE15 NO       ARBITRARY NON-CONSERVATIVE
ENDTITLE
LIST DATA INPUT
NO WRITE OPTIONAL SUMMARY
NO FLOW AUGMENTATION
STEADY STATE
TRAPEZOIDAL X-SECTIONS
NO PRINT LCD/SOLAR DATA
PLOT DO AND BOD
FIXED DNSTM COND (YES=1)=      0.0          5D-ULT BOD CONV K COEF =      0.67
INPUT METRIC (YES=1) =      0.0          OUTPUT METRIC (YES=1) =      0.0
NUMBER OF REACHES =      5.0          NUMBER OF JUNCTIONS =      0.0
NUM OF HEADWATERS =      1.0          NUMBER OF POINT LOADS =      16.0
TIME STEP (HOURS) =      0.0          LNTH COMP ELEMENT (DX)=      0.5
MAXIMUM ITERATIONS =      30.0          TIME INC. FOR RPT2 (HRS)=      0.0
LATITUDE OF BASIN (DEG) =      34.0          LONGITUDE OF BASIN (DEG)=      85.0
STANDARD MERIDIAN (DEG) =      75.0          DAY OF YEAR START TIME =      180.0
EVAP. COEFF. (AE) =1.02999E-3          EVAP. COEFF. (BE) =1.59999E-4
ELEV. OF BASIN (ELEV) =. 250.0          DUST ATTENUATION COEF. =      0.06
ENDATA1
O UPTAKE BY NH3 OXID(MG O/MG N)=      3.43 O UPTAKE BY NO2 OXID(MG O/MG N)=      1.1
O PROD BY ALGAE (MG O/MG A) =      1.6 O UPTAKE BY ALGAE (MG O/MG A) =      2.0
N CONTENT OF ALGAE (MG N/MG A) =      0.085 P CONTENT OF ALGAE (MG P/MG A) =      0.016
ALG MAX SPEC GROWTH RATE(1/DAY)=      2.5 ALGAE RESPIRATION RATE (1/DAY) =      0.03
N HALF SATURATION CONST (MG/L) =      0.2 P HALF SATURATION CONST (MG/L)=      .04
LIN ALG SHADE CO (1/N-UGCHA/L) =0.00075 NLIN SHADE (1/N-(UGCHA/L)**2/3)=      0.0
LIGHT FUNCTION OPTION (LPNOPT) =      1.0 LIGHT SATURATION COEF (INT/MIN)=      .11
DAILY AVERAGING OPTION (LAVOPT)=      2.0 TOTAL DAILY SOLAR RADTN (INT) =      0.92
NUMBER OF DAYLIGHT HOURS (DLH) =      14.0 TOTAL DAILY SOLAR RADTN (INT) =1300.0
ALCY GROWTH CALC OPTION(LOROPT)=      2.0 ALGAL PREF FOR NH3-N (PREFN) =      .9
ALC/TEMP SOLR RAD FACTOR(TFACT)=      .44 NITRIFICATION INHIBITION COEF =      10.0
ENDATA1A
ENDATA1B
STREAM REACH      1.ORCH=PANTAI-SIKAMAT      FROM      28.0      TO      19.0
STREAM REACH      2.ORCH=SIKAMAT-TEM.D.      FROM      19.0      TO      12.0
STREAM REACH      3.ORCH=TEM.D-KEPAYANG      FROM      12.0      TO      0.0
STREAM REACH      4.ORCH=KEPAYANG-MAMBAU      FROM      0.0      TO      5.0
STREAM REACH      5.ORCH=MAMBAU-LOJI      FROM      5.0      TO      0.0
ENDATA2
ENDATA3
FLAG FIELD RCH= 1.0      18.      1 2 2 2 2 2 2 2 6 2 2 2 6 2 6 2 2 6
FLAG FIELD RCH= 2.0      14      2 6 2 2 2 2 2 2 2 2 2 6 2 2 2
FLAG FIELD RCH= 3.0      8      6 2 6 2 2 6 2 2
FLAG FIELD RCH= 4.0      1 6      6 2 6 6 2 2
FLAG FIELD RCH= 5.0      10      6 6 2 2 2 6 6 2 2 5
ENDATA4
HYDRAULICS RCH= 1.0      200.0      1.0      1.0      25.0      .001      0.1
HYDRAULICS RCH= 2.0      200.0      1.0      1.0      35.0      .001      0.1
HYDRAULICS RCH= 3.0      200.0      1.0      1.0      53.0      .001      0.15
HYDRAULICS RCH= 4.0      200.0      1.0      1.0      70.0      .001      0.03
HYDRAULICS RCH= 5.0      200.0      1.0      1.0      95.0      .001      0.05
ENDATA5
REACT COEF RCH= 1.0      0.23      0.0      0.0 3.0      0.0      0.0      0.0
REACT COEF RCH= 2.0      0.23      0.0      0.0 3.0      0.0      0.0      0.0
REACT COEF RCH= 3.0      0.23      0.0      0.0 3.0      0.0      0.0      0.0
REACT COEF RCH= 4.0      0.23      0.0      0.0 3.0      0.0      0.0      0.0
REACT COEF RCH= 5.0      0.23      0.0      0.0 3.0      0.0      0.0      0.0

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ENDATA6
ENDATA6A
ENDATA6B
INITIAL COND-1 RCH= 1.0 77.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
INITIAL COND-1 RCH= 2.0 77.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
INITIAL COND-1 RCH= 3.0 77.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
INITIAL COND-1 RCH= 4.0 77.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
INITIAL COND-1 RCH= 5.0 77.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
ENDATA7
INITIAL COND-2 RCH= 1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
INITIAL COND-2 RCH= 2.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
INITIAL COND-2 RCH= 3.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
INITIAL COND-2 RCH= 4.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
INITIAL COND-2 RCH= 5.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
ENDATA7A
INCR INFLOW-1 RCH= 1.0 18.0 77.0 5.0 2.0 0.0 0.0 0.0 0.0
INCR INFLOW-1 RCH= 2.0 21.0 77.0 5.0 2.0 0.0 0.0 0.0 0.0
INCR INFLOW-1 RCH= 3.0 35.0 77.0 0.0 250.0 0.0 0.0 0.0 0.0
INCR INFLOW-1 RCH= 4.0 23.0 77.0 5.0 1.0 0.0 0.0 0.0 0.0
INCR INFLOW-1 RCH= 5.0 40.0 77.0 5.0 1.0 0.0 0.0 0.0 0.0
ENDATA8
INCR INFLOW-2 RCH= 1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
INCR INFLOW-2 RCH= 2.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
INCR INFLOW-2 RCH= 3.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
INCR INFLOW-2 RCH= 4.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
INCR INFLOW-2 RCH= 5.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
ENDATA8A
ENDATA9
HEADWTR-1 HDW= 1.0PANTAI HW 8.8 77.0 8.4 0.8 0.0 0.0 0.0
ENDATA10
HEADWTR-2 HDW= 1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
ENDATA10A
POINTLD-1 PTL= 1.0PERN.DRAIN 0.0 2.0 77.0 3.0 10.0 0.0 0.0 0.0
POINTLD-1 PTL= 2.0SG.JERLANG 0.0 5.5 77.0 5.0 2.0 0.0 0.0 0.0
POINTLD-1 PTL= 3.0SG.BLANG 0.0 6.1 77.0 8.0 2.0 0.0 0.0 0.0
POINTLD-1 PTL= 4.0SG.SIKAMAT 0.0 12.8 77.0 2.0 25.0 0.0 0.0 0.0
POINTLD-1 PTL= 5.0LAM BENG F 0.0 2.0 77.0 0.01500.0 0.0 0.0 0.0
POINTLD-1 PTL= 6.0SG.SAMPO 0.0 7.0 77.0 4.0 5.0 0.0 0.0 0.0
POINTLD-1 PTL= 7.0TEMANG D. 0.0 42.24 77.0 4.5 5.0 0.0 0.0 0.0
POINTLD-1 PTL= 8.0S.TEMIANO 0.0 35.0 77.0 2.0 23.0 0.0 0.0 0.0
POINTLD-1 PTL= 9.0S.SENAWANO 0.0 12.0 77.0 2.5 10.0 0.0 0.0 0.0
POINTLD-1 PTL= 10.0S.KEPAYANG 0.0 35.2 77.0 5.0 2.0 0.0 0.0 0.0
POINTLD-1 PTL= 11.0LOOP DRAIN 0.0 1.7 77.0 2.0 5.0 0.0 0.0 0.0
POINTLD-1 PTL= 12.0SG.MANTAU 0.0 7.3 77.0 5.0 2.0 0.0 0.0 0.0
POINTLD-1 PTL= 13.0S.A.A.GARAM 0.0 3.8 77.0 6.0 2.0 0.0 0.0 0.0
POINTLD-1 PTL= 14.0S.KAYU ARA 0.0 7.1 77.0 6.0 2.0 0.0 0.0 0.0
POINTLD-1 PTL= 15.0S.BELANGKAN 0.0 4.6 77.0 6.3 2.0 0.0 0.0 0.0
POINTLD-1 PTL= 16.0SG.NYATOH 0.0 5.0 77.0 6.0 2.0 0.0 0.0 0.0
ENDATA11
POINTLD-2 PTL= 1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
POINTLD-2 PTL= 2.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
POINTLD-2 PTL= 3.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
POINTLD-2 PTL= 4.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
POINTLD-2 PTL= 5.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
POINTLD-2 PTL= 6.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
POINTLD-2 PTL= 7.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
POINTLD-2 PTL= 8.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
POINTLD-2 PTL= 9.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
POINTLD-2 PTL= 10.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
POINTLD-2 PTL= 11.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
POINTLD-2 PTL= 12.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
POINTLD-2 PTL= 13.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
POINTLD-2 PTL= 14.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
POINTLD-2 PTL= 15.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
POINTLD-2 PTL= 16.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
ENDATA11A
ENDATA12
DOWNSTREAM BOUNDARY-1 70.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
ENDATA13
ENDATA13A
LOCAL CLIMATOLOGY 0.3 80.0 77.0 30.0 0.0
BEGIN RCH 1
PLOT RCH 1 2 3 4 5

```


programme were used in the calibration and validation of the model. During the calibration process, values of the hydraulic and reaction rate coefficients were varied or "tuned" within an allowable range with sufficient justification. Any abnormalities in the parametric values were examined in detail before the final value is considered acceptable.

The "testing" of the model on the hydraulic simulated output was accomplished by comparing the simulated and observed flows at the Mambau Gauging station. From the model output, it can be observed that the computed flow, 282.4 cfs at Mambau is significantly close to the measured value of 280.0 cfs. The statistical accuracy is within 1.0 percent. Similarly, the simulated velocity and depth profiles were tested to be within 3.5 to 4.0 percent of the observed values respectively. These are statistically acceptable values, and hence the profiles were accepted in the modeling exercise. This calibration step is very important since the hydraulic and hydrologic components of the system represents the vehicle or transport "chassis" that determines the migration and "fate" of the pollutants within the system.

The validation result of the model can be observed from Fig. 6. The simulated concentrations are plotted as continuous lines, whereas the concentrations from the data acquisition programme are represented as single observation points in the plot since they originate from discrete sample analysis.

Statistical analysis was performed on the simulated profile to determine the validity of the model. Various tests were applied using the SAS statistical package (SAS, 1982). The correlation coefficient, R , was computed to be 0.99, and the coefficient of determination, R^2 , was computed from the simple regression of the predicted to the observed DO values to be 0.98, with a standard error of estimate of 0.24. Applying the null hypothesis test at the 1.0 % significance level proved that there is a significant correlation between the predicted and the observed dissolved oxygen profiles.

From the calibration and validation processes above, the model is accepted as sufficiently capable of predicting the impacts of pollution to the Sg. Linggi due to various causative factors, and is subsequently applied to provide scenarios resulting from various potential mitigative measures as described below.

Model Application and Impact Assessment

Figures 7, 8, and 9 presents the impacts of the various mitigative control measures currently planned, proposed, or undertaken by the State Government in the efforts to improve the raw water quality, i.e., the healthy conditions of the Sg. Linggi. It is important to note that this is determined surrogately by the targetted dissolved oxygen minimum level of 5.0 at any point along the river. It is envisaged that at this level the raw water quality shall be able to meet the criteria and standards required for the purpose of supporting aquatic life within the river regime, recreational use with body contact, and be used as a source of drinking water requiring conventional treatment only. Such beneficial uses requires

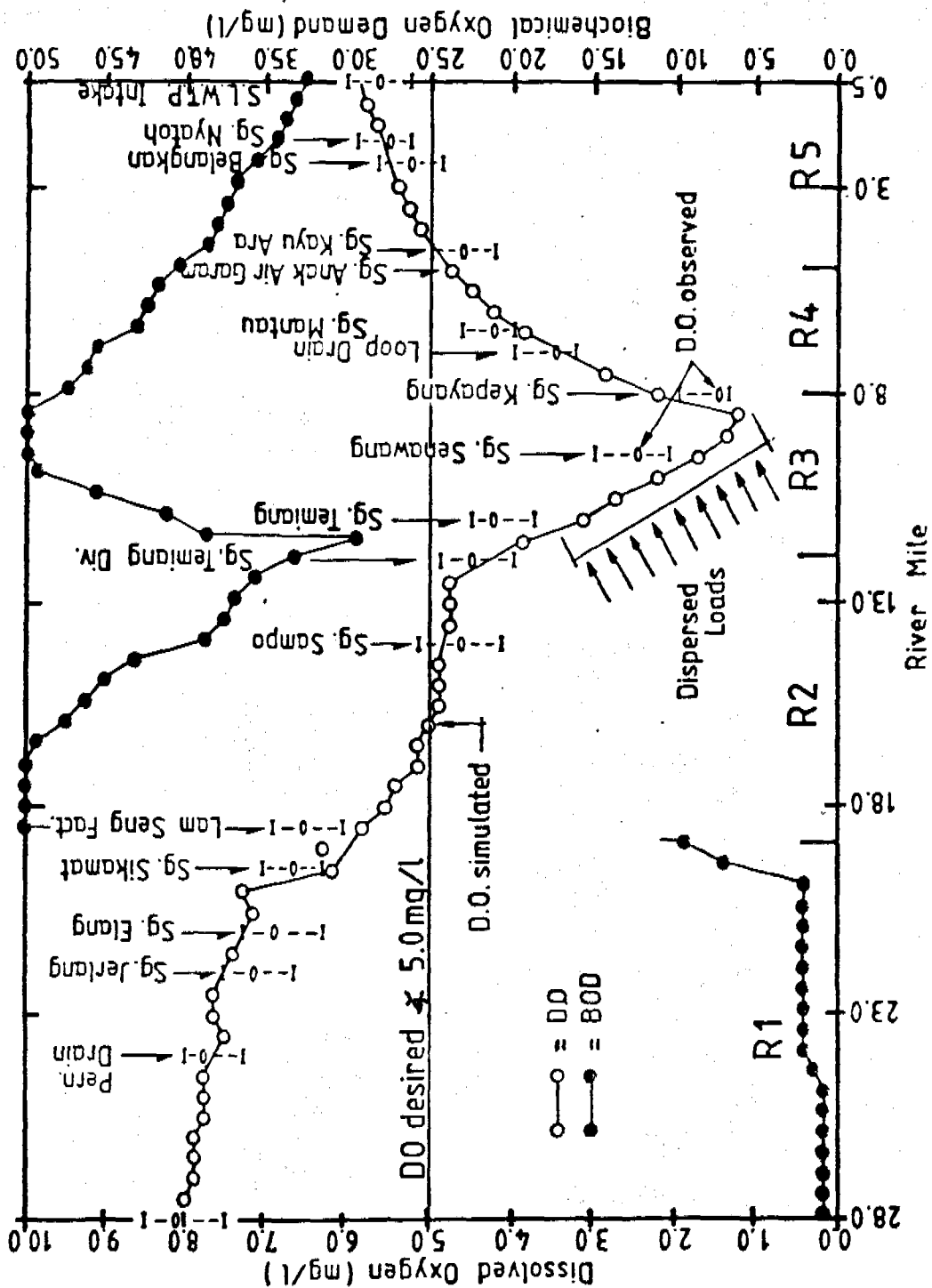


Fig. 6 Sg. Linggi Dissolved Oxygen Simulated Profile

a raw water quality conforming to the Class IIA standards as recommended by the report published by the Department of Environment (DOE) in 1986 (Goh, et al., 1988).

Figure 7 predicts the resultant impacts, i.e., the consequential improvement in the DO profile with the implementation and completion of the Greater Seremban Sewerage Masterplan Project, envisaged to be completed by 1993. The project in essence attempts to collect and divert sewage and sillage generated by the urban town of Seremban and its suburban surroundings to a central sewerage treatment plant. It can be observed that there is a significant reduction of the DO sag along river reaches R3 and R4 as expected. However, this mitigative measure by itself is insufficient to achieve the desired water quality standard as predicted by the model, where the DO is below the minimum level of 5.0 for a stretch from river mile 16.0 to 7.5., a distance of 8.5 miles.

The combined effect of the Sewerage Masterplan Implementation Project and the relocation of the Lam Seng Rubber Factory at river mile 18.5 to a site outside the Linggi catchment could be observed from Fig. 8. The predicted DO profile shows that all along the Sg. Linggi, the water quality conforms to the stipulated standard as measured by the DO predicted values, although there is a stretch of the Sg. Linggi from river miles 11.5 to 9.0 (DO sag), where the DO is at a minimum of 5.3 mg/l. Cumulatively, this in effect represents the most polluted stretch of the Sg. Linggi, significantly due to the impact of the Sg. Temiang at river mile 11.0, which drains the central area of the town of Seremban, the most urban zone.

It is interesting to note that the State Government had recently embarked on a noble major Statewide environmental Masterplan programme which includes the cleaning up of Sg. Linggi beginning with the Sg. Temiang. Details of the Sg. Temiang cleaning up operation planning and predictive modeling had been presented in a separate paper (Johari, 1992). The mitigative effect of the programme can be observed to further enhanced the predictive DO profile of the Sg. Linggi as demonstrated in Fig. 9. At all stretches of the river, the predicted DO is above 6.0 mg/l.

FINAL REMARKS

The predictive computer simulation modeling study undertaken above in summary clearly demonstrates the utility and importance of computer simulation models in the field of environmental impact assessment, wasteload allocations, and assimilative capacity evaluations.

Through water quality simulation modeling a more rational basis for making water quality control decisions, a basis which should include a defensible, credible, predictive framework within the larger framework of economic analysis could be made.

ACKNOWLEDGEMENTS

The author would like to express his appreciations to the members of

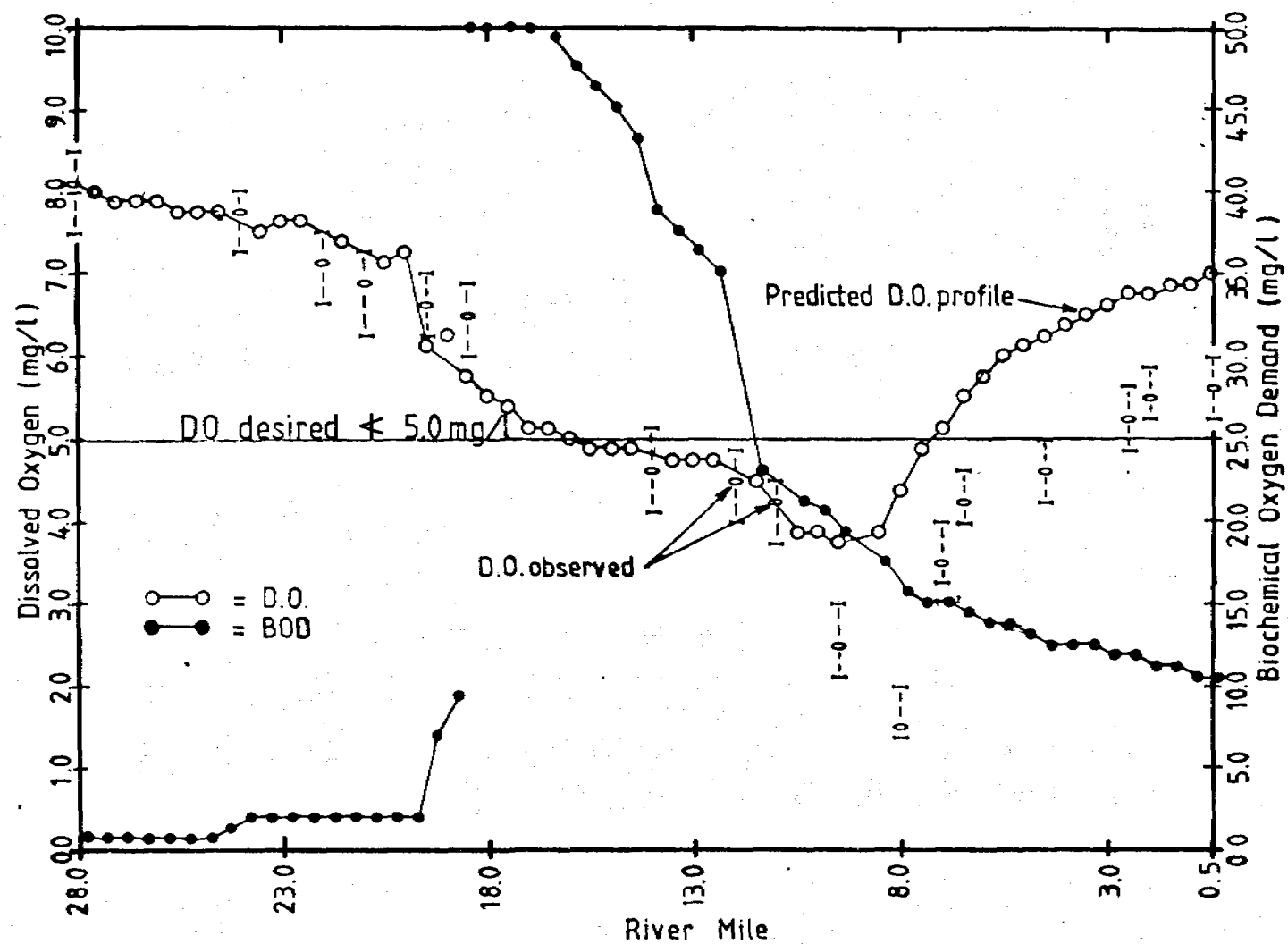


Fig.7 Mitigative Environmental Control Action 1

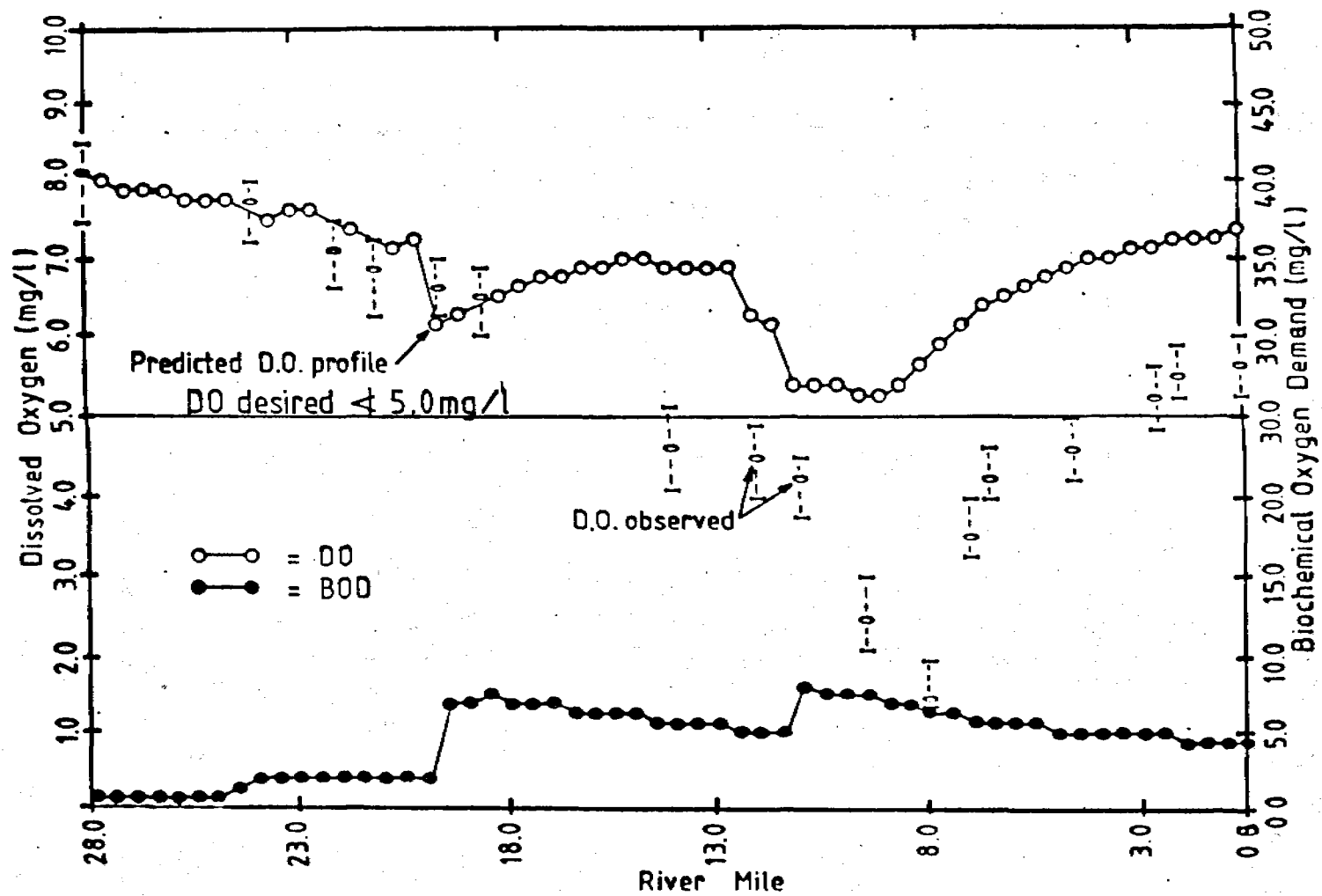


Fig. 8 Mitigative Environmental Control Action 2

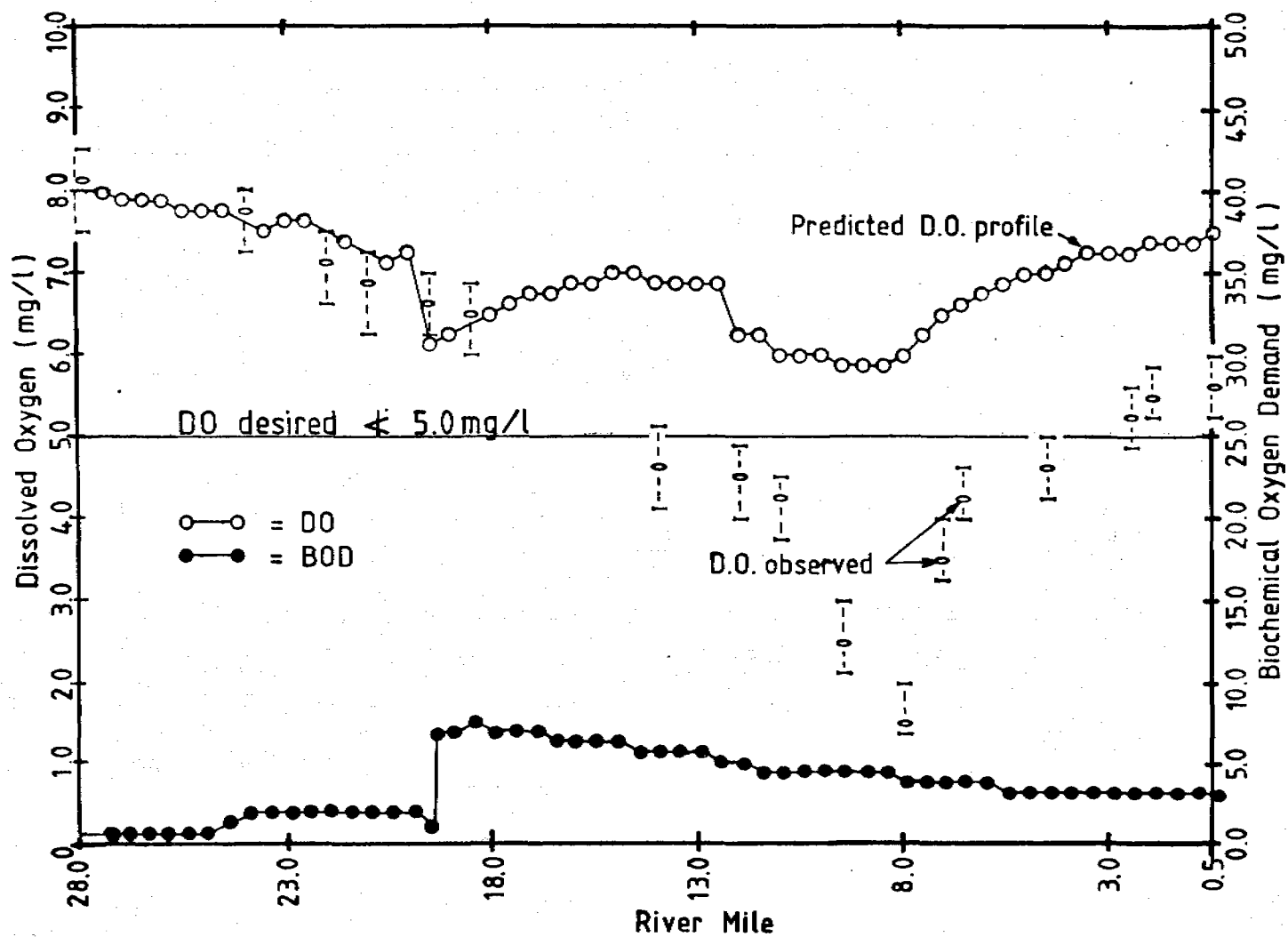


Fig.9 Mitigative Environmental Control Action 3

the Sg. Linggi Taskforce who had diligently executed their functions in the six months field and laboratory data acquisition programme. Special mention is due to Ms. Noor Azimah Mustafa who had conscientiously spent countless hours analysing the data and processing the results of the computer simulation modeling. A word of thanks is also due to Mr. Aziz Sidek for illustration.

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CLASSIFICATION OF RIVERS IN MALAYSIA ACCORDING TO VARIOUS BENEFICIAL USES AND WATER QUALITY

Dr. Fauzi Abd. Samad
Director
Syed Muhammad, Hooi dan Binnie Sdn. Bhd.
Kuala Lumpur, Malaysia

Dr. Abu Bakar Jaafar
Director General
Department of Environment, Malaysia
Kuala Lumpur, Malaysia

ABSTRACT: The program described in this paper is being undertaken by the Department of Environment to classify Malaysian rivers according to beneficial uses and water quality. It is aimed at maintaining the assets of the rivers for sustainable development. The Department started monitoring river water quality in 1978 and has classified rivers according to high and low priority. Continuing that, this program classifies rivers into six groups based on their Water Quality Index. This paper presents Kelang river basin as the case study.

1. INTRODUCTION

In order to implement water quality standards to protect and enhance the beneficial uses of rivers, a program for the designation of the various rivers/river segments was carried out by the Department of Environment in 1990. This program was an offshoot of the main program on Development of Criteria and Standards for Water Quality. The program involves detailed attainability analyses of the required standards for the rivers. About 49 major river basins in Peninsular Malaysia, 27 in Sabah and 21 in Sarawak need classifying. In the first part of this program six representative river basins were classified. They are the Sg. Muda, Sg. Perak, Sg. Kelang, Sg. Linggi, Sg. Muar and Sg. Pahang Basins. More river basins have been identified by the DOE and are being classified now. The technique categorizes water bodies involving mainly river basins, into different classes. Beneficial uses are then designated to the river segment according to the known uses. This approach was used to achieve the management objectives of maintaining quality of at least the present level while aiming for further enhancement in the long term.

Among the objectives of the project are:

- (a) to classify all major rivers into uses of water for conservation of natural environment, domestic water supplies, fisheries and aquaculture, recreational use with body contact, livestock drinking, irrigation and others
- (b) to develop a database management on the river basin which is required for the class designation process and to develop a river basin planning and management information system

- (c) to study the use of water quality index for quality assessment and presentation in the water quality management.

2. THE DOE RIVER WATER MONITORING PROGRAM

The DOE water quality monitoring program was started in 1978, when sites were set up on 33 rivers in 13 river basins. The number of sites was substantially increased in 1979 and has continued to grow since then. The aim of the monitoring program is to collect data from rivers which are known to receive wastewater discharges, particularly from palm oil and rubber factories, or which have been the subject of complaints from the public. Rivers are classified as being of high or low priority on the basis of the severity of pollution and the number of complaints received from the public. The aim of DOE is to sample the high priority rivers monthly and low priority rivers from 4 to 6 times a year.

In practice the DOE have not been able to meet these goals at a number of sites for a variety of reasons, including:-

- o loss of access to the site and inability to sample due to floods
- o lack of staff to carry out the sampling program or insufficient budget.

Since most of the routine samples are collected monthly, the data obtained from routine monitoring can be used to indicate the long-term trend in water quality in the country's river system but cannot provide the short-term variations which may occur from day to day with changes in flow.

3. APPROACH TO RIVER CLASSIFICATION

In order to classify rivers, the following approach can be used:

- (i) collect and collate data required to evaluate the beneficial uses
- (ii) process the river water quality monitoring data to establish the river water quality
- (iii) determine an aggregate classification system taking into account the desired and existing water quality.

Depending on their uses, rivers can be classified into six groups:

Class I - conservation of natural environment

- o water supply I : no treatment necessary
- o fishery I : very sensitive aquatic species

Class IIA o water supply II: conventional treatment required
o fishery II : sensitive aquatic species

Class IIB - recreational use with body contact

Class III o water supply III: extensive treatment required

- o fishery III : common species of economic value and tolerant species
- o livestock drinking

Class IV - irrigation

Class V - water unsuitable for specified beneficial uses.

3.1 Collection and Collation of Beneficial Use Data

An inventory of data for river basins should be developed. A computerized system for the storage and retrieval of data for all river basins may be used. In Malaysia, point pollution sources are identified under the categories: sewage, other industries, rubber processing factories, palm oil mills, major pig farms. Pollution will keep on increasing with time depending on abatement measures taken. Several factors which will affect future water quality include:

- (i) increased pollution loading that may occur at the point source discharges
- (ii) the extent to which treatment facilities are installed and standards enforced
- (iii) possible increase in pollution from dispersed pollution sources including run-off from irrigation systems and changes caused by removal of natural vegetation and expansion of cultivated land
- (iv) increase in rural population and industries
- (v) changes in river flows caused by regulation and increased abstraction or discharge.

In order to assess the changes that may occur in river water quality resulting from different combinations of these factors, mathematical modelling can be used to project the qualities of river water using various scenarios to test sensitivities.

The integrated database includes catchment data such as population, land-use and beneficial uses of the rivers. The population data include a listing of population in urban and rural areas. The land-use data include the types of land use found in each river basin and the area they occupied at a given date. Hence, it will be possible to calculate the proportion of the river basin over a particular land use on a specified date, or the change of a particular land use with time. The beneficial use data include water supply, irrigation, fisheries, and others. The information could also contain the names of significant intakes or discharges located upstream of the intake. It is also necessary to have a record of the river flow data.

The principal difficulties associated with the selection of beneficial-use classes are in determining what aquatic species are to be protected and how the existing level of treatment for potable water supply matches the descriptions for Class II and Class III water. Throughout most of the river system, the intention is to preserve species which are common, of economic value, and tolerant. The protection of sensitive or very sensitive species would be appropriate only for the upper reaches of the

ivers. Most reaches of river basins in Malaysia can be classified as Class III according to the existing beneficial uses. Some sections of headwaters may be appropriate for designation as Class II or Class I. The downstream may be designated Class III or Class IV.

3.2 Analysis of Existing River Water Quality

The lists of parameters can be used to classify rivers based on existing water quality.

List 1-parameters: pH, dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen (BOD₅), suspended solids (SS), ammonia- nitrogen (NH₃-N).

List 2-parameters: colour, oil and grease, detergents (MBAS), salinity, conductivity, total coliforms, faecal coliforms, cadmium, arsenic, mercury, chromium (total), lead, manganese, aluminum, copper, sulphide, cyanide, nitrate nitrogen, phosphate (as phosphorus), pesticides, phenolics.

List 3-parameters: sodium, boron, chloride, selenium.

The procedure for classification of the parameters is by determining and comparing the corresponding class for each parameter with the National Water Quality Standards (NQWS).

Water quality standards (WQS) are established to serve two purposes:-

- (i) to establish the water quality goals of a given water body
- (ii) to serve as the regulatory basis for the control and protection of the water body quality.

In principle, WQS may be derived from direct adaptation of the various sets of criteria developed for some 70 parameters or so accordingly to the different beneficial uses. For regulatory control, application of these standards to actual water body management would introduce great complexity. Each river is characterized by a set of quality conditions. No direct correlation can be contained between quality standards based on the various beneficial uses with existing quality conditions for a large variation of water bodies. It is therefore not possible to use quality standards based on the various beneficial uses for the classification of water body uses.

A solution to such constraints is to classify water bodies into classes of quality of either descending or ascending order. Beneficial uses are then designated to a river segment accordingly to the highest known use. The quality requirements are based on the corresponding criteria developed with the necessary modifications, taking into consideration site specific effects.

3.3 Aggregate Classification System

It has now been suggested that two sets of river classification be used, based on existing land uses and on existing water quality. It is necessary to determine a single aggregate classification. It is suggested that if the class of the river, determined by using one set of criteria (beneficial uses) is better than by using the other set (quality), then the better class is used. This is adopted in line with the aim of preventing the deterioration of river water quality.

If the economic costs of meeting more stringent effluent standards are prohibitive, several options may be taken:

- (i) review the water quality standards to ensure that they are not stringent
- (ii) investigate alternative means of waste disposal
- (iii) determine the feasibility of modifying the beneficial use to allow for higher pollutant levels
- (iv) terminate the beneficial uses
- (v) relocate the abstraction points for beneficial uses.

The most appropriate option, or mix of options, will need to be determined on a case-by-case basis.

4. DEVELOPMENT OF WATER QUALITY INDEX SYSTEM (WQI)

WQI is used to relate a group of variables (e.g. water quality parameters) to a common scale and combining them into a single number according to a chosen method or model. This system of rating the water quality in terms of a single number has been applied as a measure of the degree of water pollution and also as a tool in water quality classification.

In this work, part of the procedure is to establish a WQI system which can be used as a means of preliminary assessment for a water body with the standards adopted for the various classes of beneficial uses. The WQI is also used for assessment of water quality trends for management purposes, though it is not meant specifically as an absolute measure of the degree of pollution or the actual water quality. Since the use of the WQI in this work is only for ranking the water quality of a water body with respect to the present ranges of the five classes of water quality standards, the choice of the WQI system is not expected to have significant influence on the derived classification. The two types below are chosen:

- (i) an opinion - poll WQI formula in which a "panel of experts" rates the various parameters in terms of their comparative and absolute values, to develop a WQI formula (DOE-WQI)
- (ii) an objective method, such as the one proposed by Harkins based on Kendall's nonparametric multivariate ranking procedure (Harkins WQI).

Both types are applied to the river basins studied. The results obtained are compared to those derived from direct assessment of individual quality parameters of relevance to determine their applicability for future use.

4.1 WQI Based on DOE Formula

The parameters used for the WQI based on the DOE's formula are DO, BOD, VCOD, SS, An and pH. The formula used is:-

$$\text{WQI} = 0.22 * \text{SIDO} + 0.19 * \text{SIBOD} + 0.16 * \text{SICOD} \\ + 0.15 * \text{SIAN} + 0.16 * \text{SISS} + 0.12 * \text{SIpH}$$

where SI is the sub-index for each parameter.

A sample output of the calculations for the Kelang river basin is given in Table 1.

4.2 Objective WQI - Harkins Index

Harkins index follows a statistical approach for analysing water quality data based on the rank order of observations compared to a set of "control values", which is usually a set of water quality standards or recommended limits.

A sample out of the calculations for the Kelang river basin is given in Table 2.

5. CASE STUDY - SG. KELANG BASIN

5.1 The River

Sg. Kelang basin is the most densely populated and industrialised region in Malaysia. The Sg. Gombak (a tributary) discharges into Sg. Kelang in the centre of Kuala Lumpur, and thereafter the Sg. Kelang flows through developed and developing areas in the Kelang Valley, including the Federal Territory of Kuala Lumpur, Petaling Jaya and Shah Alam before it joins the sea at Kelang town. In its lower reaches below the Kuala Lumpur urban area, the river is heavily polluted, making it improbable as a source of abstraction for portable water supply. In the upper reaches, the Sg. Kelang, Sg. Batu and Sg. Gombak have already been developed for water supply. Their catchments are designated as forest reserves.

The waters of Sg. Kelang and its tributaries are used for irrigation, domestic and industrial water supply, washing and bathing, fishing and recreation. They also receive domestic and industrial effluents. Major towns, industrial estates, rubber factories, palm oil mills and animal husbandry are the chief sources of river water pollution. The sources of pollution are expected to increase due to increase in population and industrialisation and hence the water quality monitoring program has become increasingly important.

A review of the water quality monitoring program enables the river basin to be classified according to various beneficial uses and water quality.

5.2 Development of the Basin Inventory System

The DOE presently maintains two sets of pollution source data. Information provided quarterly by palm oil factories and rubber mills in accordance with the relevant Environmental Quality Regulations is stored in Lotus 1-2-3 spreadsheets. Fig.1 shows the land use for the Kelang river basin. The inventory map is shown in Fig. 2.

All known existing point-sources of pollution in the area were identified under the following categories: sewage, other industries, rubber processing factories, palm oil mills, major oil farms. Dispersed pollution sources and surface run-off were also identified. The pollution load of each of these sources was estimated and forecasted for future years.

Beneficial Use Data

Table 3 summarises the existing beneficial uses in the Kelang basin.

Water Quality Index

Tables 4 and 5 give the water quality classification based on DOE's opinion poll and the Harkins Index respectively.

Classification of the Sg. Kelang basin

Table 6 summarises the class designation for Lists 1, 2 and 3 parameters. Fig. 3 shows the map of the river (colour coded) based on water quality and beneficial uses. Areas of conflict and concern are marked. An area of conflict is where the existing river quality is not adequate for the beneficial use for which the water is drawn. An area of concern is where the water quality is poor, upstream of a beneficial use, yet near enough to it to be a cause for concern.

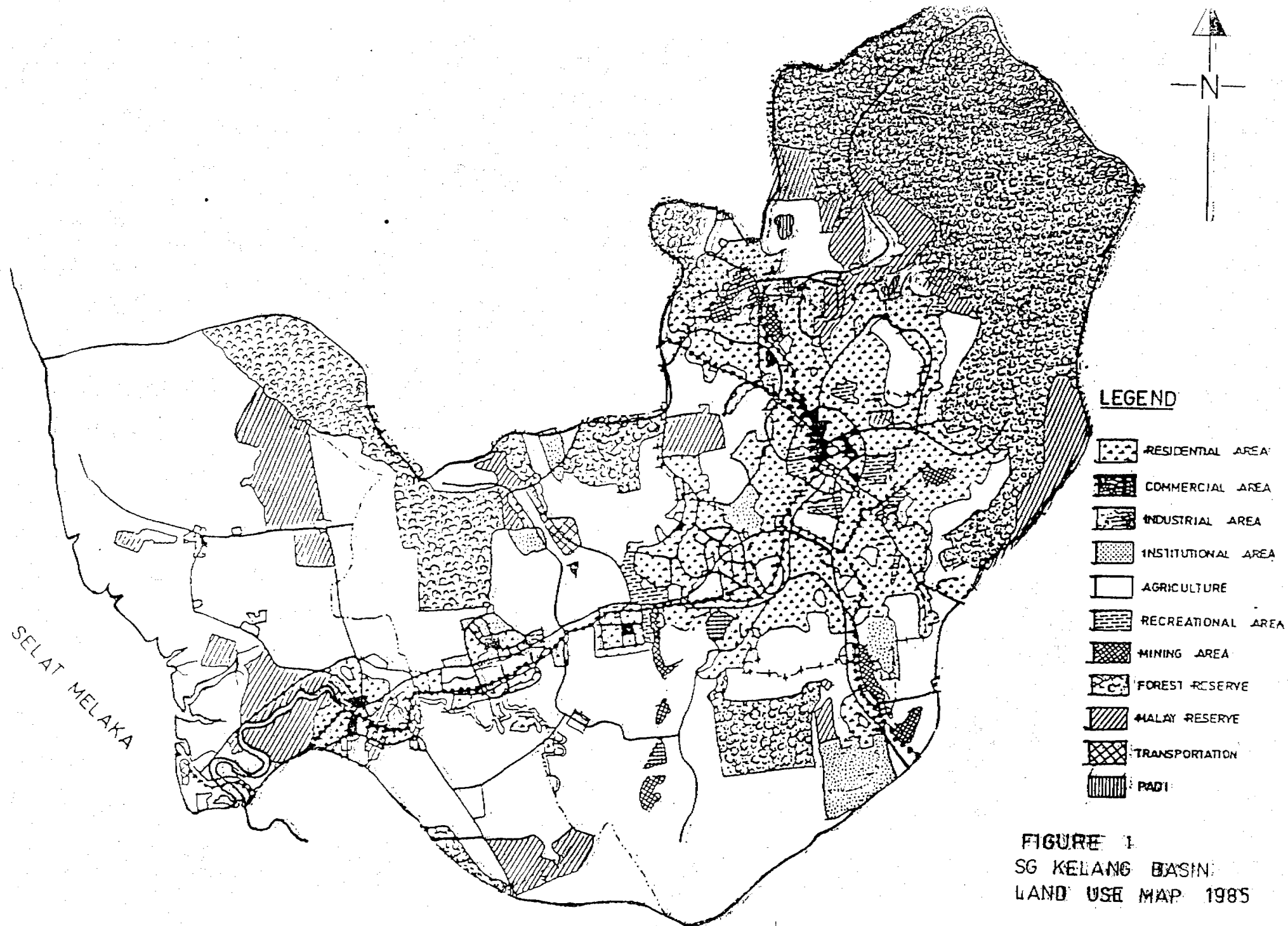
The conclusion from this study is that most reaches of the Sg. Kelang basin can be classified as Class III and below except for short stretches in the very upstream areas. The existing water quality is generally poor, in the Class IV and V categories, as the water drains through the most industrialised and densely populated region in Malaysia.

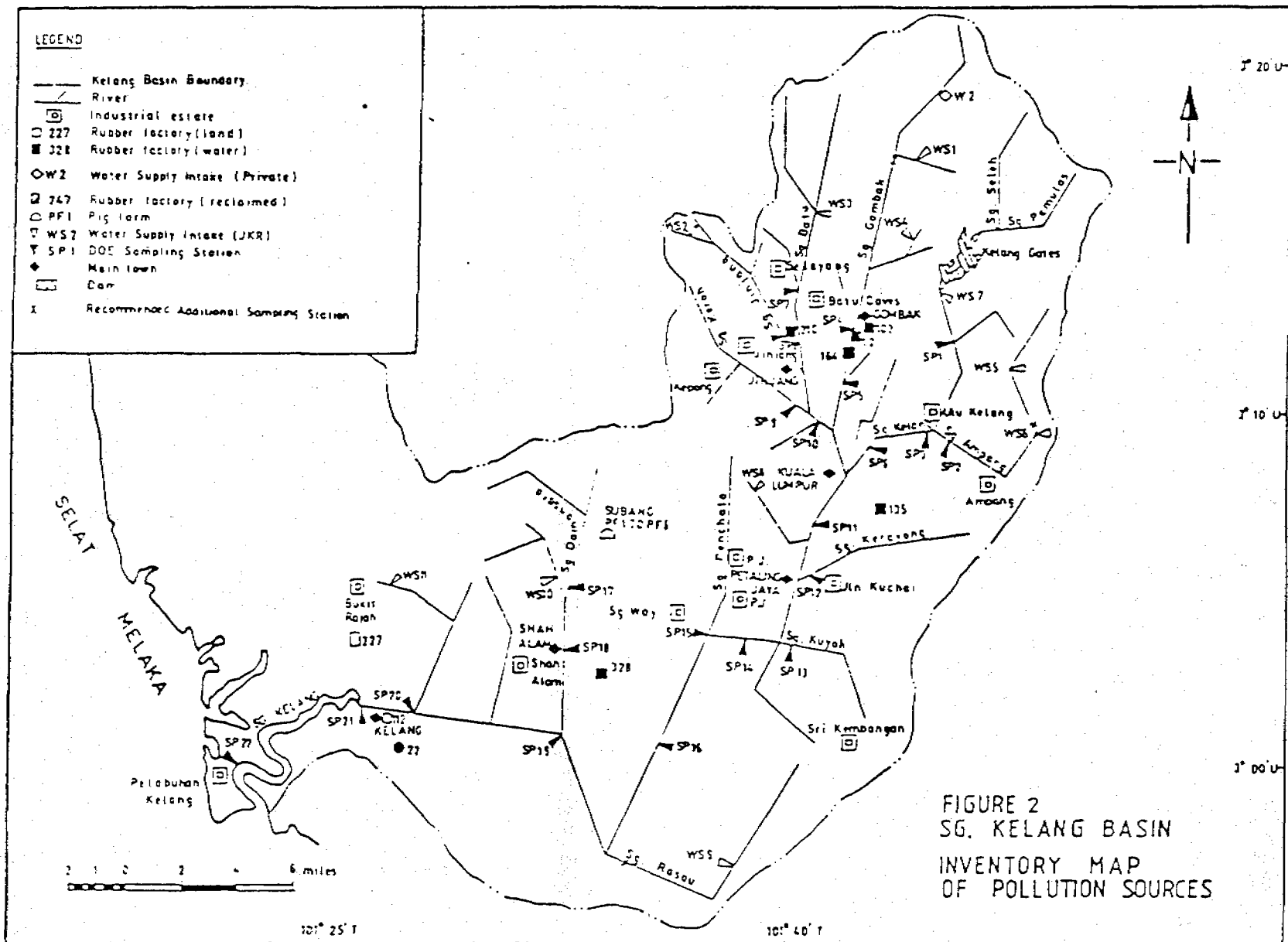
6. CONCLUSION

Presented in this paper is a methodology that can be used to classify rivers according to their beneficial uses and related to the water quality. The main aim of classifying rivers is to maintain the rivers or improve their water quality for sustainable use and development. Rivers are natural assets which need care in planning and management for their preservation.

Reference

Department of Environment, Ministry of Science, Technology and Environment Malaysia, "Development of Criteria and Standards for Water Quality (Phase II)", 1990.





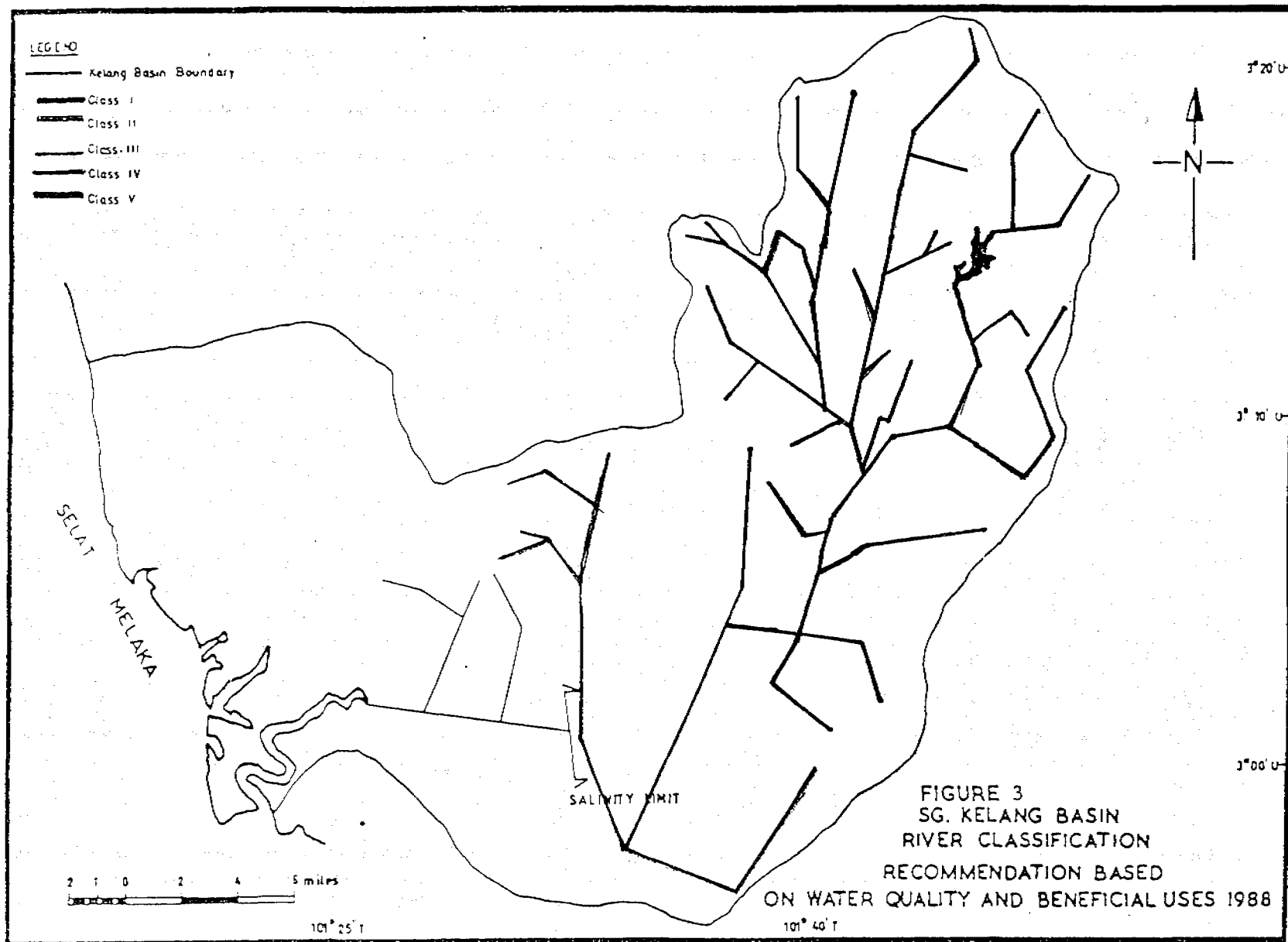


TABLE 1 : WATER QUALITY CLASSIFICATION BASED ON DOE'S OPINION - POLL WQI FOR SG. KELANG BASIN

STATION NO.	EXISTING WATER QUALITY (90-PERCENTILE)						DOE-WQI	CLASS
	DO	COD	BOD	SS	AN	pH		
Class I Std.	7.0	10.0	1.0	25	0.1	7.0	92.7	
Class II Std.	5.0	25.0	3.0	50	0.3	6.0	76.5	
Class III Std.	3.0	50.0	6.0	150	0.9	5.0	51.9	
Class IV Std.	1.0	100.0	12.0	300	2.7	5.0	31.0	
3015622	0.2	140.0	16.0	2717	8.50	6.2	24.7	V
3015631	0.2	270.0	16.5	8250	5.95	6.5	19.6	V
3015637	1.5	39.0	6.4	555	6.20	5.6	41.8	IV
3016607	0.5	128.0	19.4	2550	64.40	6.2	23.6	V
3016624	0.3	334.0	117.0	564	13.50	5.8	17.6	V
3016625	0.3	145.0	33.4	1901	27.20	5.7	29.6	V
3016631	0.8	196.0	18.3	4967	8.80	6.3	23.4	V
3116604	1.7	79.0	7.0	4702	4.70	6.5	36.6	IV
3116620	1.5	40.0	13.0	288	8.30	5.8	40.7	IV
3117605	2.1	40.0	8.3	189	5.10	5.7	46.5	IV
3117610	1.1	53.0	11.0	220	6.00	6.0	40.7	IV
3117629	0.9	33.0	5.3	281	4.10	5.7	45.6	IV
3117630	0.8	69.0	12.2	1300	5.50	6.1	31.2	IV
3216621	0.5	59.0	16.0	47	7.90	5.8	39.6	IV
3217619	5.7	38.0	18.2	678	1.45	6.1	55.9	III
3217627	3.5	47.0	4.3	1820	1.67	6.1	51.4	IV

TABLE 2 : WATER QUALITY CLASSIFICATION BASED ON HARKINS INDEX
FOR SG. KELANG BASIN

STATION	EXISTING WATER QUALITY (90 PERCENTILE)					
	DO	COD	BOD	SS	AN	pH
control	8.0	0.0	0.0	0.0	0.0	7.0
std I	7.0	10.0	1.0	25.0	0.1	7.0
std II	5.0	25.0	3.0	50.0	0.3	6.0
std III	3.0	50.0	6.0	150.0	0.9	5.0
std IV	1.0	100.0	12.0	300.0	2.7	5.0
3013601	0.7	38.0	4.7	1847.0	3.8	6.3
3014602	0.3	552.0	28.0	2786.0	7.6	6.2
3014603	0.3	162.0	1.8	2560.0	6.3	6.0
3015622	0.2	139.5	16.0	2709.0	8.5	6.2
3015631	0.1	270.0	16.5	8250.0	5.9	6.5
3015637	1.5	39.0	6.4	555.0	6.2	5.6
3016607	0.5	128.0	19.4	2550.0	64.4	6.2
3016624	0.4	334.0	117.0	563.0	13.5	5.8
3016625	0.3	145.0	33.4	1901.0	27.2	5.7
3016631	2.2	78.0	19.0	1060.0	11.3	6.3
3116604	1.7	79.0	7.0	4700.0	4.7	6.5
3116620	1.5	40.0	13.0	288.0	8.3	5.8
3117605	2.1	40.0	8.3	189.0	5.1	5.7
3117610	1.1	53.0	11.0	220.0	6.0	6.0
3117629	0.9	33.0	5.3	282.0	4.1	5.7
3117630	0.8	69.0	12.2	1180.0	5.5	6.1
3216621	0.5	59.0	16.0	47.0	7.9	5.8
3217619	5.7	37.6	18.2	678.0	1.5	6.1
3217627	3.5	47.0	4.3	1820.0	1.7	6.1

TABLE 3 : BENEFICIAL USES (1988)

SG. MELANG BASIN

SAMPLING STN. NO	JKR WATER SUPPLY INTAKES (1)	PRIVATE WATER INTAKES (2)	FISHING (3)	IRRIGATION (4)
3117628				
3117629	2 Nos. abstracting 17 Mld			
3117605				
3217619	2 Nos. abstracting 19.8 Mld	1 No. abstracting (To serve 51 people)		Multiple off-takes for 0.43 km ² padi
3117626				
3117610				
3217627	1 No. abstracting 51 Mld			Multiple off-takes for 1.0 km ² padi
3216621	1 No. abstracting 3.3 Mld			
3116620				
3116604				
3117630	1 No. abstracting 120.3 Mld			
3016625				
3016623				

Notes

Source of information (1) Jabatan Kerja Raya, Malaysia
(Cawangan Bekalan Air)

(2) Ministry of Health, Malaysia

(3) Jabatan Perikanan, Kementerian Pertanian, Malaysia

(4) Jabatan Pertanian

TABLE 4 : WATER QUALITY CLASSIFICATION BASED ON DOE'S OPINION - POLL WQI FOR SG. KELANG BASIN

STATION NO.	EXISTING WATER QUALITY (90-PERCENTILE)						DOE-WQI	CLASS
	DO	COD	BOD	SS	AN	pH		
Class I Std.	7.0	10.0	1.0	25	0.1	7.0	92.7	
Class II Std.	5.0	25.0	3.0	50	0.3	6.0	76.5	
Class III Std.	3.0	50.0	6.0	150	0.9	5.0	51.9	
Class IV Std.	1.0	100.0	12.0	300	2.7	5.0	31.0	
3015622	0.2	140.0	16.0	2717	8.50	6.2	24.7	V
3015631	0.2	270.0	16.5	8250	5.95	6.5	19.6	V
3015637	1.3	39.0	6.4	555	6.20	5.6	41.8	IV
3016607	0.5	128.0	19.4	2550	64.40	6.2	23.6	V
3016624	0.3	334.0	117.0	564	13.50	5.8	17.6	V
3016625	0.3	145.0	33.4	1901	27.20	5.7	29.6	V
3016631	0.8	196.0	18.3	4967	8.80	6.3	23.4	V
3116604	1.7	79.0	7.0	4702	4.70	6.5	36.6	IV
3116620	1.5	40.0	13.0	288	8.30	5.8	40.7	IV
3117605	2.1	40.0	8.3	189	5.10	5.7	46.5	IV
3117610	1.1	53.0	11.0	220	6.00	6.0	40.7	IV
3117629	0.9	33.0	5.3	281	4.10	5.7	45.6	IV
3117630	0.8	69.0	12.2	1300	5.50	6.1	31.2	IV
3216621	0.5	59.0	16.0	47	7.90	5.8	39.6	IV
3217619	5.7	38.0	18.2	678	1.45	6.1	55.9	III
3217627	3.5	47.0	4.3	1820	1.67	6.1	51.4	IV

TABLE 5 : WATER QUALITY CLASSIFICATION BASED ON HARKINS INDEX FOR SG. KELANG BASIN

STATION	RANK VALUES, HARKINS INDEX AND CLASSIFICATION							
	RDO	ROOD	REOD	RSS	RAN	RpH	HARKINS Index	WQI CLASS
control	24.0	1.0	1.0	1.0	1.0	1.5	0.0	
std I	23.0	2.0	2.0	2.0	2.0	1.5	0.1	(I)
std II	21.0	3.0	4.0	4.0	3.0	14.0	4.4	(II)
std III	19.0	11.0	8.0	5.0	4.0	23.5	15.7	(III)
std IV	12.0	17.0	13.0	10.0	7.0	23.5	26.2	(IV)
3013601	9.0	6.0	6.0	17.0	8.0	5.5	13.6	III
3014602	4.0	24.0	22.0	22.0	17.0	8.0	48.0	V
3014603	4.0	21.0	3.0	20.0	16.0	14.0	35.2	V
3015622	2.0	19.0	16.5	21.0	20.0	8.0	42.1	V
3015631	1.0	22.0	18.0	24.0	13.0	3.5	44.0	V
3015637	14.5	7.0	9.0	11.0	15.0	22.0	20.7	IV
3016607	7.5	18.0	21.0	19.0	24.0	8.0	42.2	V
3016624	6.0	23.0	24.0	12.0	22.0	17.0	48.7	V
3016625	4.0	20.0	23.0	18.0	23.0	20.0	53.8	V
3016631	18.0	15.0	20.0	14.0	21.0	5.5	26.8	V
3116604	16.0	16.0	10.0	23.0	10.0	3.5	21.3	IV
3116620	14.5	8.5	15.0	9.0	19.0	17.0	22.1	IV
3117605	17.0	8.5	11.0	6.0	11.0	20.0	15.4	III
3117610	13.0	12.0	12.0	7.0	14.0	14.0	16.5	IV
3117629	11.0	4.0	7.0	8.0	9.0	20.0	15.3	III
3117630	10.0	14.0	14.0	15.0	12.0	11.0	21.4	IV
3216621	7.5	13.0	16.5	3.0	18.0	17.0	27.1	V
3217619	22.0	5.0	19.0	13.0	5.0	11.0	13.5	III
3217627	20.0	10.0	5.0	16.0	6.0	11.0	10.3	III
Variance	43.9	44.0	44.0	44.0	44.0	43.5		

THE USE OF DATABASE MANAGEMENT SYSTEMS IN WATER QUALITY MANAGEMENT

I. Chanthiran
Senior Engineer
Syed Muhammad, Hooi dan Binnie Sdn. Bhd.
Kuala Lumpur, Malaysia

ABSTRACT: With the advent of computers, new techniques are becoming available to the manager. One of these techniques is the use of database systems to keep track of what is on-going and comparing it to what was in the past. One such application is in the field of water quality management.

This paper deals with the computer aspects of such an application i.e. the need for such a system, the implementation of the system, problems encountered and how they were overcome. It does not deal with the engineering aspects of the application, the results encountered or the conclusions drawn from those results.

The paper is aimed towards the manager, not the computer professional. As such, any technical jargon used is kept to a minimum and is explained clearly before being dealt with later in the paper. The main purpose of the paper is to give the manager a clearer idea into what goes on in the development of a program between conception and the finished product, the different avenues of development open to the system analyst and how what may seem to be the best choice may not be as good as another option.

1. INTRODUCTION

Nowadays, the field of science is advancing so fast that we, as engineers, have to keep pace with it or run the danger of being made outmoded. One such advance is in the use of computer technology. Only twenty years ago, the use of computers was limited to large corporations or universities where state-of-the-art technology was being developed. Nowadays, that tool has invaded our lives to an extent that would have been considered unbelievable only ten years ago. Similarly, the applications of such machines has increased from purely intensive numerical calculations to other uses such as spreadsheets, databases, wordprocessing and graphics.

As such, computers are now being used not only by the engineer or scientist but also by the manager to keep track of what is going on in the system that he is responsible for. One such technique available to him/her is the use of databases. A database may be defined as a collection of interrelated data stored together. Using this data, the manager can get up-to-date information on the state of what it is he is interested in or keep a check on how the system that he is interested in monitoring is performing over time.

This paper deals with one such application i.e. the use by the Department of Environment (Jabatan Alam Sekitar) of a database management system to keep track of the water quality in selected rivers in Malaysia.

2. TERMINOLOGY

Before we go any further, some of the technical jargon that will be used later in this paper will be clarified.

A **COMPUTER** is a tool that engineers, scientists and managers use for various applications such as number crunching and databases that is a little more complicated than a calculator and a **MICROCOMPUTER** is just a smaller, less powerful and cheaper version of the computer but still capable of carrying out the functions of the computer as described above.

A **LOCAL AREA NETWORK (LAN)** is a group of microcomputers connected together such that they have access to the same programs and data. The advantage of such a system is that data and programs are more easily accessible to everyone. The disadvantage is that two or more people may be working on the same data at the same time and changing it without the other person realising it and checks must be put in to ensure that this does not happen.

When you switch on the microcomputer, something called the **OPERATING SYSTEM** takes over. It is this operating system which governs the running of the computer much as the brain governs the running of the human body. Thankfully, we do not have to know too much about the operating system except that it exists.

When you give the operating system a command such as **DBASE**, it will then try to carry out that command, and if it so happens that you have a program like **dBase III** plus or **dBase IV** which respond to such a command, the computer will then run that program.

dBase III Plus and **dBase IV** are examples of **DATABASE MANAGEMENT PROGRAMS**. As mentioned earlier, a **DATABASE** is a collection of interrelated data stored together while a **DATABASE MANAGEMENT** program is a computer program that manages the database of information. Other examples of database management programs besides the two mentioned

earlier are Arago dBase, FoxBase, FoxPro, Paradox and Oracle.

Each set of data in a database is considered one **RECORD**. For example, if a set of data were collected for a particular water quality site over a period of days, the data might look something like what is shown below:

Basin	Site no.	Date	Dissolved oxygen	pH
Muda	1111111	1/01/87	5.6	6.3
Muda	1111111	28/02/87	6.0	6.5
Muda	1111111	2/05/87	5.9	5.9
Muda	1111111	1/07/87	4.9	5.2
Muda	1111111	1/09/87	5.4	6.0
Muda	1111111	3/11/87	5.8	6.2

This database consists of 6 records, each of site number 1111111, taken on 6 different days and showing the measurement of dissolved oxygen and pH on those days.

Furthermore, the database above would be said to have 5 **FIELDS**, each field being the heading of each of the 5 columns.

Databases can be stored in various forms. The two most common types are the **SINGLE DATABASE** form and the **RELATIONAL DATABASE** form. The differences between the two are explained in the next section together with an example and a comparison of the advantages and disadvantages of each.

Databases are kept so that one can have access to the information that is stored in them. In order to do this, one must **SEARCH** the database eg. if one wanted to look at all water quality samples from the Muda river basin where pH was less than 6.0, one would give a command in dBase III plus such as "List Site_Num, SampDate, pH for Basin = Muda and pH < 6.0". This translates into "List the site number, sample date and pH value for all samples taken from the Muda river basin and where the pH is less than 6.0."

3. TYPES OF DATABASE SYSTEMS

As mentioned in the previous section, the two most common types of databases are the single database and the relational database. The single database attempts to put all its information in one database. On the other hand, the relational database puts its information in more than one database and then relates them to one another through a common field. This is best illustrated through an example. Let us suppose that we have a set of data on river water quality sites as follows:

Site no.	River basin	River	Order
2834602	Rompin	Rompin	1
3130606	Rompin	Aur	2
3420619	Pahang	Kelau	2
3430601	Pahang	Mentiga	2
3430602	Pahang	Mentiga	2

If the **SINGLE DATABASE** approach were being used, a database containing 4 fields would be created and the data entered as shown above.

On the other hand, it can be seen that in the above database, river basin names are repeated quite frequently. As such, if the relational database approach were being used to enter data into the computer, the above database could be broken down into two databases as follows:

DATABASE 1

Basin Code	River Basin
33	Rompin
35	Pahang

DATABASE 2

Site number	Basin Code	River	Order
2834602	33	Rompin	1
3130606	33	Aur	2
3420619	35	Kelau	2
3430601	35	Mentiga	2
3430602	35	Mentiga	2

Database 1 is what is called the **LOOKUP TABLE**. Whenever database 2 encounters basin code 35, it looks up the first database table, checks the basin code there and gathers that the river basin being referred to is the Pahang river basin.

The advantages of the single database approach are as follows:

- * intuitively obvious (so it is easy to understand),
- * simple to create, and
- * easy to write a program for maintaining such a database.

However, the single database has serious shortcomings, especially when the database gets more complex or when more complicated functions are carried out. The main advantages of the relational database are as

follows:

- * Names of common fields are only put in one place in the database. If an error has been made and the name misspelled, it is easy to correct it if it is in only one place in the database. The only way to correct misspellings in a single file database is to locate every place where that particular misspelling occurred and correct it. If not every location has been found, one ends up with a database with more than one spelling of a name. This makes it more difficult to later search for occurrences of that name.
- * Unnecessary duplication of data is avoided. This leads to better system performance in that it uses less disk storage and speeds up data access.
- * There is less redundancy in data leading to less chance of data entry errors, using a properly designed database management program.
- * The concept of a **LOOKUP TABLE** means that any information about a particular river basin can be stored in that table and if a piece of information needs to be changed, it can be done in that one spot, rather than hunting round the whole database and changing that information wherever that particular river basin shows up. This leads to less chance of forgetting to change the data in one spot and thus ending up with inconsistent data.

A case study involving the application of a single database system and how it was decided to convert this to a relational database management system will now be introduced.

4. CASE STUDY

4.1 NEED FOR A SYSTEM

The Department of Environment (Jabatan Alam Sekitar) is charged with the responsibility of monitoring the state of the environment of the country and doing its best to ensure that this state is not allowed to deteriorate. As part of its responsibilities, it monitors the water quality of the rivers in this country, the pollutants that go into these rivers from various sources, (such as oil palm mills and rubber processing factories) and also any changes in landuse that may affect the water quality of these rivers.

To deal with this, the Department is subdivided into various sections. These include:

- * the Monitoring Section, which is responsible for collecting and compiling data on river water quality,
- * the Inventory Section, which is responsible for collecting

- and compiling data on pollution sources,
- * the EDP Section, which is responsible for the maintenance and upkeep of the computers in the Department, and
 - * other sections such as the Marine Section and the section dealing with air quality.

Within each section, there are different people with different responsibilities and the respective sections all work competently. However it was thought that this efficiency could be improved if the data collection and compilation could be centralised. It was proposed that a computer program be written, incorporating the present data, so as to enable easier and more efficient data collection, compilation and calculations as necessary. The advantages of such a system would be as follows:

- * easier for the manager to look at the latest information as it would be more easily available rather than from just one or two people,
- * easier for data operators as the new system would be able to check for data errors,
- * easier for the people responsible for system maintenance as a centralised system would make it easier to keep up standards, especially when training new people to compile data collected, and
- * more up-to-date knowledge of the performance of the system variable being measured as the program would be performing its calculations on all data collected and entered to date even before these data are printed out and sent to the various people concerned.

4.2 EXISTING SYSTEM

The existing system was that data were maintained on microcomputers using the dBase III Plus program. There were standard formats for storing these data which were already being used by the various sections of the DOE. These databases were stored in traditional single database format. This had the advantage of being easy to use for the individual user but there were not enough checks against data entry errors. (This is because the normal database management system does not cater for such checks and a specialised program had to be written to handle this.)

4.3 THE APPROACH USED

There were two possible approaches considered to solve this problem; the classic approach and the 'prototype' approach. Both types of approach are illustrated in Figure 1¹. After due consideration, it was decided to use the 'prototype' approach to solve this problem. This is because "it is often difficult in the beginning for the client to state all the requirements explicitly. The classic life cycle approach requires this and has difficulty accommodating the natural uncertainty that exists at

the beginning of many projects."¹ Furthermore, "a working version of the program will not be available until late in the project time span."¹ As such, the client has no direct involvement with the program until very late in the development time of the project. However, it should be pointed out that the 'prototype' approach, too has its problems, some of which are noted below:

- "1. The client sees what appears to be a working version of the software, unaware that the prototype is held together 'with chewing gum and baling wire', unaware that in the rush to get it working we haven't considered overall software quality or long term maintainability. When informed that the product must be rebuilt, the client cries 'foul' and demands that 'a few fixes' be applied to make the prototype a working product.
2. The developer often makes implementation compromises in order to get a prototype working quickly. An inefficient algorithm may be implemented simply to demonstrate capability. After a time the developer may become familiar with these choices and forget the reasons why they were inappropriate. The less-than-ideal choice has now become an integral part of the system."¹

In spite of the above disadvantages, it was considered that the 'prototype approach' was better because of the greater interaction between the program developers and the DOE staff who would be using the program later. Their constant feedback on the program was considered invaluable as they would be the ones using the final program. In addition, any of their needs which were not realised when the program specifications were drawn up could be considered. The key to using the prototype method effectively is "to define the rules of the game at the beginning; that is, the customer and developer must both agree that the prototype is built to serve as a mechanism for defining requirements. It is then to be discarded (at least in part), and the actual software engineered with an eye toward quality and maintainability."¹

At the time the program was being developed, the software being used by the DOE staff for maintaining their database was dBase III Plus. As such, it was decided that the program being written (called IRBIS, for Integrated River Basin Information System) would also be done using a language compatible with the dBase III Plus language. In this way, there would be no problems with reading the existing database of information already collected. There are other programs such as dBase and FoxBase which could also read dBase III Plus data but using these software to write IRBIS would have meant that all DOE offices which wanted to use it would have to go out and buy these software whereas they would already have the dBase III Plus software. The decision reached was to use dBase III Plus itself to write the program.

After discussion with the DOE staff, it was also decided that the program would be written in modular form. This meant that the program would be written as a series of independent modules, catering to the

different needs of the different staff but would be joined together to form a common user interface. In this way, the program would enable the users to use any of the modules. Training new users would also be simple as they would not have to learn a new system in order to learn a new module.

After discussion with the DOE staff, it was decided to break up the program into six modules, which could be further divided into twelve sub-modules, as shown below:-

Main module	Sub-module
1. Water quality	a. Water quality sites b. Water quality data
2. Flow (water quantity)	c. Flow recording stations d. Flow data
3. Pollution	e. Point pollution sources f. Pollution data
4. Geographical data	g. Regions and areas h. Land use i. Population j. Beneficial uses
5. Analysis methods	k. Analysis methods
6. Utilities	l. Data backup facilities

This is illustrated in Figure 2 and a brief description of each of the six main modules is given below.

1. Water Quality Data

This module contains information about the water quality of rivers at the DOE measuring stations. It is sub-divided into two sections; sites used for water quality monitoring and the data on river water quality collected at those sites. The information contained in the first section is basically a description of the site, such as the site number, site name and river name among others. The information in the second section not only contains the data on the river water quality analyses carried out by the Department of Chemistry but is also the module that does the calculations that help in river classifications.

2. Flow Data

This module contains information about the river flows at various flow stations, most of which are run by the DID. Like the module described above, it is sub-divided into two sections; sites used for flow measurement and the actual flows recorded.

3. Pollution source data

This module is also divided into two sections; one on factory data and one on effluent data. The section on factory data contains

information on individual factories such as the type of factory and their locations while the section on effluent data contains the data on individual effluent discharges from each factory.

4. Analysis data

This module contains descriptions on the different methods of carrying out analyses on the samples.

5. Geographical data

This module is the one that is meant as a first step towards a geographical information system. It is sub-divided into four sub-modules; regional data, population data, land use data and beneficial uses data. The section on regional data is used to subdivide the country into various regions based on districts and river catchment areas. Population data is district based and contains statistical information on the people in a particular district. The sub-module on land use contains information on land use in a particular region while the module on beneficial contains information about the beneficial uses of the rivers in each river basin.

6. Utilities

This last module is used mainly to back up information stored on the hard disk onto diskettes as a safety precaution against hard disks getting corrupted.

As far as the program structure is concerned, each of the 12 sub-modules is completely independent (i.e. they could have been, and actually were, written as separate programs). However they cannot be run independently. This is because some of the sub-modules create databases which other sub-modules need to use. For example, the water quality sites sub-module creates a new database whenever a new water quality recording site is entered. This database is then used whenever data for that particular water quality site is entered.

The data inter-relationship is a little more complicated, with some of the database files being used entirely by one module, others having all their data being used by more than one module and still others having some of their data being used by one module and some other of their data being used by other modules. For ease of design and maintenance, different sub-directories were created and the data grouped into them as follows:-

Sub-directory	Data description
1. \IRBIS	No data; only programs
2. \IRBIS\DATA	Data used by more than one main module and 'analysis methods' module
3. \IRBIS\SITE	Data used by 'water quality' module

- | | |
|------------------|-------------------------------------|
| 4. \IRBIS\FLOW | Data used by 'flow' module |
| 5. \IRBIS\SOURCE | Data used by 'pollution' module |
| 6. \IRBIS\GIS | Data used by 'geographical' module |
| 7. \IRBIS\DOC | No data; only program documentation |

(The 'utilities' module is not shown above as it uses the data in all the databases.)

This is also illustrated in Figure 2.

4.4 DOE'S DATA

This section is confined to the applications of database management systems as applied to river water quality data only. Applications to the other modules will not be dealt with as that would involve a lot of repetition.

The existing databank of river water quality data was of two types:

- * water quality sites, and
- * the data collected at those sites.

As mentioned in Section 4.2, these data were maintained on microcomputers using the dBase III Plus program. The standard format used for storing these data by the Monitoring Section of the DOE is shown in Figure 3. As can be seen, the databases were stored in traditional single database format. Advantages of this system were as follows:

1. Since it is intuitively obvious, it is easy to understand and anyone with a basic knowledge of dBase III Plus can use it to enter, modify or delete data.
2. Writing a program to be used by someone who is not familiar with dBase III Plus is simple.

However, this format has the disadvantage that when one is working with the water quality data, the only information that one has is the water quality site number. There is no other indication as to the river basin or river where that particular sample comes from. This is not too bad if the user knows where that particular station is from but is a disadvantage for the new user. There is therefore the tendency for the user to put in extra fields such as river name or river basin number as a reminder. It is this tendency that leads to problems for the different databases storing information then tend to become non-standard. There is also unnecessary duplication of data which leads to more disk storage and slower data access. Data maintenance also becomes more difficult due to data redundancy.

As such, it was decided to split up the databases and use a relational

database format to access the data using the IRBIS program. The first step was to decide whether extra information needed to be put into the databases. It was resolved that a lookup table giving river basin names to correspond to river basin numbers was needed. A list of site names to correspond to the site numbers was also desired. The next step was to decide what information was to be used in each sub-module. For example, information like water quality parameters would not be needed when using the module on water quality sites. Likewise, information on latitude and longitude would not be needed when dealing with the module on water quality data. As a result of these considerations, it was decided to split the water quality database into four separate databases as illustrated in Figure 4. The databases which each sub-module uses are shown in Figure 5.

4.5 THE WATER QUALITY SITES SUBMODULE

The two sub-modules mentioned above enable the user to carry out various operations on the data. When dealing with the data on water quality sites, the various options for the user are as follows :-

- * Add new sites.
- * Browse through data.
- * Edit data for present sites.
- * Delete old sites.
- * Print information on sites.
- * Backup sites data.

4.5.1 Add new sites.

When adding new sites, the program puts a blank form on the screen to be filled in with the information needed. Not all the data needs to be filled in at this stage if the information is not available. Later on this can be edited if necessary. However, the river basin number and site number MUST be filled in otherwise the program will reject the information. This data is known as 'key data' and is shown in Figure 5. Other data can be entered or left blank to be filled in later. If the user decides to leave a piece of information blank, he/she just has to press the "↓" key to move on to the next piece of information to be filled in. If a mistake has been made, the user can still go back to the wrong datum by using the "↑" key and then correcting it.

4.5.2 Browse through data.

This option is used to look at data for sites that have already been entered. The program will prompt the user for the site(s) that he wants. It does this by using a blank form on the screen as shown in Figure 6. The user then types in the information that he knows about the site(s) that he wants eg. if he knows that the site that he wants is in the Kelang river basin (river basin

number 13) and is on the Sungai Damansara, then he/she enters "13" for river basin number and "Damansara" under river name. The program will then return with the first site on the Sungai Damansara in the Kelang river basin valley and display all the information that it knows about that site on the screen. If there is no site with those specifications, the program will return and inform the user of this. Assuming that the site has been found and the information displayed on screen, the user then has the option of returning from this sub- option or going on to the next site that fulfils these specifications.

4.5.3 Edit data for present sites.

This option is used when the user wants to correct incorrect information for sites that have already been entered or for sites where there is incomplete data. The program will prompt the user for the site that he wants. This is done in the same way as in the option above. Once the correct site has been found, a form is put on the screen showing the information that is already in the database. The user then moves about the screen using the "↓" and "↑" keys and either adds in the missing data or corrects the wrong data.

4.5.4 Delete old sites.

This option is used when the user wants to delete all the data on a particular site. Care must be taken when using this option that one does not delete the wrong site accidentally. For this reason, the program will prompt the user for the site that he wants as in the option above and then show the data to be deleted before asking the user for confirmation as to whether to delete the site or not.

4.5.5 Print information on sites.

Under this option, the program will print the data on some or all of the sites, depending on the criteria that the user specifies. The data is shown on screen first as a check to ensure that the correct information is to be printed. Following this, the user has the option of sending the data to a printer or a diskette.

4.5.6 Backup sites data.

This option is used when the user wants to backup his data from a hard disk to floppy disks. The user should make sure that he/she has enough diskettes necessary to backup the data before attempting this and is strongly advised to number his/her diskettes before attempting this operation.

The user is also strongly advised to carry out this operation at least once a week so that in the event of a hard disk crash, the

information that the user has is one week out of date at the worst.

4.6 THE WATER QUALITY DATA SUB-MODULE

This module contains the water quality data results from the water quality monitoring stations described in the previous module. It is also the module that does the calculations that help in river classifications. The options for the user to do are as follows :-

- * Add new data.
- * Search for sample data.
- * Edit sample data.
- * Delete sample data.
- * Print data.
- * Calculations.
- * Validating data.
- * Backup data.

4.6.1 Add new data.

There are two sub-options when making this choice. The first sub-option is to add new data to a temporary database and the second sub-option is to update the files on the main database in the hard disk from the temporary database. This is to enable the user to verify all the data before transferring to the main database which contains all the data from all the stations in Malaysia.

When adding new data to a temporary database, the screen gives a blank form to be filled in with the information needed. Not all the data needs to be filled in as an analysis would not have been done for all the parameters in the DOE list. However, the site number and sampling date MUST be filled in otherwise the program will reject the information. The user will then have the option of re- entering the site number and sampling date or not adding this sample information. If the user decides to leave a piece of information blank, for example if the Total coliforms parameter has not been analysed in this sample, he/she just has to press the "↓" key to move on to the next piece of information to be filled in. If a mistake has been made, the user can still go back to the wrong datum by using the "↑" key and then correcting it.

The sub-option of updating the main database from the temporary database is used only when all the data in the temporary database has been verified by the user. The program itself carries out some checks like ensuring that the site number is that of an actual site and verifying that data entered for the parameters makes sense eg. the temperature of a sample of river water in Malaysia should not be more than 40 degrees Centigrade or less than 10 degrees Centigrade. This is a precautionary measure so as to

minimise the chances of incorrect data entering the main database.

4.6.2 Search for sample data.

This option is used to look at data for samples that have already been entered. The program will prompt the user for the sample(s) that he/she wants. It does this by using a blank form with just four fields on it; river basin number, site number, earliest sample date and latest sample date on it. This form is shown in Figure 7. The user has to enter all four data items. The first two are used to indicate the site and on-screen help is available. If the user has forgotten the river basin number, pressing '?' at the appropriate location will cause a list of all river basins in Malaysia and their number to be displayed. If the user has forgotten the site number, pressing '?' will display all sites in that river basin. The other two items of information are there to set a range of dates the user is interested in. If a sample was recorded in the database as having been taken within that range of dates, then the first such sample is shown on the screen. The program then gives the user the option of returning from this sub-option or going on to the next sample for this station in the database. If there is no sample that falls within this range of dates, or if the data for this station has been erased, the program will return and inform the user of this.

4.6.3 Edit sample data.

This option is used when the user wants to correct incorrect information for samples that have already been entered or for samples where there is incomplete data. The program will prompt the user for the sample that he/she wants. This is done in the same way as Section 4.6.2. Once the correct sample has been found, a form is put on the screen showing the information that is already in the database. The user then moves about the screen using the "↑" and "↓" keys and either adds in the missing data or corrects the wrong data.

4.6.4 Delete sample data.

This option is used when the user wants to delete all the sample data on a particular site for a particular day. Care must be taken when using this option that one does not delete the wrong sample data accidentally. For this reason, the program will show the data to be deleted before asking the user for confirmation as to whether to delete it or not.

4.6.5 Print sample data.

This option is used when the user wants to print the sample parameter values taken on a particular site for a range of dates. Like the sub-module for water quality sites, the user has the

choice of sending the output to the computer screen, a printer or to a diskette.

4.6.6 Calculations.

This option helps the user to carry out calculations on the water quality data for a specific site. There are two sub-options to this option. These two sub-options are :-

- * Basic statistical analysis on the data.
- * Calculate DOE-WQI index.

These options are all menu driven and the user just has to enter the appropriate site number, river basin number and range of dates. The statistical analysis gives the most information on any particular parameter for that site while the DOE-WQI index gives a value to the overall river water quality based on the values of six parameters (dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, suspended solids, ammoniacal nitrogen, pH) using a formula derived by the Department of Environment. The information given by the statistical analysis is presented in Figure 8.

4.6.7 Validating data

Validating data is carried out in two steps. The first step is where data which is obviously wrong is checked. This applies to data such as pH values greater than 14, dissolved oxygen values greater than 10, temperatures of 0°, etc. This is just a precautionary measure as these steps would have been checked at the data entry portion of the program. The second step is at best a subjective one where data is checked for values which may be incorrectly entered. The mean and standard deviation are calculated and any data which is more than 3 standard deviations from the mean is highlighted and brought to the operator's attention. The program itself does not change the data value, just highlights it and it is up to the user to either accept or reject the data. In the latter case, he/she can then change the data value using the "Edit Data" option mentioned earlier.

4.6.8 Backup sample data.

This option is used when the user wants to backup his data from a hard disk to floppy disks and is similar to that described in the module on water quality sites.

4.7 PROBLEMS ENCOUNTERED

Implementing this huge project was not without its share of problems. Some of the problems were as follows :-

- * prototype to implementation problems
- * hardware compatibility problems

4.7.1 Prototype to implementation problems

Much time was spent in the early part of the project developing the user interface and demonstrating the various options that it could do. These developments and demonstrations were done using a small database and a single database structure. This helped greatly in getting the clients ideas onto the project. However, the algorithms used were not suitable for large systems and implementing this took some time because not only did the algorithms have to be changed but also the entire underlying database structure (from a single database to a relational one).

4.7.2 Hardware compatibility problems

The problems of changing the prototype to the full working model were however negligible compared to another problem discovered when it was time to transfer the program and data from the consultants computer to the clients computer. This was that the program while working fine on the consultants computer refused to work on the DOE's computer. The computers on both sides were IBM compatible and other programs worked fine on both machines but the database program did not. To this day, the cause of this problem is not known but a solution was found around it although it took more than a year to discover the solution. (The solution being to transfer the source code onto the client's machine and then compile it from there.)

4.7.3 Miscellaneous other problems

There were miscellaneous other problems when implementing the program but these were rather minor compared to the two mentioned above. These include computer viruses, power shortages, etc.

5. CONCLUSION

This paper has shown one application of a database management program towards water quality management. two types of database structures were shown and both have their advantages and disadvantages. The single database format is suitable for simple systems where not much sophistication is needed but a more complex application requires a relational database structure. Besides that, any database management system should have a series of checks to ensure that data errors are not

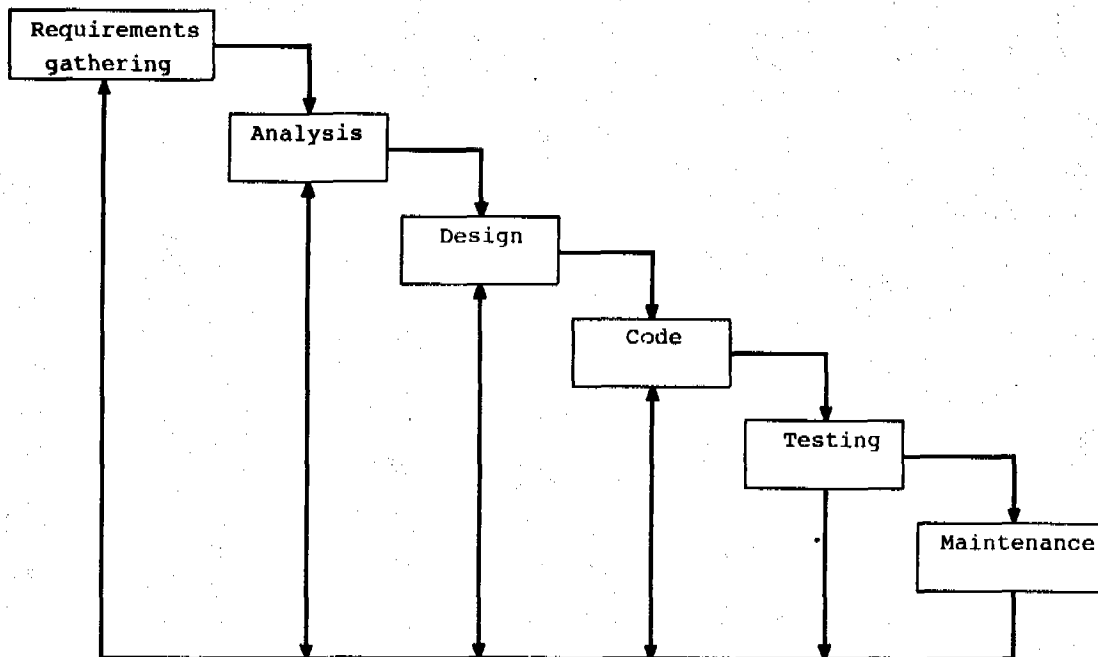
entered into the system.

6. ACKNOWLEDGEMENTS

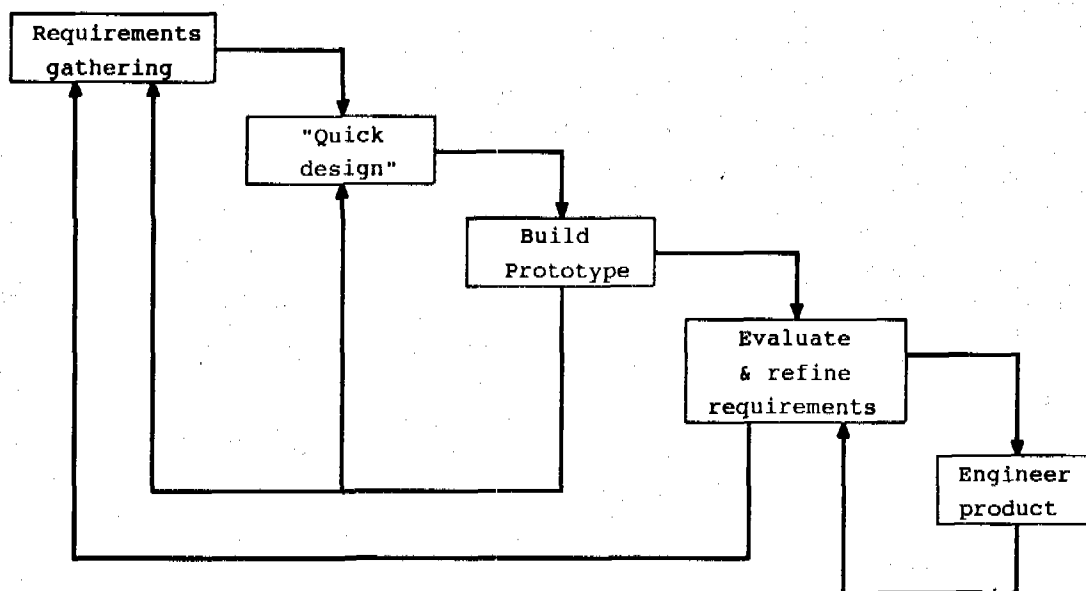
The author is grateful to the Department of Environment and to Syed Muhammad, Hooi dan Binnie Sdn Bhd for their permission for referring to the IRBIS program and to those members of the Department of Environment whose constant feedback on the program enabled it to be improved while being developed.

7. REFERENCES

1. Pressman, R.S., Software Engineering: A Practitioner's Approach, McGraw Hill, (1987)



The Classic Life Cycle Approach
of Software Engineering



The Prototyping Approach
of Software Engineering

Figure 1

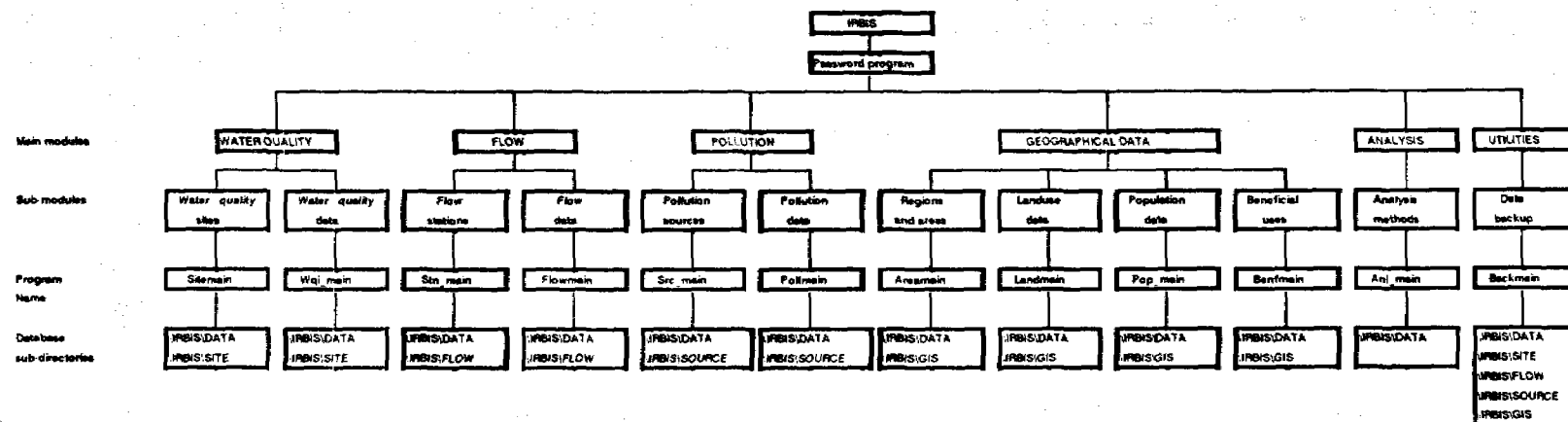


Figure 2 Breakdown of the IBIS program

Database of Water Quality Sites
River basin number
Site number
River name
River order
Distance upstream
Grid reference
Water use
Remarks
Status

Database of Water Quality Data
Site number
Date
Dissolved Oxygen
Biochemical oxygen demand
Chemical oxygen demand
pH (Field)
Ammoniacal Nitrogen
Suspended solids
45 other parameters

Fig. 3 Description of fields in the existing databank of river water quality

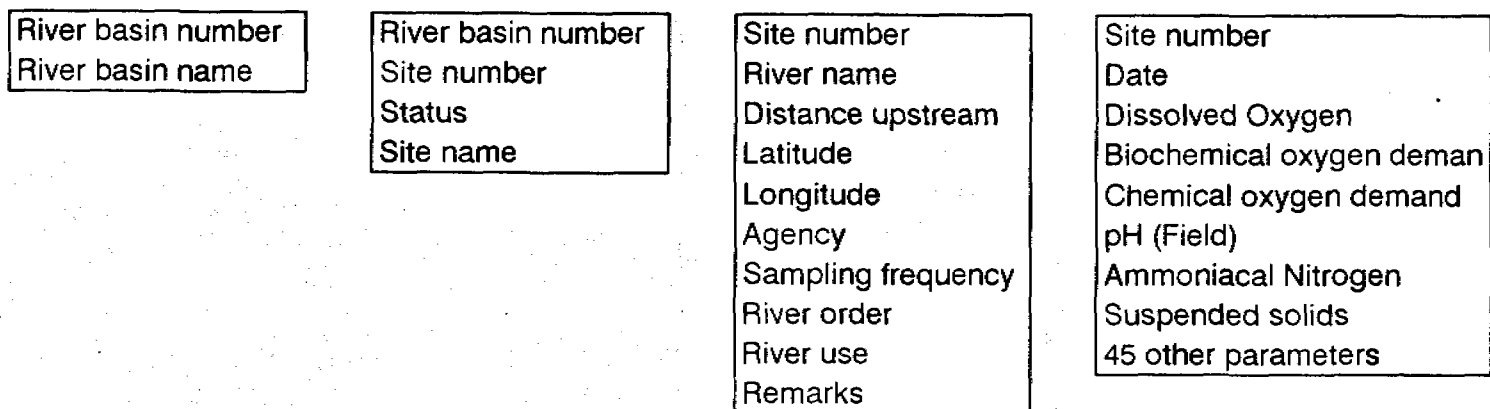
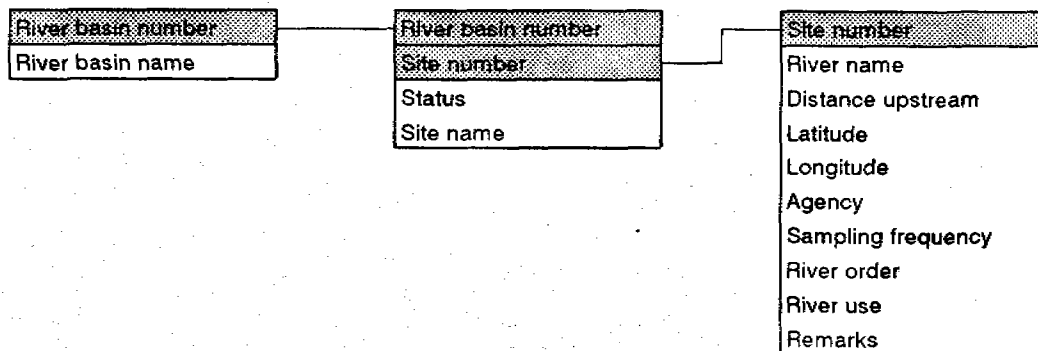
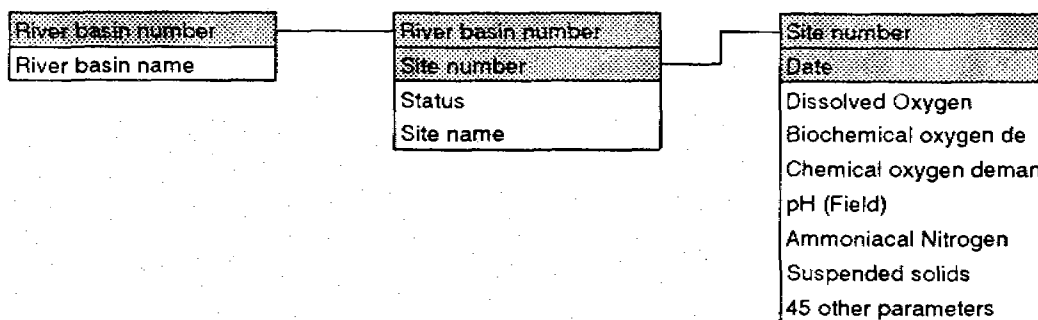


Fig. 4 The four water quality databases used in IRBIS



Databases used in river water quality sites module



Databases used in river water quality data module

Figure 5

River Basin Number		River Basin Name	
Site Number			
Site Name			
River Name		Distance upstream (km)	
Latitude			
Longitude			
Agency		Status	
Sampling frequency		(Number of samples per year)	
River Order		Beneficial Use	
Comments :			

Figure 6 Form used to search for data in water quality sites sub-module

Basin No.		
Site No.		
First Date		Last Date

Figure 7 Form used to search for data in water quality data sub-module

River Basin No. : 18	River Basin Name : SG. KELANG
Site Number : 3014602	
Site Name : KELANG	
Parameter Code : DO	Parameter Name : Dissolved oxygen
First Date asked : 01/01/70	Last Date asked : 31/12/99

Number of values : 64	Number of outlier: 0
Mean : 0.670	Median : 0.500
Standard Deviaton: 0.541	
Actual First Date: 07/01/87	Actual Last Date : 16/12/91
0 percentile : 0.100	60 percentile : 0.500
10 percentile : 0.200	70 percentile : 0.800
20 percentile : 0.260	80 percentile : 1.040
30 percentile : 0.300	90 percentile : 1.400
40 percentile : 0.400	100 percentile : 2.700
50 percentile : 0.500	

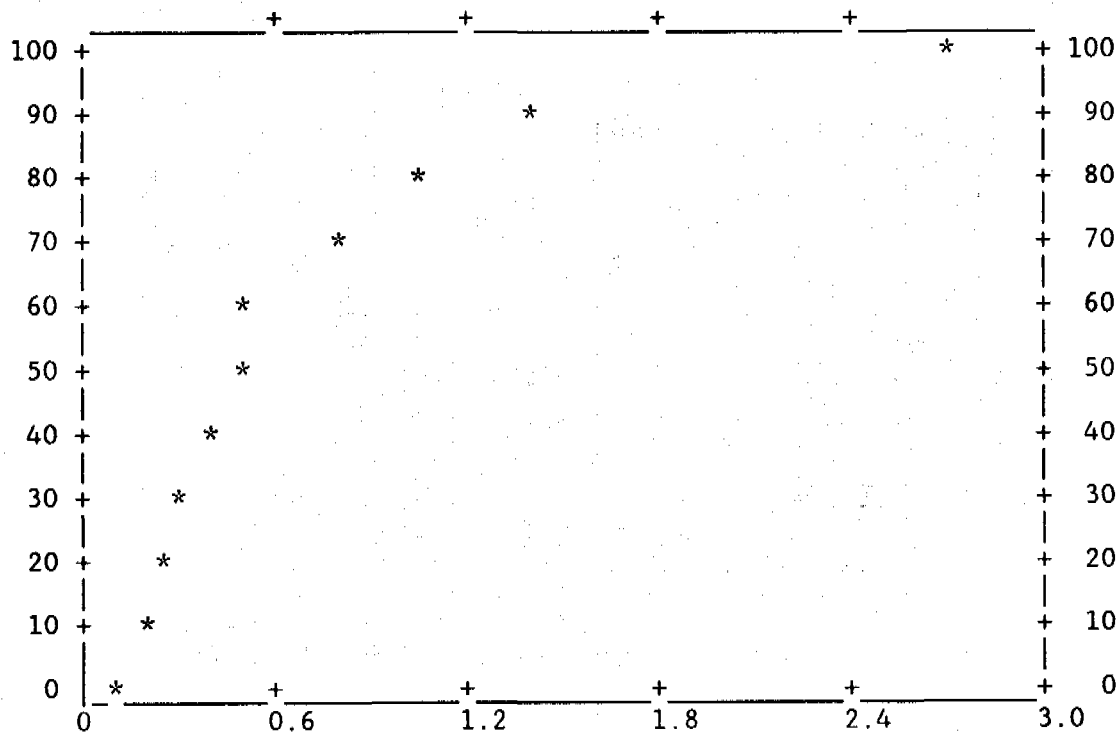


Figure 8 Typical output of calculations done on water quality data

TECHNICAL SESSION 2B
ASPECTS OF WATER SUPPLY -
GLOBAL CHANGE, STRATEGY AND CRITERIA

Impacts of Global Change on Water Supply, and Response Measures

The Strategic Aspects of Water Supply

Recent Water Resources Criteria for the Production of Drinking Water

IMPACTS OF GLOBAL CHANGE ON WATER SUPPLY AND RESPONSE MEASURES

Shinichiro Ohgaki, Tomoyasu Matsuda, Sombo Yamamura & Hiroyasu Yoda

The University of Tokyo, Tokyo, Japan

Bureau of Waterworks, Tokyo Metropolitan Government, Tokyo, Japan

Water Supply Division, Water & Environment Department, Ministry of Health & Welfare, Tokyo, Japan

Overseas Services Department, Nihon Suido Consultants Co., Ltd., Tokyo, Japan

ABSTRACT - Environmental change expected as a result of global warming, acid precipitation, ozone layer depletion, deforestation, etc. may continue to affect entire field of human activities over the next century if necessary measures are not taken. Water utilities may suffer from 1) change in runoff pattern, 2) decreased production potential of water sources and 3) water quality degradation, all derived therefrom, resulting in adoption of more elaborate quality control, energy saving process and development of supplemental water resources. These impacts may not be significant in some utilities/areas. It is however important to enhance monitoring and research into magnitude and scale of the impacts and seek for possible measures to minimize such effects on water supply. In relation to the global warming, energy conservation is recognized fundamental to reduce emissions of greenhouse gases. Water supply sector as well, of which energy consumption is fairly large, shall take immediate actions for management and preservation of global environment. This paper intends to describe potential impacts on water supply sector together with response measures and strategies.

KEYWORDS - global warming, acid precipitation, impacts assessment, energy, responsive measures, direct supply, pipe network zoning, heat pumps, and heated/cooled water supply

1. INTRODUCTION

There is growing consensus that global change in environment over the next century may give crucial impacts on overall aspects of human activities and natural ecosystems. This is a brief summary of the first Draft on "Impacts of Global Change on Water Supply, and Response Measures" prepared by Working Group in Japan. The Group, organized in October 1990, consisted of 19 officials, experts and professionals from the central government, water supply & sewerage sectors of prefectural governments, universities and private sectors. Taking specific experience and expertise of each professional into consideration, the Group was sub-grouped into three, tasked severally with (1) impact assessment and water supply overview, (2) evaluation of energy consumption and (3) response measures as envisaged on Fig-1. The first Draft, despite its insufficient description in some areas, was compiled on the basis of a review of relevant reports and documents, analyses and evaluation, a series of discussions within the Group, made during the period of more than one year.

2. IMPACT ASSESSMENT AND WATER SUPPLY OVERVIEW

2.1 Likely Impacts of Global Change

The Sub-group I concentrated its effort to assess the impacts of global change on water supply sector on the basis of review of the relevant reports and information. Global changes considered herein are increase in air temperature, change in precipitation patterns, sea level rise and acid precipitation due to increased emissions of green house gases and other toxic gases. The increase in air temperature and sea level rise predicted in the literature (IPCC reports) are 1°C by 2025 and 20 cm by 2030 respectively. Fig-2 portrays the major impacts of global change on water supply sector together with their relation and response measures.

The present study suggests that the water supply will be affected in terms of water source quality and quantity. Water quality will be worsened significantly by increased concentration of heavy metals, humus, phosphate and nitrogen in lakes and impoundments due to increased frequency of flood, acid precipitation, etc. Accelerated deforestation and change in runoff patterns may give crucial impacts on all water users. To cope with these likely impacts of global changes and to establish response strategies, intensive water quality management and monitoring, and research activities in this area are of primary importance.

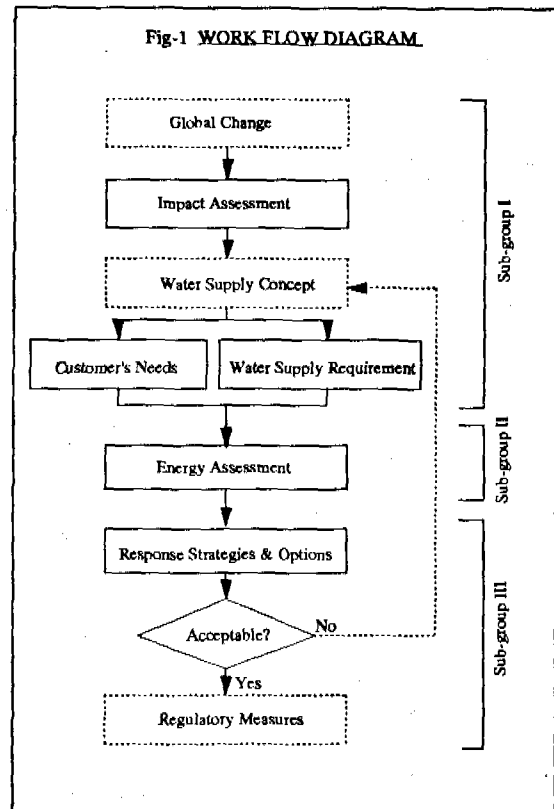
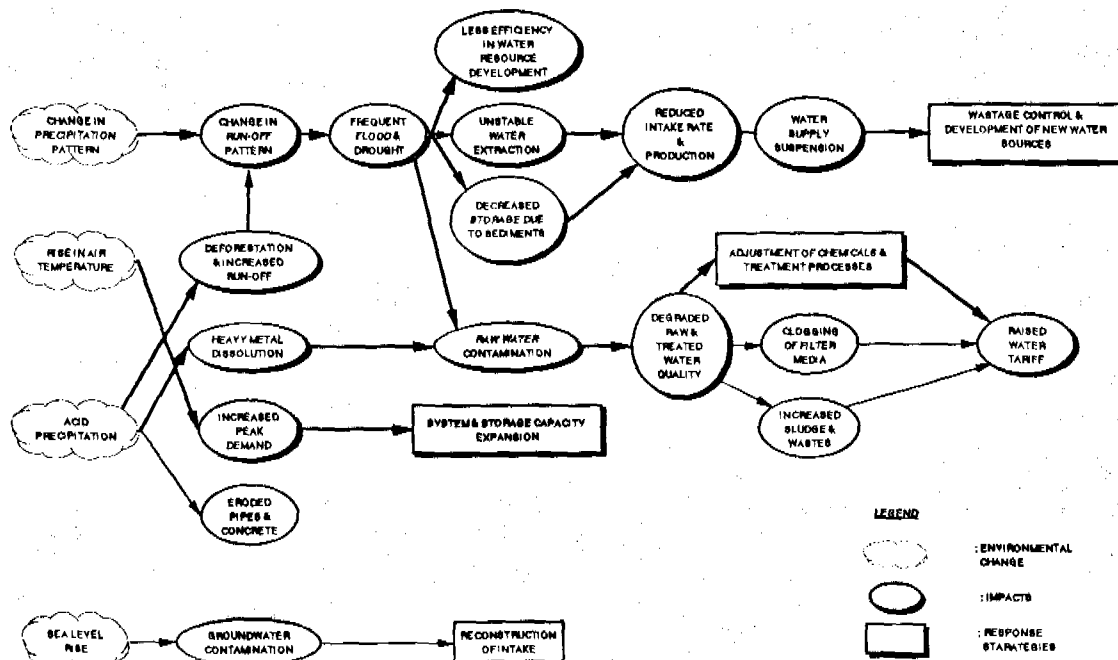


Fig-2 IMPACTS OF GLOBAL CHANGE ON WATER SUPPLY



2.2 Water Supply Overview

The Sub-group I also identified customers' needs for living amenity in the 21st century. They are classified into 6 categories: (1) needs for high-quality drinking water, (2) needs for increasing water demand for air-conditioning, car washing & gardening, (3) needs to adjust for installation of new multi-task household appliances, (4) needs for public fountains, pools, etc. for recreation, (5) needs for reliable and stable supply of water and (6) energy savings. Their potential needs are severally examined in comparison with living standard required for the future, i.e., (1) safety & sufficiency, (2) hygienic and healthy lives, (3) adjustment for changing life style, (4) adjustment for growing population of the aged and (5) increasing women's involvement to social activities. Further, the needs are evaluated from viewpoints of energy: (1) initial energy required for manufacturing, delivery and construction, (2) running energy for system operation and (3) energy for system expansion. Through these evaluation and comparison, the Sub-group clarified the relationship between the customers' needs and their energy intensity.

In contrast, difficulties water utilities are currently facing are (1) water sources scarcely available, (2) increasing needs of restoring, rehabilitating & improving obsolete facilities, (3) insufficient water supply provisions against emergency, (4) growing necessity of wastage control and multi-source water supply to save water. The Sub-group made tentative assessments to identify priority options from standpoints of the global environment, responsiveness to consumers' needs and soundness of water supply business.

3. ENERGY CONSUMPTION IN WATER SUPPLY

To reduce energy consumption and establish response strategies for regulating energy saving practices, the Sub-group II examined patterns and scale of the present energy use in water supply sector. The method applied herein is to compute energy consumption on an uniform basis equivalent to kcal/m³. Energy used during manufacturing, delivery of construction materials/equipment, system construction as well as operation of completed facilities are considered together. Formula utilized to estimate energy consumption are given in Table-1. From estimated energy breakdown according to type, scale and unit of treatment processes, and our subsequent study on energy consumption per household, it can be concluded as follows:

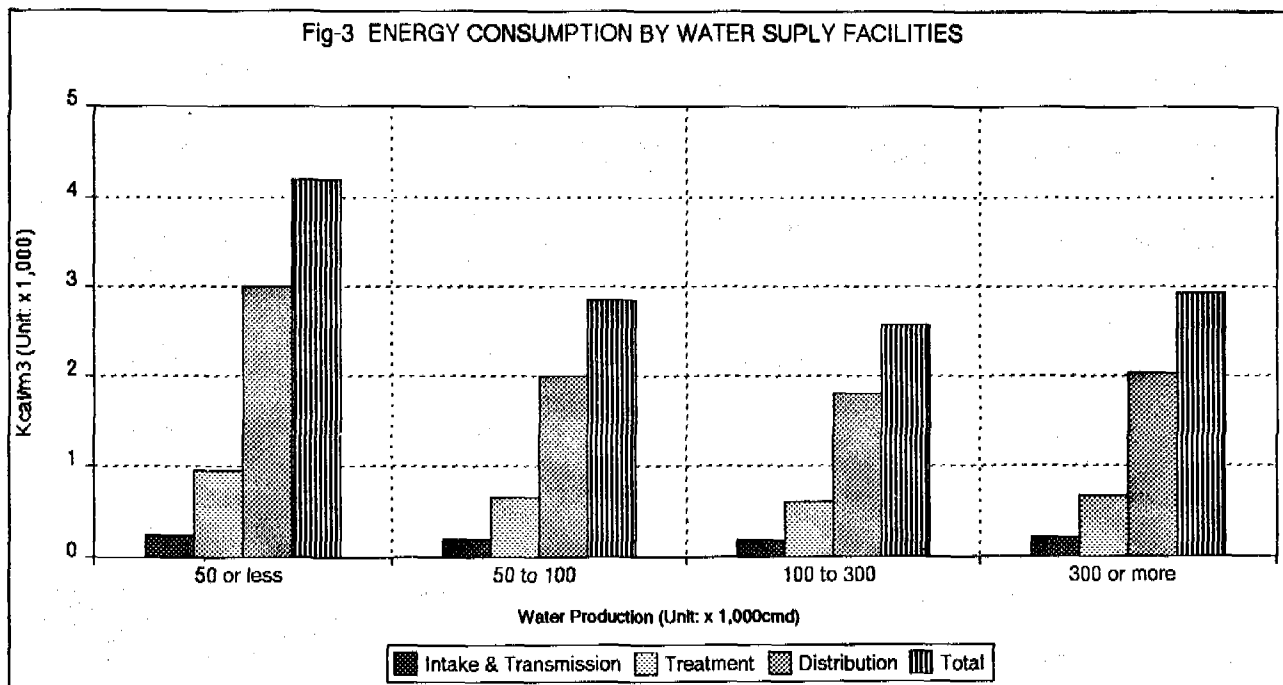
(1) Since transmission and distribution facilities consume more energy than treatment plants (see Fig-3), more attention should be paid to pipe network design/operation. State of the art technology in system control and electronics will facilitate planners in achieving significant energy savings.

Table-1 ESTIMATION OF INITIAL AND RUNNING ENERGY

ITEM	EQUATION
1. INITIAL ENERGY	
1) Conventional Treatment	= Unit Energy Consumption x Unit Weight or Cost of Materials [kcal/kg] or [kcal/Yen] [kg/m ³ or Yen/m ³]
2) Advanced Treatment -Biological, Ozonation & Carbon	= Unit Energy Consumption x Unit Construction Cost [kcal/Yen] [Yen/m ³]
2. RUNNING ENERGY	
1) Conventional Treatment	
-Electricity	= Unit Energy Consumption x Power [kcal/kwh] [kwh/m ³]
-Chemicals	= Unit Energy Consumption x Dosage Rate [kcal/g] [g/m ³]
2) Sludge Treatment	
-Electricity	= Unit Energy Consumption x Power [kcal/kwh] [kwh/m ³]
-Gas & Petroleum	= Average Power Consumption x Percentage x Unit Energy Consumption [kwh/m ³] [%] [kcal/kwh]
-Sludge Disposal	= Unit Energy Consumption x Distance x Weight [kcal/km/kg] [km] [kg/m ³]
3) Advanced Treatment	
-Biological (Honeycomb Tube)	= Unit Energy Consumption x Efficiency x Power [kcal/kwh/m ³ /day] [%] [kwh/day]
-Ozonation	= Unit Energy Consumption x Efficiency x Power [kcal/kwh/m ³ /day] [%] [kwh/day]
-Carbon	= Energy Consumption / Water Production [kcal/kg/year] [m ³ /year] + Unit Energy Consumption x Power [kcal/kwh] [kwh/m ³]

*.....'Initial energy' implies energy required for system construction and manufacturing of materials, while 'running energy' is for operation.

- (2) An excessive capital investment should be reduced by employing more reliable methods for water demand forecast and applying more effective network zoning. Economics of scale should be reconsidered to adopt the least energy consuming technology.
- (3) Advanced treatment processes currently used are mostly of the energy dependent type. Water purification processes less dependent to the energy should be developed together with enhancement of pollution control in the water sources.
- (4) Comprehensive response options should be based on review of energy consumption by water utilities and the public.



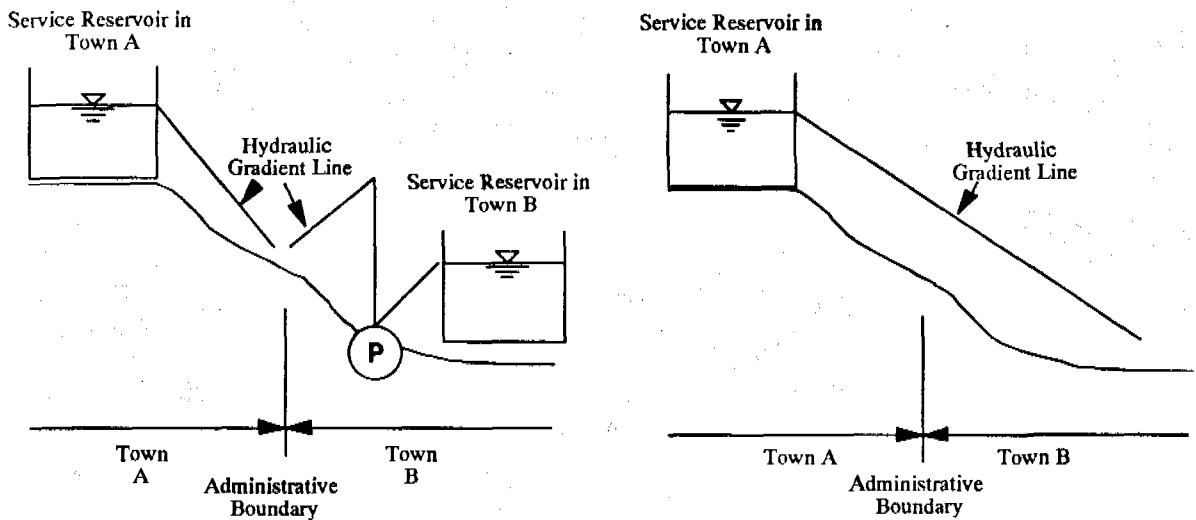
4. RESPONSE MEASURES

The Sub-group III deals with four issues related to technical options for energy savings which are outlined below together with major results:

4.1 Considerations during Planning and Design Stages

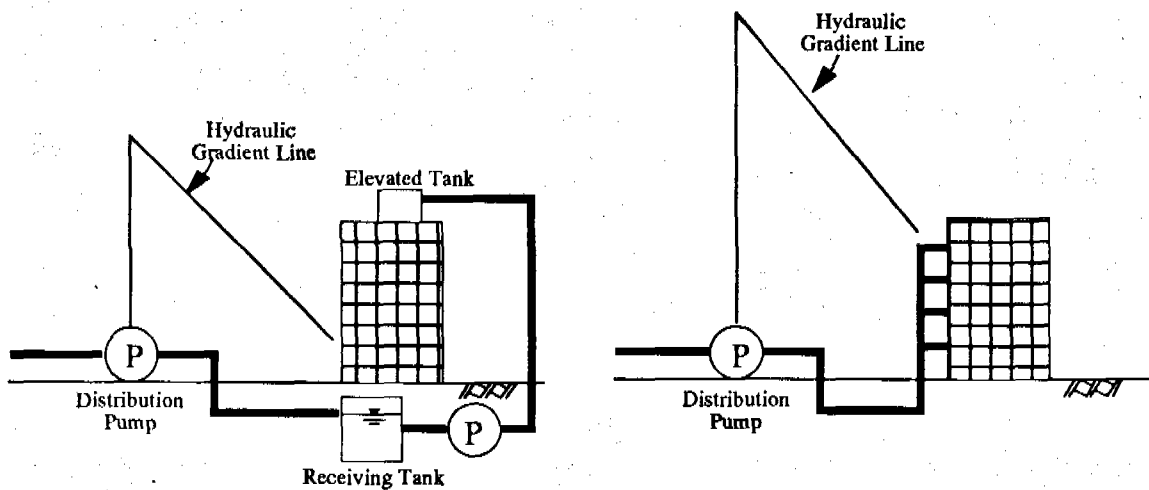
Network zoning with an appropriate pipe alignment and the gravity flow throughout the system are recommended as one of the most effective energy saving method. (See Fig-4) To achieve these, (1) impounded reservoirs, intake and treatment facilities should be located at strategic points as far as possible, (2) water resource development schemes including conventional water right system should be periodically reviewed at an appropriate interval to achieve energy saving, and (3) direct supply to multi-story buildings without receiving tanks should be introduced to reduce total energy consumption, although the receiving tank installation are currently popular in Japan. (See Fig-5) According to our case study, the more the service area contains multi-story buildings and the higher the water pressure exists at the end of service pipelines, the more the direct supply is effective in energy saving. These technical potentials, as evaluated large, should be studied further with an emphasis on development of regulatory and management measures.

Fig-4 WATER SUPPLY SYSTEMS IN JAPAN



Note: Service area of Water supply should not be based on administrative boundary but on geographical, demographic and socio-economic features of the area.

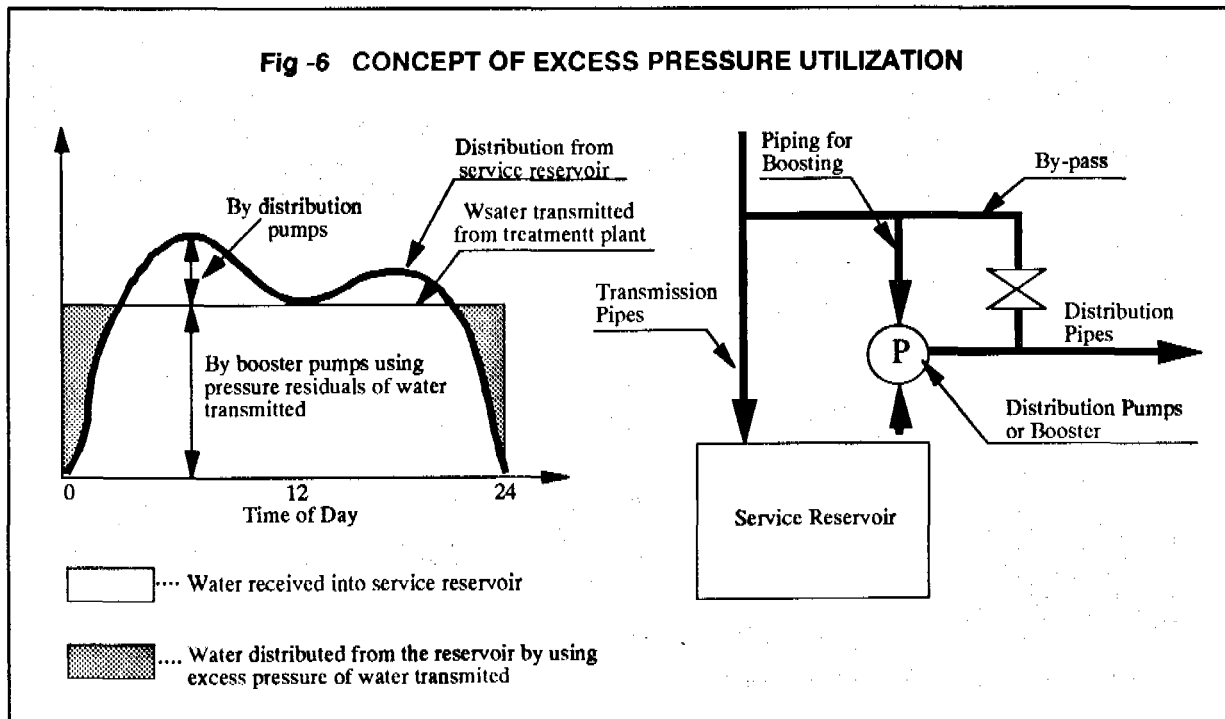
Fig-5 DISTRIBUTION WITH AND WITHOUT RECEIVING TANK



Note: Double pumping systems are often exhaustive than single system in terms of energy consumption

4.2 Effective Water Transmission

In general, energy for water supply system operation is utilized mostly at distribution and transmission facilities. It is often observed that water received at service storage reservoirs are pumped up again for distribution despite their considerably high residual pressure. Our proposed options are (1) to utilize such excess pressure for boosting, (2) installation of booster pumps for direct supply to multi-story buildings and (3) water storage in elevated tanks utilizing power during night time. As regards option (1), Fig-6 was prepared to show how to supply water from reservoir or through booster pumps installed.



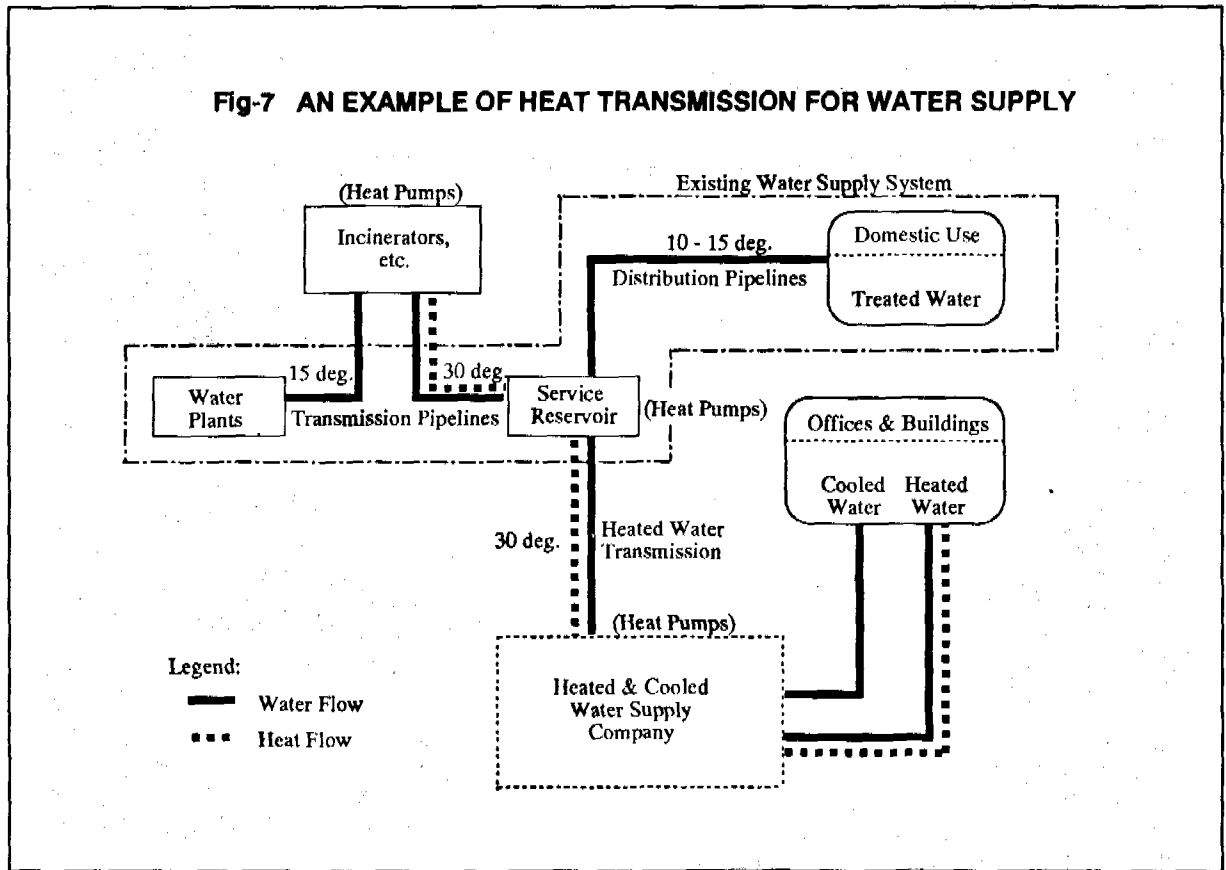
4.3 Heat Transmission through Water Pipes

Thermal potential at the existing large-scale sewage treatment plants, excessive heat at power plants and incinerators located in the metropolitan area may be reusable energy sources. If these energy can be technically and institutionally obtainable not only for newly developed urban heat supply systems but also for water supply systems, energy saving would be largely enhanced. Our recommended option is to utilize the existing water pipes as means of heat transmission in combination with the latest technology for heat pumps on condition that safety water supply would not be disturbed by such heat. It should be noted that energy savings largely depend on efficiency of heat pumps. A case study carried out by the Sub-group suggests that energy loss during heat transmission through water pipes is almost negligible.

4.4 Demand for Heated Water

The option stated above may have considerable opportunity for energy savings. The Subgroup, further, made an overview of customers' needs for heated/cooled water supply. First, patterns of present water/energy consumption in Japan were reviewed to know customers' preference and inclination. Several technical options are then proposed to reflect such consumption patterns, on condition that abundant reusable energy sources are available, adjacent to demand zones. An example option is presented on Fig-7.

Fig-7 AN EXAMPLE OF HEAT TRANSMISSION FOR WATER SUPPLY



5. RECOMMENDATION AND ACKNOWLEDGEMENT

Monitoring of the impacts of global change on water supply should be enhanced to carry out an indepth research and analysis. To reach consensus on adaptive and preventive measures against the global change, a series of international conference and framework convention will be/was held intensively. The water supply sector, as related closely to the global environmental issues, should take an appropriate measures along with an action program or consensus agreed.

Although largely depends on socio-economic conditions, possibilities of responsive measures are studied further in every country. "Think globally! Act locally!" is a basic principle for attaining sustainable development and welfare of humanity.

Our deepest appreciation goes to all the experts and officers who contributed much to compilation of our Report by providing relevant data, reports and valuable comments.

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THE STRATEGIC ASPECTS OF WATER SUPPLY

M.J. Rouse
WRc plc
Great Britain

ABSTRACT: The paper presents the various demands of water supply systems specifically in the context of river basin management and considers the importance of an integrated approach. There are sections on setting standards and on regulation and monitoring with references to the main national documents on which UK thinking is being developed. It is concluded that a vital factor for success is a thorough scientific understanding of the river system such that the effect of any proposed actions can be predicted with confidence.

INTRODUCTION

In simple terms, the strategic aspects of water supply relate to meeting all the various demands for water both in terms of quantity and quality. But there the simplicity ends because determining the justifiable and competing requirements in relation to community benefits and meeting those requirements, is complex involving interrelated political, organisational, economic, environmental and technological factors.

The organisational approach taken around the world is variable and depends as much on history and culture as on any physical factors such as a river basin. This paper concentrates on the scientific and engineering (embracing economic) aspects which are crucial to a successful strategy and which need to be managed whatever the organisational approach which might be adopted. Although each country might argue the superiority of its own structure, it has been shown in Europe, for example, that there are many different successful approaches.

DEMANDS OF WATER SUPPLY SYSTEMS

There are many demands which have to be considered:

- (i) An adequate supply of drinking water at the required health standard.
- (ii) An adequate supply of water for other domestic purposes.
- (iii) Water to meet the demands of industry at a wide range of quality standards.
- (iv) Water for irrigation.
- (v) Water for navigation.
- (vi) Water for recreation.
- (vii) Disposal of wastewater. Once delivered it almost certainly needs to be collected and hopefully recovered for further use.
- (viii) Urban drainage.
- (ix) An acceptably clean water environment.
- (x) All this at an acceptable cost.

Traditionally, (i) to (iv) would have been considered as water supply requirements but environment considerations now result in the need for an integrated approach to water without which the water supply requirements cannot be met. Equally, surface water and groundwater are not considered as separate but increasingly as interconnected systems, not only hydrologically but also via the impact of land on quality.

The increasing demands for water around the world have tended to give priority to the construction of new systems. It is now recognised, for example, in the Sixth Malaysia Plan, that effort is needed in the rehabilitation and upgrading of water supply systems (Ref. 1). Indeed, in some of the countries with relatively old systems, such as the UK, major rehabilitation programmes are underway towards meeting required service standards in the most effective way. Given the impact on water resource quality of urban drainage, a sewer rehabilitation strategy (Ref. 2) is also important in this respect.

So the demands for water and water services are virtually unlimited whereas water resources and money are finite. The task is to achieve the most, in terms of the various demands with the appropriate balance between them, with the financial resources available. This requires an integrated approach based on river basins.

AN INTEGRATED APPROACH

In essence, this means developing a comprehensive understanding of the behaviour of a river basin system such that the greatest overall benefits to the community can be achieved. The understanding has to embrace both quantity and quality and take into account all the demands of abstraction, discharges and the environment.

Gaining the required understanding requires a significant amount of effort and needs to involve all those organisations involved in regulating cost, in regulating quantity and quality and those operators required to meet the regulators' requirements throughout the river basin system. Clearly the fewer the organisations involved the easier the task but with goodwill and with the pressures from the population to cooperate and succeed, good progress has been made in very complex situations such as the River Rhine in Europe.

An outline of the task of the integrated approach as it relates to Europe is given in Fig. 1 showing the components in the hydrological cycle and Fig. 2 (Ref. 3) giving an approach to catchment management planning to achieve environmental quality standards. I consider the tasks under the following headings:

- (i) Setting standards.
- (ii) Charging for services.
- (iii) Regulation and control of resources.
- (iv) Control of pollution.

SETTING STANDARDS

These can be considered under three categories:

- (i) Health related.
- (ii) Environmental.
- (iii) Other, such as customer service measures.

The health related ones are largely those on the quality of drinking water although continuity and pressure of supply and protection against backsiphonage are important factors. The sound basis for drinking water quality are the WHO guidelines (Ref. 4), the new version of which is expected to be published in June 1993. These guidelines are based upon stated scientific bases and allow a cost benefit approach to be taken. Depending upon economic considerations, a country or region might choose to achieve a good standard throughout rather than spend additional scarce resources on seeking a higher standard at the expense of other competing requirements such as health care services. It is important to recognise that the standards chosen need to take into account not only the treatment potential but also the limitations imposed by water resources and distribution system conditions.

RIVER STANDARDS (including canals and estuaries)

The standards depend upon the uses to which the river and its water are put but also on general ecological considerations. In the UK, the National Rivers Authority (NRA) is beginning the process of introducing statutory water quality objectives (SWQOs). Proposals were set out in a consultation paper in December 1991 (Ref. 5) published at the same time as a report on the quality of rivers, canals and estuaries based on the 1990 survey (Ref. 6).

The proposed scheme of SWQOs are likely to contain three main elements: the requirements of relevant European Commission (EC) Directives (such as the Municipal Wastewater Treatment Directive), compliance with the water quality standards associated with use-related classes and the application of general classification schemes. In addition to the general uses, a special ecosystem use is proposed which would cover special requirements for nature conservation reasons together with a general ecosystem use based on biological standards by way of an ecological quality index (EQI). Overall, though, standards would remain chemically based.

The consultation paper sets down a logical sequence for setting SWQOs for each use-related stretch of waterway, through a series of questions:

- (i) What is the current quality state?
- (ii) What is the state of EC Directive compliance?
- (iii) What are the current uses?
- (iv) What are the desired uses?
- (v) What are the benefits and can they be quantified?
- (vi) How many choices of achieving are there are and what are they?
- (vii) What are the costs of achieving them?
- (viii) What is the likely timescale?

It is easy to list the questions but much work is required at each stage if the resulting SWQOs are to reflect the public (customers) requirements in relation to costs and benefits. An example of the early stages of the approach in practice is given in Reference 7.

It is important to note that any system needs to incorporate a combination of WQOs (ie EQO/EQS approach) and fixed emission standards. The latter are necessary to deal with highly toxic and persistent substances such as those included in the so-called European red list. The approach for these is BAT (best available technology not entailing excessive cost). Just as specifying technology is a good way forward for red-list substances, equally it should not be done for, say, domestic sewage, for two reasons. Firstly, it

inhibits innovation of improved methods and secondly, and probably more importantly, it concentrates on only one component of the discharge problem. An integrated approach based on WQOs is a better way forward.

OTHER STANDARDS

Other customer service standards are important and reflect attitudes towards people. Are they consumers where 'big brother' decides what is good for them or are they customers who can influence what they get for what they pay? This is part of a bigger debate on public services which in the UK is related to the 'citizens charter' concept and a subject for separate papers. The most important ones in relation to quantity and quality of drinking water are the continuity of supply and water distribution system pressure. Continuity is essential to avoid contamination of the system. Pressure has to be adequate to minimise the risk of infiltration but controlled to minimise leakage. The distribution system needs to be given equal attention to that of resources and treatment. There is little point in investing in only part of the total supply system. Equally, all the standards, those of health, environmental and customer service, need to be considered in an integrated way to achieve a sound balance in line with the resources available to achieve them.

CHARGING FOR SERVICES

It is not possible here to offer a treatise on charging policies nor one on responsibilities for basic public health. The most important issue to my mind is that as far as possible the 'customers' need to 'feel' the cost of service either directly as charges or through the strong recognition that there are limited funds available and that choices have to be made. This view is not popular amongst environmentalists but people have to understand the reality of situations.

REGULATION AND CONTROL OF RESOURCES

In the UK there is now a national approach, operated on a regional river basin catchment basis, to the control and regulation of both quantity and quality of water resources through the National Rivers Authority (NRA). However, some aspects of pollution control come under Her Majesty's Inspectorate of Pollution, HMIP, a Government department and the Ministry of Agriculture, Fisheries and Food, MAFF. Government is considering rationalising the approach and it is likely that at some stage regulation will be integrated within one Environmental Agency.

The UK approach has evolved from the first stage of a river catchment management concept with the formation of the Regional Water Authorities in 1974. In June 1989 operations were privatised and regulation was strengthened through the formation of the separate public body, the NRA. It is unlikely that State or Municipal boundaries will coincide with those of river catchment areas so it is difficult to reconcile the two structural approaches. Germany does not attempt it with States (Länder) and Cities being dominant whereas in France there is a complex combination of Agence to Bassin and city forms of regulation.

Being an island, the UK does not have to wrestle with the problems where rivers cross national boundaries. One example of a major river organisation is The Rhine Commission which deals with the problems of pollution and clean

up. However, given the abundance of water in that catchment, the issue of sharing out a scarce resource does not arise. This becomes particularly acute with such rivers as the Euphrates.

The question of interbasin transfers is often raised in the UK. Following four years of lower than average rainfall in the east and the south of England, the costs, benefits and problems associated with transferring water from the north and west are again being reviewed. The debate on the way ahead takes into account household metering, leakage control and of course environmental considerations. The way ahead will involve an integrated approach.

MONITORING OF QUALITY

River quality needs to be monitored for its general condition in relation to its ecology but also for its protection as a source for drinking water. Progress is being made in the development of automatic monitoring systems the limitation being the availability of accurate and reliable water quality sensors. Gradually the automatic systems will assume greater importance as early warning or screening systems but the traditional approach of sampling and laboratory analysis, due to the ability to apply a range of highly sensitive equipment, will always have a central place in monitoring.

Often the limitation is the sampling scheme where practical considerations in collecting samples greatly limits the value of the information which can be obtained. Experienced statisticians need to be involved in the design of the sampling schemes and in the approach to the analysis of the data.

CONTROL OF POLLUTION

This is discussed fully in Reference 3 by Fiddes and Clifforde and the broad approach is to define the requirements, measure the current position and model the various components of the system so that a range of actions can be compared. In addition to allowing the selection of the most cost-effective solutions, the approach does provide a high degree of confidence that the management plan will produce the desired results.

The integrated approach takes into account all discharges to the river including the non-point ones such as agricultural run off. It also allows the 'what if' questions to be answered such as "what if there is some accidental spillage or some indiscriminant dumping?".

It is important to stress here the need for environmental quality standards as discussed earlier. It is even more important to advise against the adoption of prescriptive solutions such as the requirement for specific types of process plant. Such approaches have resulted in high costs without the achievement of the required results because it ignores the wider system requirements. Equally damaging, there is no incentive for innovation in treatment methods.

It has to be recognised that the integrated approach does require much more effort and cost at the study stage. Effort in surveys, in measurement and in modelling. Effort specifically to validate the models to ensure that they are effectively predictive. The benefits of this higher initial cost are a significantly lower final total cost (up to 100 times the return on the

additional study cost) and a virtual guarantee that the desired result will be achieved. Decisions on these essential studies are probably the most important steps in the total management process.

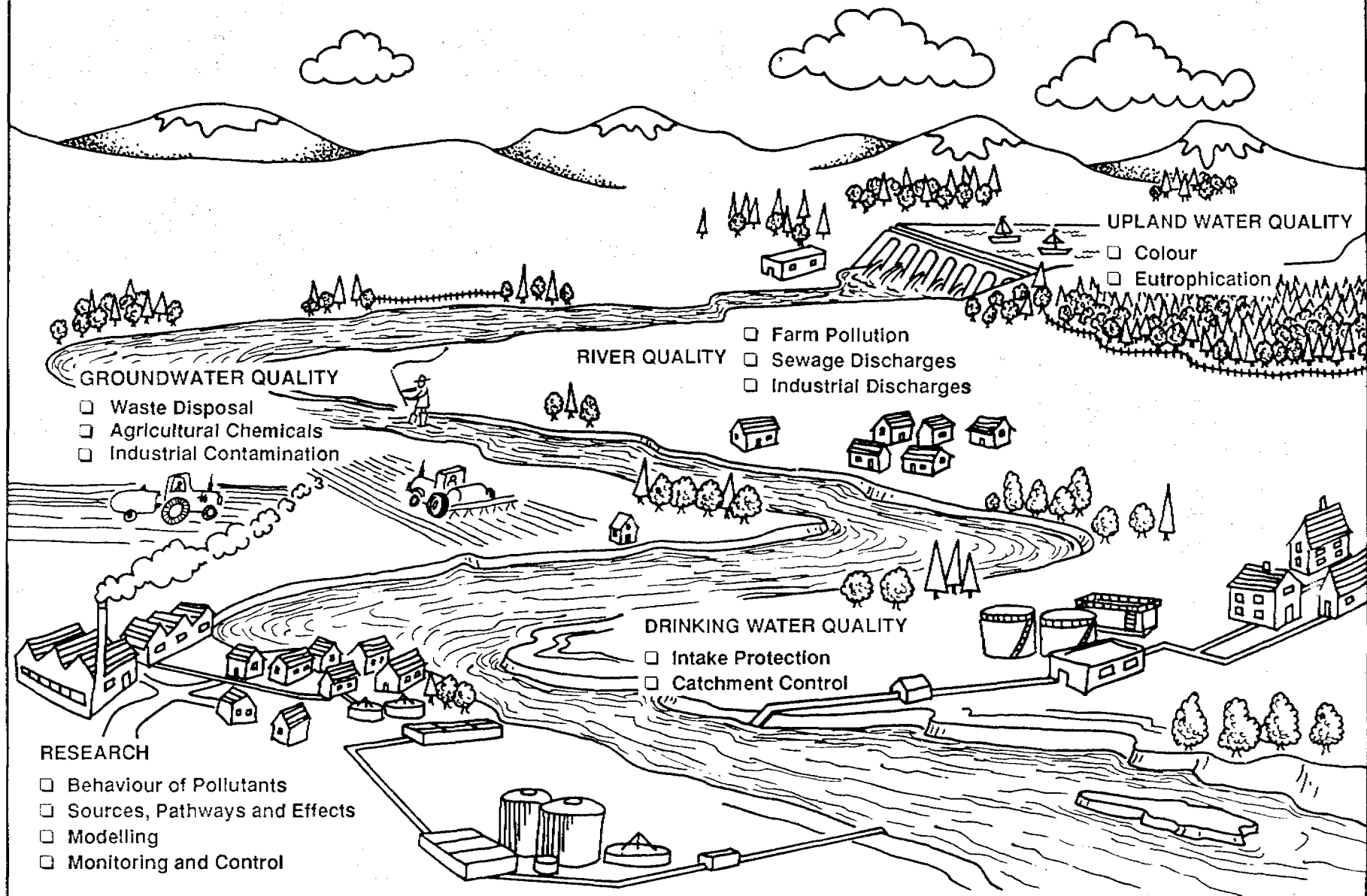
CONCLUSIONS

1. Given the many requirements of a river system which need to be met in an environmentally acceptable way, an integrated approach is essential.
2. The organisation of river basin management should take cognisance of this although a number of approaches have been shown to be acceptable.
3. An important factor for success is a thorough understanding of the catchment such that the effect of various options can be predicted with confidence.

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FIGURE 1 RIVER CATCHMENT



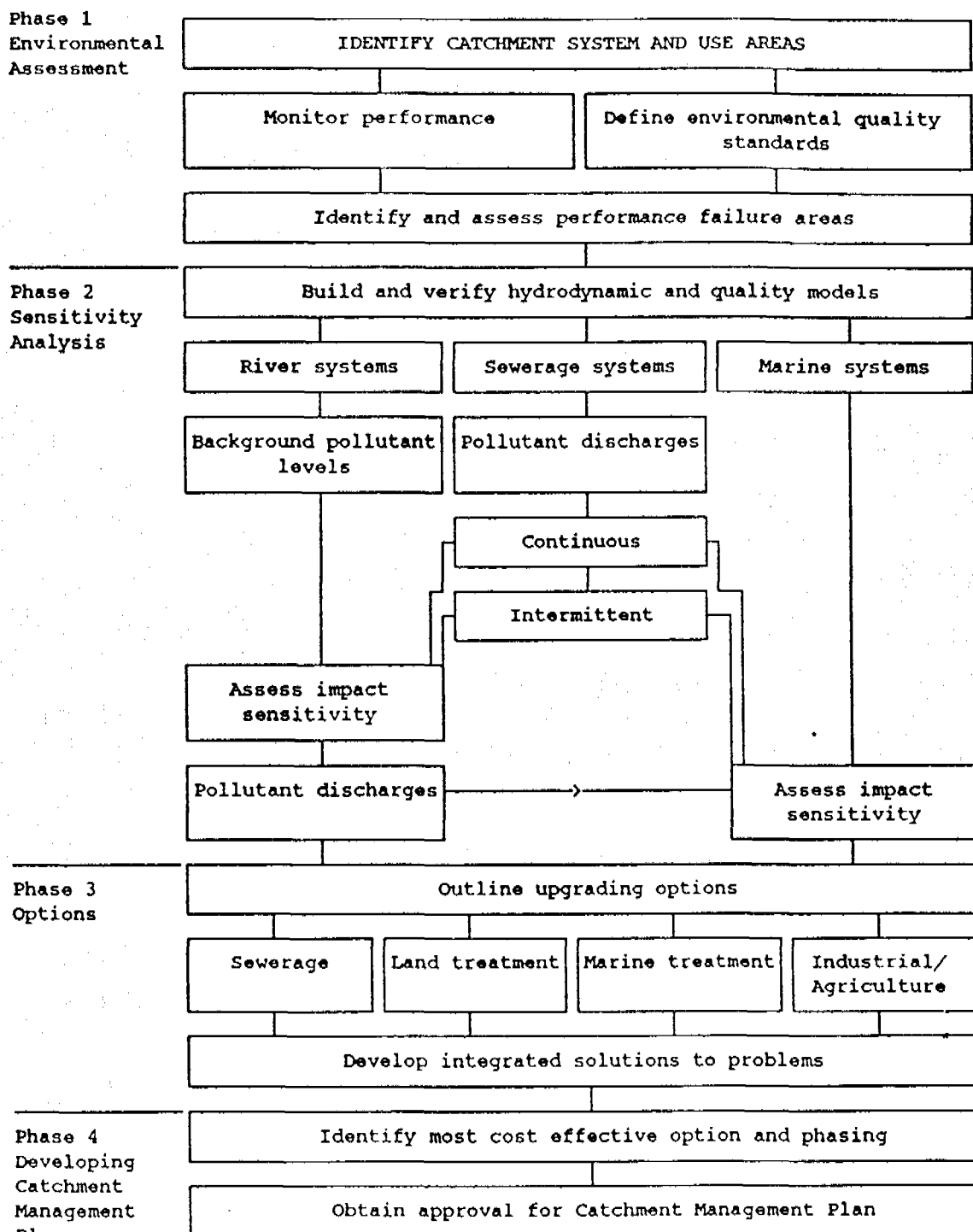


Fig 2. Catchment management plan flow diagram

RECENT WATER RESOURCES CRITERIA FOR THE PRODUCTION OF DRINKING WATER

M. Rapinat
Manager of Production Department
Compagnie Général des Eaux, France
cum President of IWSA Resources Committee

For a long time, the need for drinking water was satisfied by abstracting water from the nearest spring without paying too much attention to quality. In those days quality was, in fact, satisfactory in a great majority of cases.

The growth of the population and economic development create new constraints which must be taken into account when selecting resources.

Urban development exhausts the possibility of drawing water from the nearest aquifer, and means mobilization of new resources at far greater cost, due to the distance and treatments required for removing pollutants. The search for the optimum economic solution is henceforth an essential task. The analysis of the financial commitments attached to the various alternatives must therefore be far more meticulous than in the past.

The development of irrigation to meet the growing demands for food, increases the difficulties normally arising in period when rainfall is scant. The enlargement in the amounts of irrigation water during droughts leads to an inevitable conflict between the uses of water, a situation that requires an overall management policy which aims at avoiding the exhaustion or irreversible deterioration of resources.

Lastly, economic growth reveals new forms of pollution and the emergence of new hazards. These dangers must be included and their possible consequences made clear when assessing the vulnerability of a resource.

1) The traditional criteria

Expanding available resources to cope with increased demand always involves heavy investment. In the field of water, the volume of investment goods is very high. Only the extremely long service life of the plant and equipment, compared with the usual industrial criteria, enables capital costs to be kept at an acceptable level. The proportionate production costs are always very low compared with capital costs, even when a relatively sophisticated treatment turns out to be necessary.

It is not surprising therefore that every effort is made to look for the resource which enables investment in capital goods to be reduced. As a general rule, this means the nearest resource capable of satisfying total requirements, or to complete existing facilities. Only when the quality of the resource requires the installation of abnormally

expensive, rare and specific treatments is it preferable to fetch the water from a more distant source.

The proximity factor is therefore the basis for choosing a water resource. In temperate regions where water is relatively plentiful, water is drawn in most cases in the immediate vicinity of the area of consumption. In less fortunate areas, there is no alternative but to look for water where it happens to be, very often in the mountains or in artificial impoundments built to store water in view of dry periods.

The obviousness that water carries certain infectious diseases caused people to be suspicious of surface water. Hence there is strong pressure from public opinion in favour of using groundwater (note1). In many countries, satisfying drinking water needs is considered to have priority over other uses, and it is believed that groundwater should be increasingly reserved for public supply. Industrial needs can then be met mainly by pulling out water from rivers.

Hence, for a long while, the selection of a resource for the public water utility was, theoretically, an easy matter i.e., a good quality water aquifer, as near as possible to the network. In practice, the problem is not so simple. Besides the inevitable technical uncertainties surrounding the pumping of water from aquifers, competition might well arise between the different entities having a right to the resource. The use of surface waters is easier from both the political and administrative points of view, but requires the implementation of what can be delicate treatment scheme.

Note 1: Some opposite cases have also been reported - the occurrence of epidemics caused by contaminated wells has brought preference for treated, hence healthy, river water. However, one may consider that this is less a matter of choosing between groundwater and surface water than a policy giving preference to safety through a minimum of treatment.

2) A necessity - the diversification of resources

A breakdown in water supplies is less and less tolerated by the public. Hence suppliers explore all the means likely to avoid cutting off the water, whatever the cause. Demands are exacting. Even a pollution episode, considered in most industries as a case of force majeure, is no longer admitted as a reason for cutting off the public water supply. The argument put forward is that this type of event ought not to be regarded as an improbable occurrence in places where economic development has reached a certain level. To avoid being accused of improvidence, water suppliers secure the means of coping with such events in good conditions. The first measures taken consisted in increasing security by installing more efficient means of treatment and widening the possibility of removing pollutants. The second was to install alarm systems to enable the arrival of pollution fronts to be forecast. However, these systems, despite their undoubted efficiency, are not absolutely foolproof. There will always be pollutions that are difficult to treat. This leads us to complete the systems by looking for the possibility of supplying from different resources.

This diversity in the sources of procurement also appears attractive for facing difficult climatic conditions. When a river is very low, it is frequent to increase the amount of water drawn from the aquifer, either by adapting existing wells or boring new ones. Conversely, where there are very large impoundments used to regulate and sustain the flow rate in the river, surface waters are quite often used to back up the level of deficient aquifers. Hence in periods of drought, the fact of being able to call on these different resources, makes the situation less critical. Surface water and groundwater should be more and more often considered as being complementary.

This diversification of resources is a frequent solution applied in the big conurbations, often due initially to the limited possibilities of the various local sources of supply. However, the design of the network, the installation of high-capacity inter-connecting mains also reflect the supplier's concern to ensure safe supplies in the event of pollution, by taking advantage of the possibility of calling on diversified resources. The example of the SEDIF (Ile de France Water Board), is a case in point. A sustained effort over ten years or so resulted in a low level of vulnerability in the event of pollution even over an extensive period: if one production unit is shut down, difficulties' needs can be fully satisfied by the other water works belonging to the Board, treating water from other rivers, or the aquifer (fig 1).

In the case of small units, the problem of diversification is never acute. When difficulties occur, it is always possible to solve the problem in acceptable conditions by makeshift means, such as delivery by road tankers.

The case of average sized towns is more difficult. They often have only one source of feed water and standby methods can no longer be improvised.

The example of the town of Tours, France is eloquent in this respect. A few years ago, a fire which destroyed a chemical storage unit located about 100 km away, badly polluted an affluent of the river that supplied Tours with water (fig 2). The long distance between the fire and the treatment plant made the situation critical by extending the period of exposure to pollution. For several days, some of the districts in the town were without water and makeshift solutions had to be found, including the chartering of whole trains of tanker wagons. Yet Tour is built at the confluence of two rivers, the Loire and the Cher. It would have been simple to design water supplies to the town from both rivers and not just one. This was not done because no one was aware of the risk. Until then, no severe pollution of the Loire had occurred. Since then, a policy of diversification is systematically applied in France when water supply systems are installed.

3) Foresee the quality of the aquifers by following changing trends.

For a long time, the quality of the aquifers remained relatively stable in time. This is less and less the case.

In addition, increasing needs cause more and more water to be drawn from the aquifers. The risk of overworking them is far from insignificant and it is not difficult to cite examples in all parts of the world. When excessive drawdown lowers the level of these resources, the alert signal is clearly perceptible and the urgency of the problem is obvious to every one. However, the danger is sometimes covered up. Along the coast, for instance, salt water is sometimes drawn into fresh water resource due to heavy pumping.

Likewise, intensive agriculture can be at the origin of exceptionally serious diffused pollution, jeopardizing the possibility of using the aquifer at some future date. The case of nitrates is symptomatic. The nitrate content is slowly but surely increasing in the water aquifer located under intensive farming areas and is now approaching the generally allowed limit of 50 $\mu\text{g/l}$. The problem is made more acute by the very high cost of denitrification and often the solution adopted is to mix water of several different origins. There are times when a polluted source even has to be abandoned.

The effects induced by pollutants on natural self-purifying phenomena must also be taken into account. An increase in the concentration of phosphorous has often encouraged the growth of algae, the first step towards intensive eutrophication. Hence, phosphates may be indirectly responsible for spoiling the taste of drinking water and for big treatment difficulties.

Time is the important factor. Contamination is a very gradual process may spread over a period of several years. Unhappily, the impact of the protective measures taken is only perceptible in the long term. In spite of the organization of a stringent policy of protection, it is not rare to see the situation continuing to grow worse for several years before the opposite effect begins to be felt. Hence the insistent demands for better protection of the environment, particularly water.

Consequently, it is important for water suppliers to anticipate on the risks of deterioration, which implies having good knowledge of the tendencies. Meticulous and frequent monitoring of the quality of the aquifer from which the water is obtained is absolutely essential.

New forms of pollution are even more dangerous. They concern the micropollutants of industrial origin, such as solvents, and of agricultural origin, such as pesticides. The common characteristic is that, because they are micropollutants, extremely weak concentrations are enough to make the water unsuitable for human consumption. Deterioration can set in very fast. Unfortunately, decontamination is still a lengthy process and often requires heavy means.

Treatment is often called on to counteract these different forms of groundwater pollution. They are, unfortunately, very costly: adsorption on carbon, combined ozone and hydrogen peroxide, ion exchange, stripping.

When a new resource can be used, mixing the raw water is a means of attenuating the level of deterioration observed. In the most serious cases, we must resign ourselves to abandoning the resource and finding other supplies of raw water. This threat, and the growing demand for water, lead Water Suppliers to ask for better protection of aquifers as a whole and not just the ones currently worked.

It is obvious that the extent of such present or potential dangers hanging over a water resource is an important factor to be taken into consideration when choosing that resource. The fact of intensive urban development equates in the long term a high probability of some incident or degradation, unless ambitious and restrictive measures are taken within the limits of the zone of protection. Likewise, the existence of areas favourable to intensive farming represents a serious threat for aquifers located below those areas.

4) Taking ecological criteria into account

In developed countries, the magnitude of the deterioration reported in some places has made the public at large aware of the necessity of protecting the environment. The deterioration of water resources is a symptom of the general evolution, and reversing the tendency in the aquifers is often considered to be a priority objective, a token of the improvement of the overall situation.

For a long time attention has been focused on qualitative aspects, the objective being to reduce the pollutant and micropollutant contents.

More recently, attention has also been given to quantitative aspects. Maintaining alive the variety of species in a waterway depends not only on the presence of micropollutants, but also on there being a sufficient depth of water. The determination of the minimum flow rate has therefore been revised. Whereas, for a long time, the low water level was fixed in accordance with requirements, this value is ever more frequently calculated to ensure the survival of a wide range of fauna and flora, thus avoiding the deterioration of environmental quality.

Concern for ecological criteria has thrown doubt on certain orientations considered hitherto as conventional. Thus water intended for human consumption was traditionally drawn from upstream the town and waste water was discharged downstream. The determination to keep a sufficient level of water in the river has led to a change of this principle in certain cases. It is a fact that over 90% of the volume of water drawn for household use is discharged into the river again. Hence, wastewater, if it receives sufficiently thorough treatment, an objective made necessary by environmental protection, can be discharged near the intake point (fig.3). In this way it is possible to satisfy simultaneously the fundamental necessity of meeting drinking water requirements, better environmental quality and a higher flow rate on the river.

Important progress achieved in odour control for waste water treatment plant makes it easier to position intake structure and sewage discharge point closer together. This result, in harmony with the protection of the environment, now enables treatment plant to be installed in the heart of the town e.g. Monaco (under building) (Fig 4) or in Marseille (under the sports stadium) (fig5). In addition, this possibility is economically attractive because it reduces the cost of the sewer network.

5) Impact on water resource management method

Water Suppliers must play an increasingly active part in the management of water resources. Not only, as we have seen, must they follow the changes in water quality with enough precision to be able to foresee future tendencies, but they must also demand stricter preventive and protective measures to ensure the permanence of resources suitable for the production of drinking water.

5.1. Artificial recharging

An initial example is found in the process of artificial recharge. This technique is interesting from several points of view.

With regard to quantities, it is possible to increase the potential use of aquifers, while disposing of better possibilities for meeting requirements. Bearing in mind the considerable volume of a water aquifer, it is possible to play on the amount stored. In Winter, or in rainy seasons, larger volumes than the amounts consumed can be injected and, conversely, larger quantities can be drawn off in dry periods. The aquifer is then used, in fact, like an impoundment on the surface but with significant advantages from the points of view of quantity, quality and environment. If we stick to the quantitative aspect, underground storage avoids loss by evaporation, often a vital factor in dry or hot areas.

It is, however, the qualitative aspect that is decisive in artificial recharge. Many forms of deterioration can be avoided, such as problems caused by algae or eutrophication, a process particularly to be feared in hot countries. Moreover the quality is improved through the existence of a natural self-purifying process which takes place in the soil. This usually results in a decrease in the concentrations of ammonia and organics and the water is, generally speaking, far more stable when re-extracted. Artificial recharging can also limit infiltrations of salt in coastal aquifers. In some countries, the temperature of the water supplied is far more homogeneous, cool in summer and temperate in winter, which is greatly appreciated by consumers.

Lastly, a new element which should prove of growing interest in the future, the artificial recharge allows greater care to be taken of the environment while the building of surface reservoirs still meets with a great deal of opposition.

When selecting new resources, it is preferable to study the possibilities of artificial recharge and assess the degree of improvement it could operate. This of course

implies having access to another resource of acceptable quality, a condition which seems in any case to be indispensable in view of the necessary diversification mentioned in paragraph 1. In most cases treat the reinjected water is necessary to avoid deterioration of the aquifer.

5.2. Selective working of resources

From the moment operators dispose of a variety of resources or artificial recharge, the question is how to optimize operations.

From a quantitative point of view, we have already mentioned the possibilities of varying the volumes extracted according to the season, sparing the aquifers in winter and drawing on them in summer. Some opposite examples can be mentioned when constraints concern quality. Biological trains operate better when temperatures are above 15°C. Below 5°C, the biological purifying action slows down sharply. Hence to reduce the formation of trihalomethanes, certain Water Suppliers in the North of Europe only use surface water when it is at a temperature above that figure. During cold weather, the requirements are met by water from the aquifers alone.

A similar kind of strategy can be used in the event of pollution. In areas where there are strong risks of contamination in rivers, the aquifers can be extracted below capacity in normal times and thus be kept partly in reserve for pollution emergencies. If a serious accident occurs, temporary over-extraction can limit the consequences of pollution for the consumers. The criterion to be taken into account for management in this case is to respect a maximum drawdown during the year. An example of this method can be found at the Neuilly-sur-Marne water works belonging to the SEDIF water board extracting water from the Albien water aquifer. Normally, a single well is in service so that the flow rate can be doubled in the case of a pollution episode.

The fact of dispersing the wells in different places is also an important factor for it is a means of increasing security without adding too much to the cost of the feeder or reservoir.

In the choice of new resources, another important factor, which can even be decisive in the case of very vulnerable sites, is to weigh up the possibilities offered on the strategic level.

5.3. Constructing reservoirs to regulate the flow in rivers.

Up to this point, only the measures to improve operating conditions that Water Suppliers can take within the scope of their own facilities have been addressed. There are other fields of action, however, that are only conceivable in association with the other actors on the scene and which closely implicate public authorities.

It proves increasingly necessary to build reservoirs on rivers in order to regulate the flow of water. The main interest of these structures is the fact of being able to back up the flow rate during low water periods, hence attenuate the difficulties facing Water Suppliers in periods of dry weather. Whereas in the past the main reason for such constructions was to prevent floods, satisfying demand for drinking water is henceforth their main operating function. Water Suppliers must therefore play an active role because the existence of such reservoirs is increasingly dependent on their action.

They must also pay great attention to the way in which impoundments are managed. The objectives in view must not be limited to quantitative aspects but should also include quality criteria. The changes in water quality in reservoirs must be monitored with special care, focusing not only on eutrophication effects, but also on the impact

of raw water when the sluice gates are opened. In the Paris Region, for instance, Suppliers prefer a lower water level in August in order to keep a maximum amount for September. The reason is, that month, the reopening of a great number of factories, after the summer vacation, causing an increase in pollutant effluents. The possibility of increasing the flow rate in the host river provides a means of minimizing the deterioration of the quality of the raw water by dilution.

In some cases, reservoirs are built exclusively for the supply of drinking water. A case in point is the Biesboch reservoir in Holland which supplies water not only to the town of Rotterdam but also to a large part of the region (fig 7). In this case, it is easier to take constraints on the Water Supplier into account since the manager has customers that are all faced with the same problem.

CONCLUSION

The choice of a water resource to satisfy the needs for drinking water must allow for a growing variety of constraints and for changes appearing on the horizon. Water Suppliers are therefore faced with the difficult problem of forecasting longterm prospects.

They must be actively vigilant, not only inside their own facilities but also at the level of the resources. Taking action on resources can alleviate the difficulties experienced in the production of drinking water.

They should therefore state clearly the specific constraints that water supply exerts on the management of water resources and make the authorities aware of the emerging trends and their consequences on future objectives. This procedure should give easier access to new resources and strengthen the measures taken to protect them.

Fig.1

SECURITE DE L'ALIMENTATION EN EAU POTABLE

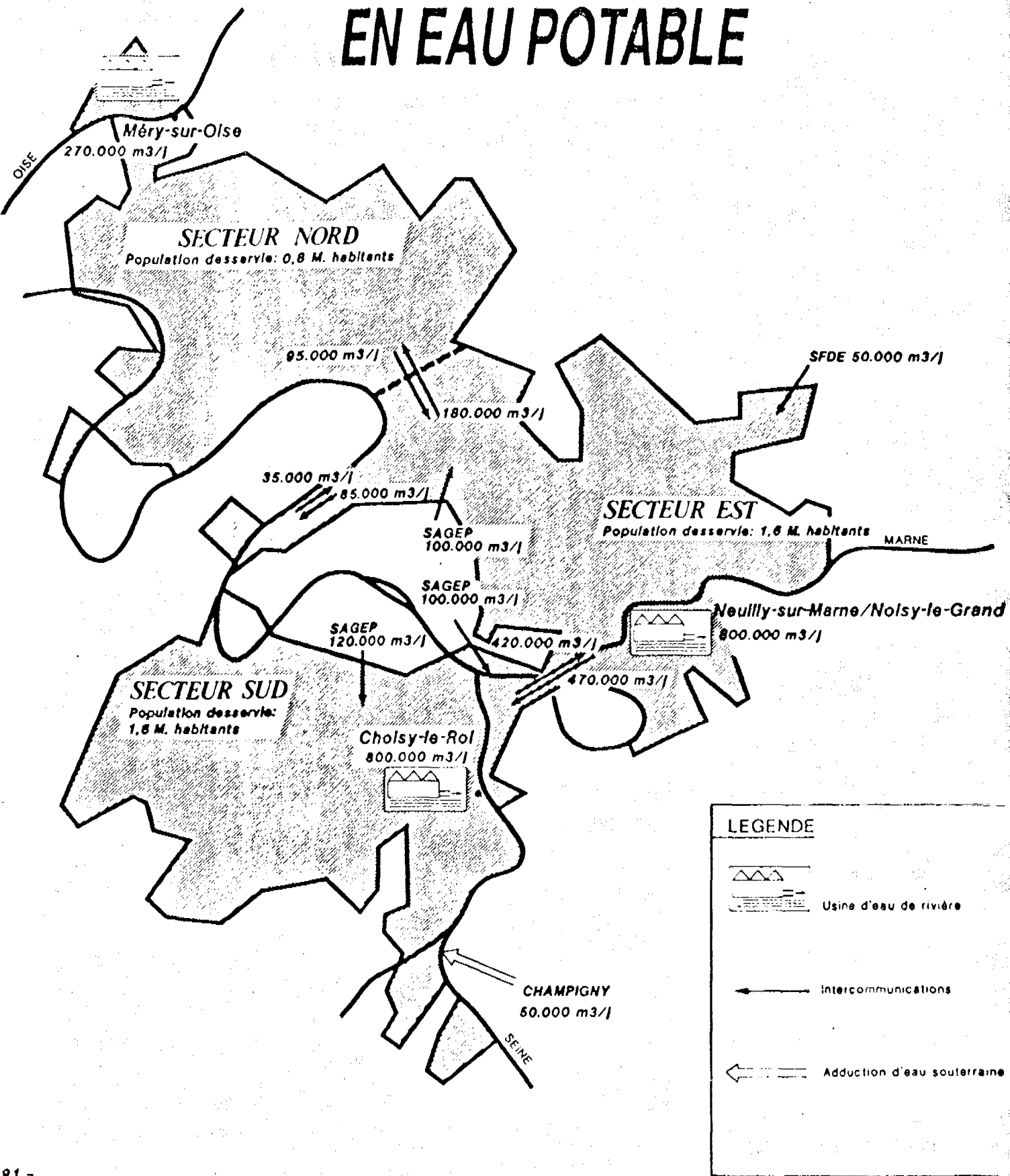
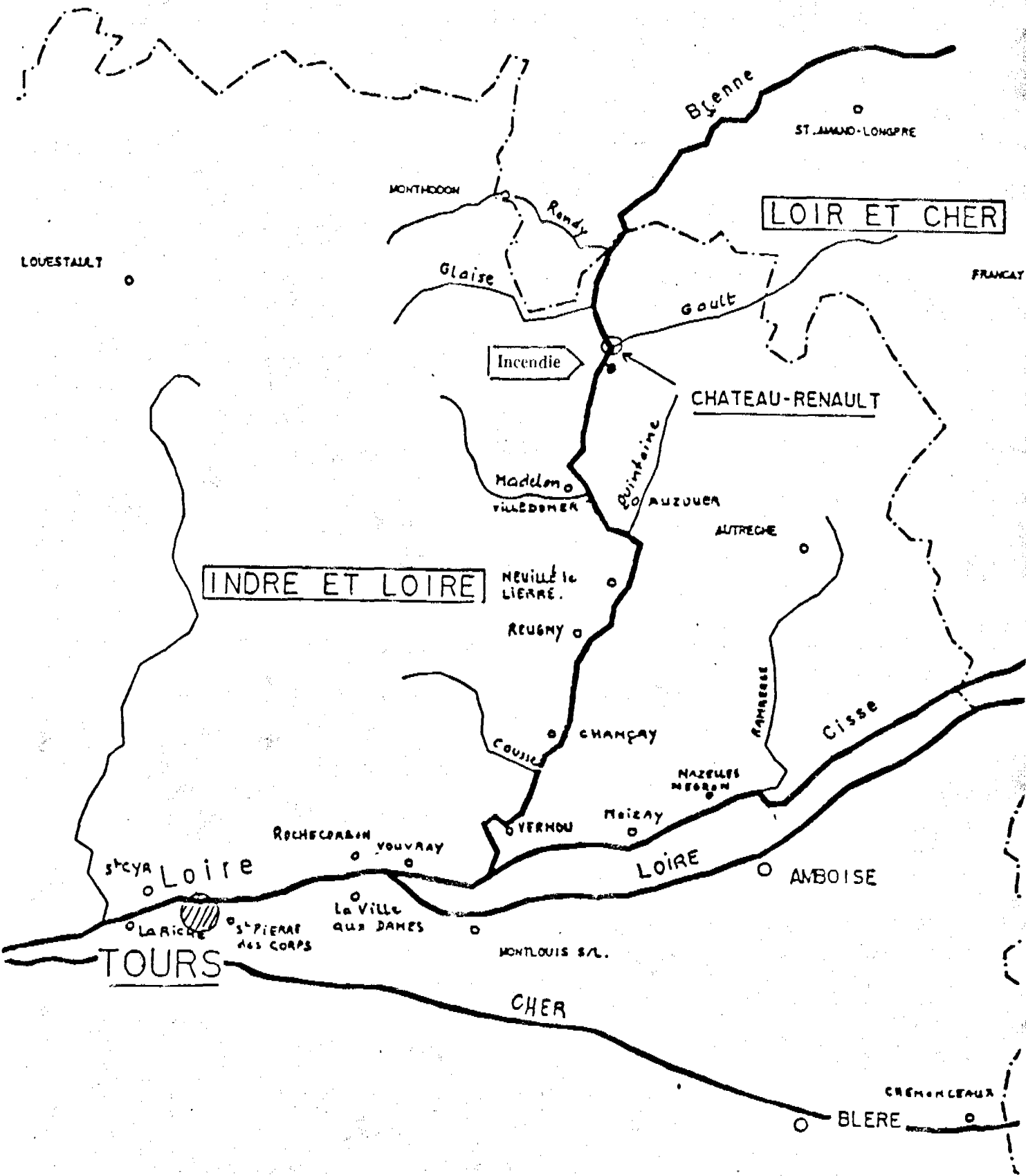


Fig. 2



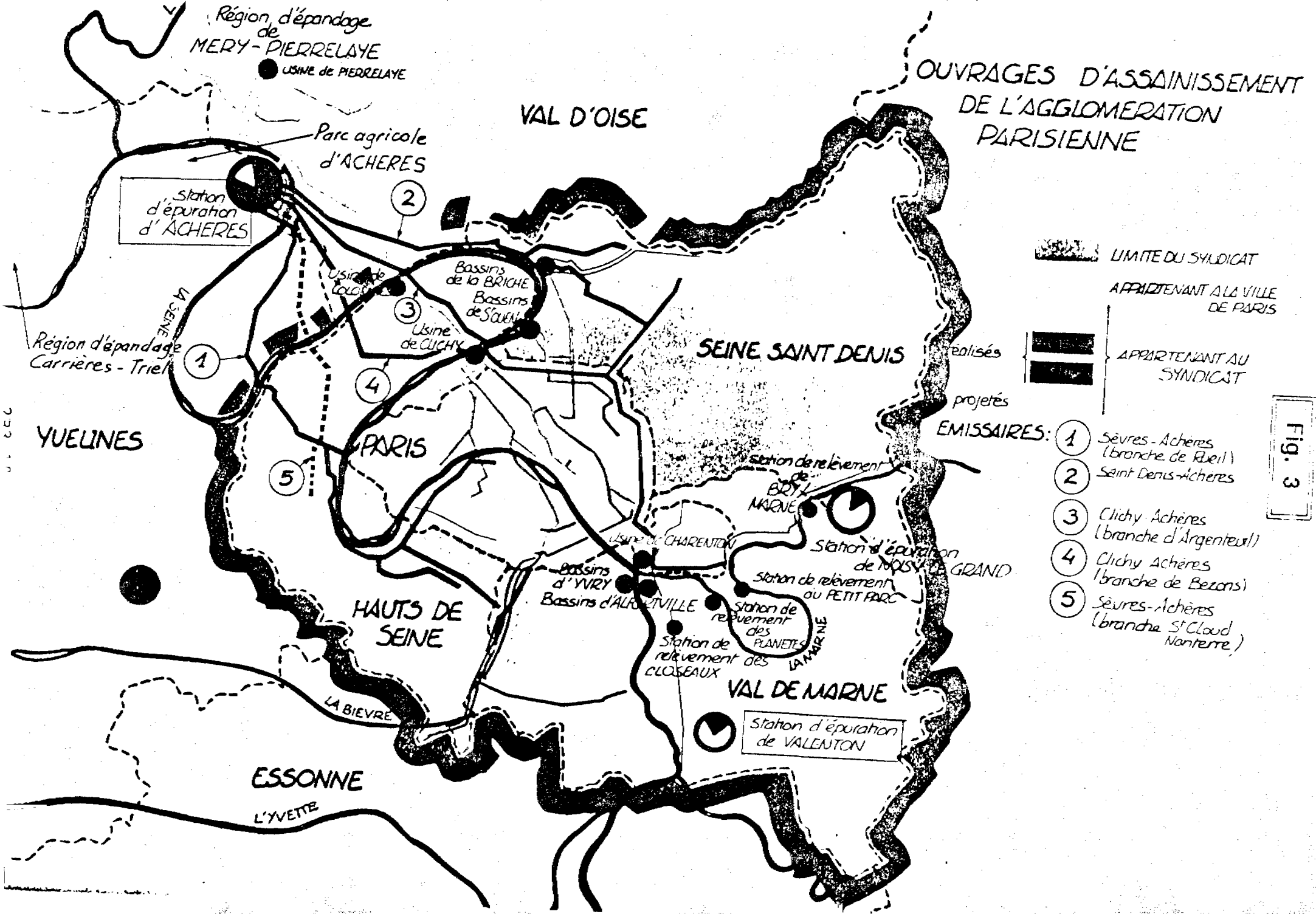


Fig. 3

Fig. 4

MONACO

TRAITEMENT EAUX USEES SOUS IMMEUBLE

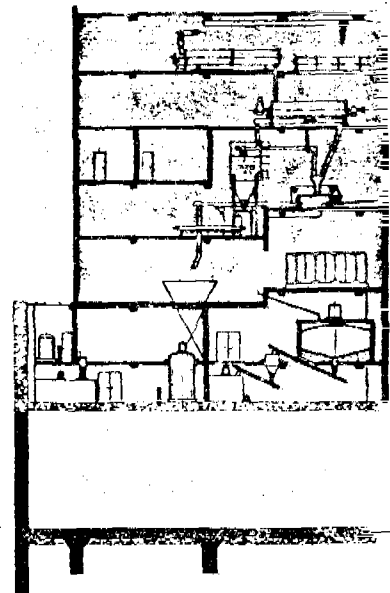
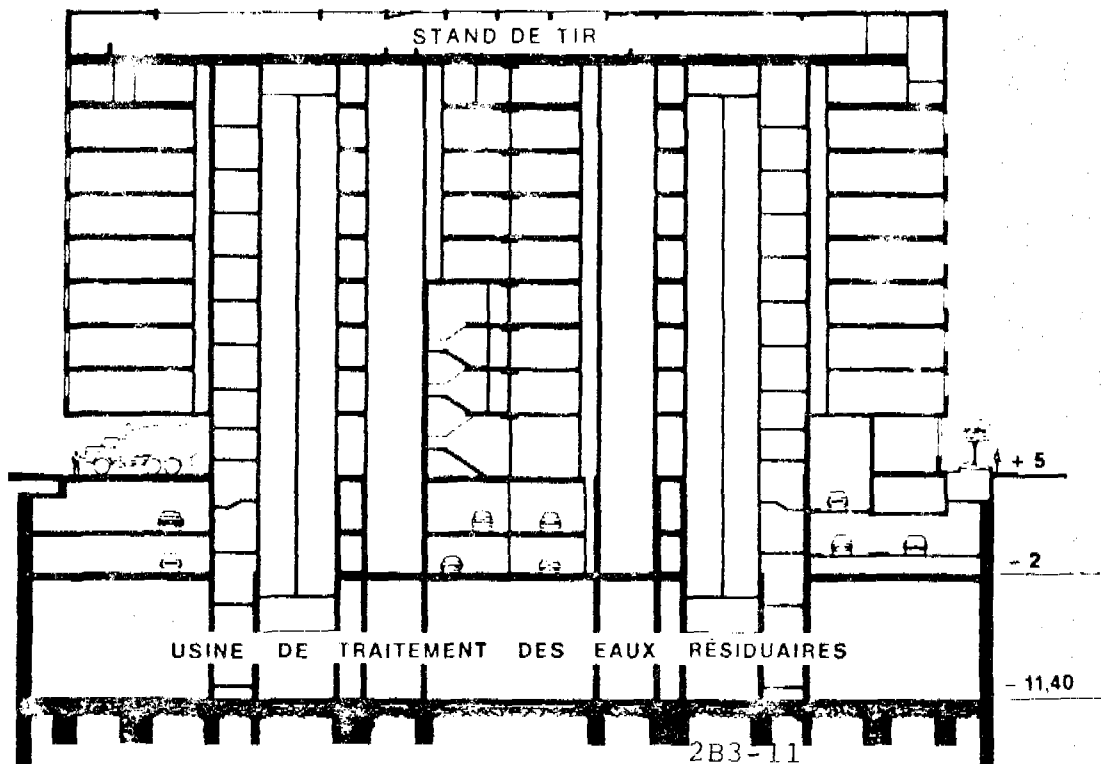
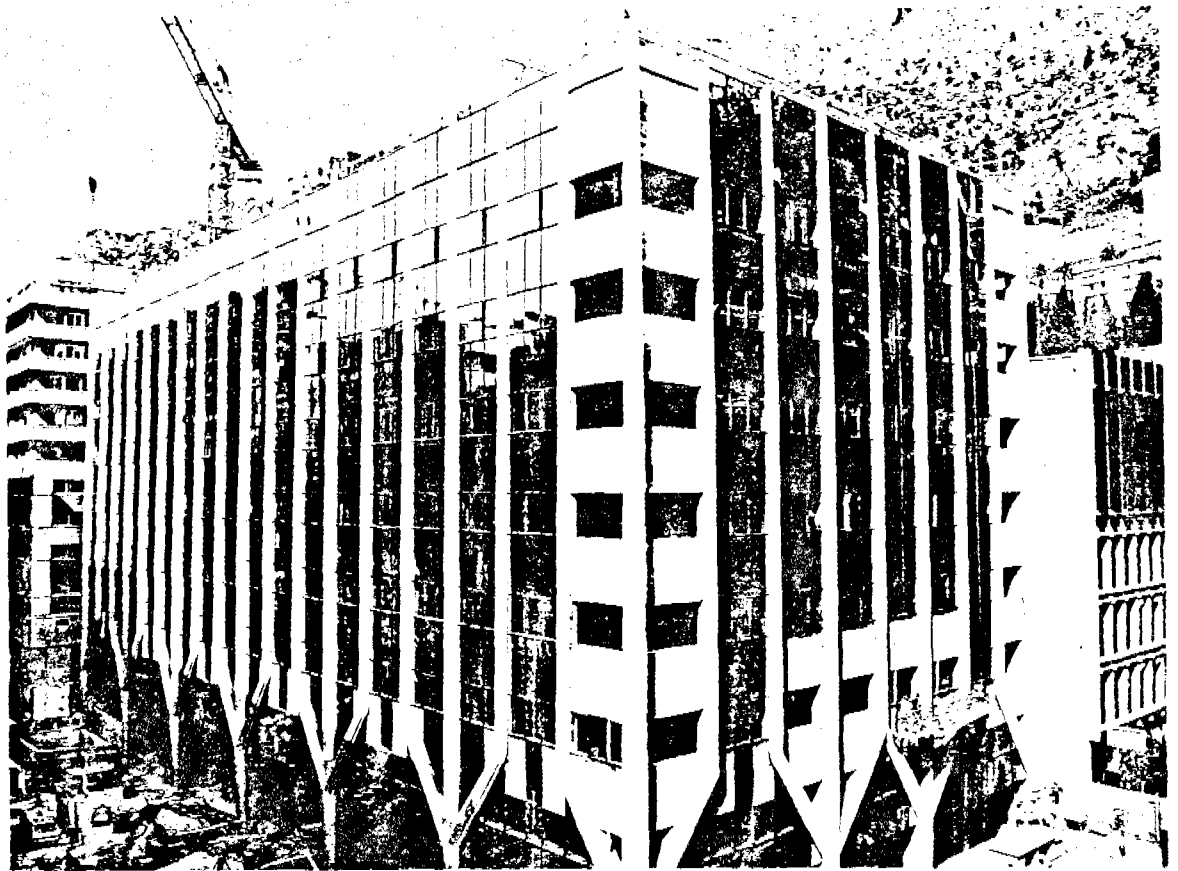
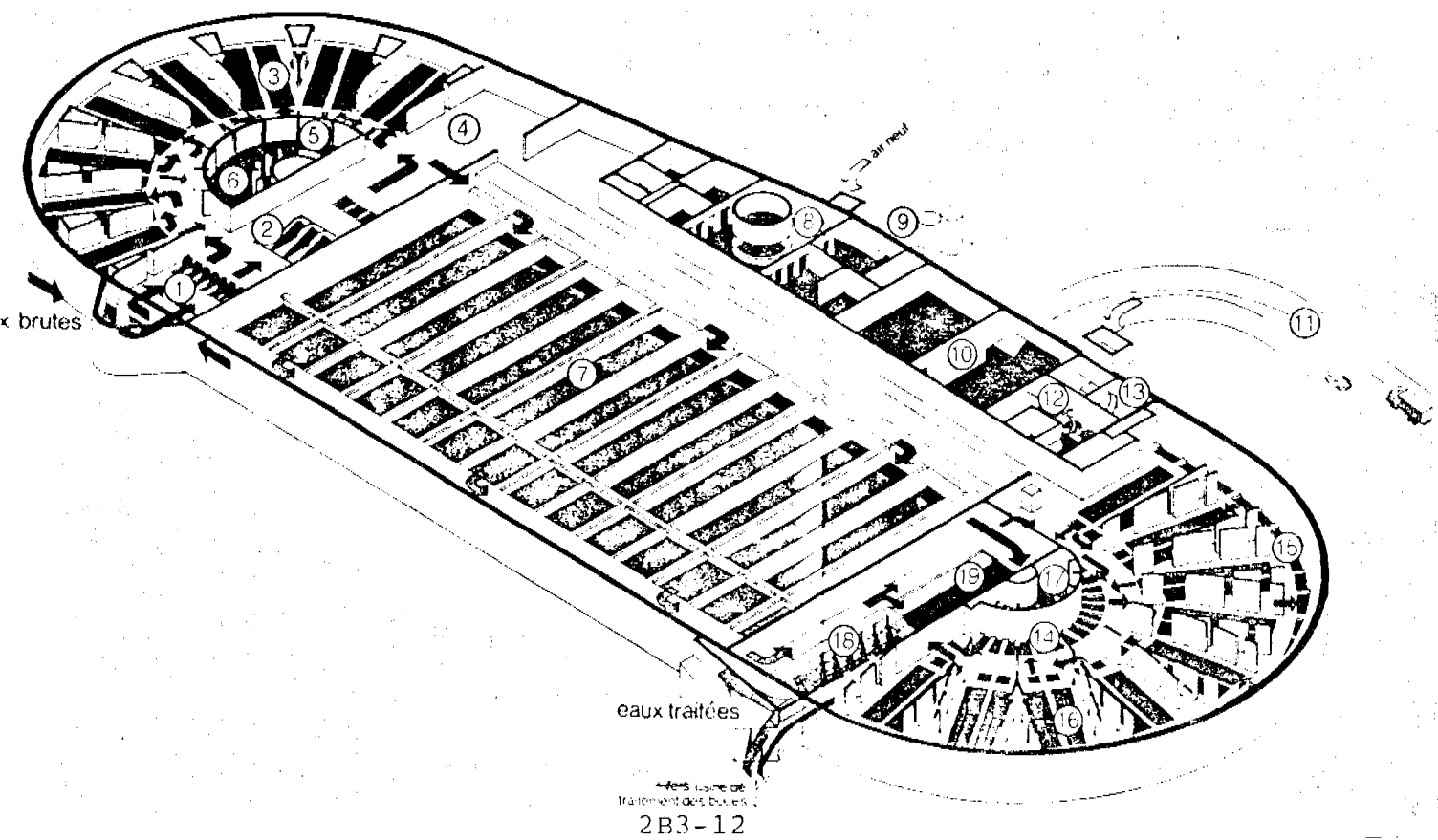
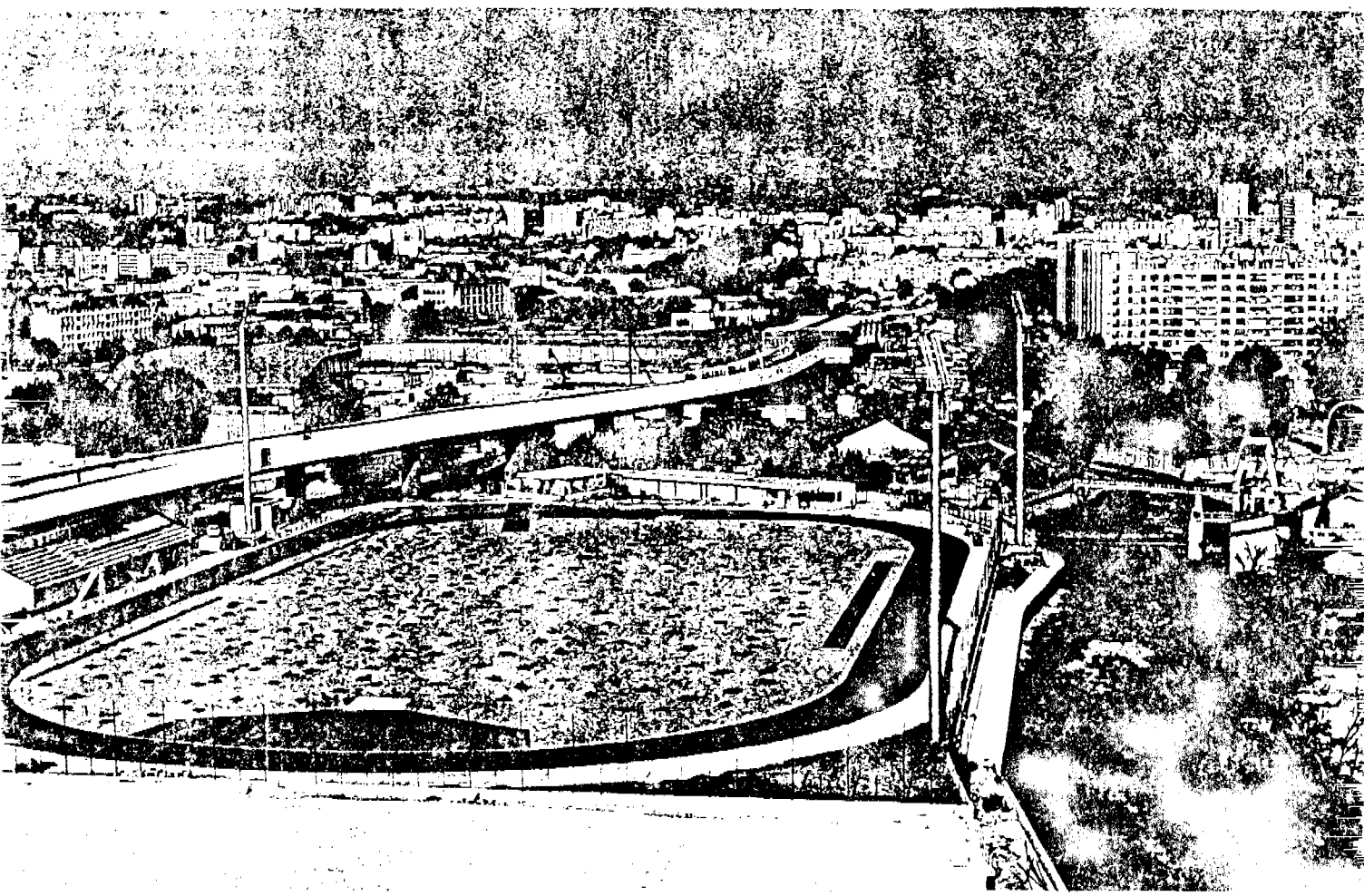


Fig. 5

MARSEILLE

TRAITEMENT EAUX USEES SOUS STADE



TECHNICAL SESSION 1C

PRIVATISATION

Privatisation of the Water Industry

Privatisation of Water Supplies - Malaysian Experience

Privatisation of Water and Wastewater Services

PRIVATISATION OF THE WATER INDUSTRY

Brian R. Thorpe
C.B.E.
Deputy Chairman
Southern Water plc
Great Britain

ABSTRACT: The purpose of this paper is to explore the background, the processes and the results of privatising water, sewerage and sewage disposal services in England and Wales.

INTRODUCTION

The transfer of important sections of the economy from the public to the private sector has been perhaps the most fundamental domestic development of the 1980's and arguably the most impressive cornerstone of the Conservative Government. It is my task to put into context the privatisation of the water industry in England and Wales and in doing so to emphasise that it is only to England and Wales that the arguments are relevant - Scotland and Northern Ireland retain water organisations that are firmly rooted in the public sector. Also important in considering the background is the recognition that when privatisation of the water industry was but a sparkle in the Minister's eye there had already been 14 privatisations (British Petroleum, Cable & Wireless, Amersham International, Associated British Ports, Enterprise Oil, Jaguar, Britoil, British Telecom, British Aerospace, National Freight, National Bus, British Shipbuilders, British Technology Group Holdings, and parts of British Rail) - others such as British Gas were in active preparation. Their very names signify their importance to the British economy, but none deals with commodities and services on which the public is so utterly dependent as water supply and sanitation. In that context the privatisation of the water industry has about it an aura which requires special efforts in the sphere of public relations and in the creation of regulatory mechanisms appropriate to a unique monopoly.

POST 1945

To understand the opportunity for privatisation along the lines actually achieved it is necessary to examine, albeit briefly, the development of the water industry following the Second World War. From 1945 onwards efforts were pursued, with varying degrees of enthusiasm, to reduce the number of bodies responsible for clean and dirty water services. They were overwhelmingly located in the public sector, the responsible bodies being local authorities acting either individually or jointly. Progress was spasmodic, but in 1974 responsibility for water and sewage services was confined to 1,600 elected local authorities and just over 30 water only statutory water companies. River management was in the hands of 29 public River Authorities, their boundaries being based on watersheds rather than local authorities.

1974 - REGIONAL WATER AUTHORITIES

It was in 1974 that the most dramatic development in the history of water based services took place by the creation of 10 Regional Water Authorities charged with the task of managing the water cycle from rainfall

to the sea. Perhaps the biggest single reason for this change was the need for substantial capital investment, particularly in sewage disposal. Local authorities had not found it attractive to spend scarce resources on improving the effluent for the benefit of communities down river, or indeed to improve sea discharges for the improvement of beaches down wind. All that remained outside these 10 Authorities covering England and Wales were the statutory water companies supplying water but not sanitation to almost a quarter of the population.

The new arrangements were never popular because, for a variety of reasons, charges were increased very considerably. Knowledgeable people, however, recognised that the new bodies were infinitely more effective, not least in overcoming water shortages and also in securing a better direction to capital investment. Large authorities with wider responsibilities were able to employ technical, scientific and administrative skills quite beyond the capability of predecessor authorities and gradually it began to show. For the first time there was a management grasp of cost in relation to standards of service. A further improvement was made in 1983 when the size of the Boards was reduced significantly with no provision for elected representatives, thereby introducing a more business orientated approach.

On the reverse side of the coin there was some disquiet that responsibility for pollution prevention did not sit easily with the operation of sewage works, many of which were very substantial polluters. The 'poacher and gamekeeper' role was a source of suspicion and aggravation. Of far greater concern, however, was the practical need to fund improvements to drinking water quality and waste water effluents to meet increasingly tough environmental standards during a period when both Labour and Conservative Governments were seeking to contain public expenditure. The Treasury insisted on higher levels of self-financing but in order to reconcile this requirement with increasingly heavy investment there could be only one result - politically unpopular price increases.

PRIVATISATION

And so the stage was set for politicians to explore the possibility of privatising the water industry. Nobody had assumed it was a natural candidate but it was becoming increasingly obvious that it was worthwhile looking at the chances of success, aided and abetted by one or two leading figures in the Industry who found Treasury control both frustrating and demoralising. Gradually it became apparent that the debate was moving away from 'whether or not' to 'how'. There were those who strove manfully to include all the existing functions, including those of a regulatory nature, in the new companies - others, who proved to be right, saw this as impossible, none clearer than that doyen of the water industry and former Chairman of the National Water Council, Lord Nugent. He said "The privatisation of the 10 Regional Water Authorities complete I do not propose to discuss, because I am sure that nobody will think that is in any way possible. But the paper sees the privatisation of the operational functions of supply and sewage treatment and disposal as being the easiest to arrange. I would agree with that."

That view prevailed and in May 1987 the Government announced that it intended to privatise the water and sewage services only, other functions being the responsibility of a newly created National Rivers Authority.

WATER ACT 1989

And so it was that the Water Act 1989 provided for:-

- (a) the management and operation of water supply and sewage services through the 10 Water Public Limited Companies (PLC's) with the same geographical boundaries as the old Water Authorities;
- (b) the regulation of water quality and environment through the National Rivers Authority (NRA) and the Drinking Water Inspectorate (DWI), and
- (c) the regulation of charges and service standards through the Office of Water Services (OFWAT), known as the Director General's Office.

As a consequence the staff and assets of the 10 water authorities were divided on vesting day, 1st September 1989, between the water and sewage utilities, the PLC's on the one hand and the NRA on the other.

REGULATION

There are therefore three regulatory bodies:-

1. The NRA with a national headquarters and 10 regional offices with boundaries corresponding with those of the Water PLC's. It licences the abstraction of water and regulates the discharge of waste water to rivers, estuaries and the sea. In addition it has operational responsibility for land drainage, flood defence and fisheries.
2. The Drinking water Inspectorate, which is part of the Department of the Environment and whose task is to ensure that drinking water in England and Wales is wholesome and measures up to standards laid down by Government and by the European Commission.
3. The Director General of Water Services regulates charges and service standards by ensuring that the companies perform their statutory functions within a price structure that he agrees. In this area the regulatory mechanisms are more stringent than in previous privatisations recognising that the Act has created not only a private monopoly but a monopoly of unique significance to its customers, the members of the public.

FLOTATION

Privatisations prior to water had involved the flotation on the Stock Market of a single company, water was very different in that it involved the simultaneous flotation of all 10 companies. It is a very real tribute to all ten companies, to the Government and to the advertising campaign that all ten companies were oversubscribed. The size of the companies at the time of their creation can be seen from the following table:-

	No of Customers 000s	Total Turnover £M 1988-89	Capex 1988-89 £M(at 1989 prices)	Expenditure 1990-2000	Manpower
Anglian	1399	401	189	3460	4328
Northumbrian	428	151	56	885	1404
North West	2550	511	206	4280	7100
Severn Trent	2529	544	228	4080	7298
Southern	802	226	111	1330	2790
South West	554	121	78	1290	1712
Thames	2843	612	240	3810	7790
Welsh	978	255	92	1755	3755
Wessex	356	148	95	1275	1639
Yorkshire	1644	355	162	2420	4591
Total	14083	3324	1457	24585	42407
29 SWCos	4688	300	80	1700	6800
Total	18771	3624	1537	26285	54703

Throughout this process the Water Authorities had very firmly taken the position that privatisation was essentially a political matter for Government, but making it work in the interests of customers, shareholders and staff was of cardinal importance and a matter on which the existing operators could and should make a major contribution. The final form of the new companies was, as a result, shaped to a very considerable extent by those who had experience of running the business. As to the success or otherwise of the final result it is possible at this early stage in the life of the new Public Limited Companies to make at least some initial observations and hopefully make judgements which will not be thought premature.

PUBLIC LIMITED COMPANIES

To have moved from the public to the private sector has completely changed the atmosphere of the business and nothing is more appreciated by those working in water than the escape from Government interference and the short-term political antics that go with it. Supplying water to customers and cleaning it up afterwards is essentially a management and operational task which is best suited to the private sector; regulating how that is done by ensuring a proper balance as between customers and shareholders is very properly the province of the public sector. Looking at the situation in that somewhat simplistic way suggests that at least in general principle the outcome of privatisation can be welcomed.

ADVANTAGES

As a consequence the new companies can embark on by far the largest capital programme they have ever planned confident in the knowledge that the capital will be available and that implementation will not be prejudiced by short-term political considerations which result in scarce capital going to health or education instead of water. That has been the great malaise of recent years.

Surely, too, the profit incentive will ensure a continuing concern about costs with increased efficiency reflected in charges to the customer, the companies' share price and in the rewards of those engaged in the business. The public sector strives manfully to measure its performance and to improve its efficiency but without the great motivation of profit which fuels the private sector. As a by-product to this vital difference there is the position of the Trade Unions which tend in England and Wales to exert undue influence in the public sector. One of the results of privatisation has been that a great deal less time needs to be spent talking to Trade Unions without any apparent disadvantage to the employees, in fact rather the reverse.

Finally, there is the positive freedom to diversify, to enlarge and expand the business outside the regulatory mechanism which must apply to the water and sanitation business. The ten companies have proceeded at different speeds and with varying objectives but they are all stimulated by the opportunities and deeply conscious of the effect which success or failure will have on their share price.

AREAS OF CONCERN

Looking at areas of concern rather than benefit, I believe it is fair to say that the new companies have yet to come to terms with their regulators. That each has a role is undeniable but there are worries about methodology, particularly the tendency to explore detail and demand constantly increasing amounts of information. And so to the final and

perhaps most important consideration, namely that of public perception. What do the customers think about the new organisations? I believe that those closest to the business understand the benefits that privatisation has already brought and the even greater prospects for the future, but as for winning the hearts and minds of the public therein lies a great deal of unfinished business. Of all the tasks that lie ahead, that, I believe, is the most important and success can only be achieved if the new companies are, and are seen to be, even more successful than their predecessors in supplying customers with quality water and sanitation services within a price structure which is regarded as reasonable.

PRIVATISATION OF WATER SUPPLIES - MALAYSIAN EXPERIENCE

Ir. V. Subramaniam
Senior Assistant Director
Selangor Water Supply Department
Selangor, Malaysia

ABSTRACT : This paper outlines the progress made so far in the privatisation of water supplies in Malaysia and some of the problems and obstacles experienced. The paper also highlights some approaches, which, in the view of the author, may be adopted for smoother implementation of the privatisation of water supply.

1. INTRODUCTION

The Government of Malaysia introduced the privatisation policy in this country 7 years ago in 1985. This policy is aimed at privatising selected Government owned services and enterprises to the private sector either by complete privatisation or partial privatisation. The Economic Planning Unit of the Prime Minister's Department which is the Government agency responsible for spearheading privatisation also drew up various guidelines on privatisation and identified services and agencies suitable for privatisation for the reference of both the Government agencies and the private sector. Among others, water supply has been identified as

one of such services suitable for privatisation. The guidelines set out the Government's objectives of privatisation, the various forms of privatisation, the identification and selection of candidates for privatisation, specific issues relating to privatisation in this country and the institutional machinery for privatisation. Since then the country's achievement in the implementation of this policy is quite credible. However, there are still many areas which need to be understood more clearly by all the parties concerned and also where improvements can be made in order to strengthen the privatisation programme and to ensure a greater success in the implementation of the privatisation policy.

This paper outlines the progress made so far in the privatisation of water supplies in this country and the extent the policy objectives have been realised along with some of the problems and obstacles experienced. The paper also highlights some approaches, which, in the view of the author, may be adopted for smoother implementation of the privatisation of water supply.

2. OBJECTIVES OF PRIVATISATION

The main objectives as set out in the Government's guidelines are as follows :-

- i) **Relieving the Financial and Administrative Burden of the Government.**

Public water supplies in most developing countries like Malaysia are undertaken by the Government

because it is an essential service. It also involves large capital investments and are quite often uneconomical to operate. However, as countries develop, living standards increase, thereby increasing the per capita demand for adequate and safe water supplies. People also expect higher quality of service. Governments are therefore continually faced with heavy financial and administrative burden to meet this demand. One of the ways to overcome this problem would be to bring in the private sector to play a greater and active role in the ownership, management and financing of public water supplies, i.e. to privatise the water supply services. It would also allow free access to private sector capital markets through equity and joint venture participations for building of new facilities as well as upgrading and improvement of existing facilities.

ii) Promoting Competition, Raising Efficiency and Productivity.

Privatisation would remove the restrictive rules and cumbersome procedures inherent in a Government department which stifles decision making. The removal of formalities and exposure to the competitive forces of the open market would provide the spur towards raising efficiency and productivity. This is true in all sectors including the water

supply sector.

iii) Accelerating the Growth of the Economy.

Increased role of the private sector in development thereby increasing private investment in the economy through privatisation would contribute towards higher growth. The commercial and profit orientation of private enterprises would also mean additional revenue for the Government to finance its development plans.

iv) Reducing the Size of the Public Sector.

The water supply industry in the public sector domain is continually plagued with the problem of staff shortage either in numbers or by way of the necessary trained professionals and skilled workers. This is further aggravated by the Government's policy on the cut-back on staff recruitments over its concern on the increasing size of the Government service. Staff salaries now constitute the single largest expenditure in the Government's budget. Privatising water supplies would not only contribute towards achieving this objective but also allow flexibility in staff recruitment.

3. PRESENT ADMINISTRATIVE AND FINANCIAL ARRANGEMENT OF PUBLIC WATER SUPPLIES

Malaysia comprises thirteen States and two Federal Territories. Constitutionally, water supply is a State Government matter. Each State Government finances the construction of new water supply projects and operates the supplies through either the State Public Works Department or the State Water Departments with the exception of 5 areas where there are Water Boards.

The Water Supplies Branch at the Federal Headquarters of the Public Works Department (PWD) functions as a Federal agency responsible for the planning and design of water supplies and for giving technical guidance and advice to the State PWD's and the State Water Departments. It coordinates all water supply projects funded by the Federal Government by way of Federal loans or grants. Water supply in Federal Territory of Labuan also comes directly under the Federal Headquarters.

Most water supplies are operated on a small deficit and are subsidised by the State Governments. The Federal Government assists the State Governments by way of grants or low interest loans for capital works. Some big projects are also financed by the Asian Development Bank or the World Bank. In recent years, due to budget constraints, the Federal Government has been gradually reducing its financial assistance to the State Governments on development of water supplies and gradually increasing its promotion of privatisa-

tion of the public water supplies.

4. DEVELOPMENTS IN THE PRIVATISATION OF WATER SUPPLIES

Apart from the six or seven forms of privatisation envisaged by the Economic Planning Unit in its guidelines to the Government Agencies and the private sector, all possible forms of privatisation applicable to water supply and their peculiarities as distinct from privatisation of other services have been discussed in several seminars and forums participated by local and foreign professionals. While private sector participation in the water supply industry may eventually cover many areas, privatisation of water supplies in Malaysia at the present moment is mainly confined to the following three forms :-

- i) Management or Service Contracts,
- ii) Build - Operate - Transfer (BOT) Contracts,
- iii) Mixed Management and BOT Contracts.

To-date, the following water supply projects/schemes that have been privatised are of the following forms :-

a) Management or Service Contracts

This form of privatisation involves transfer of the management, operation and maintenance of existing water treatment plants or those newly constructed by the Government to the private sector.

The operation of eight (8) water treatment plants and a ground water abstraction tubewells system has been privatised in this form. The privatisa-

tion of the operation of the 545 MLD Sg.Semenyih water treatment plant in the State of Selangor supplying water to the Klang Valley some six years ago is an example of this form of privatisation. The private company awarded this contract is now entirely responsible for the operation and proper maintenance of the plant. It also bears all the risks involved in the normal operation of the plant including the repair and/or replacement of the facilities. However the contract allows for adjustments due to fluctuation in the price of chemicals and electricity. In return the Government pays the company a fixed rate for the supply of water in bulk during the concession period. The contract also carries a penalty if the company fails to supply water in accordance with the specified quantity and quality. The contract was given for a period of 5 years initially but is currently extended for a further period of 5 years. At the end of the contract period the company has to hand back to the Government the plant in good working condition.

There are also 2 other contracts given solely for the supply of management staff and labour for the operation of water treatment plants. In these cases the Government pays for all the chemicals and electricity consumed as well as for the main-

tenance of the facilities. The Government also bears all the associated risks in the operation and maintenance of these plants.

b) Build - Operate - Transfer (BOT) Contracts

In the BOT form, the private company finances the complete construction, operation and maintenance of the water supply project over a fixed concession period.

Only one project, i.e. the Labuan Water Supply Project has so far been privatised in this form. Under the terms of this privatisation contract the company is fully responsible for the design and financing of the construction of the project as well as the subsequent operation and maintenance of the project over a concession period which is thirteen (13) years inclusive of construction period. Upon completion of the project, the Government purchases water in bulk from the company according to scheduled quantities. The Government pays the company in two parts for the purchase of water. The first part consists of a guaranteed monthly payment to cover the company's investment costs, financing costs and overheads. The second part consists of a variable monthly payment dependent upon the quantity of water delivered. This payment is for the chemicals and electricity consumed and also takes into account

fluctuation in the prices of chemicals and electricity. The contract also carries a penalty for failing to supply water in accordance with the specified quality or the minimum scheduled quantity. At the end of the concession period the company hands over the entire facility to the Government free of charge in good working condition.

A significant feature of the contract is that the company bears all the risks associated with fluctuating construction costs, financing costs, foreign currency exchange rates and technical problems resulting in additional variations or any delays during construction.

c) Mixed Management and BOT Contracts

This form of privatisation is really a combination of the two forms described earlier. In this case the private company takes over the operation of existing water treatment plants and undertakes the financing and construction of new facilities to meet additional water demands over a fixed concession period. Revenue to the company is still through the bulk sale of water to the Government during the concession period.

Three such contracts have been awarded, two in the State of Perak and one in the State of Johore. The concession period for all the three contracts

is twenty (20) years. The price of water changes with the phasing in of the new facilities in the Johore project. In the case of the contracts in Perak, these prices together with the phasing of the works have been fixed at the time of awarding the contracts which means that the company bears the risk of inflation over the 20 years but has the benefit of timing the construction of the new facilities depending on the actual water demand. However in Johore's case, the company is paid the new price for water only when the investment for the construction of the new facilities takes place which also takes into account inflation at that material time.

5. SUCCESS/BENEFITS OF PRIVATISATION

The success of the implementation of the privatisation policy can be judged from the extent of achievement of the objectives set out in the policy. As mentioned earlier, the privatisation main objectives are to raise efficiency and productivity, relieve Government's financial and administrative burden and reduce the size of the public sector.

5.1 Efficiency and Productivity

Despite the limited time and experience in privatisation, it is clear that in all the projects so far privatised, privatisation has led to increased efficiency. For example all the privatised water treatment plants have been operating very efficiently. It is imperative that the private opera-

tors keep their production costs low by cutting down on wastage, improving on treatment process in order to save chemical and electricity and optimising labour so as to maintain profit levels as high as possible since the price of water is fixed. Further, the standard of operation and maintenance of the facilities concerned has vastly improved due to the higher level of staff employed in the plant. There have also been little or no breakdown of the facilities due to the fault of the operators. In the case of the Labuan Water Supply project which included the laying of some 45 km of submarine steel pipeline through swamp and across the sea, the project was completed 6 months ahead of its original schedule of 18 months. The Government and the consumers benefitted by having the crucial additional water supply in Labuan early. The company in turn benefitted from the earlier completion of construction in terms of better returns on its investments.

5.2 Financial and Administrative Burden

Privatising services may not necessarily result in the service being cheaper. Even taking into account increased efficiency and productivity the net effect of a privatised service is usually more expensive than a Government operated one. This is because there are a lot of 'hidden' costs such as insurance and corporate costs which now have to be borne by the private sector. Further, the private sector has to allow for higher financing costs and all the associated risks, taxes and profit. Hence it is a question of whether

these additional costs should be passed on to the consumers, hopefully with higher level of service in return, or it should be borne by the Government. So far in practically all the cases except in the case of Labuan Water Supply Project, the Government has succeeded in relieving itself of the financial burden. In the Labuan case, however, the Government has decided to carry the financial burden and subsidised the Project without increasing the water tariff on the consumer.

In the case of the privatised operation of the water treatment plants, the additional cost of the privatised service is simply passed on to the consumers or it comes out of the Government's revenue from the sale of water. Hence the Government is not burdened further for providing an improved level of service. However the impact of this additional cost on the Government's revenue should be studied carefully in order to avoid the Government still having to ultimately subsidise the privatised services in this case as well.

In all these cases, it is also evident that the Government is relieved of its administrative burden as its role in the privatised projects is confined to that of supervision and regulation which only require minimal manpower.

5.3 Size of Public Sector

Privatisation has overcome the problem of having to recruit additional staff into the Government service to operate and maintain both the new and existing facilities. It has also helped to overcome staff shortages in that existing person-

nel can now be deployed to look after other facilities which are not privatised and which are also expanding.

Generally the level and quality of staff operating the privatised facilities are seen to have improved vastly due to the flexibility in staff recruitment in the private sector. This is important to ensure that the facilities are operating well and supplying good quality water in the long term at minimum cost.

6. PROBLEMS OF PRIVATISATION AND SUGGESTED NEW APPROACHES

Seven years of implementation of privatisation of water supply have brought to light several problems that have to be overcome to ensure a greater success. Some of these problems are summarised as follows :-

a) Economic Viability of Project for Privatisation

There has been a tendency among some Water Supply Authorities to privatise water supply projects for which they have no budget, irrespective whether the project is viable or not. They seem to work on their erroneous assumption that once they privatise these projects, the private sector with its better efficiency will be able to solve their problems including those of financing. This is not always true for everything has its cost. The private sector has to raise funds to execute their project and sometimes the private sector's cost may require the pricing of water sale of the project to be much higher than the current State

water tariff in which case the State may not have the cashflow to pay for the project even on a BOT basis. To avoid inexperienced privatisation operators spending time and money to analyse the situation, it may be better for the Water Authority to assess the economic viability of any project and the State's affordability to pay before deciding to privatise it.

b) Criteria for Invitation of Privatisation Proposals

Two very important criteria that have to be satisfied before any Water Supply Authority embarks on the invitation to the private sector to submit privatisation proposals are :-

- (i) there is an urgent need to implement the project;
- (ii) there is exclusivity provided to the company invited to study and submit proposals.

If these criteria are not met it can result in the private sector wasting a lot of time and money putting up proposals. If a Water Authority has a genuine need to privatise a project it should invite the private sector to apply for prequalification. After prequalification, only one company should be invited to carry out a detailed study and submit a proposal so that the other companies not so well qualified need not be made to spend time and money on the project.

c) Financing of Water Supply Infrastructure

Relatively the local banking circle is still quite inexperienced in providing financing for Government infrastructure projects as compared to international lending agencies like the World Bank and the Asian Development Bank. Because of this lack of experience local banks tend to equate Government infrastructure projects with, for example, housing projects which they have been financing. Government water supply projects are low risk in terms of financing in that the buyer is the Government, the business is a monopoly and the water sale is always on the increase, whereas the housing and other similar development projects is subject to the ups and downs of the market trend resulting in high risk of financing. Yet the current trend among most bankers is to assign the same risks and interest terms to water supply projects as housing and other similar development projects. Further, the financier requires the whole works including pipelines which make up the greater part of the project cost to be insured against all risks. Hence the cost of financing of water supply projects has been unnecessarily increased. A review of the financing policy for water supply projects among local bankers is necessary.

d) Impact of Existing Taxation Laws on Privatisation

The current tax laws does not take into account their effects on privatisation. Under the current tax laws, income from BOT projects are not tax deductible even for the loan repayment component. Also depreciation of assets is also not permitted for tax deduction. Hence BOT projects have to be priced higher to include the 35% corporate tax payable. This tax is invariably passed on to the consumer. The tax laws should be reviewed such that the consumers need not bear the burden of additional taxes upon transfer of management and operation from the Government to the private sector.

7. Conclusion

Privatisation of water supply in Malaysia has been confined mainly to management contracts, BOT contracts and a combination of these two. To a great extent privatisation has been successful in that consumers are able to enjoy a higher level of service without very high increase in cost to them. The Government has also benefitted in being able to keep within limits the size of its staff despite of increase in the number facilities constructed. The Government has also been able to cut down its development budget on water supply.

The next area of privatisation of water supply is the distribution system which so far does not appear to be attrac-

tive to the private sector. Serious thought has to be given to this as the distribution system with its high non-revenue water levels urgently needs the participation of the private sector which is acknowledged to be more efficient.

Even in similar projects which have been successfully privatised there are rooms for improvement and problems to be resolved such as the need to check on the economic viability of the project prior to privatisation, setting the right criteria for the invitation of privatisation proposals, review of financing terms and policies by local bankers and review of the tax laws by the Authorities to encourage privatisation and to lower the cost of the privatised services to the consumers.

23/9/92

PRIVATISATION OF WATER AND WASTEWATER SERVICES

The Need for and the Duties of the Regulatory Authorities

T.A. Rogers
BSc.(Hons.), CEng, FICE, FIWEM, MHKIE, MIWM
Senior Project Manager
Thames Water International Services Ltd
Great Britain

1.0 PRIVATISATIONS IN MALAYSIA

Privatisation of water and waste water services is becoming increasingly attractive to public sector authorities in many parts of the world. In Malaysia the principle of privatisation is well established and there are many more privatisation projects in preparation.

In Malaysia the interest in the privatisation of water services has been much higher than for wastewater or sewerage. This is due to three main factors:-

- i) Water is saleable, sewage, generally, is not.
- ii) Water facilities, dams, pumping stations, water treatment works, distribution systems are established, mature and working. Sewerage and sewage treatment facilities to not exist to the same extent, in fact only 10 to 15% of Malaysia is sewered.
- iii) Water facilities are generally cheaper in terms of cost per capita than sewerage facilities.

Although in England and Wales sewerage and sewage treatment facilities are well established they are currently being extended and upgraded to meet the latest environmental requirements of the UK and European Community.

You will note that reference is made to England and Wales rather than the United Kingdom as arrangements for water and sewerage services in Scotland and Northern Ireland are different as they have not been privatised.

THE ORGANISATION OF THE UK WATER INDUSTRY LEADING TOWARDS PRIVATISATION 1974-89

Before 1974 responsibilities for water and sewerage services had been dispersed between 1,600 elected local authorities, using direct labour to operate the services, and a small number of private water only companies. River management was the responsibility of public river authorities. Other water related functions were carried out by a mixture of local authorities and public bodies. The reorganisation of 1974 transferred all these responsibilities - water supply, sewerage, sewage collection treatment and disposal, river management, pollution control, land drainage, conservation, recreation, navigation and fisheries - to 10 multi-purpose regional authorities whose boundaries related to the main river basins. This approach became known as integrated river basin management.

The form of reorganisation in 1974 was controversial, although both main political parties supported it. A particular concern was the integration of water and sewage operations and their potentially polluting activities, with responsibility for regulating pollution of the water environment. In practice, any conflict was overcome by ensuring that the regional authorities were not allowed to consent their own discharges. They were obliged to seek consents from the Secretary of State. There were also internal processes of discussion and consultation, the involvement of local authority representatives and the need to publish plans and results which helped to ensure that authorities behaved objectively and impartially. However, this "poacher and gamekeeper" role remained for some a source of suspicion and weakness.

More serious was the practical problem of improving the quality of drinking water and wastewater effluents to meet increasingly tough environmental standards during a period when Governments, both Labour and Conservative, were trying very hard to contain public expenditure. For much of the 1970s capital investment in water was reducing, when it should have been increasing. During the early 1980s as this trend began to be reversed, the Treasury insisted on higher levels of self financing and reduced public sector borrowing. Government meanwhile

hovered between encouraging the higher prices this policy required and discouraging "excessive" increases that would be politically unpopular. It became progressively more difficult to reconcile public sector financing with the heavy investment needed to improve the quality of water.

The contradictions and tensions inherent in this situation were becoming intolerable. At the same time, the Government was developing its privatisation philosophy. By the end of 1985 there had already been 14 privatisations (British Petroleum, Cable and Wireless, Associated British Ports, Enterprise Oil, Jaguar, Britoil, British Telecom, British Aerospace, National Freight, National Bus, British Shipbuilders, British Technology Group Holdings, parts of British Rail) with others such as British Gas being planned. The Government's commitment to a general policy of privatisation had not previously included water.

Nevertheless, the Government decided to consider the question of privatising the water authorities and were vigorously supported by some of the authority Chairmen who saw privatisation as the only practicable way of resolving the unsatisfactory financial and operational position outlined above. However, the prospect of privatisation was not then universally popular in the industry and several Chairmen were at that stage opposed.

The initial caution about privatising water authorities and how it might be done was reflected in all the subsequent discussion. The final form of privatisation was very different from the initial proposals presented first in a preliminary consultation paper of April 1985 and then in a White Paper "Privatisation of the Water Authorities in England and Wales", of 5 February 1986. At first several of the authorities were very much opposed to a form of privatisation which broke up the existing structure. However, the Government's new approach, which was confirmed in December 1987 following a period of public consultation, cleared away many of the objections to the form of privatisation. Subsequently, debate concentrated on details of the proposed systems of economic and environmental regulation, although the Labour Party, and some other significant groups continued to object to the whole principle of privatising a utility which was a natural

monopoly and fundamental to public health and amenity.

3.0 RESTRUCTURING AND PRIVATISATION, 1989

The Water Act, 1989, which built on and consolidated to some extent previous water legislation, in the main did four things:

- restructured the 10, public, multi-purpose water authorities into 10 new private water and sewerage only companies;
- provided for the regulation of these and of any other water service companies appointed under the Act;
- established new institutions to regulate the companies and the water environment; and
- amended the law relating to water supply, sewerage and sewage, and the abstraction and pollution of water.

The staff and assets of the 10 water authorities were divided on vesting day, 1 September 1989, into water and sewage utilities on the one hand and the NRA on the other. The staff and assets of the authorities not transferred to the NRA were transferred to the 10 new privatised companies.

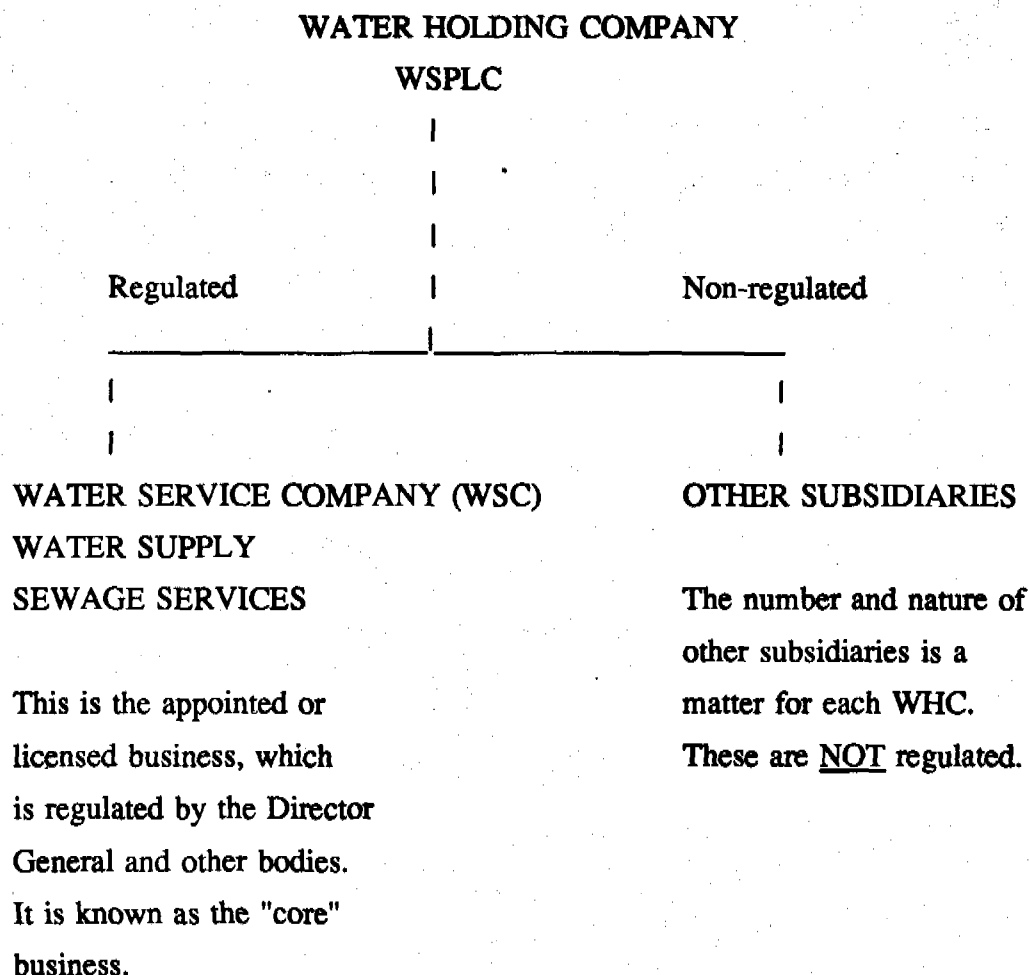
The structure established by the 1989 Water Act consists of three key elements:

- ten Water Holding Companies each with an appointed Water Service Company;
- the National Rivers Authority (NRA);
- the Office of Water Services (OWS) known as the Director-General's Office.

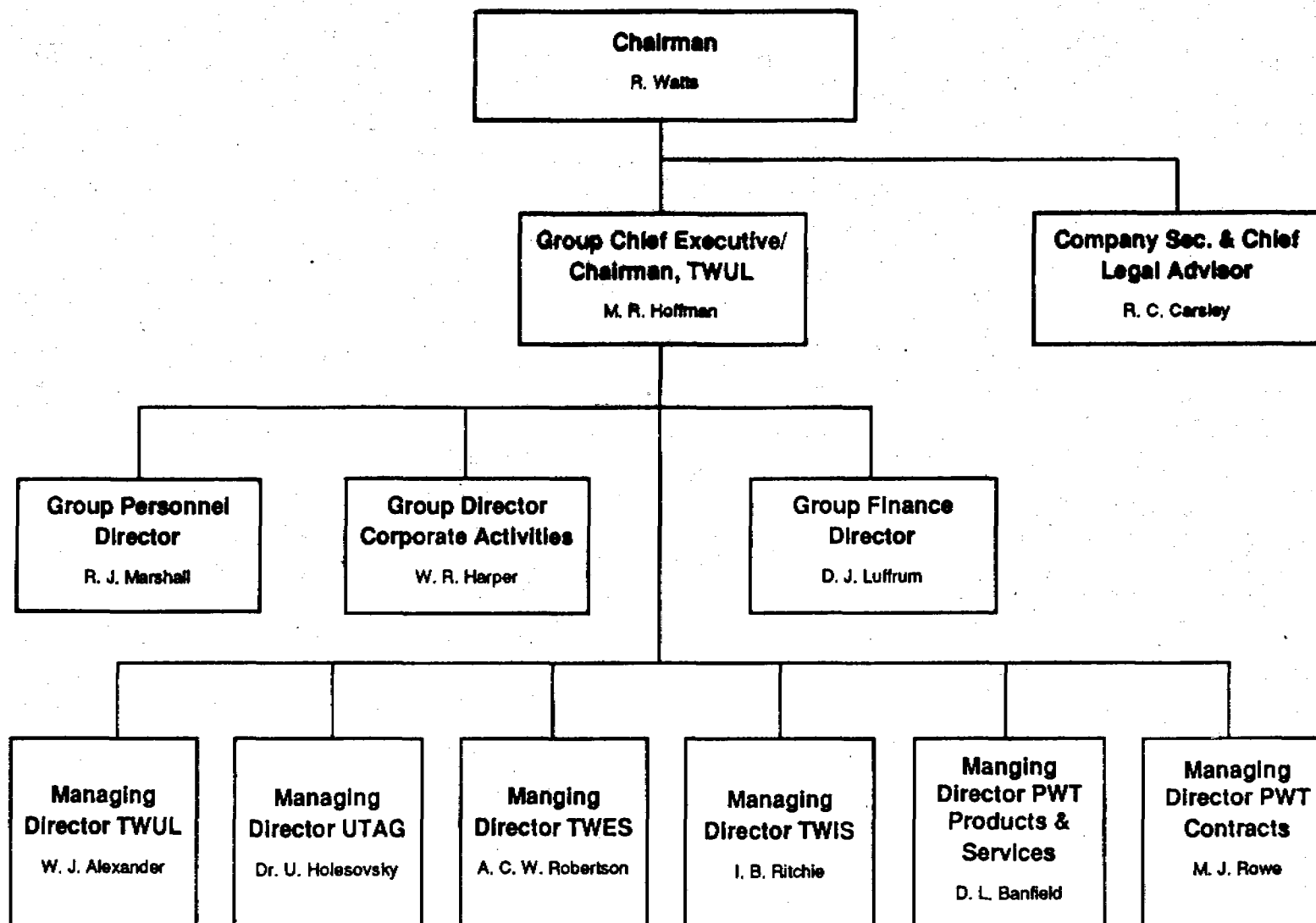
THE PRIVATELY OWNED WATER SERVICE COMPANIES

The ten companies set up by the Act are shown in the map in Annex I. They consist of 10 Water Holding companies - the WSPLCs - each of which has an appointed water business and appointed sewage business. This appointed subsidiary is known as a Water Service Company (WSC). These WSCs, the core businesses, are 'appointed' or 'licensed' by the Secretary of State and regulated by the Director General. They operate within the same geographical areas previously served by the authorities and at present form the bulk of the business for the new WSPLCs. Each WSPLC may have in addition other subsidiaries and each of them at vesting had at least one other subsidiary company. These other subsidiaries are not regulated and are not necessarily connected with water.

The basic organisation of each company is:



Thames Water Plc Group Structure



103-7

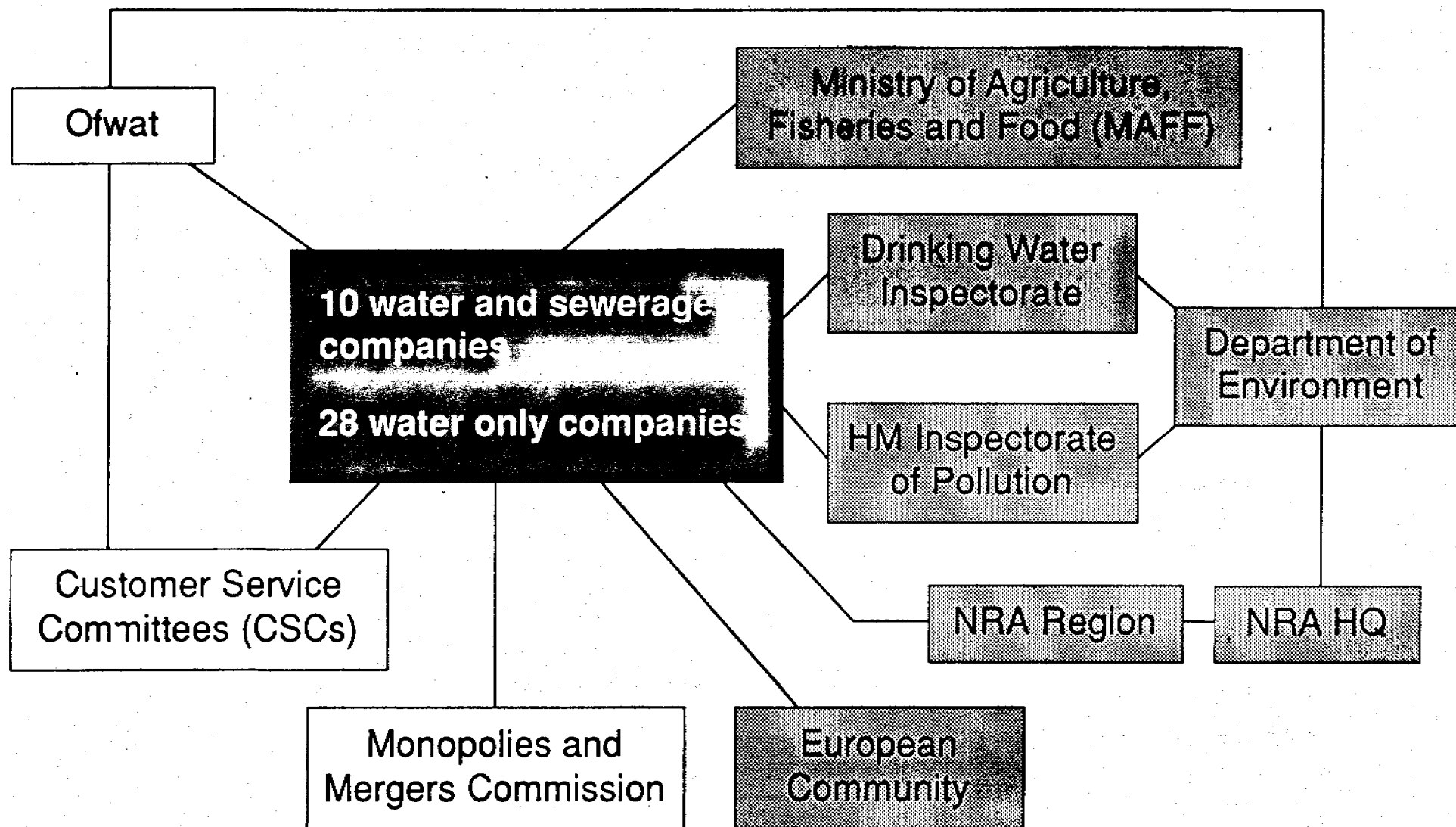
Regulation of the water industry



Quality standards



Customer protection



Governments to place statutory requirements on the water industry and then to refuse the industry the means of financing them. The new financing arrangements, therefore, represent a significant improvement.

THE OFFICE OF WATER SERVICES (OWS) AND THE DIRECTOR GENERAL (DG)

The OWS is headed by a Director General who has about one hundred staff. His job involves:

a) The Regulation of Charges

- protecting the interests of customers by limiting increases in charges and comparing the performance of the 39 different companies to encourage their greater efficiency;
- ensuring that prices fixed by the companies are fair between different classes of customer so that for example, domestic and industrial users pay their fair share.

b) The Regulation of Supply Standards

c) The Regulation of Disposal of Land

d) Administers Customer Services Committees

e) Regulates with Compliance with Appointment Conditions

- monitoring the performance of the companies and seeing that they comply with the conditions under which they are appointed.

Environmental Regulation

Turning to environmental matters, there is no doubt at all that compared with other privatised businesses the water industry faces tighter environmental regulation and many more environmental requirements, in particular from the European Community (EC). Most of these requirements result in non-revenue earning expenditure. Improvements in drinking water quality, or sewage effluent, or bathing waters do not, as such, increase revenue. All of them require heavy expenditure. However, the Bill and the appointment together attempt to deal with these requirements. The new companies can look to the Director General to ensure that they will be able to finance new requirements, and also in the process obtain a reasonable rate of return on their expenditure. For the first time environmental improvement is becoming a profitable activity. Under public ownership, a new EC directive was always bad news for a water authority because it meant new burdens which they were not likely to be able adequately to finance. The new proposals change this fundamentally and should enable the Companies not merely to tolerate, but to welcome, necessary environmental and water quality improvements.

Regarding the environmental work still to do, first there is an historical backlog to make good. It is important not to exaggerate this. The stereotype of crumbling sewers, for example, which was sometimes presented by the critics of privatisation does not match the reality that most sewers have been built since the second world war. Less than a quarter go back to the first years of this century, let alone the last. Nevertheless, the WSCs do have to make good past deficiencies, for example the complete re-sewering of many major cities or the Mersey scheme to treat sewage instead of disposing of it untreated into that river.

Secondly, the Companies have to meet current standards set by the UK Government and the EC. Under investment whilst publicly owned now has to be made good. Thirdly, standards are being tightened all the time as environmental expectations increase. There are new EC Directives in draft which will shortly place new requirements on the Companies. Finally, the WSCs are faced with

6.1

Previously Established

There were also some regulatory bodies which were already established which had direct control on certain aspects of the Water Plc's.

REGULATORY BODIES

SECRETARY OF STATE FOR THE ENVIRONMENT (SoS)(and Sos for Wales)	- Appoints DG and NRA. - Makes initial Water and - Sewage appointments. - Enforcing authority for Water Act, with DG and other bodies.
MONOPOLIES AND MERGERS COMMISSION (MMC)	- Reports on references made by DG (or companies). - Reports on proposed mergers.

The Government introduced a special merger policy for water companies under which any proposal to merge companies with assets of more than £30m (\$50m) is automatically referred to the Monopolies and Mergers Commission (MMC) which is required to consider the impact of the merger on "comparative competition" between the Companies. The presumption in the Water Act is that it is desirable not to reduce the number of water companies under independent control so as not to prejudice the DGs ability to make comparisons between them. If merger is to be approved then either it must not conflict with that principle, or there must be some other benefit which is of substantially greater significance in relation to the public interest. In addition to this general policy, there is a restriction of 15% on individual shareholdings. Company articles oblige Directors to seek disinvestment of shareholdings in excess of this amount; and these articles cannot be changed without the consent of the Government which holds a special share. Both the articles and the special share lapse automatically five years from flotation except in the case of Welsh Water in which the special share, but not the relevant articles, lapses after five years. Despite the protections against predatory

takeovers, the companies ultimately are subject to takeover and each has a strong need to establish in the market its own independent identity.

6.2 Economic Regulation

The WSCs are regional, privately owned monopolies that are very tightly regulated. There is no doubt at all that Government faced head on the problem of privatising such monopolies. The Water Act provides tight regulation for three areas of the business namely:

- water quality;
- service standards;
- charges.

Some idea of the extent of regulation can be obtained from Annex II.

Regulation of charges and standards is the responsibility of the Director General of Water Services. The Water Act gives the Director General two primary duties, namely to ensure:

- that the companies perform their job;
- that they can finance that performance and obtain a reasonable return on capital.

These are reinforced in the appointment by means of the mechanism known as 'cost pass through'. This is the passing through into charges of the costs of new environmental or other obligations imposed upon the companies. Both these financial safeguards are stronger than the financial provisions of the previous nationalisation statutes which were so vague that they enabled successive

dynamic change and rising expectations. As technology, tastes and personal standards change, they have to adapt their processes to those changes. People are no longer prepared to put up with unsatisfactory drinking water. They want to replace short sea outfalls with proper marine treatment so as to enjoy good bathing waters. Everyone wants to use shampoos, detergents, herbicides and pesticides to make easier domestic and garden chores. Farmers wish to produce more intensively and this means the use of chemicals and factory farming methods.

All these changes require changes in clean water treatment and sewage treatment. The regulatory and financing provisions of the new, privatised, statutory framework recognise these requirements not only by regulating the Companies, but also by providing the means whereby they can profitably finance the necessary improvements.

THE NATIONAL RIVERS AUTHORITY (NRA)

The NRA is a non departmental public body to which the river basin regulatory functions of the ten authorities were transferred. A total of 6,500 former authority staff were vested in the new body which is responsible for the functions shown below:

	Land drainage Flood defence	Pollution control
Conservation Amenity Recreation Navigation	NRA	
	Fisheries	Water resources

The NRA licences the abstraction of water, independently monitors river quality and consents discharges to river, including discharges from waste water treatment plants. The main impact of the NRA on the privatised water companies is:

- in regulating the abstraction of water from rivers;
- in regulating discharges of waste water to rivers, estuaries and the sea (bathing waters).

As well as regulating the water companies, the NRA regulates all other water users including industry and agriculture.

ENVIRONMENTAL REGULATORY BODIES

- | | | |
|--|---|---|
| HER MAJESTY'S INSPECTORATE
OF POLLUTION (HMIP) | - | Regulates dangerous
substances. |
| | - | Disposal of sewage sludge to
land. |
| MINISTRY OF AGRICULTURE
FISHERIES AND FOOD (MAFF) | - | Licences disposal of sewage
to sea and agricultural land. |
| | - | Designates nitrate protection
zones. |
| DRINKING WATER INSPECTORATE | - | A new inspectorate in DoE. |
| LOCAL AUTHORITIES | - | Regulation of wholesomeness
of drinking water. |
| | - | Licence disposal of sewage
sludge to landfill. |
| EUROPEAN COMMUNITY (EC) | - | Currently Directives on
drinking water, surface waters
and bathing waters. |

The above are specific to water. In addition, the Companies will be subject to other legislation that affects all Companies except any that are specifically amended by the Water Act.

CONCLUSIONS

The fact is that whether water companies are privatised or nationalised there are some inescapable requirements:

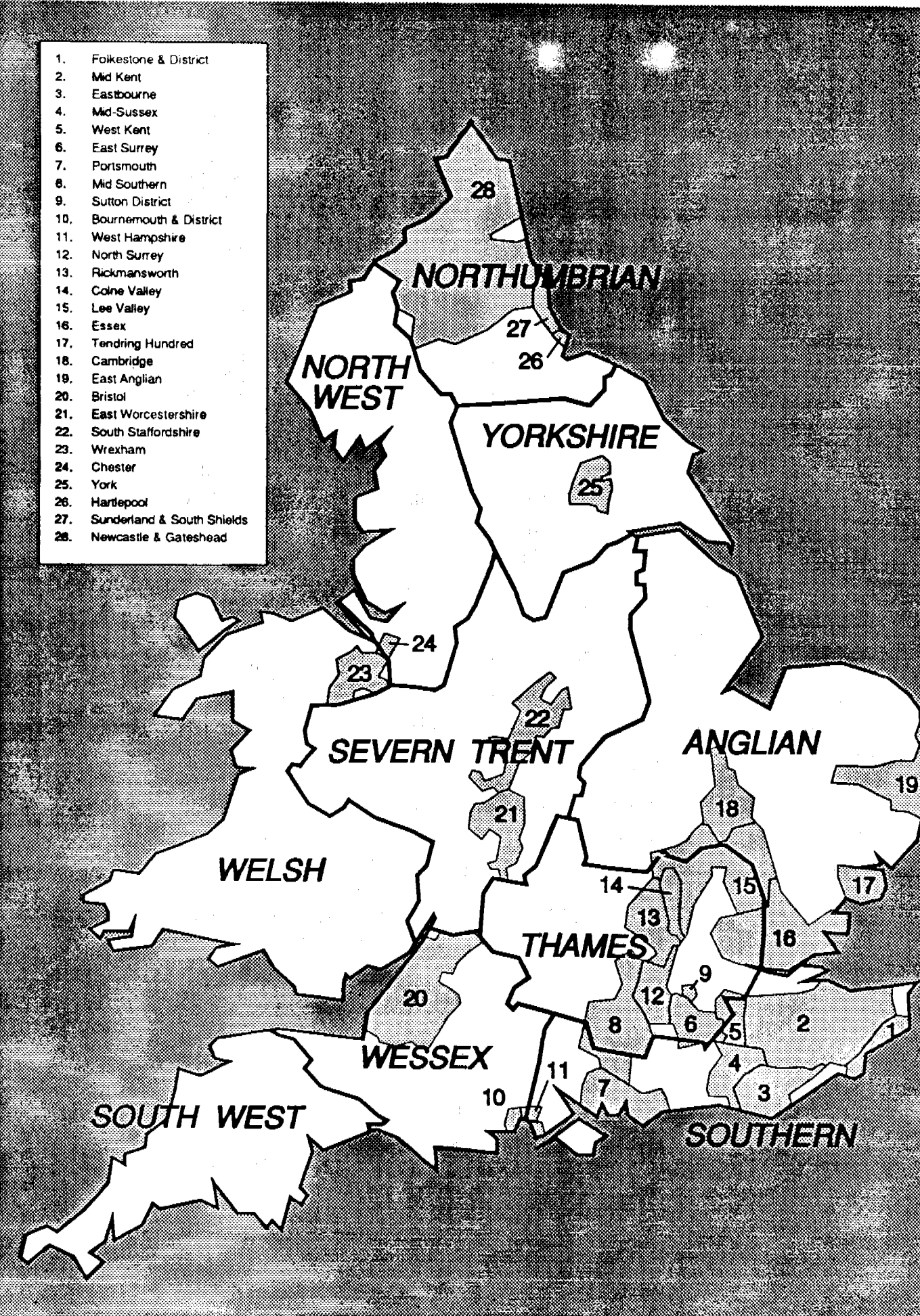
- water suppliers have a monopoly and have to be regulated;
- water services have to be provided safely, efficiently, economically and profitably;
- water quality has to be improved further to meet the higher standards now required by the UK Government, the EC and the general public;
- higher standards will require higher expenditure and this has to be financed by higher charges;
- new methods of charging will have to be found to replace rateable value which can no longer be used as a basis for charges after 2000.

A monopoly supplier has to be regulated to prevent abuse either by its Government owners or its shareholders. The public's health demands clean drinking water and effective and safe sewage disposal. The public's purse also demands that these requirements are met as economically as possible. Public water authorities or private water companies have to be profitable in order to pay interest on loans, meet rates of return set by Government or dividends to shareholders. The achievement of high standards does not depend on ownership. Successive Governments, reflecting both the requirements of the UK voters and the EC, have demanded higher standards of water quality, but have not so readily agreed the means of financing them. Current standards of drinking water are high and most of them meet EC requirements, but some supplies do not meet all the "parameters" of the EC Directive - in particular aesthetic requirements such as appearance and colour of drinking water. The UK shares also the difficulties experienced by other EC countries in meeting everywhere other standards, for

example, for nitrates and pesticides.

Higher standards require higher expenditure and large work programmes, but the nationalised authorities had reached Treasury limits of financial tolerance. There seemed little prospect of financing within the public sector the large programmes of improvement now required. Treasury was not keen to increase public borrowing limits; and Ministers were always nervous of increasing prices, whatever Government or EC quality standards might require. This classic public sector dilemma had not been resolved during the previous 40 years and showed no signs of being resolved in future. If higher standards are required, then they have to be financed. Public or private, the money is needed and has to be found. In the end, the only realistic source is the customer; not unreasonably, since it is the customer in the main who benefits.

The Water Service Plc's & Water Companies of England & Wales



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TECHNICAL SESSION 2C

PRIVATISATION

Privatised Water - Organisation, Regulation and Funding

**Involvement of the Private Company in Water Supply
The New Development Era in Indonesia**

**The Impact of The Private Development of Water Systems in
Urban Areas of Mindanao**

PRIVATISED WATER - ORGANISATION, REGULATION AND FUNDING

J. Jeffery
North Surrey Water Limited
Middlesex, Great Britain

ABSTRACT: In many parts of the world, increasing interest is being shown in the possibilities of private sector involvement in the water industry. The paper describes some of the methods through which this can be approached, controlled and funded. It is illustrated by examples from England and Wales showing how the system of control of price increases introduced by the Water Act 1989 was applied, and gives some evidence of the regulatory problems, and how they were and are being tackled.

It also outlines the ways in which the private sector works with municipalities in the provision of water services in France, usually through either concession or affermage contracts. In both cases, prices are controlled, but unlike the system in England and Wales, whether funded by municipality or contractor, the assets ultimately are owned by the municipality.

Consideration is also given to ways in which funding of capital expenditure in Eastern Europe may be approached.

Moves towards greater private sector involvement in the state of New South Wales in Australia are also mentioned.

INTRODUCTION

The provision of water services is organised in many different ways throughout the world. In the UK, for centuries there have been both public and private sector bodies involved in water supply, and there continue to be important differences between the water industries in England and Wales, Scotland and Northern Ireland. Where private companies had responsibility for water supply in the past, they were regulated through controls on dividends and reserves. The Water Act 1989 completely changed the organisation of water services in England and Wales. Under it licenses were issued to private companies to provide water services under a system of regulation based on defined levels of service, environmental regulation through the National Rivers Authority and the Drinking Water Inspectorate, and economic regulation based on limitation of price increases, administered through the Office of Water Services, OFWAT. A detailed description of the arrangements was given by Carney¹ (1991).

Organisation of water pre-privatisation

Since the second world war, several major pieces of legislation concerning water have been introduced in England and Wales. The 1945 Water Act set out many of the principles to which we still work in water supply, and this was followed by several Acts aimed at the control of pollution and of water resources. For example, the River Boards Act of 1948 created 32 River Boards covering the whole of England and Wales except the Thames and Lee catchments. These River Boards took responsibility for land drainage, fisheries and control of river pollution. In 1963, the Water Resources Act replaced the Boards by setting up 27 river authorities, with new functions in the field of water resources, as well as the existing functions of the Rivers Boards. These new functions were also applied to the River Thames and the Lee Conservancy Catchment Boards. Each river authority was required to assess the water resources of its area in terms of existing and future demands for water, as well as formulating proposals for new works, including the possible transfer of resources to another river authority area. From July 1965, abstractions of water were generally required to be licensed by the river authority, and existing discharge consent provisions were extended to discharges into the underground strata.

By the time of the Water Act 1973, the water cycle in England and Wales was administered by 29 river authorities, plus about 200 water supply undertakings, with several hundred municipalities responsible for sewage disposal. Most of the water supply undertakings were based on municipalities, but 29 were statutory companies, together responsible for about a quarter of the water supply, and regulated essentially by control of profits. The Water Act 1973 brought together all of these organisations, except the 29 statutory water companies, into 10 regional water authorities. Each of these regional water authorities was made responsible for the whole of the water cycle, introducing the concept of integrated river basin management which was central to the approach of the Act. As the 29 statutory water companies also had statutory obligations for water supply within the areas of the regional water authorities, there was created a dual responsibility, which might have been a recipe for disaster, but which in fact, created few problems.

Privatisation - the regulatory framework

The 10 regional water authorities operated within a set of financial controls fixed by government. These included annual limits on the money which the authorities could borrow from government, known as the external financing limit, or EFL. During the 1980s, these EFLs tended gradually to be reduced, while at the same time, the government was increasing the rate of return which the authorities were required to produce on the current cost valuation of their assets. Both of these factors tended to increase the degree of self financing, and the charges of the authorities. Arguments began to be put forward that charges were having to increase faster than was justified economically because of this trend to financing capital expenditure from revenue, and through a rate of return being set which was higher than would be required of a commercial company. As a result, there was a debate in the House of Commons on the financial targets being set for the regional water authorities, and in responding to this debate, the Minister said that the government would "look at a measure of privatisation of the water industry".

In February 1986, the government published a White Paper which proposed the conversion of the existing 10 regional water authorities into 10 water services public limited companies, with essentially the same powers and responsibilities as the authorities. These proposals were welcomed by the leaders of the water authorities, but the fact that the proposals meant giving legal powers and regulatory functions to public limited companies, some of which could be exercised over other public limited companies, generated opposition from a wide range of interested groups. As a result, in July 1986, the government announced that it was reconsidering its policy, and in July 1987, proposals for a public sector environmental regulatory body in a privatised water industry were published. Under them, the environmental regulatory functions of the regional water authorities would be transferred to a new public body, to be called the National Rivers Authority, leaving the water authorities to be privatised with responsibility only for the operational functions of water supply and sewage disposal.

In considering the economic regulation to be applied to the new privatised water industry, the government made an early decision to reject the statutory water company approach based on control of profits, in favour of the alternative based on control of prices. The method which was adopted links price increases by the water companies to the retail price index (RPI) through a factor known originally as RPI-X. "X" represented an amount by which price increases would be below RPI, to be made possible by the efficiency gains assumed to arise from the pressures of operating in the private sector. Gradually it was realised that the capital intensive nature of the water industry and the long planning horizons, meant that a water plc might choose to delay capital expenditure in order to make profits under a simple system of price increase controls. In other words, while economists would argue that regulation based on profit control could lead to over investment, (so-called "gold plating"), regulation based on price control could lead to under investment. So a complex regulatory framework has evolved based on defined levels of service to be provided by the water companies, accompanied by approval of the long term capital expenditure plans of each company to meet those levels of service, leading to price increase limits being set which allow for the funding of those capital programmes. This process has resulted in a recognition that water charges would generally have to rise faster than inflation for a considerable period and the charges control factor has become known as $RPI+k$ where 'k' is the percentage above RPI by which each company is allowed to increase its prices, year on year.

Eventually, formal charges increase limits for the 10 newly privatised companies and the 29 existing companies were set for each of 10 years, and another new regulatory body, the Office of Water Services (OFWAT), was established to administer the economic regulation of the companies.

However, while those negotiations were taking place, the government and the industry was having to cope with a much increased public awareness of water quality. The EC Drinking Water Directive came into force in the UK in 1985, but differences in interpretation soon appeared. Many of the limits in the directive are based on the well established recommendations of the World Health Organisation, but whereas the values quoted in the World Health Organisation guidelines are generally based on lifetime exposure, those same values often appear in the directive as "maximum admissible

concentrations", which is clearly a very different concept. The Department of the Environment attempted a sensible interpretation of the directive, based on average concentrations, but at the end of 1987 the Department withdrew this interpretation of compliance, and accepted that the directive limits applied to individual samples. This had obvious implications for the capital expenditure plans of the industry, which the industry at that time was beginning to work out as part of the process leading to the setting of limits on price increases. It is part of the reason for increases in water charges commonly being set to rise above the rate of inflation for some years to come.

Then, as part of the privatisation process, the government put in place water quality regulations, which embodied the provisions of the EC Drinking Water Directive. These regulations gave legal force to limits for over 60 determinands, some aesthetic, some with public health significance. They also defined the sampling approach to be adopted by water companies in demonstrating compliance with the regulations. Companies were also required to provide public access to a water quality register.

The government recognised a need for a further regulator to be appointed, to be responsible for monitoring the compliance performance of companies, and set up the Drinking Water Inspectorate. The first report of the Chief Inspector covered 1990, and was published in mid 1991. It showed companies achieving a high degree of compliance, but made one or two general criticisms. One of these was on the need for most companies to improve their analytical quality control procedures, and this subject has received a great deal of attention as a result. Another common problem identified in the report was the quality deterioration commonly occurring within distribution systems. In this area also, criticisms in the report are leading to action.

The existence of the Drinking Water Inspectorate has undoubtedly had a considerable impact on the attitudes of the industry to water quality, and the strict but fair policies being adopted give it a high degree of credibility all round.

In the 'k' setting discussions between the companies and the government, there was another factor which had to be considered. This was the problem of recognising the responsibility of the companies to make financial provision for solutions to problems where the methods of solving the problems were not clear, and therefore, not costed. An example of such problems was, and remains, compliance with the EC limit for pesticides. This limit is $0.1\mu\text{g}/\text{litre}$ for individual pesticides and $0.5\mu\text{g}/\text{litre}$ for total pesticides, and by the late eighties, herbicides such as atrazine and simazine were frequently being found in drinking water at concentrations above $0.1\mu\text{g}/\text{litre}$. Medical and toxicological evidence defines safe limits for these substances which are considerably higher than the general limit for all pesticides in the EC Directive. However, the legal limit is $0.1\mu\text{g}/\text{litre}$, so arrangements were made between the government and a number of companies, under which companies gave legally binding undertakings to the government to investigate treatment methods, and introduce appropriate processes to enable compliance by an agreed date.

As in many cases, the costs of this work could not be properly estimated, the work became a 'notified item'. This meant that the requirement for the

work had been recognised, and the need for an increase in the company's 'k' had been agreed. The amount of the increase would have to be agreed by OFWAT at the time that the programme of work was decided.

The main principles of the method of regulation adopted were that companies should have the ability to generate profits as an incentive to efficiency, while at the same time having their capital requirements recognised by 'k' setting. Customers were to benefit through having defined levels of service, and would be protected against abuse of the monopoly powers of the companies by regulatory bodies which also were given the responsibility of monitoring the performance of companies in achieving the levels of service defined by the regulations.

In most respects, the system is working well. The real cost of water will rise substantially by the end of the century, but so will the standards of service, and the level of information about the service provided. The capital investment programmes of the companies are vast. For the industry as a whole in England and Wales, they total approaching £30 billion over 10 years, and there is no doubt that the benefits of this increased expenditure will be seen by customers for many years to come.

There is also a new atmosphere of challenge and excitement in the industry, to which the involvement of several French companies is contributing. For example, Compagnie Générale des Eaux operates in Britain through General Utilities plc, which holds stock in several English water companies, including control of Three Valleys plc, Folkestone and District Water Company, Tendring Hundred Waterworks Company, and North Surrey Water Limited. A club known as General Utilities Scientific and Technical Organisation (GUSTO) has been formed, to which subsidiary and affiliated companies in Britain and France may belong. It provides a forum for technical exchange and the formulation of joint research projects, and already it has made co-operation possible on a number of interesting topics, including pesticides and mains rehabilitation.

Other privatisation models

In France, the private sector has had a strong involvement in the water industry for very many years. Compagnie Générale des Eaux was formed in 1853, and other companies in this field include Lyonnais des Eaux and Saur. However, the system in France is completely different from that adopted in England and Wales under the Water Act 1989.

The French approach leaves the primary responsibility for water services with the Mayor of the local municipality. The municipality may decide to provide water services directly, or may opt to contract out all or part of the operation to a private company. The private companies may do everything, including providing finance for capital expenditure, designing and constructing works, and operating those works. In such cases, the contract between the company and the municipality might be for 25 to 30 years, to allow a proper amortisation of the capital. At the other extreme, the company may provide only a limited service, such as meter reading, and in between, there could be an almost infinite variety of contracts, each suiting the particular needs of the municipality, with prices agreed through local negotiations. The 3 obvious differences between this approach and water privatisation in England and Wales are -

- (i) in France, the municipalities own the capital assets, whereas in England and Wales, the licence holding companies own the assets.
- (ii) the opportunities for competition between companies are greater under the French system.
- (iii) price limits are set by a national body for English and Welsh companies, and agreed locally in France, by elected representatives.

Government and public bodies in many other parts of the world have in recent years decided to look at the possibilities of private sector involvement in provision of services. The reasons are primarily the increasing costs of funding infrastructure developments and services, but occasionally they include labour relations problems. Such decisions are not being taken only where political control rests with parties from one side of politics. For example, the Labour-controlled local authority in Liverpool decided in the summer of 1991 to contract out its waste collection function.

The political changes in Eastern Europe are also leading to an examination of ways in which private sector capital may be attracted in order to help overcome some of the infrastructure and pollution problems which exist. Funding agencies such as the World Bank clearly have a role, but there are also ideas being explored based on companies being given commercial opportunities in return for the provision of public services. In such a case, a municipality may obtain water or waste collection services from a private company at low cost. In return, the private company could, for example, be granted a long, low-cost lease on a site, with permission to develop an hotel and conference centre, the profits from which will cover the shortfall in costs of providing the water, or other public service. Imaginative approaches such as this could play a part in rehabilitating economies which are in serious difficulties.

Another part of the world where private sector involvement in provision of services traditionally in the public sector is being investigated is Australia. Several schemes are being opened to private sector funding and operation, including the Sydney Harbour Tunnel, and water treatment projects for Sydney Water Board which are being considered as Build/Own/Operate/Transfer (BOOT) contracts.

These water treatment schemes involve large capital expenditure, and have required the creation of tendering consortia covering financing, engineering, consultancy and contracting, and operating resources. Complex international relationships are being developed, because the possibilities at Sydney have attracted the interest of water companies in England and France, as well as financial organisations and engineering firms in several parts of the world. It will be interesting to observe the outcome of the Sydney contracts, and of other changes taking place in Australia, such as the possible corporatisation of Hunter Water Board in New South Wales.

CONCLUSION

All of these moves to increase private sector involvement in water have been, and will continue to be, opposed by many people who sincerely see water as a natural monopoly which should be kept in public hands.

Perhaps the distinction which needs to be made is that made by Nicholas Ridley, British Secretary of State for the Environment at the time of the Water Act 1989. He separated operation from regulation, arguing that the private sector was better at operating services than governments, and that the proper job of government is regulation. John Winward² (1991), of The British Consumers Association has made a similar point, saying "Consumer organisations have always been sceptical of the weight put on ownership, preferring to draw attention to the relative balance of power between producers and consumers, which itself is much more a reflection of market structures, contractual relationships and redress mechanisms".

Regulation may be applied nationally to licenced companies owning water assets, as in England and Wales, or locally, through various forms of contracting out, as in many non-water local authority services in Britain, and in water services in France.

Provided the regulation is effective, it may be argued that public control of the natural water monopoly remains satisfactorily in place.

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INVOLVEMENT OF THE PRIVATE COMPANY IN WATER SUPPLY, THE NEW DEVELOPMENT ERA IN INDONESIA

Priyono Salim
Department of Public Works
Jakarta, Indonesia

ABSTRACT : This paper is concerned with the development of water supply spesifically by mean of participation of Private Sector and Investor in Indonesia.

Over the last twenty years of experiencing on water supply development, Indonesia has reached to a signifikan level to fullfill basic human need on water supply. How ever since the requirement are remain high, among other is because of the result of the development itself, in addition Indonesia already enter into Industrial era, where consequently the water consumption becoming higher. There fore the conventional approach of the development, need to be innovated.

One among potential resources with has not been fully explored for development, is the private sector participation. The Government already launches this concept which were positively responded by the private sectors and investors. Therefore the Government offers to share this responsibilities and benefits with the partner in development, private sectors, to this promising bussines.

1. INTRODUCTION.

1.1. Indonesia, the country and it's Population.

Indonesia is a country of contrasts. Physically, its an archipelago of large and small islands which stretches for 3000 km from East to West along the Equator.

Culturally, it is a rich mixture of people which gives it a unique blend of old world charm and modern day mystique. Economically, it has the potential to feed, cloth and house its 180 million inhabitants. As happened in most developing countries, Indonesia has limited resources to develop its assets of oil, natural gas, minerals, timber, coal etc. which are widely located from processing centres and from the markets. Transportation costs present one set of inhibiting factors to the development of the country. However, this diversity in people, places and things is also its greatest strength.

Since Independence in 1945, the population has grown from 110 million in 1960 to its 1991 size of app. 180 million inhabitants. 60% or (+/- 80 million) live on the island of Java. The larger island of Sumatra has another 25 % (equal to 45

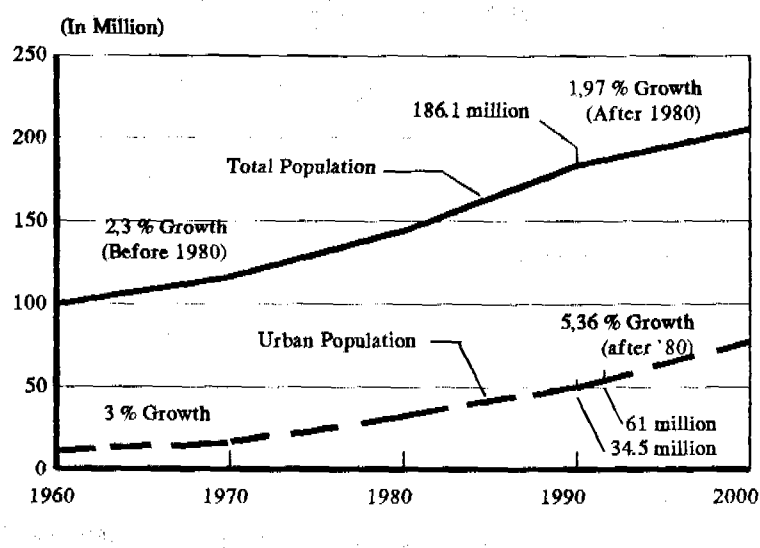


Figure 1

Trends of Population Growth (1961 - 2000)

*) Shows, that due to urbanization, higher growth occurs in the urban areas.

*) Higher supply standard were required ---> more investment needed.

million), The remainder live in many of the other 3000 inhabited islands.

The uneven distribution of population, the disparity of income and the relatively large unskilled population presents serious challenges to the Government in terms of economic development, housing provision, social services and a decent standard of living.

Roughly 55 million live in over 800 urban centres. This situation causes enormous problems in the provision of water supply.

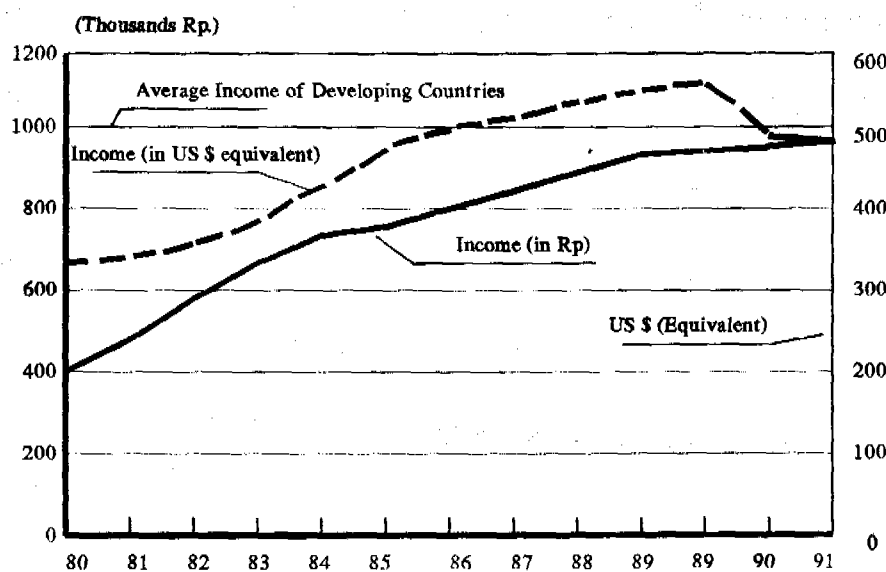


Figure 2

Per Capita Income (1980 - 1991)

Shows the stable economic growth; an asset for future development.

In addition, rural-urban migration presents one of the most serious problems facing any developing country, including Indonesia. Densities have reached over 500 persons per hectare in some large and medium sized cities. Local governments are then faced with a rising demand for services and, for many reasons, are unable to provide them.

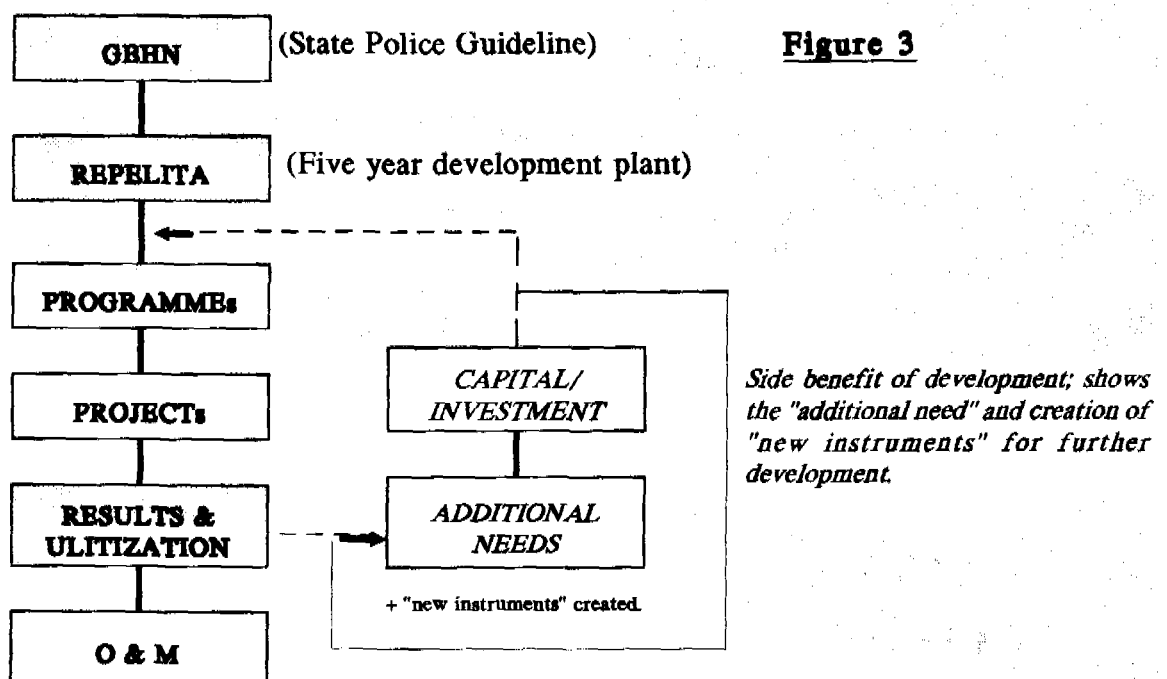
1.2. Development Objectives & Approaches.

The development objectives of the Government is to achieve the equal prosperity for the people, in all over the country; the goal was planned to construct in phases.

Indonesia is now entering into the 3rd year of PELITA V (five year development plan); in which the Government by all effort, mobilized the resources in order to achieve the target. The program was part of the long term planning covering 25 years, which are devided into 5(five) of "five year plan"; which again breaks into yearly planning of development.

This plan contains statements that ensure goals are made specific in the development objecties.

Figure 3 shows the general steps andcycle of the development.



Beside to provides the basic necessity for human life, the water supply has considered as one of the very strategic sector which is enable to stimulate the growth of the other economic sector, such as tourism, industry, commerce, ect.

1.3. Phisical objectives....to fill the gap.....

The objectives are intended to achieve certain targets, specifically to statishfy the basic standard (Indonesia has set 60 l/day per capita as a standard reference to meet the basic needs).

With this level of services, the target up to 1994 was planned to cover 80% of the urban population, and 60% of the rural population. With this planning, the additional target population to be served up to 1994 is 14 million more inhabitants.

The growth in the urban population, according to the 1990 urban population, was from 33 million in 1980 to 55 million in 1990, representing an increase of 22 million or 5,3% per year. Piped water production capacity over the same period was doubled; urban water supply coverage increased from 35% in 1980 to 41% in 1990 (see figure .. below).

The competing use of scarce financial resources caused the Government to develop new ways to attract funds for implementing these plant. The potential use of private resources in various ventures, joint operation or other means, was seen as a viable alternative.

The remainder gap between total investment needs with capacity of the government, as shown on the following graph, should be obtained through the other means.

Indonesia now were exploring the private sector possibilities to fill in the gap.

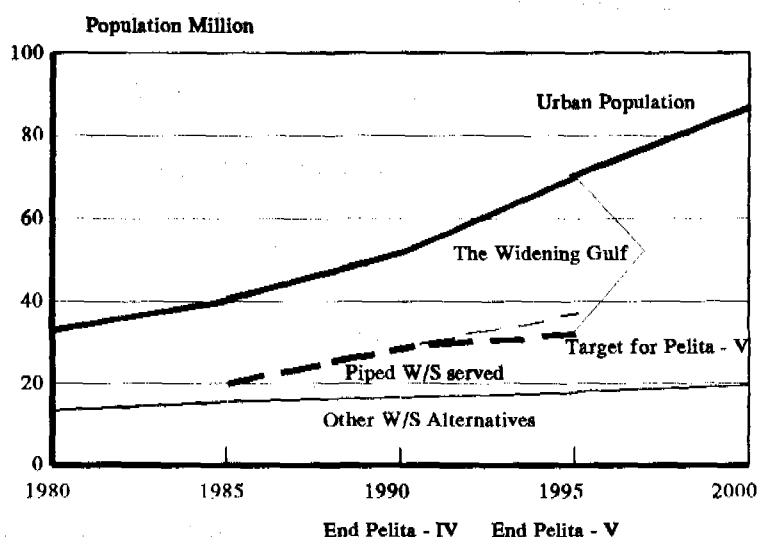


Figure 4

Water Supply Needs & Provision in Urban Area

Widening gulf, due to additional requirement/standart, v.s capability of development.

- — Piped W/S
- — W/S Needs
- — Piped W/S Target
- — Other

1.5. Funding policy

For over a decade, most of the funding for infrastructure and facilities investment takes place with the assistance of development loans and grants (mostly the Government Projects).

It was the intention of the Government to reduce its dependence on loans and grants from foreign sources (from 80% in 1980 to 30% by the year 2000), which consequentially has caused it to look the private sector to make up the shortfall.

The Government has, therefore, stimulated the private sector through incentives to invest in the areas which are traditionally held in the public domain.

2. DEVELOPMENT STAGES & EXISTING SITUATION OF WATER SUPPLY FACILITIES.

By ending the PELITA V, entering PELITA VI, the 1st long term planning will be soon terminated (by 1994), and Indonesia soon will enter into 2nd 25 years plan (up to the year of 2009). Therefore 1992 considered as an important year to face the next challenge of National Development.

The important issues facing the next Development era is, that the Indonesian Government declared that PELITA VI would consider as the period to start to take off

2.1. Take-Off Stage

This statement could have different meaning and could be misleading to some extent;

- the .."take off".. could be describes as to the attitude of development, or....
- as the commitment toward development by the community together with the Government, meaning that the Development will be relied more on the community potential base, or.....
- even private, with more liberal arrangement, in the sense of economic capacity... in other words.... less resources from the Government origin (wich basically also gained from the public).

This effort is considered already as a big leap for Indonesia, which among the Developing Countries by income criteria still classified as category B by many International monetary agencies (ADB, IBRD, ect.);

However Indonesia also declared to reduces it dependencies on foreign assistances.

To quote the statement of the press covering the visit of the President Suharto to Senegal in November 1991, saying that Indonesia now is doing . . . "a silent revolution on economic growth".

As the consequences, resuming the result of the 1st long-range Development stage, for the following stage the Government would uses the" instruments" such as :

- a. The "Strength" (in the positive sense) of the Government administration; with the equal knowledge of development needs (after experiencing along more than 25 year development periode). that have already spreads, exist among the administrators in different level, their function as being the public servant will contribute in achieving the optimum result.

- b. Deregulations, which were the result from the past experience have attracted the private sector to invest in different sector of development, including the water sector.
- c. Natural Resources exploration; ..This may include the information on the potential natural resources such as information on water resources for water supply, as well as classication on which sources were commercially sound, and might be an interest for the investors.
- d. The growing water supply related industries, such as pipe and treatment plant manufacturers, consulting services, contactors, ect., were ready to support the next development stages.
- e. Monetary system (Government policies, bankings, insurances, ect.) has strongly support the business needs.
- g. Political commitment of Indonesian Government to encourage the private sector to support the achievement of development target.
- h. etc ... etc

Furthermore, the most significant result of the 1st long range development stage is the creation and increment of higher development requirement, more demand, etc.; and the "wheels" , just couldn't be stoped.

2.2. Existing Situation of Water Supply Development

Indonesia is rich in surface and ground water, by exception that smaller island in the Lesser Sundas are relatively dry.

Rainfall varies throughout the archipelago from a low of 200 mm/year to as high as 5000 mm/year; average rainfall is around 2000 mm/year. Surface water is mainly used for irrigation, flood control, hydro electric power and human consumption. It is regulated by law that priority should be given to the basic needs (drinking water) of human life.

Figure 5 (page 7), shows the varios utilization of the raw water resources in the different urban cities.

That may conclude that the water supply have been considered as to provide the basic necessity for the community as well as to support the growth of strategic economic sectors..

However, extraction and transmission are at times affected by poor quality, distance from urban centres and seasonal variations.

Water, its extraction, development, distribution, and its eventual delivery to consumer, is considered a public good, which comes under the supervision of the Government and the guidance of the Constitutions. The Involvement of the private sector in water supply must, therefore, satisfy the Constitutional and legal requirements.

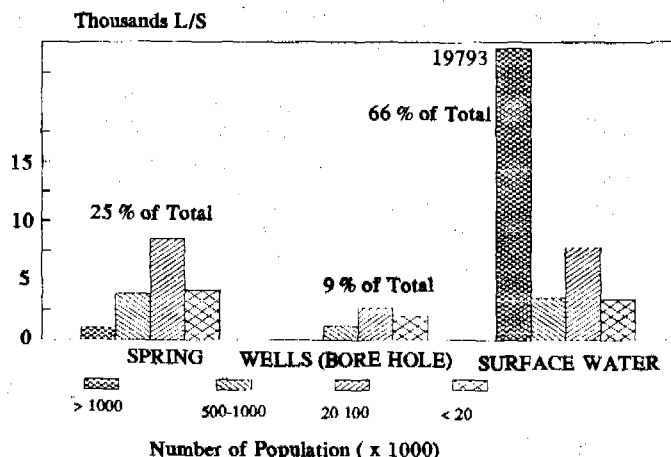


Figure 5
PRIMARY WATER SOURCES FOR
URBAN & SEMI URBAN WATER SUPPLY
(For Different City Sizes)

Shows the dependency of the urban cities more to the surface water, require careful water management.

The role and investment of the private sector in urban water supply presently, covering the services as follows:

- To construct, operate, and manage the service in the real estate area.
- To Invest and construct, together in the certain recreation and tourist resort.
- Other small water supply scheme which serves different beneficiaries.

Those were cases which were not always in accordance to the Government guidelines and regulation; however it shown that the Government has stimulated the involvement of the private sectors; ease the cases; and just take necessary action such as to control the water quality. The Government concentrates more to the effort on the realization of large schemes water supply development.

In accordance to the Government regulation, water supply provisions is basically responsibilities of the Local Government. Presently, the Local Government still required assistance, then the Central Government initially provides the water supply provisions, after that, gradually situation would changed and the Local Government will be able to manage further investment by their own resources, with limited assistant from the Central Government.

The Central Government has continuously prepared the policies, technical assistance and guidance to the Local Government on project development, implementation and monitoring. When ever necessary, the central Government does direct intervention through financial support, technical advices and supervision.

The total Installed capacity in the urban area by 1991 is app. 51.000 Ltr/sec, with coverage of +/- 45%, in the rural area the services reach to +/- 25% of populations coverage, served by "potable water"

As describes in the previous chapter, the development was set as such to meet the equal services for the people as soon as possible.

Therefore standard services was lowered by considering that improvement could be made after the first constructions erected.

The past results shows the reflection of previous economic's profile of the country. The BNA Standard stands for "..basic need approach.." provision of the supply, was build just to meet the average limit of the basic demand of drinking water.

Operationally this concept will provide the water merely on the sub standard basic, which standard target in PELITA-V would provided the water for households as many as 60 ltr/cap/day (average through out the country), with coverage of 80% population in urban area and 60% in the rural.

But from the quality point of view, the water provided could be describes as clean water and the Government still does not recommend to drink the water directly from the taps.

The short of the resources (funds, man power, ect.), which were mainly from the Government sources, tend to grow toward conservative development pace. To accomplish the task, Government has encourage the beneficiaries(consumers) by introducing the system to generates the equity from their self generating fund. This effort has proved statisfactorily. The water supply managements were improved, number and capacity of the man power were adequate to control and maintain the facilities, ect

The trends in water supply development, provision and supply at the National and sectoral level shown in the figure 6 below.

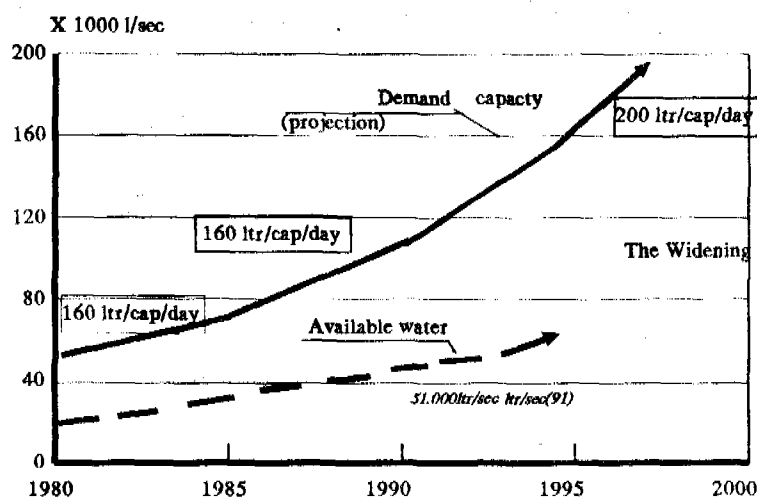


Figure 6

Demand Projection v.s Development capacity (in Urban Area).

* The more demand, the more

Investmen required, demand

* calculate base on different per-capita consumption level:

FUTURE PROSPECT FOR WATER SUPPLY DEVELOPMENT.

3.1. Government Provision for Water Supply Infrastructures.

The growth in demand for water in the urban areas correspond closely to the growth of the urban population and the growth of economic profile of the community.

The Repelita-V target of 80% to be served with piped water in the urban areas has not yet been achieved.

In fact, projection for the next ten years shows that the urban population will range between 75 and 80 million; means the additional water required of 14.000 ltr/sec or investment of approximately US \$1.9 billion in 5 (five) year period. Even with its most hard efforts to supply piped water to the urban areas, it would be unrealistic to expect the achievement of the objectives; unless the approach may otherwise.

This preceived demand for water in the urban areas has caused the Government to examine his approaches to private sector partici pation in water supply.

Although the trends indicated a widening gulf between demand and supply, the Government is actively developing various options such as Build, Operate and Transfer (BOT), Joint Ventures, Concession Options and Divestiture; not only in water supply but also in the other fields such as transportation, telecommunication, toll roads, transportation, electricity and solid waste diposal. Those step assures the public that the Government optimistically able to accomplish the task.

3.2. Opportunity for the Private Sector

Under the basic Government administration in Indonesia, there were share of responsibilities among different level of Government, which majoring to Central Government and Local Government (Province and Municipalities/Regencies). To some extent this arrangement works closely and harmonious. However this might required to include under the law in order to secure the interest of private sector.

Major Laws related to water supply affairs, main law, by law regulations guidelines, are shown in the annex 2.

Participation ranges from the performance of a Service Contract in which the "Public Body" has complete control, to possibly divestiture, in which the private sector has complete control through the purchase of the assets.

The following Table shows types of private sector participation and its possible implementation in water supply provision.

Types of W/S Cooperation Scheme/Example of the Implementation

- | | |
|------------------------|---|
| 1. Services Contract | - Meter reading & billing collections task by the Private Co. |
| 2. Management Contract | - Private Co. has responsibility to operate to maintain the facilities |
| 3. Lease Contract | - Private Co. to lease the facilities from PDAM and operate the production & maintain the facilities. |

4. B.O.T. Scheme

- Private Co. to build and operate the facilities on certain concession period which would be transferred to PDAM after due time.

5. Divestiture Scheme

- Private Co. take over the management & operation of facilities from PDAM in case that PDAM couldn't perform the services.

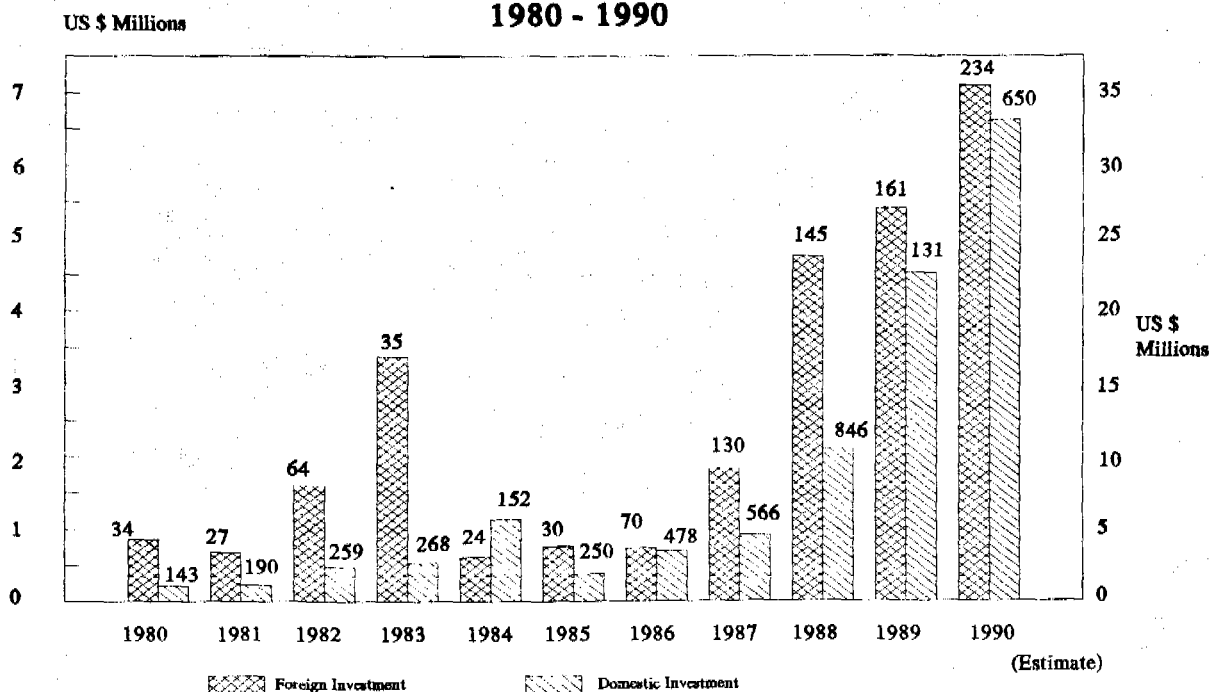
3.3. Conditions for Investment in Indonesia

In contrast with the objective of the public sector in providing a public good through a service, the private sector's objective is that of covering costs and heavily profit oriented undertakings.

The private sector is willing to consider investing in the water supply sector provided there is an operating environment with clear regulations, consistent administration of procedures and mechanisms to ensure that agreements are enforced.

Figure 7

Investment Trends 1980 - 1990



The results of a recent study (May 1991) , by the Directorate General of Human Settlements, found-out that local investors were willing to invest in water supply projects with the unit costs of about US\$ 10 million while foreign investors were willing to invest in projects of the unit costs of more than US\$ 50 million.

The experience to date by private participation in water supply has been limited by negotiation. Two types were identified in the study mentioned above are : "supply led" and "enclave" investment. In the first example, the type of project encompasses the bulk water development, treatment, transmission and sale. The second type is closely associated with and forms part of a larger project such as a tourist centre, and industrial estate or a housing complex.

Current guidelines on joint public/private participation in water extraction, raw water transmission, clean water production and clean water distribution define the role of private sector participation. Twenty three (23) capital investment project identification studies are being conducted with the purpose of encouraging private sector participation in order to provide capital to increase water supply capacity and distribution to urban areas.

From the description mentioned above, the possible area for the investor are:

- a. Commercial area, include in this area are industries, tourist resort, harbour. This type of consumer need to be in the sort of estate or enclave; mix area or individuals are not recommended.
- b. "Special" housing community, applicable to the community which have the income per capita "above the average".

Two major consumer mentioned above allowing the private sector more liberal to execute their business interest, how ever when they enter the business to the other consumers area(mix), the investor must be in joint venture with local Government company.

The list of the prospect of the Indonesian water Supply project in several Cities, involving the private sector shown in the annex 1.

3.4. Constrains and opportunity

Some constraints identified in the effort of encouraging the private sector participation in the water supply provisions were :

- a. Some investor has identified the lack of policies on the autonomy of water supply management;
- b. Ambiguities across several Government involvement in Water Supply affairs;
- c. Dependencies on tariff justification which are still requires the Government consultation.
- d. Lack of information on the potential water demand, consumer willingness to pay, ect.
- e. Available short and medium term financing are costly; investor tends to stay away from domestic financing due to high charges. In the other hand, foreign loan are considered too complicated and time consuming.

Conditions for investment on water supply provisions by private sector were considered as attractive enough the following table show the level of attractiveness.

Conditions on the aspect of :	Priority by Investor	Level of Difficulties to provides such conditions :
1. Consistency of legal Conditions	- High	- Medium
2. Financial Incentives	- High	- High
3. Autonomous in operational activities	- High	- Low
4. Tariff Adjustment	- High	- Low
5. Institutions	- High	- Low

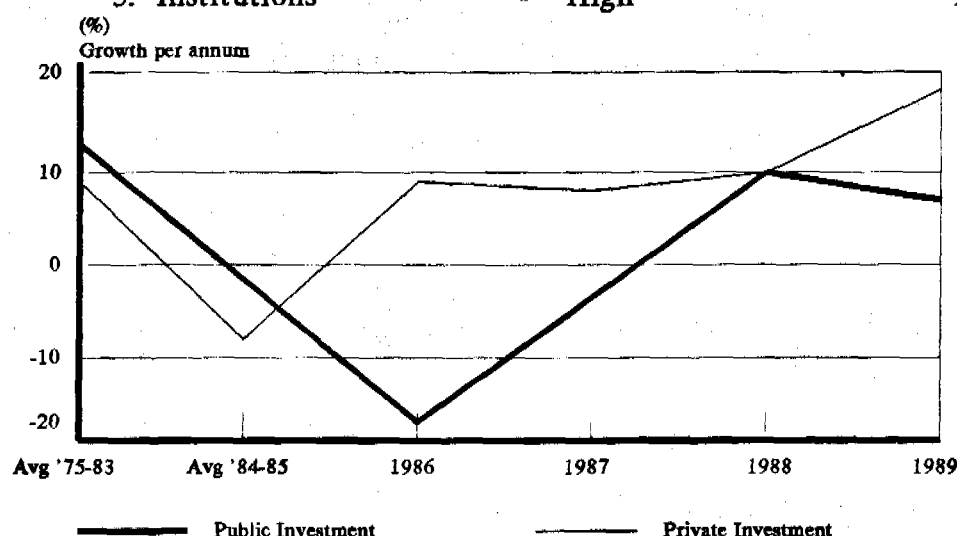


Figure 8
FIXED PUBLIC
INVESTMENT
(at 1983 Prices)

World bank, May 90

3.5. Law and Regulation related to Private Sector Participation on Water Supply Provisions:

The basis of Government action lies in the 1945 Constitution, Amendments to it and the Regulations promulgated under its authority. Section 33 Subsection 3 refers to natural resources being within the public domain and any development of them must take place within the frame work of a social good.

The interpretation of this section apparently means that the Government, acting on behalf of the people, has the sole right to develop the country's natural resources. However, by creating the cooperation with the privates, or non government entity,

endorsement could be opened to the privates to enter on this business, securely.

In addition, there are laws and regulations that define:

- the responsibilities of the local water authorities (PDAMs and BPAMs);
- laws that govern domestic and foreign sector investment (Law No. 1 of 1962 Law No. 1 of 1967 and Presidential Decree No. 21 of 1989);
- regulations dealing with taxes and tariffs and....
- laws and regulations that govern the operation of public utilities, (Regulation No. 4 of 1986 from the Ministry of Home Affairs).

These Laws and Regulations have several features which influence directly the level and nature of participation of private sector involvement in urban water supply. At the moment, the Government is in the process of considering streamlining ambiguous or conflicting laws to further encourage the private sector participation in investment in water supply. On February 20, 1991, water was declared as a mineral resource. The implications for private sector intervention in the provision of water supply, therefore, present many challenges.

Elaboration of the principles as stated in the Constitution is contained in the 1988's Guidelines of State Policy (Garis-garis Besar Haluan Negara-GBHN).

The Guidelines refine the goal of the Constitution with regard to the private sector participation and give some guidance on their use. While capital investment (both foreign and domestic) is encouraged, for example by Presidential Decree No. 21 of 1989, which removed water supply from the restricted investment list; its promotion is directed to private sector participation and the improvement of economic growth.

Its secondary objectives are the equitable distribution of economic gains, job creation and opportunity, transfer of technology and a strong and healthy business community.

4. Conclusions.

- a The Government of Indonesia is very obvious in the opening opportunity for the private sector participations in water supply provision. The Government is in acting to improve the environment and conditions for private sector investment, especially to encourage the approach "Off budget Investment" in water supply provisions.
- b. Private Sector participation in the form of "Supply Led Devt Project" and "Enclave Devt Project" were the most possible system, where average investment capacity were between US\$ 10 to US\$ 150 million.

- c. The risk of investor was obvious, but the Government (including PDAMs, the local water company) have understand the risk and ready for starting the joint cooperation and negotiation.
- d. Partnership with Domestic Investor were recommended, which also very beneficial to minimize the business risk for the foreign investor.
- e. The market segment for private sector participation was quite significant; at least up-to 20 year from now is still attractive for the business.
- f. The Government required to prepare the more clear prospectus of the project, which would be offered to the private investor.

Jakarta, June 1992

ANNEX 1

Table 1. Prospect On water Supply Project
(Possible Private Sector Participation)

NO	City/ Location	User Industries Comercial/ vs Public	Water Sources	Investment Amount	Status
1.	Surabaya	50/50	- Karang Pilang II (2 M3/s)	US\$ 40 Mio	open
		80/20	- Umbulan Spring*) (4 M3/s)	US\$140 Mio	Negotiation stage/open
2.	Semarang	75/25	- Kali-Jajar (Demak) or - Klambu Dam as (alternative)	US\$ 80 Mio	Feastudy
3.	Bekasi	80/20	- Jatiluhur Canal	US\$ 50 Mio	Open
4.	B o g o r	50/50	- Cisadane River	US\$ 40 Mio	Open
5.	D u m a i	70/30	- Rokan River	US\$ 80 Mio	Negotiation stage
6.	Pekanbaru	60/40		US\$ 30 Mio	Open
7.	M e d a n	50/50		US\$ - Mio	Open
8.	Lhok Seumawe	90/10		US\$ 60 Mio	Negotiation stage
9.	B i n t a n	95/5	- Estuaries dam	US\$ 1300 Mio	Comitted

ANNEX 2**THE LEGAL ISSUES CONCERNING WATER SUPPLY IN INDONESIA**

The organization of, delegation of authority within, the Indonesian Government with regards to water utilities, involves many tiers of law-and regulation-making and enforcing bodies.

A. The Principal Ministries involved in water utility affairs are:

1. The Ministry of Public Works (Departemen Pekerjaan Umum /Dept."PU")
Under PU, the Directorate General of Human Settlement (Direktorat Jenderal Cipta Karya) is the responsible agency for Urban development, in which the Directorate for Water Supply [Direktorat Air Bersih ("D.A.B")] is one of its Directorate which is responsible for development and technical assistance of water supply affairs.

Also under PU but concerned only with irrigation and water resources issues is the Directorate General of Water Resources [Direktorat Jenderal Pengairan ("DIT.JEN.AIR")].

2. The Ministry of Home Affairs (Departemen Dalam Negeri / ("DEPDAGRI").

Under DEPDAGRI is the Directorate General of Regional Development Affairs [Direktorat Jenderal Pembangunan Daerah (BANGDA)] and the Directorate General of the General Governmental Affairs and Regional Autonomy [Direktorat Jenderal Pemerintahan Umum dan Otonomi Daerah ("PUOD")] which in turn, delegate the authority over to the Directorate for the Development of Regional Enterprises (Direktorat Bina Perusahaan Daerah) to control the performance of the enterprises.

3. The Ministry of Finance [Departemen Keuangan (DEPKEU)]; which is responsible to assist and give the general guidelines as regard to all financial and monetary issues.
4. The Ministry of Health [Departemen Kesehatan ("DEPKES"); whom responsible to control the quality of the public water supply.
5. The Ministry of Industry [Departemen Perindustrian ("DEPERIN"); responsible to promote water supply equipment & industries
6. The Ministry of Mining and Energy (Departemen Pertambangan dan Energi) which is responsible for authorizing the use of groundwater resources.
7. The State Minister for Environmental and Population Affairs [Menteri Negara Kependudukan dan Lingkungan Hidup ("KLH"); which is responsible to

maintain & control the environmental impact of any development.

8. National Planning Board ("BAPPENAS"); responsible to manage the program and planning through out the country.

At the Province level there also "BAPPEDA" (the Provincial Planning Board).

A diagram of the organization and government agencies regulating BPAMs, PDAMs, and PDABs is presented in ANNEX 3.

B. The principal laws and regulations relevant to water supply are :

1. The Basic Law of 1945 (the Indonesian Constitution), particularly Article 33 which provides that" Production branches which are important to the State and provide for the needs of the people must be under control of the Government" "and ..."Earth, water and other ground resources have to be managed/utilized by the Government for the maximum prosperity of the people."
2. Law No. 5 of 1962 which is concerned with the establishment of State Enterprises at provincial/local levels. It serves as the fundamental legal basis for the establishment of PDAMs and PDABs. The current status of this Law is ambiguous; it was revoked by Law No. 6 of 1969, but revocation was made contingent up on the enactment of a new law to replace Law No. 5 of 1962. No such superseding law was ever enacted.
3. Law No. 11 of 1974 regarding water resources and which has wide applicability to all public water utility issues.
4. Government Regulation No. 22 of 1982 regarding water management, as it concerns sourcing of water supplies from streams and groundwater.
5. Presidential Decree No. 21 of 1989 concerning the exhaustive list of 75 economic sectors that are restricted for designated forms of new foreign and domestic private investment.

"Water supply or drinking water" is not listed as restricted sector. This may supersede Article 6 of Law No. 1 of 1967 which designates nine economic sectors including "drinking water" as being closed to foreign investment because they were of National Strategic Importance for which the Government of Indonesia will retain as the sole exclusive authority.

6. Joint Ministerial Decree of the Ministers of Home Affairs, Public Works, and Finance Nos. 160 of 1978, 281 of 1978, and 360/KMK.011 of 1978 regarding the execution and development of clean water development projects.
7. Joint Ministerial Decrees of the Ministers of Home Affairs and Public Works Nos. 3 of 1984 and 26 of 1984 and 27 of 1984 regarding the establishment

of local drinking water enterprises and the development of PDAMs. These Decrees assigned the Ministry of Public Works responsibility for initial water supply planning and the technical aspects of water enterprises.

Joint responsibility was assigned to the Ministries of Home Affairs and Public Works for formulating guidelines for the organizational structure of PDAMs.

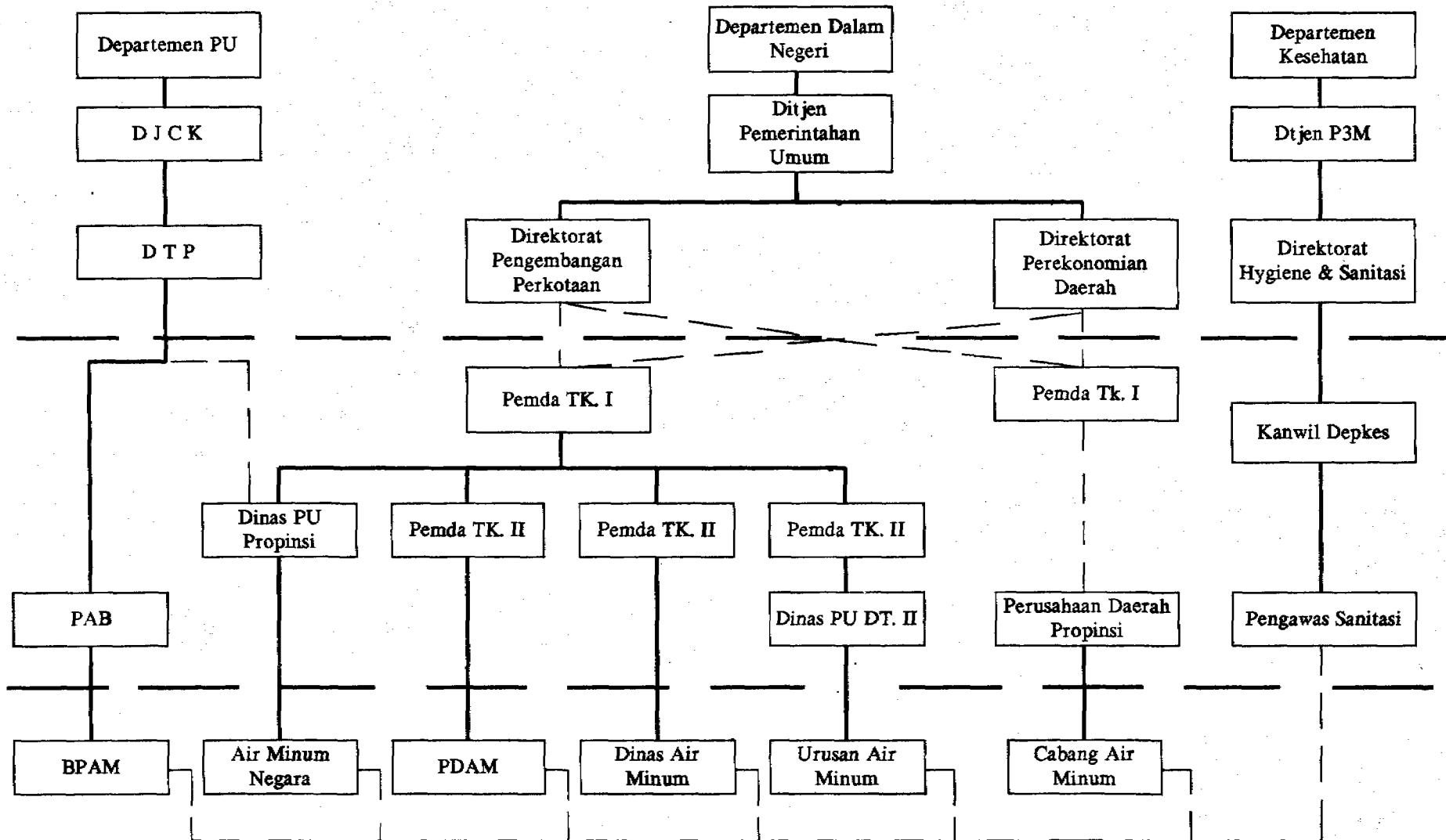
8. Joint Ministerial Decree of the Ministers of Home Affairs and Public Works Nos. 5 of 1984 and 28 of 1984 concerning guidelines on the calculation of drinking water tariff, organization, accounting systems, budgeting and cost calculations of water utilities.
9. Decree of the Minister of Finance No. 540/KMK.011 of 1979 regarding the Government Policy for financing of water utilities development projects.
10. Decree of the Minister of Public Works No. 269/KPTS of 1984 to regulate the shortening of the temporary status of BPAM.s, than expedite the establishment of PDAM.
11. Regulation of the Minister of Mining and Energy No. 03/P/M/Pertamben of 1983, requiring licensing of all private use of the ground water and spring water.
It also regulate the delegation of authority to the Governor of the Province to act on his behalve upon the binding advice of the Directorate General of Geology on this issues.
12. Regulation of the Minister of Home Affairs No. 690.536 of 1988, dealing with guidelines of the water tarif structure.

This provides that water prices application to the consumers must be decided by the Head of the Local Government, subject to the Governotarial approval after the proposal was made by the management of the water company. This eliminated the requirement for ratification by DPRD Tk II (Parliament) as provided in Regulation of the Minister of Home Affairs No. 690-1572 of 1985.
13. Regulation of the Minister of Public Works No. 65/KPTS of 1989 establishing the Joint Technical Team for the Water Supply facilities development which will be funded by the private Investor.
14. Circular Letter of the Minister of Home Affairs No. 690/7072/SJ dated July 10, 1985, providing the exemted of the profit sharing of 55% of the net profit of the water company to the local Government as provided under Article 25 of Law No. 5 of 1962.
15. Circular Letter of the Minister of Home Affairs No. 690-1595, 1985 regarding the authorization to establishment of the PMDUs.

16. Instruction Letter of the Minister of Home Affairs No. 5 dated March 19, 1990, regarding the optionals of the status of all Local Government Enterprises to either PERUMDA (Perusahaan Umum Daerah or Regional Public Company) and PERSEKRODA (Perusahaan Perseroan Daerah or Regional Limited Liability Company), following enactment of the law to substitute the Law No. 5 of 1962.
 17. Guidelines on the Accounting System of PDAMs of August 1990 issued by the Minister of Home Affairs.
 18. Organizational structure of PDAMs issued by the Minister of Home Affairs.
 19. Implementation Guidelines of the Regulation No. 690-536 of 1988 regarding the calculation of drinking water tariffs.
 20. NA.
-

LEMBAGA-LEMBAGA PEMERINTAH

ANNEX 3



THE IMPACT OF THE PRIVATE DEVELOPMENT OF WATER SYSTEMS IN URBAN AREAS OF MINDANAO

Ernesto B. San Juan
General Manager
Cagayan de Oro City Water District
Mindanao, Philippines

ABSTRACT: This paper is concerned with the impact of the private development of water systems in the three urban areas of Mindanao, namely, Cagayan de Oro City in Region 10, Davao City in Region 11 and Zamboanga City in Region 9. The study covers the time when the water systems in these areas were managed by the now defunct National Waterworks and Sewerage Authority (NAWASA) and their respective local governments, until the water districts took over in 1973. It shows the technical, financial and institutional development of the water system under the water district concept and the continuing expansion of the systems in these three cities today to meet the rapidly growing demands of their communities.

BACKGROUND

Mindanao is the southernmost and second largest island in the Philippine Archipelago. It has a population of 14,222,000. Cagayan de Oro, which is known as the City of Golden Friendship, is the premier city in Region 10. It is situated on the northeastern part of the island and considered one of the most progressive cities in the entire country, because of its rapid economic growth. It is also the gateway to Mindanao.

Davao City, which is known as Durian City, is the biggest, both in area and in population. It is located in the southeastern part of Mindanao and is the capital city in Region 11. It is also called the Queen City of the South.

Zamboanga City, the capital city of Region 9, is located in the southwestern portion of Mindanao. It is called the City of Flowers because of its exotic gardens.

Prior to 1973, most water systems in the country were managed by the now defunct National Waterworks and Sewerage Authority or the NAWASA. This was true for the cities of Zamboanga, Cagayan de Oro and Davao. The existing waterworks in these cities were not only antiquated and in constant disrepair, but were also either poorly designed, improperly operated or generally rundown. Most distribution systems had old, corroded and leaking

pipes, resulting in wastage of whatever little water was produced. The quality of water did not meet the drinking standards, bacteriologically, physically, and even biologically. In short, the systems in these cities did not meet the water requirement of these cities, both in quality and quantity.

In Cagayan de Oro City, where groundwater is the main source of water supply, water was not enough for the population that it served. Most of the groundwater sources were contaminated with iron and chloride, thus making it unsuitable for commercial and industrial uses, not to mention that it was not safe for drinking purposes. The delivery of water was intermittent, ranging from one to several hours. The pressure in the lines was very low, hence, the system was not sufficient for fire-fighting purposes. Even after 1970 when the City Government took over the management of the system, the same conditions prevailed. The system continued to deteriorate for the simple reason that the City Government had no appropriation for its maintenance and expansion.

In Davao City, despite big expenditures, both by the national and local governments, the system was practically inoperational. Likewise, the source of water was not acceptable and almost all people did not avail of the drinking water. Instead they relied on drinking water, while those who could afford had their own deep wells.

Of the three cities, Zamboanga City had the most developed system. Its water source, which is surface water, was sufficient in quantity. It had a fairly good distribution system, but the system did not have good and adequate treatment facilities as required for surface water. It just used plain sedimentation and chlorination which were very inadequate to assure good or quality water in their distribution system. As you can see, the deficiencies in the three cities under study were the following: poor quality of water or lack of sufficient treatment, big unaccounted-for water resulting from system age, wastage and leakages. Hence, we can say that the water systems were not sufficient to meet the needs of the cities, both in volume and quality.

THE PROVINCIAL WATER UTILITIES ACT OF 1973

The Provincial Water Utilities Act of 1973, also called Presidential Decree 198, was passed on May 25, 1973. It revolutionized the management of local water systems throughout the country through the formation, on a local option basis, of independent, locally controlled water districts, and authorized the transfer thereto of existing water supply and wastewater disposal facilities.

Now independent of the local government, the water district introduced a new concept in water management. It metered all connections and required water users to pay for the water service in full. To enable it to operate on a self-reliant, self-supporting basis, the Act armed the water district with measures to make it economically viable. To meet its cash requirements for operational expenses and repayment of loans, it authorized the water district to formulate and adopt reasonable water rates and charges, and thus increased its internal revenue-generating capabilities. It also allowed the water district to formulate, adopt and levy a production assessment charge, in the event the board of the district finds, after notice

and hearing, that the production of groundwater by other entities within the district for commercial and industrial uses is injuring the district's financial condition, to compensate for such loss.

The Provincial Water Utilities Act gave the water district the right to protect its waters and facilities, providing penalties for their violation.

It also organized the Local Water Utilities Administration (LWUA), the government agency whose main function is to extend technical know-how and capital improvement funds by means of loans to water districts. LWUA prescribes the minimum regulations and monitors local water standards to enable water districts to maintain acceptable standards in their maintenance and operation. Personnel training, accounting and fiscal practices are also areas which the LWUA undertakes to strengthen.

For the purpose of carrying out the objectives of the enabling Act, water districts were granted the power of eminent domain, the exercise of which is subject to review by LWUA. A district may purchase, construct or otherwise acquire works, water rights and privileges useful or necessary to convey, supply, store, collect, treat, dispose of, or make other use of water or water rights.

THE ORGANIZATION AND OPERATION OF WATER DISTRICTS

As early as the middle of 1973, water districts were formed all over the country through LWUA. Most of the cities and capital towns of the country were the first ones to respond due to the need to improve their systems. Cagayan de Oro, Davao and Zamboanga cities were among the first twenty water districts formed and given their certificates of conformance. This enabled them to be given priority in the application for technical and financial loans from LWUA.

After receiving their certificates of conformance, the water districts operated under a new set-up: the Board of Directors were installed as policy-makers, while management of the district was placed in the hands of the general manager. Five members composed the board of directors. One represented the professional groups, the second was from civic-oriented groups, the third from the educational sector, the fourth from the business groups and the fifth from the women sector. None of them were connected with the government. The board of directors became responsible for the enactment of the utility personnel regulations and other policies. On the other hand, the General Manager, also a professional, served on a full-time basis. He is responsible in running the affairs of the District.

The first major development in the District was the organization and hiring of appropriate and qualified personnel. The second was the massive rehabilitation of the existing system, particularly the provision of one-hundred percent metering. All the water to be delivered to the public had to be chlorinated. Once the loan was available to the District, the following activities were implemented, namely: feasibility studies of the system, detailed engineering design and construction of the system. A master plan had to be developed for each district covering a period of 30 years. The improvement and expansion of the system were done in three phases, consisting of a period of ten years for each phase. The cities

under study are presently on the third phase of their development, and they are all contemplating to revise their master plans.

As a result of the District's improvement and expansion of the water systems, there have been tremendous improvement of the systems, both in infrastructure, as well as in their financial capability.

Cagayan de Oro City Water District, with barely one million pesos worth of assets is now worth almost P150-million. Its gross income increased from half-a million pesos to more than P70-million. The service connections also increased from a little more than 3,000 to 38,000. The production capacity of the system increased from four million cubic meters to twenty-four million cubic meters per annum. It is well above the water demand of the city and on top of it all, the unaccounted water is within the allowable percentage for a good water system. The length of pipelines within the system has likewise increased from 30 kilometers to 220 kilometers, various sizes.

The Cagayan de Oro City water system after the second phase of improvement is now technically capable of serving the people within its service area with sufficient water continuously for 24 hours with strong pressure. The water has met the requirement of the National Drinking Standards. It is also financially viable because it is generating sufficient funds to meet its operational and maintenance expenses, debt service expenses and some amount for expansion. (Please see attached graphs)

With the approval of the national project creating cause Cagayan de Oro, the District is now working on a study of the new areas which include Cagayan de Oro City and six adjoining municipalities of the province of Misamis Oriental. Feasibility studies have already been conducted by Louis Berger International, Inc., which was funded by a grant from the USAID. The detailed engineering studies for these Metro areas are now being prepared, as well as the study of water resources (groundwater and surface water) of the service areas.

These conditions are similar for Davao City Water District and Zamboanga City Water District. They are both technically and financially viable. However, one the of the important features of Zamboanga City Water District differs from the two water districts in that the entire sources of its water supply is surface water. Zamboanga City Water District has already installed two water treatment plants. One was completed as early as 1980, and the other was in 1990. Their sources have undergone complete treatment, thus ensuring that water is safe for human consumption. Davao City Water District sources are groundwater. Because of the city's big population, which is over one million, they are now considering to tap surface water in addition to their underground sources, to assure them of sufficient supply. The development of surface water will be part of their third phase of improvement.

The three water districts are recognized by LWUA not only as pioneer water districts, but also because they consistently topped the yearly recognition awards given to water districts. Both Zamboanga Water District and Cagayan de Oro Water District were recipients of the Hall of Fame Awards for having been chosen as the most outstanding water districts for four consecutive years.

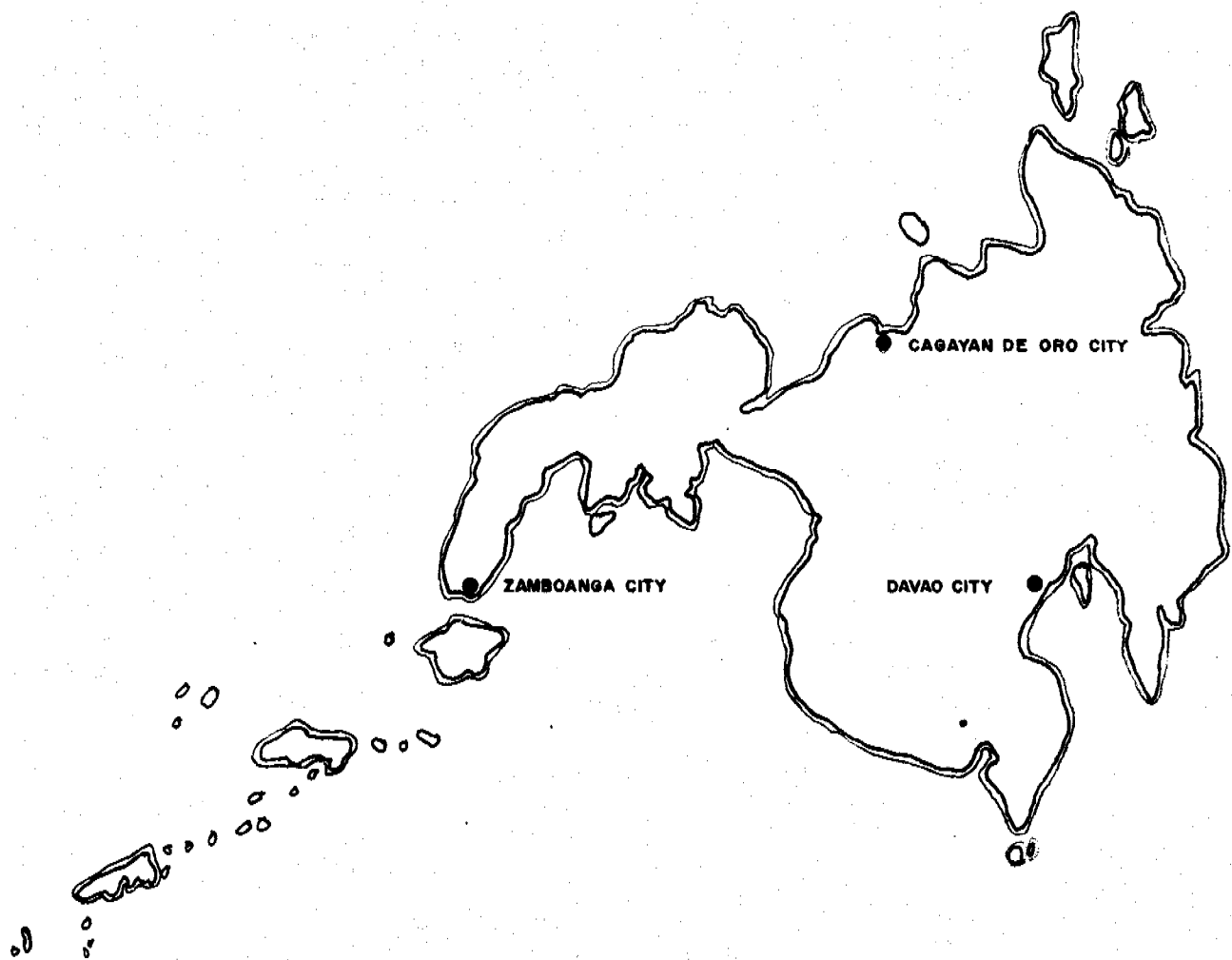
In addition, the three water districts were considered the Godfather Water Districts in their respective regions. They are now helping other districts in their respective areas, in terms of technical, financial, as well as institutional development. They have their own human resources training facilities and water laboratory for physical, bacteriological and chemical analyses, which are also being made available to all water districts.

SUMMARY

1. The three water districts, as shown in the supporting graphs, are now financially viable.
2. They are also technically viable because they are meeting the water requirement, both in quality and quantity.
3. The three water districts have programs to meet the future water needs of the city as contained in their master plan of development. They are now preparing for the implementation of Phase 3 development.
4. Support facilities have been developed to assure effective management of the system. They have office buildings, shop buildings, communications system, office equipment, vehicles and other support facilities necessary for efficient operation.
5. There is continuous human resources development of the District personnel. They are not only trained in their respective local training centers, but they are also sent to Manila and even abroad to acquire knowledge on the latest trends in water technology, both in technical and financial aspects.

RECOMMENDATIONS

1. In order to assure enough funds to finance the development of water districts, LWUA has to increase its capitalization. LWUA is the sole government agency responsible for the funding of water system development in the different parts of the country.
2. LWUA should continue to search for foreign loans or grants that will reduce the rate of lending to the water districts. This is very important to prevent the increase in water rates charged by water districts.
3. LWUA should continue to assist the water districts in human resources training. They should look for study grants abroad for the staff of water districts to enable them to acquire advance knowledge in water technology.



M A P O F M I N D A N A O
PLATE I

POPULATION GROWTH OF SERVICE AREA From 1976 Until 1991

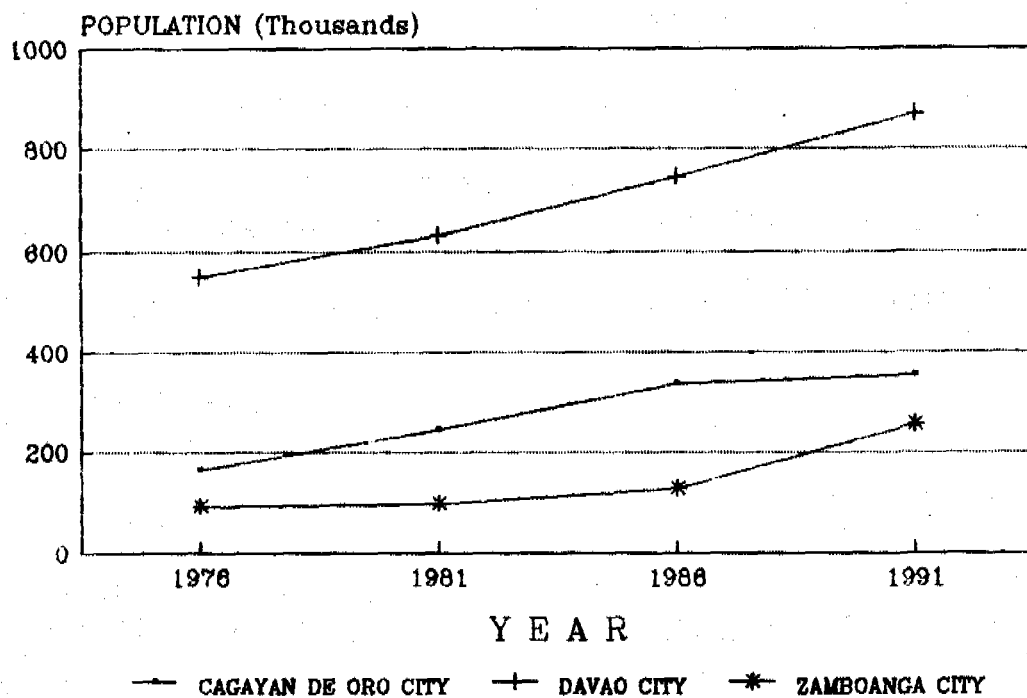


FIGURE 1.1

GROWTH OF POPULATION SERVED BY SYSTEM From 1976 Until 1991

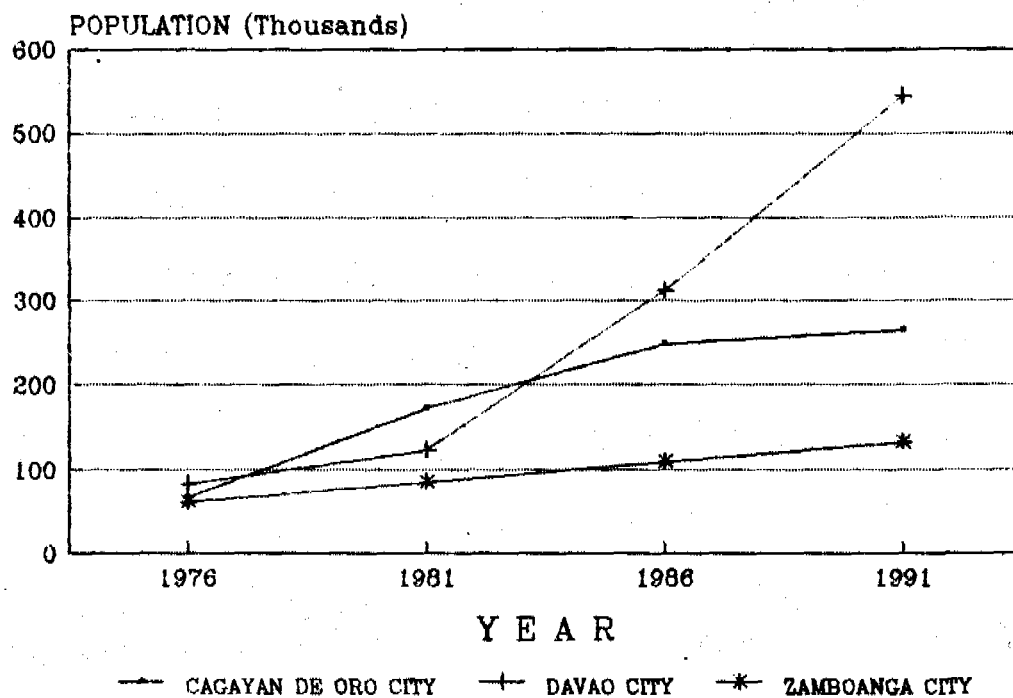


FIGURE 1.2

PERCENT OF POPULATION SERVED BY SYSTEM From 1976 Until 1991

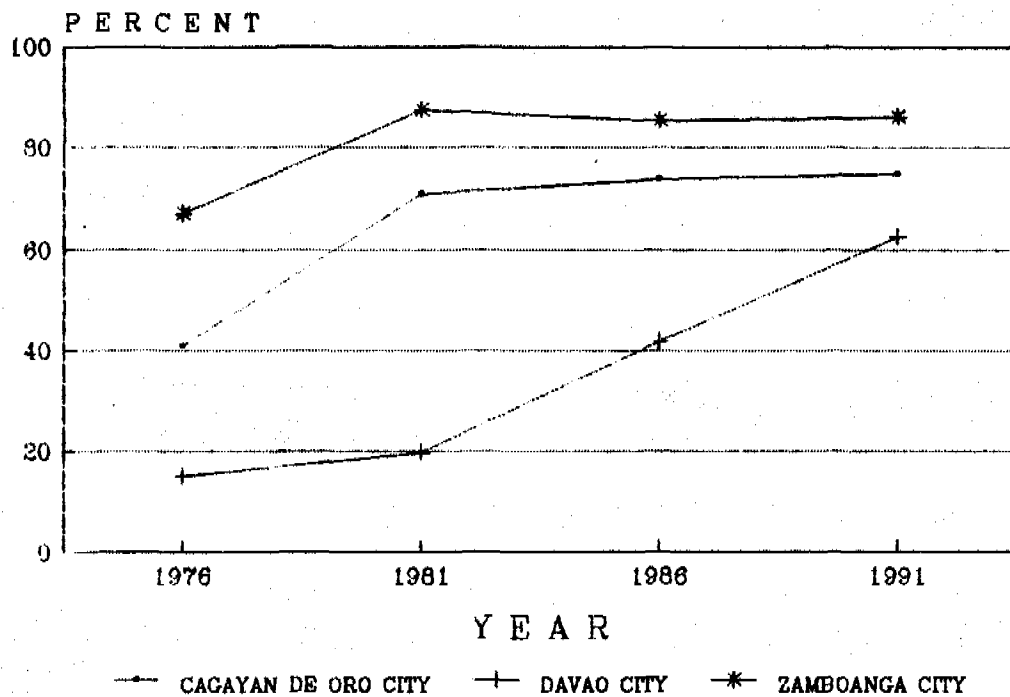


FIGURE 1.3

SERVICE CONNECTION GROWTH OF SYSTEM From 1976 Until 1991

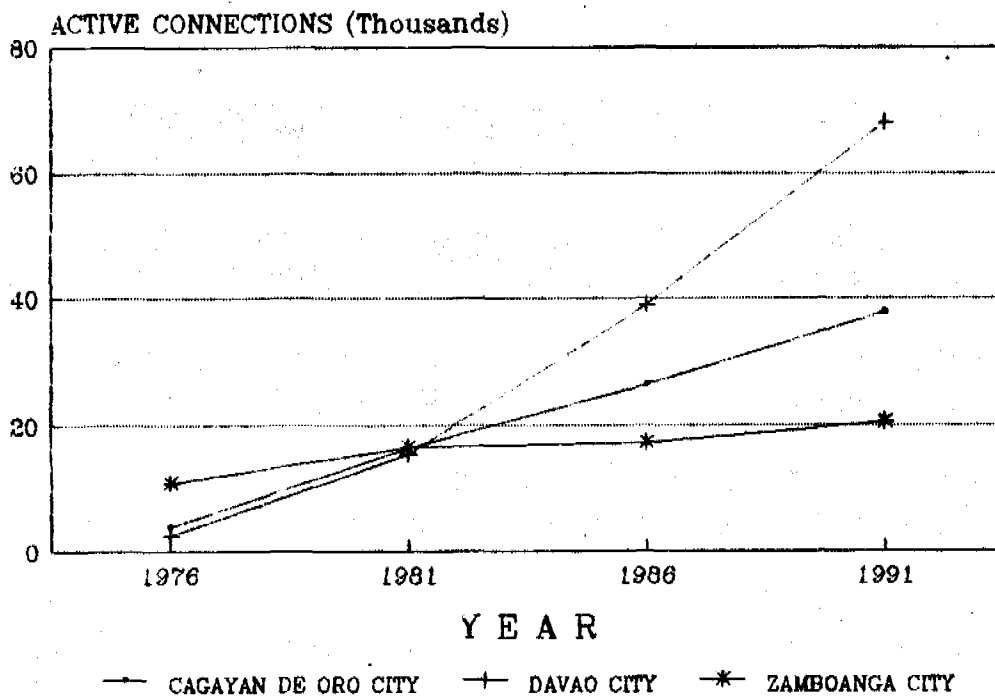


FIGURE 2

LENGTH OF PIPELINE OPERATED BY SYSTEM

From 1976 Until 1991

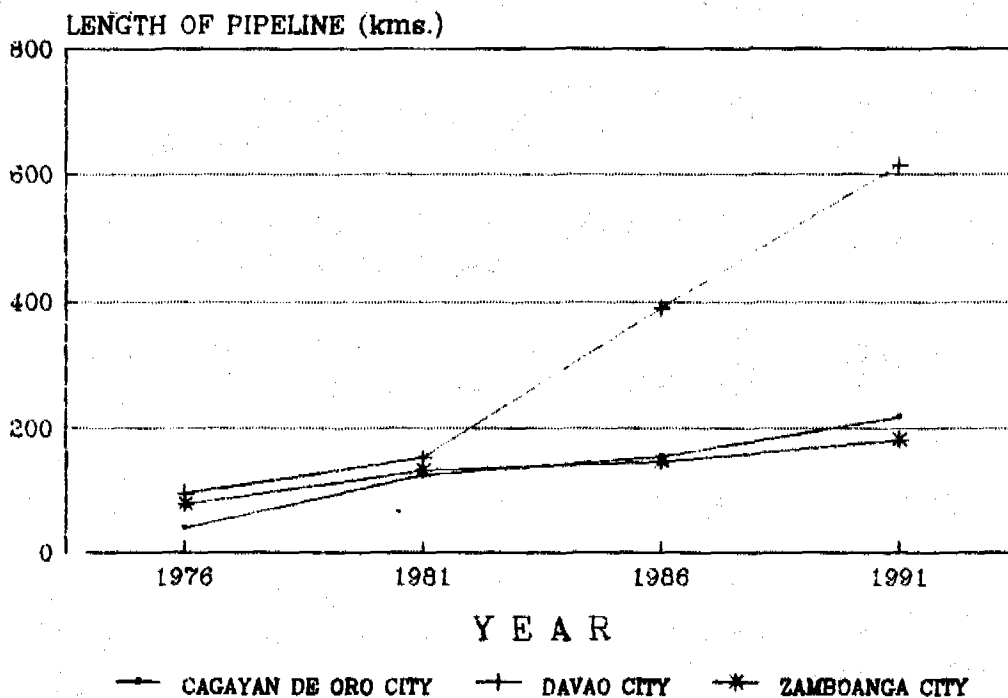


FIGURE 3.

CAGAYAN DE ORO CITY

Capacity / Production / Unaccounted

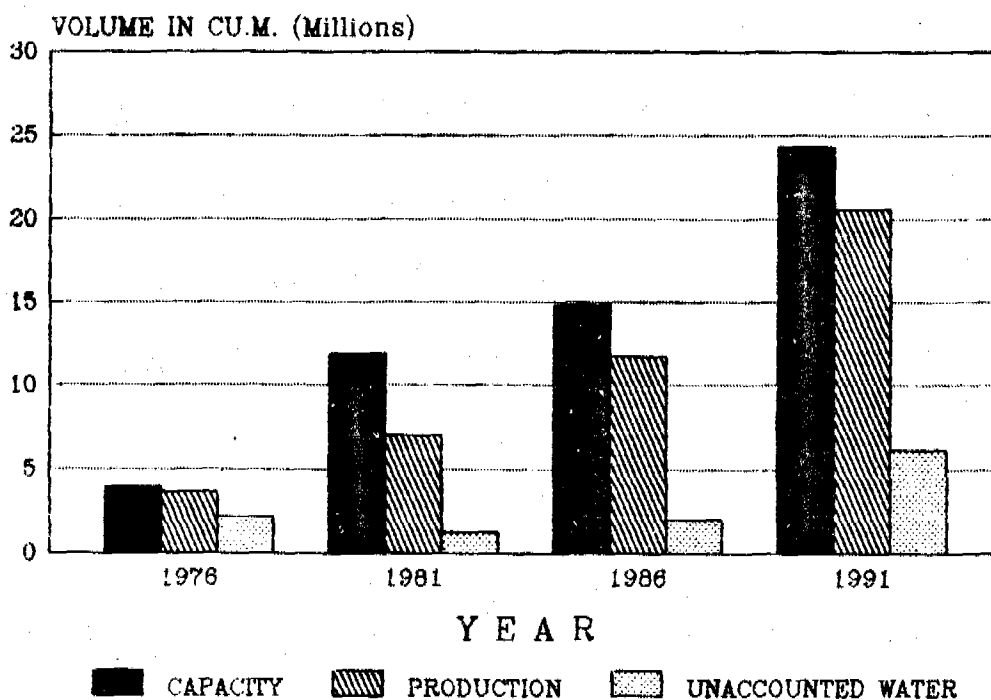


FIGURE 4.1

DAVAO CITY Capacity / Production / Unaccounted

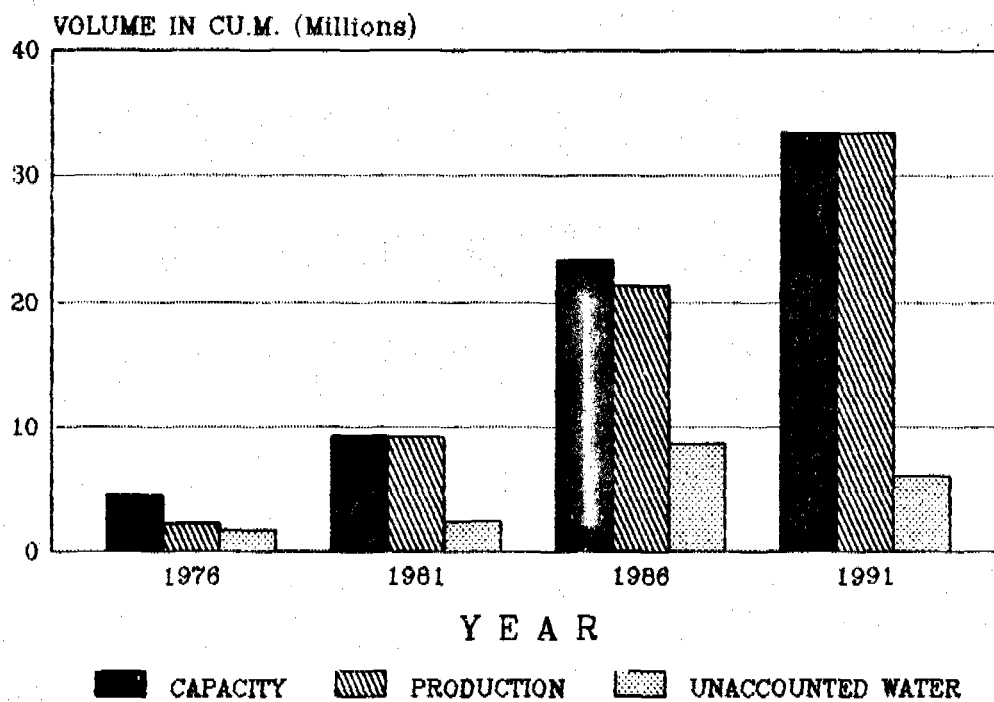


FIGURE 4.2

ZAMBOANGA CITY Capacity / Production / Unaccounted

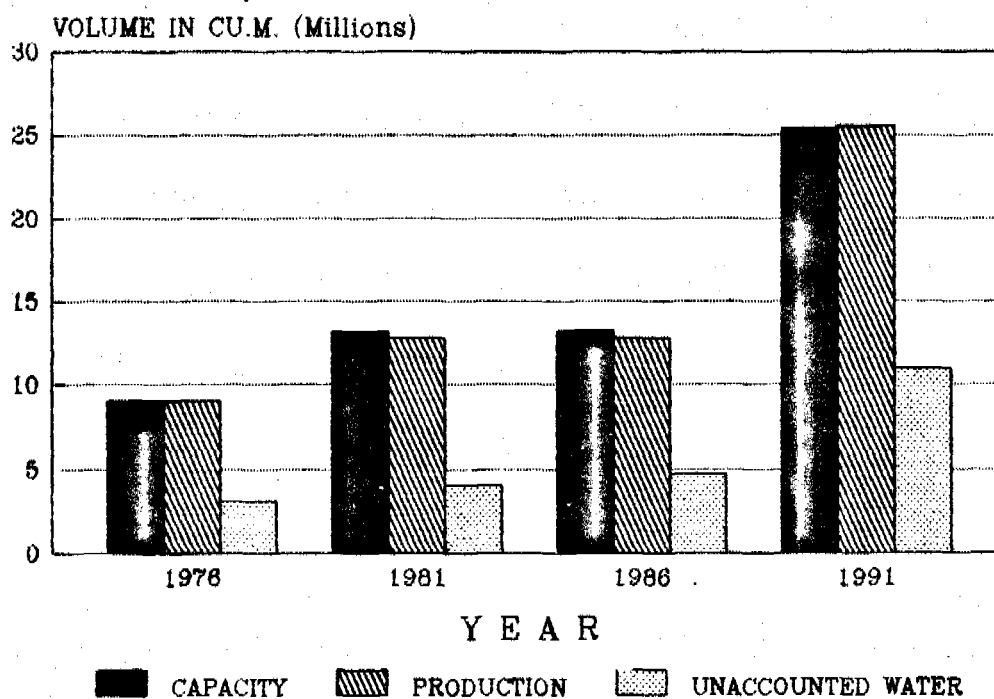


FIGURE 4.3

PERCENTAGE OF UNACCOUNTED WATER From 1976 Until 1991

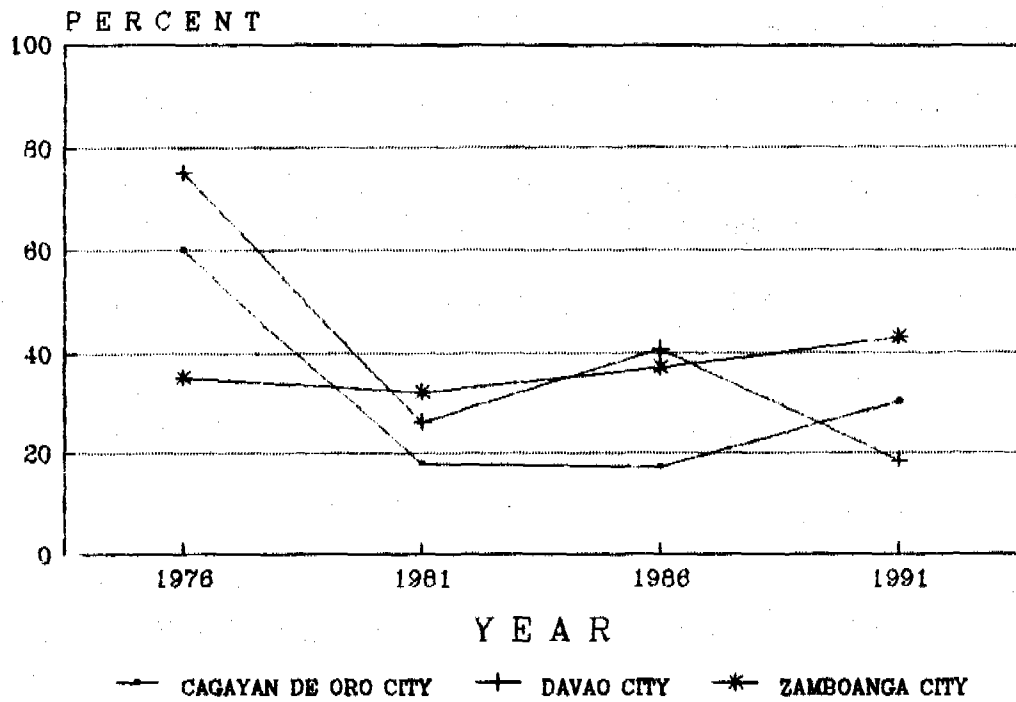


FIGURE 4.4

GROWTH OF VOLUME OF WATER PRODUCED From 1976 Until 1991

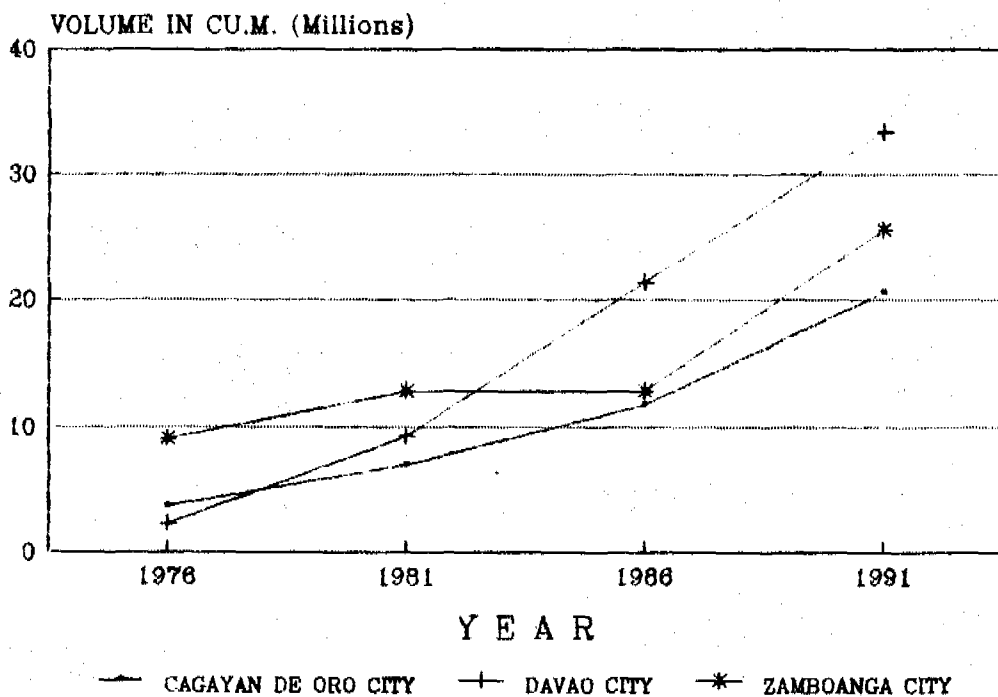


FIGURE 4.5

GROWTH OF TOTAL ASSETS

From 1976 Until 1991

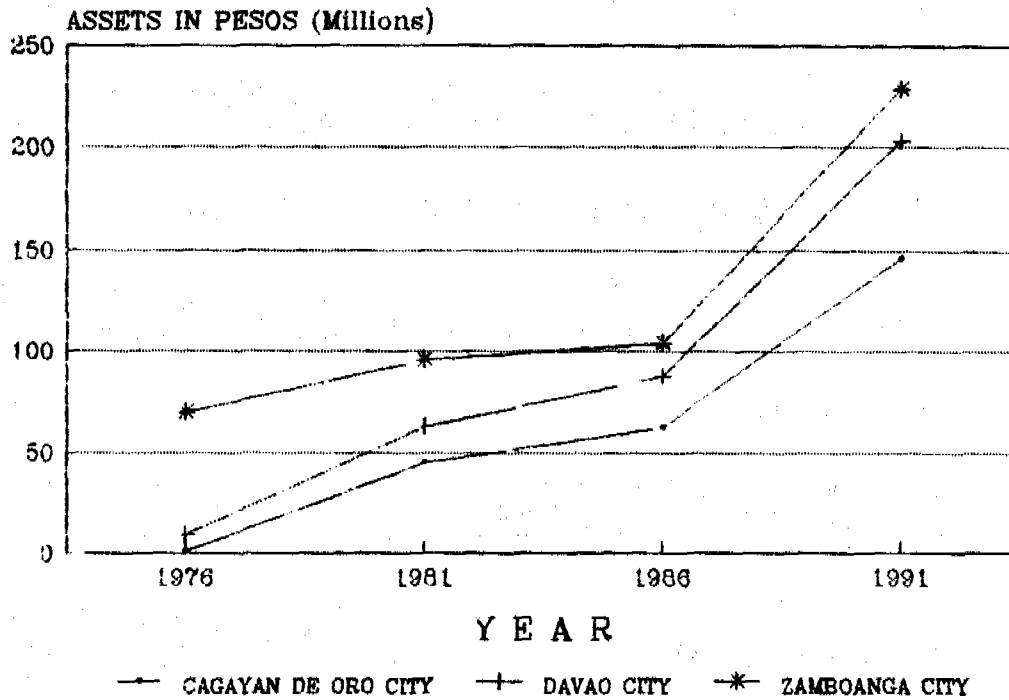


FIGURE 5.1

GROWTH OF GROSS INCOME

From 1976 Until 1991

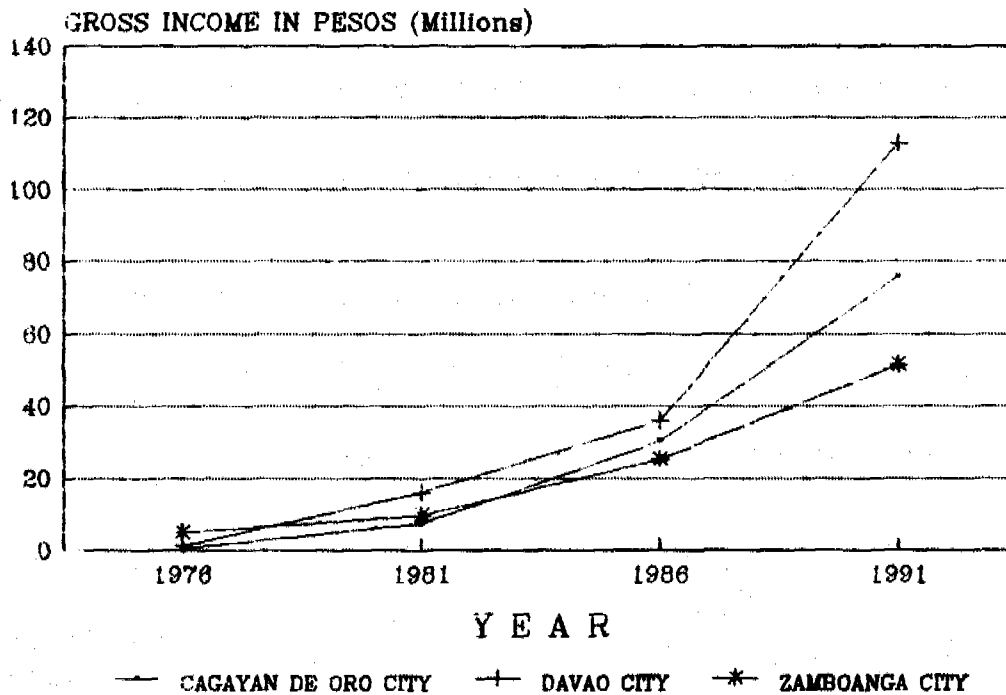


FIGURE 5.2