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Regional Workshop on

WATER RESOURCES, ENVIRONMENT AND NATIONAL DEVELOPMENT

Singapore · March 13-17, 1972

VOLUME I : SUMMARY OF PROCEEDINGS

Proceedings of the Workshop jointly sponsored by

SCIENCE COUNCIL OF SINGAPORE

and

NATIONAL ACADEMY OF SCIENCES OF THE U.S.A.

VOLUME I: SUMMARY OF PROCEEDINGS

VOLUME II: SELECTED PAPERS

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FOREWORD

The amount of natural resources is finite but as human population doubles itself every 25 years the consumption of these resources is not only accelerated but also brings in its wake the problem of disposal of waste-products. Water is a natural resource. It is essential for consumption, irrigation and industrial purposes, but its use is threatened by persistent and continuous pollution. The problem of controlling population, increasing pressure on consumption of natural resources and control of pollution will become dangerous points for stress and conflicts in the next 50 years if there is no attempt to promote understanding and international regulation throughout the world.

This Regional Workshop under the joint sponsorship of the Science Council of Singapore and the National Academy of Sciences of the U.S.A. is opportune as it deals with contemporary problems vital to governments and their nations.

Dr. Toh Chin Chye
Minister for Science & Technology
Singapore

ACKNOWLEDGEMENTS

The Organising Committee wishes to thank Mr. Lim Kim San, Minister for Education and Chairman of the Public Utilities Board for officiating at the Opening Ceremony.

Participation of the delegates from the Regional Countries and the National Academy of Sciences was made possible through the financial support of the Asia Foundation and the U.S. Agency for International Development, respectively. The Office of Regional Economic Development and the Singapore Government provided funds for printing, stationery and local expenses. The Organising Committee wishes to express its gratitude to all these organisations and the Singapore Government for their generosity.

Thanks are also due to Dr. Toh Chin Chye, Minister for Science and Technology; the Port of Singapore Authority; and the Science Council's Science Ball Organising Committee for their warm hospitality during the Workshop. The assistance given by the various Government departments and statutory bodies such as in providing secretariat staff, is gratefully acknowledged.

The Committee is further indebted to all panel members, participants and observers for contributing working papers and active discussion.

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SECTION A

INTRODUCTION

WORKSHOP ARRANGEMENTS

PURPOSE OF HOLDING THE WORKSHOP

The Workshop was organised under the joint sponsorship of the Science Council of Singapore and the National Academy of Sciences of the U.S.A. Its main purpose was to focus attention on current problems of water resources and the environment faced by countries of the South-east Asian region, and stimulate regional co-operation in seeking solutions.

DATES AND VENUE

The Workshop discussions were held from March 13th to 17th, 1972 at the Singapore Conference Hall, Shenton Way.

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Lye Thim Fatt
Sung Tsoong Tuh

Staff Representatives
National Academy of Sciences of the U.S.A. — John C. Hurley
Science Council of Singapore — Khoo Hun Hock & Miss Chan Joo Phek

PARTICIPATION

Besides Singapore, the Regional countries represented were: Indonesia, Malaysia, Philippines, Thailand and Vietnam. As the National Academy of Sciences of the U.S.A. was a joint sponsor, participation by American experts in these fields was made possible. France, Japan, Sweden and the United Kingdom also sent representatives. A complete list of Workshop registrants is given in Appendix IV.

WORKSHOP PROGRAMME

On the first day, an Opening Ceremony was held followed by the First Plenary Session. The Workshop then split up into three Working Groups which met concurrently for the next three days. On the fifth day, the Final Plenary Session was convened, and the Workshop brought to a close.

The various topics were discussed in the order indicated in Section B, Working Group Summaries.

OFFICIALS

Chairman — Mr. Hiew Siew Nam
Co-Chairman — Prof. Gerard A. Rohlich

The names of the Convenors, Discussion Leaders and Rapporteurs for each Working Group are given in the respective Working Group Summary.

OPENING CEREMONY

OPENING STATEMENT BY DR. LEE KUM TATT
Chairman, Science Council of Singapore
Chairman, Organising Committee

Mr. Lim Kim San,
The Hon. Minister for Education and Chairman of the Public Utilities Board,
Your Excellencies,
Distinguished Participants and Guests,
Ladies and Gentlemen:

On behalf of the Science Council of Singapore, I would like to extend to all of you a very warm welcome to the Opening of this Regional Workshop on Water Resources, Environment and National Development. This Workshop is jointly sponsored by the Science Council of Singapore and the U.S. National Academy of Sciences of the U.S.A. — I must say to our distinguished guests that your presence here in Singapore has already enhanced our environment.

During the next few days the Workshop will be discussing very important issues on the interaction of water and the environment and their effects on national development. These issues are not confined to the boundaries of the countries we represent but they are common crucial problems which will affect the progress and development of this region as a whole. It has been estimated that during the 1970-80 decade the urban population of this region will increase by 50%. The consequences are that existing water supply facilities will not be adequate to meet the expanding needs. More water will be required for irrigation, domestic use and for the fast growing and expanding industries. It has also been estimated that some S$120 billion would have to be invested in water resources development to meet this need in the ECAFE countries. Careful long term planning and development programmes are therefore required if these expanding needs for water are to be met.

Rapid industrialisation has brought economic benefits to many people in the region by providing them with jobs and a better livelihood. However, industrialisation has also created the problem of pollution; pollution of the air and pollution of our streams, rivers and seas. In this Workshop we shall confine ourselves to the pollution of our water resources. Much of the wastes which include sewage sludge, industrial wastes, construction and demolition debris, chemicals and miscellaneous materials and oil spills contain materials that have a number of adverse effects and many are toxic to human and marine life by depleting the oxygen necessary to maintain the marine ecosystem. I do not have to overstress the importance of eliminating or controlling pollutants harmful to man. Pollutants which kill fishes or reduce their population can cause serious economic porblems to the fishing industries and the fishermen in our countries.

The problem of the environment and national development is therefore a very complex one. While the technology for the production of marketable goods is very well developed, the technology for disposing of the wastes produced by the manufacturing processes is still in its infancy. This is so because until quite recently there is no money to be made in the latter technology, i.e. the technology of getting rid of wastes. Economic pressures permitted the uncontrolled dumping of these wastes, thus causing all kinds of pollution. The enormous gap that exists between the two technologies have therefore created this pollution problem.

It is true that many of us from the developing countries are pre-occupied with the acceleration of economic growth and industrialisation. These pressures may make some of us view with suspicion any suggestion that these economic efforts or activities be restrained because of possible pollution effects. How much pollution a country is prepared to accept in order that the country's economy could be diversified is a decision for the politicians in the Government to make. Some of us are of the view that whilst we should not relax our concentration on diversification of our economies through industrialisation, early recognition of the importance of proper utilisation of our natural resources with a view to maintaining the quality of the environment and the quality of life will in the long run bring about more lasting benefits.

Therefore as scientists and technologists we feel that it is our duty to make our governments aware, without causing undue hysteria, of the seriousness of some of the environmental problems, and very likely our governments will face up to these problems and act. Some of our governments may probably like to know what institutions should be created before they can act and how to act. Some of these institutions are already in existence in some countries. Probably we may need a regional institution or organisation to assist in the co-ordination of activities and help find solutions to common problems of the region in environmental control. This I hope will be one of the topics this Workshop will discuss.

In Singapore we have our share of water and environmental problems. With a population of over two million people, living on an island of 583 sq. km., it is not difficult to see that our main environmental problems arise from the scarcity of land and indigenous water resources. Incompatible land use and the consequential difficulties in waste disposal will give rise to pollution of our waterways. Rapid industrialisation and an increasing population, although at a relatively low rate of 2 per cent per annum, due to the successful implementation of our family planning programme, have necessitated the formulation of plans to increase our water supply by tapping subsurface water or by recycling treated water for industrial use. Strict measures to control pollution of the environment are therefore absolutely necessary. In Singapore, control of environmental pollution has become everybody's business. There is active participation of the population in "Keeping Singapore Mosquito Free", in "Making Singapore a Clean and Green City", and now the campaign is on in "Making Singapore Pollution Free". Control of *this nature will no doubt conflict with certain individual interests, but this should not serve as an excuse for us not to act. In any society every individual has his share of social responsibility to carry if that society is to survive. All these measures are necessary to preserve our environment and to improve the quality of life which we all strive so hard to achieve. I am sure in other countries in the region, as a result of increasing urbanisation and industrialisation, similar problems of water supply, waste disposal, pollution of the environment do exist. These problems are highly complex and they may have different priority levels in different countries.*

One of the questions very often posed to us is that we do not know enough about environmental conditions to enable us to take definite and positive actions. Our knowledge of the problems may be inadequate and it is necessary to act with prudence, but we would be grossly at fault if we fail to find out, at least what we do know about the environment. You will no doubt agree that the people within our region normally have a better insight into the problems of the region and it is through regional workshops such as this one, that cross-fertilisation of knowledge and experience amongst its participants can be made possible. We are also very fortunate to have with us many distinguished scientists and engineers from the developed countries, including the United States of America, Sweden, France, Japan and the United Kingdom participating in this Workshop. Their knowledge and experience will be invaluable to us in the efforts we are making to try to find solutions to our problems.

I am sure the discussions that are about to take place in the next few days will be extremely useful and it is hoped that at the conclusion of this Workshop, we would have achieved the objectives of:—

(i) Formulating strategies and action programmes for the integrated use and prevention of pollution of water resources in the region;

(ii) Establishing criteria and procedures for the selection of priorities for research on water and pollution problems;

(iii) Strengthening the role of scientists and scientific institutions through the region in planning a more effective use of water resources;

(iv) Developing practical findings to guide decision-making in the planning units and relevant departments and ministries of participating countries; and last but not least,

(v) Encouraging regional co-operation on problems of protection and improvement of the environment.

On behalf of the Science Council of Singapore, I would like to thank the Minister, Mr. Lim Kim San, for having kindly consented to officiate at the Opening of this Workshop. I would also like to thank all of you for *coming here this morning. To our foreign guests I hope you will have an enjoyable time in Singapore and that you will find your stay in Singapore worthwhile. The Science Council is very honoured to have so many responsible people like yourselves here to discuss such important issues in a regional context. Although it may be the first Workshop of its kind in Singapore, I feel confident that this Workshop will be the forerunner of many more to come. The succeeding workshops will probably be held in other capitals of the countries in the region.*

I would also like to take this opportunity to thank each and every member of my organising committee and sub-committees, the Asia Foundation and all those who have given us support without which this Workshop would not have been made possible. In conclusion, I wish the Workshop every success.

OPENING STATEMENT BY PROF. GERARD A. ROHLICH
National Academy of Sciences of The U.S.A.
Co-Chairman of the Workshop

Honourable Minister, Mr. Lim Kim San,
Dr. Lee,
Members of the Conference,
Ladies and Gentlemen:

It is a very distinguished honour and privilege for me to be here to speak on behalf of the National Academy of Sciences of the U.S.A. First of all, I bring you greetings from Dr. Philip Handler, President of the National Academy of Sciences and from the Foreign Secretary, Dr. Harrison Brown. I think it is particularly significant that the Science Council of Singapore and the National Academy of Sciences of the U.S.A. have joined hands in sponsoring this particular Conference.

I wish to draw attention to some significant points with regard to the Conference which appear obvious. First, the word "environment" is added. I believe that not many years ago if this Conference were held in Singapore, New York or in any other city or country the title would be "Water Resources and National Development". Now it is "Water Resources, Environment and National Development". This is a reflection of the interest of the public. It is a reflection that in the past few years there has developed great public concern over development and the environment, whether it be development of water resources or other natural resources that a country may possess.

Another significant point is seen in the various papers presented. There is a relationship indicated in many of the papers that scientists and technologists no longer are considering science and technology only as the wherewithall to accomplish specific goals, but are realising the necessity for making inputs to the economic, social and political aspects of particular problems. We must realise that this responsibility has come perhaps only recently from the scientific community in realizing the relevancy of their scientific and technological work to environmental impacts. This is a particularly significant development, and one we can explore in the many facets of this particular conference where we will have our attention directed to technological assessment. In the prelimary steps the problem is tackled but the secondary and tertiary effects that arise from technology and resources development must be evaluated.

Again it is indeed a pleasure to participate and I look forward to this Workshop — a busy one I am sure, and with the promise of being a very fruitful one, particularly in view of the excellent programme that has been arranged by the Science Council of Singapore.

Thank you.

INAUGURAL ADDRESS BY MR. LIM KIM SAN
Minister for Education and Chairman of the Public Utilities Board

Mr. Chairman,
Distinguished Participants,
Observers and Guests,
Ladies & Gentlemen:

The Chinese say that water is the source of wealth. It is more than that — it is the source of life itself. For billions of years after our planet was formed, it was incapable of sustaining any form of life. It was only after the earth had been cooled by torrential rains for thousands of years and the oceans and rivers had formed that life in its simplest form emerged. Many more millenia passed before the ancestors of modern man appeared on the scene. The first human settlements were invariably located along river banks, close to a supply of water. Today, after many civilisations have come and gone, we are no less dependent on water for our survival than our primitive ancestors.

And yet, in cities throughout the world, the instant availability of water is something that is taken for granted. Everybody expects water to flow out of a tap. No thought is given to the source of supply at the other end, to the huge investments of money and manpower required to maintain this service. Worse still, a great deal of water is wasted unnecessarily and measures to combat wate. pollution receive scant public support. Water has become so much a part of everyday life that no one pauses to consider what would happen if the taps suddenly ran dry.

Water is not the only thing we cannot live without. Clean air is another. If the air we breathe is no longer fit for breathing, then all human activity becomes meaningless. Why talk about development or GNP or peace or international understanding when the human species is threatened with extinction?

Within the last 100 years or so of his 50,000 years on earth, Man has acquired the power to change his environment. So far, the changes have all been for the worse. These changes have been brought about mainly by the greatly increased use of energy in recent times. According to one estimate, half of all the energy consumed by Man in the past 2,000 years has been consumed in the last one hundred. Coupled with the explosion in population and knowledge and the scientific and technological breakthroughs, this enormous expenditure of energy has produced a variety of goods and services for human consumption. In the process, Man has produced immense quantities of waste which he finds increasingly difficult to dispose of. He piles it up on land to desecrate the countryside; he spills it into rivers and lakes and seas to pollute the waters; he discharges it into the air to poison himself. Perhaps too late, Man has awakened to the fact that he cannot upset the cycle of life without paying for the consequences. This rapid deterioration *in the quality of life has in recent years caused worldwide concern, to the extent that the United Nations will be convening an international conference on the human environment in Stockholm in June this year.*

In my opinion it is a mistake to think that environmental quality concerns only the highly industrialised nations, that pollution is a disease peculiar to the developed countries, and that developing countries have more urgent problems to solve than problems of the environment. On the contrary, developing nations, embarked as they are on major schemes of development, should consider each and every scheme in terms of its impact on the environment. They have the unique opportunity of learning from the mistakes made by the developed nations. They are starting off with a clean sheet. In the long run, prevention is not only better, but also cheaper, than cure.

The purpose of the Workshop we are engaged in is to identify the problems of water resources in particular, and of the environment in general, in relation to national development. We have among us distinguished participants from many Southeast Asian nations who are in a position to influence their countries' future; we have scientists of international repute who are specialists in various fields of environmental science; we have keen observers from international agencies and private foundations who have the necessary resources to provide assistance to regional projects to preserve and conserve the environment. To all these important people, I extend a very warm welcome to Singapore. I hope that your discussions will be both stimulating and fruitful, and your stay both beneficial and enjoyable. With such a meeting of minds, I have no doubt of a successful outcome.

I now take great pleasure in declaring open the Workshop on Water Resources, Environment and National Development.

PLENARY SESSIONS

The First Plenary Session was held on the first day to spell out the problems, and the Final Plenary Session on the last day to adopt the recommendations made.

At the First Plenary Session, the Workshop Chairman, Mr. Hiew Siew Nam introduced the subject and named the Workshop objectives. Keynote addresses were then presented by Mrs. W.S. Srimoerni Doelhomid (on behalf of Prof. J.A. Katili (Head of the Indonesian delegation), Dr. Pradisth Cheosakul (Head of the Thai delegation), Prof. Gerard A. Rohlich (Head of the U.S. delegation and Workshop Co-Chairman) and Mr. Khong Kit Soon (Member of the Singapore delegation). Texts of these addresses may be found in Appendix I.

The Final Plenary Session saw the formal adoption of recommendations made as a result of the Working Group discussions. These recommendations are given on page 29 of this report.

WORKING GROUP SESSIONS

Working Group Sessions were held on the second, third and fourth days of the Workshop. Three Working Groups were in session concurrently, each concerned with discussion on papers contributed in the following areas:—

Working Group I — Water Resources
Working Group II — Water Pollution
Working Group III — Critical Problems of the Environment

The Working Group proceedings are summarised in the next section of this report. Abstracts of papers contributed may be found in Appendix II.

SECTION B

WORKING GROUP SUMMARIES

WORKING GROUP I

WATER RESOURCES

Convenor: *Chong Koon Kee (Malaysia)*

Discussion Leaders: *Assoc. Prof. Gene E. Likens (U.S.A.), Prof. Raymond C. Loehr (U.S.A.), James K. Rice (U.S.A.), Gordon G. Robeck (U.S.A.), Sung Tsoong Tuh (Singapore), Prof. Gilbert F. White (U.S.A.).*

Rapporteurs: *Chang Kin Koon (Singapore), George F. 'Worts (U.S.A.).*

TUESDAY, MARCH 14, 1972 – WATER SUPPLY AND DEVELOPMENT OF RESOURCES

Water Requirements

Water is required for domestic, industrial and agricultural uses. It is difficult to estimate the water demand for each of these uses. Some factors that need to be considered in projecting demands are: population growth, increasing social affluence, minimum social and health requirements, change in water rates, improvement in technology, industrial growth. In the case of agricultural water, planning may be based on land area and available water supply.

Urban areas have a higher standard of water supply compared to rural areas. However, water needs in expanding suburban areas are not being catered for. A problem in water planning lies in the population migration from rural to urban areas. It is difficult to estimate water requirements in relation to this move.

Availability of Water

The sources of water supply are: surface water, groundwater and cloud seeding, each with certain limitations.

Groundwater development in Singapore is not very promising, but may constitute a substantial source of supply in other Regional countries and should be evaluated. However, there is a lack of expert groundwater geologists in the Region. As a source of water, cloud-seeding is of questionable value although it has been used to clear fog from airports and has been experimented with for the control of hurricanes. If floodwaters of rainy seasons can be conserved for use during dry seasons, this would provide another source of supply.

Land use affects water loss and surface run-off. When forests are cleared, surface run-off increases by 20-40% but water quality deteriorates.

There is a need for adequate hydrologic network for the planning of flood control, long term supply, reservoirs, dams, bridges and other structures. Water quality and sediment stations are also needed at the sites of gauging stations.

Development of Water Resources

In some countries, too many departments are involved in water management, resulting in difficulties in water planning.

Floods are problems in many areas. Multi-purpose dams and dikes can be used for flood control. Adequate flood warning systems are also needed. It is desirable to separate storm water from sewage so that the former can be cleaned up for use.

Sedimentation of lakes and channels can destroy fisheries. In Malaysia, the relation between land management and sedimentation is being studied in an experimental watershed.

Off-channel storage has certain advantages. In areas which are flood-prone during rainy seasons and have low flow during dry seasons, storage reservoirs should be provided in upland areas and soil conservation carried out. This would be a partial solution towards the problems of finding the most economical way of developing such water resources. Barriers can be constructed in coastal areas to prevent contamination of rivers and aquifers by salt water.

Water loss by evaporation can be controlled by using mono-molecular films. However, the success that has been achieved so far is only moderate.

WEDNESDAY, MARCH 15, 1972 – WATER QUALITY, RE-USE AND MANAGEMENT

Water Quality

Water quality can be defined by physical, chemical and biological parameters. Varying standards for water quality have been adopted by different countries due to different interpretations of what constitutes pure, wholesome water, and also to attempts to supply this water at moderate cost. Certain standards have been set by the World Health Organisation which are followed in most of the Regional Countries.

In the United States, different criteria for water quality are adopted for the different uses to which water is put. Here the standards of drinking water need to be updated and upper limits set for pesticides, mercury, etc. In the case of industrial water, quantity is more critical than quality because modern technology is able to upgrade quality to the desired level. The type of industrial processes and products are important determining factors for the quality of industrial water. The quality of water intended for agricultural use however, depends on the type of crops being grown.

DDT and other pesticides are known contaminants of water. The effect of DDT on human beings when absorbed through the food chain is so far known to be only minor, but the effect on the ecology might be considerable. Mosquitoes, for example, build up an immunity towards DDT and other pesticides have to be employed.

One of the ways in which water supplies may be polluted is by permitting reservoirs to be used as recreational areas as well. Good judgement and proper control in this case have to be exercised. Pollution may also occur when there are undesirable biological growths in the pipelines that carry water supplies.

In the treatment of water, there is a need to organize treatment techniques in Regional countries. Sometimes water has to be given complex treatment to render it safe for consumption because of chemical waste discharge not only from industry but also from private households. It is desirable to group together water systems in order to achieve better water management and more efficient operations. Personnel should also be trained to manage and operate treatment plants and their status raised.

Re-use of Water

Water should be re-cycled on a "planned re-use" basis, with water of varying qualities used for different purposes. Dual supply systems can be provided in which salt water can be supplied for non-potable domestic uses. In Singapore, it is planned to use reclaimed water for toilet flushing in the new flats of Jurong Town. It is estimated that in Britain, about 11 gallons of water out of 31½ gallons used per head per day in households, is for the flushing of toilets.

Desalination

Desalination is now in wide use and is expanding. Scientists are actively engaged in the design of very large plants, the largest now in operation having a capacity of 10 mgd. The reverse osmosis unit is being studied for wide usage in small installations, and promises prospects for water reclamation. The cost of potable water produced by desalination techniques is constantly decreasing as the technology improves.

Economics

Economic analysis, commonly expressed as a benefit/cost ratio is a necessary step in securing funds for water projects. Unfortunately, many of the benefits cannot be expressed in monetary terms. Cost analysis involves choice of alternatives, and often this is over-ridden by political aims. The whole subject of economics is now complicated by environmental impact evaluation. The World Bank which expects a modest rate of return from projects, supports consideration being given to social benefits in project feasibility evaluations.

Funds loaned for rural water supply projects should not be expected to realise immediate financial returns, but should be considered as a social service to improve the health of the community, thereby uplifting the overall national economy. Self-help schemes, whereby the local population contribute free assistance, can be used to develop water supplies for small communities, thus reducing the amount of capital investment. This has already been done in some countries.

Priority of need is an important factor in the allocation of funds for water projects in hydro-electric power, agriculture, public supply, etc. Efforts should be made to plan projects for multi-purposes.

Water Resources Management and Planning

The main objective of water management and planning is to encourage the efficient use of water and reduce pipeline losses to a minimum by waste detection systems. In Singapore savings were achieved by reclaiming backwash water, and attempts made to catch and collect as much rainwater as possible. Singapore, Hong Kong and Israel are acknowledged leaders in the use of all possible sources of water supply. Compilation of an inventory of all available water resources is an essential step in water planning.

Co-ordination is essential among all agencies involved in water planning development and management. The Water Resources Council was formed in the United States for the purpose of co-ordinating water planning for both short and long term uses. Its function is also to co-ordinate the activities of all water and related government agencies in the United States, as well as to create a river basins commission. Several countries indicated that similar bodies have been formed in their countries.

THURSDAY, MARCH 16, 1972 — EDUCATION, RESEARCH AND TRAINING

Education and training for professional and sub-professional staff engaged in water resources development should cover other related sciences such as social and biological sciences. Research on water resources development should also be conducted to solve new problems such as the collection and treatment of polluted raw water, and the re-use of treated water. In the United States there is a lack of training programmes for sub-professional staff, but this will be rectified in the next 5-year training programme.

Many students from Regional countries failed to return to their own countries after training in the United States and other western countries. The resultant "brain drain" problem has been solved with some success in the United States, by providing training only in selected fields for foreign students.

The need exists for the establishment of a regional training programme for environmental control including air pollution, for the Region. Training facilities could be set up within the Region. Oil companies would be prepared to support such a regional training programme. Training and research programmes must however be geared to the needs of each individual country.

WORKING GROUP II

WATER POLLUTION

Convenor: *Bienvenido N. Garcia (Philippines)*

Discussion Leaders: *Assoc. Prof. Gene E. Likens (U.S.A.), Lye Thim Fatt (Singapore), Prof. Donald J. O'Connor (U.S.A.), Prof. Daniel A. Okun (U.S.A.), James K. Rice (U.S.A.), Prof. Gerard A. Rohlich (U.S.A.).*

Rapporteurs: *L.D.J. Chelliah (Singapore), Prof. Donald J. Hood (U.S.A.), Wong Yew Kwan (Singapore).*

TUESDAY, MARCH 14, 1972 — WATER POLLUTION AND CONTROL IN INLAND WATERS

Necessity for Water Pollution Control

Water pollution control is fundamental to the sound development of any country. Despite this generally accepted principle, clean water is often neglected in the interest of more visible activities such as construction of buildings, roads, schools and public edifices. Since prevention of pollution is more satisfactory than elimination, it is important that the often apathetic attitude of emerging nations about pollution be corrected early lest serious health and water resource problems arise. Delay in doing this can result in the costs of correcting heavily polluted water courses increasing to levels that may be beyond the ability of the people to pay.

Pollution correction and abatement must begin early in a nation's industrial development history. High priority at all levels of government must be given to water pollution and waste management if a country wishes to assure continued growth and a high quality of life for its people.

Treatment of Sewage

Inexpensive, easily maintained waste disposal methods for the developing countries are a necessity, since sophisticated treatment plants are expensive to build and require highly-skilled personnel to operate. Even if such personnel is available, they are usually involved in other high priority problems of the country. Fortunately much can be done to guard against pollution by using simple land- and labour-intensive abatement systems. Such systems should be utilized at the early stages of devleopment.

As industrial development progresses and population centres grow, it will then be necessary to move ahead towards fully-integrated waste treatment and disposal systems. Large central facilities for treatment of compatible industrial and municipal wastes, rather than proliferation of many smaller plants are usually desirable. The large plants can operate more efficiently and also have the advantage of being able to employ more highly-skilled personnel. It will, nevertheless, always be necessary for industrial plants to treat their own wastes to a level compatible with the requirements of the central treatment plant, and to accomplish the maximum benefits from waste recovery and re-cycling procedures. Plants should be designed to maximize water re-cycling with a high quality effluent component which will meet potential effluent standards that may be imposed.

Standards for Effluent Water

Standards for effluents should be set by every developing country or group of countries in co-operation with industrial, academic and government representatives. Much help in setting these standards can be obtained from developed countries but the standards set should be tailored to the situation of each locality. Blanket standards for large regions may be administratively attractive but are usually environmentally unsound. In setting standards, every effort should be made to regard the entire water-course, bay or estuary as a system with special consideration given to potential water use.

Standards should be realistic and should strive to give maximum cost-benefit to the community. Once standards are set they should be changed according to new information and water quality needs, but changes should be orderly so as to provide sufficient time for phasing into the new program, without imposing unreasonable financial hardships on those who must comply. Standards once set must be fully enforced.

Instilling Public Awareness

High quality water resources in any country is only brought about by constant vigilance and total public awareness of the importance of water to the quality of life. Public health education at all levels is probably the most effective way to ensure the maximum potential utilization of any country's water resources. The developing countries should now begin to educate their people and avoid many of the pitfalls faced by the developed countries.

WEDNESDAY, MARCH 15, 1972— OIL POLLUTION AND SEA POLLUTION

Slop Oil

The various methods of treating slop oil were discussed. The residual sludge could be disposed of by incineration or landfill.

The dangers of untreated discharge were recognised, and the need for ports to provide slop oil disposal facilities was stressed. It was noted that in providing such facilities, major costs incurred would be in building and maintaining the necessary quays and wharves.

Discharge of Sewage into the Sea

It was suggested that the standard of discharge should vary according to what use the sea is put, and that it should not give rise to offence. Based on studies and data collected, mathematical models can be constructed to determine the best locations of waste discharge points.

As nutrients are not appreciably removed by inland works, there should be no necessity to remove them from discharges into sea. Studies in the Region indicate that marine life is not affected by effluent from treatment plants handling domestic sewage. However, there was concern over the impending discharge from plants which would treat toxic industrial waste.

Standards for Discharges into the Sea

In setting standards, there is a need to understand the assimilative capacity concepts of receiving waters. Otherwise, it will be necessary to establish standards based on worldwide experience in order to initiate pollution control measures.

Authorities might tend to establish standards on the conservative side, whilst industry might choose more liberal requirements.

The period for introducing and enforcing pollution control requirements is important, as industry is concerned about possible early amendments which will necessitate the premature writing-off of expensive equipment.

The control technology available should be reviewed regularly, and there should be a realisation of the enforcement personnel required. It was noted that standards should be set to achieve realistic objectives, and should be capable of being easily administered.

It was also suggested that for industry, standards should be based on the quantity of pollutant per unit of product.

Handling of Oil Spills

The need for regional co-operation was recognised, and the important recommendation made that a regional environmental control organisation be set up. There was a need for the regional countries to act immediately, and to formulate emergency measures.

The recruitment of all possible resources from neighbouring Regional countries is more economical, and the combined effort will achieve better results. The need to waive normal customs and immigration procedures in this connection was stressed.

It was noted that mechanical methods were more suited for calm waters, whereas dispersion methods should be used in rough seas with strong winds and large waves.

It was emphasised that proper pre-planning to determine possible areas of accidents, the condition of the sea, and the type and quantity of standing equipment and materials required to handle the size of spill envisaged, would result in successful operations.

It was also mentioned that certain types of spills, such as "white oil" were not worth handling. It was also pointed out that there is much literature on this subject which could be easily made available.

THURSDAY, MARCH 16, 1972 — EUTROPHICATION AND OTHER BIOLOGICAL PHENOMENA

Phyto-Plankton Distribution

Some work has been done on the tolerance levels of chemical nutrients in water in relation to algal bloom. The findings are limited as they covered only the relationship between phosphate levels and phyto-plankton distribution. Water samples from Seletar, Pierce and MacRitchie reservoirs in Singapore indicate that blue-green algae dominated in the more eutrophic water of Seletar Reservoir. The probable cause of this has been attributed to its higher phosphate levels. This in turn is possibly due to farming activities as well as synthetic detergents. Nitrates were discounted as a possible cause because there did not appear to be any correlation between nitrate levels and algal bloom.

As some rain waters are known to contain a very high proportion of various chemical radicals such as phosphate, sulphate and nitrate, they should be analysed. Near the Jurong Industrial Estate in Singapore, the sulphate values of water samples were relatively higher than normal, and could be due to the sulphur dioxide in the industrial aerial effluents.

Blue-Green Algae

Blue-green algae were observed to be formed in fresh waters in Singapore although they are calcium-poor and of low pH. Algae predominantly of the *Anabaenoid* group can proliferate when fish are fed in ponds.

Control of Plankton Population

It should be borne in mind that it would be much better to prevent the creation of environmental conditions favourable for bloom formation rather than remedy the ill-effects of algal blooms. Amoebae are possible predators of the blue-green algae. Fish culture can also help in controlling the algae.

Results of studies should eventually lead to the formulation of raw water standards. However, instead of looking at factors one at a time, a multivariate analysis (e.g. Principle Component Analysis) was needed for the study of many factors and organisms at the same time. Such an analysis would eventually reveal all the component factors at work leading to the proliferation of undesirable algae. From this tolerance levels for different nutrients can be set. This analysis can be applied to data on plankton population and nutrient levels of a body of water which has been pronounced impotable.

Mariculture

Various projects have been undertaken in Singapore to study a red seaweed of commercial importance, a local oyster, a green mussel and a local marine fish *(Chanda kopsii).* It is hoped that the organic pollutants would provide nutrients for commercially important marine organisms. However, ecological conditions may be changed by channelling industrial effluents into the sewers as they will eventually find their way into the coastal waters.

Harmful Effects of Water Pollutants

In Vietnam, following complaints of fish life having been affected by polluted waters, a bio-assay method for the study of industrial effluents has been carried out with gold fish as the test animal. Findings indicate that effluent water from factories manufacturing hydrochloric acid and certain alkalies are less toxic than effluent water coming from factories manufacturing galvanised materials and textile materials. Toxicity values from these various sources of water correlate very well with the BOD values of the water. Investigation has been extended to cover lake pollution by pesticides. It has been found that water near the shores of the lake had high toxicity levels whereas water at the centre of the lake seemed to be free from toxic materials.

Preliminary findings suggested that 2,4-D and 2,4,5-T, two commonly-used defoliating chemicals, can cause embryonic damage to organisms. Furthermore, studies in certain parts of the United States show that forest trees can have a very efficient hold on the nitrate contents of the ecosystem but once deforestation takes place, the nitrates can be leached out of the soil and can find their way into the streams so much so that the nitrate content of the water can be more than double the tolerance levels permitted in drinking water.

WORKING GROUP III

CRITICAL PROBLEMS OF THE ENVIRONMENT

Convenor: *Prof. Le Van Thoi (Vietnam)*

Discussion Leaders: *Chua Peng Chye (Singapore), Dr. Goh Ewe Hock (Singapore), Assoc. Prof. Gene E. Likens (U.S.A.), Prof. Raymond C. Loehr (U.S.A.), Prof. Daniel A. Okun (U.S.A.).*

Rapporteurs: *S. Nadesvaran (Singapore), Prof. Donald J. O'Connor (U.S.A.) Prof. Daniel A. Okun (U.S.A.), James K. Rice (U.S.A.).*

TUESDAY, MARCH 14, 1972 — BUILT AREAS

Environmental Problems

Many problems common to the region exist, and these are found in varying degrees. Air, water and land pollution and unsatisfactory housing conditions are found particularly in the urban/metropolitan areas. South Vietnam faces the unique problem of defoliation because of the war.

There is diversity and separation of responsibility and authority in the implementation of public projects, examples of which are public housing, disposal of refuse, construction of roads, etc. with respect to environmental control. This appears to be a common problem.

It is necessary to seek a balance between economic development and environmental quality. Although some compromises may be made initially, a long range plan to improve pollution control should be formulated now. Involvement of social, economic and political scientists in the analysis of the problems and in the formulation of plans is necessary. There exist problems associated with the enforcement of environmental quality standards.

Waste Disposal

There are probably more elements common to Regional countries, in problems of refuse disposal than in any other areas of environmental quality.

As with other areas of environmental quality control there are residues which affect other elements of the environment, e.g. water pollution from the sanitary land-fill and solid residue from the composting plant. It is an area in which political considerations are involved as well as other aspects. Data is needed not only with respect to the needs of designing the first stage of disposal but also with respect to its residual effects.

WEDNESDAY, MARCH 15, 1972 — URBAN LIVING

Education, Development and Research

Education and training for the technical fields involved in the management of the environment need to be initiated and expanded. Such programs are necessary for operating personnel and technicians as well as for professional and scientific personnel.

The type and quality of education are important factors in stimulating development. There is therefore a need to re-examine the type and quality of education with respect to the national goals of development.

Development can be impeded if Man is incapable of curbing the less favourable consequences of technology, if there is no concern for other values besides the economic, and if individual nations cannot find "local" solutions to "local" problems but borrow wholesale, ideas from other nations.

To solve the problems of development, then, there is the need for research and action to go hand in hand, involving the co-operation of scientists and administrators from various fields of studies.

Mental Health

An aspect of urban living that has been receiving a lot of attention lately is that of mental health. The urban environment tends to aggravate the factors associated with mental ill-health, e.g. social isolation, depersonalizing and dehumanizing milieu with a diminishing regard for basic human rights and possible cultural conflict leading to deculturalization. There is therefore a need for research and understanding of the socio-psychological aspects of the urban environment so that mental illness can be prevented or lessened.

Solid Waste

An analysis has been made of solid waste refuse in Singapore over a 9-year period. The salvage potential of refuse by separation at source should be further looked into. There is a need for a regional data collection centre.

Litter control in Singapore is being tackled in two phases:—

(a) By education and persuasion through various media, e.g. public health campaigns, display of posters, etc.

(b) By enforcement through effective legislation — the Environmental Public Health Act provides for fines of up to S$500 for first offences and S$2,000 for subsequent ones.

A need exists for up-to-date and time-series statistics. Enforcement must be vigorous to achieve success but a period of education must be allowed.

Health campaigns in the developing countries can improve the tourist trade.

Mosquitoes

It has been shown that the *Culex* larvae in Singapore is resistant to DDT, possibly because of the presence of this insecticide in the soil. The control of the mosquito vector in Singapore was also discussed, and delegates expressed the desire to share the experience gained by their Singapore counterparts.

Hawkers and Markets

According to a hawker census carried out in 1968/69, there were some 25,000 hawkers in Singapore. There is a need to control these hawkers by re-siting them and later, improving such allocated sites by the provision of proper drainage and washing facilities.

Eating from hawker stalls is a way of life in Regional countries, and their total eradication is not necessarily desirable in the immediate future.

Environmental Health in the Philippines

The Filipino delegation reported that there is inadequate control generally of health problems in the Philippines for the following reasons:

(a) Geographical pattern of the country with 7,100 islands and the provincialised system or decentralised setup of the Department of Health, and

(b) There is a poor system of communications between different government agencies having identical or allied objectives towards the enhancement of environmental health.

The main problem is water supply — 80% of the population is without safe water supplies. The next biggest problem is the disposal of excreta, air pollution being less acute. The disposal of solid waste is often by dumping. More money has been spent on curative medicine than on prevention.

Air Pollution

Surveys carried out on quarry workers have shown an increase in the incidence of silicosis. This may be attributed to the lack of dust control measures. There is therefore a need for control measures to be adopted.

In Sweden the rainfall and snow show a high incidence of acidity, with pH ranging from 5.7 to 3.0. This can lead to many adverse effects, such as loss of nutrients in soil, increase in plant diseases, detriment to marine life, and corrosion to buildings. More data on the pH of rainfall in Southeast Asian countries is needed.

THURSDAY, MARCH 16, 1972 — CONCLUSIONS

There are many problems common to countries in this region. The solutions may vary because of differences between areas where economic development permits full employment and areas where unemployment is a problem, and also because of differing social and cultural patterns.

Political backing is absolutely essential to tackle pollution problems. Public support is also necessary especially since political backing is required. Anti-pollution measures cut across the responsibilities of many governmental departments. Therefore, it is necessary to establish the control department at a very high level so that effective action can be taken.

Trained personnel is difficult to obtain, and therefore staffing poses a problem. It is important to choose able and dedicated persons as they would be able to benefit most from training and speedily pass on the expertise.

A central theme is the very real and immediate need to establish a Regional Environmental Control Organisation. This body would have the advantage of size and hence can undertake programmes which individual countries would not be able to afford. In addition, it would provide facilities for the distribution and dissemination of information. It is recognised that air, water and noise pollution cut across international boundaries, and can constitute political problems especially when the tempo of industrialisation increases. To minimise conflict there is therefore a need to establish such a regional organisation at a very early date.

SECTION C

RECOMMENDATIONS

RECOMMENDATIONS

NOTING the experiences of developed countries where environmental pollution is now causing grave concern, the importation of western technology into the Countries of the Region for economic and national development, especially in the development of industries and essential services like water supply, power and communications, should not bring in its wake or repeat such deterioration of the environment as to adversely affect the ecology in the Countries of the Region and be detrimental to the health and well-being of their people;

APPRECIATING that in the development of cities and urban areas of the Region, the provision of a safe water supply and an effective waste collection, treatment and disposal system are essential requirements, there should be no compromise in the obtaining and the supplying of an adequate and safe water supply;

REALISING also that for an assurance of a continuing supply of safe water for the increasing needs of the people in the Countries of the Region, including uses for agriculture and industries, pollution of both surface and ground water will have to be prevented, so that the present sources of supply can continue to be available and further sources can be developed;

THIS REGIONAL WORKSHOP ON WATER RESOURCES, ENVIRONMENT AND NATIONAL DEVELOPMENT HEREBY MAKES THE FOLLOWING RECOMMENDATIONS:—

1. **Conservation of Water** — It was recognised that great quantities of potable water are unnecessarily wasted. More information and data should be collected on minimum social and health requirements so that effective measures can be taken to reduce water consumption.

2. **Water Requirements in Urban Areas** — The water supply in most cities of the Region cannot cope with the rapid increase in water demand due to the large migration from rural areas. As shortage of a potable supply results in health hazards, catering for this demand should be given priority in water planning.

3. **Water Requirements in Rural Areas** — Because of high capital costs and low rates of return, it was recognised that there are difficulties in securing funds for water-supply projects in rural areas. Hence, more attention is needed by the controlling authorities of funds, on the intangible benefits such as control and reduction of water-borne diseases, improvement in the standard of living, and other social benefits derived from water-supply projects.

4. **Need for Hydrologic Data** — For water planning and the design of water structures, hydrologic data is required. Adequate hydrologic network as well as water quality and sediment stations must be established as soon as possible, if they do not already exist.

5. **Groundwater** — There is a great need to carry out groundwater surveys and development in the Countries of the Region. It was recognised that there is a shortage of hydrogeologists.

6. **Re-cycling of Used Water** — The rapid increase in water demand on one hand, and the limited water resources on the other, was noted. As a solution to the problem, when available water resources have been fully developed, consideration should be given towards supplying water of different qualities for selected uses, and to planned re-use.

7. **Treatment of Used Water Before Discharge** — The pollution of the environment by industrial wastes should be minimised by requiring and incorporating in industrial plants, facilities for the treatment of such wastes sufficient to ensure no undue deterioration of the receiving waters, or damage to the sewerage and waste disposal system.

8. **Central Treatment Plants** — For maintenance and administrative reasons, treatment of wastes should be carried out where possible in central treatment plants, rather than proliferating smaller units.

9. **Minimising Waste in Effluent Water** — Disposal of wastes by dilution and dispersion alone may not be a total solution to the pollution problem, and good housekeeping to review and improve industrial processes towards the removal of injurious material and re-use of recoverable components of each waste is advocated.

10. **Effluent Standards** — Waste treatment requirements and effluent quality standards for both domestic sewage and industrial wastes should be established, and should be realistic and commensurate with the capacities of the receiving waters to assimilate such effluents.

11. **Adaptation of Technology** — Present knowledge of waste treatment techniques should be modified and adapted to the environmental conditions in the Countries of this Region so as to make maximum use of the land and labour potentials to meet the essential criteria of simplicity of design, construction and operation in preference to more sophisticated or intricate equipment and mechanism.

12. **Public Housing** — Public housing may be regarded as an economic development step since it stimulates growth particularly of the construction industry, and is able to absorb a substantial number of unskilled or semi-skilled labour. Unless otherwise dictated by the economic situation in a given country, public housing should receive higher priority.

13. **National Co-Ordinating Bodies** — A central body should be set up in each of the Regional countries to co-ordinate *water planning* for both short-term and long-term developments. This will help to ensure that water resources are developed not just for immediate single-purpose uses, but integrated into overall planning. Similar bodies should likewise be set up for *environmental control*, and to be effective, must be given the highest possible level of authority and support in the government.

14. **Priorities and Action Programmes** — The type and scale of pollution problems should be identified and clear priorities established so as to optimise the use of limited financial and technical resources. In doing this, the interest of the human being in the society and environment should receive prime consideration. Action-oriented programmes to deal with the problems of planning, management and control of the human environment for economic and social development should be initiated by national environmental control bodies.

15. **Training and Research** — Training at all levels of skill should be carried out in hydrogeology, and in the operation and maintenance of water treatment plants. Research and training at all levels should be carried out in environmental engineering, under conditions prevailing in the Region, and in Regional institutions.

16. **Public Awareness** — Every effort should be made to encourage greater awareness on the part of all sections of the public to the conservation of water in quantity and quality, and to the problems of environmental pollution. Such awareness should be inculcated through education and the mass media.

17. **Regional Co-Operation in Sea Pollution** — Immediate formulation of an emergency operation plan for the pooling of resources in the Countries of this Region, and the deploying of men and equipment quickly without any time-consuming procedures of protocol, customs and immigration clearance, is required to deal with pollution of the sea by oil and other hazardous material, especially those associated with major incidents.

18. **Regional Environmental Control Organisation** — Formation of a Regional Environmental Control Organisation, to perform such tasks as enumerated below, will facilitate and enhance the efforts of the engineers, scientists, planners and administrators in conserving the environment for the health and well-being of the people in the Countries of this Region:—

    (a) the collection, collation and dissemination of research, practical data, and experiences of the Countries of the Region in environmental control activities,

(b) the exchange of scientific and technical experts,

(c) the training of personnel, and

(d) the exchange of ideas and experiences in seminars and workshop sessions, etc.

The setting up of the Regional Environmental Organisation is recommended as a first, but necessary step towards combating the many common environmental problems of the Region.

19. Assistance from the Developed Countries — The developed countries should give every assistance, including funding, training of personnel and advisory services, towards making the formation of the Environmental Control Organisation in this Region a reality.

APPENDICES

APPENDIX I

PLENARY ADDRESSES

INTRODUCTORY STATEMENT BY MR. HIEW SIEW NAM, WORKSHOP CHAIRMAN

May I call to order the First Plenary Session of the Regional Workshop on Water Resources, Environment & National Development. First, I wish to convey the Organising Committee's profound gratitude for your presence here today, particularly to all our regional and international Panel Members and also overseas and local participants who have responded so enthusiastically to our invitations. As a matter of fact, this Workshop has aroused considerable interest in both developed and developing countries the world over. This is not unexpected as the topics chosen for discussion, namely, "Water Resources, Environment and National Development" are not only of global interest but they are matters of vital concern to many countries, both within and outside this region.

Singapore, as you all know, is an island Republic with only 225 sq miles of land area. Due to population growth and rapid industrialisation, land use has become more intense and this coupled with the accelerated pace in urbanisation will exert enormous pressure on transportation, sanitation and other public services and amenities such as water supply.

A good and adequate water supply is a pre-requisite in any national physical development plan. However, faced with the problem of limited land area which is made worse by mounting demands for large land areas for recreational, education and health institutions by a progressively affluent and sophisticated population, a difficult balance has to be struck in maintaining enough areas for water catchment purposes without retarding physical growth and development. To supplement land requirements for water resources, every stream and river in the Republic will have to be rendered pollution-free for impounding and extraction purposes so that more use can be made of the abundant rainfall which falls in the Republic.

Water resources development and effective pollution control involve very complex environmental problems which require considerable experience and expertise for comprehensive solution. These expertise and resources are presently lacking not only in Singapore but also in this region. It was, therefore, thought that a Workshop on these problems would be most timely and beneficial. As these problems are common and of serious concern to countries in this region, it was decided that Singapore will host this Regional Workshop as a first step towards regional co-operation.

Towards this end, the Science Council of Singapore and the National Academy of Sciences of the U.S.A. have, as early as September last year, agreed to proceed with the organisation of this Workshop. Several meetings were held subsequently with representatives of the National Academy of Sciences and also top scientists from the Regional countries. The final Workshop structure and form of proceedings, etc. were than agreed on, finalised and adopted.

The adopted proceedings and time-table of the Workshop are as set out in the information programme circulated. In this plenary session, there will be five keynote addresses by the following panel members:—

1. Mrs. W.S. Srimoerni Doelhomid, Hydrological Engineer, Indonesian Institute of Science (on behalf of Prof. J.A. Katili)

2. Dr. Pradisth Cheosakul, Head of Delegation from Thailand; Secretary-General, National Research Council; Chairman, Committee on Environmental Quality Control

3. Dr. Gerard A. Rohlich, Head of Delegation, U.S.A., University of Texas

4. Mr. Khong Kit Soon, Panel Member, Singapore; Chief Water Engineer and Acting General Manager, Public Utilities Board, Singapore

These keynote addresses will give some background information on the water resources and environmental problems of the countries concerned and will also focus on the role of water in urbanisation, health, industrial and agricultural developments.

After this opening session the next three days will be devoted to Workshop discussions. The Workshop will be split into three Working Groups running concurrently, each dealing with a specific topic. The Workshop will close on the fifth day with a Plenary Session where recommendations of the various groups will be brought up for discussion and adoption.

Convenors and discussion leaders for the Working Groups are as follows:-

Working Group I: Water Resources
Convenor: Mr. Chong Koon Kee, Malaysia
Discussion Leaders: Mr. Sung Tsoong Tuh, Singapore and a panel member from the U.S. Delegation

Working Group II: Water Pollution
Convenor: Mr. Bienvenido N. Garcia
Discussion Leaders: Mr. Lye Thim Fatt, Singapore and a panel member from the U.S. Delegation

Working Group III: Critical Problems of the Environment
Convenor: Prof. Le Van Thoi, South Vietnam
Discussion Leaders: Mr. Chua Peng Chye, Singapore and a panel member from the U.S. Delegation

Response to our request for technical papers has been unexpectedly good but unfortunately most submissions could not meet our date-line, resulting in delay in the printing of these papers for early distribution to the participants.

With the limited time available, it is regretted that we have to impose a time limit to all participants who wish to present their views on any particular subject and it will therefore not be possible for every participant to present his paper. We very much regret this and I hope the convenors and discussion leaders of all Working Groups will exercise their discretion to ensure that agenda items are well covered within the time allocated. We would like to point out that a Workshop is unlike a seminar and its main emphasis is to identify problems and to seek and recommend solutions through discussions.

Therefore, it is hoped that the Workshop, besides establishing present-day trends and practices, identifying and recommending solutions to the problems faced by countries in the Region, will also try to achieve the following objectives:—

(a) Formulate strategies, identify research needs and suggest action programmes for the integrated use and protection of water resources in the region and in the participating countries.

(b) Establish criteria and procedures for selection of priorities for research on water and pollution problems.

(c) Strengthen the role of scientists and scientific institutions throughout the region in planning for a more effective use of water resources.

(d) Develop practical findings to guide decision-making in the planning units and relevant departments and ministries of participating countries.

(e) Encourage Regional co-operation on problems of protection and utilisation of water resources, and stimulate further regional initiatives on other topics of mutual concern.

(f) Identify and explore available solutions to the more critical and urgent environmental problems of the Region.

(g) Deliberate on the Region's physical growth processes and potential, and consider ways in which national physical development plans can be accelerated without aggravating environmental problems or creating new ones.

(h) Establish a more satisfying means of exchanging experiences, research findings and know-how, so as to deal, on a concerted regional basis, with critical environmental problems common to the region such as the establishment of a Regional Environmental Control Organisation.

These may appear to be ambitious, but with the aid and guidance of our foreign scientists and specialists and with the close co-operation of the regional experts, I am confident that much can be achieved.

I hope you will find this Workshop a useful and rewarding experience.

Thank you.

KEYNOTE ADDRESS BY
PROF. JOHN A. KATILI, INDONESIA
(Read on his behalf by Mrs. W.S. Srimoerni Doelhomid)

POTENTIALS, UTILIZATION AND ENVIRONMENTAL PROBLEMS OF WATER RESOURCES WITH SPECIAL REFERENCE TO INDONESIA.

Water is essential to a wide range of economic activity as well as being a necessity to life. Because of its many uses water is one of the most important natural resources.

In urban areas like Singapore, water is mostly used by industry in generating power, cooling, flushing, washing and processing, while in the rural areas of Thailand, Philippines, Malaysia and Indonesia the agricultural use of water is dominated by irrigation.

The importance of natural resources in relation to development is well recognized in developing countries. Together with human resources, natural resources comprise our principal economic assets.

The countries of Southeast Asia are situated in the humid tropical region characterized by high temperatures, high humidity and abundant rainfall.

Geologically, Southeast Asia is the place of interaction of at least three gigantic crustal plates all of which are moving relative to each other. These interactions of the Indo-Australian, Pacific and Eurasian plates should be held responsible for the existence of hundreds of active volcanoes in the Indonesia-Philippines region, which in turn provide good aquifers such as lava, but which also create problems in that the rivers have to carry a larger load than usual.

With the growing population and rising standards of living in developing countries, the need and consumption of water is not only increasing, but pollution and the shortage of clean water are becoming major obstacles for our developing economies.

The problem of providing water is not only of concern to individual countries but also to the entire region, and can only be solved successfully through regional co-operation.

It is because of this necessity for regional co-operation, the similarities in climatologic, hydrologic and geologic conditions, the stage of the scientific and technological development of the countries in Southeast Asia that we consider this Workshop which has been initiated by the Science Council of Singapore to be of paramount importance.

Before dwelling in more detail on the water resources of Indonesia it is necessary to elaborate upon the development of natural resources in general since they are not independent of each other. The inter-relation and inter-dependence of natural resources can be illustrated by the fact that land erosion which may be caused by the illegal cutting of trees and deforestation can lower the potential production of hydro-electric energy in a river basin. Deforestation or reafforestation may also affect the climate, soil and other plants and animals.

Development of Natural Resources of Indonesia and its Impact on the Environment

Indonesia is an archipelago which consists of 18 large islands and some 3,000 small ones, covering an area of about 2 million square kilometres. The more than 500 young volcanoes, 128 of which are considered to be still active, make Indonesia the most volcanic country of the world. The highest mountain (more than 5,000 metres) is located in West Irian, covered by eternal tropical snow.

The Indonesian part of the ocean is quite large comprising a complex system of water ways, of shallows and deeps. Basically it consists of the broad, shallow Sunda and Sahul Shelves, and the intervening and bordering small, deep ocean basins.

In Indonesia every day of the year is sufficiently warm for the growth of plants and nearly everywhere the rainfall is sufficient to produce at least one crop a year without irrigation. Monsoonal winds affect the marine waters strongly since Indonesia is located between the Asian and Australian continents.

About 1.2 million square kilometres or 2/3 of the total land area is covered by forest.

Sixteen million hectares are used for agriculture. About 80 to 85% of the agricultural area is used for subsistence farming (rice and food crops); the remaining 15 to 20% is cultivated with commercial crops.

The current population amounts to 125 million which is unevenly distributed throughout the islands. About 75% of the whole Indonesian population lives in Java and Madura. It is estimated that with the present 2.6% rate of growth the population will reach 260 million in the year 2000.

The contribution of natural resources to the development of Indonesia both in the long term and within the framework of the current Five-Year Plan cuts across the major priority sectors such as agriculture, industry, mining and infrastructure, and is given attention in the plans and programmes of a number of key ministries.

The intensive exploration activities into Indonesia's natural resources may last for another ten or fifteen years for the following reasons:—

(a) The 120 million hectares of forests available have not yet been fully explored and exploited; and

(b) Out of the total land area of Indonesia only 5% has been geologically mapped systematically, 75% cursorily reconnoitred and the remaining 20% is still unknown, while the offshore regions are scarcely known.

There is currently a rush in forest exploration in the outer islands. The export of logs jumped from US$3.6 million in 1966 to US$90 million in 1970, and in 1971 reached US$150 million.

The majority of smallholders, who contribute about 65% of the total export, do not have much experience in this field, are after quick profits and do not pay much attention to the principle of sustained yield.

The large companies seem to be looking for long term investments. The problem here seems to lie not in the irresponsibilities of the companies but in the shortage of basic data for rational management of the forest resources.

At present more than 40 petroleum companies and 10 big mining enterprises are exploring our offshore and onshore areas. Since 1967 about a half billion U.S. dollars have been spent on exploration work even in the remote forests and mountains of Sumatra, Borneo, Irian and the other islands.

The offshore area between the islands of Sumatra, Borneo, Java and Celebes known as the Sunda Shelf is now totally covered by work areas of about 20 petroleum companies. Thirty-five prospects have been drilled since late 1968 with oil and/or gas being discovered in 50% of these ventures. Some 25,000 miles of seismic work and 45 test wells have been completed in this area. The shelf area bordering West Irian and the islands west of it is currently under exploration.

Large parts of Indonesia are being covered by mining companies prospecting for base metals, bauxite, nickel, tin, etc.

The major minerals currently in production are petroleum, tin, bauxite, nickel and gold, and within two or three years' time Indonesia will become one of the biggest copper-producing countries in Southeast Asia. Nearly 10% of the world's tin production is contributed by Indonesia.

Crude oil production has risen steadily over the last five years. In early 1972, production reached 1,000,000 barrels per day. Petroleum export has increased from US$330 million (1968) to US$366 million (1969), US$426 million (1970), US$552 million (1971), and is expected to reach US$1,014 million in 1972.

Only recently was oil discovered off the coast of the densely-populated island of Java. In 1970 at least 15 new oil fields and 5 new gas fields were found in Indonesian waters. Exploitation of this oil will doubtless bring with it all of the attendant problems of pollution and potential pollution which are faced in such a situation. The producing wells may affect fisheries which may cause the displacement of thousands of fishermen.

Most of Indonesia's minerals such as tin, bauxite, nickel and iron ore are the result of rock weathering under humid tropical conditions. Under special circumstances in which the decomposing rocks contain appreciable quantities of certain constituents, weathering may lead to the formation of residual mineral accumulation and mechanical mineral concentrations of economic importance. The minerals are concentrated at the earth's surface, and the mining of such deposits is usually carried out by stripping the soils which contain these minerals. It is well-known that strip-mining and open-pit mining have a very hazardous effect on the environment.

Open-pit or strip-mining can radically influence the environment. The change of the geomorphology of the mining area can readily be observed, such as the disappearance of hills, damming and changes in the courses of rivers, deforestation, and the forming of hundreds of metres of deep holes. Other changes in the environment which occur gradually are the lowering of the ground-water level with all its consequences, such as the disappearance of vegetation, increase of erosion, etc. The effect of open-pit mining in the tin islands of Bangka and Billiton can be seen in the barren landscapes, deeply-eroded hills and artificial ponds.

Another example which could be cited is the mining of bauxite in the island of Bintan. Mining of the bauxite ore is preceded by the removal of the overburden consisting of layers of soil 20 to 50 cm thick along with the vegetation and humus. Then followed the mining of the ore itself consisting of pebbles and hard concretions mixed with some clay. The remainder comprises hard clay. It can be observed that in areas which were mined 40 years ago, no vegetation, not even *alang-alang*, can grow.

The disposal of tailings in the sulphur mines of Wanaradja, West Java is another serious problem. It is beginning to affect the fertility of the surrounding areas. Similar problems as outlined above can also be expected very soon in the nickel-mining areas of Celebes and other islands in the eastern part of Indonesia.

In the field of agriculture, there are active efforts to increase production. The area brought under the intensification programme is steadily increasing from 9,900 ha in 1965 to 2,828,200 ha in 1970. The intensification programme has resulted in an increase in consumption of fertilizers.

Taking the population increase in Indonesia at about 2.6% a year it is estimated that the demand of nitrogen in 1972/1973 will be 750,000 tons above that of 1967-1968. The consumption of pesticides is also increasing. The pesticides include not only insecticides but also herbicides and fungicides.

Due to the completion of multi-purpose dams and the rehabilitation of existing irrigation ditches, thousands of hectares of land have currently been brought under irrigation.

The extension programmes have increased the harvested area of lowland as well as upland rice, i.e. from 4,780,500 ha in 1950 to 6,076,000 ha in 1967 for lowland rice, and from 919,125 ha in 1950 to 1,790,000 ha in 1967 for upland rice.

The expansion of the agricultural areas is achieved by converting forests into agricultural fields, by developing irrigation in new areas and bringing tidal swamps under cultivation.

It goes without saying that all these developmental schemes bring benefits to the country. However, as can be foreseen, all these efforts are also having an impact on the environment.

Not all of the fertilizers are absorbed by plants or fixed by soil colloids, particularly the nitrogenous fertilizers. Under upland conditions they are easily leached by high rainfall and, together with wastes from cities and farms, these nutrients have in some areas enriched the water of rivers and lakes which have caused eutrophication problems. The Rawa Pening Lake in Central Java is extensively overgrown with water hyacinth, to such an extent that it significantly reduces the power of the electric generators, and fish and rice yields.

The behaviour of pesticides under tropical conditions should be studied in more detail. There are reports that the persistent chlorinated hydrocarbons are readily decomposed under submersed conditions.

There are indications that pesticides are also influencing faunal and floral composition, such as shifts in the degree of importance of various pests, etc.

The completion of new dams and irrigation is expected to create problems such as schitomiasis. This disease is present in some of the lake areas in Central Celebes and it is not impossible that this parasite will be introduced into the densely-populated areas of Java.

Potentials and Utilization of Water Resources in Indonesia and Some Problems Involved

The large islands like Sumatra, Borneo, Java and Irian harbour the big rivers with discharges amounting to 2000 or more cu metres per second in the rainy season, while in the dry season the discharge may be only a fraction of it. The large lakes are also situated in the large islands but only a few of these have been surveyed for the generation of electricity. The alluvial plains mostly covered by swamps, are encountered in East Sumatra, South Borneo and the southern part of West Irian.

Being a country which is endowed with abundant rainfall —rainfall of 3000 mm per year or more is widespread — groundwater has been left virtually untouched in Indonesia for many years. Only recently have there been efforts to assess the country's groundwater potentials. Good aquifers are lava streams — yielding in some cases over 2000 litres of water per second — and limestones. Good water-bearing formations are the alluvial-plain deposits along many coasts and rivers and sites of sub-recent lakes. It may be stated that the Quaternary deposits are the best water-bearing layers, whereas the older formations consisting mostly of consolidated sediments and crystalline rocks, except for some limestones, are poor ones.

The quantity of water used for irrigation in Indonesia is the greatest as compared to other needs and varies between 10,000 and 12,000 cu metres per hectare per season for the so-called wet rice. Another kind of rice depends upon rainwater only. Owing to the limited amount of irrigation water available during the dry season, the cultivation of rice has to be reduced to 30% or less.

Sugar-cane grown on rice-fields does not need additional water during the wet season, but in the dry season the required amount is about 37.5% that of rice.

Efforts have been undertaken to raise the production of rice by the construction of dams and reservoirs especially in the densely-populated areas of Java. The biggest dam situated in West Java has been completed and possesses the capacity of irrigating some 300,000 hectares of rice fields. In East Java, the Karangkates Dam is nearing completion and has an effective capacity of about 253,000 cu metres.

Out of a total rice field area of 7 million ha only 3,796,216 ha is currently using irrigated water and 60% of this needs rehabilitation.

Groundwater has been utilized on a limited scale for irrigation, such as in East Java.

There are about 140 cities and towns throughout Indonesia which have piped water supply. Springs at the foot of volcanoes provide most of the water in the rural areas, and to a smaller extent water is being provided by artesian drilling.

Many towns and thousands of villages depend upon dug-wells for their domestic water supply. About 100,000,000 Indonesian people use untreated surface water for domestic purposes.

New water supply systems originating from river water have recently been completed for ten big cities. Nevertheless the capacity for providing drinking water for the 24 million people living in urban areas is only 40% or 900 litres per second.

Industrial development at present is oriented towards those industries which support the agricultural sector, clothing industries, towards medium and small industries to absorb manpower and towards those industries which can support the country's balance of payment.

Industry in Indonesia currently embraces factories such as pulp and paper, cement, glass and ceramics, tyre and rubber, fertilizer and salt, soda, oxygen, carbon dioxide, soap, petroleum refining, tin smelting, food canning and processing, cane sugar, textile mills and printing, manufacturing of metal products, etc.

The location of these factories is near the big rivers as water for these purposes is obtained primarily from rivers. Such agglomerations of industries are found along the big rivers such as the Tjiliwung and Tjitarum rivers in West Java, the Brantas and Solo rivers in East Java and the Musi River in Sumatra.

Indonesia is gifted with several river systems like the Musi, Batanghari and Siak in Sumatra, and the Mahakam, Barito and Kapuas in Borneo. The total length of the Indonesian rivers is about 18,000 kilometres of which 10,000 kilometres is navigable in the dry season.

With Belgian assistance the Ministry of Communications has recently finished a general survey of 9 rivers in Borneo and 6 rivers in Sumatra. This will be followed by a more detailed investigation regarding the economic importance of these big rivers.

The inland waters of Indonesia consist of 13,760,932 ha occupied by rivers, lakes, swamps and 287,691 ha by fish ponds. The annual catch of inland fish is 446,953 tons.

Indonesia has a coastline of about 61,146 kilometres, two continental shelves occupying a total area of 788,400 square miles, and a large number of gulfs and bays along the coast. This alone indicates a vast potential of marine resources such as marine algae, fish and other edible animals, as well as minerals.

The petroleum potentials of Indonesia's shelf areas have already been discussed and the search for oil is now underway in our deep-sea basins, which are usually situated in the eastern part of the archipelago. Other mineral potentials of our seabeds are tin, titaniferrous ores and other detrital heavy minerals.

The marine salt industry is already fairly established. The State salt industry supports about 40% of Indonesia's salt consumption, while the rest are supplied by the so-called "people salt".

Out of the total fish production of 1,248,953 tons annually, about 802,000 tons are marine. Of the marine fisheries the most important ones are scombers, sardines, carangids and prawns. In 1970 Indonesia exported 18,605,973 kg of fish and other marine products worth US$5,902,460. The sea fisheries exploited are confined to areas 30 miles from the coast.

Seaweed is a promising source of food which still remains unexploited in Indonesia. The Institute of Marine Research has launched a survey including geographical and seasonal distribution, measuring the potential productivity of each season, ecological study, chemical analyses, and measuring the nutritional value of edible seaweeds. Unfortunately, Indonesia's ability to supply seaweed is being neglected at present and the reason seems to be the unreliable content of the different shipments made. Steps are being explored to remedy this trouble.

The problems related to water resources in Indonesia are manifold and only the most important ones will be mentioned here.

The most crucial problem especially in densely-populated areas such as Java, Madura and Bali, is to find suitable places, hydrologically as well as geologically, to store damaging flood water in the rainy season in order that it can be used in the dry period.

The humid tropical climate, with its rainfall exceeding 5000 millimetres per year in some places, and active processes of mountain-building, with vertical movements of several millimetres and horizontal movements of several centimetres a year, are the main factors causing rapid denudation in Indonesia. Many drainage basins exhibit denudation values of one millimetre per year, while annual values of 4 millimetres have been recorded in Central Java.

River water, especially where cultivation of land and deforestation is quite intensive, is heavily loaded with silt, containing in some cases as much as 7 kilograms per cu metre. Such silt-laden water is not suited for irrigational purposes and has to be clarified first by means of settling basins.

The problems created by frequent volcanic eruptions are well known in East Java. The erupted pyroclastic material from the volcano Kelud combine with high rainfall which carry away the very unstable debris have created critical sediment problems in the Brantas River. Within a period of five years following the 1951 eruption about 23,000,000 cubic metres of erupted material came down from the summit area into the Brantas River, causing the rise of the riverbed of about 1.5 metres.

The increase in population, coupled with deforestation is another serious problem. The forests suffer from illegal cutting of trees and deforestation due to land-hunger for cultivation of maize, cassava, etc., and for cattle-grazing. The extensive damage suffered by forests has caused frequent floods, droughts and erosion to such an extent that several watersheds have been declared critical. Floods occuring frequently in low-lying areas are a constant menace. The approximate extent of threatened areas in the whole country is about 250,000 ha, of which 200,000 ha are in Java, which harbours 75% of the whole population.

Artesian basins in big cities like Djakarta with rapidly-growing industries are currently suffering from too much withdrawal. A drop of the piezometric level of more than 20 metres within the last few decades has been recorded.

No city in Indonesia has an adequately functioning sewerage system. Sewage is usually treated to a limited extent only. In good urban and surburban areas human waste is disposed of by using septic tanks. The construction of septic tanks is no longer recommended due to the fact that groundwater could be polluted by seepage. The increasing pollution of public water by public waste is a very serious problem in the big cities, and this is reflected by the prevalance of waterborne diseases.

It is very difficult to find out exactly how much and what kind of solid waste is produced. Only about 50% of the total solid waste product can be collected and disposed of, resulting in the accumulation of waste even in streams, canals and ditches. Projections for the population of Java in 1985 indicate an increase of the order of 40 million in the urban population. It is obvious that the requirements in terms of water supply, sewage and refuse disposal and other facilities will involve very great investments in the next fifteen years.

The inadequacy of hydrological data and the reliability of the recorded data are also problems which make planning extremely difficult. The country has only 200 gauging stations. In the islands outside Java one has often to depend entirely on extrapolation or comparison with similar situations elsewhere. The hydrology of volvanic areas is still largely unknown.

Present Level of Activity and Future Trends

From the proceeding discussion it is quite obvious that the problems of water resources in Indonesia are of high-level concern to the Ministries of Agriculture, Industry, Mining, Public Works, Education and Health, and are being given priorities in the current Five-Year Plan.

The Ministry of Public Works is in charge of the following sectors:—

(a) development of water resources for agricultural food production, including irrigation works, construction of dams, flood control, river training and hydrotechnique in general;

(b) electric power, namely exploitation of power resources as a stimulation for economic development;

(c) water supply for industrial purposes and urban facilities.

The list of priorities for the programme to develop water resources is as follows:—

(a) work on land and water conservation and erosion control;

(b) flood control programmes, including river improvement;

(c) rehabilitation and improvement of existing irrigation networks;

(d) opening new ricefield areas in the islands outside Java, Madura, Bali to promote transmigration. This will help to solve the problem of population (better dispersal of population) and will increase food production as well;

(e) surveys, planning and feasibility studies as preparation for executing large-scale water resources development programmes;

(f) the strengthening and upgrading of the Institute of Hydraulic Engineering, as the scientific backbone of further water resources development programmes; and

(g) the preparation of manuals and setting-up of new laws and regulations, to strengthen water management.

The target for 1973 as outlined by the Ministry of Public Works is the rehabilitation of 50% of the existing irrigation network plus the construction of new works. The existing irrigated paddy fields to be rehabilitated amount to 825,470 ha, while intensification work will involve 430,131 ha. The reclamation of swampy areas in the islands outside Java is about 1,575,000 ha, which will increase to 2,625,000 ha in 1978.

Investment in the above sectors are large-scale and serves to highlight the critical importance of the choice of technological systems since such large investment tends to commit the country to a particular system. In this connection, the necessity to devote a significant amount of resources to "research and investigations" (which include survey, systems design, feasibility studies in addition to R and D proper) have been recognized. A very arbitrary breakdown of the 1970-1971 budget by resource areas in science indicates for hydrology the amount of 953.3 million rupiahs, and for oceanography 71.5 million rupiahs. It should be emphasized that these figures are only ministerial budget and are not complete.

A National Committee for the International Hydrological Decade was established some years ago by the Indonesian Institute of Sciences. This body has the capacity to initiate and co-ordinate research, and has prepared an integrated hydrologic research proposal which encompasses water balance studies, quality of natural waters, stream-bed evolution and deposition of sediments and Man's influence on hydrologic phenomena. The Tjimanuk River basin has been selected for case study.

There is no systematic research in hydrolc ᵛv in Indonesia. Since 1963 however research efforts are being carried out in the Waspada experimental basin to obtain data on water balance. During the past two years the Institute of Hydraulic Engineering in Bandung has started with a new section, the Geohydrology Section. In the future this section may become more important now that UNDP is assisting the development of this Institute.

The atomic reactor in Bandung has meanwhile started to apply isotope techniques in hydrological work, including groundwater investigations.

The Geological Survey of Indonesia is presently actively engaged in hydrogeological mapping work, the results of whcih are compiled in the form of hydrogeological maps.

Under a grant from the U.K., groundwater surveys have been performed in Central Java and another survey in the Brantas basin is under way to assess the possibility of providing supplementary water for irrigation.

A Colombo Plan grant from the Australian Government is assisting groundwater survey in Bali and the Bogor area for city water supplies.

The Government has already started with the study of many river basins and is getting technical assistance from many countries, each for a special basin, a group of basins or even a whole island.

A study group on pollution was set up in 1970 at the Institute of Oil and Gas which operates under the Ministry of Mines. The main purpose is to study, evaluate and set up recommendations on problems related to pollution in general. Some minor problems are encountered by this study group since an interdisciplinary approach is something new in a developing country. The study group consists of scientists from many disciplines such as oceanography, geology, microbiology, biostatistics, geography, economics, anthropology, zoology and botany and is expected to become more active due to the help provided to this body by the Indonesian Petroleum Association, an organization comprising the State Oil Company and most foreign oil companies operating in Indonesia.

Very soon the Smithsonian Institution in co-operation with the Institute of Oil and Gas is going to start a project aimed at studying pollution caused by offshore oil drilling in the Java Sea. Emphasis will be put on oil seeps as well as drilling operations.

From the disposition presented above it is quite obvious that with our inadequate funds, limited knowledge, weakness in scientific and technological infrastructure, the development of the water resources of Indonesia is a demanding challenge. The problems to be encountered are so numerous and so complex that a satisfying solution will not be so easily achieved without regional and international co-operation.

KEYNOTE ADDRESS BY DR. PRADISTH CHEOSAKUL, THAILAND

I am greatly honoured to have the privilege to address the Plenary Session today. The Regional Workshop on Water Resources, Environment, and National Development will be one of the most significant steps towards international co-operation in the combat against environmental pollution.

It is now realized that environmental pollution problems are not confined only to the rich industrialized countries, but also exist in the developing countries. Governments of developing nations are now fully aware of the rapidly deteriorating quality of the environment in their countries. They have also recognized the damaging consequences of environmental pollution to their economic progress and on the health of their people.

The problems of environmental pollution in Thailand are complex and intertwined with all elements in the economic development. Industrial development and population explosion have deteriorated the environment in Thailand to an alarming level. Water pollution is now the gravest environmental problem facing the country. The public is very cautious of this matter and the Government regards water pollution abatement to be of top priority in the control of environmental pollution.

Various academic institutions and government organisations in Thailand have dealt, in one way or another, with environmental pollution. However, there was virtually no co-operation nor co-ordination among the organisations concerned and no organisation was directly responsible for planning or making policy on pollution abatement. The necessity of having such an organisation is thus apparent. These conditions led the National Research Council to propose the formation of the "Committee on Environmental Quality Control" to the government. The committee was appointed in February 1971 and is responsible for the following functions:—

(a) to set up national programmes, plans and policies on environmental pollution control;

(b) to provide suggestions and recommendations to the government on the prevention and solution of environmental problems; and

(c) to encourage and promote co-ordination and co-operation among various government or overseas organisations engaged in research on environmental pollution problems.

The committee is under the chairmanship of the Secretary-General of the National Research Council, and consists of 18 other members representing ministries and organisations involved in various tasks of economic development.

The causes of environmental problems in the developing countries are similar. Solutions effective in the developed countries might not work in the developing countries because of the great difference in environmental and technological conditions. This Regional Workshop will be extremely beneficial in that it will provide an excellent opportunity for scientists and engineers from the developed and developing countries to exchange views and experiences they have gathered in their countries. As a result solutions appropriate for the developing countries may be derived. I believe the benefits to be accrued from this Regional Workshop will be immense. It is not too optimistic to say that the future of the environment in the developing countries will be brighter through international co-operation and co-ordination like this Workshop.

KEYNOTE ADDRESS BY PROF. GERARD A. ROHLICH, U.S.A.

Thank you very much Mr. Chairman. I am very pleased that the Chairman has pointed out that I will speak in general terms because it is obvious if I speak of environmental problems in this part of the world I would be speaking surely from a minimum amount of knowledge of your particular problems.

There is also a certain amount of uncertainty behind my remarks because many of the policy questions to be discussed are subject to rapid changes taking place in our country. Some of the projects that have been undertaken in the U.S. towards meeting the problems of the environment are not applicable to many parts of the world.

Recently I had a moment for retrospection and reading, and re-read a most important document with which some of you are familiar; a document prepared in 1842 by Edmund Chadwick, Chairman of the Poor Commission of Great Britain. Sir Edmund Chadwick's report was entitled "The Sanitary Conditions of the Working Population of Great Britain". Chadwick was an attorney and had been working about three years on this document which was based on four principal axioms. The first half of the report was devoted to a discussion of the information that was available to establish the relationship between inadequate housing, inadequate sanitation and inadequate water supply, with the incidence of disease, ill health, and mortality. I looked upon the details of his report in this respect and noted that he had gathered a great deal of information to be used for the basis of his report. The second axiom dealt with the economic cost of ill health. The third axiom dealt with the social cost of squalor, and the fourth axiom with the lack of adequate institutional arrangements required to fully meet the challenge of correcting the conditions existing thus far as to the sanitary conditions of the working population at that time.

It seems to me that Chadwick's report of 130 years ago expresses the same kinds of approaches needed at the present time. First, scientific information and sound data are required on which to establish the relationship between the conditions of environment and the inadequacy existing in so far as water supply, sanitary conditions and housing are concerned. This is a simple model, the manner in which to move from the basic data called criteria, or the qualities which must be identified and may have to be controlled in order to provide the basis for establishing standards to provide a satisfactory environment. If we talk about these qualities and their identification, we must develop means of identification. We rely on scientific personnel to provide these means. In the case of water supply, these are the contributions made by the chemist, biologist and sanitary engineers in establishing the scientific information to tell us the effects that may occur in a particular situation.

The next step is to establish a monitoring system of the environment so that we can measure both temporally and spatially those qualities which may have to be controlled. If we have a sound basis of criteria, identification and monitoring, then we have a rational approach towards establishing standards of quality. Standards are not based only on the information available through the contribution of the scientific community, but also on the information supplied by political scientists and by sociologists and economists. The responsibility of the scientific and engineering groups, of course, is to provide information so that the political scientists and administrators are in a position to understand the constraints that these inputs have on the development of satisfactory standards.

Obviously in many situations, to eliminate and reduce the concentration of pollutants in the air, water, and land resources the development of standards is somewhat limited. Too often we look at waste treatment plants and air pollution controls as individual entities, without giving full consideration to an understanding of the interchange that occurs between or among the air, water and the land resources. If we can understand this simple model it will become possible to develop more comprehensive plans which must rely heavily on the planning abilities that are available to us.

As we look at some of the problems of our environment and at the question of pollution, I would like to define pollution because these days we find that there is a mis-use of the word "pollution". The definitions of pollution are many, but if we define pollution as the introduction of energy or material of any form into a resource which interferes with or degrades a beneficial use of the resource we have introduced the use concept into the definition of pollution.

Thus we find in many instances, particularly in water pollution, there have been definite zonings and allocation of various parts of the water resource. We begin to take scientific data and use the data to assess the impact that occurs by the introduction of material to the resource which adversely affects its use. Many difficulties arise, however, because our problem at the present time is that in many instances there is a multiplicity of use, overlap of use, conflict of use and difficulty in determining what the use may be. It is not a question of wanting clean water, but a question of how clean do we want the water, how clean do we want the air. In using a resource we introduce materials which bring about alteration in the quality and adversely affect the resource, to the extent that we encounter a degree of pollution.

Thus we move from a series of objectives where we attempt to determine scientifically the criteria, i.e. the scientific information, from which we form a basis for judgement decision, moving from the identification stage, to the monitoring stage, to the establishment of standards. But this is also a system which has feedback and therefore the standards must be flexible because we find variations and changes in the future use of the resource. In many instances we must upgrade the standard in order to meet the objective we have for a particular water or air resource use.

These simple steps lead us then to the possibility of developing a comprehensive plan. What I am suggesting is that the analysis of the complexity of the relationship between air, water and land resources can be understood better by the development of mathematical models. The mathematical models for environmental control are in an elementary stage, but there are tools now available and we hope that during the next three days of the Workshop sessions we can discuss the shortcomings of the tools of the mathematical models so that we can use these to analyse past data.

We were encouraged in the U.S. in 1965 by the passage of the Water Quality Act at the Federal level. The 1965 Act required that each of the 50 States in the Union to provide standards of quality on interstate waters, and a plan of implementation of those standards. This act also included a statement that the objective was to enhance the quality of the existing waters. One of the first steps is to know the existing water quality. The data we have are fragmentary. A considerable amount of data may have been on hand but when we analyse it critically, we found it was lacking in many aspects, particularly in defining criteria and in having established criteria needed to form a sound basis on which to assess existing conditions. A certain amount of past data and present conditions were assessed in order to project the future needs for corrective measures.

Developing the scientific and engineering information as well as the economic, social and political data to arrive at practical programmes necessary for solution of immediate problems and problems in a long range plan, is not without great complication. Alternate plans involving changes in production and treatment methods all pointed out earlier this afternoon, need of course to be investigated to determine the optimal solution. We need input from the scientific community, input from technology, input from economists, input from the social and political sciences if we are to develop a satisfactory model to predict future effects on the environment. These are the approaches we see outlined in the Workshop for the next 2½ days. We not only have the problem of solving the immediate gross pollution problems, but we must allow also for future social and industrial development. Whether it be in a highly developed nation or a developing nation, we must make judgement decisions as to the values that are involved and values that will be achieved, as well as the costs that will be required. We must talk about relationships not only in terms of economic costs and economic benefits but in terms of values — values that are not readily measured in dollars. We recognise that there must be sufficient flexibility to assimilate the unexpected and rapid development. Rapid development is something we have not fully recognised in the initial establishment of any kind of model, for detailed assessments to be made.

Another great weakness is in determining the proper guides to the monitoring programme. Many standards in some of our States have been established on a single number concept. This concept is one with which many disagree, but it is easy to handle in terms of the administrator, or in terms of the bureaucracy charged with the implementation of control programmes. One finds in a country such as the U.S., which has many different geographical regions, the simple number cannot be considered the soundest concept on which to base decisions, yet to have a flexible valuation or standard is a difficult one to administer. What kind of values do you wish to project? Production of catfish in Mississippi is important, but in Lake Superior of no significance. To express different kinds of values in different parts of the nation, and to establish uniform standards at the Federal level is not easily dealt with.

A further item is the operational schemes that can be employed for the most satisfactory implementation of control plans. Another area in which our scientific knowledge is lacking is an understanding of how the man-made plan can be synchronised with the natural cycle. It was pointed out earlier that in many instances we may lack good hydrologic information. We may lack good meteorological information in relation to movement of air masses and movements of air pollution. There is great need for additional monitoring so that the variations in the natural cycles can be synchronised with the man-made plans or man-made goals. Mathematical models can provide a liaison between the man-made plan and the natural cycle, but certainly we need an appreciation of the dynamics of this natural cycle, and we find that the scientists can make significant contributions. These in turn have use by transfer to technological and administrative people so that there is a reasonable programme for the solution of problems. With this kind of background it is possible then that the models can be made consistent by continuous upgrading in the light of knowledge and development and observation.

What I am saying, in brief, is that the problem of management of environmental quality is a dynamic problem which constantly changes and we cannot make decisions at this moment which we expect can last for all time. We are certainly going to make decisions to correct the gross kinds of pollution problem that exist in our country in many locations, and in many parts of the world, but after all one of our objectives is to make Man's physical and biological environment compatible with social and economic needs. It is not a matter where we have as an objective, something in terms of quality considered aside from Man himself, because Man himself is part of the environment, and since Man is dynamic he will constantly change the environment and adjustments must be made.

As far as water is concerned in the U.S. we have looked at the problem and the National Water Commission has tried to make an assessment of water needs in the nation. There are some people who say in the year 2000 we will be running out of water. In the U.S., of the 4,200 billion gallons of water from daily rainfall, about 70% is lost in evapotranspiration leaving 30%, or 1,260 billion gallons potentially available. Of this 1,200 billion gallons, one-half or 600 billion gallons a day is under control and about half of that under control is presently being used. Making projections in the U.S. by the year 2000 we will need 1,300 billion gallons per day. This analysis has been used by some to suggest that we will be running out of water. Yet water is a renewable resource. It can be recycled. We can recycle water directly after proper treatment but we will have to forego to some degree water use on a once through basis. This means our technology for direct recycling will have to be further developed, and we will not actually run out of water. I for one am not concerned that we will run out of water. I am only concerned that the technology may lag for recycling water as often as we like.

We can provide direct reuse and in fact you are making direct reuse here in Singapore. This approach will receive more attention and more effort will be expended which means that the cost of water will increase. In the U.S., on the average, water costs in the neighbourhood of 25¢ per 1,000 gallons. 1,000 gallons is a little more than 4 tons, so the cost is 5¢ to 6¢ a ton. This high quality raw material at this price is a real bargain, and it is not unlikely we must spend a little more for this vital raw material. We must face the fact we have got to do that if we are to continue to use water in the volume to which we have become accustomed. We have done very little about reducing the quantity of water used. Little time has been given to reducing the water that individuals demand.

Another problem repeats what was said earlier in the day — the manner in which we must treat our waste. Today there is concern for reducing the amount of organic material present in waste. Yet some twenty years ago or more we knew of the problem of eutrophication. In the city of Madison, Wisconsin, where I taught for 26 years there are four lakes and sewage was discharged into one of the lakes. The city was progressive, and as early as 1890 had a sewage treatment plant, with effluent discharged into one of the lakes. In 1920 because of excessive algal bloom and macrophytes growing in the lake a serious problem existed. A report was written in 1920 about the cause of odor nuisance in the lake which was attributed to phosphate and nitrates. That was 52 years ago. Nothing was done at that time except to say we will now bypass the effluent around the lake, and put it in a lower lake. In 1940 the lower lake developed algal blooms. A great flurry was stirred up and a group called together and a report written. The report said the odor nuisance in the lower lake resulted from excess nitrogen and phosphorus. A decision was made to bypass this lake and to discharge the treated sewage to a stream below the lowest lake in the community. People who lived downstream into which the effluent flows were concerned, and so it went on in many other locations.

We have finally learned there is no such thing as throwing our wastes away, because there is no "away" Diversion may be a temporary solution, but with increasing population and increasing urbanisation, we must continue to conduct research and technology development which will make it possible for us to use this waste as a resource because pollution is a form of energy. It really is a resource that is out of place. We must somehow get it back into cycle so that it will be a useful resource in place. In the future, this concept will bring about the kind of developments that are necessary to put resources in proper perspective and put them back into circulation in a well-defined approach.

Let me say a word about another problem which has reached somewhat major proportions, the problem of increased power requirements. This can create air pollution from plants using coal, and water pollution problems from thermal discharge. Environmentalists call it thermal pollution. Industrialists call it thermal enrichment. Professors call it thermal addition. We struggle now with what the standards should be, what the controls should be, whether or not agencies should prescribe an end result or methods for attaining the end result. Lake Michigan on the Wisconsin side has four large nuclear power plants. It is quite interesting to see the conflict which developed and was not concerned with thermal pollution, but about the aesthetic values that arose when consideration was given to the construction of cooling towers. Cooling towers were built to reduce temperature, but some people were against the cooling towers, against the unsightliness of the structures. This kind of question has to be finally resolved and the public must have the opportunity to express their viewpoints so that the conflicts can be exposed to public scrutiny.

There has been a significant piece of legislation enacted a short while ago in the U.S. National Environmental Protection Act. A Council on Environmental Quality was established which is advisory to the President and co-ordinates the activities of various departments such as the Department of Agriculture, Department of Health Education and Welfare, the Department of the Interior, Department of Transportation, Department of Commerce and Department of Defence. At the present time any project undertaken by an agency must have an environmental impact statement. If a power plant is to be built or a highway is to be constructed — no matter what facility, it is necessary to provide a statement discussing what the environmental impact will be. This has caused a lot of problems and difficulties and slowed down a number of projects, but it reflects the current awareness of the public to environmental problems. There are no easy solutions to any of these problems as we see them at the present time, but it is particularly encouraging to see the increased awareness to these problems.

One of the shortcomings of those of us in the field of education is that we have not as yet been able to fully convey to the public the balance in values because of the complexity of the environmental problem. Even though we probably do not fully understand the complexity of environmental systems, the very fact that we have become aware that they are complex is a step in the right direction. It is hoped that the systems approach and the model approach, even though they might have glaring weaknesses, will enable us to put into perspective some of the various constraints and values that can be used in the assessment of environmental problems. The task is a formidable one but as an optimist I think the rewards are also very great. During these next few days, as I see the programme, we will be addressing ourselves to some of these questions.

Thank you.

KEYNOTE ADDRESS BY MR. KHONG KIT SOON, SINGAPORE

WATER IN RELATION TO SOCIAL AND ECONOMIC DEVELOPMENT — A STUDY OF WATER USE IN SINGAPORE.

Water supply is a public utility service and it plays an essential role in national development in the developing countries today. Water is part of the social and economic infrastructure of development. A recent World Bank paper on "Water Supply and Sewerage" says — "Urban communities of any size without adequate piped water and sewerage are not viable and thus seriously compromise national development prospects . . . "

In any highly urbanised society, the provision of an adequate and safe water supply is a daily necessity. Water is needed for flushing drains, street cleaning, watering of public parks and gardens, and firefighting. Water is required for use in schools and hospitals. A lot of water is consumed at construction sites and a much greater amount is used in households and factories. Water is required for the proper disposal of human wastes and industrial effluents, which is essential to the health of the community. In Singapore the supply of clean potable water has resulted in an absence of enteric diseases, and fluoridation has also reduced dental caries in children.

The use of water for agriculture and farming is limited to poultry and pig farms and vegetable gardens. Though about 24.5% of the total land area is under cultivation, agriculture accounts for less than 5% of economic activity in Singapore. Surface and ground sources supply most of the water requirements for animal husbandry and horticultural uses. But surface run-off from farms and gardens leaves behind salts in the soil after evaporation. Also, farm wastes contribute to pollution of water sources.

In Singapore the recent economic growth and social development are reflected in a considerable increase in water demand in the domestic and commercial/industrial sectors. Water consumption spiralled upwards in the sixties as a result of both the new industrialisation policy and public housing programme which had been launched shortly after Singapore attained internal self-government, to meet the challenges of rapid population growth and urbanisation. Water supply matched the highly stepped-up demand from homes and factories and made both social and economic development possible.

Economic and Social Development

Industrialisation in the past decade has transformed the structure of the country's traditional entrepot economy. The manufacturing sector has considerably expanded, now contributing one-fifth of the total Gross Domestic Product compared to one-tenth a decade ago.

Though there has been a decline in the importance of the entrepot trade, rapid growth has been seen in the shipbuilding/repairing and petroleum refining industries in the last few years. The economy also has a large service sector comprising mainly banking, financial, transportation and communication services. And since 1963 the tourist industry has expanded almost five-fold.

The standard of living has risen at an unprecedented rate. The Gross Domestic Product increased by nearly 180% during this period — from $2,046 million in 1960 to $5,675 million in 1970. Per capita income more than doubled from $1,262 in 1960 to $2,794 in 1970.

An index of this pace of growth can be seen on the roads. Whereas in 1960 there were only about 63,000 registered privately-owned motor cars, the number increased to over 142,000 in 1970, and the number of motorcycles and scooters grew from 19,000 in 1960 to 105,000 in 1970. There were more cars than other motorised vehicles on the road. All this impinged on daily water consumption as more vehicles were washed and serviced each day.

By 1959 the housing shortage had become one of the most serious problems in Singapore. In 1960 public housing became part of Singapore's First Development Plan. The first five-year Plan was completed in mid-1965 ahead of schedule with more than 54,000 units completed. This number has more than doubled since and more than 700,000 people (about 35% of the population) now occupy Housing Board flats. Since the introduction of the House Ownership Scheme for the people in 1964, over 34,800 families now own Housing Board flats which they occupy.

The Urban Renewal Programme was inaugurated in late 1964 to clear the slums in the city centre occupying an area of 1,700 acres or 1.2% of the total land area of Singapore. The main objectives are to revitalise the city centre, improve the city's environment, and provide services and amenities for both social betterment and economic development.

All the construction and reconstruction work as well as the housing "boom" in both public and private sectors at the same time as industrial production was being rapidly accelerated, generated a considerable impact on the daily water use in Singapore.

Impact of Development on Water Consumption

Daily domestic consumption grew from an average of 24.5 million gallons for an estimated population of 1.65 million in 1960, to 42.8 million gallons in 1970 for a population of 2.07 million — reflecting the rise in living standard. This increase in daily water use at home stood out more strikingly when compared to the 1950 daily domestic consumption of 10.0 million gallons for an estimated population of 1.02 million.

Commercial/industrial consumption rose from 12.0 million gallons per day in 1960 to 21.5 million gallons per day in 1970 — a 78.8% increase in this ten-year period. In 1950 consumption in this category averaged only 8.9 million gallons per day.

The total daily consumption increased from 64.5 million gallons in 1960 to 102.4 million gallons in 1970. This is equivalent to an increase in per capita consumption of 39.1 gallons per day in 1960 to 49.4 gallons per day in 1970. The increase in total daily consumption averaged 5.9% per annum as compared with a population increase of about 2.5% in the same period. Total daily consumption in 1970 showed more than a three-fold increase when compared to the daily total of 31.3 million gallons per day in 1950.

Apart from the two major consumers — domestic and commercial/industrial accounting for 41.8% and 21.0% of total water consumption in 1970 respectively — Government and statutory bodies consumed 18.8% and Armed Forces 7.1%, their consumption fluctuating from year to year in contrast to the steady annual increase in use for the major consumers. Shipping accounted for 1.3% of total consumption in the Republic.

Meeting Future Demand

Water consumption in the Republic is expected to increase at more or less the same rate as it has done in the past ten years. By 1984, daily consumption is expected to exceed 200 million gallons per day for a projected population of around 2.7 million. How is this future demand to be met?

The answer to this question involves finding solutions to many problems of geography, demography and environmental control.

Physically, the Republic occupies only a small land area of 225 square miles — the smallest state in Southeast Asia. The island proper is 209 square miles, being 26 miles long and 14 miles broad, with a coastline 83 miles long.

The central region of this island is hilly with massive deposits of granite, the southwest region is of shale and snadstone, while the eastern region contains poorly-consolidated sands and gravels. The longest river is about 9 miles long, and except for the central protected catchment areas of the Public Utilities Board's impounding reservoirs, all the rivers and streams are badly polluted.

A central plateau of about 12.7 square miles, comprising 6.0% of total land area, is demarcated for a catchment area and forest reserve, containing the remnants of the island's original vegetation.

Added to this problem of land scarcity is the problem of high population density — more than 9,000 per square mile. Problems of water resources and environmental control thus converge on the need to provide more water for greater domestic and industrial consumption in the future.

These daunting problems would perhaps be insuperable if there was also lack of human ingenuity and skill to take advantage of the generous precipitation of the rain-bearing monsoon winds. Singapore's average annual rainfall is over 90 inches.

With effective anti-pollution measures, it will be possible to extract much more than what is being extracted today from the annual rainfall. Thus all canals, rivers and streams must be cleaned up.

Waste water, whether domestic or industrial, must go into the sewers and not into open drains, canals, or rivers. At present more than 50 million gallons per day of waste water is still being discharged into the various rivers and streams in Singapore, resulting in pollution of the water courses and coastal areas.

The whole of Singapore will be sewered in phases. The present sewerage network totals about 450 miles in length, serving half the population. It must be extended so that in 10 years' time every home can reach a main sewer economically. All bath, kitchen, dirty household or industrial waste water must go into the sewers.

As spelt out by the Environmental Public Health (Prohibition of Discharge of Trade Effluents into Water Courses) Regulations, 1971, trade effluents must be treated to acceptable limits before discharge into drains and water courses.

Drainage will be further improved to bring storm water under control. Floods have been caused by the destruction of vegetation and soil erosion in the drainage basins due to land clearance for housing and other development. For many catchments in built-up areas, there has been a considerable increase in run-off as a result of construction of roads and buildings. Many flood-alleviation schemes have been implemented in the city and rural areas — waterways improved by the concrete-lining of drains and canals, and streams regraded and generally improved. Stamford Canal in the city area has been chosen as the pilot project for anti-pollution and purification of river and canal waters.

To meet the demand in the immediate future, two new projects — the Kranji/Pandan and Upper Pierce — have been started to create new reservoirs not only to expand storage capacity but also to increase daily yield. Another new reservoir is being planned at Bedok to cater to developmental needs in the eastern part of Singapore.

Other measures to increase water supply in the Republic include feasibility studies on groundwater and re-circulation and re-use of water.

Ground sources are being investigated. Though the result of a recent geophysical survey in the Bedok/Changi area has not been promising, further explorations may be made to establish whether there are aquifers that can yield substantial quantities of groundwater.

Water can be re-treated after use and re-distributed as potable water. Effluent from a secondary treatment plant contains less foreign material than sea water, and tertiary treatment presently appears to be cheaper than desalination. With re-use certain to become necessary in the near future, water quality becomes a matter of paramount concern. Singapore already has an industrial plant at Jurong capable of producing 10 million gallons per day of industrial water using effluent from a secondary treatment plant. While the Government is encouraging more industries to make use of industrial water, there is also a plan to use it for flushing systems. More of the treated effluent could be used for other purposes such as gardening and filling artificial lakes for public recreation.

Through careful and economic usage, it has been found that daily consumption could be reduced by as much as 20%. The people are being inculcated with the idea of the preciousness of water so that prevention of wastage will become a habit of life.

Waste detection measures will be stepped up to reduce loss of water in the distribution network. Water-saving devices for domestic fittings such as water closets and faucets will be used if found to be effective.

Beyond 1980, the eventual answer will most probably be provided by desalination. There should be an economic breakthrough within a decade when large desalting plants producing 100 million gallons per day and more would be commercially operational. Like many countries in the world, Singapore looks forward to this development to meet its water needs for future economic and social growth.

Conclusion

The critical factor for orderly social change and economic development lies in the management of natural resources — of which the maximum utilisation of the previous water resources is of fundamental importance in Singapore. Population growth, rapid industrialisation and increasing affluence contribute not only to an increasing water demand, but also high pollutional loads to the water courses. With constraints placed on sources of supply in Singapore due to the size and natural configuration of the country, the conventional sources are very limited and augmentation of these sources must come from unconventional means which must be within acceptable economic limits. This makes the water engineer's task of planning for the future all the more formidable and challenging. It also entails the collaboration of many experts in related fields of environmental control.

In Singapore the lesson is that water supply is dependent on environmental control which is the key to turn on fresh supplies to meet further developmental needs.

This Workshop will provide for a interchange of ideas and experiences between developing countries in the region sharing similar water and environmental problems. And it is to be hoped that a general consensus will emerge for the need to establish a permanent regional centre to foster cooperation in solving environmental problems, particularly as environmental control hinges on regional cooperation in order to bring about the better quality of life for all people concerned.

APPENDIX II

ABSTRACTS OF TECHNICAL PAPERS

Working Group I

WATER RESOURCES

PAPER I/1

Groundwater Investigations In Singapore

by Chou Tai Choong — Senior Engineer (Design), Water Planning Unit, Public Utilities Board, Singapore

Previous investigations conducted in the eastern part of the Island of Singapore which led to the subsequent development of the Bedok Wells, is reviewed. These wells averaging 80 feet in depth, tap the shallow aquifer in the Recent or Younger Alluvium near its contact with the Older Alluvium.

It is followed by an account of the recent investigations to determine the groundwater potential in the lower depths of the Older Alluvium by means of geophysical surveys and test drilling.

PAPER I/2

Water Resources Planning and Development in Singapore

by Sung Tsoong Tuh — Superintending Engineer, Water Department, Public Utilities Board, Singapore

The urgency to plan and develop all available water resources in the Republic to meet its rapid increase in demand for water has to be acknowledged as a national priority. It is imperative to embark on both short-term and long-term schemes now.

Singapore's water supplies depend on its rainfall, varying in time and space from the average 96 in. per year. In view of its limited land resources and with no further protected catchment available for conventional impounding, water planner must now adopt a changed policy criterion, departing from the past, in accepting low quality raw waters from unprotected rural catchments for treatment to a high quality water supply.

In the past, water supply development was the sole concern of a single engineering discipline. This is no more valid. Singapore's ability and success to develop water resources will have from now on to depend as much on its ability and success to protect the environment. Water quality standards, ecological equilibria in reservoirs, and other environmental aspects are additional criteria required to be studied in depth.

An outline on resources planning and development together with projects in hand and schemes under study is briefly described.

The impact of waste-water re-use, desalination and water conservation on Singapore's overall water supply situation is also included.

PAPER I/3

Flood Control and Water Conservation Works in Bukit Timah Catchment, Singapore

by David Chow Siong Keng and Chang Kin Koon — Drainage & Marine Branch, Public Works Department, Singapore

The paper deals with land drainage works in the Bukit Timah Catchment in the south central area of the Island of Singapore. The land drainage works aim to achieve the dual objectives of flood control and water conservation for water supply. The works consist of three stages: diversion, improvement of existing channels and building of a reservoir.

PAPER I/4

Hydrological Activities in Singapore

by Chang Kin Koon — Drainage & Marine Branch, Public Works Department, Singapore

The paper gives a cross-section of the hydrological records available in Singapore. Proposed works which are either under implementation or at the planning stage are also included. Publications and reports dealing with Singapore hydrology are listed.

PAPER I/5

The Re-Use of Sewage Effluent for Industrial Purpose in Singapore

by Tan Teng Huat — Sewerage Branch, Public Works Department, Singapore

The paper deals in some detail with the short history of the re-use of sewage effluent for industrial purposes in Singapore. It discusses briefly the general methods available for the tertiary and advanced methods of treatment of sewage effluents.

It then deals in greater detail with the Industrial Water Works at the Jurong Industrial Estate and discusses the uses to which the water is put. It also touches on the distribution system, the problems encountered, the steps taken to overcome them including plans for improvement and plans for the future.

The discussions are supplemented with line diagrams, maps and some appendices.

PAPER I/6

Some Factors Affecting the Annual Rainfall of Singapore

by Gan Tong Liang — Singapore Meteorological Service, Singapore

The first part of the paper utilises continuous rainfall records for 96 years from two close together rainfall stations on Singapore Island to (a) show the relationship between the current year's annual rainfall and the following year's annual rainfall, (b) plot the 10-year running mean annual rainfall, to determine if any definite trend in the annual rainfall for Singapore existed.

The second part of the paper consists of a brief study of the relationship between exceptionally heavy rain spells during the first half of the Northeast Monsoon and spells of dry weather conditions in the latter half of the same Monsoon Season over Singapore.

A diagram has been constructed, which attempts to provide guidance on the estimation of total rainfall for May-September from the total rainfall for January-April the same year.

PAPER I/7

Integrated Water Supply & Sewerage is a Required Social Overhead Facility in Developing Countries

by Leonards V. Gutierrez Jr. — Camp Dresser & McKee Inc., U.S.A.

Drawing from experience in planning for water/sewerage facilities in developing countries, a realistic guideline for which rate these facilities will have to be constructed is presented. Expenditures on water handling facilities are to be considered as a necessary social overhead investment, strengthened through governmental subsidies. In the lesser economically endowed communities, subsidy will constitute the difference between annual capitalized and operating cost and the customer's "paying ability". Presented also is a rule-of-thumb for what may be considered as "paying ability". Furthermore, traditional attitudes towards hygiene and cleanliness will need reorientation.

PAPER I/8

Re-Use of Industrial Water

by Raja V. Subrahmanyam — Dept. of Civil Engineering & Engineering Analysis, University of Singapore, Singapore

The importance of re-use of industrial water is discussed along with a brief review of the current practice in this area. The necessity of further research in re-use technology for Singapore is also emphasised.

PAPER I/9

The Planning and Maintenance of Hydrological Networks

by Foong Meng Yin — Binnie & Partners (Malaysia), Malaysia

Hydrological data are the basis for the planning, design and operation of water utilization projects and adequate, reliable data of this nature enable the optimum utilization of a country's limited water resources. Hydrologists, working in developing countries face the problem of a short history of hydrological data collection. The importance of designing adequate hydrological networks that provide the maximum information for a recognised purpose within the limits of time and money allowed, cannot be over emphasised. There are no hydrological laws for the design of networks and the spacing of the stations comprising them. Instead the hydrological characteristics of an area and the use to which the data will be put should determine the nature of the networks.

Hydrological networks once established, should always be maintained to function at their maximum capability, as unreliable hydrological data can be misleading.

PAPER I/10

Development of Water Supply in Vietnam

by Nguyen Sy Tin — Environmental Sanitation Service,
Ministry of Health, Saigon, Vietnam

The total population of South Vietnam is 18 million, 55% of which is rural and 45% urban. The water supply system includes (a) municipal water supply and (b) rural water supply. The municipal water supply system is under the responsibility of the National Water Supply Agency dating back to 1957. The cities of Saigon and Danang have their own Water Board. In rural areas, the Ministry of Health is responsible for water supply for villages and hamlets having a population of 5,000 or less. According to Decree No. 3118/BYT/PC/ND, September 16, 1966, the Ministry of Health is responsible for the quality of drinking water and for stipulating water standards. In addition to quality control of drinking water, training courses for plant operators are organised.

(Abstracted by Chin Kee Kean)

PAPER I/11

Quality Control of Potable Water in the Saigon Area (1964-1972)

by Nguyen Van Ai, Phan The Tran and Do Thi Thuan Bich
— Pasteur Institute, Saigon, Vietnam

The control of potable water in the Saigon-Cholon-Giadinh area is performed routinely in the Pasteur Institute's Department of Water Sanitation and Toxicology, Saigon (Vietnam).

The routine physical and chemical examinations cover turbidity, pH, conductivity, chloride, iron, free chlorine, while the bacteriological examinations include the coliform group and the fecal streptococcal group by the membrane filter technique.

Prior to 1966 the supply of potable water in Saigon came either from deep drilled wells, Layne type (80%) or from superficial ground water (20%). Chemical examinations have indicated that these waters were unsuitable for domestic or industrial use because of their high acidity and additionally, in the case of Layne well water, because of their high content in iron compounds. However, these waters were adequate bacteriologically, chlorination was not even necessary in the case of Layne well water.

PAPER I/12

Municipal Wastewater Reclamation and Re-Use

by Robert H. Culver and Robert H. Thomas
— Camp Dresser & McKee Inc., U.S.A. *Inc., U.S.A.*

As the world population increases and the principal cities grow at an accelerated rate, local shortages of water for municipal and industrial use will become more common. Many methods are being explored to meet existing demands and future needs for water. One of the most promising new sources for municipal and industrial water supplies is the spent water of the community. If the spent water can be successfully reclaimed, it will provide an important resource.

The paper presents a review of the most promising methods presently being used to reclaim usable water from municipal wastewater. It discusses the results obtained, and the costs of construction and operation. The precautions to be observed in the use of reclaimed water are pointed out. Alternative potential uses of reclaimed water are considered. The water reclamation projects at Santee and South Lake Tahoe in California, and at Windheok in Southwest Africa are described in detail.

PAPER I/13

Difficulties in Planning Water Supply Schemes in West Malaysia

by Chong Koon Kee — Director, Water Supply, Jabatan Kerja Raya, Malaysia

The Government of Malaysia has been spending large sums of money in extending existing water supplies and in developing new ones as part of her programme of national development to raise the standard of living of the people.

There is lack of a long range master plan for urban and industrial development. The paper highlights problems encountered in water resources development as a result of rapid urbanisation and changing patterns of industrialization. Lack of data and experienced staff make population estimation and estimation of reliable yield of catchment area difficult. Problems also arise when there is conflict of interests of the beneficial uses of waterways among water resources development and industrial, mining and agricultural development.

In recent years, attention has also been given to exploration and exploitation of underground water. Results have not been satisfactory because of lack of experience in geohydrological investigations and the complete absence of details on geological data.

These problems coupled with limited financial resources and experienced technical personnel hamper the implementation of the plan for water resources development.

(Abstracted by Chin Kee Kean)

PAPER I/14

Water Resources Development in West Malaysia

by Cheong Chup Lim & Goh Kiam Seng
— Jabatan Parit dan Taliayer, Malaysia

West Malaysia has only moderate water resources due to its high potential evapotranspiration. Development of water resources has been going on at a rapid rate. This has given rise to a number of water problems. Rational utilisation and conservation of the available water resources will be necessary in the interest of long-term development needs of the nation.

PAPER I/15

Improved Water Management for Paddy Rice Production in the Philippines

by Sebastian I. Julian — Head, Water Management Project,
National Irrigation Administration, Philippines

The establishment of pilot projects on water management in a representative irrigation system within the eight irrigation regions of the Philippines was made possible, with the technical and financial assistance given by the Asian Development Bank. It was a bold and determined effort initiated by the National Irrigation Administration of the Republic of the Philippines, as an integral part of its socio-economic development program.

Improved water management for paddy rice production include the integrated processes of diversion, conveyance, regulation, measurement, distribution, and application of the right amount of water at the proper time and removal of excess water from farms to promote increased production in conjunction with improved cultural practices.

The project covers the broader aspects of bringing agriculture, science and technology to the rural areas, concerning the judicious use of irrigation water in consonance with the proper use and application of production inputs, training of NIA technical and subtechnical personnel, re-education and extension services for farmers and undertaking of basic and applied research studies on water use in conjunction with improved cultural practices.

As an innovative approach in the management and use of irrigation water in the Philippines, activities were geared toward a continuing effort to search for a new direction in pursuing a realistic programme and be able to work out and demonstrate the most suitable water management practices, to increase the crop area satisfactorily and profitably served, with a suitable cropping pattern for increased productivity and possible income, due to proper land use; and to organize the farmers into viable irrigators' associations within the command area of the system or project for the successful implementation of a well co-ordinated water distribution program.

Water management involves disciplines in irrigation/civil/agricultural engineering, agronomy, economics, extension and adult-farmers education, sociology, hydro-meteorology and co-operatives.

Water as the life-blood of all farm activities can spell abundance if managed and pursued towards the right direction.

PAPER I/16

Progress in Desalination

by J.K. Rice — President and General Manager, Cyrus Wm. Rice Division, NUS Corporation, Pittsburgh, Pennsylvania, U.S.A.

Desalination must be considered as a water supply/water resources alternative. Plants are commercially available up to 10 million gallons per day; plants over 50 MGD can be practically considered for the late 1970's or early 1980's. Extensive research and development and operations information has been made available by the U.S. Office of Saline Water. Future design information will lie increasingly with proprietary sources, such as engineering firms and suppliers involved in the present development.

PAPER I/17

Planning for Water Reuse

by Daniel A. Okun — Head, Department of Environmental Sciences and Engineering, School of Public Health, University of North Carolina, U.S.A.

Urbanization and industrialization throughout the world are exerting great pressures on limited water resources. Although nature renews the volume of pure fresh water available annually, we have been wasteful of it and have often had to use highly polluted sources for public water supplies. In virtually all urban areas where sources of naturally pure waters are being exhausted, these limited supplies are being squandered on uses than can be met with waters of much lower quality, such as waters from polluted rivers or waters reclaimed from wastewaters directly.

Reclaiming wastewaters for non-potable purposes, such as for urban irrigation, industry and toilet flushing, in a planned water resource program:

(a) relieves the pressure on limited resources of high quality water, so that these can serve larger populations;

(b) reduces the cost of water for non-potable purposes, as reclaiming wastewater is likely to be much less costly than developing additional high quality fresh water sources;

(c) reduces pollution of the receiving bodies of water; and

(d) reduces the risk to the population of ingesting contaminants present in polluted waters that would be used for drinking if such a water reclamation programme were not instituted.

The use of polluted waters or wastewaters for potable public water supplies poses many problems:

(a) water and wastewater treatment plants do not assure the removal of chemical contaminants that are likely to be present in the urban wastewaters;

(b) the operation of wastewater treatment facilities is always below the design intention;

(c) the technology for routine monitoring of potable waters is not available to assure their safety when the water is drawn from contaminated sources; and

(d) fail-safe technology to guarantee a high quality of water, suitable for drinking, from polluted sources is not available.

A hierarchy of water quality is proposed, whereby high quality fresh waters would be reserved for high quality uses such as drinking and cooking, while polluted waters and reclaimed wastewaters would be used for non-potable purposes.

PAPER I/18

Rational Use of Water

by W.S. Srimoerni Doelhomid — Director General of Water Resources Development, Ministry of Public Works and Electrical Energy, Djakarta, Indonesia

In the densely populated islands of Java, Bali and Lombok, water use is becoming very intensive, not only for drinking and domestic purposes, but also for irrigation, industry and town water. Besides, flood problems need to be solved. Therefore the use of water should be rationalized which could be achieved by sound integrated planning.

Transmigration could not effectively solve the population problem of the densely populated islands of Indonesia, but should be seen as a measure of labour supply for the development of the less populated areas, with abundant soil and water resources.

Indonesia has no problem of shortage of water resources, but has an unequal rainfall distribution over the year. The problem of Singapore is different; it has a real shortage of water resources. Even so, water is wasted; surface run-off is flowing unused into the sea. Estuarial storage, in creeks along the coast has been proposed as the only way to store all available water, and could be a cheaper solution than re-cycling of very dirty town water or desalination of sea water.

PAPER I/19

Environmental and Sanitary Engineering Graduate Education in the U.S.

by Raymond C. Loehr — Professor of Agricultural Engineering & Civil Engineering, Cornell University, U.S.A.

During the past decades, the term "sanitary engineering" has grown to designate water quality management. Environmental engineering is now used as the generic term to cover all the engineering aspects of environmental quality management.

Graduate environmental engineering education in the United States has largely been supported by research and training grants from federal agencies. During the 1950-1965 period, approximately 3,000 individuals have received MS or Ph.D degrees in environmental engineering areas. Training grant support now primarily supports masters level students, while research fellowships are used to support doctoral candidates.

The investment of the federal agencies in faculty, equipment, and facilities at colleges and universities resulted in a large number of institutions offering graduate education in environmental engineering and science. The return on this investment is now high, with an average of 81% of the training grant support being used to support graduate students.

Environmental engineering and science graduate students receiving support by training grants and research fellowships are about 55% of the total number of students being educated. The training grants are the backbone of many graduate programs. Without the federal support for these programs the current numbers of trained professional environmental engineers and scientists would not be available.

Most programs have interdisciplinary opportunities and a number have a specific interdisciplinary emphasis. Engineers and scientists frequently take many of the same courses permitting a greater understanding of the totality of environmental quality management. The future will see a greater emphasis on interdisciplinary graduates in environmental engineering.

Almost all of the graduate environmental engineers have remained in the environmental protection field. Approximately 90% of the graduates have been at the masters level. The initial employment of the graduates has been in governmental agencies, industry and consulting, and teaching and research in that order. Overall the professional graduate environmental engineering education of the past decades has been successful, both in training the students to successfully attack environmental problems and in meeting the manpower needs of the nation.

Additional environmental protection manpower will be needed in the next decade. The future will see continued education of engineers and scientists and increased emphasis on the education of treatment plant operators and environmental technicians. Graduate education increasingly will stress the interdisciplinary nature of environmental quality management, as well as produce scientifically competent and solution-minded individuals.

Working Group II

WATER POLLUTION

PAPER II/2

Sewerage, Sewage Treatment and Disposal in Singapore

by Tan Teng Huat — Sewerage Branch, Public Works Department, Singapore

The paper deals in brief with the history of the sewerage system in Singapore from the time of its first inception up to the present day.

It then deals in greater detail with the methods of nightsoil and sewage treatment and disposal, starting with the collection and disposal of nightsoil, the first sewage treatment works at Alexandra Road, the early Kim Chuan Sewage Treatment Works and its attendant Sludge Treatment Works at Serangoon, the development of the Ulu Pandan Sewage Treatment Works which replaced the Alexandra Road Sewage Treatment Works, and the later phases of the Kim Chuan Sewage Treatment Works including the new Kim Chuan East Works, the Ulu Pandan Sewage Treatment Works extensions and the Serangoon Sludge Works Extensions. It also deals with the smaller sewage treatment plants including septic tanks and cesspits.

In the discussions on the Works, the method of treatment and *modus operandi* are discussed in some detail; capital and operating costs are also discussed. The paper also discusses the future of the existing Works, the need for additional treatment works to cater for the future and thoughts on the types of works for the future.

The discussions are supplemented with various appendices, flow diagrams, maps and photographs.

PAPER II/3

Disposal of Industrial Trade Effluents from the Food Industries

by Tan Hui Boon — Singapore Institute of Standards and Industrial Research, Singapore

The paper outlines the problems of trade effluent disposal faced by the food industries in Singapore.

It attempts to define water pollution and discusses the question of disposal of effluents into the public sewers and water courses.

It illustrates the types of effluent presently disposed by the different types of food industry, including those which manufacture meat, vegetable, dairy, oil and fermented products. Partly because of the character of the trade effluents, it may be possible to channel such wastes direct into sewers subject to a levy imposed by the relevant authority.

PAPER II/4

Pollution Control of Discharges into Rivers, Streams and Seas

by C.N. McColl — BP Refinery Singapore Pte. Ltd., Singapore

Legislation is necessary in order to provide a uniform code on pollution control for industries to conform to. The technical solutions to pollution problems are generally known, as are also the costs of overcoming or avoiding such problems. In an industrially competitive society the additional costs of achieving pollution control are eventually passed to the consumer. Realistic control limits are therefore needed. This paper is confined to effluents likely from the petroleum industry.

PAPER II/6

Aims of Water Pollution Control

by P.J. Norris — Binnie & Partners Consulting Engineers, London, United Kingdom

Ideally the aims of water pollution control are to ensure the availability of water for public supply, to eliminate health risks and to preserve amenities. The paper discusses the way in which economic considerations often dictate the extent to which these aims can be achieved in practice.

PAPER II/7

The Slop Oil Problem in Singapore

by William Tan Peck Seng — Ministry of Science & Technology, Singapore

Slop oil is the oil/water mixture resulting from tank cleaning operations from ocean-going tankers. At this moment over 3,300 tankers totalling 177 million deadweight tons are plying the "oil routes" of the world. In 1970 they carry over 1,200 million tons of oil. On an average of once a year to 18 months these tankers are docked for inspection and/or repairs. Sometimes they berth alongside for emergency repairs. Safety ordinances require their tanks to be cleaned, gas freed and the slop discharged before the tankers can be docked or berthed. If shore reception facilities do not exist, half a million tons of oil would be discharged into the seas from "repairing" tankers alone. Including "normal" tanker operations, accidents and the discharge from ships bilge the total oil spill (from ships) could come to over a million tons per year.

Oiled waters can and do cast numerous troubles ranging from dead sea birds to extermination of whole colonies of shellfish. Potentially, the most serious could be a reduction in the population of phytoplanktons which reside just below the ocean surface. Phytoplankton are responsible for converting a major part of the carbon dioxide into oxygen and its wholesale annihilation could mean an irreversible change in the oxygen cycle. Also fishery resources would be affected by a decline in the population of marine organisms. In the decades to come, this could be a setback to a world hungry for protein.

The rationale for slop receiving facilities have been accepted by major ship repairing countries who have put several into operations. The usage of such facilities have also been largely accepted by tanker owners despite the penalties incurred.

In the case of Singapore, the quantitative need for slop facilities has been assessed by the author in a technoeconomic study for the Port of Singapore Authority. Due to proprietary conditions, only the technical part of the study is presented in this paper. The main conclusions are as follows: the economics of scale suggests a central depot to service the various ship repairers; forecasts of tanker repair turnover show that by 1975 Singapore will be repairing nearly 20% of the world's tankers and the total slop discharged could amount to over 680,000 tons per year. Slop can be crude, heavy fuel oil or "white oil" slop. Findings show that crude will predominate. White slop has tetraethyl lead which is undesirable in refinery operations.

Reception facilities start with the provision of wharves suitable for berthing supertankers in ballast condition. Study of wharf facilities are carried out separately and not included in this paper. After reception in standard oil tanks, the oil is processed from the slop and stored for final disposal. Four methods of final disposal are given, the most promising being one where arrangements are made with oil refineries to accept the processed oil as a small part of their feed stock in the case of crude or for blending in the cases of fuel or white oil.

Coincident with the need for slop facilities, the oil depot at Pulau Sebarok is being vacated by an oil company. It was found that this would be a suitable site for a slop centre. Some modifications to the existing pipes, tanks and other facilities are being carried out and slop reception is scheduled to commence from February 1972.

PAPER II/8

The Control of Wastewater and Oil Discharges to the Sea, with Particular Regard to Studies Recently Carried Out in Singapore's Southern Coastal Waters

by J.R. Preston — J.D. & D.M. Watson, Westminister, London, U.K.

The paper discusses the characteristics by which pollution in wastewater can be described and quantified; they include suspended solids, biochemical oxygen demand, coliform bacteria, oils and greases, heavy metals and other toxics and nutrient concentrations. It reviews the standards commonly associated with wastewater discharges into inland waterways, and compares them with standards which might be upheld for marine discharges, taking health, amenity, fishing and shipping into account. The difficulties in quantifying ecological factors and the importance of such factors in enclosed waterways are mentioned. Dilution and dispersion mechanics from marine outfalls are recounted and hydrographic and hydrological techniques summarised. The engineering feasibility of outfall construction is reviewed, and methods are described. Marine investigations recently carried out in Singapore's southern waters are summarised and related to the general parameters discussed earlier in the paper. The principal conclusions of the investigations are set down.

Lastly, the problems associated with pollution from oil handling and from accidental oil spillages are stated and the precautions and remedies are suggested, with particular reference to Singapore's position as a major oil port.

PAPER II/9

Petroleum Refinery Effluent Quality Control

by Richard Kilpert — Esso Research & Engineering Co., U.S.A.

The protection of our water environment is of continuing concern to the petroleum industry. Further, population growth, greater energy demand and urbanization will promptly increased regulation of industrial discharges. Effective and economical long range planning and implementation of pollution control facilities requires that responsible authorities use a reasonable, scientific approach when setting allowable contaminant levels. The magnitude and characteristics of typical refinery unit effluents are covered. Principal potential pollutants are described, and their effect on the environment is discussed. The state of the art in equipment available for minimizing or removing contaminants is reviewed. The separation of oil and water by the classic American Petroleum Institute (API) separator is covered, as well as newer techniques, i.e. dissolved air flotation, mixed media filtration, chemical flocculation The capabilities and limitations of secondary treatment facilities are reviewed, e.g. biological treatment, activated carbon. Pollution control requirements are having greater influence upon the design of refining facilities. Typical refinery water pollution control systems for salt and fresh water environments are presented.

PAPER II/10

The Handling of Oil Spills

by Richard Kilpert — Esso Research & Engineering Co., U.S.A.

The effectiveness of oil spill cleanup is significantly influenced by environmental conditions at the spill area and the degree of preparedness that has been achieved. Anticipated problems are first defined, based on historical data from past incidents, in terms of spill size, location, type of oil involved and wind/sea conditions. The characteristics of the oil spilled, the location and extent of the spill and existing environmental factors, will influence the decisions on how an oil spill should be handled. Containment, confinement, removal and disposal are commonly-used methods for control and recovery of spilled oil. The various cleanup alternatives are explored. Current state of the art involving equipment and materials, for removing oil from the surface of water, is reviewed. Included in the discussion are booms, sorbent materials, chemicals and skimming devices. The basic requirements of preplanning and subsequent development of effective contingency plans are discussed. In the event containment and removal are not feasible, the role that chemical dispersion can play in minimizing and/or mitigating the harmful effects of the spilled oil will be outlined.

PAPER II/11

Sea Pollution in Singapore

by Capt. Kuttan C. — Port of Singapore Authority, Singapore

The sea pollution problem in Singapore is broadly two-fold, i.e. pollution that emanates directly from a variety of sources within the territory of Singapore and the constant threat posed by the international shipping, particularly the tankers.

To a satisfactory extent surveillance is maintained against minor forms of pollution and also constant remedial action is taken to ensure that the sea around the Republic is clean. The difficulty at the moment is effective surveillance during the hours of darkness when pollution detection is not possible except by means of spot checks.

However, these problems may be considered insignificant when compared with the disastrous effects that ocean-going ships and tankers could bring about as a result of collision and grounding. Such a threat is greater now than ever before owing to the general increase in the world shipping tonnage and the continuing increase in the size and draft of tankers. The other factor which has a detrimental influence on the general situation is the configuration of the waterway around the Republic where bottlenecks exist on the west, south and east. These three locations, off Tanjong Piat, off Raffles Lighthouse and at the approaches to Horsburgh Lighthouse, besides being narrow and shallow are also bends where ships have to alter their course which introduces a further element of risk of collision or grounding.

The remedy against a major pollution threat may be two-fold, i.e. by creating a national anti-sea pollution organisation which is properly equipped, organised and conducted, and secondly by promoting international understanding and co-operation and drawing up an international scheme to combat any pollution disaster that may occur in the region.

It is also vital that those industries which deal in bulk quantities of oil or in the transportation of such oil exercise greater awareness of the threat and accept responsibility and liability for a major oil pollution however caused.

PAPER II/12

Sewage Treatment in Sweden

by Erik Isgard — Swedish Consulting Group, Sweden

In the last 20 years interest in sewage treatment in Sweden has been growing stronger and has become more and more widespread. As a result. about 80 per cent of the densely populated areas are connected to commoi sewage treatment plants, giving Sweden internationally high standards. Of general interest have been such questions as the choice of receiving waters, the construction of local versus regional treatment plants, etc. Interest in satisfactory protection of receiving waters has encouraged the development of new treatment methods. The discharge of phosphorus has caused eutrophication problems and so chemical treatment has been enhanced.

The number of biological treatment plants has increased rapidly, from about 10 in 1950 to 820 by 1st May 1971. In addition there are 7 plants for chemical treatment only and about 90 for both biological and chemical treatment. It is expected that 50 per cent of the population will be connected to plants including chemical treatment by the end of 1974.

In the densely populated regions of Stockholm and Gothenburg there has been joint efforts between the municipalities towards large treatment plants and discharge of the effluent into suitable receiving waters. Several sewage treatment works have been excavated underground in solid rock, thereby diminishing the problem of finding a suitable place for the works in built-up areas.

The largest treatment plant in Sweden is situated in Henrikdsdal, treating 370,000 m^3/d from 650,000 people plus a population equivalent of 75,000 people. On the top of the hill of the treatment works are apartment buildings for 2,000 people. Other examples of modern treatment plants are Kappala, Rya-Gothenburg, Norsa-Koping (a combination of sewage treatment plant with a district heating plant and an incineration plant) Small plants are constructed according to the "compact" system.

Chemical treatment is applied in Sweden according to either of the following processes:— pre-precipitation, direct precipitation, simultaneous precipitation or post-precipitation. Alum is most widely used. The sludge is dewatered in centrifuges or band presses. The hot gases from the garbage incineration plant of the community are in some cases used to dry the sludge. The sludge can be used in agriculture, but care has to be taken regarding the content of heavy metals and chlorinated hydrocarbons. Cadmium and mercury especially have to be taken into account.

The demand for good process control of the treatment process has increased because of the necessity for a reliable operation and a consistently good quality of the effluent. The present investments in Sweden in sewage treatment plants amount to 300-350 million Sw.Cr. annually, corresponding to 40 Sw.Cr. per inhabitant and year. The costs for a modern treatment plant for a 90 per cent reduction of BOD and phosporus are given. The Government subsidises the construction costs with up to 50 per cent of the cost, but not exceeding 5 million Sw.Cr. for each plant.

PAPER II/13

Indication of the Relationship Between Phyto-Plankton Distribution and Phosphate Levels

by Chen Foo Yen — Primary Production Department, Singapore
and Akihiko Shirota — Marine Fisheries Research Department, Singapore

Phosphates and nitrates are known to cause algal 'bloom' in impounding reservoirs, if they are present in appreciable quantities in the water. From an earlier study, these radicals are known to be present in varying quantities in our streams. However, in the Republic, no tolerance levels have been set either for running streams or for stored water in the reservoirs. A project was initiated in December, 1971 to study phyto-plankton distribution in relation to levels of these radicals in our reservoirs, which, it is hoped, eventually will help formulate raw water standards for these two radicals.

This report deals with some preliminary findings on phosphate values and phyto-plankton distribution. Water samples were collected at various depths from Seletar Reservoir (280 ha), Pierce Reservoir (110 ha) and MacRitchie Reservoir (102 ha). A total of 11 stations were sampled in Seletar Reservoir and 4 each in Pierce and MacRitchie Reservoirs.

The phosphate values (expressed as elemental P) at various depths in MacRitchie Reservoir range from 0.26 μg-atom/1 to 0.78 μg-atom/1 (mean = 0.45 μg-atom/1); those of Pierce Reservoir from 0.05 to 0.50 μg-atom/1 (mean = 0.28 μg-atom/1); and those of Seletar Reservoir from 0.31 to 1.46 μg-atom/1 (mean = 0.88 μg-atom/1).

Although from this preliminary analysis, it is not possible to state the exact phosphate level at which undesirable algae begin to proliferate in the water, there is clear indication that the higher phosphate levels of Seletar Reservoir have given rise to an algal population commonly found in highly eutrophic waters and consisting predominantly of genera such as *Dictyosphaerium*, *Scenedesmus*, *Coelastrum* (Chlorophyta), *Microcystis*, *Oscillatoria*, *Phormidium*, *Aphanocapsa* and *Merismopedia* (Cyanophyta).

Contrasting, one notes a high proportion of innocuous algae such as *Cosmarium* and *Staurastrum* (Chlorophyta) in Pierce and MacRitchie Reservoirs in which phosphate values are lower. These 2 genera constitute 80% of the algae in Pierce Reservoir and 96% of the algae in MacRitchie Reservoir.

Growth of pure culture of *Scenedesmus* species were observed in filtered water collected from the 3 reservoirs and the best growth was observed in the Seletar water indicating once again possible correlation with the phosphate values.

PAPER II/14

Research on the Culture of Certain Common Marine Organisms in Singapore Waters

by Tham Ah Kow, Chua Thia Eng, Yang Swee Ling, To Chang Mun, Teng Seng Keh & Tan Wee Hin — Fisheries Biology Unit, University of Singapore, Singapore

Singapore is an island and it is only natural that some research effort should be devoted to the study of the biology of the more common marine organisms. Among some of the problems presented by the trade in marine resources is that of the diminishing supply of oysters, mussels, certain seaweeds, marine prawns, exotic marine aquarium fish and certain species of marine food fish used for the restaurant trade.

The experimental cultivation of *Eucheuma spinosum*, a local red alga, which is being harvested by fishermen in increasing quantities and exported to USA, Europe and other developed countries is described. The experimental cultivation of the local green mussel, *Mytilus viridis*, a local oyster, *Crassostrea cucullata* and certain marine prawns as well as a marine copepod, *Paracalanus crassirostris* is also described. The main problems encountered in this type of mariculture are also briefly described.

PAPER II/15

Development of Blooms of Blue-Green Algae in Non-Alkaline Waters in Equatorial Regions

by D.S. Johnson — Zoology Department, University of Singapore, Singapore

On the basis of temperate experience, it has been generally believed that blooms of blue-green algae are unlikely to be a problem in freshwaters unless these are calcium-rich, with high alkalinity, and with high basic pH. Thus the occasional reports of blue-green algal blooms in reservoirs in Malaysia, and of incipient blooms (fortunately not developing further) in Singapore reservoirs are unexpected since the majority of these habitats are calcium-poor, low alkalinity, low pH habitats which are generally low in dissolved minerals. Further our general investigations have shown that a number of fishponds in Singapore with well-developed blue-green blooms were not excessively rich in calcium. Usually, indeed the calcium was high by local standards yet low enough for the ponds to be classed as calcium-poor on a world scale.

During the last two years, we have been investigating the primary production of an experimental pond at Sembawang as part of a contract under the International Atomatic Energy Agency. This has given us the opportunity to examine the development of blue-green blooms in an acid water pond. The pond is extremely calcium-poor on world standards (3.0-4.5 parts per million). At the start of the survey, the mid-day pH varied from 6.3 to 7.0 with still lower levels at night; the alkalinity ranged from 0.14 to 0.29 meq./1. and the phytoplankton was a diversified soft-water assemblage dominated by green algae and with an abundance of desmids. These conditions had probably persisted for some time as the pond has been out of use. It was stocked with fish and these were given supplemental feeding, carefully controlled so as not to pollute the water. No other fertilization was used but the incidental fertilization was sufficient to initiate a spectacular blue-green bloom which finally rose to over 51,000 organisms per litre before partially collapsing during the dull, rainy weather of December-January.

The pond was drained, refilled, and restocked in early 1971 and we have been able to follow the subsequent succession leading to a blue-green bloom which later collapsed to yield a moderately rich, persistent plankton assemblage still dominated by blue-green algae. During this latter period, it has been possible to show clearly the fall in plankton levels associated with the development of the blue-green bloom. Whilst there is thus a definite connection between phosphate and blue-green blooms, we have found correlations to be less clear at other times and agree with a number of workers in temperate zones in finding that bloom collapse occurs before phosphate exhaustion, suggesting ultimate control by other factors. It is also noteworthy that the phosphate levels involved, though high compared to those of local unproductive waters, are nonetheless lower than are common in bloom-forming waters in temperate areas.

We conclude that blue-green blooms develop much more readily in equatorial climates than in temperate climates. They are likely to develop in waters in which they would not occur in temperate areas, at relatively low levels of fertilization, and at any period of the year where there is not long-continued dull weather. Thus more stringent control is necessary to avoid eutrophication than would be required in temperate areas.

PAPER II/16

Water Pollution and Environmental Health

by A. Sekarajasekaran — Senior Public Health Engineer, Ministry of Health, Malaysia

Urbanization, industrialization and land development in West Malaysia have been growing at a rapid rate. Existing legislation to cope with pollution problems is reviewed. It is clear that existing legislation was designed to cope with special problems as they have arisen and have been designed on the basis of expediency to try to eliminate some of the gross and obvious nuisance problems. This legislation has failed to control pollution and this has been due to inability to recruit and train adequate technical staff to carry out knowledgeable implementation.

The paper calls for comprehensive water quality control legislation co-ordinated with an overall environmental quality control enabling act. Such legislation must include provision for recruitment and training of adequate staff and other factors relating to implementation.

(Abstracted by Chin Kee Kean)

PAPER II/17

Toxicity Control of Industrial Wastewaters and Pesticide-Polluted Waters in Vietnam

by Phan The Tran & Do Thi Thuan Bich — Department of Water Sanitation and Toxicology, Pasteur Institute, Saigon, Vietnam

A bioassay evaluating the acute toxicity to *Carassius auratus*, has been used to test the toxicity of industrial wastewaters and pesticide-polluted waters in Vietnam.

PAPER II/18

Improvement of Soil Cover for Water Conservation, Prevention of Sedimentation and Pollution Control in the Philippines

by Pedro N. Laudencia — Chief, Division of Agriculture and National Resources Research, National Science Development Board, Manila, Philippines

Surface water resources such as rivers, streams, and lakes which abound in the Philippines are slowly being clogged with sediments and soil deposits or are heavily polluted to the extent that only a few of the not-so-delicate species of fish remains. Places which used to be the haven for recreation become murky and quicksandy. Water turbidity caused by suspended fine particles carried by runoff water diminishes the population of phytoplankton which serve as food for fish. Suspended fine particles also suffocate fish by clogging their gills. Rivers and streams which used to be the source of potable water in the rural areas are slowly becoming useless for such purpose.

One activity being given impetus by the Philippine Government which may help alleviate the worsening condition of surface water resources is the improvement of the soil cover designed to minimise water erosion, sedimentation and pollution. This is being accomplished through:

(a) improvement of agricultural practices in the field of soil and water conservation;

(b) engineering measures; and

(c) forest protection and reforestation.

This paper discusses present practices and researches being undertaken to achieve this objective. Researches on planting of cover crops, pasture improvement and selection of fast-growing reforestation tree species which are also utilizable for pulp and paper manufacture are described.

PAPER II/19

Pollution Control of Discharge Into Rivers, Lakes and Coastal Waters in the Philippines

by Bienvenido N. Garcia — Officer-in-Charge, National Water and Air Pollution Control Commission, National Science Development Board, Manila, Philippines

Pollution has been and will continue to be an environmental problem as a consequence of industrialization, urbanization, increasing number of vehicles and the use of pesticides in agriculture. It is an economic as well as a social problem directly affecting many industries, urban and regional development, and patterns of land use.

Pollutants which are entering our water courses are industrial wastes, toxic chemicals, domestic sewage, mine tailings, detergents and pesticides. Steps taken by industry for the abatement of these pollutants are:

(a) reduction of wastewater volume;
(b) process changes;
(c) equipment modification;
(d) segregation of wastes; and
(e) by-product recovery.

After applying the above preventive measures, the concentrated wastewater has still to be treated. Wastewater treatment may consist of one or a combination of the following:—

(a) neutralization;
(b) sedimentation;
(c) flotation;
(d) coagulation;
(e) lagooning;
(f) activated sludge process; and
(g) trickling filtration.

Pollution control of discharge into rivers, lakes and coastal waters in the Philippines is vested by law under the National Water and Air Pollution Control Commission. Pursuant to the pertinent provisions of the law it adopted water quality standards. Due to varied usage and location of different streams, lakes or other bodies of water, classification of bodies of water has to be based on their best usage. The water quality standard for drinking and other domestic purposes is of a higher quality while that for navigation, agriculture and industry is of a lower quality. The water quality standard then adopted is the basis for determining the degree of wastewater treatment required for each firm.

The Commission recognizes the contribution of industry to the economic development of the country so that it has always sought co-operation and voluntary compliance rather than compelling industry under the threat of the penal provisions of the law.

PAPER II/20

Water Pollution in Thailand

by Sermpol Ratasuk — Research Officer, Environmental and Ecological Research Institute, Applied Scientific Research Corporation, Thailand

Water pollution problems exist in various parts of Thailand with varying degrees of seriousness. The causes, nature, and extent of the water pollution are described in some detail. Legislative controls of water pollution such as industrial effluent standards are discussed. Various problems responsible for the unsatisfactory combat against water pollution are elaborated. Research activities on water pollution are briefly described.

PAPER II/21

Summary Report on Pollution Control in Indonesia

by A. Aziz Sasmitadihardja — Directorate of Sanitary Engineering, Ministry of Public Works & Electrical Energy, Indonesia

The paper outlines the efforts made and problems encountered in pollution control in Indonesia. There are about 124 million population in Indonesia unevenly distributed over the Archipelago extending 3,200 miles west to east and 1,000 miles north to south. The island of Java and Madura have 65% of the total population. Of the population about 100 million is rural. The size of the country and its large population constitutes a major problem for economic development, including water management and its pollution control.

Urbanization and industrialization have given rise to solid waste collection and disposal problems. Surveys in Bandung municipality in 1971 indicates an average 2 to 4 litres of solid waste per capita per day. The present disposal method is inadequate and the Central Government is providing technical and financial assistance to the locality to develop solid waste management systems. The ever-increasing rapid urbanization and industrialization in large cities are causing serious water pollution problems which result in major public health hazards and the general deterioration of natural water resources. In the city of Djakarta a water pollution committee for the formulation of water pollution legislation was established in 1970 to cope with the problem. Steps have been taken in recent years through legislation, education and research to deal with domestic trade and farm wastes. The problem has always been the lack of technical know-how and financial resources.

The paper calls for appropriate international assistance and close regional collaboration in dealing with these problems. In regions where people still struggle to obtain adequate drinking water supply, it is important to disseminate research, training, education and information programmes to create greater appreciation and awareness towards preservation of the environment.

(Abstracted by Chin Kee Kean)

PAPER II/22

Sea Pollution — Some Aspects and the Need to Fight It

by Wahjudi Wisaksono — Indonesian Petroleum Institute

Industrial development and the significance of nature and the environment as vital resources for human needs are important for developing countries.

Estimating the significance of these two sectors combined, there are two aspects to be considered:

(a) the technological impact upon the environment, which in this particular case, concerns crude oil and its biological effects; and

(b) the economical impact of the subsequent interaction of the latter. Petroleum industry circles in Indonesia are well aware of the danger of pollution. In view of this, it is therefore proposed to (i) secure the services of a bio-economist or an economic biologist for implementing an environmental management scheme and (ii) to call for the closest co-operation between the neighbouring countries united in ASEAN and to establish an interim working committee or a permanent executive body for this purpose.

PAPER II/23

New Ideas for Fighting Urban and Industrial Pollution

by H.C. Rasch — Swedis'· Consulting Group, Sweden

Introduction: Sweden, population distribution, recent development on sewage treatment.

Environmental Planning: Noise air pollution, sewage and refuse disposal in a Stockholm suburb.

Combined plant for sewage treatment, refuse incineration and district heating: Combined plant for a Swedish town emphasis on environmental questions.

Chemical treatment of sewage: Phosphorus removal with pre-precipitation versus post-precipitation.

Food industry plant: Canning and deep-freezing of meat, vegetables, fruits and berries, recirculation of washing and cooling water, discharge of sewage water into regional plant.

Fibre sludge treatment: Separation of fibre sludge from wood industries, treatment of sludge.

Modern urban development: Layout of a town for 25,000 people, residential, civic, shopping, schooling and recreational areas, district heating.

Working Group III

CRITICAL PROBLEMS OF THE ENVIRONMENT

PAPER III/1

Environmental Problems in Singapore

by S. Nadesvaran — Planning Department, Singapore

Singapore is blessed with an abundance of fresh air as developed and developable land lies in doughbut form, sandwiched between sea and the central hilly water catchment area and nature reserves. But, as virtually all living and activity has been concentrated within a 5-mile radius of the city, due to the economics of concentration, environmental problems have therefore become a major concern in Singapore. These are pollution, urban land misuse and natural resource depletion.

Pollution manifests itself in three forms — air, water and solid waste. The major air pollutants in Singapore are sulphur oxides, smoke and dust, emitted primarily from motor vehicles, chimney stacks of power stations and industrial establishments located mainly in the western part of the island. Air pollution as yet does not constitute a critical problem in Singapore. This is because housing is segregated to the east of the island where few industries exist. Industrial concentrations, too have not reached a very high density. However, an Anti-Pollution Unit was established in the Prime Minister's Office in 1970 to keep a watch on the situation.

Singapore's water catchment areas are adequately protected and free from pollution but the tapping of rivers outside the catchment area to cater for Singapore's growing water needs would, however, need pollution control. The discharge of domestic, trade and industrial wastes into rivers, especially the Singapore River requires stringent control, whilst sea-pollution by ships is being subjected to increasing control by the Port of Singapore Authority.

Sewage treatment capacity is adequate and swamp lands are presently available for garbage disposal. As long-term measures, new methods of compacting rubbish and of incineration are being looked into by the Ministry of Health and of direct sewage non-pollution discharge into the sea by Public Works Department.

Pollution as a critical environmental factor, is therefore not likely to become an issue as serious as in the West.

The Statutory Master Plan of Singapore together with the long-range 1990 Concept Plan for Singapore prepared by the U.N.-assisted State and City Planning Project ensures adequate control over land use in Singapore. Together with such factors as the planning tradition of Singapore dating back to the thirties and present government policies to keep Singapore clean and green, urban land misuse is kept to a minimum in Singapore.

Singapore has very limited natural resources and, therefore, no major problems arise here. Non-scarring of lands and non-depletion of hill features are nevertheless being consciously looked into.

Two problem levels exist. At long range, problems arise primarily because of population growth. As industrial development has to be selectively done for long-run employment creation so as not to pollute the environment, the shift will have to be towards tertiary service rather than secondary industries. In day-to-day development control, mop-up operations have to be carried out to ensure that junk yards within the city are eliminated to avoid health hazards (mosquito) and visual pollution. So small-scale industries which tend to proliferate in run-down areas and in the twilight fringes of the city have to be resited and fostered in functional and healthier surroundings.

There are no major environmental problems in Singapore as in the West, but the situation bears watching because of our concentration of building, plant and activity within a 5-mile belt along the southern coast.

PAPER III/2

Public Housing and Resettlement in Singapore: An Overview

by Stephen Yeh and Kwok Chuon Wei — Statistics & Research Department, Housing & Development Board, Singapore

A brief review of the history of Singapore's public housing and an outline of the major policy developments in the last decade. Also an evaluation of the social and the economic consequences of the Government's low-cost housing efforts as well as an assessment of trends for the immediate future.

PAPER III/3

Urban Renewal in Singapore and its Associated Problems

by Tan Sioe An — Urban Renewal Department, Housing & Development Board, Singapore

This paper outlines the problems and achievements in Urban Renewal in Singapore. Launched in 1966, to date urban renewal in the Central Area has carried out the clearance of about 100 ha of slum and squatter ridden areas, re-housing the people in new public housing estates. Careful consideration is given towards achieving a satisfactory balance between the needs for easy access by cars to all parts of the central areas and the adverse effects created by cars. Plans are also programmed to maintain a large residential population in the Central Area. Through special incentives, private sectors also participate in the Urban Renewal programmes.

A special problem in re-development in the Central Area is the relocation and clearance of non-conforming uses such as backyard industries and warehousing. Resettling of identical and related cottage industries as a group within industrial sites on the fringes of the Central Area has been carried out with considerable success.

(Abstracted by Chin Kee Kean)

PAPER III/4

Jurong Town — Singapore's Experience in the Planning and Development of an Industrial Complex

by Fong Tiew Weng — Singapore Institute of Planners, Singapore

Industrialisation can be said to be a completely new venture and experiment to Singapore, which was started barely a decade ago. Among the numerous development strategies and priorities adopted by the Singapore Government, creating and providing a big scale industrial estate with all the necessary industrial facilities and infra structure was one of the main tools used by the Singapore Government in its attempt to launch its industrialisation programme successfully. In the process of creating such an estate, countless problems of technical, social, economic, environmental nature were experienced.

This paper simply attempts to relate briefly the story of Jurong and some of the problems which were experienced during the implementation of the project.

PAPER III/4A

Industrial Development and Environment in Singapore

by Fong Tiew Weng — Singapore Institute of Planners, Singapore

Rightly or wrongly, it has more or less been universally regarded as a natural order of things that industrial development and environmental pollution and disruption are inseparable cause and effect.

Without exception, Singapore, having launched its industrialisation programme out of necessity about a decade back, but not at all unaware of the inherent environmental problems that would arise from industrialisation, is confronted with the necessity to study the same problem.

This paper attempts to briefly examine the experiences that have been gathered from the industrial development during the past decade or so, and to touch upon some of the environmental issues which have or are going to become apparent.

PAPER III/6

The Changing Characteristics of Solid Wasté in Singapore

by C.R. Ananthan — Public Health Engineering Branch, Ministry of Health, Singapore

A refuse analysis was carried out in December 1971. The results are compared with similar analyses carried out in 1963, 1967 and 1970. Significant trends are seen in certain constituents and the factors responsible for influencing the changes are dealt with under each separate classification. The effects of some of these constituents, including paper and plastics, on the present and future methods of disposal are also indicated.

PAPER III/7

The Control of the Litter Problem in Singapore

by Koh Thong Sam & Yap Kim Seng — Ministry of Health, Singapore

The multiple factors comprising high population density, humid climate and rapid urbanisation and industrialisation of Singapore have contributed to a pollution problem which includes among other things, the litter problem.

This litter problem is an acute and sensitive one and the task of solving this problem is enormous. This problem is being tackled through mass education and strict enforcement. The 'war' against litterbugs is a long and relentless one. With closer public co-operation and stricter enforcement, Singapore is now way ahead towards its goal of a cleaner and healthier environment.

PAPER III/8

The Problem of Dust in Granite Quarries in Singapore

by Harry K.C. Wong & Chew Pin Kee — Industrial Health Unit, Ministry of Labour

There are 25 granite quarries operating in Singapore. These are of various sizes and employ methods of different degrees of sophistication but the basic processes involved are similar. A brief description is given of these processes.

A survey is described of a sample of these quarries. Dust counts were taken in relation to the various processes, comparing the dust concentrations between the different processes and between the various quarries. A brief discussion of the methods of dust control currently used is made.

PAPER III/9

Mental Health Aspects of Urban Living

by Nalla Tan — Faculty of Medicine, University of Singapore, Singapore

The paper deals with specific aspects of mental health in urban living. Seven aspects are touched on briefly.

1. General assertions are made in terms of mental health being one of the biggest problems facing humanity today, and these basically, are due to social disorganisation leading to mental disorganisation.

2. Change is said to be the reason for both social and mental disorganisation, the rate of change being an important consideration.

3. The specific effects of change in urban living are social isolation, conflict of cultures leading to deculturisation, depersonalisation and finally dehumanisation. The four sequelae are each discussed in turn.

4. The recognition that the etiology of attitudinal and behavioural change in urban living is complex, because reactions to various mental stimuli may be immediate but it can also occur at any time in the future thus presenting difficulties in pinpointing a specific etiology.

5. Reference is made to continual transition in various zones of urban living resulting in continuous disorganisation and insecurity.

6. Prevention, treatment and readjustment are briefly mentioned as well as the high costs of rehabilitation and readjustment which can be reduced if further effort is put on prevention.

7. Prosperity in urban areas is not equated with happiness. The high rate of mental stress with material success is referred to in relation to the Happiness Index.

PAPER III/10

Education, Development and Research

by Ruth H.K. Wong — Ministry of Education, Singapore

There are two commonly accepted concepts about education which may bear examination. One is that education is implicit in schooling; the other is that the more institutionalised instruction which the individual receives, the better he is for such. These two concepts have led to the over-simplistic view that education and development are positively correlated when, in fact, such an outcome depends more specifically on the quality and relevance of the schooling received to development needs.

A changing environment with new challenges and new needs, with knowledge explosion and obsolescence does not require so much a content-oriented curriculum as a value-directed curriculum. The central study in schools should be principles of human action based on an understanding that in a shrunken world there has to be a "mutual coercion mutually agreed upon".*

Mutual agreement implies mutually acceptable criteria which students may well do to understand as soon as they are capable of doing so. The study of all other subjects should be related to this central theme. In other words, the other disciplines should be presented from an inter-disciplinary viewpoint rather than as isolates providing a great deal of detailed and unrelated data. Each subject studied should yield important basic principles for the building up of positive mental and emotional attitudes while affording those skills in thinking and doing which will enable the individual to develop such attitudes. This does not exclude the sciences nor even the technical education subjects which purport to teach specific manual skills.

The individual whom we prepare for the future will not be judged by how much of history or geography he has factually accrued, but how much of a glimpse he has caught of the good or ill consequences brought on through the struggles of man with environment, of man with man so that he may learn to avoid those paths which lead to costly destruction and insensitive unawareness of man's common destiny. Likewise, he will not be considered expert for having committed to memory the formulae of science and mathematics (the machine can do that for him), but he will need to know how to use science without consequential tears.

The problems of development stem essentially from a triad of lags — a perception lag, a value lag and an action lag.

The trappings of technology — the machines, the consumer goods, modern transport and even the ubiquitous mass media — do not necessarily imply an understanding of what technology means or does. Some suffer from a perception lag of the purpose and promise of technology.

A setting in of moral turpitude and a prevalent laissez faire about consequences of actions have resulted in a general lack of moral concern about the economic motive and the vested interests. Herein lies the value lag.

*An apt phrase used by G. Hardin in an article, "The Tragedy of the Commons", published in ENVIRONMENT (Ed. J.W.G. Ivany), Addison-Wesley Pub. Co. Inc., Philippines, 1972.

There is also the lag of methods and ideas behind needs. This constitutes the action lag. Not that action is not swift enough. Packaged solutions are too readily available. Imported from affluent societies and designed for their cultures, they are frequently beyond the reach of majority needs. Underdevelopment, according to Illich* signifies the "surrender of social consciousness to prepackaged solutions". One may impute much of the relevance too in education to this cause.

To understand more fully the proper relationship between education and development is, therefore, an important concern which needs to be supported by research. The following are basic problems associated with this concern:

(a) Basic assumptions about development need to be examined. Are the economic indices used for the measurement of development valid? Are we using development as a guise for ensuring a continuing loyalty to the producers who have both created and pandered to our wants? Does social and national development consist merely of economic growth and material affluence or is there now an urgent need to seek diligently the moral-spiritual component that we have not only overlooked, but in every underdeveloped country sought to remove as a thing of superstition, a hindrance to modernisation?

(b) Next, there is need to seek new alternatives to solutions. If mass education is required, how should it be organised to produce the best results within the means available? Of what should it comprise? Concomitant with this is the need to evaluate alternatives. Too frequently in a given situation there is nothing entirely right or wrong. The control of environment, for example, is important, but the methods used must be assessed.

(c) Thirdly, how do we deal with man himself? How to bring him to his senses lest he continues to destroy his own heritage?

(d) Fourthly, there is need to select from the universe of values those most related to our well-being in the future; to find out what individual liberty would need to be sacrificed for the greater freedom of all, to decide on what values common consensus may rest for the good of the community.

(e) Last, but not least, is the need for practical and concrete measures and alternatives to support solutions which are a result of studies made. A common failing is to leave mooted solutions at the word-level without practical demonstration of feasibility. On the part of the schools what form of responsibility should the teachers take? Teaching a course on environment and pollution control alone is not sufficient. How should parents and the community be actively involved? What forms of training must be given to change agents whose main problem will be the need to counter basic individualism and selfish unawareness of others?

*Illich, I., "Outwitting the Developed Countries", CHURCH AND SOCIETY, Nov./Dec. 1970, p. 64.

It is obvious that in the approach to these needs, education cannot go it along. The research and the practical action have to come from inter-disciplinary effort — from theorists and practitioners, from the particularly concerned and the man-in-the-street, from scientists, technologists and humanists — all will have to work together.

PAPER III/11

Susceptibility of *Culex Pipiens Fatigans* (Wied) Larvae to Insecticides in Singapore

by Agnes G.H. Sih and Chan Kai Lok — Vector Control & Research Branch, Ministry of Health, Singapore

The susceptibility levels of *C. p. fatigans* larvae in Singapore to three chlorinated hydrocarbons and three organophosphorous compounds were studied and their toxicity was as follows: Fenthion > Diazinon > Malathion > Dieldrin > Gamma BHC. Results also showed that the larvae were susceptible to all the insecticides tested except DDT. Unpublished report from a previous study investigated by the first author revealed that the adults were also resistant to DDT. This usage was stopped completely since 1968 except under emergencies. Previous to that, DDT was not known to be used extensively and thus it is very likely that *C. p. fatigans* in Singapore is naturally refractory to DDT.

PAPER III/12

Sulphur Content in Fuel Oil and its Contribution to Air Pollution in Singapore

by Chua Yong Hai — Anti-Pollution Unit, Prime Minister's Office, Singapore

High sulphur-bearing petroleum fuels are under scrutiny in a number of countries and limitations on permissible sulphur contents in these fuels are getting more stringent each year. In Singapore, the combustion of petroleum fuels is the principal source of SO_2 emissions into the atmosphere. Petroleum fuel consumptions will increase as energy demands increase. SO_2 emissions will increase correspondingly. Trends of these increases for the period 1963 to 1970 are reported. Ground-level SO_2 measurements have been conducted and results obtained so far indicate that the SO_2 pollution is generally satisfactory as compared to that in some industrialised cities in other countries. The pollution, however, is on the increase. Desulphurisation of crude and fuel oils and stack gases is at present economically unfavourable. For the time being, tall chimneys will help to reduce ground-level SO_2 concentration, while sulphur recovery in oil refineries will help to decrease total SO_2 emissions.

PAPER III/14

Environmental Control of Markets and Hawkers

by Roland De Souza and Goon Peng Yam — Hawkers Branch, Ministry of Health, Singapore

The hawkers population as it affects our environment and the need for their control and identification by licensing in the short and long term process.

Formulation of positive action to resite and license the hawkers at temporary open sites, as a form of 'holding action', and ultimately to house them permanently within buildings where proper sanitary facilities and anti-pollution measures are provided.

PAPER III/15

Disposal of Refuse in an Urban Environment

by Lye Thim Fatt — Senior Public Health Engineer, Public Health Division, Ministry of Health, Singapore

The present refuse production rate in Singapore is about 1.48 pounds per capita per day and is increasing at a rate of 2% per annum as a result of rapid industrialization and urbanization. With limited land area, traditional sanitary landfill method is clearly not the solution for refuse disposal in Singapore. Other refuse treatment techniques which will give maximum reduction in the refuse volume for final disposal will have to be adopted. There is an urgent need to appreciate the requirement for adequate land reservation and land allocation for refuse treatment plants and the final disposal ground, to receive, treat and finally dispose of the solid wastes from a communnity.

(Abstracted by Chin Kee Kean)

PAPER III/16

Solid Waste Disposal in Saigon

by Nguyen Sy Tin — Chief of Environmental Sanitation Service, Ministry of Health, Saigon, South Vietnam

Saigon's prefecture covered 70 km^2 with a population of 1.8 million. Due to rapid urbanisation, the city is overcrowded and faced with many new problems, especially that of solid waste disposal. Total refuse collected daily amounts to 3.100 m^3 in volume. This refuse is high in organic content (80%). The paper outlines the method used in collection and disposal of the refuse and highlights the problems encountered in this operation. A "modified sanitary landfill" method is developed to suit the city's particular needs.

(Abstracted by Chin Kee Kean)

PAPER III/18

Water Sanitation and Public Health Education at Saigon University, Faculty of Pharmacy

by Phan The Tran — Faculty of Pharmacy, Saigon University, Department of Public Health & Water Sanitation, Vietnam

The Water Sanitation curriculum, the only one of its kind offered in Vietnam, is listed and connected with the Public Health curriculum taught to Saigon University's Faculty of Pharmacy students.

PAPER III/19

Environmental Health Problems and Control in the Philippines

by Jose Morales — Chief, Division of Environmental Sanitation, Bureau of Health Services, National Science Development Board, Manila, Philippines

Adverse geographical conditions in the Philippines make provisions for the health of the people difficult. Furthermore, aggravations from rapid industrialisation, urbanisation and high growth rate of population increase environmental health problems. This calls for concerted action by a well-coordinated Department of Health in planning on a long-term basis to eradicate these problems.

(Abstracted by Chan Joo Phek)

PAPER III/21

Quelques Problemes de l'Environment au Vietnam

by Pham-Hoang Ho — Department of Botany, Faculty of Science, University of Saigon, Vietnam

The author discusses several environmental factors in Vietnam. The air pollution is very grave, particularly in Saigon. Fresh water, still abundant, begins to be polluted by agriculture and industry. There are no regulations against noise. The destruction of forests presents a serious problem for many future generations. Accelerated urbanisation on account of the war, makes many unadapted people.

APPENDIX III

BIBLIOGRAPHY
OF WATER RESOURCES, WATER POLLUTION
AND ENVIRONMENTAL PROBLEMS
in the Southeast Asian Region

(Based on references cited in the Workshop papers)

NOTE: The number in square brackets after eaoh reference is the number of the Workshop paper in which it was cited.

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APPENDIX IV

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" . . . it is a mistake to think that environmental quality concerns only the highly industrialised nations, that pollution is a disease peculiar to the developed countries, and that developing countries have more urgent problems to solve than problems of the environment. On the contrary, developing nations, embarked as they are on major schemes of development, should consider each and every scheme in terms of its impact on the environment. They have the unique opportunity of learning from the mistakes made by the developed nations."

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WORKING GROUP I

WATER RESOURCES

Paper No. I/1

GROUNDWATER INVESTIGATIONS IN SINGAPORE

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ABSTRACT

Previous investigations conducted in the eastern part of the Island of Singapore which led to the subsequent development of the Bedok Wells, is reviewed. These wells averaging 80 feet in depth, tap the shallow aquifer in the Recent or Younger Alluvium near its contact with the Older Alluvium.

It is followed by an account of the recent investigations to determine the groundwater potential in the lower depth of the Older Alluvium by means of geophysical survey and test drilling.

INTRODUCTION

Since 1860's, water supply in Singapore is based mainly on surface water sources. The unfavourable geological conditions as deduced from surface observations and shallow boring, and the general lack of detailed knowledge of the deep subsurface conditions in the absence of any deep drilling, have discouraged the large-scale exploitation of ground water as a possible source of supply. In the early period of water supply development, very high quality surface water obtainable from the central protected catchments on the Island was sufficient to supply the small population, not all of whom were supplied with piped water. Others, especially those in the rural areas, continued to rely on the shallow dug wells for their supplies. As these surface sources were fully developed by early 1920's, water engineers turned to the mainland where larger rivers fed by large jungled catchments offered abundant and good quality raw water.

It was, therefore, not until 1950 in the context of the emergency situation on the mainland, that the first serious consideration was given to the possible large-scale exploitation of local groundwater as an emergency source of supply. This resulted in the development of the Bedok Wells in 1955-1959. Contrary to the expectation of the consultants, the yield from these wells when in full operations had proved to be very limited.

In view of the poor performance of the Bedok Wells, no further consideration was given to ground water exploration until the recent investigation which was directed to determine the ground water potential in the lower depth of the quaternary sediments locally known as Older Alluvium which extended several hundred feet below the ground surface to the depth of its contact with the basement rock in the eastern part of the Island.

GENERAL BACKGROUND

Location

The Republic of Singapore consists of the main Singapore Island and 61 other off-shore islands covering a total area of 224 square miles. Geographically, the Republic lies off the southern tip of the Malay Peninsula, and can be located between the lines of longitude E 103° 38' and 104° 05', and latitude N 1° 09' and 1° 29'.

The approximate extent of the eastern alluvial plain which is considered the most promising area for ground water exploitation is shown in Figure 1. In general, this plain of over 40 square miles in

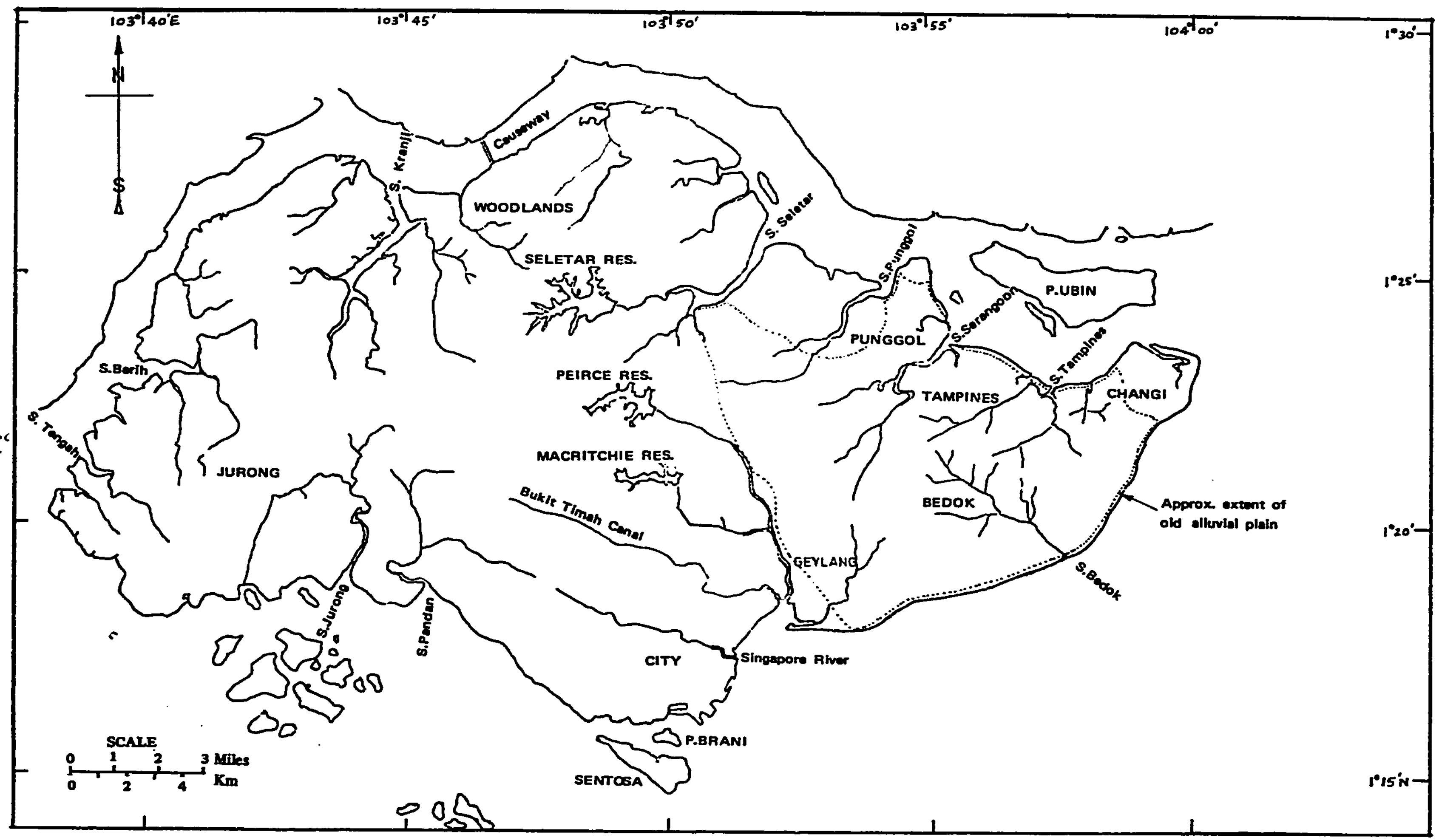

Fig. 1. Republic of Singapore – General Map

area covers nearly all the eastern one-fifth of the Island situated east of the Seletar River.

Climate

The climate of Singapore is humid and tropical. It is characterized by uniform temperature and pressure, copious rainfall and high humidity. Table 1 shows the mean climatological data recorded at the Singapore Airport Meteorological Station.

The mean annual temperature is 80^{0}F with an with an annual range of 3^{0}F against a daily range of 15^{0}F. Relative humidity is always high with a mean annual value of 84% and an annual range of 4%.

Although there is no distinct wet or dry seasons since rain falls during every month of the year, the climatic conditions can be broadly divided into 2 monsoon periods associated with the prevailing monsoon winds, with 2 shorter inter-monsoon periods in between. These 2 main periods are the Southwest Monsoon from May to September, and the wetter Northeast Monsoon from November to March in the following year. The mean annual rainfall recorded at the Airport Station is 95 ins. In general, rainfalls in the central and northern parts of the Island are higher, and those in the southern, south-western and eastern parts are lower. Mean annual rainfall of 85 ins is recorded over the eastern alluvial plain.

Physical Features

On the whole, the Island of Singapore is low lying with a maximum elevation of 581 ft above sea level on top of the Bukit Timah Hill. Only 10% of the land surface is above 100 ft and nearly 35% of the land is more than 50ft above sea level. The drainage system is rather complex with over 40 drainage basins of which 30 are less than 5 square miles each. Most of the rivers are short, and are in fact streams which are subjected to strong tidal influence far inland on account of the flat terrain. The larger rivers, e.g. Seletar and Kranji have wide estuaries covered by mangrove swamps.

In the eastern part of the Island, apart from the ridge east of the Airport and several hills of modest elevation, the land is generally less than 100 ft above sea level. A dense network of streams are cut into the Older Alluvium giving rise to the highest drainage density of the island. In recent years, sand mining activities on the hill slopes of the Tampines and Bedok basins have caused denudation and erosion of the natural landscape which is also affected by the cut and fill of the Bedok Coastal Reclamation scheme.

Geology

Geologically,the Island of Singapore is composed of 3 main groups of rocks each occuring in distinct areas (Figure 2). Superimposed on these older groups of rocks is the recent drainage system covered by the recent deposits or Younger Alluvium.

The western two-fifths and the southern part of the island are formed of ridges and partly isolated hills of complexly folded and faulted older sedimmentary rocks. These rocks are mainly quartzites, shales and volcanic rocks which have been reduced by weathering to sandstones, crumbling shales and clay. A similar group of sedimentary rocks is also located near the tip of the Ponggol Peninsula. The ages of these rocks are believed to date from Permo-Carboniferous to Triassic-Jurassic time. The thin strata of sandstones interbedded with impermeable shales and siltstones exposed or covered by a mantle of laterite residual clay preclude the formation of large subsurface aquifers in the western and southern parts of the Island.

The intrusive igneous rocks of late Mesozoic or Tertiary age are found in the central part of the island, the Changi area in the extreme east, and the island of Pulau Ubin. The main batholith is composed of granite, norite, diorite and their hybrids with occasional pegmatite veins, and dolerite and porphyry dykes. The main rock of the intrusion at Changi is a metamorphosed hornblende soda granite. The upper parts of these rocks weather to a clay containing varying amounts of quartz grains. The depth of weathering varies considerably and may reach one hundred feet or more. The impermeability of the rocks themselves, as well as the overlying layer of residual weathered material precludes the natural underground storage of water in the granite areas except in very small amounts in fissures and faults.

The eastern part of Singapore is covered by Older Alluvium, which is described as a poorly sorted mass of semi-consolidated sands, gravels, and pebble beds with seams and patches of clay laid down in the Quaternary period. Alexander described these quaternary sediments as "a mixture of the characteristics of shallow-water marine deposits and river deposits that were probably laid down in a wide estuary and are not in fact a true river alluvium." Along its western limit and at Changi, the Older Alluvium thins out against the granite and passes imperceptibly into granite wash. In the central part of the alluvial plain, the actual thickness of the alluvium and the configuration of its contact with the basement rock are unknown. The alluvial plain in the eastern part of the Island is considered the only area in which there is a possibility of large-scale natural underground storage.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Air Temperature, ^{0}F	78.0	79.0	79.8	80.6	81.2	81.3	80.9	80.7	80.5	80.0	79.1	78.2	79.9
Relative Humidity, %	85.0	83.1	84.1	84.8	84.5	82.9	82.5	82.8	83.1	84.3	86.1	86.5	84.1
Sunshine, hrs/day	5.03	6.34	6.11	5.93	5.90	6.09	6.21	5.97	5.58	5.20	4.65	4.51	5.63
Wind Speed, m/s	2.1	2.0	1.5	1.1	1.2	1.5	1.7	1.7	1.5	1.3	1.3	1.6	1.5
Rainfall, inches	10.01	6.96	7.70	7.36	6.84	6.78	6.37	7.31	6.69	7.99	10.03	10.94	94.98
Evaporation, inches	5.86	6.34	6.60	5.63	5.52	5.28	5.66	6.03	5.85	5.58	4.74	4.49	67.58

Table 1. Climatological Data at Singapore Airport

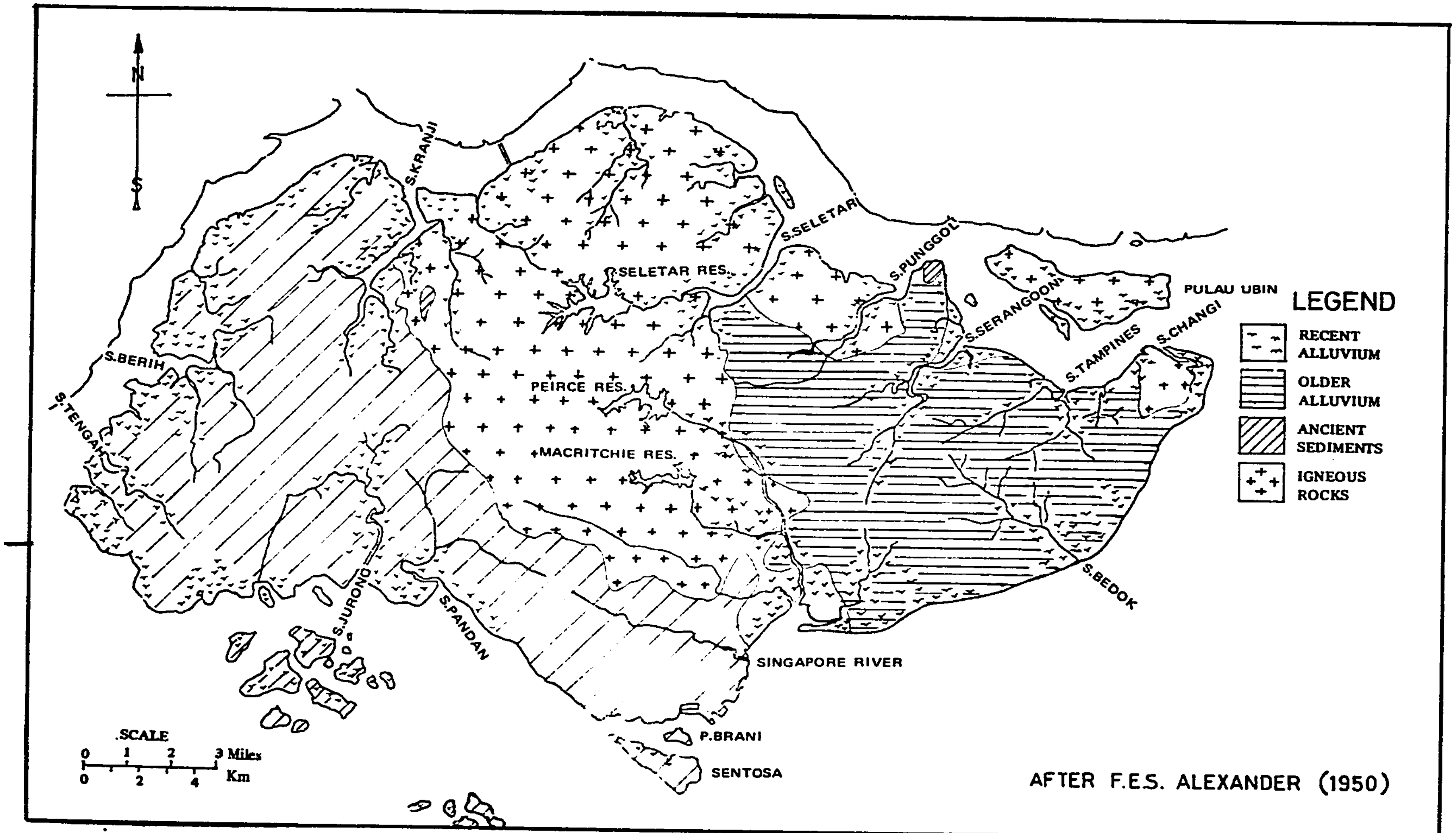

Fig. 2. Republic of Singapore – Geological Map

PREVIOUS INVESTIGATION AND RESULTS

The 1950, the Government engaged a firm of overseas consultants to investigate, inter alia, the old alluvial plain in the eastern part of the Island with a view to determining its extent and water-bearing capacity for ground water development.

As part of the investigation, a programme of field boring and geophysical survey was undertaken on contract by an overseas drilling company. Unfortunately, the results of the geophysical survey could not be used as the validity of the methods used and their interpretation were in doubt. Of the 2 boreholes made, the one in the Bedok Valley was recorded to have encountered weathered granite at a depth of 165 ft after passing through a sequence of sand and clay, and the other one in the Tampines Valley was terminated at 85ft after passing through a dense layer of cemented sand underlying clay and clayey sand beds.

After further field investigation which was handicapped by the absence of suitable boring equipment and experienced personnel at that ti e, the consultants arrived at the following conclusions in 1952 :-

(1) Possibly as much as one-third of the rain which falls on the plain finds its way out to the sea underground.

(2) The base of the Older Alluvium goes down to 150 ft below sea level over much of the area.

(3) The alluvial plain is saturated with water but with the exception of the Bedok Valley, the ground is of such nature that it will not part freely with the water.

(4) If wells of a suitable size are sunk in the Bedok Valley, it should be possible to obtain a minimum supply of 3 million gallons of water per day. (Recommendations on the location of 6 wells were given).

DEVELOPMENT OF THE BEDOK WELLS

Based on the above findings and recommendations, 10 wells were subsequently sunk in the Bedok Valley between 1955-1956 as indicated in Figure 3. These wells averaging 80 ft in depth penetrated the shallow aquifer in the Younger Alluvium near its contact with the Older Alluvium. This sand and gravel aquifer is overlain by a layer of peat and blue clay (See Figure 4).

Recent review and analysis of pumping test data recorded during well development indicated that the coefficients of transmissibility and permeability of the aquifer in the Younger Alluvium were, at best, 7,000 gpd/ft and 320 gpd/sq ft respectively and could be as low as 1,800 gpd/sq ft and 80 gpd/sq ft respectively. Such low values for these sandy materials could be attributed to bad sorting and cementation by clay. Operation of the 10 wells over a period of several years proved that the sustained yield was not more than ¾ million gallons per day instead of the anticipated 3 mgd for 6 wells.

Results of chemical analyses of well water taken during pumping tests (See Table 2) showed the ground water to be of inferior quality. However, the water could be rendered potable after full treatment involving chemical coagulation, sand filtration and chlorination.

Even in the peak year of operation, the yield from the Bedok wells contributed to less than 1% of the total water requirements.

RECENT PROGRAMME OF INVESTIGATION

Objectives

In 1970, the Public Utilities Board, after consultation with ECAFE experts, decided to investigate further the possibility that aquifers could be present at lower depths or near the base of the much more extensive deposits of the Older Alluvium. The initial programme of investigation intended to assess the groundwater potential of the Older Alluvium called for

(1) Permeability and other tests of the near surface soil samples to ascertain the rate of penetration of the rainfall into the ground on which the natural recharge of the aquifers depended.

(2) A geophysical survey to be followed by test drilling to determine the configuration of the basement floor, and the thickness and lithology of the overlying sediments.

Field Methods and Laboratory Tests.

Soil Sampling and Tests

To obtain information on the rate of penetration of rainwater into the gound, soil samples for laboratory tests were taken from 44 locations in the alluvial plain and fringe areas selected after an extensive field reconnaissance by the supervising hydrogeologist. These samples were generally taken from freshly excavated pits at a depth of 2 ft below ground surface. A few special samples were also taken from vertical faces of existing quarries and from the granite area such as Bukit Timah and the MacRitchie Catchment for comparison. Laboratory permeability tests were performed on one-quarter of the total number of samples. Per-

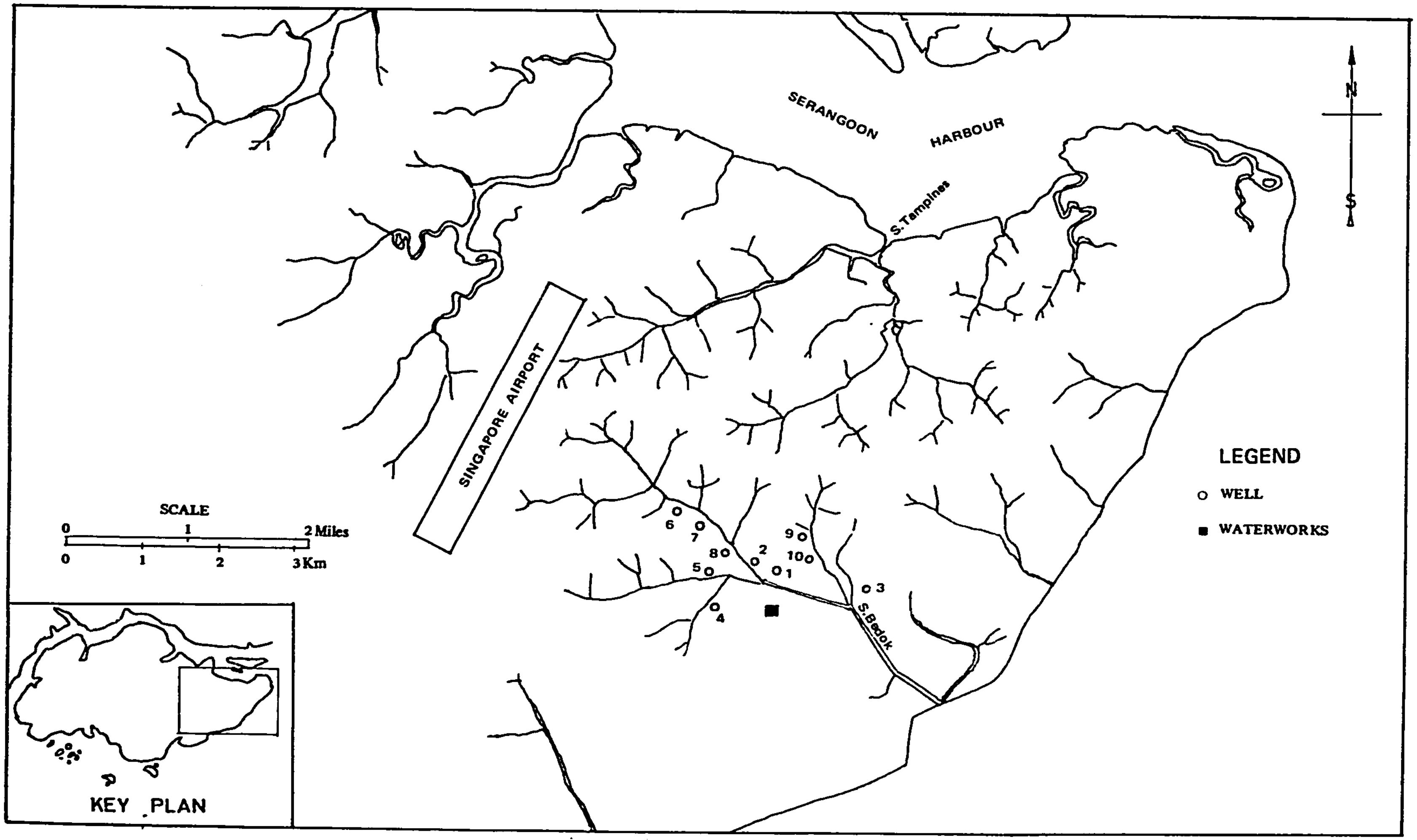

Fig. 3. Republic of Singapore – Location of Bedok Wells

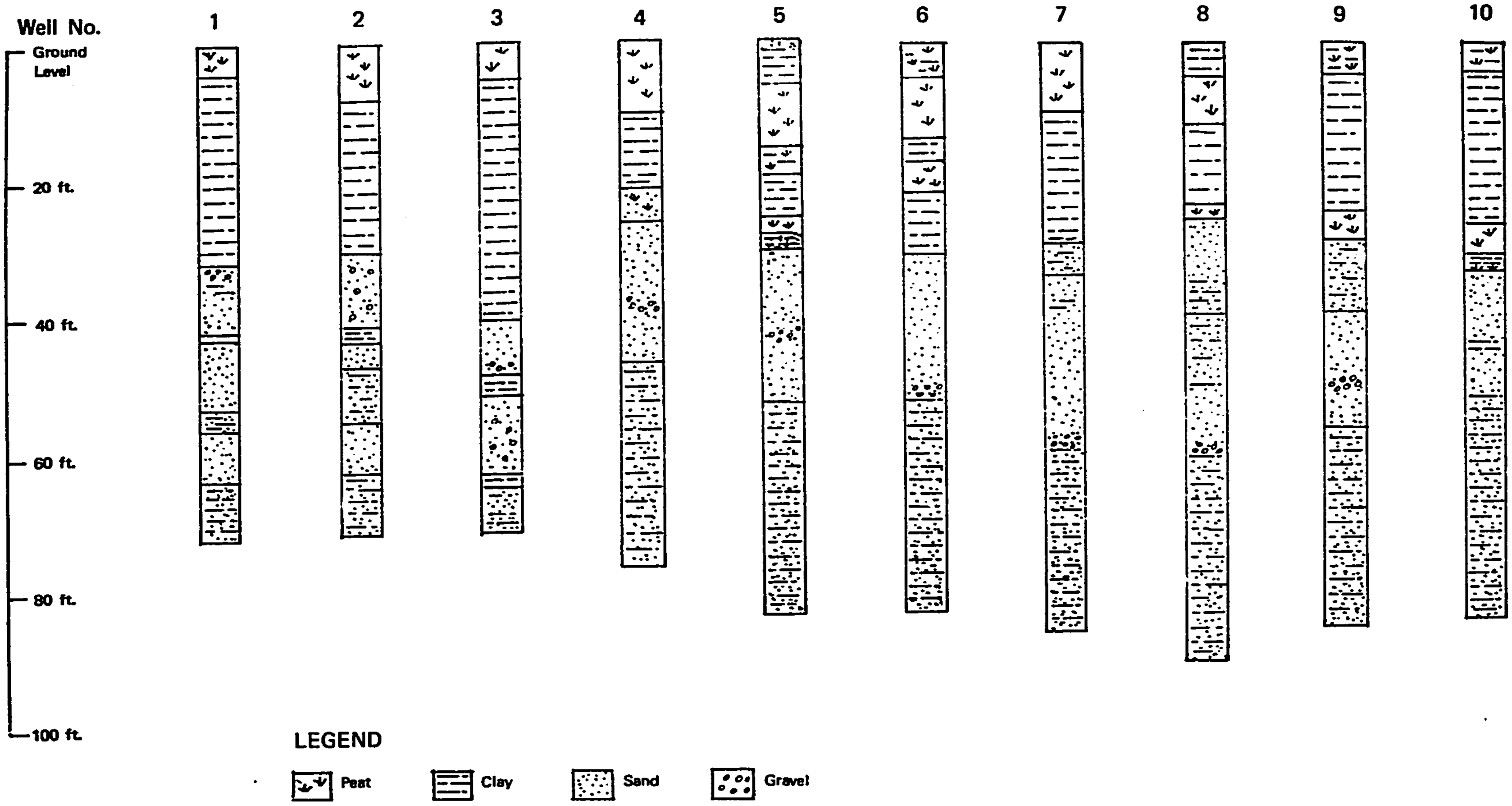

Fig. 4. Bedok Well Logs

pH Value	6.2 – 6.9
Ammoniacal Nitrogen (as N)	0.32 – 3.8
Albuminoid Nitrogen (as N)	0.08 – 0.8
Nitrite Nitrogen (as N)	Trace
Nitrate Nitrogen (as N)	0.2 – 1.05
Carbon Dioxide	24 – 116
Iron (as Fe)	2.2 – 27.5
Chlorides (as C1)	14 – 57
Oxygen absorbed from Permanganate in 4 hours	0.44 – 4.72
BOD in 3 days	0.27 – 4.26
Total Alkalinity (as $CaCO_3$)	36 – 206
Total Hardness (as $CaCO_3$)	22 – 190
Total Solid Residue	98 – 449
Inorganic Ash	58 – 365
Organic Solid	40 – 113

Table 2. Chemical Analysis of Bedok Well Water (in parts per million except pH)

meability coefficients for the remaining samples were derived from grain size analysis by the Hazen formula.

In addition petrographic examinations were also performed on selected test drilling samples for identification of rock types.

Geophysical Survey

A geophysical survey by geoelectrical resistivity measurements using modern portable equipment was adopted in order to minimize the number of costly test drilling required in such investigation. 250 soundings or measurements were made using the 4-point electrode system with a Schlumberger arrangement and direct current equipment (Figure 5).

Two measuring teams completed the field work in one month under the supervision of an experienced geophysicist.

In general, the soundings were limited to a depth of 500 to 600 ft mainly on account of the difficulty in obtaining open and unobstructed ground for electrode spacing of more than 1800 ft and the interference due to the presence of buried water pipes. Initial test soundings were made in the MacRitchie Reservoir area where granite bedrock was known to exist, for proving the high resistivities of the granite. Preliminary mathematical interpretation of the results was made by the geophysicist during the progress and immediately at the end of the field survey to enable the selection of the locations for test drilling. Final interpretation of the survey was based on drill logs and other available information.

Test Drilling

6 test holes ranging in depths from 156 ft. to 600 ft were drilled by contract to provide hydrogeologic data for the interpretation of the geophysical survey. The locations of these 6 holes are shown in Figure 5. The rotary method using small diameter casings was adopted in view of the depths involved and no pumping tests were envisaged in this initial stage of investigation. As such, difficulty was encountered in flushing the drillhole when ground water samples were taken during test drilling.

Interpretation and Discussion of Results

Rate of Penetration of Rainwater

Laboratory tests on the near surface soil samples taken from the alluvial plain indicate that with the exception of 2 samples having permeability coefficients of 20 gpd/sq ft practically all other samples are virtually impermeable with very low values ranging from 2 to 0.0002 gpd/sq ft. In fact, 80% of the samples have high clay content ranging from 21.6% to 47.5%. Results of samples taken from the fringe areas of the plain near its contact with the granite, as well as from the granite area, fall within similar range of low values. However, it cannot be ruled out totally that there may be a few limited areas so far undetected, where the soil has higher permeability values.

Examination of rainfall and evaporation data recorded at the Airport and elsewhere, together with short-term observation of some of the streams in the area and long-term water balance in the central catchment area, indicate that the previous conclusion that as much as 1/3 of the rainfall seeps into the underground cannot be supported. It has been further estimated that the rate of penetration of the rainwater is of the order of 2 to 3% only.

The above findings imply that the recharge rate from rainfall is very low due to the general low permeabilities of the near surface materials. Since the potential recharge area on the island is very limited, the total volume of recharge is accordingly very low and cannot provide adequate replenishment to any extensive aquifers even if found.

Thickness and Lithology of the Older Alluvium

One of the most interesting aspects of the recent investigation is to establish the thickness of the Older Alluvium or the depth of its contact with the basement rock in the central part of the alluvial basin. Contrary to the earlier investigation in the Bedok area which concluded that this thickness is approximately 150 ft over much of the basin, the recent investigation by geophysical survey and test drilling surprisingly reveals that this thickness is in fact 500 ft or more.

Geoelectrical soundings indicate that the resistivities of the Older Alluvium in the greater part of the alluvial plain are in the range of 15 to 40 ohm-metres from sea level down to a depth of 600 ft. Prior to test drilling, these low resistivities in contrast to the high resistivities (ranging from 200 to 2,000 ohm-metres) as proven in the granite area near the MacRitchie Reservoir, imply that the granitic basement is much deeper than 600 feet. Alternatively, if granite bedrock is present, such low resistivities can only be explained by the presence of fissure and joints filled with saline water. Subsequent test drilling (Figures 5 and 6) proves that in drillhole BHI, the Older Alluvium has a thickness of 500 ft underlain by deposits of some 100 ft thick of weathered pyroclastic materials. In fact, the granitic basement was not encountered when drilling terminated at 600 ft. In addition, test drilling reveals that the higher percentage of permeable layers in the total alluvial sequence accounts for the higher resistivities of 40 ohm-metres and 24 ohm-metres measured at locations BH3 and BH2 respectively as against the

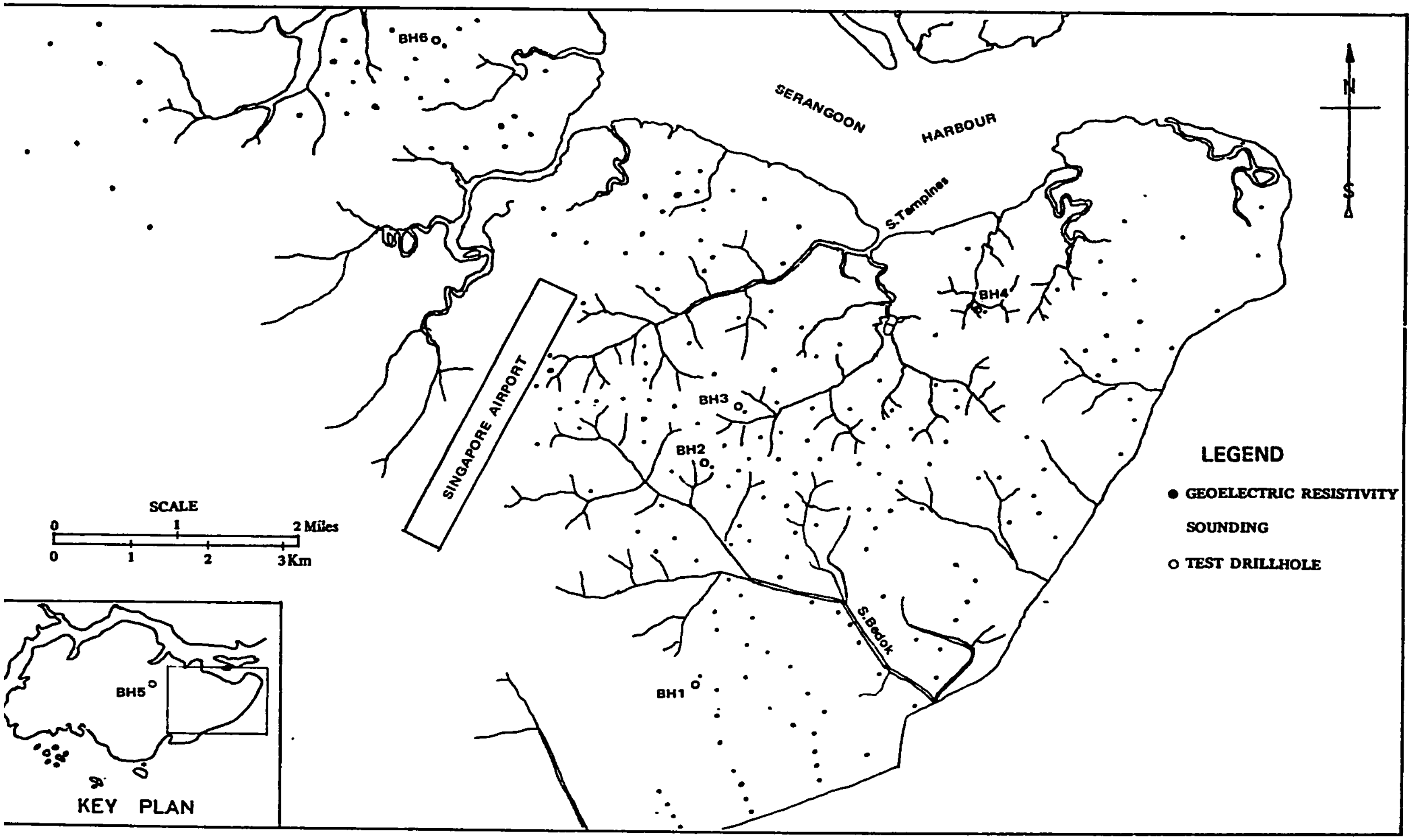

Fig. 5. Republic of Singapore – Geophysical Survev

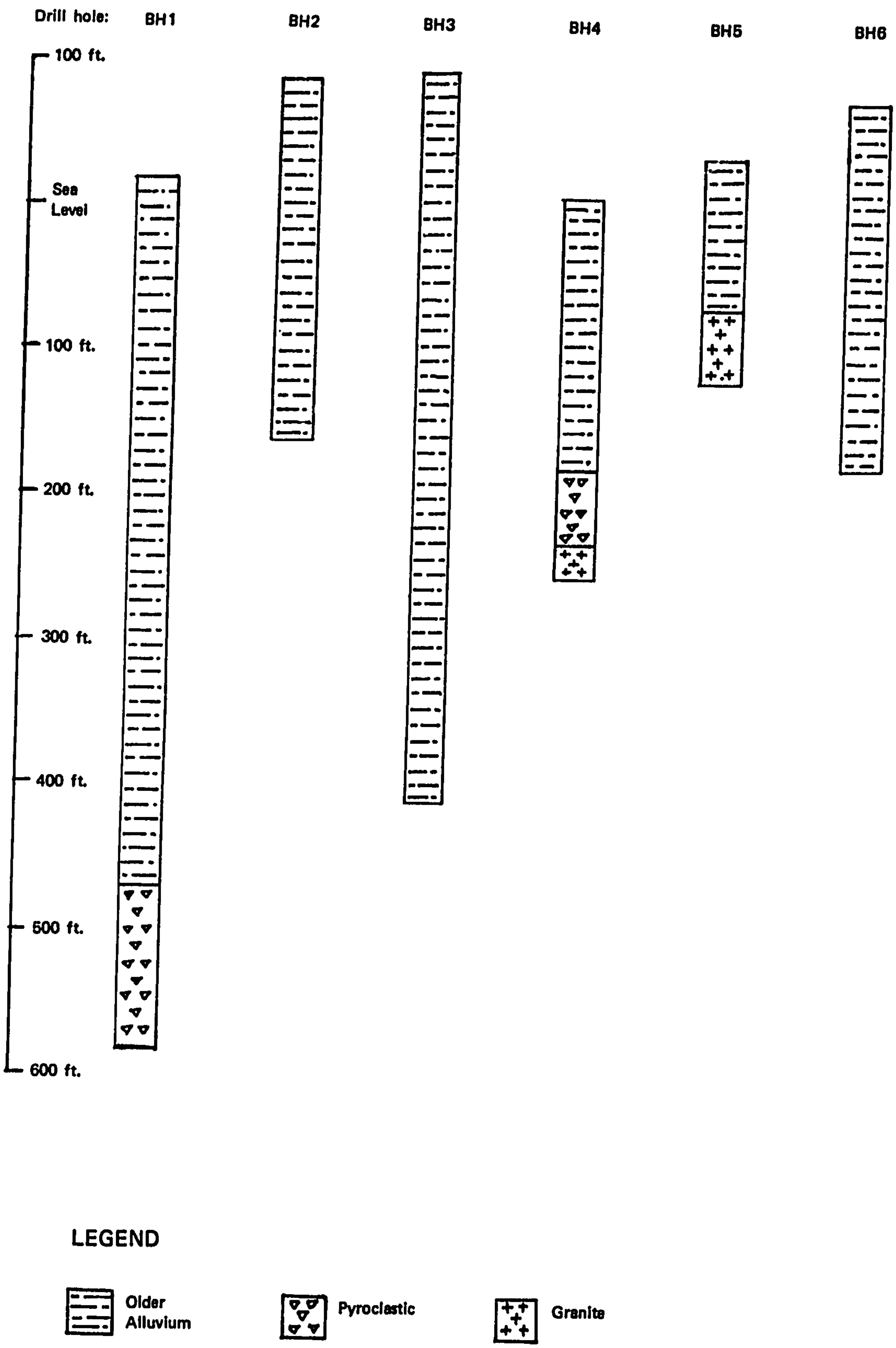

Fig. 6. Drillhole Logs

lower resistivities of 18 and 20 ohm-metres at locations BH1 and BH6.

In the eastern margin (Changi area) and the north-western margin (east of Seletar River) of the alluvial basin, high resistivities (200 ohm-metres) at depths of 150-250 ft indicate the presence of the granitic basement as the basin thins out. Apart from confirming the above findings, test holes BH4 and BH5 show that the basement is overlain by predominantly impermeable weathered materials consisting of arkosic sands contaminated with clay.

As anticipated, geoelectrical measurements along the coastal areas show low resistivities indicating the influence of the sea water which generally extends to ½ mile inland. Results of the chemical analysis of ground water samples taken in the course of the test drilling yield very low chloride content (10 ppm) and total hardness (90 ppm) indicating that there is no connate salt water in the sediments up to the depths encountered.

Based on the results of the geophysical survey and the test drilling discussed earlier, a diagrammatic section as shown in Figure 7 can be constructed to give a general picture of the thickness and lithology of the Older Alluvium and the configuration of the basin. In general, the Older Alluvium, up to the depths investigated, is composed of mainly semi-permeable and impermeable silty and clayey sediments intercalated with thin lenses (generally less than 20 ft thick) of sands of limited extension.

The recent investigation indicates that the presence of extensive aquifers which will yield substantial quantity of ground water is very remote if not impossible. Small quantity of ground-water for limited private supplies may be abstracted from the thin sand layers, the exact quantity of which can only be determined from sustained pumping tests. The cost of abstraction from such low yielding sources will be very expensive and uneconomical as proven in the case of the Bedok wells.

Summary

The recent investigation has shown that the groundwater potential in the Older Alluvium covering the eastern part of Singapore, up to the depths investigated is very limited in view of poor prospects of natural recharge from the ground surface and the unfavourable lithology of the sediments forming the alluvial basin.

In spite of the unfavourable results as far as groundwater exploitation is concerned, the recent investigation has contributed valuable knowledge on the subsurface geology of the alluvial plain in the eastern part of Singapore.

ACKNOWLEDGEMENT

The recent investigation was conducted in collaboration with the ECAFE and the Bundesanstalt fur Bodenforschung, Hanover.

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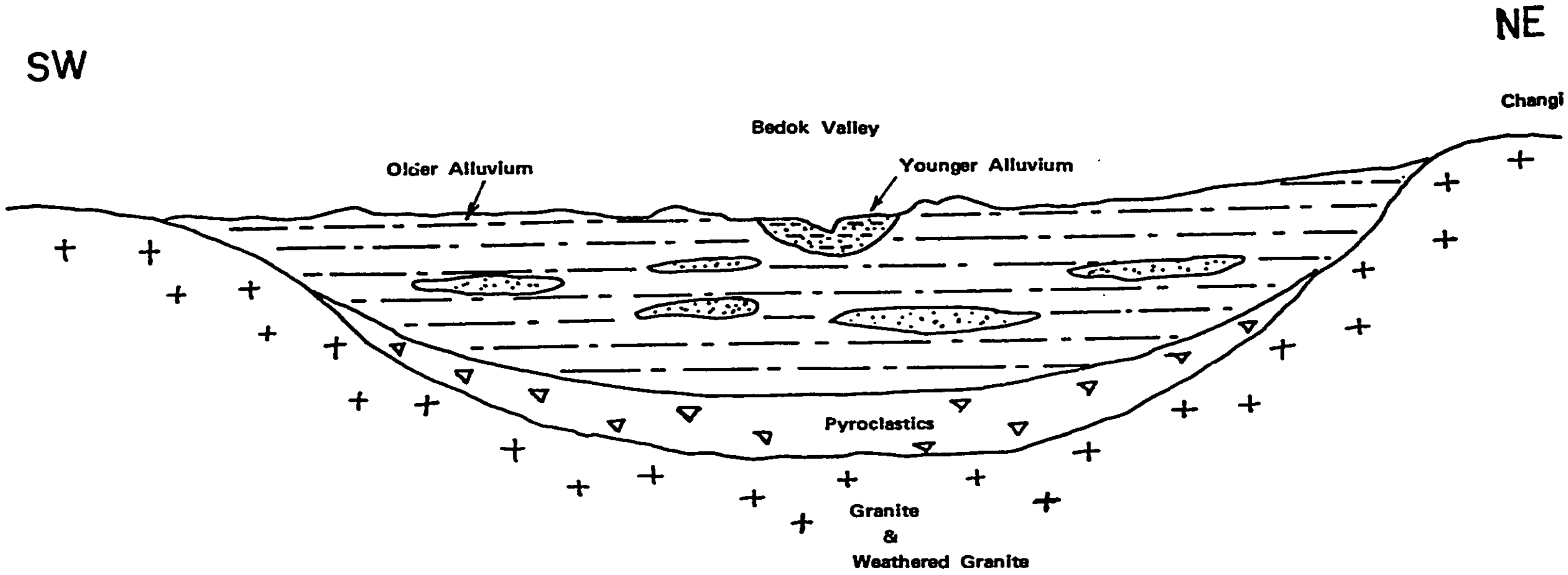

Fig. 7. Diagramatic Section of Alluvial Basin

Paper No. 1/2

WATER RESOURCES PLANNING AND DEVELOPMENT SINGAPORE

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ABSTRACT

The urgency to plan and develop all available water resources in the Republic to meet its rapid increase in demand for water has to be acknowledged as a national priority. It is imperative to embark on both short-term and long-term schemes now.

Singapore's water supplies depend on its rainfall varying, in time and space from the average 96 inches per year. In view of its limited land resources and with no further protected catchment available for conventional impounding, water planners must now adopt a changed policy criterion, departing from the past, in accepting low quality raw waters from unprotected rural catchments for treatment to a high quality water supply.

In the past, water supply development was the sole concern of a single engineering discipline. This is no more valid. Singapore's ability and success to develop water resources will have from now on to depend as much on its ability and success to protect the environment. Water quality standards, ecological equilibria in reservoirs, and other environmental aspects are additional criteria required to be studied in depth.

An outline on resources planning and development together with projects in hand and schemes under study is briefly described.

The impact of wastewater reuse, desalination and water conservation on Singapore's overall water supply situation is also included.

INTRODUCTION

In a land-thirsty, rapidly developing country with limited land resources, water supply development under these circumstances tends to become an extremely complicated proposition.

Singapore with its accelerated industrial, social and economic growth and the inevitable but understandable keen competition for land-use by various development bodies, falls in the above category. Furthermore, the generally low relief of the Island together with large tracts of estuarial swamplands does not afford any easy and economic solution.

In former days, the water planner had a choice to look for a high quality water source for collection from across the Causeway and also an opportunity to perform economic appraisals on alternative sources and schemes. However, immediately after its independence in 1965, water supply planning criterion, likewise, has to undergo a radical change. The immediate task facing the water planner is logically to plan and develop all available internal resources as quickly as possible and as much as practicable. The desirability to achieve self-sufficiency in this vital commodity is obvious.

Low quality waters from streams in unprotected rural catchments, rejected for their polluted nature in former days, must now be accepted for treatment without any decline in the present high quality drinking water standard. This objective could only be achieved through effective pollution control, detection and surveillance measures in conjunction with sophisticated treatment processes known. The planning policy is nothing more than "to collect drops to become a pond" concept. Water is simply too valuable to be allowed to go to waste.

Conventional impounding involving sterilization of vast tracts of valuable land could no longer be considered. It is apparent unconventional approaches in water collection and storage have to be applied without much choice.

In dealing with low quality supply sources, an adequate storage facility affording long retention period prior to withdrawal for treatment is of prime importance. And in this connection, estuarial-storage and a high dam within an existing reservoir are likely solutions to obtain extra storage capacity without the need to take up additional areas of useful land.

RESOURCES

Singapore's water resources arise from its rainfall, averaging 96 ins per years, that falls on its 207 square mile area. The total evapo-transpiration, etc. loss is around 46 ins to 50 ins per annum. The actual amount of rainfall varies from month to month, from year to year and from the wettest part in the north of the Island to the driest in the south-west. The highest annual rainfall recorded in the past 10 years is 115 ins and the lowest 62ins. On the whole, rainfall can be regarded as fairly evenly distributed throughout the year.

Resources relating to the surface, underground and supra-surface are discussed below.

Surface

So far, only 24.3 square miles (or 11% of the Island's area) have been utilised for water collection. The protected catchments of the Island's 3 impounding reservoirs – Seletar, Peirce and MacRitchie – occupy an area of 12.3 square miles. The remaining 12 square miles are the unprotected catchments of the 8 streams in the partial pumped-storage Seletar scheme.

The objective to maximize collection of surface resources by extending the present 24.3 square miles collection grounds to 156 square miles (or 75% of the Island's area) is outlined in Fig. 1.

Theoretically, the total runoff from the 156 square miles catchment area would be adequate to meet the Island's needs up to 1980. It is assumed, of course, that sufficiently large storage reservoirs are provided to cover deficiencies during drought periods.

Stormwater Runoff

The unhatched areas of some 51 square miles comprising mostly of developed urban and suburban districts and industrial complex have not been included in the present phase of development.

Due to gross pollution in the urban canals and waterways, the possibility of utilizing this urban runoff must await the full impact of the present pollution control enforcement act to be felt. Time is required for the quality of this water to improve to a treatable standard.

However, the comparatively clean runoff from suburban, tourist resort and institutional grounds in isolated cases could of course, in the meantime, be developed individually for localized non-potable use.

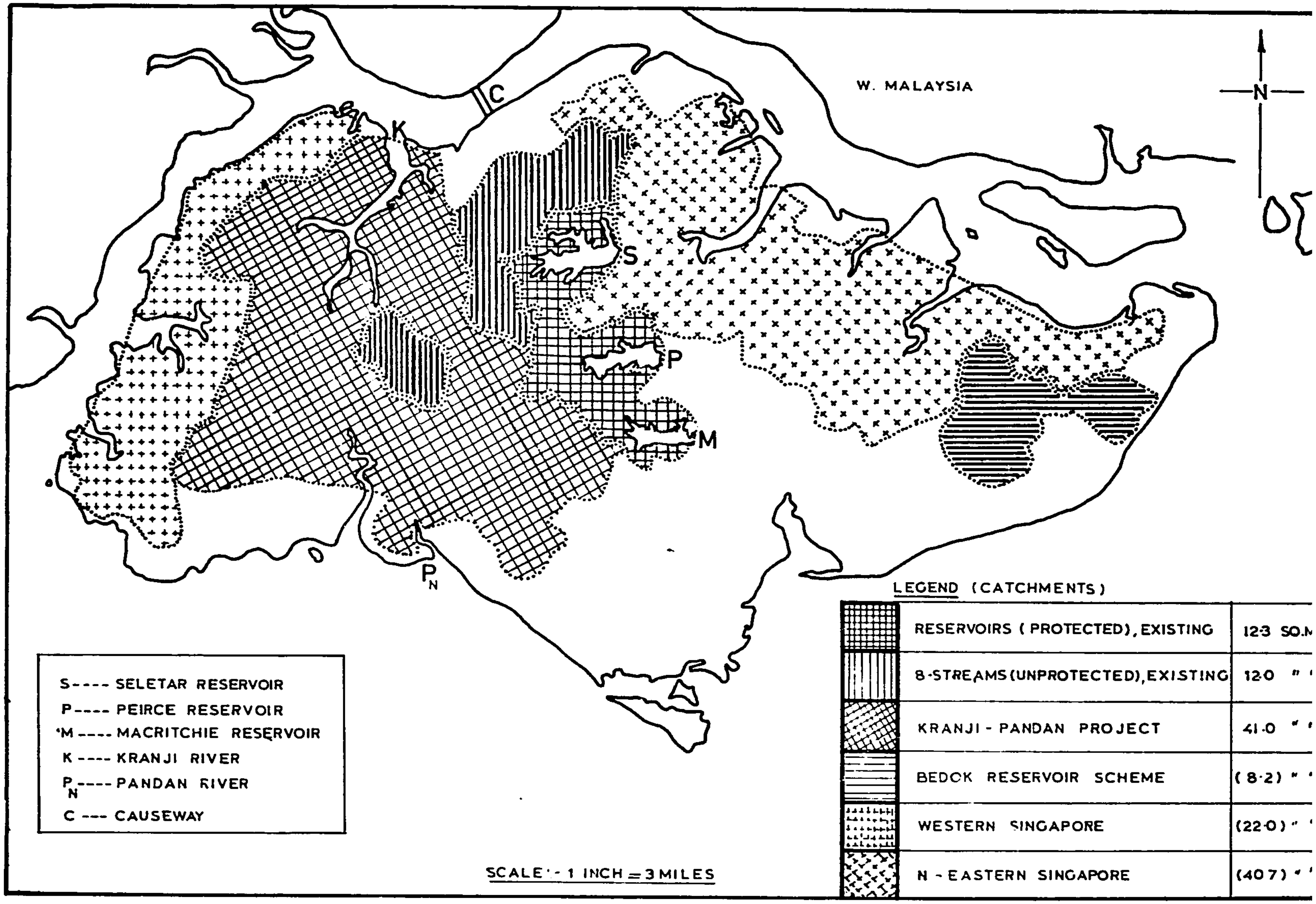

Fig. 1. Location of Reservoirs and Catchments

In this connection, the existence of any favourable low ground nearby that could readily be converted to serve as a storage pond at little cost, would be an important economic consideration.

Underground

As a separate paper on this subject is being presented in this Workshop, it is suffice to mention briefly that a recent geoelectric resistivity-survey carried out in the Island's eastern alluvium indicates the unlikelihood of favourable underground aquifers in existence.

Although a substantial quantity of ground water is believed to have finally seeped into the sea, the widespread nature and low transmissibility of the soil does not afford any effective solution in its abstraction in any significant quantity.

It may be considered profitable at a later stage, to assess in more detail, the potential water-bearing strata in selected areas by sinking large diameter boreholes and conducting in-situ pumping tests. Should any of the selected areas prove to have the right soil conditions and to be at the right place, the creation of an artificial underground aquifer by sub-surface retaining barrier-structures may prove feasible.

Supra-Surface

This refers to water resources existing in gaseous form as clouds above the Island.

Various attempts to tap these resources have been performed including the historic cannonading to induce precipitation. Latest cloud seeding experiments using ice-crystals or the Bergeron-Findeisen process and the accretion process do not however yield conclusive results.

Earlier cloud seeding attempts in Singapore had also not produced any desired precipitation. This failure could be attributable to one or a combination of a number of factors such as: cloud formation, cloud depth, wind direction and velocity, ambient temperature etc. Giving the right conditions and the right seeding agent, artificial precipitation could yet be anticipated as a reality in the near future.

With the planning of extending catchment grounds to 156 square miles as against the present 24.3 square miles, the chance of artificial precipitation to fall within a much larger area for collection increases.

PROBLEMS

The present developed area in Singapore has already taken away some 29% of the Island's area. This factor is expected to reach 64% in the year 2,000 with a population then approaching the 4 million mark.

It is obvious, land is too valuable for its use to be restricted to cater for the interest of a single-purpose national development. Water supply schemes must face up to this reality and will have to be planned to co-exist with other land users by unconventional approaches and thinking. Likewise, other development bodies in sharing land-use in catchment areas need to ensure that pollution does not result from their development projects.

The water planning policy to collect and store as much as possible of the precipitation that falls on the Island sounds simple and straight forward, if not for the fact that these sources are polluted with much environmental problems.

The Problem

All unconventional estuary-barrage, pumped-storage, urban stormwater collection and waste-water reuse schemes are rather involved affairs, because:

(1) The quality of all contributing water sources needs to be strictly controlled and kept at an acceptable standard. All pollutants and contaminants at sources will have to be first identified and effectively removed. Lack of a continuing surveillance and monitoring will cause degradation in water quality; its prolonged effect could end in dire consequences.

(2) Soil erosion as a result of intensive constructional activities – unavoidable in a developing country – is again a pollutional problem, if unabated.

(3) The ecological change and its effects in an estuarial impoundment from a salt water to that of a fresh water environment has to be carefully assessed. This is especially so in a humid tropical locale.

(4) The physical, chemical and biological forces interacting in a partial pumped-storage scheme must not be allowed to affect the natural ecosystems in the reservoir due to excess nutrients contained in the stream runoffs.

The aquatic living systems in the reservoir in perpetuating the self-purifying cycle endowed by nature in an open healthy body of water must be maintained in equilibrium.

(5) Faecal viruses of human and non-human origin present in the supply sources are not removed by filtration or self-purification process. Unfortunately the present scientific and technological advance has not reached the stage to make easy laboratory identification possible as is the case for bacteria. Total destruction of viruses must depend on a more costly virucidal disinfection agent such as ozone.

The above problems require in-depth studies if a pure and wholesome public water supply is the final objective.

Other Disciplines

The water planner, apart from engineering considerations, needs to call for studies and collaborations from a number of other disciplines involving: ecology, biology and limnology, microbiology and physiology. The last mentioned discipline is thought valuable in assessing the long-term cumulative effects on human health of some minerals and compounds existing in water, the precise physiological effects of which are not fully known at the moment.

Pollution Control

The problem in water pollution control and enforcement for a water quality standard will increase in scale as and when progressively larger areas of rural catchment are incorporated in the water supply projects. The appreciable task in installing and maintaining a large number of fully automatic or semi-automatic monitoring systems to analyse and register some of the selected parameters for quality control at various locations can well be imagined.

PLANNING & DEVELOPMENT

In any overall water planning study, invariably 2 vital factors – yield and demand – need be considered. Unfortunately, both these factors involve a number of variables and are in turn influenced by other variables. To achieve any degree of precise accuracy is extremely difficult and indeed to some extent may prove superficial. This is especially so in the case of a water-scarce, rapidly developing country such as Singapore.

The materialization of a single large water-consuming industrial complex could upset demand forecast by a wide margin at short notice. It can only be hoped that on a long-term basis errors in forecast would tend to even out. It is not the intention of this paper, therefore, to go into details relating to hydrology, runoff and yield, demand, growth rate, etc. studies.

Only in-hand projects and schemes in connection with the Island's surface resources (Fig. 1) will be briefly described.

Projects in Hand

There are 2 water projects under implementation :–

Kranji-Pandan

This is the Republic's first estuary-barrage cum off-stream storage project. Under this project, a dam is to be constructed at the mouth of the Kranji river in the north to impound runoff from the Kranji river and its tributaries. An off-stream reservoir is to be constructed at Pandan at the south end to store the Upper Bukit Timah canal and Pandan river runoff. These waters will be pumped to a new treatment-works to be constructed at Choa Chu Kang for treatment.

The pollutional aspects existing within the catchments, originating from domestic, animal, farming and industrial wastes are being surveyed. The pollution control programme is likely to follow a course of abatement and improvement of the environment in the initial stage and a phased-out total elimination of pollution at sources as the final objective.

Apart from the essential pollution control measures, considerations regarding likely problems arising from ecological changes within the estuarial regime and its required period of desaltingare included in the planning study. This project will undoubtedly provide much needed information to serve as a guideline for other similar schemes to follow.

When completed, the project will provide an additional 4,600 m.g. storage capacity in the Island and an expected yield of some 40 mgd from its 41 square miles catchment.

Upper Peirce

This project involves the construction of a secondary high dam in the existing Peirce Reservoir and a new treatment-works. When completed, the project will increase the reservoir storage capacity from its original 800 m.g. to some 6,600 m.g. Since the additional 5,800 m.g. storage capacity is to be obtained within the reservoir's existing protected catchment, the question of additional land acquisition does not arise.

Schemes under Study

Schemes under feasibility study are :

(1) Estuary-barrage schemes in connection with streams in the north-eastern part of Singapore. The total catchment involved is about 41 square miles.
Studies on hydrology, tidal effect, soil condition, water quality, environmental pollution, ecology, salinity and period of desalination, engineering and cost aspects are in hand.
The creation of a large estuarial-storage reservoir will be deemed a valuable asset in connection with sewage effluent reuse after receiving suitable tertiary treatment. Long retention with consequent self-purification in a large reservoir could assist in removing the psychological objection in its use as potable supply.

(2) The partial pumped-storage reservoir at Bedok. This scheme envisages the creation of an excavated reservoir of some 1,800 m.g. storage capacity in the Bedok Valley. In addition to its 2,340 acres of natural catchment, flows in 4 nearby streams with a combined catchment of 2,940 acres are to be pumped and stored in this reservoir to increase its yield.
A hill in the Bedok Valley is to be levelled and excavated to form a large deep pit. Cut material obtained is to be used to reclaim valuable coastland.
Necessary soil investigation, in-sity borehole pumping test and slope-stability study will have to be conducted to ensure water-tightness of the pit to serve ultimately as a reservoir.

Other Schemes

Possible estuary-barrage and stream abstraction schemes in the west of Singapore are being looked into.

The existence of extensive coastal swamplands and the segmented nature of the numerous watersheds within this 22 square miles collection ground could create problems both economic and engineering-wise in the water supply scheme.

The solution to the above could lie in a co-operative effort with other development bodies. The coastal strip of swamplands might be reclaimed for industries and the inner swamplands in the main rivers be dredged as reservoirs.

Urban Stormwater Runoff

Stormwater runoff from urban areas are grossly polluted and could not be accepted for treatment. Time is to be allowed for the water to improve in quality to an acceptable standard as discussed earlier.

As all drainage system is on the rapid discharge principle, the conflict in design criteria for drainage and water supply abstraction needs to be reconciled.

The present drainage systems may have to be drastically readjusted to satisfy the water supply objective.

To efficiently capture and retain periodic high intensity runoffs, land requirements for detention tanks, conveyance conduits, relift pumping stations and transmission mains in the densely developed central area are hard facts to be faced. However, any estuarial-storage that could be located in the city area, would of course ease the above problem.

In selected suburban areas with comparatively clean discharges, these could be utilized for non-potable use as discussed previously. The treatment to a high quality water is however not considered economically feasible at the present stage. As and when nearby reservoirs are completed, runoff from these drainage basins could be channelled there for storage. Any costly plant installed could be found redundant at a later date.

WASTEWATER REUSE

The continuing improvement in wastewater treatment has enabled wastewater reuse to become an increasingly valuable supply source for industrial and other purpose.

However, the direct use of treated wastewater as a source of public water supply has not been considered acceptable by world water authorities, the reason being that the present treatment technology has not yet been developed to such an advanced degree.

In the context of Singapore's potential wastewater reuse, reference will be made mainly to that of sewage effluent and to a minor extent that of filter wash-water.

Recycle of treated industrial wastewater within factory premises for further process application must be viewed as an important factor in good management to be fully exploited by industrialists.

Sewage Effluent

Singapore has 2 sewage treatment works – Ulu Pandan and Kim Chuan, both of these works using the activated sludge process to bring down BOD and suspended solids. The effluent quality is unsuitable for direct industrial use.

A portion of the Ulu Pandan effluent is being channelled to the Jurong Industrial Waterworks to receive chlorination and filtration treatment. The treated water is now being used by some of the industries at Jurong.
The amount of effluent utilized in above connection is however only a small fraction of the average 45 m.g. of effluent generated and wasted to sea each day.

A right solution in reclaiming this valuable and reliable daily source of supply for its rational use is therefore imperative. It is obvious, if this low quality effluent is to serve any useful purpose, its quality must first be upgraded by further treatment. The degree of further treatment necessary must depend on final use of this redeveloped source to be applied.

A high degree of purity will not be necessary if the reclaimed wastewater is to be intended for industrial and non-potable purpose. It would suffice to eliminate undesirable dissolved solids up to specific tolerance levels and to a quality standard that could readily be acceptable by most. of the Republic's industries.

If the prime objective is that it is to ultimately serve as a potable water supply, a high degree of tertiary treatment would be required. Although there are known processes to reduce total dissolved solids, their cost-effective factors are best to be determined initially by pilot plants before a full scale plant is to be decided upon.

There is not the slightest doubt that in time to come, reclamation of sewage effluent for rational use will become very much an economic necessity The important role it will assume as a normal part of Singapore's future urban water cycle can well be imagined. The establishment of pilot plants with flexibility in the removal of various dissolved solids and toxic compounds to determine desired quality parameters for various uses, is an urgent necessity.

In above connection, it must be added that the direct use of treated effluent as a source of potable water supply is not advocated. Apart from its psychological objection, there remains always the real health danger of a breakthrough during treatment even for a very brief interval. The possibility that the major part of these objections might be removed if the treated effluent is first diluted in a large impounding reservoir affording long retention period to undergo self-purifying process prior to withdrawal for treatment, needs to be fully explored.

Filter Washwater

The reclamation of filter and other wash-water in waterworks represents an additional source of supply which is now being wasted.

The quantity of wash-water recoverable is about 2 to 2½% of the total output of the water treated in the waterworks. Its recovery could be achieved by sludge-lagoons or where space is limited by chemical or mechanical means.

The former method of wash-water recovery has been provided for in the Upper Peirce dam project where one of the tributary inlets within the catchment will be dammed off to serve as a sludge lagoon. The supernatant water is to be decanted back to the reservoir.

DESALINATION

Singapore's final water supply solution when its natural water resources are fully exploited and developed, must rely on desalination. Sea water, being inexhaustible, is indeed a dependable source of supply that will not be subjected to unpredictable weather conditions.

Technologically, current desalting techniques whether using distillation, electrodialysis, membrane or freezing process are valid means of converting salt water into fresh water. Unfortunately, it has to be acknowledged that so far there is no dramatic breakthrough in desalting techniques to reduce cost of water. The downward trend in unit cost is mainly evident in increased plant scale.

An initial study by the United Nations of the working of 87 desalting plants in 21 countries shows that there are considerable difference between the cost of water on similar plants working under different conditions.

It appears that the actual cost of water is much higher than given in most of the published studies. Apart from capital, interest, fuel, etc., cost, the production cost is also dependent on annual load factor, single or dual purpose, labour, etc. The use of thin-tubing techniques and more corrosion-resistant tubing material undoubtedly helped in reducing maintenance and replacement costs.

The realization of desalting sea water using the multi-stage flash distillation technique on an increasingly large scale in the near future is promising. Already it has been reported that by 1974 Hong Kong will have a 20 mgd desalting plant comprising 2 to 4 separate large units with an output of 5 to 10 mgd per unit at an estimated cost of £13 million. The continuous operation cost for 12 months has been put at £1.44 million. The above project, when completed, will afford valuable and much needed data for future similar undertakings in this region.

In the context of Singapore's water supply, desalination will most likely be considered initially in conjunction with its natural resources for intermittent operation during drought periods. It is not considered economically feasible at the present stage for large scale production.

The installation of a pilot desalting plant of suitable output capacity to gain basic operation and maintenance data at first hand in the interim before full scale plant is contemplated, would of course be extremely valuable. As the theory involved in flash-distillation is comparatively simple, the above practical know-how gained could generate manufacturing possibilities locally in the fields of infrastructure plant accessories.

WATER CONSERVATION

To enable the Republic's available water resources to be stretched to the maximum for various uses, water conservation and wastage reduction is very much a part of good water management.

Any reduction in consumption through a rational and economic water use will mean:– much less of water to be treated; improvement in water stocks; and a general gain in delayed capital outlay in enlarged distribution systems and water supply projects.

Wastege

The amount of water wasted daily because of inconsiderate use-habit and faulty fittings and inefficient appliances can be appreciable. The Republic's appeal to save water during its last drought in 1971 received excellent response from all consumers. As a result of which, water consumption registered a sharp drop by some 12% on the average. Evidently a large proportion of this was due to wastage which could be conserved through good water-use habit. Effective measures to reduce wastage, apart from educational efforts, in the introduction of water-saving devices and fittings are now being actively implemented.

Recycle

In the industrial sector, managements will now have to analyse and to reassess their minimum quantum of water required for processing. As all industrial wastewater will have to be treated before disposal, the less water used to achieve the same produce result will give immediate savings both in water consumption and subsequent disposal treatment. And if the degree of disposal treatment proposed is geared to possible recycle of the treated wastewater for further process application in mind, further economy could again be achieved.

CONCLUSION

Singapore's water resources development is very much an environmental issue. Its capability and success to develop water supply schemes must depend on its ability to protect the environment.

The pollution problem and ecological damage in this country, admittedly, has not reached the dimensions of the highly industrialised nations. Nevertheless, it is still a problem of serious concern. If unabated and allowed to get into an uncontrollable degree, it could and will degrade to a danger level. Singapore has a high population density of over 9,000 persons to a square mile and as such it would not be possible to become pollution free. What is possible to achieve of course would be that for any harmful pollutants that might be released into the environment these must be carefully controlled to within tolerance levels so as not to create environmental health-hazards.

The solution is not a simple one, although this could partially be achieved through a combination of persuasion and prosecution, a great deal must however depend on socio-habitual reform.

The individual's selfishness, indifference and thoughtlessness must give way to that of environment-consciousness, i.e., the awareness of what is at stake and the individual's personal responsibility of the environment.

Finally, as the Water Department of the Public Utilities Board is responsible for the supply of a safe and wholesome water to consumers, the extent of this responsibility will increase as and when more and more low quality raw waters are treated and introduced into the supply system. This is a responsibility that cannot be treated lightly.

ACKNOWLEDGEMENT

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Paper No. I/3

FLOOD CONTROL AND WATER CONSERVATION WORKS IN BUKIT TIMAH CATCHMENT, SINGAPORE

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ABSTRACT

The paper deals with land drainage works in the Bukit Timah Catchment in the south central area of the Island of Singapore. The land drainage works aim to achieve the dual objectives of flood control and water conservation for water supply. The works consist of three stages : diversion, improvement of existing channels and building of a reservoir.

INTRODUCTION

This paper deals with land drainage works in Bukit Timah catchment in the south central area of the Island of Singapore.

The land drainage works are:-

(1) Bukit Timah Flood Alleviation Scheme (Phase I),
(2) Improvement and concrete-lining of Bukit Timah Canal from Ewart Circus to Newton Circus,
(3) Multi-purpose storage reservoir at Singapore University ground fronting Bukit Timah Road.

which aim to achieve the dual objectives of flood control and water conservation for water supply.

CATCHMENT CHARACTERISTICS

The Singapore Island, situated approximately 85 miles (137 km) north of the Equator, covers an area of 210 square miles (543 km^2) with surface generally flat and undulating, higher inland and sloping towards the coast. Because of this physical feature and topography, drainage areas are in small size and streams discharge radially from inland to sea; waterways are shallow but with wide flood plains created by flash flows and are under tidal influence extending as far as mid-way to three-quarter way upstream from coastline. Outlets of these streams are in marshy, swamp land.

The city and the port of Singapore are situated in the southern area of the Island. Since the development of the port demands godowns to be built as near as possible to the sea and the increase in population, commerce, industry and traffic demands more land for housing, shops, offices, factories and roads, swamp lands at the outlets of streams had been filled up, which lead to narrow outlets and extension of the outlet channels resulting in flooding not only upstream area but also in reclaimed land. This is what has happened to the Bukit Timah Catchment in the south central area of the Island (Fig. 1). Originally, the Bukit Timah Canal discharged into the tidal creek at Serangoon Road. The tidal creek was later reclaimed by constructing the Rochore Canal of more than a mile long with outlet at Kallang Basin. The reclaimed land with ground surface at 6 to 12 inches (0.30 to 0.60 m) above H. W. O. S. T. has been subjected to frequent flooding. The Bukit Timah Valley was flooded because of the reclamation of the tidal creek and the building of roads and houses on flood plain without filling up the land at early dates and of land development which increases surface runoff at later dates. The following table shows the total land area being

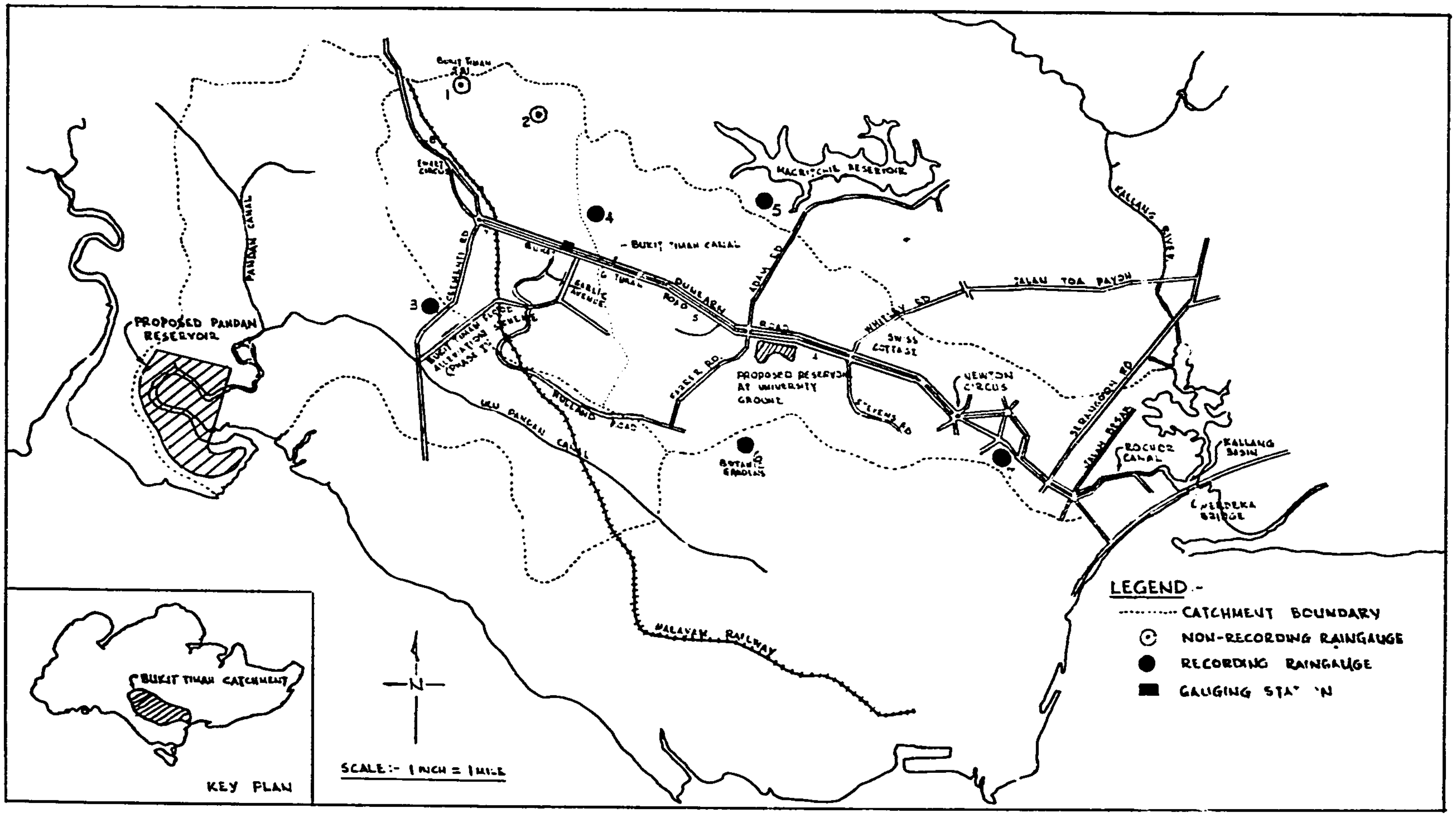

Fig. 1. Site Plan

applied for development (mainly housing) in the Bukit Timah Catchment each year for the past five years.

Year	Land area applied for development
1967	123 acres (49.8 ha)
1968	133 acres (53.9 ha)
1969	16 acres (6.5 ha)
1970	217 acres (88.0 ha)
1971	254 acres (103 ha)
Total:	743 acres (301.2 ha)

As shown in Fig. 1, the Bukit Timah Catchment refers to the catchment upstream of Serangoon Road, covering an area of 6,770 acres (2,740 ha). The summit of the catchment is the Bukit Timah Hill, the highest hill in Singapore at an elevation of 581 ft (177 m) above mean sea level. At the summit, about 50 acres (20 ha) of land is protected as nature forest reserve. The canal downstream of Serangoon Road is the Rochore Canal. The land on both banks of the Rochore Canal as reclaimed from swamp land is protected from tidal inundation by a tide gate. The total drainage area at the outlet is 7,250 acres (2,940 ha).

The Bukit Timah Catchment is largely devoted to high-class residential development. From Serangoon Road to the outlet, the land development is predominantly shophouses and business premises. The main approach roads to the city from West Malaysia are Bukit Timah Road and Dunearn Road both running parallel to the Bukit Timah Canal. The traffic on the two roads is often interrupted by floods.

The length of the canal from its summit to Serangoon Road is about 40,000 ft (12,200 m) with gradient about 1 in 600 upstream to about 1 in 3,000 near the outlet. It is low-lying on both sides of the canal from about midway to the outlet where floods frequently occur. The paved area represents about 25 to 30% of the total catchment area.

Centre, N., N.E. and N.W.	90 – 100 ins. (2280 – 2540 mm)
S.E. and S.E.	80 – 90 ins. (2030 – 2250 mm)
W. and S.W.	65 – 85 ins. (1650 – 2160 mm)

The rainiest months are November, December and January during the Northeast: Monsoon season and the total rainfall for the three months represents 33.5% of the total annual rainfall [3]. The mean monthly and annual isohyetal maps show about the same pattern [6]. There are seven rain gauges in the Bukit Timah Catchment and its immediate adjacent area (Fig. 1), five of which are recording gauges and the remaining two daily storage gauges with different length of record [3]. From the monthly and annual isohyetal maps (Water Resources Consulting Group, 1966), it appears that the rainfall recorded at Botanic Gardens represents the average rainfall over the Bukit Timah Catchment. Based on 35 years of record (1936 to 1971) at this station, the mean monthly, maximum and minimum rainfalls in inches are shown in Fig. 2 with mean annual, maximum and minimum rainfalls as follows:-

Annual Rainfall

mean:	96.58 ins	(2,450 mm)
maximum:	126.76 ins	(3,220 mm)
minimum:	67.08 ins	(1,700 mm)

Most storms are short-lived, lasting one hour or less and the individual centres have little movement, but the intensity is sometimes very high [13]. The highest rainfall recorded at different durations in Singapore based on records up to 1971 is shown in Fig. 3.

Most storms are heavy at initial stage and the average temporal pattern of storms is as follows [2]:

$\frac{\text{Time}}{\text{Duration}}$ (%)	0	20	40	60	80	100
$\frac{\text{Cumulative Rainfall}}{\text{Total Rainfall}}$ (%)	0	35	60	80	94	100

RAINFALL CHARACTERISTICS

The areal distribution of the mean annual rainfall based on the record from 1953 to 1966 for the Singapore Island is as follows [6]:

The frequency of rainfall adopted for drainage in Singapore is once in 5 years and the values are as follows [5]:

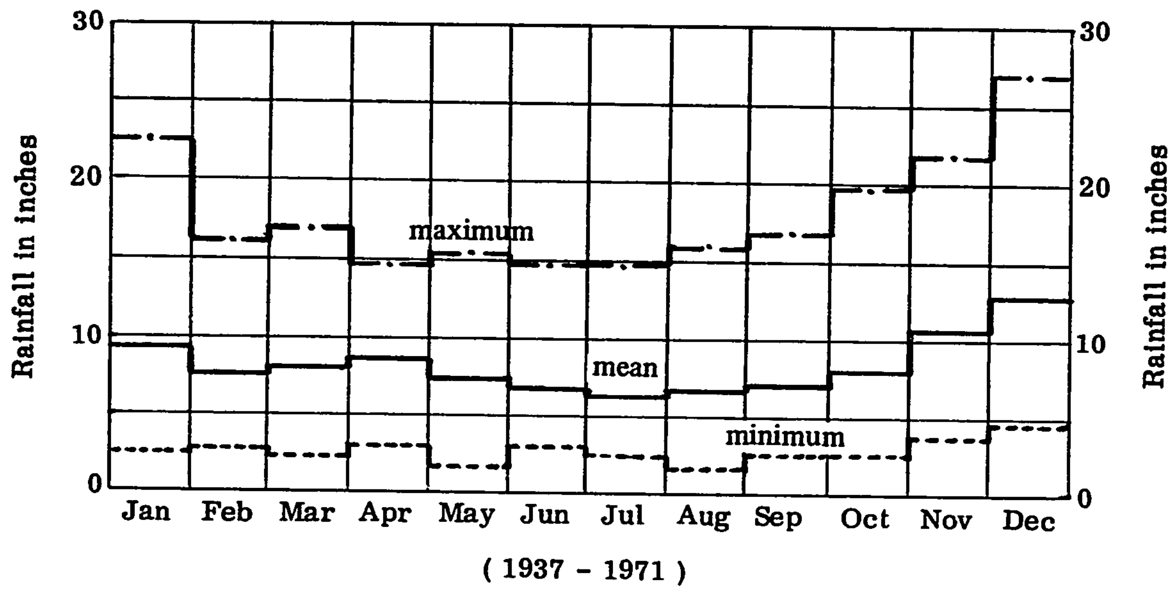

Fig. 2. Rainfall at Botanic Gardens (Station No. 6, Refer to Fig. 1)

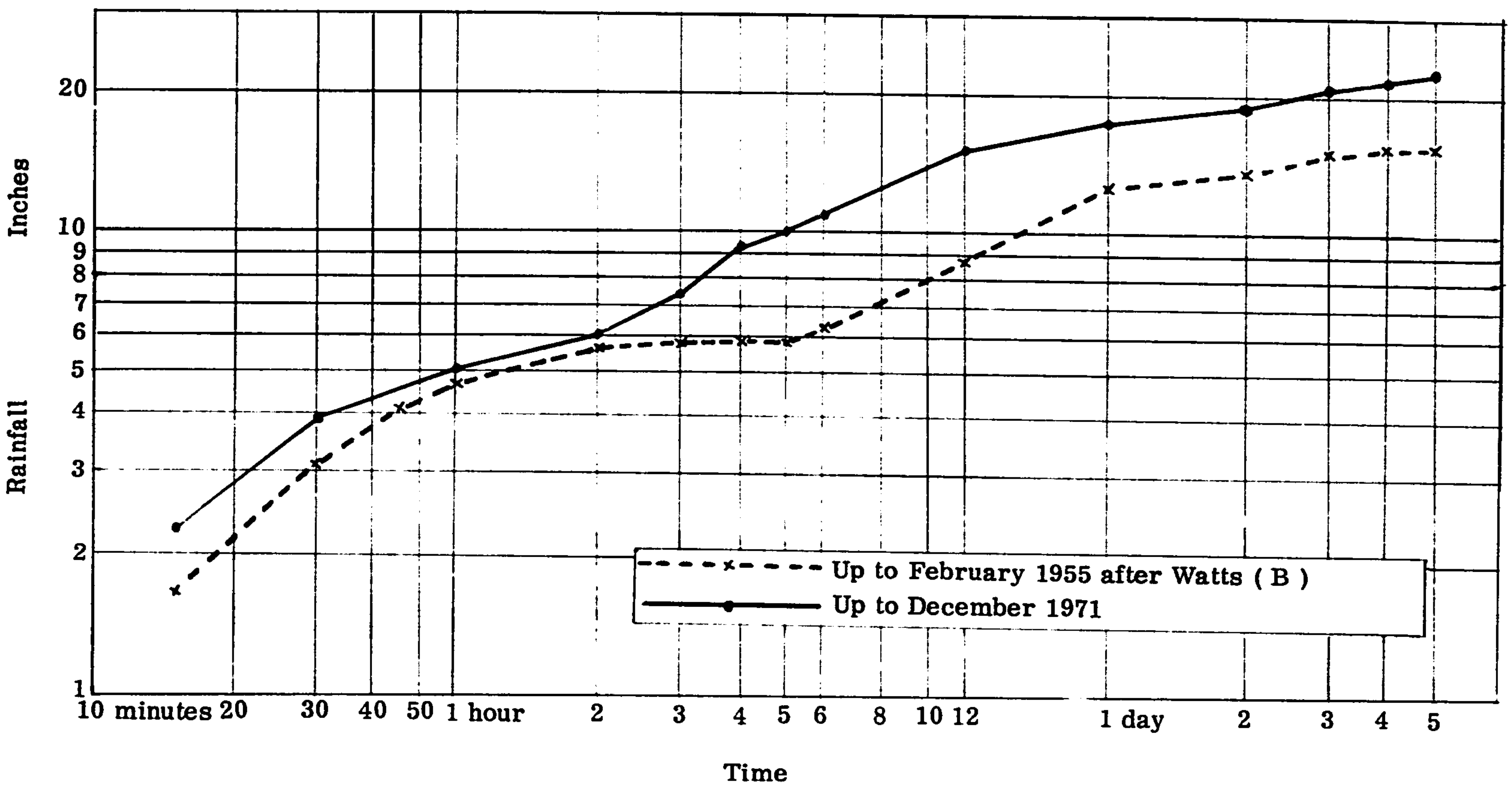

Fig. 3. Maximum Observed Rainfall Intensities in Singapore

Time (mins)	5	15	30	60	120	180	240	300	720
Rainfall Intensity (ins /hr)	9.0*	6.0	4.4	3.0	1.9	1.4	1.0	0.82	0.39
(mm/hr)	228*	152	112	76.2	48.3	35.6	25.4	20.8	9.90

* max. intensity adopted for drainage design is is 6.0 ins /hour (152 mm/hr)

FLOOD OBSERVATIONS AND STREAMFLOW DATA

The flooding in the Bukit Timah Catchment as caused by the factors discussed earlier has a very long history. The first attempt to alleviate the flooding in the Bukit Timah Catchment was probably carried out in 1935 [12] while the catchment was relatively undeveloped. However, the flood problem remains till today. The flood of 9th December 1954, inundated 864 acres of land [8] and the record flood of 10th December, 1969 inundated 1,221 acres of land [10]. The magnitude and frequency of flooding for the past four years are as follows:

Year	No. of floods	Highest water depth on Duneam Road and Bukit Timah Road
1968	7	2.5 ft (0.76 metre)
1969	14	5.5 ft (1.68 metres)
1970	7	1.3 ft (0.40 metre)
1971	6	2.1 ft (0.64 metre)
Total	34	

A flood survey was carried out after the record flood of 10th December, 1969, and the details were contained in a report [10]. The flood damage to private properties alone within the Bukit Timah Catchment amounted to about $0.8 million. The inundated area of 1,221 acres represents 18.5% of the total Bukit Timah catchment area.

Though flood observations had been made earlier, yet systematic collection of flood data did not commence until the Public Works Department installed 16 crest gauges and established a gauging station in the Bukit Timah Catchment in 1968. The present network of crest-stage gauges and gauging station for Singapore is shown in Fig. 4. The highest flood level recorded each year by each crest-stage gauge is published in the Public Works Department annual reports since 1968. The record of hourly and daily discharge at the gauging station at 6 m.s. Bukit Timah Road for the period from October 1968 to December 1970 has been compiled and published [9].

LAND DRAINAGE WORKS

The present water consumption in Singapore is about 110 mgd (500,000 cu m/day) and it is projected to reach 200 mgd (910,000 cu m/day) by 1990. Even at this present consumption, Singapore is not self-sufficient in water supply and has the problem of finding enough water for her population and industry even though the average annual rainfall is 95 ins (2413 mm).

On the other hand, huge quantities of flood storm waters in Bukit Timah Catchment has been running to waste especially during the North-east Monsoon from November to January. It is estimated that more than 10 mgd of storm waters from the Bukit Timah Canal could be tapped and utilized to augment the water supply yield.

It is essential that any land drainage works in Bukit Timah Catchment has to achieve the two objectives i.e. flood control and water conservation.

With the two objectives in mind Public Works Department has three land drainage works to Bukit Timah Catchment. They are:-

(1) Bukit Timah Flood Alleviation Scheme (Phase I),

(2) Improvement and concrete-lining of Bukit Timah Canal from Ewart Circus to Newton Circus,

(3) Multi-purpose storage reservoir at Singapore University ground along Bukit Timah Road.

BUKIT TIMAH FLOOD ALLEVIATION SCHEME (PHASE I)

The scheme was planned and designed primarily to reduce and mitigate the extent and magnitude of flooding at the lower stretch of Bukit Timah Catchment and secondly in order that flood storm waters could be impounded in a proposed storage reservoir (for water supply usage) at the

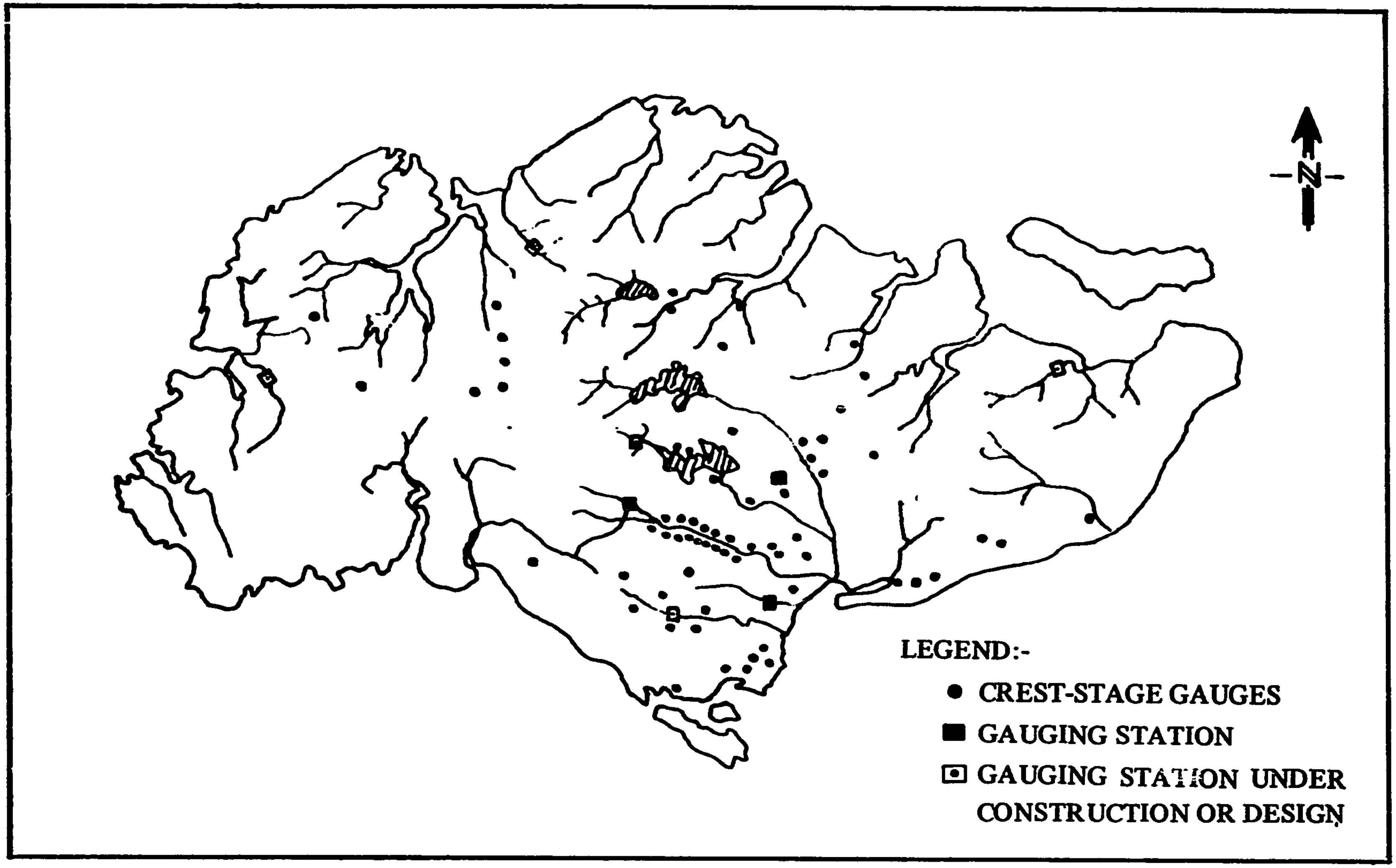

Fig. 4. Network of Crest-Stage Gauges and Gauging Stations in Singapore

mouth of Sungei Pandan to be executed by the Water Department of Public Utilities Board, the statutory body in Singapore entrusted with water resources development.

The total drainage catchment of Bukit Timah was 6,770 acres (2,740 ha) with outlet at Rochore Canal. Rochore Canal is just as inadequate as Bukit Timah Canal. The widening and deepening of Bukit Timah Canal and Rochore Canal to its adequate size, the simplest and traditional method of alleviating floods in the context of Singapore, is ruled out on economic and physical grounds. It had been estimated that it would cost in the region of $40/- to $50/- million [8]. Since it is economic prohibitive to reconstruct the two canals, the practical solution lies in diverting away as much flood waters into an entirely new outlet and its flood storm waters to be conserved and impounded.

The new outlet where its present discharge capacity is adequate enough to receive additional flood storm waters from Bukit Timah Canal is Ulu Pandan Canal and Sungei Pandan from which an impounding reservoir could be constructed.

The scheme is to divert the storm waters from Upper Bukit Timah Catchment amounting to 2,670 acres to a new outlet at Sg. Pandan through the diversion system and the existing Ulu Pandan Canal. The scheme involves the construction of an entirely new man-made water course in the form of open concrete canals, culverts and tunnels starting at 6 m.s. Bukit Timah Road and connected to Ulu Pandan Canal at Clementi Road. This diversion route was decided due to the following criteria :-

(1) Sufficient hydraulic head to drive the flood storm waters from 6 m.s. Bukit Timah Road.

(2) State land available with minimum acquisition.

(3) Scheme could be speedily executed without much clearance and resettlement problems.

The new man-made water course has a total length of 10,335 ft (3,150 m) consisting of 1,505 ft (458 m) of twin tunnels each with an internal diameter of 13½ ft (4.12 m), 572 ft (174 m) of box culverts and 8,258 ft (2517 m) of concrete-lined trapezoidal canals which has a top width of of 59 ft (18 m) and is as wide as the existing Rochore Canal.

The scheme was implemented in November 1966 and completed in August 1971. All works were undertaken by the Public Works Department's staff and local contractors. The total expenditure of the scheme including land acquisition and salaries of the staff amounts to about $7.1 million.

At the time when the scheme was designed, there was no stream-flow record available. The upstream end of the canal at 6 m.s. Bukit Timah Road serves a drainage area of 1,570 acres (635 ha) and the estimated peak discharge based on 5-year rainfall and calculated by the rational formula is 2,200 cusecs (62.4 cu m/sec). The downstream end of the canal at Clementi Road serves a drainage area of 2,670 acres (1,080 ha) and the estimated peak discharge is 3,370 cusecs (95.5 cu m/sec).

In October 1968, a gauging station was established at 6 m.s. Bukit Timah Road. Unitgraphs were then derived in 1970 from the record and the design discharge of the canal was checked. The peak discharge as estimated by the unitgraph method is 2,040 cusecs (57.7 cu m/sec) at 6 m.s. Bukit Timah Road and 2,920 cusecs (82.7 cu m/sec) at Clementi Road. The difference of the peak discharge from the original estimate by the rational formula is insignificant. The estimated flood hydrographs are shown in Fig. 5 and Fig. 6. It may be pointed out that in the latter flood study, the design storm is based on revised depth–duration–frequency relations [5] and on average temporal pattern [2]. The loss rate is assumed to be 0.20 inch (5.1 mm) per hour. The unitgraph at Clementi Road was derived from the unitgraph at 6 m.s. Bukit Timah Road by Snyder's method [7].

On completion of the scheme, the effect on flood relief in the lower stretch of Bukit Timah catchment can be approximately gauged from the reduction in drainage area as follows:-

Location	Drainage area reduced after the scheme
Adam Road/Farrer Road Bridge	60%
Whitley Road/Stevens Road Bridge	50%
Newton Circus	45%
Jalan Besar Bridge	39%
Outlet	37%

The scheme will benefit the area from 6 m.s. Bukit Timah Road to Adam Road and Farrer Road Bridge most as the drainage area is reduced by more than 60%.

It is also of interest to assess the reduction in flood peaks after the completion of the scheme. The results for the place at Newton Circus as estimated by means of unitgraph method for different recurrence intervals are plotted in Fig. 7. The average reduction in peak discharge is about 33%. (The unitgraphs were derived from flow measurements and observations of river stage during floods).

Open uniform flow was used in the design in the hydraulic structures for the scheme except the transitions between the tunnels and open canals. Manning formula was used to evaluate the dis-

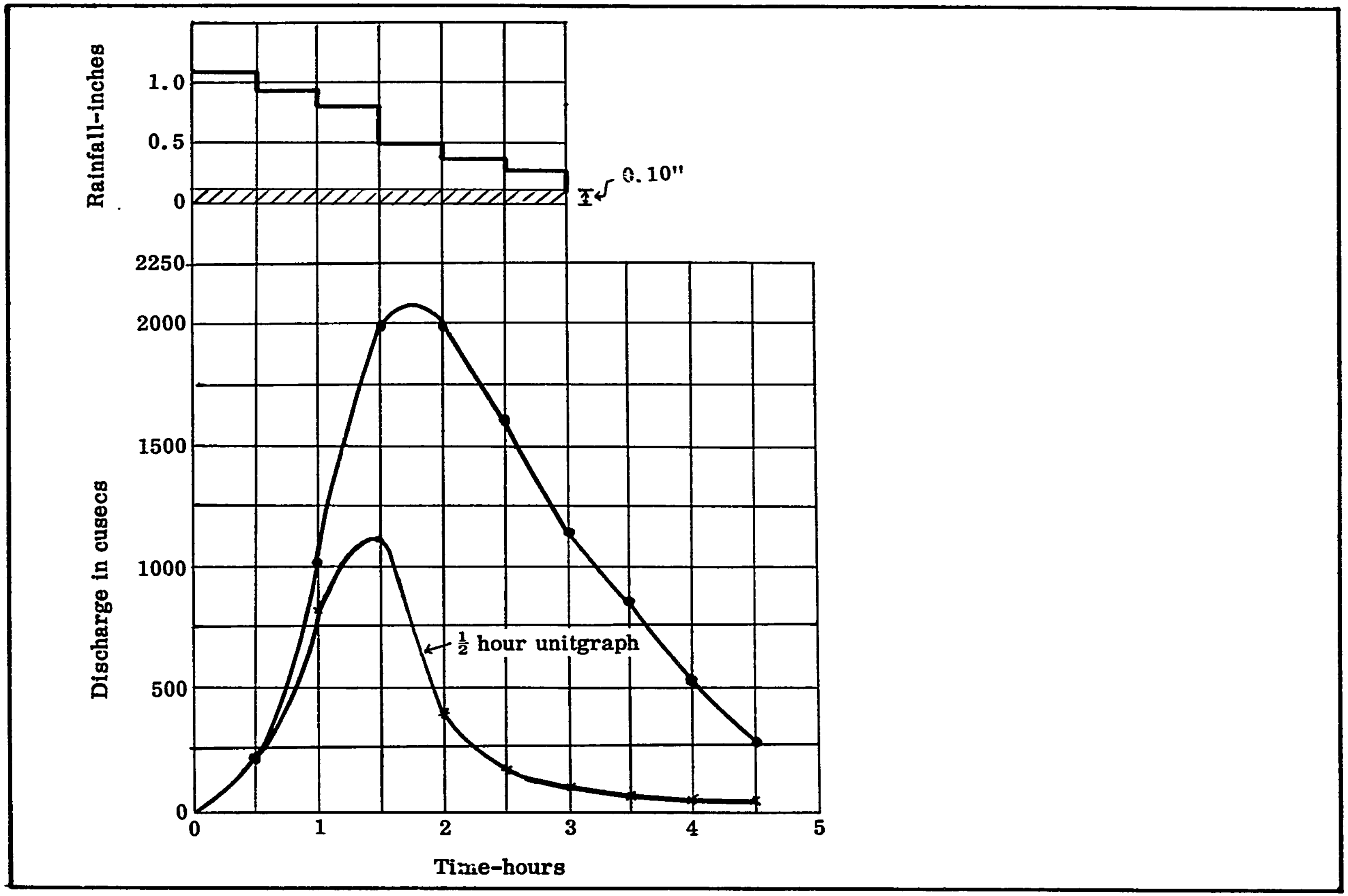

Fig. 5. Estimated 5-Year Flood Hydrograph at 6 m.s. Bukit Timah Road

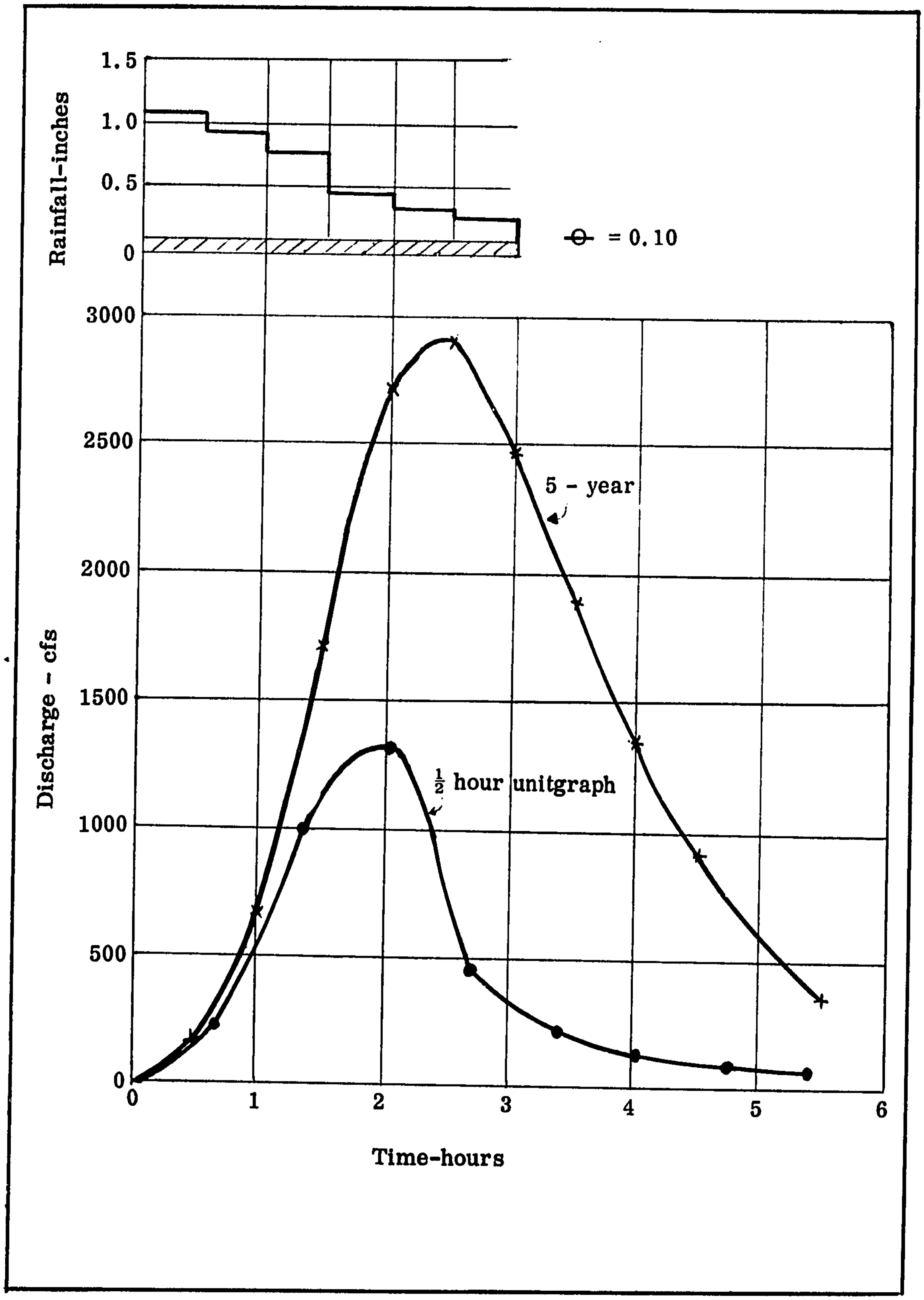

Fig. 6. Estimated 5-Year Flood Hydrograph for First Diversion Channel at Clementi Road

charge capacity of the hydraulic structures with allowance of 1½ ft (0.46 m) free board. In view of the available 10 ft (3.05 m) hydraulic head drop between Ulu Pandan Canal and Bukit Timah Canal, the 10 fps (3.05 m/sec) maximum velocity in the open canals and 16 fps (4.88 m/sec) maximum velocity in the tunnels at full flow were utilized.

Box culverts were designed to take full overburden load and full traffic load as specified in the British Ministry of Transport loading and in accordance to site and soil conditions. The design and construction of open concrete canals are given under improvement and concrete-lining of Bukit Timah Canals.

Liner Plate Method was used in the design and construction of the tunnelling in the scheme which has three stretches of twin tunnels. They are under Garlick Avenue (545 ft/166 m), Malaysian Railway Track (210 ft/64 m) and Military Hill (750 ft/229 m) at Ulu Pandan. The twin tunnels were spaced at two diameters apart and were to take on full overburden load of 30 ft (9.1 m) to 120 ft (36.6 m) depending on site conditions and full traffic load or full train load with 50% impact factor.

The design used a combination of corrugated steel liner plates assembled into a ring with curved R.S.J. ribs wedged together to form the primary lining of the tunnels. It was then coated with 15 inches (0.38 m) thick reinforced concrete of 1:2:4 mix to form the permanent lining or secondary lining of the tunnels. Twin tunnels were used as against a single tunnel. This is to utilize the tunnel cross-sectional area in hydraulically the most efficient manner. Circular shapes were used for their ease of construction and interchangeable of the segments that made up the primary lining of the tunnels.

The soils encountered in the tunnelling range from

(1) Stiff yellow-orange laterite earth beneath a bungalow house and road at Garlick Avenue tunnels.

(2) Soft plastic greyish soil with pockets of running sand at Malaysian Railway Track tunnels where soil stabilization using channel grouting was used to enable tunnel excavation to be executed safely and satisfactorily.

(3) Fragmented shale rock where blasting had to be introduced to enable tunnel excavation to be executed.

IMPROVEMENT AND CONCRETE-LINING OF BUKIT TIMAH CANAL FROM EWART CIRCUS TO NEWTON CIRCUS

The main canal that serves the Bukit Timah Catchment is the earth canal from Ewart Circus to Newton Circus, a length of 27,000 ft (8,230 m) and having a discharge capacity of 1,000 cusec (28.3 cu m/sec) and the concrete canal from Newton Circus to Serangoon Road Bridge, a length of 6,300 ft (1,920 m) and having a discharge capacity of 1,800 cusec (51.0 cu m/sec) (without free board).

To complete the flood control works in Bukit Timah Catchment, that stretch of earth canal is being improved and concrete-lined to a discharge capacity of 2,600 cusec (73.7 cu m/sec) below 6 m.s. Bukit Timah Road and 2,200 cusec (62.3 cu m/sec) above 6 m.s. Bukit Timah Road.

The concrete-lining scheme was implemented in September 1970 and is expected to be completed in 1973 at an estimated cost of $2.97 million.

The new concrete canal under the canal lining scheme is an open trapezoidal-shaped canal with a maximum top width of 50 ft (15.2 m) and a free board of 1 ft (3.05 m). The slope embankment to the canals has been designed to be stable by themselves and coated with 3½ inches thick of reinforced concrete of 1:2:4 mix. Hard core of broken bricks and stones topped up with lean concrete of 1:3:6 mix are used as the foundation to the open canals and in the context of Singapore a sound construction practice. Weepholes and their ancillary sub-soil drainage are provided to guard against the build up of excess soil water pressure on the canal lining.

MULTI-PURPOSE STORAGE RESERVOIR AT SINGAPORE UNIVERSITY GROUND

The Bukit Timah Flood Alleviation Scheme (Phase I) brings away storm water of 2,670 acres (1,080 ha) of the Upper Bukit Timah Catchment. The remaining drainage area is 2,340 acres (947 ha) at the Singapore University Ground and 3,268 (1,440 ha) at Newton Circus. The section of the canal between Newton Circus and Serangoon Road had been concrete-lined and its capacity is 1,510 cusecs (42.8 cu m/sec) with 1 ft (0.30 m) of freeboard. The capacity of the Rochore Canal which had also been concrete-lined decades ago is 2,340 cusecs (66.2 cu m/sec) with 1 ft (0.30m) of freeboard. To avoid the reconstruction of the concrete canal downstream of Newton Circus, it is proposed that the flow in the Bukit Timah Canal at the University Ground be stored up and released down in such a manner and magnitude that the existing canal capacity, downstream of Newton Circus is not exceeded. At the same time, the stored up flood waters could be utilized for water supply usage if effective water pollution control measures were carried out.

The Singapore University Ground level is about +8.00 ft (2.44 m) above mean sea level and it is about 3 to 4 ft (0.92 to 1.22 m) below the Bukit Timah Road. It is proposed to excavate the ground to a level of -10.00 ft. (-3.05 m) to form a reservoir with a capacity of 180 million gallons (820,000 cu m). Two weirs would have to be constructed in the Bukit Timah Canal, one across the canal to control the release and the other along one side of the canal to control the diversion into the proposed reservoir. The detailed design and arrangement of the two weirs are now under hydraulic model test. However, for the purpose of feasibility study, some uncontrolled Ogee weirs are assumed.

The storage reservoir is designed to cater for 5-year floods as the Bukit Timah Flood Alleviation Scheme (Phase I). The flood hydrograph as derived with the same earlier considerations as Bukit Timah Flood Alleviation Scheme (Phase I) is then routed through the two weirs. After a number of trials and adjustments, the weirs across the canal should be at a level of + 4.50 ft (1.37 m) and 10 ft (3.05 m) long. When the water level upstream is highest at + 9.30 ft (2.84 m), the outflow of the weir is 400 cusecs (11.3 cu m/sec).

The weir along the canal side consists of two parts. One part is 10 ft. (3.05 m) long with a crest level of +3.50 ft (1.07 m) to divert low flows into the reservoir. The other part is 40 ft (12.2 m) long with a crest level of +5.00 ft (1.53 m) to cater for flood flows. At highest water level of +9.30 ft (2.84 m) in the channel, the total flow over the side weir into the reservoir is 2,210 cusecs (62.6 cu m/sec). Therefore, the total flow over the two weirs is 2,610 cusecs (73.9 cu m/sec) which is equal to the inflow peak. However, the reservoir reaches its highest level of +9.70 ft (2.96 m) three hours later and the maximum outflow is 460 cusecs (13.0 cu m/sec). The reservoir with surrounding level at +12.00 ft (3.66 m) is not overtopped. Therefore, the arrangement is satisfactory. The inflow and outflow hydrographs and also the reservoir level are shown in Fig. 8.

At Newton Circus which is 9,000 ft (2,740m) downstream of the Singapore University Ground, the estimated flood peak due to the drainage area between the University and Newton Circus is 1,090 cusecs (30.9 cu m/sec). Ignoring the attenuation effect of canal storage and time delay, the outflow from the storage reservoir is added onto the flow at Newton Circus yielding a flood peak of 1,450 cusecs (41.1 cu m/sec) which does not exceed the existing channel capacity of 1,510 cusecs (42.8 cu m/sec) downstream of Newton Circus (Fig. 9).

Therefore, the arrangement is also satisfactory.

As the proposed reservoir at the University Ground is situated in the middle of high-class residential area and there are a number of hotels around, it is decided to include recreational facilities and to landscape the area to form a park. The detailed landscape design is now in progress and recreational facilities will include boating and fishing in the reservoir in which a minimum depth of 5 ft (1.53 m) water will be maintained at all times for the purpose.

CONCLUSIONS

On completion of the Bukit Timah Flood Alleviation Scheme (Phase I) in August 1971, it is of interest to note that on 23rd September, 1971 the diversion channel was almost running full due to a storm of high intensity. The rainfall recorded by the four rain gauges in the upper catchment were as follows:-

Section No. *	Rainfall	Highest intensity per hour
1	3.01 ins (76 mm)	(non-recording)
2	3.01 " (76 mm)	(non-recording)
3	3.98 ins (101 mm)	3.15 ins (80 mm)
4	4.96 ins (126 mm)	3.46 ins (88 mm)

* Fig. 1.

The highest rainfall intensity as observed at station No. 4 exceeded the intensity with a recurrence interval of 5 years as discussed earlier. The flood hydrograph (Fig. 10) as observed at 6 m.s. Bukit Timah Road had a peak discharge of about 2,100 cusecs (59.5 cu m/sec) which is about the design discharge for the Bukit Timah Flood Alleviation Scheme (Phase I). The Lower Bukit Timah valley was flooded and the deepest inundation at 4 m.s. Bukit Timah Road was about 2.1 ft (0.69 m). The flood illustrates that a second phase of the flood alleviation scheme is absolutely necessary. On the other hand, if the first diversion scheme was not completed in time, the deepest inundation was expected to be 4 to 5 ft (1.2 to 1.5 m).

The lining of the Bukit Timah Canal from 6 m.s. Bukit Timah Road to Newton Circus was completed in February, 1972. The constriction of the flow now is the section downstream of Newton Circus where the maximum channel capacity is 1,800 cusecs (51.0 cu m/sec). The estimated twice a year peak discharge at Newton Circus is about 2,000 cusecs (56.7 cu m/sec) (Fig. 7) after the completion of the first diversion scheme. If this estimation is correct, it is expected that on the average the Lower Bukit Timah valley will be flooded about 2 times as against about 8 times a year in the past 4 years.

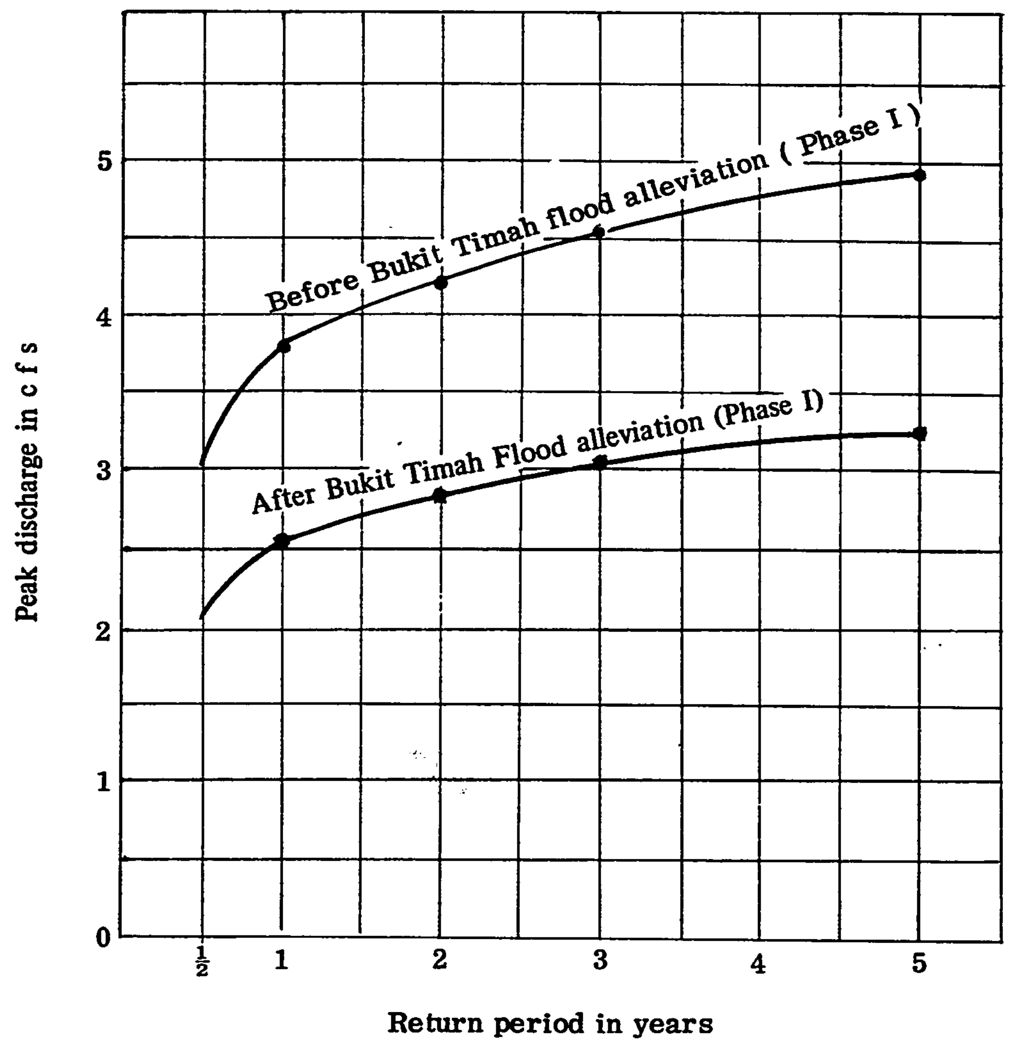

Fig. 7. Estimated Flood Peaks at Newton Circus

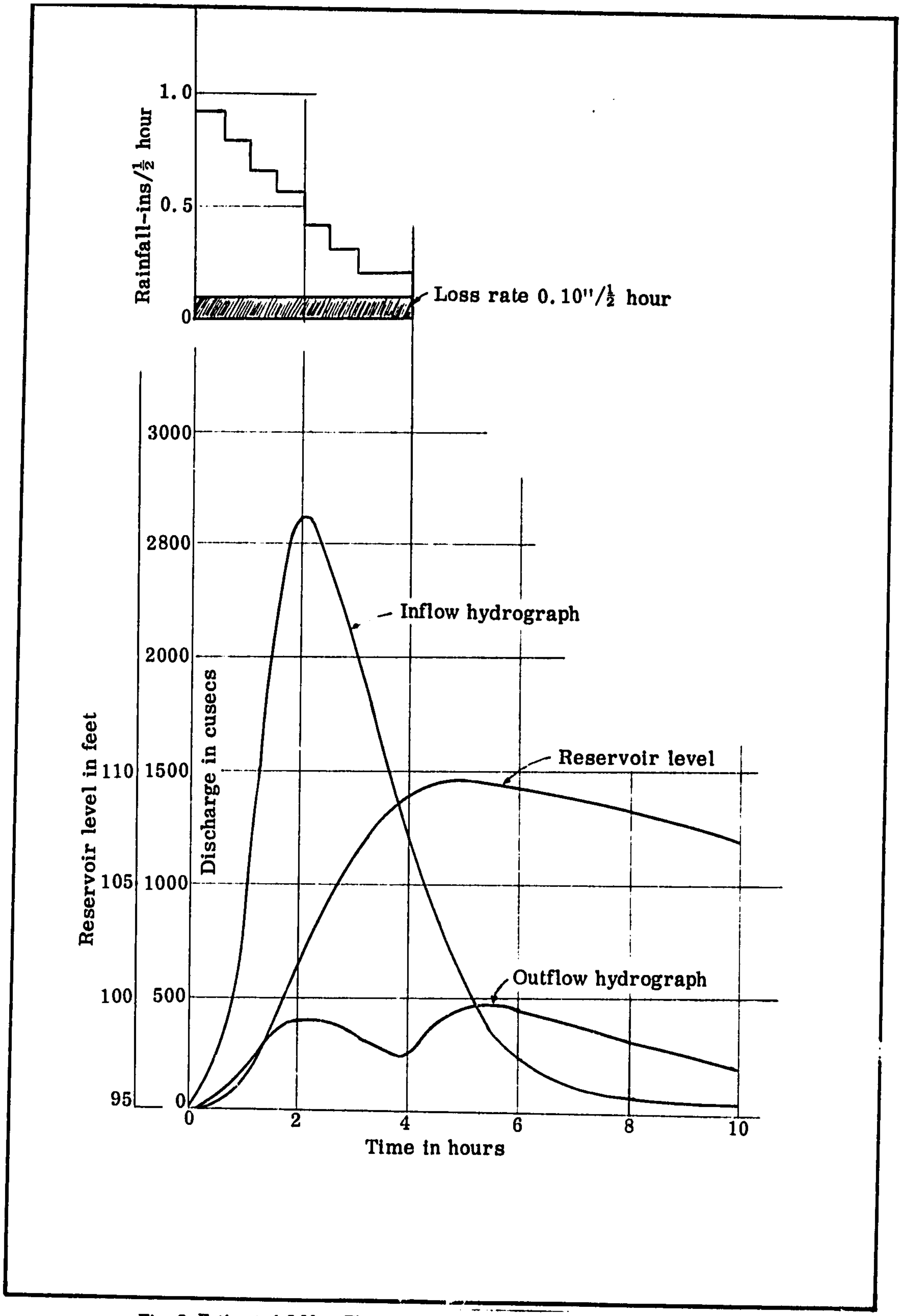

Fig. 8. Estimated 5-Year Flood Hydrographs for Bukit Timah Canal at University (Catchment Area = 2340 Acres)

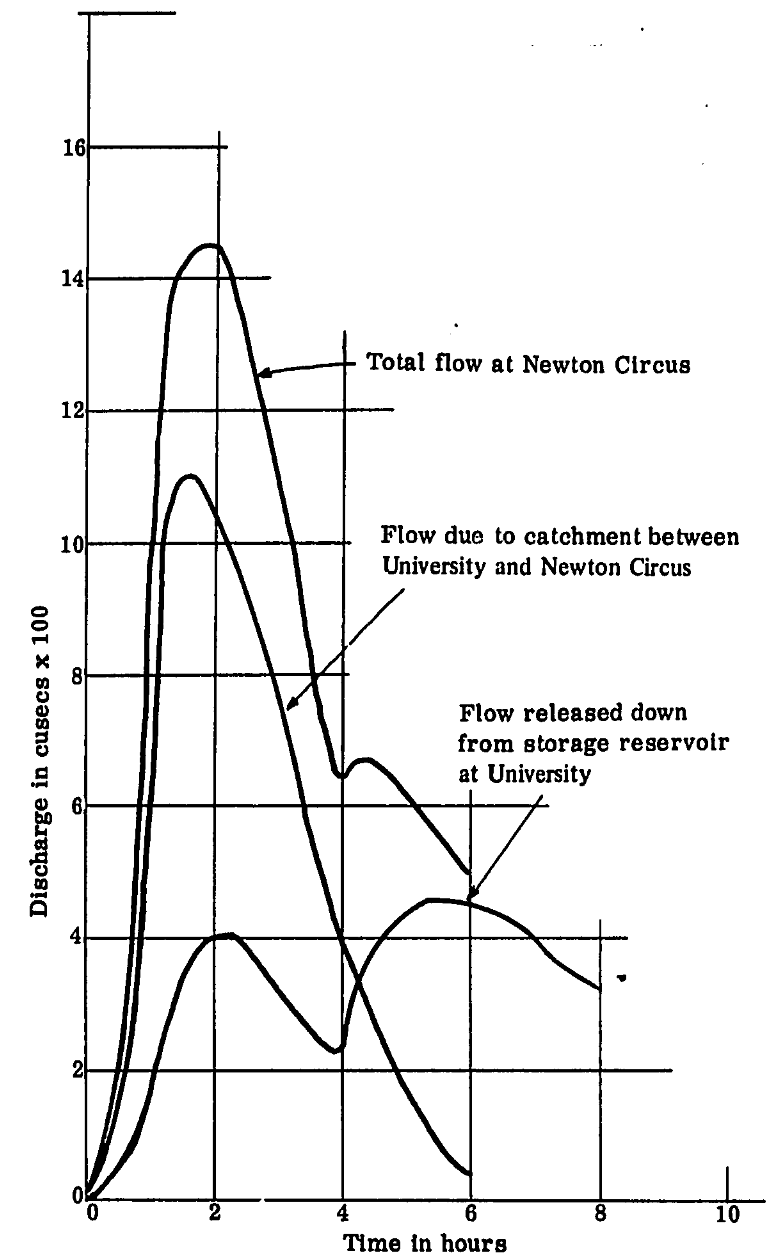

Fig. 9. Estimated 5-Year Flood Hydrographs for Bukit Timah Canal at Newton Circus (Area = 928 Acres)

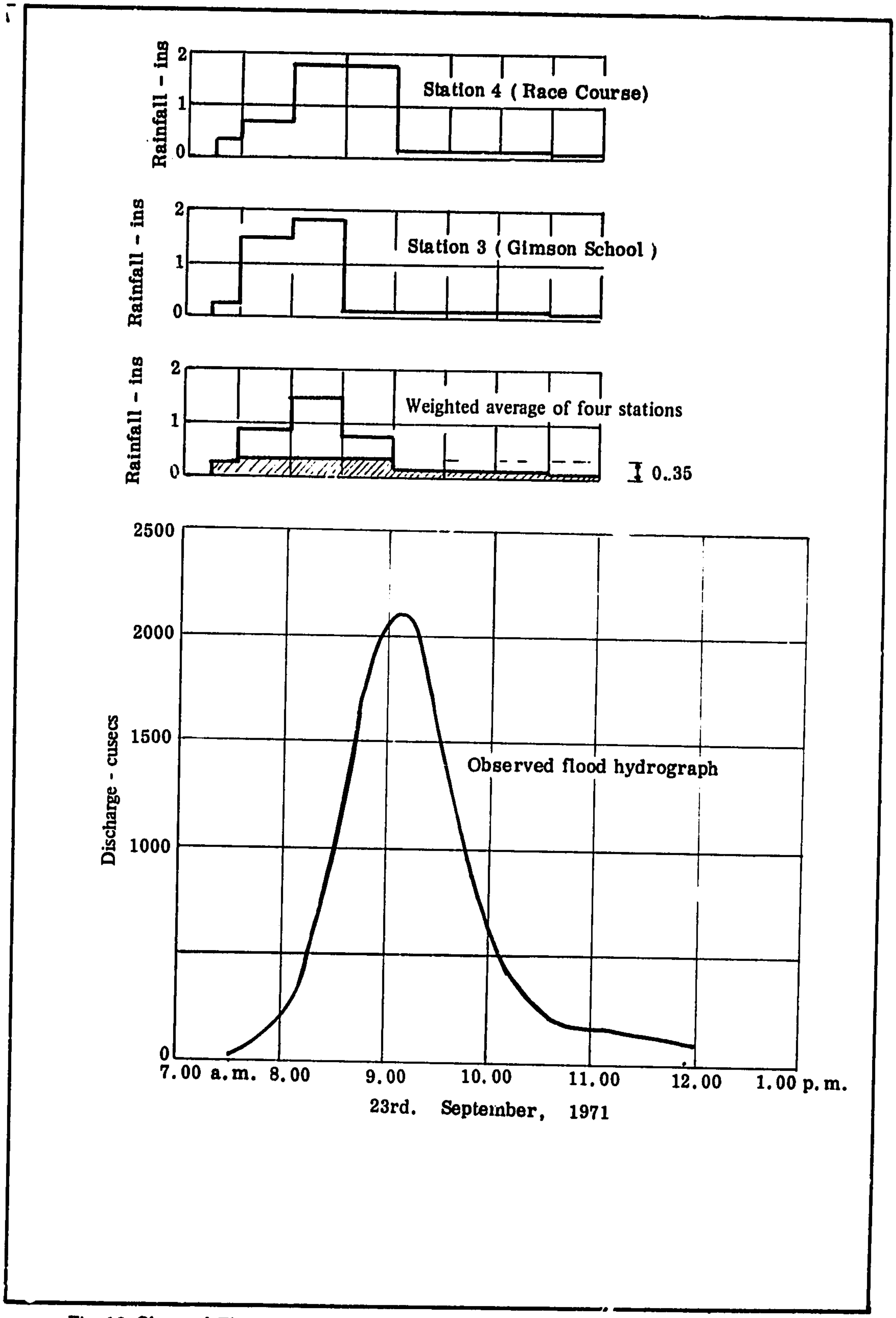

Fig. 10. Observed Flood Hydrograph of 23rd. September, 1971 at 6 m.s. Bukit Timah Road

The storm water diverted from the Upper Bukit Timah Catchment to the Ulu Pandan Canal will be impounded at the mouth of the Sungei Pandan and utilized. The work will be executed by the Water Department of Public Utilities Board.

The concrete lining of the Bukit Timah Canal from Ewart Circus to Newton Circus will not only help to alleviate the flooding but also will provide a healthier environment and more attractive scenery and landscape for the area as can be observed from the completed section of the canal lining from 6 m.s. Bukit Timah Road to Newton Circus.

The implementation of the reservoir at the Singapore University Ground will not only complete the flood alleviation schem. in the Bukit Timah Catchment but also will provide a recreational park in the midst of residential area and has the benefit of conserving the large quantity of flood waters which provides a potential source for water supply. It is possible to pump the water from the proposed reservoir to the existing MacRitchie Reservoir (Fig. 1) to increase its yield for water supply purpose.

It may be pointed out that the flood alleviation scheme for the Bukit Timah Catchment under the first diversion scheme and the proposed reservoir at the Singapore University Ground involves a total drainage area of 5,010 acres (2,030 ha) which represents 75% of the whole Bukit Timah catchment area or 2½ times the catchment of the MacRitchie Reservoir.

The proportion of the land utilization on the Island of Singapore is approximately as follows [2]:

Land Use	Percentage
Central area (mainly public administration and commercial)	1.3
Urban area (mainly residential)	18.9
Rural area	73.4
Water catchment and forest reserves	6.4

The flood alleviation schemes and drainage improvement works are implemented in conjunction with land development. It is of interest to note that more than 70% of the land area or about 147 sq. miles (380 km) on the Island is rural area. If the flood alleviation schemes and drainage improvement works for the remaining areas are carried out in the similar manner as for the Bukit Timah Catchment, there is hope to conserve and make optimum use of the available water resources in Singapore.

ACKNOWLEDGEMENTS

The authors are indebted to Mr. Hiew Siew Nam, Director of Public Works Department for his comments and permission to present this paper.

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Paper No. I/4

HYDROLOGICAL ACTIVITIES IN SINGAPORE

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ABSTRACT

The paper gives a cross-section of the hydrological records available in Singapore. Proposed works which are either under implementation or at the planning stage are also included. Publications and reports dealing with Singapore hydrology are listed.

INTRODUCTION

As there is no one central, independent authority handling all hydrological records in Singapore, very often when hydrological data are required for a certain project, it is always time consuming to make a search for the required data. It is therefore felt that a compilation of the hydrological activities in the country will help planners and designers engaged in water resources development, water management, drainage and flood alleviation projects. The review will also benefit research workers and other people and organizations interested in this subject.

The review gives a cross-section of the hydrological records available with some comments on the existing network. An attempt is made to include all publications and reports dealing with Singapore hydrology. Some of the more important proposed works which are either under implementation or at planning stage are included to indicate that much more work have to be done in order to bring the hydrological activities up to the required level in the country.

Three main departments, namely the Meteorological Service, the Water Department and the Public Works Department are involved in hydrological works in which the Meteorological Service is concerned with meteorological aspects and the latter two departments are more interested in water quantity and quality. The Meteorological Office of the Royal Air Force had also played an important role in the collection of meteorological data in the past. However, since the withdrawal of the British Forces from Singapore in 1971, the observations formerly undertaken by the Meteorological Office of the Royal Air Force are now continued by the Meteorological Service. Recently, the University of Singapore has also shown interest in hydrological works and has installed a meteorological station at the Seletar Reservoir as a joint project with the Meteorological Service, the Water Department and the Public Works Department. The Ministry of Health is also concerned with water pollution and they have carried out water-quality survey since 1969.

RAINFALL NETWORK

The longest continuous rainfall record is that collected at the MacRitchie Reservoir from 1878 to date. Possibly it was a daily storage gauge installed at early dates but only monthly records could be extracted from the annual reports and files of the Water Department for the period from 1878 to 1952 [21]. In January 1953, a recording gauge was installed and the pluviometer record is available since then at this station.

Same type of monthly rainfall records is available at the Peirce and Seletar Reservoirs from the year 1904 to 1939 and 1947 to date. However, the pluviometer record at the Peirce Reservoir started in January 1957 and that at the Seletar Reservoir in March 1958.

The monthly rainfall of the three reservoirs just mentioned has been compiled by Binnie and Partners [2] and the Water Department.

Other old daily or monthly observations available in the records of the Meteorological Department are as follows [33] :–

Convict Jail (present Outram Park)	1869–1874
Kandang Kerbau Hospital	1875–1928
Tan Tock Seng Hospital	1871–1919
Woodleigh Filters	1874–1919
Killiney Estate	1912–1940
Kallang Airport	1935–1940
Botanic Gardens	1937–1940
Mount Faber	1929–1933

Taylor [29] in his rainfall-intensity study mentioned the records of five recording gauges over a period of 8 years (1925 to 1932) and three recording gauges moved from time to time over a period of 3 years (1930 – 1932). These gauges were installed in the central and southern areas of the Singapore Island but no such records can now be found. The oldest pluviometer record available is that observed at Mount Faber. It started in January 1931, but in June 1934, the recorder was moved to the Kallang Airport. No observation was made from February 1942 to December 1947. The same recorder was moved again to Paya Lebar Airport in August 1955. The recorder charts for the pre-war period are now kept by the Meteorological Service at the Upper Air Observatory at Kim Chuan Road.

In January 1949, two recording gauges were installed, one at Tengah and one at Changi by the Royal Air Force,(Watts [33] mentioned a recording gauge installed at Gate No. 9 of the Port of Singapore Authority in 1949 but the earliest pluviometer record available at this station is from January, 1953). In 1952 and 1953, eight more recording gauges were installed (Watts [33] mentioned 32 recording gauges maintained in 1953 but most of the records cannot be found). To date, the total number of recording gauges in operation amounts to 31 and the non-recording daily gauges amounts to 14 forming the present network as shown in Fig. 1. Fig. 2 shows all the rainfall stations mentioned and Fig. 3 is a bar chart depicting the length and form of all rainfall records available in Singapore.

The recording gauges used in Singapore are mostly of syphon type and their charts are changed daily round about 7.30 a.m. The non-recording gauges are of 8-inch and 5-inch diameters made of copper and they are read daily at 7.30 a.m. Thus, the daily rainfall referred to is in fact the rainfall recorded from 7.30 a.m. on the date indicated to 7.30 a.m. next day.

Out of the total 45 gauges now in operation, 8 are maintained by the Water Department, 3 by the Economic Development Board, 1 by the Primary Production Department, 7 by the Public Works Department, 1 by the Nanyang University and the rest by the Meteorological Service. However, all the collected data are compiled each month by the Meteorological Service though the recorder charts may be kept by the department and organizations which operate and maintain the stations. The compiled records in the form of daily and monthly totals for each station are readily available from the Meteorological Service for all people interested.

The total number of rain gauges in the existing network is sufficient. It is about 5.0 square miles per gauge on the average. However, the distributtion could be improved especially along the southeast coast of the Island where there is no recording gauge. Improvement to some existing stations is necessary and this has been listed out in detail by an ECAFE Water Resources Consulting Group [13]. The improvement mostly concerns the height, stability and exposure of gauge and some involves shifting of the gauge to a better location. The Meteorological Service is carrying out the improvement work.

STREAMGAUGING NETWORK

The earliest streamflow measurements and establishment of gauging stations in Singapore were most probably made by Taylor [29] around 1930's. But no streamflow records can be found besides some old gauging equipment being left with the Public Works Department and some gauging structures being seen along the Bukit Timah Canal.

The longest streamflow record available is the monthly in-flows into the MacRitchie Reservoir which were estimated from reservoir water balance

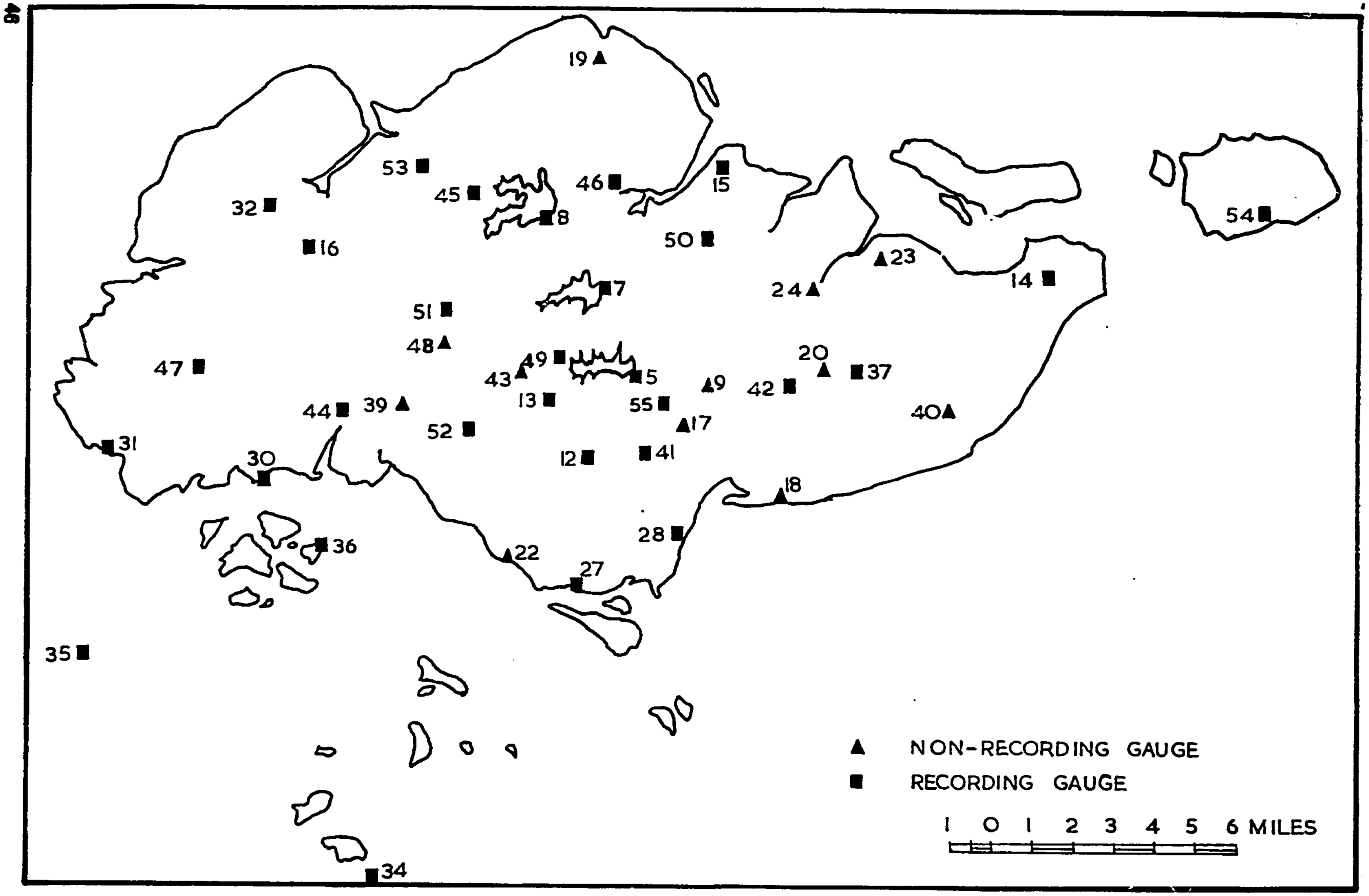

Fig. 1. Singapore – Present Rainfall Network

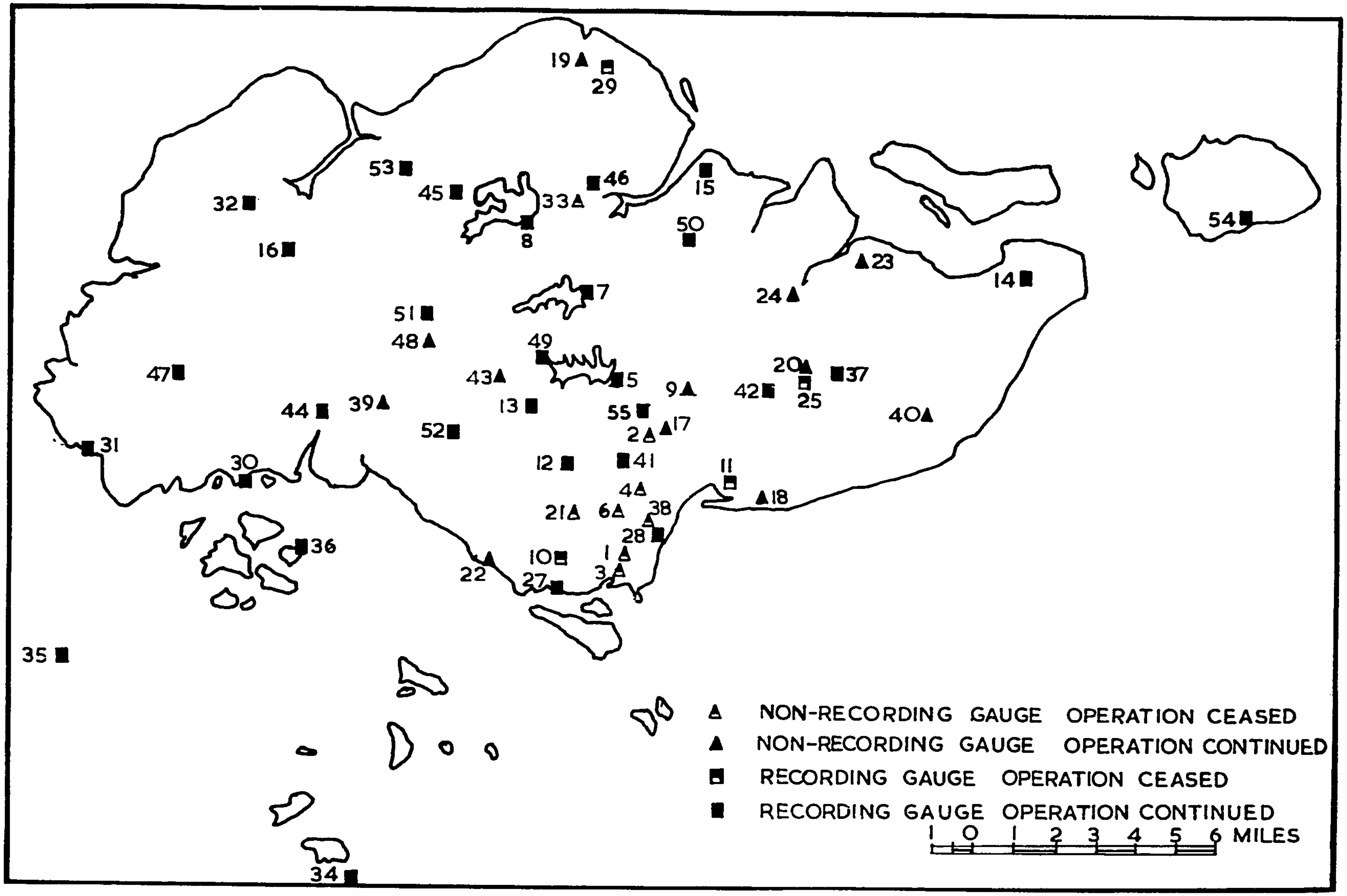

Fig. 2. Singapore – The Rainfall Stations

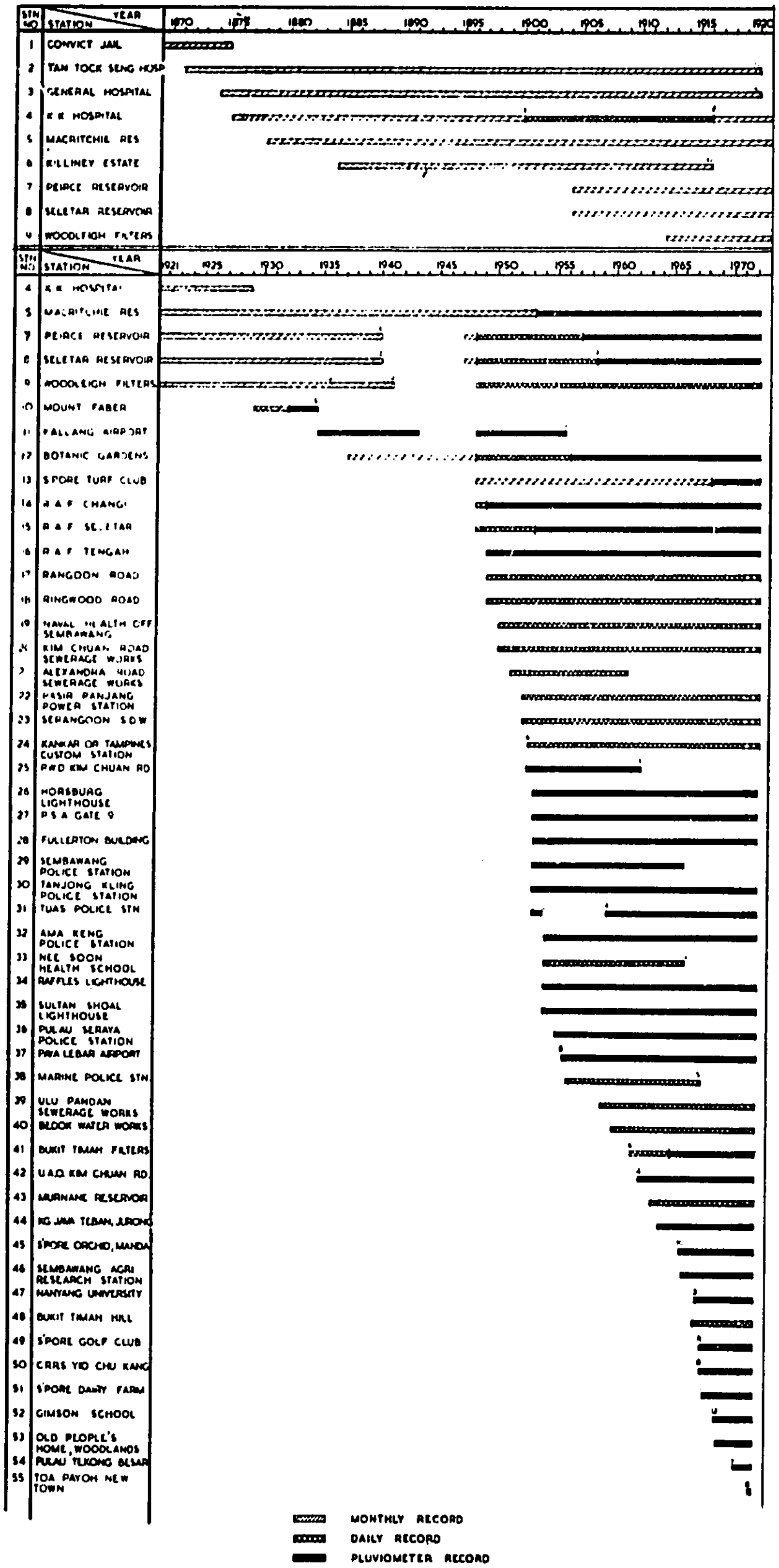

Fig. 3. Rainfall Data

using operation data. Inflow records are also available for the Peirce and Seletar reservoirs. The period of record for each reservoir is as follows :-

MacRitchie Reservoir	1895,1898–1939, 1951 – date
Peirce Reservoir	1914–1939,1951–date
Seletar Reservoir	1951 – date
MacRitchie and Peirce Combined	1914–1939,1949–date
MacRitchie, Peirce and Seletar Combined	1951 – date.

The monthly inflows for the three reservoirs have been compiled by Binnie and Partners [2] and the Water Department. The reason for including combined reservoir inflows is that they can exclude consideration of the quantities transferred between reservoirs, which have for some period unmeasured, and against which no form of double-check is available. These combined inflows, apart from the uncertain quantity of spills, provide a more reliable record than that for a single reservoir. The combined inflows for the MacRitchie and Peirce reservoirs for the years 1949 and 1950 have not been included in Binnie and Partners' report [2] as the record was discovered later by the Water Department. Also the Seletar Reservoir was reconstructed during the period from April 1967 to August 1968. During the reconstruction period, no inflow record was collected. After the reconstruction, flows from 8 streams in the adjacent catchments are diverted to the new Seletar Reservoir and the flow data are available up to date.

In January 1966, the first hydrological investigation was carried out in Singapore by a consultant firm, Binnie and Partners in connection with the Seletar Reservoir Scheme. The investigation was for one-year period and the results were presented in a report [2]. In this investigation, spot discharge measurements were made on the Bukit Timah Canal, Sungei Pang Sua, Sungei Ulu Pandan, Sungei Seletar and Sungei Simpang Kiri; and in addition to discharge measurements, water-levels were taken twice daily for the Sungei Namly, Sungei Peng Siang, Sungei Mandai, Sungei Sembawang, Sungei Sembawang Kechil, Sungei Pandan and Sungei Choa Chu Kang. In September, 1966, a timber flume and water-level recorder were installed on the Sungei Peng Siang, Sungei Pang Sua and Sungei Mandai.

After the completion of the investigation period, the gauging network as established by the consultant firm was maintained by a newly created Hydrology Unit in the Water Department. The Hydrology Unit has extended the work to include water sampling and tidal observations. However, out of the three timber flumes installed by the consultant firm, two warped, one was washed away and the operation of the stations was stopped later.

In 1968, a Hydrology Unit was also created in the Public Works Department to collect hydrological data for drainage design and flood alleviation projects. In October, 1968, a hydrometric station was established on the Bukit Timah Canal at 6th milestone Bukit Timah Road. At this station, an Ott water-level recorder and a triangular weir with 5-to-1 side slopes as developed by the United States Department of Agriculture [31] was installed. The record of hourly and daily mean discharge at this station for the period from October 1968 to December 1970 has been published by the Public Works Department [22]. The Hydrology Unit put up a proposal of setting up a hydrologic network in Singapore in 1968 and this proposal was approved in 1971. Since the approval of the proposal, one hydrometric station was installed in Toa Payoh New Town in August 1971 and one on the Stamford Canal at Buyong Road in January 1972; 2 stations are under construction, one on the Sungei Mandai and one on the southern tributary of the MacRitchie Reservoir; 3 more stations are under planning and design, one on the Alexandra Canal, one on the Sungei Choa Chu Kang and one on the Sungei Api Api. The gauging network will consist of about 12 stations on completion, the actual location of the remaining 4 stations being not yet fixed.

The gauging network mentioned earlier is shown in Fig. 4, and the length and form of the streamflow records are shown in Fig. 5.

FLOOD LEVELS

Flood levels are useful data and the Public Works Department have installed and maintained 64 flood gauges and crest-stage gauges in various areas subject to flooding in Singapore (Fig. 6). The flood gauge is merely a staff gauge graduated in feet and inches erected by the roadside with zero mark set in level with the road surface so that the reading gives the water depth on the road. The crest-stage gauge consists of a 2-inch diameter galvanized iron pipe set vertically and capped at both ends with holes for water entry at the side of the bottom end. It contains a wooden staff gauge held in place by the caps. It is clamped to a flood gauge. A small quantity of powdered cork is introduced into the bottom of the pipe. When a flood passes, the cork is lifted and at the crest is left clinging to the staff. The staff is read when the gauge is visited after the flood.

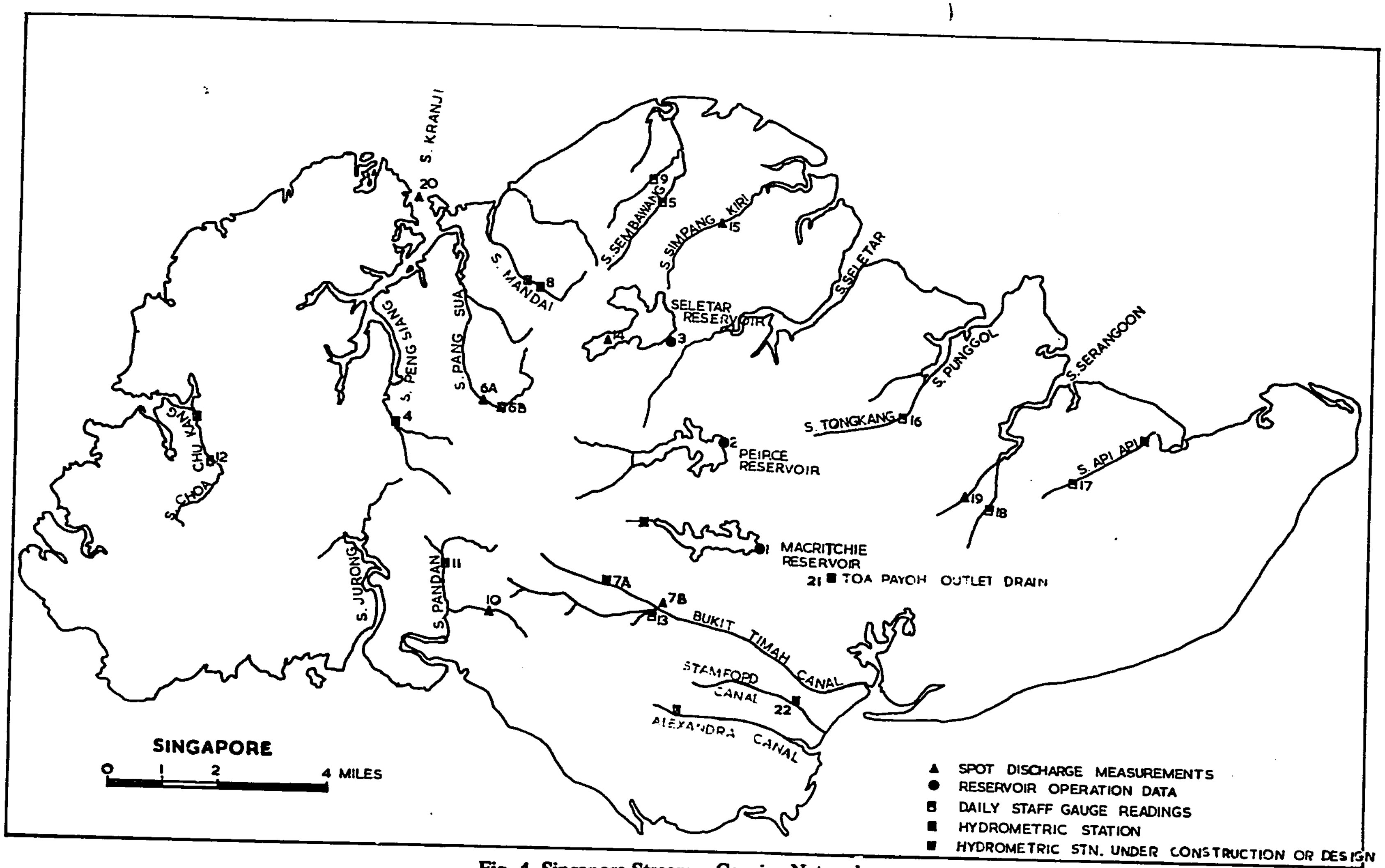

Fig. 4. Singapore Stream – Gauging Network

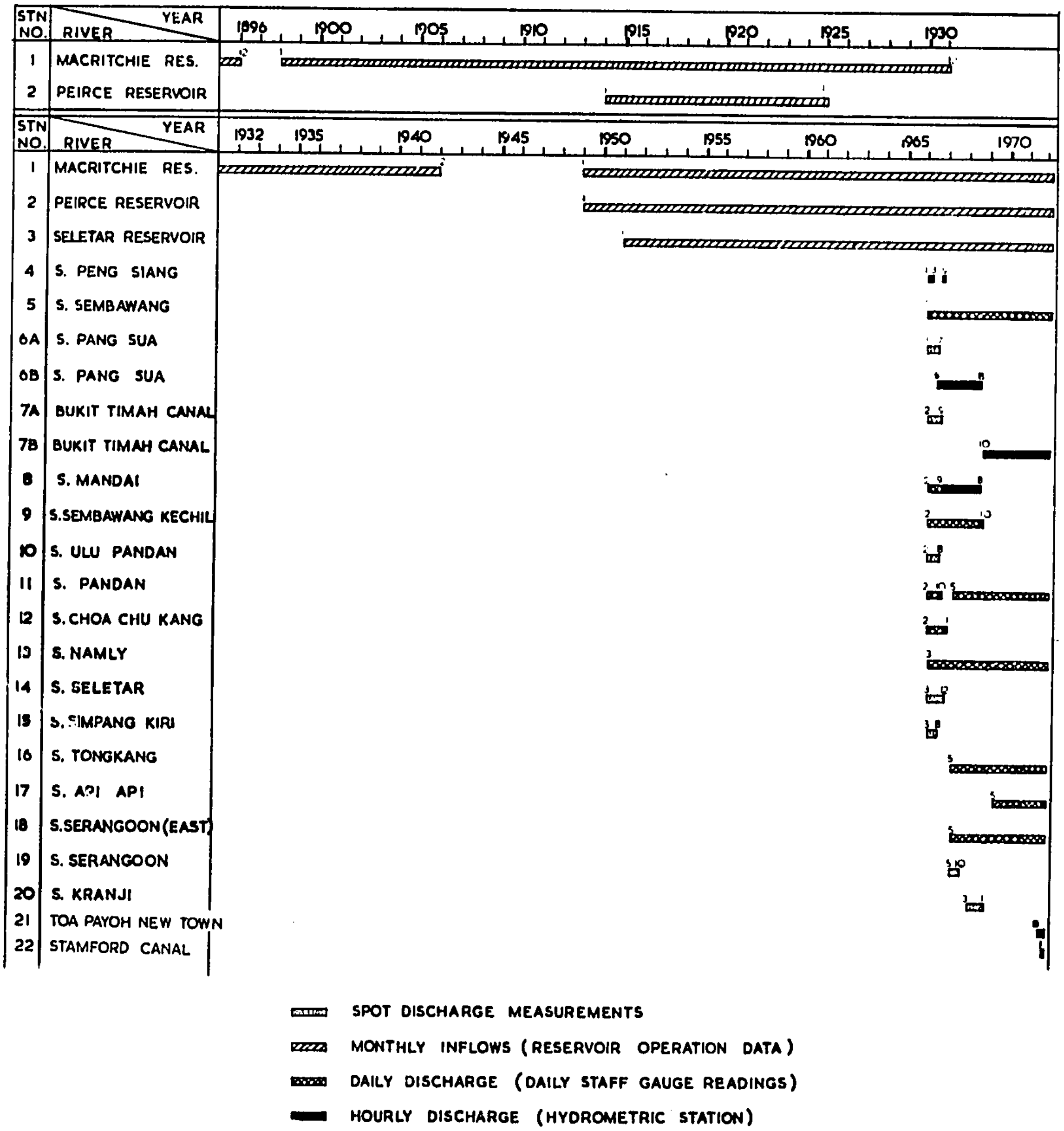

Fig. 5. Streamflow Data

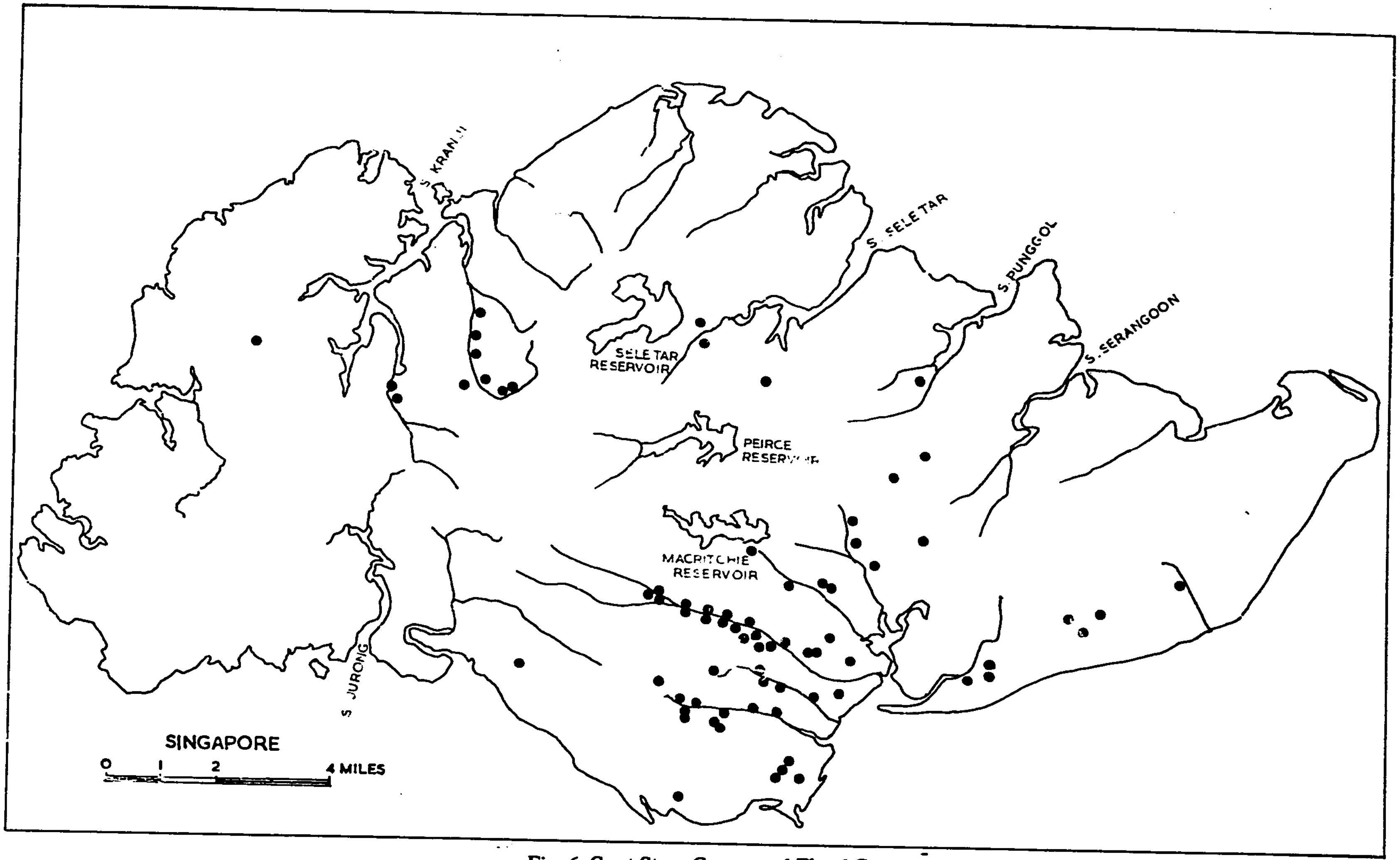

Fig. 6. Crest Stage Gauges and Flood Gauges

The highest flood level recorded by each crest-stage gauge in each year is published in the Annual Report of the Public Works Department since 1968.

TIDAL OBSERVATIONS

There are three recording tidal gauges in Singapore. One belongs to the Port of Singapore Authority installed at the Victoria Dock. The record started in 1954. Another recording gauge is at the Naval Base in the Straits of Johore maintained for a long period by the Royal Navy. The Water Department installed a tide-level recorder in December 1968 on the western side of the Singapore-Johore Causeway.

The Public Works Department has installed 15 crest-stage gauges to record high-tide levels at estuaries and around the coast of Singapore Island since 1970. The Water Department also makes spot observations of tidal levels at 8 locations around the coast of the Island since 1967.

The network of tidal observations is shown in Fig. 7 and the length and form of records are shown in Fig. 8.

It may be noted that tide tables [56] are published annually to give predictions of the height of tides at Singapore Town and Naval Dockyard and also give tidal stream predictions in direction and magnitude in the Singapore Strait at Western Approaches to Keppel Harbour and off Horsburgh Light House. These tide tables can be purchased from the Marine Department.

WATER QUALITY

The Ministry of Health carries out water sampling mostly in built up urban and residential areas whereas the Water Department are more concerned with rural areas associated with water supply projects. At each sampling point, water sample is collected mostly once a month for chemical and bacteriological tests. The sampling network is shown in Fig. 9 and the detail of records available is shown in Fig. 10. The Hydrology Unit of the Water Department carried out rather extensive water-quality surveys from 1966 to 1969 for 16 streams and the survey for 8 of these streams is continued by the Supply Branch of the same Department up to date. The Supply Branch of the Water Department also carries out water sampling for the water diverted from 8 streams to the Seletar Reservoir at Cascades. The Ministry of Health carries out rather comprehensive water-quality surveys for 19 streams since 1969. One drawback of the water-quality surveys is that it does not tie in with flow quantity. As the gauging network is now being set up, water samples will be collected at hydrometric stations in the future.

METEOROLOGICAL STATIONS

There are 2 meteorological stations in Singapore. One is at the Paya Lebar Airport maintained by the Meteorological Service with the following records available :–

(1) pluviometer record - from September 1955 to date ;
(2) evaporation record by a British Meteorological Service type square pan - from July 1958 to date ;
(3) evaporation record by a U.S. Class A pan - from February 1966 to date ;
(4) wind record - from September 1955 to date ;
(5) sunshine record - from September 1955 to date ;
(6) temperature record - from September to date;
(7) radiation record - from January 1961 to date;
(8) atmospheric pressure record - from September 1955 to date;
(9) relative humidity record - from September 1955 to date;

The other one is at the Seletar Reservoir installed May 1971 by the University of Singapore as a joint project with the Public Works Department, the Public Utilities Board and the Meteorological Service. The equipment and instruments installed are similar to those at the Paya Lebar Airport consisting of the following items :

(1) large thermometer screen
(2) rainfall recorder
(3) raingauge, 8-inch diameter
(4) thermometers
(5) barograph
(6) hair hygrograph
(7) hair hygrometer
(8) U.S. Class A evaporation pan
(9) evaporation hook gauge and still well
(10) Piche evaporimeter
(11) sunshine recorder
(12) anemometer
(13) bimetallic actinograph

In addition, a water-level recorder is installed to record the water level of the Seletar Reservoir. Also, a deep-water thermometer will be used to

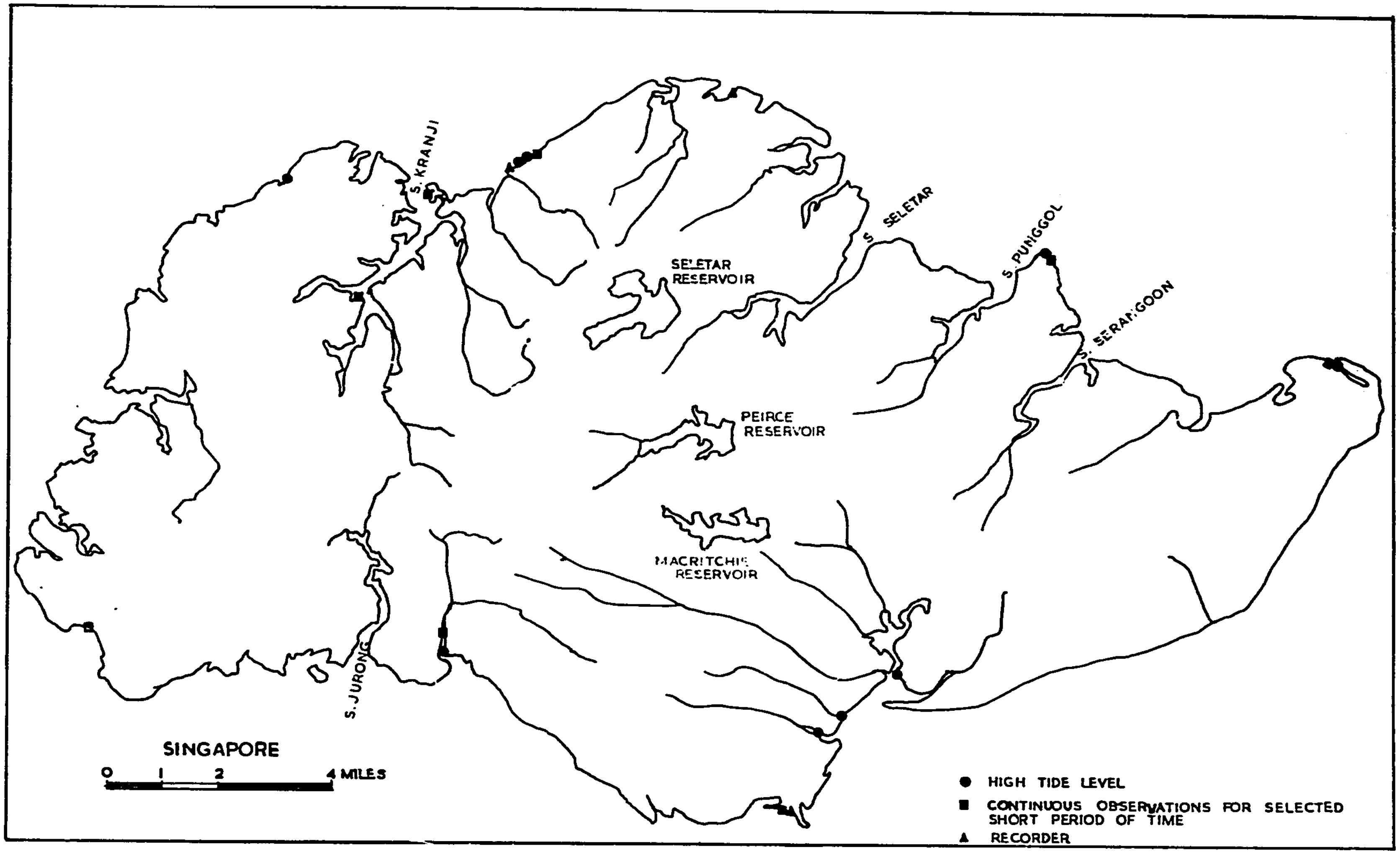

Fig. 7. Tidal Observation Stations

STN. NO.	LOCATION	1955 1957 1959 1961 1963 1965 1967 1969 1971	REMARKS
1	VICTORIA DOCK, P.S.A.		
2	NAVAL BASE OF ROYAL NAVY	RECORDER ACTUAL PERIOD OF RECORD IS NOT KNOWN	
3	JOHORE CAUSEWAY ON EASTERN SIDE AT JETTY		14 OBSERVATIONS
4	JOHORE CAUSEWAY ON WESTERN SIDE AT JETTY		
5	SUNGEI KRANJI ESTUARY AT END OF KRANJI ROAD		9 OBSERVATIONS
6	SUNGEI TENGAH AT LORONG AYAM JALAK		7 OBSERVATIONS
7	SUNGEI PANDAN OFF WEST COAST ROAD		12 OBSERVATIONS
8	VICTORIA DOCK, WEST SIDE ENTRANCE		20 OBSERVATIONS
9	CHANGI POINT NEAR CUSTOM JETTY		16 OBSERVATIONS
10	SERANGOON HARBOUR, TRACK 24 OFF PONGGOL ROAD		14 OBSERVATIONS
11	TUAS, END OF JURONG ROAD		15 OBSERVATIONS
12	P.W.D. MARINE DEPOT		5 OBSERVATIONS
13	STAMFORD CANAL MOUTH AT NICOLL HIGHWAY		1 OBSERVATION
14	JOHORE CAUSEWAY ON EASTERN SIDE AT WATER PIPE ABUTMENT		3 OBSERVATIONS
15	JOHORE CAUSEWAY AT LORONG FATIMAH NEAR JETTY		3 OBSERVATIONS
16	JOHORE STRAIT AT PUNGGOL POINT AT JETTY		3 OBSERVATIONS
17	JOHORE STRAIT AT CHANGI POINT* AT FISHERIES SCHOOL		3 OBSERVATIONS
18	SEMBILAN STRAIT AT SUNGEI PANDAN TIDE-GATE		2 OBSERVATIONS
19	JOHORE STRAIT, END OF LIM CHU KANG ROAD		1 OBSERVATION
20	SINGAPORE RIVER MOUTH AT EMPRESS PLACE		14 OBSERVATIONS

HIGH-TIDE LEVEL

CONTINUOUS OBSERVATIONS FOR SELECTED SHORT PERIOD OF TIME

RECORDER

Fig. 8. Tide-Level Observations

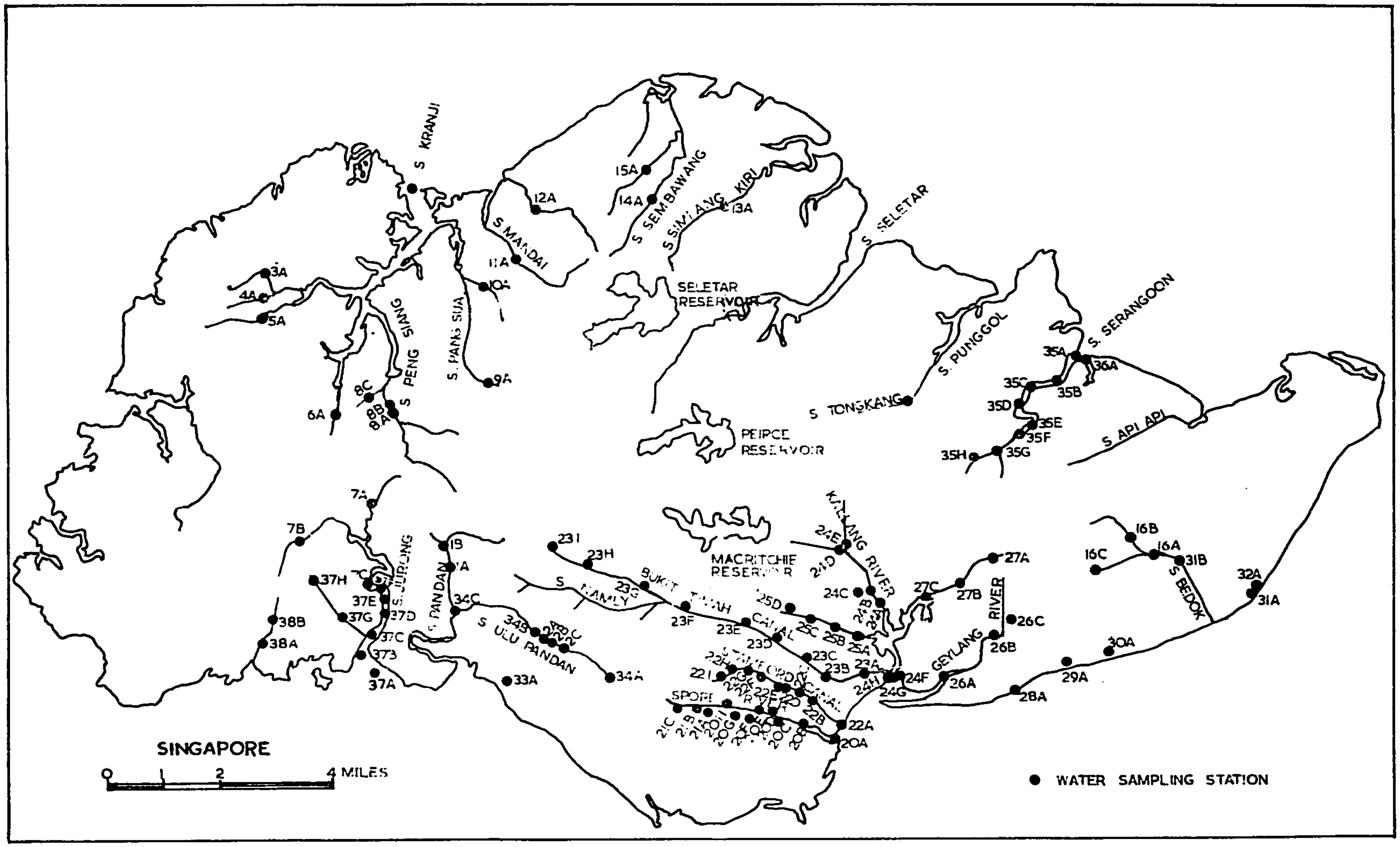

Fig. 9. Water Sampling Network

STREAM	STATION NO	1966 1968 1970 1972	REMARKS
S PANDAN	1A		WATER SAMPLE COLLECTED AT LEAST ONCE A MONTH BY THE WATER DEPT
	1B		- DO -
S ULU PANDAN	2A		- DO -
	2B		- DO -
	2C		- DO -
S SIMPANG MAK WAI (NORTH)	3A		- DO -
S SIMPANG MAK WAI (SOUTH)	4A		- DO -
S KANGKAR	5A		- DO -
S TENGAH	6A		- DO -
S JURONG	7A		- DO -
	7B		- DO -
	7C		- DO -
S. PENG SIANG	8A		- DO -
	8B		- DO -
	8C		- DO -
S PANG SUA	9A		- DO -
S. BUKIT MANDAI	10A		- DO -
S MANDAI	11A		- DO -
S MANDAI KECHIL	12A		- DO -
S SIMPANG KIRI	13A		- DO -
S SEMBAWANG	14A		- DO -
S SEMBAWANG	15A		- DO -
S. BEDOK	16A		- DO -
	16B		- DO -
	16C		- DO -
S PANG SUA CASCADE AT SELETAR RESERVOIR	17A		WEEKLY CHEMICAL RESULTS AND MONTHLY BACTERIOLOGICAL RESULTS (WATER DEPT)
S MANDAI CASCADE AT SELETAR RESERVOIR	18A		- DO -
S SEMBAWANG CASCADE AT SELETAR RESERVOIR	19A		- DO -
SINGAPORE RIVER	20A-20H		WATER SAMPLES COLLECTED ONCE A MONTH AT EACH STATION BY THE MINISTRY OF HEALTH.
ALEXANDRA CANAL	21A 21B 21C		- DO -
STAMFORD CANAL	22A-22I		- DO -
ROCHORE CANAL AND BUKIT TIMAH CANAL	23A-23I		- DO -
KALLANG RIVER	24A-24H		- DO -
S WHAMPOA	25A-25D		- DO -
GEYLANG RIVER	26A-26C		- DO -
PELTON CANAL	27A-27C		- DO -
HAIG ROAD OUTLET DRAIN	28A		- DO -
SIGLAP CANAL	29A		- DO -
OPERA ESTATE OUTLET DRAIN	30A		- DO -
S BEDOK	31A 31B		- DO -
S KETAPANG	32A		- DO -
S PANDAN KECHIL	33A		- DO -
S ULU PANDAN	34A-34C		- DO -
SERANGOON RIVER	35A-35H		- DO -
S BULVAR	36A		- DO -
JURONG RIVER	37A-37H		- DO -
JURONG RIVER (WEST)	38A 38B		- DO -

CHEMICAL ANALYSIS
BACTERIOLOGICAL ANALYSIS
CHEMICAL AND BACTERIOLOGICAL ANALYSES

Fig. 10. Water Quality Data

measure the temperature of the reservoir at different depths.

INTERNATIONAL HYDROLOGICAL DECADE

Singapore participates in the International Hydrological Decade (1965 – 1974) organized by the United Nations. The activities of the Singapore participation are coordinated by the National Committee for the International Hydrological Decade with committee members from the Public Works Department, the Water Department and the Meteorological Service. The activities may be referred to the report [6] presented to the Regional Meeting of the Asian National Committees for the International Hydrological Decade in Bangkok in October 1970. The programme of the activities consists of 4 projects : (1) Decade Stations, (2) Global Water Balance, (3) Depth-Duration-Frequency Relations of Precipitation, and (4) Experimental and Representative Basins.

SOME REPORTS AND PUBLICATIONS

On various aspects of rainfall in Singapore, Watts made a comprehensive study and presented an excellent paper in 1955 [33]. However, due to short length and lack of rainfall data, some points studied could not be conclusive. For example, the areal distribution of monthly and annual rainfalls over the Singapore Island could not be estimated and this study was carried out in 1967 by the ECAFE Water Resources Consulting Group [13].

On the rainfall depth-duration-frequency relations as important information for drainage works, Taylor made the first study in 1933 [29] and Chow and Chang made a revision in 1968 based on all the pluviometer records available up to December 1967 [11]. Chang made a study on the temporal pattern of design storms for Singapore in 1969 [5].

In 1965, the Meteorological Service published a report [19] which includes the summary of monthly and annual rainfalls for records up to 1964, isohyetal maps for monthly and annual mean rainfalls, number of rainy days for each month and the year, and the highest rainfall depth recorded at different durations from 15 minutes to 96 hours. The Meteorological Service also publishes monthly the summary of rainfall and meteorological data collected each month [18].

With regard to the programme and organization of the hydrological works in Singapore, the ECAFE Water Resources Consulting Group put up a report in 1967 [13] which examined the existing network and recommended the type of organization to maintain the existing network and to implement the new work. The report has suggested that the hydrological works be undertaken by a single authority.

Another two topics which may be of interest are the record floods of 10th December 1969 and the cloud seeding project undertaken in 1963. The relevant reports on these two topics may be referred to [23], [17], [9], [10] and [28] in the reference list.

Some other valuable articles which either have been published or unpublished are included in the reference list. This list is by no means complete.

EDUCATION AND TRAINING

At the moment, there is no hydrological training facility in Singapore and hydrologists are trained overseas. However, the sub-professional staff engaged in hydrological works are trained departmentally by hydrologists. The Public Works Department conducts a hydrology course for their own technicians and the Singapore Polytechnic also includes hydrology as a subject in their technician certificate course.

CONCLUSIONS

Hydrology is the backbone of water resources development and water management. Its importtance need not be emphasized. In Singapore, besides the rainfall network being more satisfactory, other data collection especially streamflow data is insufficient and some even non-existent. It is highly desirable that the data collection be carried out as soon as possible.

The situation of the hydrological works in Singapore is the same as that mentioned in the Regional Meeting for the Asian National Committees for the International Hydrological Decade [30] :

"The meeting noted that, in most developing countries, requests for aid for hydrology projects receive a low priority from Governments in formulating their overall requests for aid. The low priority given by Governments to hydrology projects probably stems from a general lack of appreciation and understanding by the population of water problems. It was agreed that there was no short-term solution to this problem, but that the position would be improved in the long-term by the inclusion in primary and secondary school, syllabi of material on hydrology and water resources investigations and management ".

Singapore is limited in both land area and water resources. The problems of drainage, flood alleviation and water supply should be carefully studied in conjunction with land development which tremendously affect both water quantity and quality. Hydrological data are required for these studies. Thus, the most urgent task now in the hydrological works will be the setting up of a hydrologic network which shall include establishment of hydrometric stations, collection of water samples for chemical and bacteriological tests and for sediment analyses.

Singapore is virtually a metropolitan city and the hydrological works if fully implemented will no doubt make a valuable contribution towards urban hydrology in this part of the world.

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THE REUSE OF SEWAGE EFFLUENT FOR INDUSTRIAL PURPOSES IN SINGAPORE

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ABSTRACT

The paper deals in some detail with the short history of the reuse of sewage effluent for industrial purposes in Singapore. It discusses briefly the general methods available for the tertiary and advanced methods of treatment of sewage effluents.

It then deals in greater detail with the Industrial Water Works at the Jurong Industrial Estate and discusses the uses to which the water is put. It also touches on the distribution system, the problems encountered, the steps taken to overcome them including plans for improvement and plans for the future.

The discussions are supplemented with line diagrams, mapsand some appendices.

INTRODUCTION

The reuse of sewage effluent in Singapore has been practised since the first treatment works, the Alexandra Road Sewage Disposal Works, was established in 1915. The final effluent from the Works was, as it is still today in the other works, used for multiple purposes such as the cleaning of tanks, watering of plants and cooling of engines.

In all these purposes no further treatment was applied to the effluent and it was as it is now used only once i.e. it is not re-circulated. The need to reuse the effluent for other than the above purposes did not arise principally because water consumption was low and the potable water supply available was sufficient to meet the demands of both domestic and industrial users.

However, in the early sixties the planning of an industrialization programme for Singapore necessitated the planning and enlargement of water resources to meet this demand for water. In cataloguing the types of water resources available the reuse of sewage effluent was given due consideration as a potential source of readily available water.

HISTORICAL BACKGROUND

There are at present two large sewage treatment works in Singapore, the Kim Chuan Sewage Treatment Works and the Ulu Pandan Sewage Treatment Works, and together they discharge some 50 mgd of final effluent into the Serangoon and Jurong rivers respectively. These effluents are of a high standard, complying with the Royal Commission Standard of 20 mg/l BOD and 30 mg/l suspended solids, and are the end products of the activated sludge treatment process employed by both Works.

In 1963 when the Jurong Industrial Estate was in its early stages of development the idea of using the final effluent from the Ulu Pandan Sewage Treatment Works for industrial purposes was considered by the Economic Development Board as a supplementary supply of industrial water for the Estate. As a result of this, experts from ECAFE were asked to look into the matter and submit a report on the feasibility of such a scheme.

The ECAFE experts submitted their report in 1964 and the salient points of their investigations were:

(1) Potable water for domestic and industrial use in the Jurong Industrial Estate could only be supplied by the Water Department of the Public Utilities Board.

(2) The water requirements for industrial water should be supplied in two stages. The first stage should supply the immediate water requirements by applying a minimum treatment (rapid filtration and chlorination) to the final sewage effluent from the Ulu Pandan Sewage Treatment Works which was discharging about 10 mgd in 1964.

(3) The second stage which will supply an additional 6 mgd will utilize the Jurong River as the source of industrial water supply. In the operation of the second stage, the sewage effluent could be mixed with the Jurong River water and the mixture could then be treated for industrial use. Any further increase in the demand for industrial water could be met from the expected increase in the yield of the Ulu Pandan Sewage Treatment Works.

(4) It was reported at that time that the quality of the Jurong River water was very poor because of its high salinity, acidity and iron and sulphate content. It was therefore not recommended that it be used till the river bed was leached off the salt and other toxic materials.

It was estimated at that time that by 1965 the water requirements of the Estate would be as follows:

Potable water for domestic purposes	0.32 mgd
Potable water for industrial uses	5.64 mgd
and industrial water	5.16 mgd

and that 10 to 15 years from then the demand will rise to about:

10.0 mgd for domestic purposes	potable quality
13.1 mgd for industrial use	
14.3 mgd for industrial water	

THE JURONG INDUSTRIAL WATER WORKS

As a result of the ECAFE findings, it was decided to set up an industrial water treatment plant at the Jurong Industrial Estate to further treat the final effluent discharged by the Ulu Pandan Sewage Treatment Works for use as industrial water. The site chosen was very close to the Jurong River to enable easy tapping of the final effluent from Ulu Pandan Sewage Treatment Works which is discharged into the Jurong River by means of dispersion effluent outfall fingers. The location of the Works and the distribution system in relation to the industries served (shown shaded) are shown in Fig. 1.

The Works stands on a 4-acre site, but additional land (10 acres) is available should it become necessary to expand the works. It was originally designed to produce 10 mgd of industrial water, provision having been made to double this capacity when required. The capital cost of the Works inclusive of land was S$5.6million and the Works was commissioned in mid–1966.

THE DESCRIPTION AND MODE OF OPERATION OF THE WORKS

The general layout of the Works is shown schematically in Fig. 2 and in section in Fig. 3. The Works comprises the following units:

(1) the intake chambers
(2) the low lift pump house
(3) the bank of gravity filters, the aerator, the filtered water tank cum pump well, the high lift pump house which also houses the administration office, store, laboratory and chlorine room.

The treated water is piped away to a 5 mgd covered concrete storage reservoir and is distributed by 10 miles of A.C. industrial water mains to the industries.

The Intake Chamber

This is built over the 72-inch diameter effluent

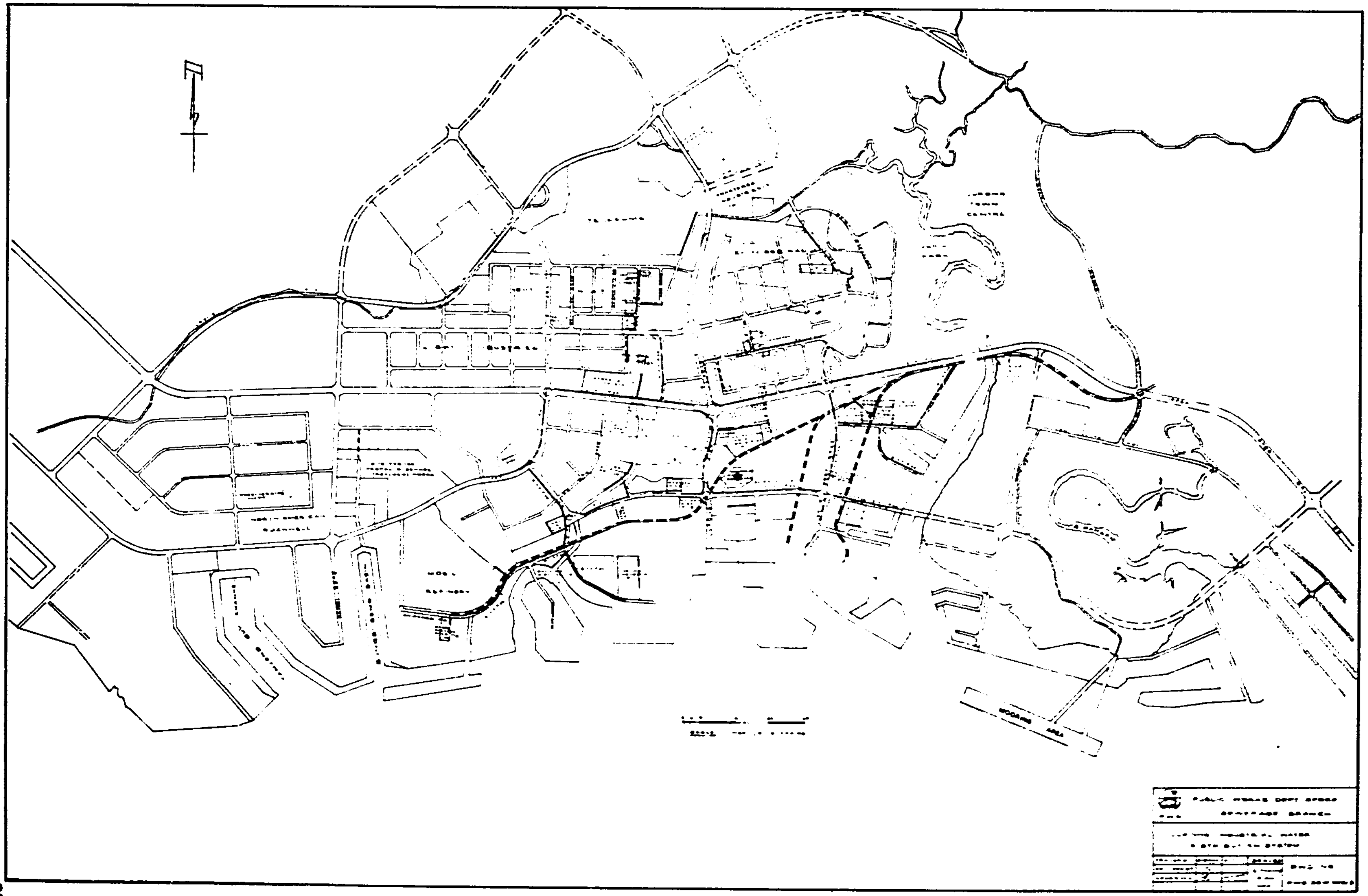

Fig. 1. Jurong Industrial Water Distribution System

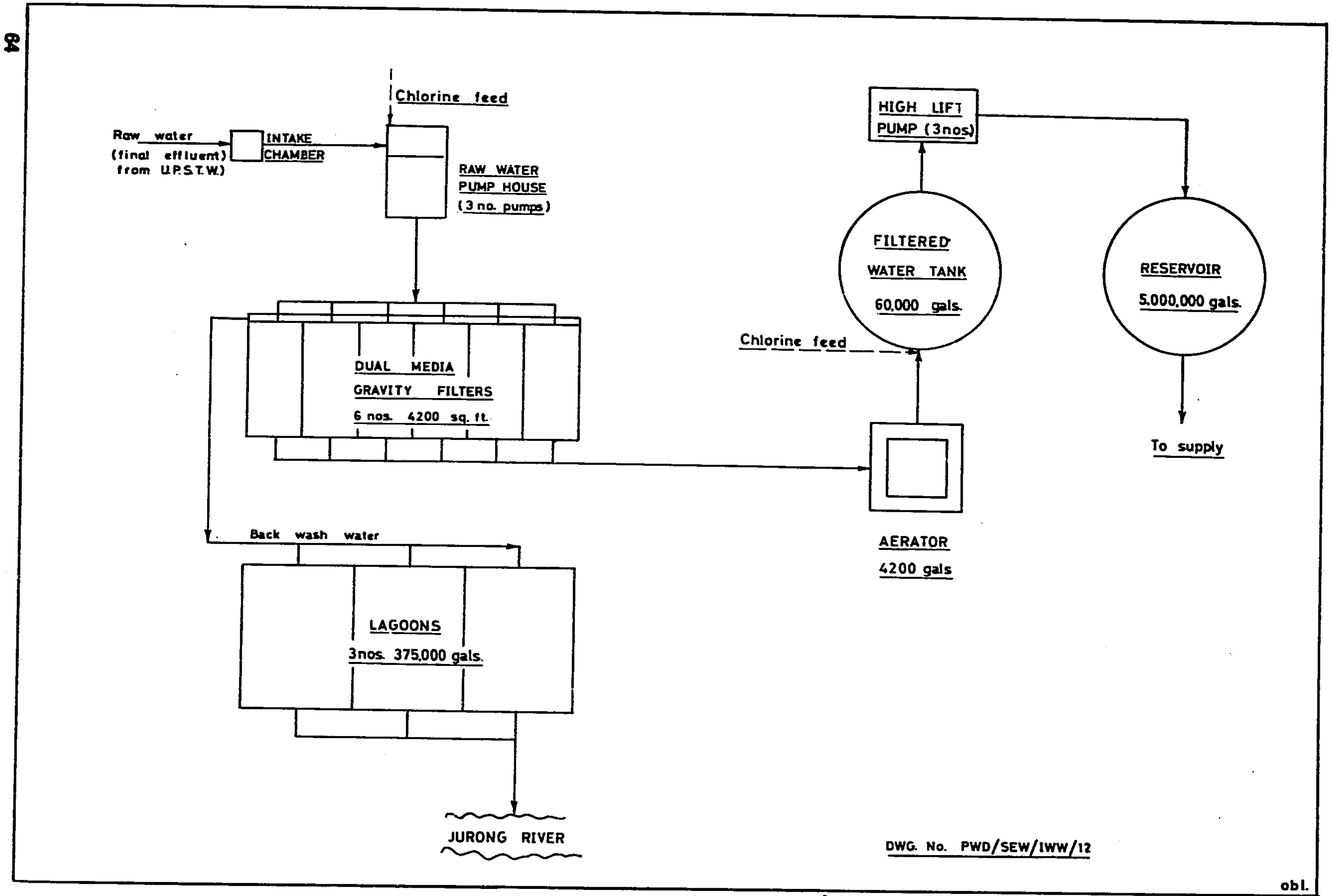

Fig. 2. Jurong Industrial Water Works

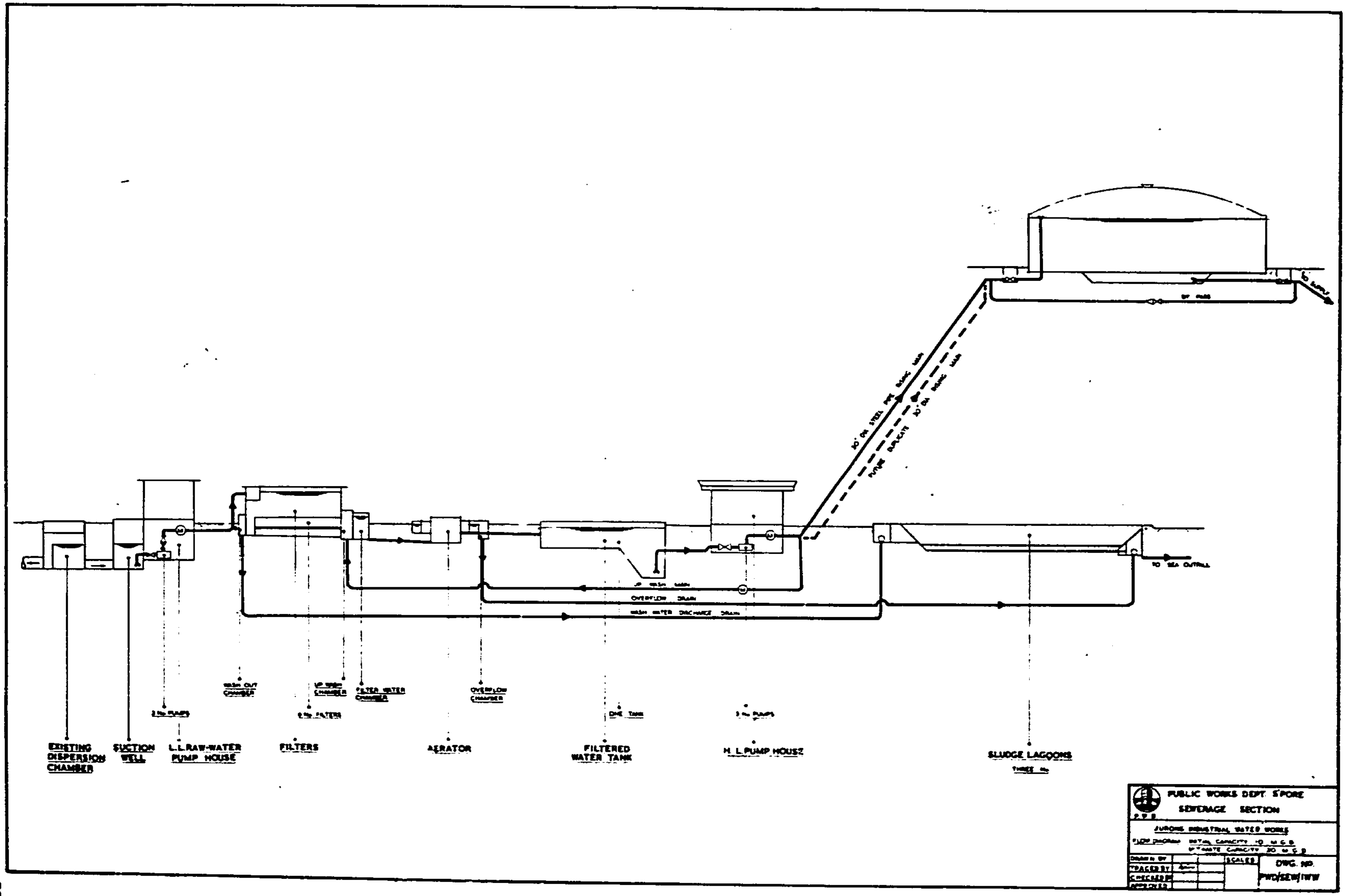

Fig. 3. Jurong Industrial Water Works – Flow Diagram

outfall sewer and by-passes part of the effluent to a 30-inch diameter concrete pipe which conveys the "raw" water to the head of the Works. Screens are incorporated and remove flotsam, etc. in the raw water. Regular removal of screenings are carried out daily and spray-lines suppress foaming in the chamber.

The Low Lift Pump House

This is a concrete-framed building and the raw water is discharged from the delivery pipe into a sump annexed to the main structure. Screens are incorporated to further remove any flotsam which are not removed in the intake chamber. Pre-chlorination of the raw water is introduced after the screens and about 3 ppm of chlorine is dosed. The raw water is pumped to a bank of six-filters by horizontal centrifugal pumps. Each pump has a rated capacity of 3500 gpm at 750 rpm delivering against a head of 30 ft and is powered by a 45 hp electric motor. Normally 2 pumps are used but at times, it becomes necessary to run 3 pumps.

Filter Beds

There are altogether 6 filter beds each having an area of 698 sq ft rated at 100 gall/sq ft /hour. The filter beds consist of 12 ins each of coarse sand (mesh 7–14) as a bottom layer, fine sand (mesh 14–25) as an intermediate layer and anthracite (mesh 7–14) as the top layer. The pre-chlorinated raw water is fed to the filters by a 24-inch diameter rising main which discharges into a common channel above the filter beds. Distribution to each bed is effected by penstocks and drop pipes. Incorporated in the filters are back-washing facilities including air scouring.

Normally 5 filters are in use so that about 400,000 gallons of water is filtered per hour. The filters are back-washed on alternate days, i.e. 3 out of 6 filters are back-washed daily. Under present operating conditions, it is possible to load the filters at the rate of 2 g/sq ft/min. The filtered water is channelled to an aerator.

The Aerator

This is a concrete tank with 2 sets of weir walls. The filtered water enters the aerator in the centre and cascades over the weirs. In so doing the water is aerated and some improvement to the water can be observed. Post-chlorination is applied to the water after the aeration process and about 5 ppm of chlorine is applied.

The Filtered Water Tank

This collects the water after passing through the aerator and acts as a sump for the high lift pumps. It is a circular concrete tank having a capacity of 60,000 gallons.

The High Lift Pump House

This is a concrete-framed structure and houses the high lift pumps, stores, laboratory administration offices and chlorine room. There are 3 horizontal centrifugal pumps each having a capacity of 3,500 gpm rated at 1,460 rpm against a head of 160 ft and driven by 220 hp electric motors. These pumps deliver the treated water through a 30-inch diameter steel rising main to a covered concrete reservoir situated on a hill 90 ft above mean sea level off Jalan Buroh. An air blower for air scouring of the filters is also located in the pump house. A meter panel indicates the raw and treated water flow rate and also the level of the reservoir.

The chlorine room has a partition wall which separates the liquid chlorine drums from the chlorinators. Two chlorinators, one of the Paterson Candy and the other of the Chlorination Equipment type provide the necessary equipment for the pre and post chlorination of the effluent, about 25 lbs/hr of liquid chlorine is used in both processes, this amounts to about 7,000 lbs per month.

The laboratory is very small but will shortly be expanded in order to carry out the range of analysis necessary for the quality control of the treated water.

THE DISTRIBUTION SYSTEM

This comprises an industrial water reservoir and some 10 miles of pipline varying in size from 6-inch diameter to 21-inch diameter A.C. pipes. The reservoir is situated on a hill and has a capacity of 5 m.g. Water from it is fed to the distribution network by gravity and at the moment some 34 factories are making use of the water. The total daily consumption is about 3 m.g. Fig. 1 shows the position of the Industrial Water Works and the industries served by it.

THE INDUSTRIAL WATER

As explained earlier the industrial water produced is basically the final sewage effluent from Ulu Pandan Sewage Treatment Works which has been further treated by filtration and chlorination. The average quality of the water is as set out in Table I. Altogether 34 industries are using industrial water for cooling or in their manufacturing processes. Table II shows the list of industries using industrial water and the types of use the water is put to.

It is unfortunate that due to the high concentration of ammonia and total dissolved solids (mainly chlorides) in the raw water the end-product still has high concentrations of these. Because of this scaling and corrosion of the heat exchangers and pipe work of cooling systems have arisen. Although the water is chlorinated, it is difficult to achieve effective killing of bacterial life as the high ammonia concentration exerts a great chlorine demand. Resulting from this, the formation of bacteria slime in pipework, etc. is not uncommon after prolonged use of industrial water.

The quality of the water produced, apart from the items stated above, is generally acceptable for use in rough washing processes, the manufacture of coloured paper and for cooling purposes. It should be stressed that should a better quality water be required, it would be more economical if further treatment be given at the consumer's end. This would in most cases be mainly demineralisation and possibly colour removal. The tariffs for industrial water is relatively cheap compared to potable water for industrial uses so that even with the incorporation of further treatment processes at the consumer's end it would still be cheaper to use industrial water. The current charges for industrial water is set out in Table II and no minimum charge is levied.

Every effort is being made to improve the quality of the water produced. This includes the proposed installation of a much larger Wallace and Teirnan Chlorinator (2,000 lb/24 hrs), the incorporation of more effective screens, the tapping of raw water only when the quality appears to be amenable to further treatment–turbidity and conductivity monitors will be installed in the raw water intake chamber to ensure that only acceptable quality of raw water will be drawn for treatment. It is hope that with the installation of the larger chlorinator bacteria slime growth can be minimised. Steps are being considered to introduce micro-strainers with or without chemical coagulation of the raw water to further improve the quality of the water. It is regrettable that the existing plant is of the packaged type and therefore has limited flexibility. Any improvements to the plant will be limited by the inherent constraints of a package plant.

Industries are still reluctant to use industrial water in their manufaaturing processes. Of some 400 questionnaires sent out asking industrialists whether they would consider using industrial water in place of potable water wherever possible only 150 have so far replied and of these not more than 10% are interested in using industrial water. Reluctance on the part of some industrialists is understandable as no substantial savings will be effected if their water consumption is low. However, for paper manufacturing processes other than white paper, the use of industrial water will be ideal as large quantities of water are required, so also for certain processes in textile manufacture. The water consumption in the Jurong Industrial Estate in 1971 was made up as follows :-

Potable water for domestic purposes	:0.8 mgd
Potable water for industrial purposes	:6.0 mgd
Industrial water	:3.0 mgd

OTHER REUSE OF SEWAGE EFFLUENT

Apart from the Industrial Water Works at Jurong direct reuse of final sewage effluents from both Ulu Pandan Sewage Treatment Works and Kim Chuan Sewage Treatment Works has been practised since the Works were set up. These include the use of the final effluent for cooling engines and blowers in the Works. However, it should be noted that the effluent is used only once through, no recirculation being practised. Effluent is also used for the watering of plants in the Works as well as way-side trees and plants maintained by the Parks and Trees Branch of the Public Works Department, and for general purpose cleaning of tanks, etc. About 200,000 gallons of effluent a day are being directly reused and this figure will increase as demand for potable water increases.

WATER RECLAMATION AND REUSE

The reclamation of water from industrial and

Item	Test	Result	
		Raw water	Treated water
1.	Colour (H.U.)	47	38
2.	$KMnO_4$ - Consumption (4 Hrs.)	10.1	7.3
3.	B O D (5 days 20°C)	15.5	7.8
4.	C O D	110	62
5.	Dissolved Oxygen	3.3	4.4
6.	Free Ammonia (as N)	29.3	23.7
7.	Albuminoid Ammonia (as N)	2.7	0.7
8.	Nitrite Nitrogen (as N)	1.1	3.0
9.	Nitrate Nitrogen (as N)	0.1	0.1
10.	pH-Value	7.2	7.0
11.	Total Residual Chlorine Reservoir	–	0.87
12.	Free Residual Chlorine Reservoir	–	0.36
13.	Total Residual Chlorine C.W.T.	–	1.29
14.	Suspended Solids	21	4
15.	Total Solids	903	847
16.	Chlorine (as Cl)	388	383
17.	Total Hardness (as $CaCO_3$)	147	139
18.	Sulphates (as SO_4)	102	89
19.	Iron (as Fe)	0.05	Not detected

Table I(a) Average Results of Analysis of Industrial Water for 1971

(Results of analysis are expressed in milligrams per litre unless otherwise stated)

Sampling Points	Free Residual Chlorine (ppm)	Total Residual Chlorine (ppm)	Total Colony Counts (per ml at 37°C in 48hr)	Presumptive Coliform Test	Faecal Coliform Test
(Raw water) By-pass Chamber	–	–	162.3×10^6	10^{-7}	10^{-4}
(Pre-chlorination) Low Lift Sump	0.52	1.20	$12,500 \times 10^6$	10^{-6}	10^{-3}
Filter Inlet Channel	0.37	0.97	25×10^6	10^{-5}	10^{-2}
Aerator	0.11	0.26	500×10^6	10^{-6}	10^{-3}
(Post-chlorination) Clear Water Tank	0.40	1.29	80,300	10^{-2}	10^{-1}
Reservoir	0.36	0.87	97,400	10^{-1}	+ 10 ml
(Consumer) Singapore Polymer	0.08	0.20	80,300	10^{-2}	+ 10 ml
(Consumer) Unitex	0.10	0.23	83,600	10^{-1}	+ 10 ml

Table I(b) Average Results of Chlorine and Bacteriological Analysis

TARIFFS:

1st 300,000 gallons/month	70cts/1,000 gallons
Next 3 million gallons/month	50cts/1,000 gallons
Next 5 million gallons/month	40cts/1,000 gallons
Next 14 million gallons/month	30cts/1,000 gallons
In excess of 22.3 million gallons/month	20cts/1,000 gallons

	Name of Industry	Type of Industry	Uses of Industrial Water
1.	Acma Electrical Ind. Ltd.	electrical	cooling compressor
2.	Adler Cosmetic Ltd.	soap	cooling of ploughing and drying M/cs.
3.	Aluminium Pioneer Ltd.	aluminium sheet	cooling extruder
4.	Associated Motor Ind. Ltd.	rubber products	cooling machines
5.	Biau Sim Paper Industries	paper	making paper
6.	Dah Yung Steel Co. (S) Ltd.	steel works	cooling of acetylene generator
7.	Dunlop Sdn. Bhd.	mattress	cooling of moulds, washing of products
8.	East Asiatic Co. Ltd.	scooter assembly	cooling machines
9.	Eastern Wire Co. Ltd.	wire	cooling machines
10.	Eupoc Pulp & Paper	paper	making paper (ceased production)
11.	General Electric Appliance Co.	electric	cooling heat exchangers
12.	Hon Mun Feather Works	feather works	washing of feathers
13.	Hop Lion Feather Works	feather works	absorption of bad odour gas in scrubbing tower
14.	Hong Kong Dyeing & Weaving Ltd.	textile	boiler, cooling, dyeing and washing
15.	Jurong Industries	detinning & calcium compounds	cleaning & processing detinning section
16.	Lea Hin Lamp & Stove Ltd.	lantern & Stove	rinsing of finished electro-plated products
17.	Malaysia Steel Pipes Manuf.	steel pipes	washing finished products and metal pickling
18.	Min Ngai Knitting	textile	dyeing, bleaching & scouring
19.	National Tile Manuf. Ltd.	tiles	cooling and grinding
20.	New Continent Enterprises	rubber	washing of raw rubber
21.	Power Foam	mattress foam	washing of raw rubber
22.	Singapore Nissan Motors	car-assembly	cooling & washing
23.	Singapore Textiles Industries	textile	dyeing, bleaching, washing, etc.
24.	Singapore Polymer	PVC. polymers	cooling
25.	Sinpak Marble Industries	marble	grinding process
26.	Tenyru (S) Pte. Ltd.	watch casing	cooling machines
27.	Toho Rubber Processing Co. (Pte) Ltd.	rubber works	washing raw rubber
28.	United Eastern Co. Ltd.	rubber products	washing raw rubber
29.	United Pulp & Paper Co. Ltd.	paper	making paper
30.	Unitex (M) Ltd.	textile	washing, dyeing & cooling
31.	Yamatai Plastics Industries	plastic	cooling of extruder
32.	Chemical Industries	manufacture of chlorine and other by-products	process cooling
33.	Printcraft Pte. Ltd.	textile pattern printing	process cooling
34.	Jurong Bird Park	park	watering of plants and cleaning purposes
35.	Polynit Pte. Ltd.	garment manufacture	dyeing process
36.	Caltex Service Stn.	servicing of cars	car-washing & general cleaning

Table II. Tariffs for Industrial Water and Industries Using Industrial Water sewage effluents for reuse is a possibility and in the not too distant future a necessity. The degree to which the water reclaimed should be treated is dependent on the nature of its reuse, the ultimate being as a direct source of potable water. The most expensive unit process in the reclamation of effluents is the removal of dissolved solids from the water. The concentration of dissolved solids increases with each cycle of reuse. Several methods for the removal of salts are currently available viz. desalination, reverse osmosis and electro-dialysis to name a few among the better known ones. All these processes require energy and are therefore expensive to operate. So far only small pilot plants using these processes have been established and it will take some time before very large scale plants employing these methods will ultimately be common place.

As the level of ammonia in the final effluents of the existing treatment Works is high, up to 30 mg/l, ammonia stripping will be necessary if corrosiveness of the water is to be minimised. With the demand for potable water increasing by leaps and bounds with each passing year, the reuse of sewage effluent on a larger scale employing advanced waste treatment techniques will become both a reality and a necessity in the very near future.

CONCLUSION

The reuse of sewage effluent for cooling, cleaning and other general purposes has been practised since the establishment of the Alexandra Road Sewage Disposal Works and this is still the case with the effluent from the Ulu Pandan Sewage Treatment Works and Kim Chuan Sewage Treatment Works.

With the establishment of the Jurong Industrial Estate, an Industrial Water Works was set up to further treat the final effluent from the Ulu Pandan Sewage Treatment Works for reuse as industrial water. The unit processes employed are filtration and chlorination. About 3 mgd of industrial water is used daily by some 34 industries. Response to the request to use more industrial water in place of potable water, wherever applicable, has been disappointing. With the demand for potable water on the increase with each passing year, there is a real need to resort to the reuse of sewage effluent on a wider scale. Advanced waste treatment techniques for the reclamation of water from sewage and industrial effluents have progressed sufficiently to make the reuse of these sources of raw water both technically feasible and in due course economically practical. The degree of treatment required is dependent on the type of reuse envisaged.

ACKNOWLEDGMENT

The author wishes to express his gratitude to the Director of Public Works, Mr. Hiew Siew Nam, for permission to present this paper and to the Senior Executive Engineer, Sewage Branch, Mr. L. D. J. Chelliah, for his encouragement in the writing of this paper. I would also like to thank the staff of the Sewage Branch for all the help rendered.

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Paper No. I/6

SOME FACTORS AFFECTING THE ANNUAL RAINFALL OF SINGAPORE

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ABSTRACT

The first part of the paper utilises continuous rainfall records for 96 years from two close together rainfall stations on Singapore Island to (1) show the relationship between the current year's annual rainfall and the following year's annual rainfall, (2) plot the 10-year unning mean annual rainfall to determine if any definite trend in the annual rainfall for Singapore existed.

The second part of the paper consists of a brief study of the relationship between exceptionally heavy rain spells during the first half of the Northeast Monsoon and spells of dry weather conditons in the later half of the same monsoon season over Singapore.

A diagram has been constructed which attempts to provide guidance on the estimation of total rainfall for May - September from the total rainfall for January – April the same year.

LONG-TERM RAINFALL DATA OF SINGAPORE

Although rainfall data for one or two stations on Singapore Main Island were available as far back as 1835, continuous rainfall records from one station from that date were not available. It was therefore decided to examine data from stations with continuous records for longest available periods. The two selected stations, whose combined records totalled 96 years sit e sited about 3 miles apart. They were:-

Name and Location of Station	Period of Records	Mean Annual Rainfall
(a) Kandang Kerbau Hospital	1875–1928 (54 years)	96.15 ins
(b) MacRitchie Reservoir	1929–1970 (42 years)	95.55 ins
Kandang Kerbau Hospital & MacRitchie Reservoir	1875–1970 (96years)	95.85 ins

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As the difference in the mean annual rainfalls for Kandang Kerbau Hospital and MacRitchie Reservoir was less than 1% of the mean annual rainfall for the 96-year period obtained by a combination of the records for these two stations, it was considered that these records may be combined without serious error. This assumption was supported by the isohyets of mean annual rainfall (Fig.1) compiled from checked records for the 10-year period 1961 to 1970 for 20 stations on the Island. The isohyets indicated that MacRitchie Reservoir and Kandang Kerbau Hospital were situated in an area of fairly slack rainfall gradient.

The total rainfall for each year from 1875 to 1970 for the above two stations were plotted relative to the mean annual rainfall for the 96-year period in Fig. 2. A superficial examination of these plots show that:-

(1) An exceptionally dry year, i.e., with rainfall equal to or more than 20% below average was not followed by another year which was also exceptionally dry;

(2) An exceptionally wet year, i.e., with rainfall equal to or more than 20% above average was often followed by a year with rainfall below average. There were 2 occasions in the 14 exceptionally wet years, when rainfall in the following year was above average but did not reach the 20% above average mark.

In order to illustrate these two points more clearly, a diagram (Fig. 3) was constructed by plotting the current year's rainfall against the following year's rainfall and drawing the enveloping curve.

Points A and B on the enveloping curve were selected so that their values along the X-axis were 77 ins (20% below average annual rainfall) and 115 ins (20% above average annual rainfall) respectively.

The diagram in Fig. 3 indicated that if the rainfall for any one year was 77 ins or less, the rainfall for the following year would be 81 ins or more up to a limit of about 123 ins. Also, if the rainfall for any one year was 115 ins or more, the rainfall for the following year would be less than 107 ins with a lower limit of 63 ins.

Fig. 4 gives plots of the 10-year running mean annual rainfall for the period 1875 to 1970 using rainfall data for Kandang Kerbau Hospital (1875 to 1928) and MacRitchie Reservoir (1929 to 1970). The plots appear to indicate the existence of long-period fluctuations in the annual rainfall. The well-defined dip in the curve from about 1955 to 1965 which indicates a downward trend is of interest as it may represent part of the natural long-period oscillations or an indication of a change related to accelerated topographic modifications and urbanisation of Singapore in the years following the last World War. This can only be ascertained when rainfall data for future years become available.

DRY SPELLS IN SINGAPORE

The synoptic charts and rainfall records for Singapore and rainfall records from meteorolgical stations near Singapore appear to indicate that severe Northeast Monsoon storms that brought spells of exceptionally heavy rain to the east coast of West Malaysia, Singapore or the coastal areas of Sarawak in East Malaysia were frequently followed by dry conditions at Singapore during suceeding months.

Rainfall records for Mersing, Kuching and three rainfall stations at Changi Airfield, Tengah Airfield and MacRitchie Reservoir on Singapore Island for the 23-year period 1949 to 1971 were examined.

Mersing is situated on the east coast of West Malaysia about 60 miles north of Singapore. Kuching is situated on the coast of Sarawak in East Malaysia about 400 miles east of Singapore. The positions of Changi Airfield, Tengah Airfield and MacRitchie Reservoir are given in Fig. 1.

The minimum rainfall for any 30-day period from January to April each year were extracted from the rainfall records for Changi Airfield and listed in Table 1. The Changi rainfall records show that during the 23-year period 1949 to 1971, there were ten occasions when the 30-day minimum rainfall was about 1 inch or less. Rainfall figures for these occasions were underline in Table 1 and designated as "DRY SPELLS".

The rainfall for the months of November and December for Mersing for the years 1949 to 1971 were examined and the highest monthly rainfall for these two months each year compared with the adjusted rainfall for Kuching for the following January each year. The highest monthly rainfall value for November, December and following January each year was then selected and listed in Table 1. The January rainfall for Kuching was adjusted before comparison by multiplying with the factor 0.85 as the average December rainfall for Mersing was lower than the average January rainfall for Kuching by this factor. December was the month with the highest mean monthly rainfall for Mersing and January the month with the highest mean monthly rainfall for Kuching.

The sum total of the rainfall for the Singapore Rainfall Stations at Changi, MacRitchie Reservoir and Tengah for November and December each year were then compared and the highest value listed in

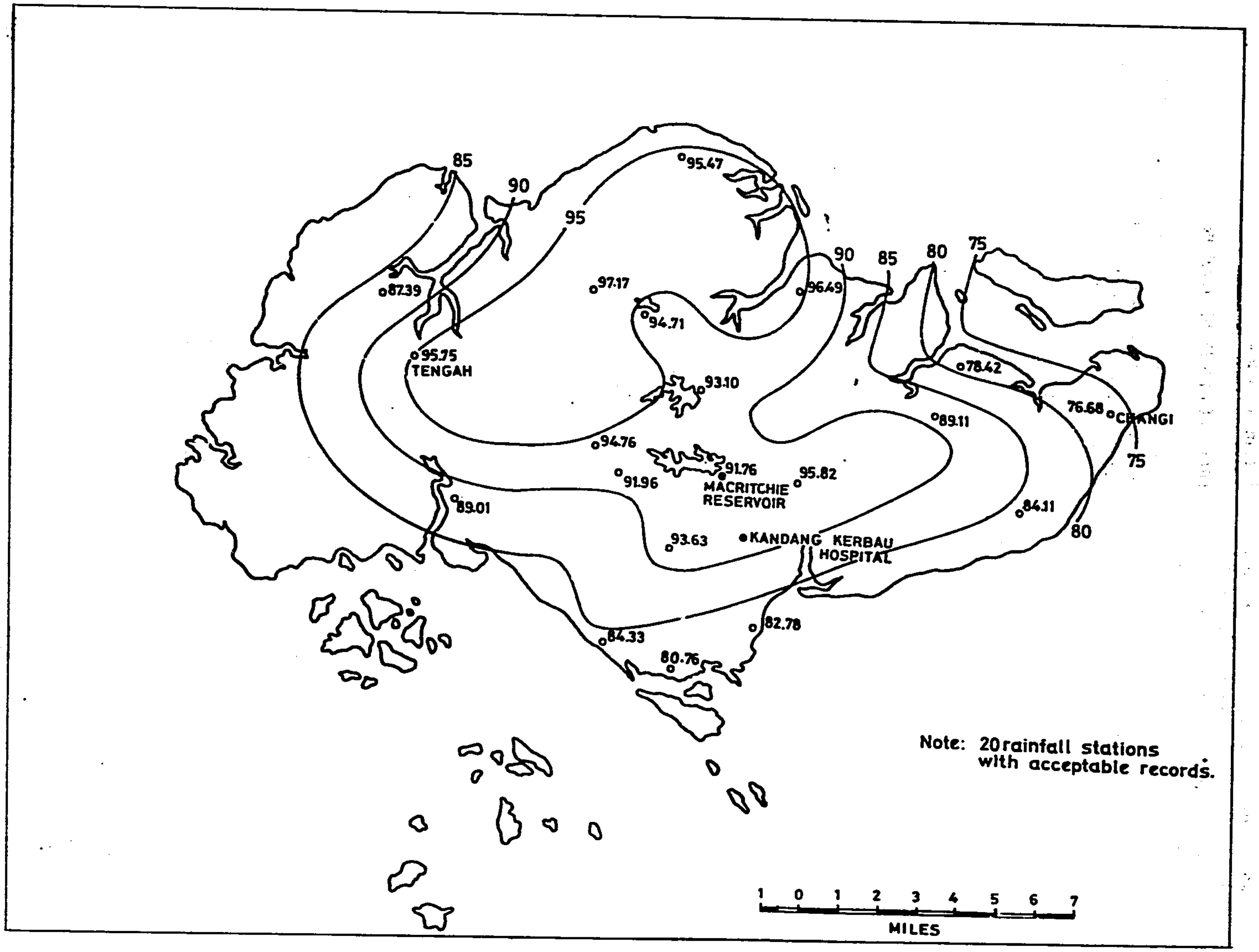

Fig. 1. Mean Annual Rainfall Isohyets (1961 – 1970)

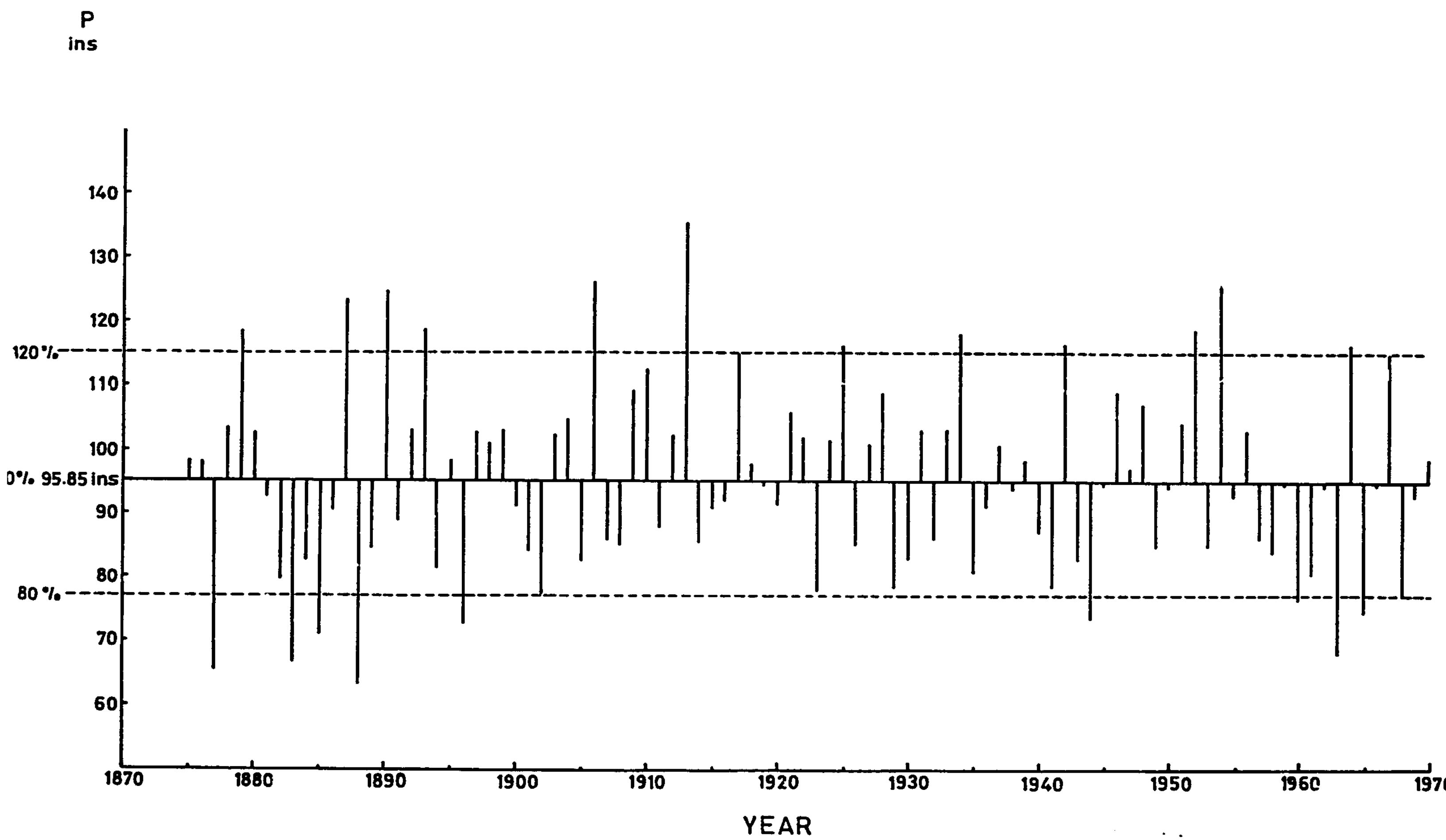

Fig. 2. Annual Rainfall 1875 – 1970 (relative to mean annual rainfall of 95.85 ins.)

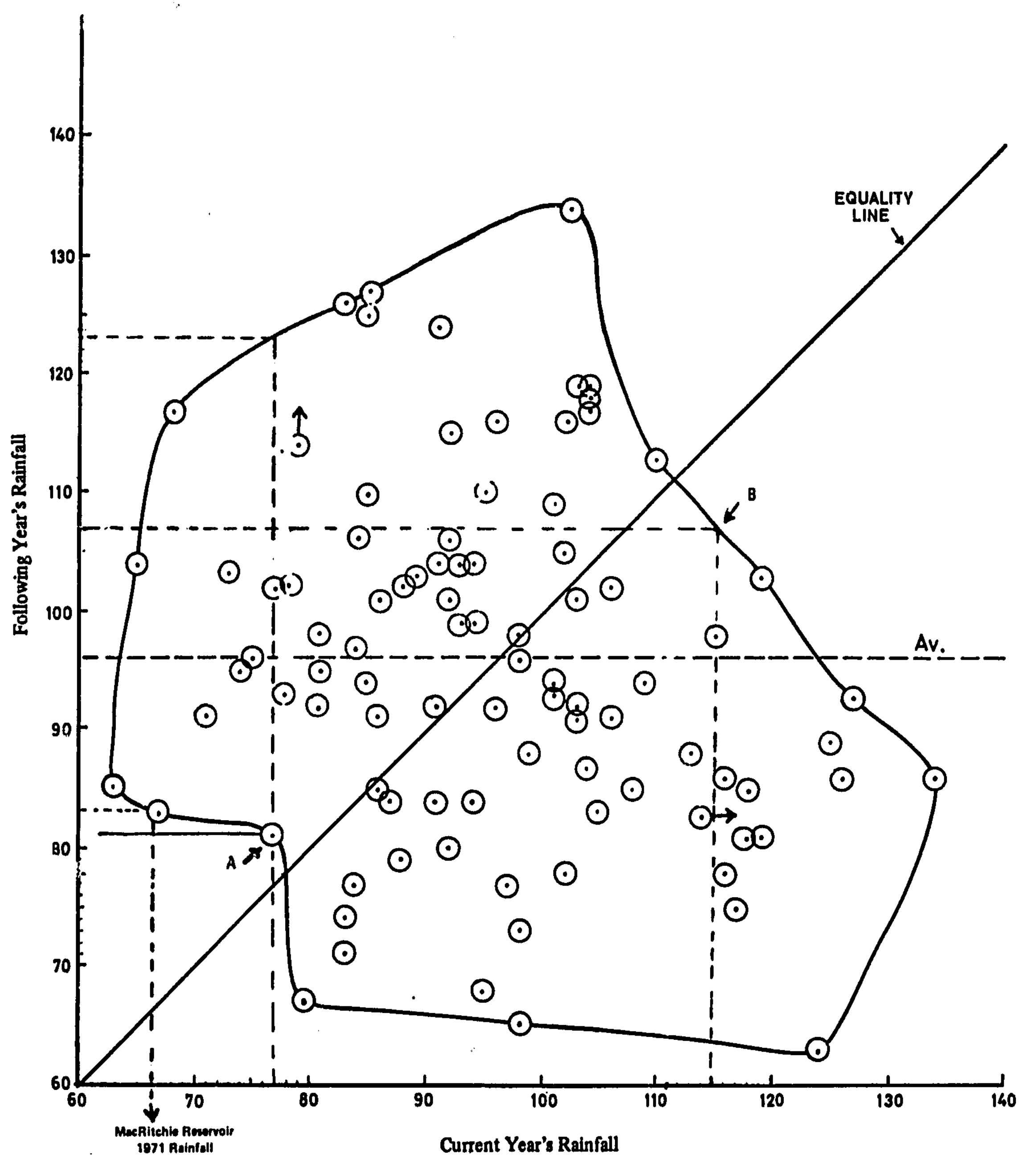

Fig. 3. Projection of Annual Rainfall

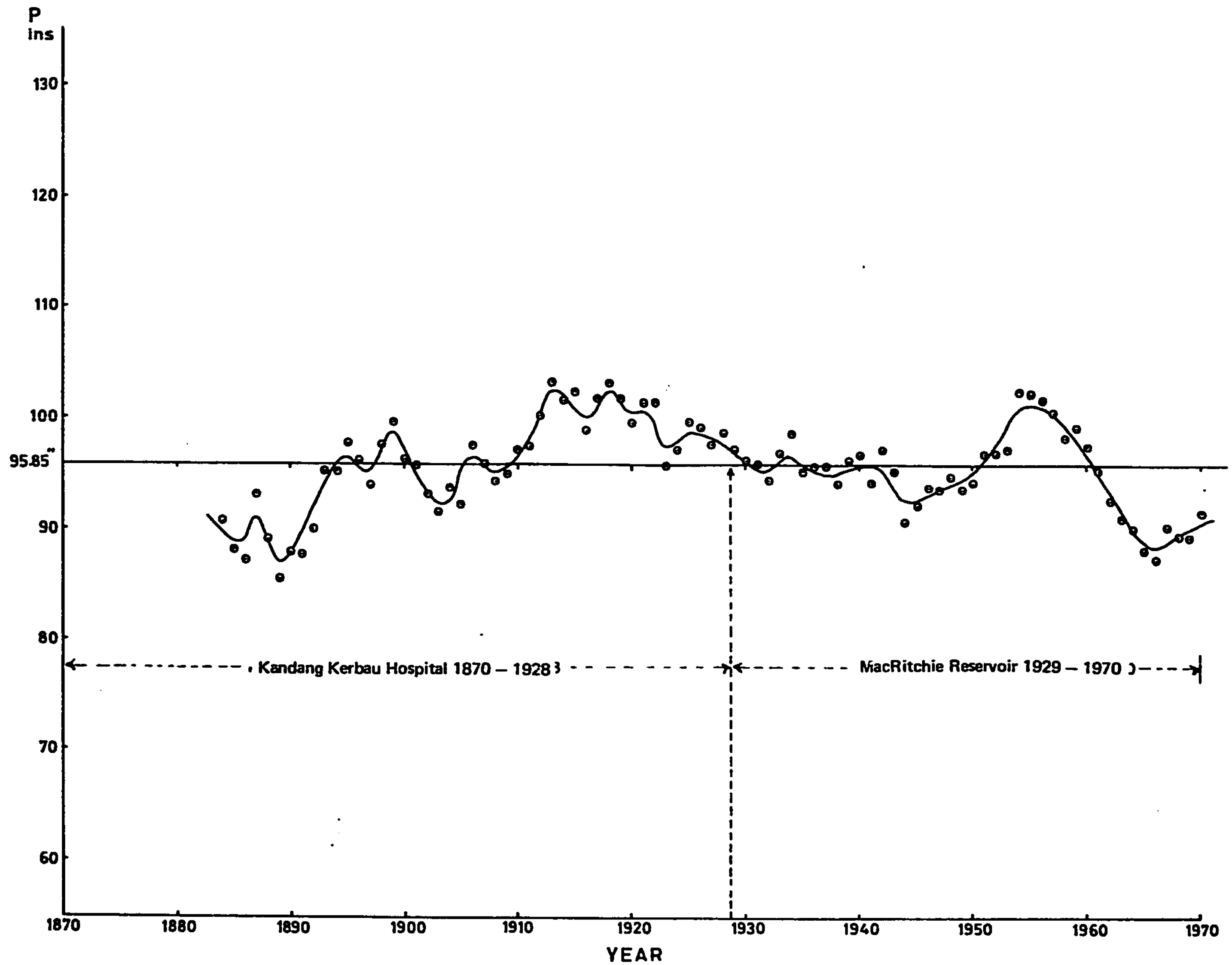

Fig. 4. Running 10-Year Mean Rainfall 1875 – 1970 (96-year mean annual rainfall . . . 95.85 ins.)

YEAR	KUCHING HEAVY RAIN SPELLS * MTH.	RAINFALL INS	MERSING HEAVY RAIN SPELLS MTH.	RAINFALL INS	SINGAPORE HEAVY RAIN SPELLS ** MTH.	RAINFALL INS	SINGAPORE 30-DAY MIN. RAINFALL PERIODS *** DATES	RAINFALL INS	YEAR	REMARKS
1948			DEC	16.5	DEC	38.6			1948	Heavy Rain Spell 43 ins in Nov. 1948 at Kuala Trengganu
1949			DEC	22.1	DEC	35.0	1 MAR 30 MAR	0.64	1949	
1950			DEC	30.1	NOV	38.9	7 MAR 5 APR	5.61	1950	
1951					NOV	31.1	26 FEB 27 MAR	2.91	1951	
1952	JAN	21.0			NOV	29.2	22 FEB 22 MAR	4.15	1952	
1953	JAN	27.8			DEC	21.5	9 MAR 7 APR	5.04	1953	
1954	JAN	13.6			DEC	85.1	28 JAN 26 FEB	1.41	1954	
1955	JAN	36.2	DEC	22.7	DEC	32.0	7 MAR 5 APR	0.46	1955	
1956			NOV	19.1	NOV	56.2	21 FEB 21 MAR	1.20	1956	
1957			DEC	32.7	DEC	43.3	9 JAN 7 FEB	0.87	1957	
1958					NOV	43.7	21 FEB 22 MAR	2.68	1958	
1959	JAN	29.3	DEC	18.7	DEC	45.3	7 FEB 8 MAR	1.26	1959	
1960			DEC	40.4	DEC	29.3	2 MAR 31 MAR	2.76	1960	
1961					NOV	35.8	15 JAN 13 FEB	0.86	1961	
1962	JAN	35.5			DEC	34.4	3 FEB 4 MAR	0.96	1962	
1963	JAN	39.2	DEC	18.2	DEC	37.5	28 MAR 26 APR	1.02	1963	
1964			DEC	39.7	DEC	48.4	18 MAR 16 APR	4.86	1964	
1965					DEC	19.6	11 JAN 9 FEB	0.26	1965	
1966	JAN	15.0			NOV	53.0	15 JAN 13 FEB	2.01	1966	
1967	JAN	21.0	DEC	38.8	DEC	69.3	12 MAR 10 APR	1.15	1967	
1968			DEC	20.5	NOV	28.3	8 FEB 8 MAR	Tr	1968	
1969			DEC	31.4	DEC	65.2	11 MAR 9 APR	2.72	1969	
1970					DEC	35.4	10 FEB 11 MAR	NIL	1970	
1971	JAN	40.5	DEC	45.6	NOV	22.8	23 MAR 21 APR	0.06	1971	
1972									1972	

* Recorded values, not adjusted values

** Sum total of rainfall at Changi, Tengah and MacRitchie Reservoir rainfall stations on Singapore Island.

*** Extracted from Changi rainfall records only. Any 30-day period with rainfall of about 1 inch or less is underlined and considered a DRY SPELL.

NOTE: MERSING mean monthly rainfall November 13.34 ins, December 21.53 ins.

KUCHING mean monthly rainfall January 24.87 ins.

SINGAPORE (Changi + MacRitchie + Tengah) mean monthly rainfall November 29.45 ins. December 35.79 ins.

Table 1. Heavy Rain Spells at Kuching, Mersing, Singapore in Nov., Dec., Jan. and 30-Day Minimum Rainfall Periods Singapore Jan. – April.

Table 1.

Table 1 showed that with one exception, the listed occasions of "DRY SPELLS" were preceded by exceptional Northeast Monsoon storms which brought more than 40% average rainfall to Mersing, Singapore or Kuching either in November, December or January. The one exception was the 1–30 March 1949 "DRY SPELL" which however was preceded by heavy rain (43 ins in November 1948 at Kuala Trengganu on the east coast of West Malaysia about 250 miles north of Singapore.

The data listed in Table 1 were used to construct an isogram of 30–day minimum rainfall recorded at Changi Airfield during the months of January to April. The highest monthly rainfall for November, December or January each year during the period 1949 to 1970 recorded at Mersing or Kuching was plotted on the X-axis against the corresponding highest monthly rainfall (total of Changi + MacRitchie Reservoir + Tengah Airfield) for November or December each year plotted on the Y-axis. The year (for example 1955 written as 55) and the 30-day minimum rainfall in inches for Changi were written by the side of each plotted point. 23 points were thus plotted and isopleths of 30-day minimum rainfall drawn. The completed isogram showed that dry years i.e. years with low rainfall between January to April were well separated from wet years although plots for 1949, 1954 and 1956 did not fit very well.

The isogram in Fig. 5 therefore showed quite clearly that exceptional storms during the Northeast Monsoon months of November, December and January that brought heavy rain spells to Singapore or areas near Singapore were often followed by periods of exceptionally low rainfall at Changi in the succeeding months of January to April.

It may be of interest to note that the point plotted in Fig. 5 for 1972 (Mersing, December 1971 rainfall 45.6 ins Singapore, November 1971 rainfall 22.8 ins, indicated the likely occurrence of a 30-day "DRY SPELL" with rainfall of about 1 inch or less between January–April 1972 in the Changi area.

The rainfall records of Changi, MacRitchie Reservoir and Tengah were then examined to see if the conclusions derived from the isogram in Fig. 5 based on the 30-day minimum rainfall at Changi only would be more generally applicable to the rest of Singapore.. These three stations were situated roughly east west across the Island and any good correlation between the "DRY SPELLS" in the Changi rainfall records and low rainfall in the combined Changi, MacRitchie Reservoir, Tengah rainfall records would be a good indication that Fig. 5 would be representative of conditions over a wider area.

The rainfall records were also scrutinised for indications of the approximate length of "DRY SPELLS" and their effect on the annual rainfall.

Table 2 was then constructed to summarise the following data for the years 1949 – 1971.

Column (a) of Table 2 listed the Changi 30-day minimum rainfall for the period January-April each year. This data was extracted from Table 1 and the lowest 10 rainfall amounts were underlined.

Using readily available monthly rainfall totals, the value for each year listed under column (b) of Table 2 was obtained by totalling the individual values of minimum rainfall for a calendar month in the period January – April for the three stations at Changi, MacRitchie Reservoir and Tengah. The minimum 1 calendar month rainfall for individual stations may not have occurred during the same calendar month, however, this procedure was considered justified as the value obtained would still be representative of the "DRYNESS" of the January – April period. The lowest 10 rainfall amounts were underlined.

The values listed in column (c) of Table 2 were selected using the same procedure as for column (b) except that the lowest rainfall for two calendar months during the period January – April for each station was first extracted and the total for the three stations Changi, MacRitchie Reservoir and Tengah listed. Also the lowest rainfall for each station may not have occurred during the same two months. The lowest 10 rainfall amounts were underlined.

Column (d) of Table 2 listed the total rainfall for the 3 stations Changi, MacRitchie Reservoir, Tengah for the months of February – September each year and column (e) listed the total of the annual rainfalls for the same three stations. The lowest 10 rainfall amounts in each of these columns were underlined.

When the data listed in the columns (a) and (b) of Table 2 were compared, it could be seen that 9 out of the 10 underlined rainfall amounts occurred in the same years. It may thus be concluded that the "DRY SPELLS" indicated by the Changi 30-day minimum rainfall (January to April) were representative of probably island wide conditions.

As may be expected a close correlation existed between the underlined values in columns (b) and (c) of Table 2 in that 8 out of the 10 lowest rainfall amounts in each column occurred in the same years. Also, these values occurred in the months following exceptionally heavy rain spells at Mersing, Kuching or Singapore during the North-

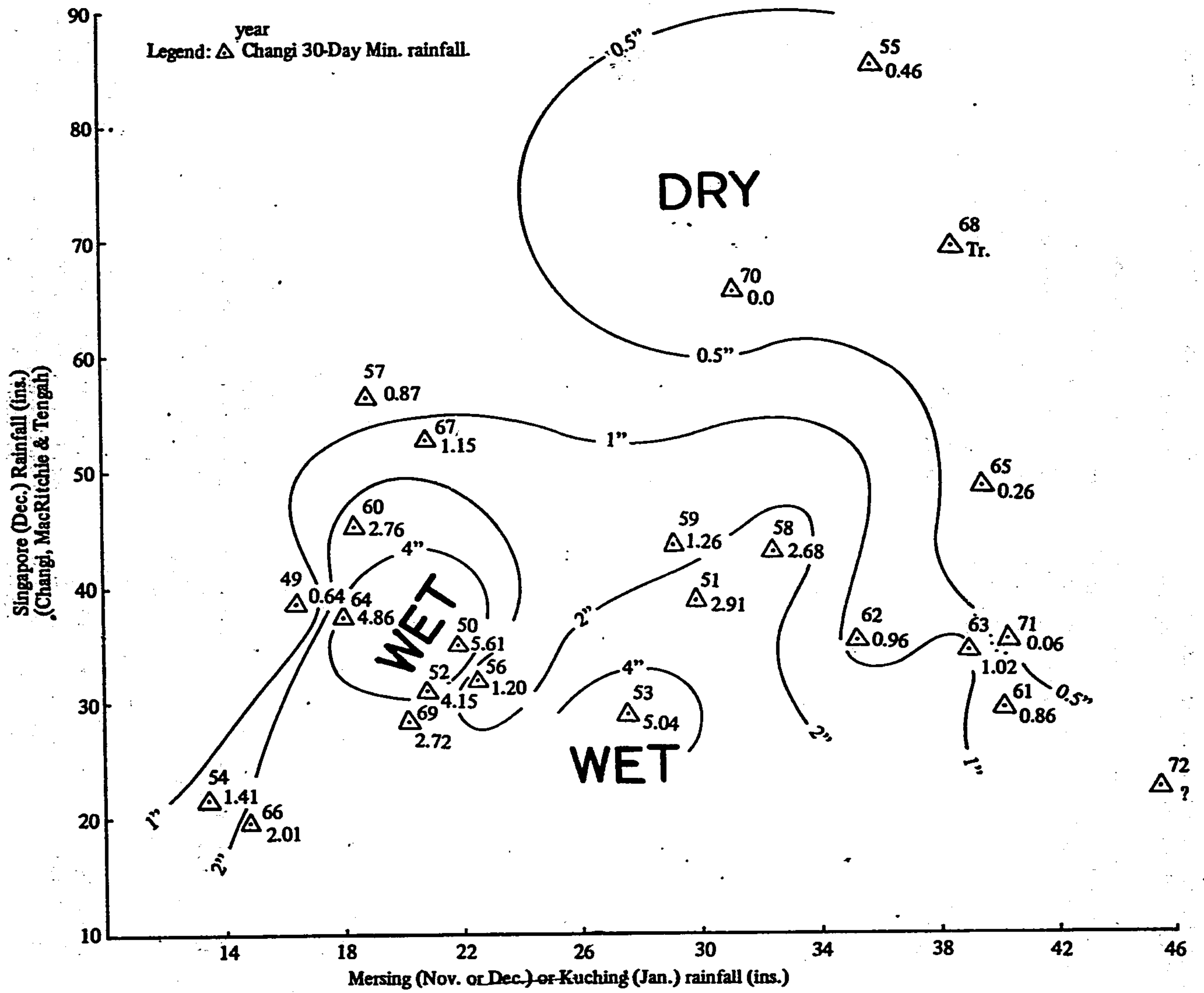

Fig. 5. Isopleths of 30-Day Minimum Rainfall (Jan. – Apr.) at Changi

YEAR	CHANGI (a) 30-day min. Rainfall JAN-APR	CHANGI + MACRITCHIE + TENGAH (b) 1 calendar mth. min. rainfall JAN-APR	(c) 2 calendar mths. min. rainfall JAN-APR	(d) Total Rainfall FEB-SEPT	(e) Annual Rainfall
1949	0.64	9.14	26.61	148.26	263.50
1950	5.61	15.69	37.34	166.91	283.19
1951	2.91	14.60	39.96	159.34	308.52
1952	4.15	22.73	58.68	208.50	328.67
1953	5.04	22.54	49.59	190.15	271.44
1954	1.41	14.46	36.54	188.93	361.44
1955	0.46	5.82	14.01	132.33	281.80
1956	1.20	10.71	27.80	164.05	311.00
1957	0.87	6.97	20.09	148.56	256.90
1958	2.68	12.04	27.00	150.90	255.31
1959	1.26	15.36	37.09	178.13	291.35
1960	2.76	17.08	37.62	165.04	252.46
1961	0.86	14.65	36.27	136.23	224.66
1962	0.96	9.60	26.39	147.20	263.22
1963	1.02	3.74	12.41	107.57	198.79
1964	4.86	23.87	51.24	211.44	333.00
1965	0.26	2.32	15.95	140.70	222.81
1966	2.01	13.47	35.67	142.51	276.31
1967	1.15	4.78	30.84	149.47	326.87
1968	Tr	5.99	21.18	144.70	243.06
1969	2.72	11.37	27.42	162.52	278.55
1970	Nil	10.34	28.75	154.84	257.91
1971	0.06	6.17	15.93	117.47	191.58

Table 2. Rainfall Values in Inches

east Monsoon season. Moreover, the rainfall records showed that on 6 out of the 8 occasions the "DRY SPELL" persisted for more than one month.

The data in columns (d) and (e) of Table 2 were included to see whether "DRY SPELLS" early in the year would be compensated by heavier rainfall later in the same year. This did not appear to have been the case as 8 out of the 10 underlined rainfall amounts in columns (b) (c) and (d) occurred in the same years and 7 out of the 10 underlined lowest rainfall amounts in columns (b) and (e) occurred in the same years. All these occasions were preceded by exceptionally heavy rainfall at Mersing, Kuching or Singaproe.

Using the data listed in columns (c) and (d) of Table 2 a diagram Fig. 6 was constructed with the values in column (c) plotted along the X-axis and the corresponding values in column (d) plotted along the Y-axis. Nearly all the plotted points fall within the two enveloping straight lines. This diagram may therefore be used to estimate the probable total rainfall at Changi, MacRitchie Reservoir and Tengah together for the months of May to September of any year at the end of April of the same year. The error for this 5 months (May – September) total would be plus or minus 4½ ins of rain

RAINFALL PROSPECTS FOR 1972

An attempt is now made to estimate the probable rainfall for 1972 using diagrams and tables referred to earlier.

The total rainfall for 1971 recorded at MacRitchie Reservoir was 66.60 ins. Referring to the diagram in Fig. 3 it may be estimated that the total rainfall for 1972 at MacRitchie Reservoir would be more than 83 ins. However, Table 2 indicates good chances that the 1972 rainfall would be below average. The estimated total rainfall for 1972 at MacRitchie Reservoir is therefore between 83 ins – 96 ins.

Referring to Table 2, the December 1971 rainfall for Mersing was 45.6 ins which was in fact the highest amount ever recorded at Mersing for December over a 49-year period. This was plotted against the December 1971 rainfall total for Changi, MacRitchie Reservoir and Tengah in Fig. 5. The position of this plot in Fig. 5 indicates that a "DRY SPELL" with 30-day minimum rainfall of about 1 inch or less may be expected during the period January-April 1972 in the vicinity of Changi which would probably coincide with fairly widespread dry conditions over Singapore. Table 2 also indicates a high probability that the February – September 1972 rainfall total would be below average and fair chances that the annual rainfall for 1972 would be below average.

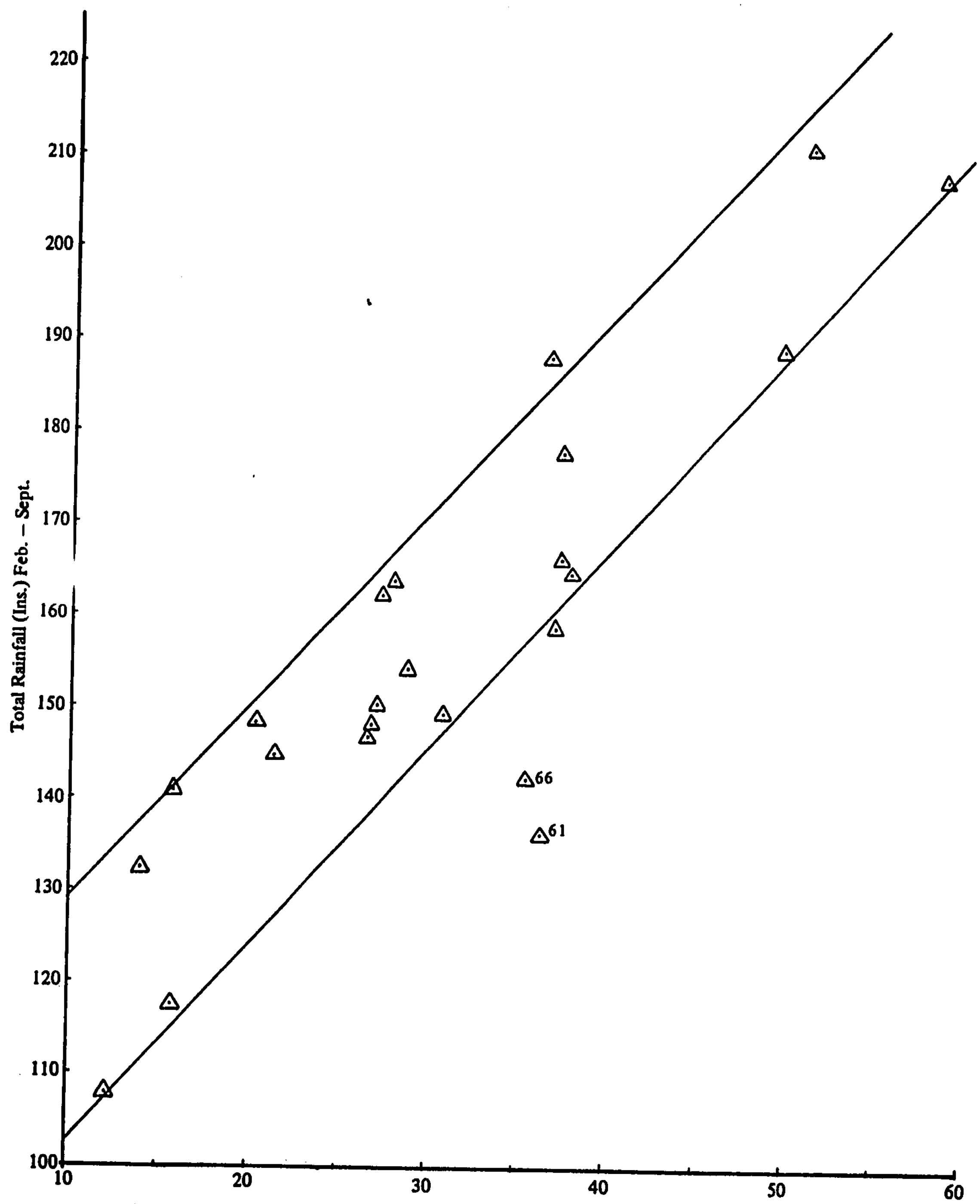

Fig. 6. Rainfall Average for Changi, Tengah & MacRitchie Reservoir

DEVELOPMENT OF WATER SUPPLY IN VIETNAM

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ABSTRACT

The total population of South Vietnam is 18 million, 55% of which is rural and 45% urban. The water supply system includes (1) municipal water supply and (2) rural water supply. The municipal water supply system is under the responsibility of the National Water Supply Agency dating back to 1957. The cities of Saigon and Danang have their own Water Board. In rural areas, the Ministry of Health is responsible for water supply for villages and hamlets having a population of 5,000 or less. According to Decree No. 3118/BYT/PC/ND, September 16, 1966, the Ministry of Health is responsible for the quality of drinking water and for stipulating water standards. In addition to quality control of drinking water, training courses for plant operators are organised.
(Abstracted by Chin Kee Kean)

GENERAL

The Republic of Vietnam in South East Asia has 173.263 km^2 within its boundary, limited by the 8th and 17th latitude and the 102^0 and 109^0 longitude. This peninsula looking at the Pacific Ocean is divided in 4 regions: the North, the Highland, the Coastal and the Delta of Mekong. The climate is tropical with monsoons. The average rainfall is high, the following was recorded during 1968.

Regions	Rainfall
I	2.276
II	1.395
III	1.485
IV	1.670

In the South, the rainy season is from May to November and the dry season from December to April. The average temperature is 25^{0}C during the monsoon and 26^{0}C in the dry season. The Republic of Vietnam is divided into 55 administrative units i.e., 44 provinces, 9 municipalities, one prefectural capital and one special military district.

The total population is 18 million with an average density 103 people per square kilometre. According to the recent census, 55% of the population is rural and 45% of the population is urban. The individual income is very low (US $185 per capita per year) with the standard of living needing considerable improvement.

The long war continues to be the main obstacle retarding the nations development, especially the development of necessary water systems.

WATER SUPPLY IN VIETNAM

The water supply in Vietnam is comprised of two types:

Municipal Water Supply

The municipal water supply is under the responsibility of the National Water Supply Agency created by Decree No. 9CC/GT, January 11, 1957. This organization has the responsibility of building new water plants, repairing or extending the old ones according to the needs of the local people. When a municipal water plan becomes operational, it becomes an autonomous body managed by an administrative board of which the mayor is usually the chairman. 39 water plants are actually autonomous bodies now in Vietnam. Besides, the two large cities, Saigon and Danang have their own independent water supply board.

Saigon Water Board was created by Decree No. 329-CC/GT, November 23, 1959. This board provides water supply for the Saigon metropolitan area. This new water treatment plant was completed in 1967. It provides 400,000 m^3 daily to the population of Saigon and the adjacent areas. The plant was financed by the Government of South Vietnam providing 1 billion piasters in local Vietnamese currency and 17.5 millions of dollars loaned from the Development Loan Fund. This is to be paid back by 1990 at an interest rate of 3½ percent per year.

Danang Water Board created by Decree No. 49/SL/CC, March 18, 1967 is responsible for the water supply to the Danang Municipality and its adjacent suburbs. This new water plant construction is being undertaken by the Australian Government, will furnish 72,000 m^3/daily and will cost approximately 3,668,000 Australian dollars and $995,610,000 Vietnamese piasters.

Rural Water Supply

In rural areas, the water supply in villages and hamlets having a population of 5,000 or less is the responsibility of the Ministry of Health. This programme is implemented in parallel with the sanitation hamlet programme by:-

- constructing small water systems for populated villages.
- providing support to dig new wells or repair the old ones
- building domestic and filters for private houses.
- chlorinating the drinking water.

The Ministry of Health will provide a small amount of funds, materials and chemicals for water treatment upon request from the Provincial Health Service to carry out the rural water programme. The villagers should be motivated to the cause of self-help community development if the projects are to be successful.

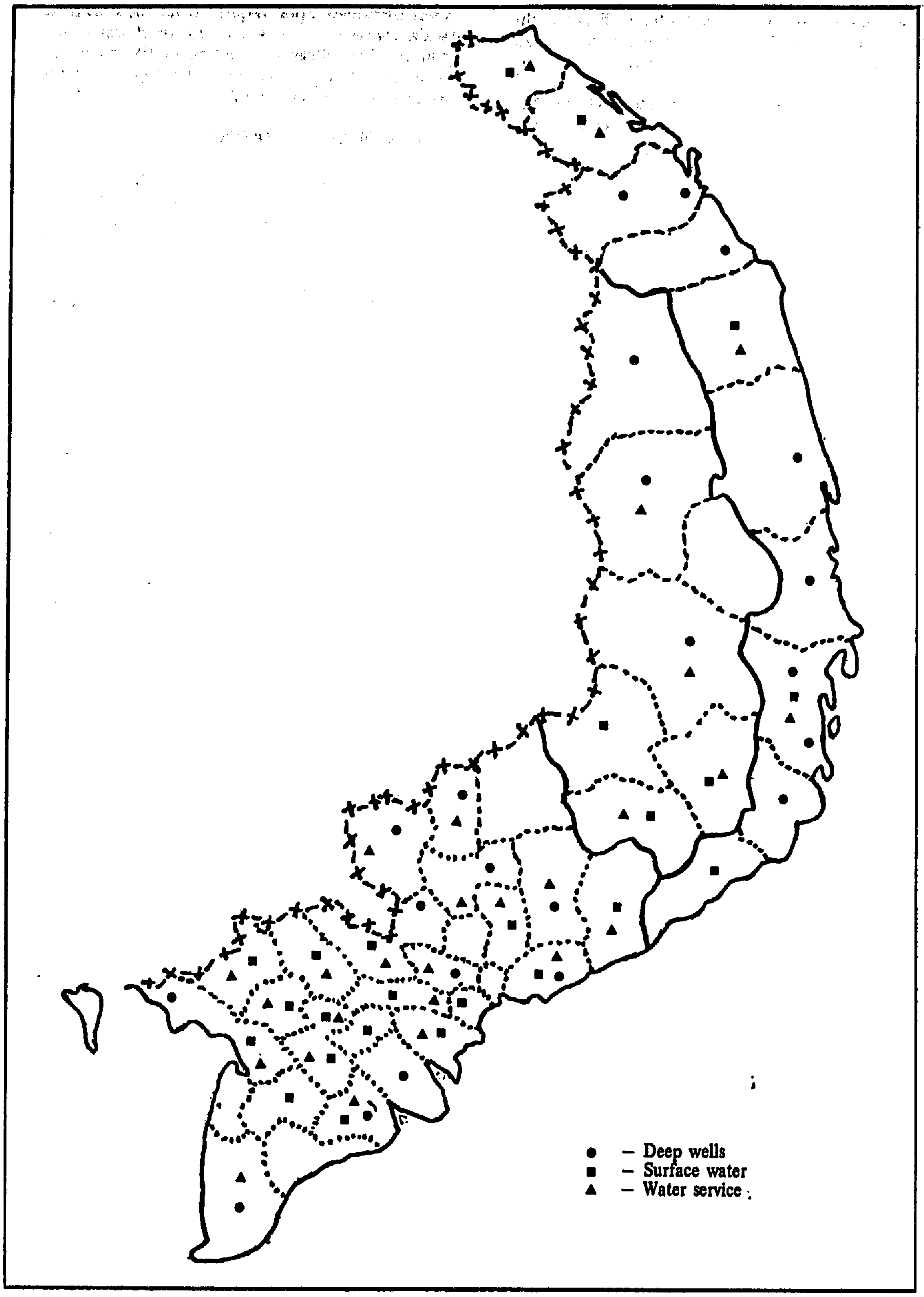
WATER QUALITY CONTROL

According to Decree No. 3118/BYT/PC/ND, September, 16 1966. The Ministry of Health is responsible for the quality of drinking water and of stipulating water standards. If test results show that drinking water is not potable, the Environmental Sanitation Department will inform the National Water Supply Agency and the local Water Supply Service in question, for the latter to take appropriate corrective measures. Water quality control examinations can be done at:

- the Water Laboratory of the National Institute of Public Health
- the Water Control Laboratory of Pasteur Institute.
- the Regional Water Laboratory

Besides the routine control of the quality of the drinking water, the Environmental Sanitation Department also cooperates with the National Institute of Public Health and the National Water Supply Agency in organizing training courses for water plants operators. In this training, emphasis will be put on the chemical treatment of water. Local Provincial Health and Sanitation Service conduct periodic inspections of water plants, taking water samples for routine analysis.

In conclusion, the Vietnamese Government, although burdened with the war situation, continues to progress in developing the water supply systems and in reducing enteric diseases.



Development of Water Supply in Vietnam

Paper No. I/12

MUNICIPAL WASTEWATER RECLAMATION AND REUSE

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ABSTRACT

As the world population increases and the principal cities grow at an accelerated rate, local shortages of water for municipal and industrial use will become more common. Many methods are being explored to meet existing demands and future needs for water. One of the most promising new sources of municipal and industrial water supplies is the spent water of the community. If the spent water can be successfully reclaimed, it will provide an important resource.

The paper presents a review of the most promising methods presently being used to reclaim usable water from municipal wastewater. It discusses the results obtained, and the costs of construction and operation. The precautions to be observed in the use of reclaimed water are pointed out. Alternative potential uses of reclaimed water are considered. The water reclamation projects at Santee and South Lake Tahoe in California, and at Windhoek in Southwest Africa are described in detail.
(Abstracted by Chin Kee Kean)

INTRODUCTION

It is not always easy to distinguish where pollution control ends and wastewater reclamation begins. It may be convenient to define reclamation as treatment to a high degree of quality for direct reuse, while pollution control is directed toward relief from objectionable characteristics. This is not an exact definition but will suffice to indicate the scope of this paper.

Wastewater treatment and reuse involving the application of wastewaters or treated effluents to the soil, to crops and pasture and for replenishment of ground and surface waters have generally relied heavily on natural self-purification. The combination of population growth and developing technology is making it both necessary and feasible to treat and re-cycle wastewaters for certain uses with a minimum reliance on self-purification.

It is technologically possible to produce water of any given quality from any water source. However, if there is to be any practical use made of these techniques for production and distribution of usable water they must be economically feasible. It is for this reason, attention is beginning to be directed to wastewater reclamation and reuse rather than to seawater desalination for many uses. Recently this has become an extremely fashionable subject for research and discussion.

EXAMPLES OF FULL SCALE REUSE

Ground water recharge by municipal wastewater has been practised in a number of places. Pilot attempts have been made to recharge aquifers by direct injection of treated wastewaters. [1] [II]. Other methods include irrigation of non-edible crops and spreading basins. In spite of the great and growing interest in the technology and economics of wastewater reclamation and reuse, the number of full-scale operating examples of renovation of municipal sewage for direct uses requiring high quality water is extremely limited.

EXAMPLES OF DIRECT MUNICIPAL REUSE

There have been 2 principal examples of full-scale renovation for full municipal water supply use. The first was largely inadvertent. A drought in 1957 forced the City of Chanute, Kansas, [8] to re-cycle trickling filter effuent through a 17-day retention pond directly to the water supply softening plant intake. Although, the dissolved solids and detergent contents of the water rose to uncomfortably high levels; there were no known adverse effects. Drinking water was trucked into the city on a small scale for optional use. Volume records indicate that such use was minimal.

The second example of full-scale municipal reuse is the facility at Windhoek, in Southwest Africa. [12]. Following several years of pilot studies, a full-scale municipal wastewater renovation facility was constructed and put into service in 1969 for this rapidly growing and water-short city. Sewage is treated by conventional means, consisting of sedimentation, trickling filters, secondary sedimentation and 14-day retention facultative lagoon. Part of the effluent is treated by recarbonation, algae flotation, foam fractionation, chemical flocculation, breakpoint chlorination, clarification, sand filtration and activated carbon filtration and mixed with treated water supplied from other sources and chlorinated to 0.2 ppm free residual before distribution. In this situation, the algae activity in the sewage treatment lagoons, assisted by the high temperatures, produces an effluent with a high pH and a low ammonia content. Recarbonation reduces the pH from an average of 9.0 to 7.5. Flocculation with alum and surface skimming, assisted by the release of the gases added during recarbonation, facilitate removal of the algae. Detergents are removed by foam fractionation, the foam being skimmed and collapsed by water jets. Lime and alum are added prior to conventional water treatment processes, with the addition of activated carbon filtration for removal of dissolved organic compounds before final chlorination.

In the first 9 months of operation, up to June 1969, although viruses were found in the raw sewage and in the pond effluent, none were found after the foam fractionation step in the reclamation plant. Total bacterial count was reduced to below 100 per ml following chlorination. Total dissolved solids increased during treatment from 740 to 810 mg/l because of chemical dosing. Alum requirements varied from 130 to 220 mg/l. A final reclaimed water was eventually produced having COD less than 10 mg/l and ABS less than 0.2 mg/l. Phosphate was reduced to 0.5 mg/l and organic nitrogen to 0.7 mg/l, primarily by removal of coagulated and suspended matter before sand filtration. BOD was reduced by 98 percent, primarily in the flotation, sand filtration and carbon absorption stages. Carbon-chloroform extract levels were reduced to 0.13 mg/1 and nitrate nitrogen to 18 mg/l.

EXAMPLES OF DIRECT RECREATIONAL REUSE

Treatment in stabilization ponds for subsequent recreational use has been undertaken in several places. Where treatment is by stabilization ponds, additional treatment is required following the ponds in order to break the diurnal cycle of algal photosynthesis and bacterial respiration. Unless the cycle is broken, retention of the effluent will lead to extremely wide fluctuations in dissolved oxygen level and to a high pH level, between 8.5 and 9.5. These conditions are adverse for fish and the green colour associated with the algae is not aesthetically generally compatible with recreational use.

The cycle can be broken by removal of the algae and of phosphorus. This has been achieved by alum coagulation and dissolved air flotation for example on a full-scale at Windhoek [12] and in pilot studies in Bangkok, Thailand [6].

Stabilization pond effluent is filtered through a natural aquifer to produce inflow to a series of recreational lakes at Santee, California [7]. The town's wastewaters have been treated since 1963 by conventional activated sludge followed by nominal 30-day retention in a stabilization pond. The effluent is filtered horizontally through a natural shallow aquifer, chlorinated and discharged to a series of small lakes which are used for swimming, boating and fishing.

Not only BOD and suspended solids, but also nitrogen and phosphorus are reduced to very low levels (N, 2-3 mg/l; P typically 0.2 mg/l). After the chlorination step, coliform MPN is less than 2 per 100 ml. Virus studies included a period of alternated polio feeding to the Santee community. These increased raw sewage polio virus levels a thousand-fold. In addition, an enteric virus was isolated from the raw sewage. However, no virus was found in the recreational waters.

Occasional blooms of algae have been reported in the recreational lakes. Dissolved oxygen was sustained at near 100 percent of saturation during the first 3 years of operation. However, there was a buildup of sulphurous sludge on the bottom in the deeper parts of the lakes.

Following conventional secondary processes, advanced treatment to produce water for water contact recreational use has been successfully practiced for several years in a 7.5 mgd facility at South Lake Tahoe, California [3].

The processes include conventional activated sludge treatment followed by lime precipitation of phosphate, ammonia stripping, recarbonation, mixed media filtration, activated carbon adsorption and chlorination. Primary sludge and thickened activated sludge are centrifuged and burned. Lime mud is thickened, centrifuged, burned and reused. Carbon is dewatered after use and regenerated by burning.

The treatment of secondary effluent by lime, followed by flocculation and clarification removes most of the phosphates and raises the pH to a high enough level to convert ammonium ion to ammonia. This is stripped out of half of the flow in a tower by droplet formation and circulation of large quantities of air. Recarbonation is carried out in two steps. The first lowers the pH to 9.3 for maximum calcium recovery, and the second to 7.0-8.5 to prevent deposition of calcium carbonate in the filters. The mixed media filters are loaded at 5 gpm/sq ft and are backwashed automatically. The upflow carbon columns give a contact time of 17 minutes, producing an effluent that is colourless, odourless, sparkling clear, low in organics and having a low chlorine demand. Carbon regeneration, sludge incineration and lime recalcining are carried out in three separate multiple hearth furnaces.

A comparision of percentage removals by typical primary/secondary and the Tahoe processes is given in Table 1 together with typical Tahoe reclaimed water quality.

INDUSTRIAL REUSE

The water quality requirements of industry vary widely. They vary not only between industries but also from process to process within any one plant. The economics of municipal wastewater renovation for industrial reuse tend to favour renovation to a level suited to the lowest common level of use, which is also in many cases the largest volumetric water requirement, namely that for cooling water.

Six examples of industrial cooling use of effluents from primary plus biological secondary plants in amounts ranging from 1 to 80 mgd (million imperial gallons per day) have been reported by Porter [10]. In many cases, however, higher quality waters are required by industry, even for cooling purposes.

ADVANCED TECHNOLOGY AVAILABLE FOR WASTEWATER RENOVATION

Rapid progress is taking place in the advanced treatment of wastewaters. This progress results from adaptation of industrial processes, desalination methods, modifications of standard water treatment practices, and the development of new wastewater treatment techniques. Not all advanced treatment facilites are designed as additions to traditional biological processes of wastewater treatment. Table 2 includes a partial summary of treatment processes and their usefulness of potential functions in this field.

ECONOMICS

The economics of wastewater reclamation and reuse vary widely from case to case. Even ignoring variations in the availability of alternative water sources and in the value of the treated water, the costs depend not only on the processes selected but also on local economic factors and on the size of the facility. Each case must be studied individually.

In general, economy is favoured by the selection of processes which do not require the application of large amounts of energy. It is also favoured by construction of the reclamation plant at the same site as the wastewater treatment plant.

Preliminary prototype scale studies sponsored by the U.S. Federal Water Quality Administration at Pomona, California indicate that at a capacity of 8 mgd (million imperial gallons per day), costs of the indicated unit processes will be approximately as follows: [13].

Unit Process	U.S. cents/1,000 imp gallons
Granular carbon adsorption	11
Ion exchange (90% demineralization)	30
Electro-dialysis (35% demineralization)	20
Reverse osmosis (30% demineralization)	50
Alum addition (chemical only) for P removal	7

Approximate costs for complete treatment plants were estimated by Porter [10] on the basis of 1968 U.S. prices. For 100 mgd installations, including in each case preliminary primary sedimentation and activated sludge treatment, and final chlorination, the resulting figures were:

	Typical Secondary Removal (%)	Typical Tahoe Removal (%)	Typical Tahoe Effluent (2)
BOD	90	99.8	1.0
COD	86	96	10
Suspended solids	89	100	0
Turbidity	96	99.8	0.3
MBAS (detergents)	93	98	0.10
Colour	Incomplete	100	2
Odour	Incomplete	100	None
Coliform bacteria	95	99.99 +	2.0
Phosphorus (as P)			0.06

(1) Taken from Culp and Culp [3] p. 288 and 289.

(2) In mg/l except: colour in units, coliform in MPN/100 ml, turbidity in Jackson units.

Table 1. Reclaimed Water Quality at Lake Tahoe (1)

Function	Process	Remarks
Suspended solids removal	1. Sedimentation	
	2. Air flotation	
	3. Stabilization ponds	
	4. Chemical coagulation	Alum, ferric, polymers
	5. Sand or dual media filtration	Low suspended solids (following secondary treatment)
	6. Microscreening	Nonchemical solids
Dissolved solids removal (following suspended solids removal)	1. Distillation	
	2. Ion exchange	
	3. Reverse osmosis	
	4. Electrodialysis	
Carbonaceous BOD removal	1. Trickling filters	
	2. Activated sludge	
	3. Stabilization ponds	
	4. Granular carbon absorption	Low suspended solids (polishing)
	5. Powdered carbon	Carbon lost. Expensive.
	6. Lime precipitation	
Nitrogenous BOD removal	1. Second-stage activated sludge	
	2. Stabilization ponds	
	3. Granular carbon	Carbon regenerated
	4. Powdered carbon absorption	Carbon lost. Can add coagulant.
	5. Break-point chlorination	Polishing only
Phosphorus removal	1. Precipitation with alum, ferric salts (esp. multistage)	Flexible, moderate capital cost, large sludge volume
	2. Precipitation with lime (esp. multistage)	Moderate operating cost, if lime recovered by recalcining
Algae removal	1. Alum coagulation	
	2. Air flotation	
	3. Microscreening	
	4. Sand filtration	Coarse aquifer, or polishing only
Nitrogen removal	1. Biological denitrification	In sand filter after nitrification needs carbon source
	2. Ammonia stripping	High ambient temperature
Trace organics removal	1. Granular carbon absorption	Carbon regenerated
	2. Powdered carbon absorption	Carbon lost. Can add with coagulant
pH control	1. Recarbonation	
	2. Acid addition	
	3. Lime or soda ash addition	
Sludge stabilization	1. Digestion and dewatering	
	2. Incineration	Especially if lime recovered by incineration
	3. Wet oxidation	
	4. Heat drying	High BOD, degradable effluent
	5. Vacuum filtration	Raw sludge
Sludge dewatering	1. Air drying	
	2. Vacuum filtration	After chemical conditioning
	3. Centrifuging	
	4. Flocculation	Preliminary
	5. Thickening	Flocculation
Disinfection	1. Chlorination	Following solids and BOD removal
	2. Irradiation	

Table 2. Unit Reclamation Processes in Use or under Pilot Scale Study

Processes	Approx. cost in U.S. cents per 1,000 imp gallons
Sand filtration	18
Sand filtration, carbon filtration	20
Carbon filtration, lime treatment, ammonia stripping	30
Carbon filtration, electro-dialysis	36

Recent estimates by Camp Dresser & McKee indicate that, for U.S. average conditions expected to apply at the end of 1971, the construction cost of a treatment facility; including two-stage activated sludge treatment for reduction of carbonaceous and nitrogenous BOD, precipitation of phosphorus by lime treatment of pH 11.0 including sedimentation, recarbonation to pH 9.3, clarification, further pH reduction by recarbonation, rapid gravity dual media filtration, chlorination, aeration, centrifuging and incineration of sludge, and lime recovery, will have a capital cost approximately double that of conventional activated sludge treatment. At a plant capacity of 21 mgd, the total construction cost, excluding engineering and administrative costs, would be approximately $19 million (economy of scale exponent approximately 0.72). The corresponding operating cost would be about 9 U.S. cents per 1,000 imperial gallons but this would decrease with increasing scale.

The expected effluent from such a plant would average about 4 mg/l of BOD_5, 10 mg/l of suspended solids, 5 mg/l of dissolved oxygen and 0.1 mg/l of phosphorus. Denitrification could be achieved by the simple addition of methanol before filtration.

It must be remembered that studies of the overall economics of alternative water sources, including renovation of wastewaters, must take into account distribution costs as well as treatment costs.

HEALTH ASPECTS

There are many ways in which municipal wastewaters can be treated so that, if necessary after dilution by surface or ground water, they can be treated by conventional water treatment processes and then meet the health-related requirements of generally accepted drinking water quality standards. This does not necessarily mean that the resulting waters can be regarded as safe for use as drinking water.

The reason is that drinking water standards in general use were developed for water supplies obtained from streams, lakes or ground water and not from re-cycled wastewater. There are many components which can appear in wastewaters, and which may persist after certain forms of advanced treatment, which are dangerous to health and which are not covered by the standard. These include certain toxic elements and compounds, and certain micro-organisms. The techniques are not yet available to adequately monitor and control certain of these components.

In addition, some contaminants will appear at some times and not at others, both because of variations in discharge, and because of mishaps or failures at the wastewater treatment plants.

The recommendation by Long and Bell [5] that any reclamation and re-cycling for "intimate" use of the water must incorporate fail-safe features, is endorsed. Such features would include standby units, holding basins for monitoring purposes, alternative means of disposal of the wastewater and warning procedures and devices.

In addition, until more is known about (1) the transmission of viruses by water supplies and the possible health effects and control, (2) the possible problems of chlorine-resistant bacteria and (3) the effects, monitoring and control of organic and other non-degradable chemicals, renovated wastewater should not be used for drinking purposes unless there is no other practical choice. Even then, it should form only part of the total domestic supply, so that any buildup of concentration of any substance due to repeated reuse will be limited.

The experience at Windhoek will be watched with great interest by health authorities in other arid areas.

On the basis of health danger, distillation and reverse osmosis have clear advantages over all other processes of renovating wastewater for drinking purposes. The use of any other process involves risks which cannot yet be properly evaluated.

DUAL SYSTEM

In view of the possible public health risks associated with reuse of reclaimed municipal wastewater for domestic purposes including drinking (except after treatment by distillation or reverse osmosis), as indicated above, consideration must be given to the use of dual water supply systems in certain cases.

Coalinga, California, has been operating a dual system for over 30 years. The available ground water supply is bacteriologically safe but extremely hard. Drinking water is distributed by a parallel pipe system to kitchen taps. Use of the soft water supply averaged 2-2½ gall/day/cap in 1960 [1]. However, if a separate potable supply were to be used for all kitchen purposes and also for bathing, the requirement would be considerably greater.

McGarry and Tonghasame have suggested that in a typical Asian city it may be feasible to supply 1 imp gall/day/cap for drinking and other culinary uses only from a potable source, with a reclaimed supply for all other purposes supplying about 32 imp gall/day/cap for household uses and an approximately equal amount for industry. The required volume of make-up water (excluding the drinking water supply) due to non-return was estimated to be approximately 30 percent of the total supply.

Suggestions for the adoption of dual systems have been made over a long period of years in the United States but have always foundered on the twin rocks: cost and health risk due to possible cross connections. These two factors must still be overcome today. It does appear, however, where water is sufficiently short that expensive reclamation procedures are necessary, especially in locations where the dwellings are yet to be constructed, that the economics are well worth studying in particular cases, but on 3 very important conditions.

These conditions are: (1) that the system of training and licensing of plumbers, and the degree of control exercised over connections to the water supply system be such that any cross connections between the two systems will be extremely rare events, (2) that the source and treatment of the reclaimed or other non-potable supply be such as to render it in substantial conformity with the health-related requirements of normal drinking water standards and (3) that suitable consumer education and quality monitoring programme be maintained.

PRACTICAL IMPLEMENTATION

There are some distinct differences between advanced treatment of wastewaters for the purpose of reuse of part of the flow and such treatment for improved disposal of the whole flow. In the latter case, the whole flow must always be treated, whereas for direct reuse the quantity treated can be selected to suit the operating characteristics of the plant and the demand.

An example of this is the Whittier Narrows plant in California. This is an activated sludge plant providing effluent for recharging ground water through spreading basins. At this plant, even at low-flow periods, there is more than enough flow to meet the reclamation plant requirements. Reclamation can therefore take place at an efficient constant rate of flow and, if necessary to sustain an even solids loading, can even be increased at night when the sewage is weaker [9].

There is a substantial cost advantage in locating a wastewater reclamation facility upstream, or at the same site as, a major wastewater treatment facility. This is because, there is no need to construct sludge handling and disposal facilities for the reclamation plant. For Whittier Narrows, the ability to return all sludge to the trunk sewer was estimated to reduce plant construction costs by 25 - 30 percent [9].

From both a functional and an economic point of view, pilot studies are very often necessary. This is partly because of the present rapid development of the technology in this field, and because of differences in the constitution of wastewaters and in the uses of reclaimed waters from place to place.

There are several other important practical matters which need to be faced in the implementation of wastewater reclamation and reuse procedures on a municipal scale. These include:

(1) Financial and legal aspects, including the division of reponsibilities and costs between the wastewater collection and disposal agency and the water surveyor, if these are different.

(2) The need to obtain public acceptance. The Windhoek and Santee projects have been particularly successful in this respect, because of well-conceived and thorough testing and public relations programme.

(3) The need for means of disposal of waste solids and liquids from the reclamation operation.

(4) The economic and functional relationship between the level and cost of reclamation, on the one hand, and the proposed use and value of the renovated water, on the other. This may involve detailed study where the potential users are industries having different quality requirements and able, if it appears economical, to treat their own water supplies.

(5) The need to exclude any industrial wastes which are incompatible with the intended use of the reclaimed water and which cannot be dealt with by the selected renovation processes. This might be achieved by appropriate selection of the point of withdrawal of wastes from the collection system or by control of industrial discharges.

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Paper No. I/13

DIFFICULTIES IN PLANNING WATER SUPPLY SCHEMES IN WEST MALAYSIA

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ABSTRACT

The Government of Malaysia has been spending large sums of money in extending existing water supplies and in developing new ones as part of its programme of national development to raise the standard of living of the people.

There is lack of long range master plan for urban and industrial development. The paper highlights problems encountered in water resources development as a result of rapid urbanization and changing patterns of industrialization. Lack of data and experienced staff make population estimation and estimation of reliable yield of catchment area difficult. Problems also arise when there is conflict of interests of the beneficial uses of waterways among water resources development and industrial, mining and agricultural development.

In recent years, attention has also been given to exploration of underground water. Results have not been satisfactory because of lack of experience in geohydrological investigations and the complete absence of details on geological data.

These problems coupled with limited financial resources and experienced technical personnel hamper the implementation of the plan for water resources development.

(Abstracted by Chin Kee Kean)

Since 1961, the Government of Malaysia as well as the respective State Governments have been embarking upon a very heavy programme of development in order to raise the standard of living of the people and to improve the economy of the country. Realising that an adequate supply of potable water is a pre-requisite to all health programmes as well as social, economic and industrial progress, the Government has been willingly spending large sums of money in extending existing water supplies and in developing new ones, even though some of the new supplies are not viable economically. The total capacity of all water installations has been increased from 105.6 mgd at the end of 1960 to 232.6 mgd by the end of 1970. Parallel with the development and extension of public water supplies, large schemes have also been implemented to provide more water for irrigation and for hydroelectric power to meet the steadily increasing demand of industrial development. All these have entailed great efforts in the development of water resources, and the intensive search for water has brought to light certain difficulties which were not apparent

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or so serious in the past when national progress was not so dynamic.

The first activity in the planning of a water supply scheme is of course an assessment of the water demand and the distribution of demand. Difficulties associated with this activity are encountered in estimating the population and its growth rate, the per capita daily demand, and in the case of rural areas where people have recourse to wells and streams, the response to a new public water supply. Population censuses are in some instance not a good guide. Due to the nature of the main industry, i.e. tin mining, and to the large unemployment population, there has been tendency for migration to centres of industries and employment. The tendency of migration depends largely on the rapidity of industrialisation. Thus in the case of Kinta Valley and Dungun, the reduction in tin and iron ore mining activities contributes to the migration away from these areas, whereas in the case of Kuala Lumpur, Petaling Jaya and Klang Valley the attainment of international diplomatic status and rapid industrialisation cause increase of population at rates which are difficult to assess in between population censuses. It is therefore difficult if not impossible to estimate population of certain areas and to forecast migration trend. In fact, when the New Kuala Lumpur Water Supply was planned in the latter half of 1960's, there was considerable difference of opinion between the water supply planning authority and the World Bank over the estimated population of Kuala Lumpur.

Coupled with the difficulty in population estimation is the non-availability of properly evaluated figures for per capita water demand. Past average per capita demand may be very unreliable as the average, in many cases, had been based on figures which were distorted by the shortage of existing supply over many years. Questions have often been asked why study on such matter has not been instituted. The answer is simply that due to the phenomenal volume of development work launched in a developing country such as ours, the staff available in the water supply authority is over committed even just to carry out the development work and the daily maintenance and operation activities.

The difficulty in estimating demand is further accentuated by the need to cater for industries. Government's wish to encourage the development of industries is known. But what type of industries, where and when any industry will be set up are not known. There are many urban areas in the country where no master development plan exists, and development appears piecemeal. In the absence of development plan for industries, the usual method of catering for industrial water demand is to add a certain arbitrary quantity to the already probably unreliable per capita demand. This method of catering for industrial water demand is, of course, illogical. A water supply system so planned and constructed will have a greater reserve of capacity and facilities in a populous area than in less populous area, whereas industrialists tend to set up their industrial complexes in less populous areas where land is cheaper and where the nuisance associated with industries will be less prominent. The need to provide facilities to divert water, even if available for the purpose, from one area to another area which has not been planned for, is time consuming and sometimes uneconomic, and results in the uneconomic use of the facilities which have been installed.

In the planning of a water supply to serve a rural area, the estimation of the water demand and growth of demand is even more difficult. Normally people in such an area will demand to be served with public water supply after they have experienced one or more drought periods when their traditional sources of supply i.e. the wells and little streams, become insufficient or dry up. Even if the population of the area and its predicted rate of growth is properly assessed, the percentage of the population who will actually want to take water from the public water supply system in the future is most uncertain. Instances have occurred, where water supply was extended to such areas at great cost, but the number of consumers turned out to be disappointingly small.

Thus it is very difficult to forecast long-term water demand in the planning of water supply in the country.

Although West Malaysia is endowed with an abundant rainfall, the seasonal distribution of the rainfall is however, by no means uniform. Most of the rain in the country falls in the form of very heavy storms.

Difficulty is often encountered in the estimation of the reliable yield of a catchment area and the flood flow as well as the level of most, if not all, rivers and streams because of the lack of, or insufficient, continuous basic hydrological data. At present, only limited data are available, although steps are being taken to rectify this deficiency. Rainfall data at various stations are collected and recorded by the Drainage and Irrigation Department, the Meteorological Department, the Agricultural Department, the National Electricity Board. River level and flow at various stations are measured and recorded by the Drainage and Irrigation Department and the National Electricity Board. It must be stated that many of the data observations and collections mentioned above are of recent introduction, while old records contain too many salient gaps, and still older records had been obtained by methods which can scarcely be considered as standard. There is a serious absence f sufficient rainfall and other hydrological data in ıe hilly and jungle covered areas. This lack or ıadequacy of basic hydrological data causes diffiulties in the estimation of reliable yield and ood level which are most important in the election of sources for water supply and in the lanning of intake works. As an example, the ıfe yield from the impounding reservoir which ıpplies water to Kuala Lumpur, the capital of alaysia, has been variously estimated at somehere between 30 to 37 mgd. In another case, ıe absolute minimum flow at the water supply take on Sungei Padang was estimated at between) and 15 cusec, but five years after the intake eatment works were completed, the flow was ›served to fall to about 0.80 cusec. In yet another ıse, a treatment plant was constructed at Kapong wah, Pahang, above the level which was, from formation and inquiry, believed to be the hight flood level. Three and half years after complet-n the plant was flooded to a depth of 4¼ ft. nother 3 years later, even the wash water tank ljacent to the plant was submerged in another ›od.

The difficulty posed by the inadequacy of ısic hydrological data is further aggravated by the ortage of experts on hydrology and the large ale clearing of jungles for land development hemes.

There is a long standing conflict between water resources development and tin mining interest. While tin mining earns high revenue per acre of land and is next to rubber in importance to the national economy, it is also a very devastating activity. Not only does it render large tracts of land unfit for cultivation, but it also competes for sources of water for its operation, and produces effluent heavily laden with fine silt. Although the maximum silt content of mining effluent allowed to be discharged into streams is laid down in the mining lease, and the miner is required to reduce the excess silt by ponding before discharging into surface streams, the effective enforcement of the miner's obligation is, to say the least, difficult. Rivers downstream of tin mines are invariably laden with silt. Past experience has taught all water resources development authorities to avoid the use of rivers where mining is, or is expected to be, in operation further upstream. A river intake at Changkat Jong which supplied water to the coastal town of Telok Anson and its surrounding areas suffered so badly from silting as a result of mining operations that another source in the jungle catchment about 20 miles further inland had to be constructed and the water conveyed through long and expensive mains to serve the areas.

In addition to the conflict with mining interests, conflict with timber interest is also often encountered. Slightly more than 1/4 of the country is comprised of forest reserves, and 2/3 of these reserves are production forests. As water resources development expands, production forest reserves perforce become water catchment areas. It is neither wise to log these forests prematurely nor is it economical to abandon them. At the same time, water resources development cannot be deferred. The usual compromise is to have a planned and staggered logging programme, reducing to a minimum the amount of erosion in the catchment and the silt content of the river water. But reaching such a compromise is usually a lengthy process causing much delay in water resources development programmes. Enforcement to ensure that logging is carried out according to a planned programme is again difficult. A source of water at Ampang Intake near Kuala Lumpur was so badly polluted due to logging that the water could not be used for a period of time.

The use of sodium arsenite as a weed-killer in rubber estates and forest reserves is a constant source of concern to public water supply authorities. These authorities would like to ban the spraying of sodium arsenite, but it has been argued by estate and forest interests that it is difficult to find an economic substitute for sodium arsenite and that there has not been serious pollution of surface water by such spraying. As a compromise, it has been decided to review the situation when permission for the extended use of sodium arsenite comes up for renewal each year. As a further compromise, it is generally agreed that the use of sodium aresenite should not be allowed in specific catchments. But this restriction has proved of limited value in practice. It is not possible to prohibit spraying in vast tracts of the country in the basins of big rivers which are the sources of supply to towns along their lower reaches. Even in small catchments the weedicide may find its way into the water courses through accidents, careless handling or ignorance. In one instance where the water contained more than 0.05 ppm of arsenic, investigations suggested that pollution was not due to spraying of the compound, but to the washing of old sodium arsenite drums.

Coming into prominence during recent years is the problem of pollution of water sources by industries. Instances have occurred where due to lack of liaison between the authorities concerned, factories which would produce effluent detrimental to water sources sprang up in catchment areas of water supply intakes, and quick action had to be taken to avoid pollution of the water supply.

Action is now in hand to review and amend existing laws to ensure better control over discharges of effluents.

A rather unique experience was gained a few years ago in connection with the development of a certain type of swamp water for public supply.

In the southern part of West Malaysia, there are large areas of 'Gelam' swamps through which rivers flow. Normally the water in the rivers can be satisfactorily treated to produce potable water. But sulphides occur in the 'Gelam' soils. Under the reducing conditions which normally exist in these swampy areas, they have no nuisance value. If, however, there is a long drought or a lowering of the water table, the sulphides become exposed and are oxidized to sulphates and sulphuric acid. These in turn dissolve iron, aluminium, and other mineral compounds in the soil. Under such conditions, the water collected from such areas are acidic and contain large amounts of soluble sulphates, iron and aluminium. This phenomenon was unexpectedly encountered in 1961 at a 3/4 mgd treatment plant at Parit Sulong which serves Batu Pahat, and again in 1963 at a 4 mgd treatment plant at Bukit Sebukor which serves Malacca. The normal treatment given to the water had been satisfactory since the plants were contructed, except that on occasions when the pH of the raw water had been noted to fall. Increased dosage of lime had been sufficient to correct this condition. But after a long drought in 1961 in Parit Sulong, and in 1963 in Malacca, it was found that unusually large quantities of lime were required, and large amounts of floc were produced. The floc settled rapidly, but on chlorinating the clear filtered water turned brown. Eventually, it became impossible to produce an acceptable final water, and production had to be stopped. The repercussion was most unpleasant, especially in Malacca where an epidemic of cholera was raging at that time.

The problems associated with 'Gelam' water appear to occur at the onset of a rainy season after an unusual, severe drought, and to clear up as the rain continues and the water table rises. But the period taken for the difficulty to clear itself is uncertain. For the purpose of public water supply, it is now considered prudent to avoid the use of any source which is affected by 'Gelam' soils.

With regard to the development of underground water supply, little attention was given to the exploration and exploitation of this source of supply in West Malaysia prior to World War II. Surface water had been able to meet the demand, and the need for underground water did not arise except for a few scattered rubber estates which had to resort to underground water. Within the last few years, however, there has been an increasing awareness of the need for exploiting underground water in areas such as the coastal plains where there are only limited surface sources of water free from saline water intrusion. The first region to be explored on a more or less systematic basis is the north-western corner of West Malaysia. The preliminary survey undertaken by the Department of Geological Survey was hampered by several factors, including lack of experience in geohydrological investigations at that time, the almost complete absence of details on the composition and structure of the alluvium which covered much of the area, and an imperfect knowledge of the details of the bedrock geology. As was to be expected, the results in some areas were disappointing. At Arau in Perlis, and at Pantai Remis in Perak, underground water has, however, been successfully developed. But the investigation for underground water is a very time consuming undertaking and success is very uncertain. For example, long and futile attempts were made to locate underground water for North Perlis Water Supply and Padang Besar Water Supply, although underground water was found in adjacent area for a sugar factory. Such uncertain venture is not one which any planner would like to undertake unless there is no other alternative.

The location of suitable sources of water for any water supply scheme is thus becoming more and more difficult.

After the difficulties in the planning have been successfully overcome, the planner's next problem is to justify the implementation of the water supply scheme in order to bid for Government's limited financial resources in competition with other development projects. The criteria in justification are the 'Rates of Return' and the 'Benefit/Cost Ratio'. The determination of the internal rate of return in order to compare the investment with the opportunity cost of money is perhaps a sound basis for the evaluation of a scheme. But to achieve a rate of return of 8% to 10% from a water supply scheme planned and constructed, to serve scattered rural population or even small urban population, is almost an impossible task taking into consideration the difficulties mentioned in this paper, unless the rates of water charges are raised above the level at which the general consumers are able or willing to pay.

In the calculation of benefits, a number of intangibles such as control and reduction of water-borne diseases, improvement in the standard of living, social benefits, and contentment of the citizens do not seem to receive enough attention by the controlling authorities of funds because these cannot be easily quantified into monetary values. There certainly is need for evaluating these intangibles in the benefit/cost study of water supply schemes.

A number of planned water supply schemes have been left in abeyance just because they cannot meet the criteria mentioned above.

Until the end of the 1950's the planning and design of all water supply schemes were almost exclusively carried out by the Public Works

Department, the City Council of Georgetown, Penang and the Municipal Council of Malacca. The knowledge and experience required in such work were therefore confined within these three bodies. But since 1961, the staff available in these three bodies cannot cope up with the work load entailed in the enormous magnitude of the development programmes and the rapidity with which they have to be carried out. It has been necessary to appoint consulting engineers to carry out the planning, design and supervision of construction of some of the water supply schemes. At the beginning, such expertise was not found among the local consulting engineers who until then were mainly engaged in structural design. Foreign or foreign based consulting engineers had therefore to be used. But foreign consulting engineers tended to be too sophisticated in their approach, which may be suitable in developed countries but not so in a developing country like Malaysia. The result was that expensive sophisticated facilities were installed giving rise to maintenance problems under local conditions. At the same time, some work has also to be assigned to local consulting engineers in order that they may have a chance to gain experience in this field of engineering. But due to their lack of experience in this field, the already overloaded staff of the Public Works Department has also to guide them and scrutinise the work. In effect the enormous programme of water supply development has to be undertaken with limited suitable manpower in the country.

Paper No. I/14

WATER RESOURCES DEVELOPMENT IN WEST MALAYSIA

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ABSTRACT

West Malaysia has only moderate water resources due to its high potential evapotranspiration. Development of water resources has been going on at a rapid rate. This has given rise to a number of water problems. Rational utilisation and conservation of the available water resources will be necessary in the interest of long-term development needs of the nation.

INTRODUCTION

The fact that the annual rainfall in West Malaysia averages 100 ins generally gives rise to the belief that it has water resources in abundance. However, because of the high potential evapotranspiration which has been estimated to reach nearly 70 ins per annum, the water resources available for use are only moderate.

Although, there is year-round precipitation, the rainfall is by no means evenly distributed. Very heavy convective falls may occur within the space of time varying from a few minutes to several hours. Intensities greater than 4 inches per hour are commonly experienced. In addition, West Malaysia is influenced by two surface winds, namely the Northeast Monsoon and Southwest Monsoon. The Northeast Monsoon often brings heavy rains. In exceptional cases, precipitation resulting from continuous heavy rain can exceed 24 ins within a matter of 24 hours. Also the east and northwest coasts of West Malaysia are occasionally subject to droughts up to 3 months' duration.

Rivers in West Malaysia are generally short and steep for the greater part of their courses, generally with an absence of natural lakes or storage areas. Although, the main river courses are never completely dry at any time of the year, the dry weather flows are generally low compared to flood flows. Annual river flows show high fluctuations.

Hitherto water resources in West Malaysia have been developed for a variety of uses. These, however, are almost exclusively confined to surface water resources. Due to rapid economic development in recent years, utilisation is fast approaching the limit of surface water in certain localities.

PRESENT STATUS OF WATER RESOURCES DEVELOPMENT

Irrigation

Irrigation is by far the biggest consumer of water. Up to 1969, the Drainage and Irrigation Department of Malaysia had a total of 600,000 acres of padi land under its irrigation schemes. This is expected to increase up to about 800,000 acres by 1975 of which 600,000 acres will be under double cropping.

Irrigated rice needs an average of 45 ins of water for the first and over 70 ins for the second crop. Where extensive areas are to be irrigated for 2 crops of rice, the run-of-river schemes are no longer capable of ensuring a reliable irrigation supply. Storage schemes have therefore been developed in recent years for irrigation purposes. The most notable ones are the Krian Irrigation Scheme and the Muda Irrigation Scheme which give a total storage of over 850,000 acre feet.

Water Supply

Development of water resources for water supply for domestic, industrial and municipal uses has increased in recent years by leaps and bounds. The Public Works Department water installation has increased in its total capacity from 105.6 mgd at the end of 1960 to 232.6 mgd by the end of 1970. This is expected to increase by 35% by 1975.

The Federal Land Development Authority schemes account for a substantial portion of increase in water development for domestic and industrial uses. Up to 1970, about 300,000 acres have been developed and a further 300,000 acres will be developed under the Second Malaysia Plan at the rate of 60,000 acres per annum.

The promotion of both urban and rural industries since recent years will further require the development of water resources for additional water supply.

Hydroelectric Power

The installed capacity attributed to hydroelectric power is estimated to be 270 MW. It is expected, that this figure will be increased several fold in the very near future to meet the domestic and industrial needs. The National Electricity Board and the Perak Hydro have to-date impounded some 2,900 sq miles of watershed for power generation. Future possible schemes may command a further 10,000 sq miles of watershed.

Flood Control

Flood problems in West Malaysia are largely inherent from the fact, that the bulk of the population is centred on the valley tracts and coastal plains liable to be subjected to flooding. Consequently, floods occur on a very vast scale. In the 1967 catastrophic flood for instance, over half a million people in the Kelantan basin were affected. The cost of damage was estimated at M$30 million. Further flood damage is bound to increase considerably due to increased development and prosperity in such populated areas as are likely to be subjected to flooding.

Flood control will therefore play a more and more important role in the future development and the conservation of water resources. To be effective, flood-control should be a combination of structural and non-structural measures. Flood forecasting and warning, flood plain zoning and watershed management are all as much an integral part of flood control as other physical flood control measures such as flood retention dams, channel improvement, and flood bypasses, etc.

Water Quality Control

Various forms of river pollution exist in West Malaysia. Physical pollution in the form of sedimentation is largely attributed to mining activities, land development activities, forest exploitation and natural erosion. The scale of physical pollution due to land development activities has been on the increase in recent years as is evident by the large acreage of forest being converted to agricultural land. During the last ten years, approximately ¾ million acres of jungle have been opened up for agricultural purposes.

Chemical pollution is also on the increase due to a greater use of fertilizers and pesticides, etc. for agricultural purposes and also due to effluent and wastes of a chemical nature discharged from factory plants.

Legislation has been in existence for the control of physical pollution. Of late legislation has also been introduced to control chemical pollution. Whilst it is not practicable to have absolute control on pollution, it is desirable to exercise judicious control to achieve an optimum condition, whereby industrial development can take place without serious adverse effect on the water resources. Practical guidelines will have to be developed and tested in order that such judicious control can be brought about.

WATER PROBLEMS

The rapid rate of development of water resources projects in West Malaysia has brought about many problems. Whilst the total available surface and ground water resources will not increase, the utilisation of such resources will be at a greater rate in the years ahead. Apart from the fact that in certain localities, exploitation of surface water resources has reached its limit, there are also signs of competition amongst different water users. Problems associated with water resources development may be listed briefly below.

In the first place, there is little account of the availability of water resouces for planning purposes. As a result, planners of water development projects often find difficulty in making a quick and reliable assessment of the water resources available in the project areas. In many instances, the lack of hydrological data has caused delay in project implementation or otherwise costly projects to be undertaken in order to allow for contingencies.

Forestry no doubt plays an important role in conserving the available moderate water resources in West Malaysia. The effects of large-scale clearing of forests and jungles for agricultural and other uses has attracted more and more attention in recent years. Among some of the more severe consequences are the reduction of dry weather flows, increase in peak flood flows and erosion and subsequent silting up of reservoirs and river channels.

It will be noted from the discussions above, that the water resources available for development decrease with the increase of the quantity of such resources being polluted. In river basins, where urbanisation and industrialisations are fast taking place, the degree of stress on water resources will become more and more apparent.

WATER RESOURCES PLANNING

The problems posed by the diminishing uncommitted water resources and the rapid rate of water resources development call for a rational utilisation of water and a concerted effort towards water conservation. This in turn necessitates a total water resources planning approach.

Basic to this requirement is a proper inventory of the available surface and groundwater resources, an account of water resources that have already been committed for various uses. Areas of stresses in terms of water resources can then be identified. Similarly opportunities for further water resources development can then be made known. There is also a need to monitor pollution of water resources of various forms and to introduce judicious control with a view to preserve the water quality whilst at the same time permitting other forms of economic development to take place.

There is finally the need for integrated water resources planning on the basis of a total river basin taking into account the inter-relationship of agricultural and other development and the various forms of water development with a view to achieving optimum catchment development conditions.

Paper No. I/15

IMPROVED WATER MANAGEMENT FOR PADDY RICE PRODUCTION IN THE PHILIPPINES

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ABSTRACT

The establishment of pilot projects on water management in a representative irrigation system within the 8 irrigation regions of the Philippines was made possible, with the technical and financial assistance given by the Asian Development Bank. It was a bold and determined effort initiated by the National Irrigation Administration of the Republic of the Philippines, as an integral part of its socio-economic development programme.

Improved water management for paddy rice production include the integrated processes of diversion, conveyance, regulation, measurement, distribution, and application of the right amount of water at the proper time and removal of excess water from farms to promote increased production in conjunction with improved cultural practices.

The project covers the broader aspects of bringing agriculture, science and technology to the rural areas, concerning the judicious use of irrigation water in consonance with the proper use and application of inputs, training of NIA technical and subtechnical personnel re-education and extension services for farmers and undertaking of basic and applied research studies on water use in conjunction with improved cultural practices.

As an innovative approach in the management and use of irrigation water in the Philippines, activities were geared toward a continuing effort to search for a new direction in pursuing a realistic programme and be able to work out and demonstrate the most suitable water management practices, to increase the crop area satisfactorily and profitably served, with a suitable cropping pattern for increased productivitiy and possible income, due to proper land use; and to organize the farmers into viable irrigators' associations within the command area of the system or project for the successful implementation of a well coordinated water distribution programme.

Water management involves disciplines in irrigation/civil/agricultural engineering, agronomy, economics, extension and adult-farmers education, sociology, hydro-meteorology and cooperatives.

Water as the life-blood of all farm activities can spell abundance if managed and pursued towards the right direction.

INTRODUCTION

Insufficient water resources and poor management of irrigation water have been singled out as one of the main reasons why the Philippine irrigation systems could not fully irrigate its potential irrigable areas, as originally designed. The above-mentioned impressions and situation can be changed with the implementation of several water resources development projects. Initial steps were taken when a bold and determined water management project was set-up in the Philippines through the National Irrigation Administration (NIA) with technical and financial assistance from the Asian Development Bank (ADB).

The National Irrigation Administration of the Republic of the Philippines, the implementing agency for irrigation, prior to the establishment of the NIA-ADB Water Management Project has 86 national and 2 Friar land irrigation systems with a total potential irrigable area of 324, 193 ha, 82.61% of which could be irrigated during the wet season and 34.42% during the dry season. The irrigation system under such a situation either does not deliver the necessary water requirement for the service area and/or the end users/farmers are wasteful in its use of irrigation water. A combination of these unmindful attitudes of the farmers further aggravate the problems during the dry season, when there is no rainfall.

Fiscal policy experts and economic planners of the government of the Republic of the Philippines, thought of constructing additional systems and storage dams, but it requires a large amount of capital investment without assurance that irrigation water will be used properly.

Improvement of irrigation water management, therefore, appeared to be the most logical solution to these problems, economy-wise. With proper tie-up with the agricultural sector, the end users or farmers; equitable water delivery schedule and distribution, use of high yielding varieties of rice, fertilizers and farm chemicals and other cultural and management practices, increased production is highly expected, barring unforeseen calamities.

With the advent of the NIA-ADB Agreement, 8 pilot projects on improved water management were established in the Philippines, strategically located in the 6 regional irrigation offices in the country.

WATER MANAGEMENT DEFINED

Water management is the integrated processes of diversion, conveyance, regulation, measurement, distribution, and application of the right amount of water at the proper time and removal of excess water from farms to promote increased production in conjunction with improved cultural practices.

Increasing the capability of the land for sustained agricultural production, through proper water and land use are clearly indicated in the definition, thus the improvement of the level of living conditions of the people within the service area of a water resource development project can be easily attained provided proper water use can be correlated with the use of proper and the right amount of production inputs such as fertilizers, farm chemicals, etc.

PROGRAMME OBJECTIVES AND OPERATING GOALS

The Improved Water Management Project for paddy production in the Philippines has 4 distinct objectives:

(1) to work out and demonstrate the most suitable water management practices to increase the crop area satisfactorily/profitably served;
(2) to work out and demonstrate a more suitable cropping pattern to increase productivity and possibly income;
(3) to organize irrigators association for the successful implementation of a well coordinated water distribution.
(4) to adopt the pilot area as a training center for on-the-job training of NIA personnel and farmers.

The joint venture of the NIA-ADB on improved water management is the first case attempt ever made along this line in the Philippines, and maybe in Asia.

The National Irrigation Administration (NIA) and the Asian Development Bank (ADB) implemented water management on a team-approach basis. The team is action-oriented, composed of irrigation engineers, water management experts, agronomists, agricultural economists and soil classification experts.

It should be understood in this connection, that rice plant and other crops need only a certain amount of water under its different growth stages and development to produce optimum production, provided the use of inputs is coordinated or tied-up with the irrigation water application.

The implementation of water management within a pre-selected area in an operational irrigation system, is coordinated by the pilot project in-charge, with the chief or irrigation systems, and/or irrigation superintendents or provincial irrigation engineers.

BRIEFS OF ACCOMPLISHMENTS

Inventory of Terminal Facilities

Proper irrigation, water delivery and equitable water distribution within the service area of an irrigation system can only be made possible via a complete terminal facilities and other essential irrigation structures.

As a first step, therefore, upon the start of the NIA-ADB Project, aimed at improved water management in the country, proper inventory of these facilities and structures were undertaken.

Data Collection

Data on meteorology, agronomy, soil, water, and other items of great interest in the planners and implementors of the water management project were likewise collected, to serve as a benchmark and as a guide for the initial operation of the project on a pilot scheme basis.

Agro-Socio-Economic Survey

An agro-socio-economic survey was also conducted, to determine the socio-economic status of farmers within the project area. Data collected were analyzed and were used as basis for recommending proper procedural approaches on what work schedules, varieties of rice to use, fertilizers and farm chemicals to apply and the weakest point possible on the side of the farmers, if and/or when provided with remedial measures or appropriate recommendations will result in proper land use, efficient water utilization and inputs use in consonant with the tangible aim of the project of increasing production.

Construction of Measuring Devices and Other Terminal Facilities

The necessary measuring devices to measure and/or determine the proper amount of water to deliver, as required in the design of paddy water requirement within the pre-selected pilot areas, including other terminal facilities for efficient and equitable water delivery and distribution, were constructed after serious consideration and study.

Operating Strategies on a Pilot Scheme Basis

Eight pilot projects in 8 irrigation systems representing the 6 irrigation regions of the Philippines, were pre-selected, and an accessible area for implementing water management practices, became the focus of attention, from a team of a skeletal force, designated and given the responsibility of introducing water management innovation.

The pilot projects are within the geographical service areas of the Angat River Irrigation System, Bulacan; Binahaan River Irrigation System, Leyte; Cagaycay River Irrigation System, Camarines Sur; Jalaur River Irrigation System, Iloilo; Magat River Irrigation System, Isabela; Penaranda River Irrigation System, Nueva Ecija; Sta. Cruz River Irrigation System, Laguna; and Libungan River Irrigation System, Cotabato.

The main staging areas of operation, however, are the pilot projects in the ARIS area in Bulacan and PRIS pilot area in Nueva Ecija; where detailed technical assistance in planning and field implementation were concentrated. For proper dialogue with the farmers, field offices in all the pilot project areas were constructed as their common meeting place.

The 140 hectare pilot farm in the ARIS area was subjected to a rotational irrigation practice by section of farmditches as designed on a 6½ day interval during the dry season at 12 mm per day water requirement. The rotation interval, however, during the rainy season is 6½ days at 10 mm per day water requirement.

As the project progresses, water requirement was reduced to 10 mm per day for the dry season and 8 mm per day during the rainy season.

Diffused on Division Level Basis and Other NIA Systems

Later on, the service area of Lateral D, ARIS, Bulacan was selected as a pilot project on water management on a division level basis consisting of an area of 1,524 ha.

Records of the previous operation and maintenance undertaking in ARIS, shows that 6 barrios (villages) do not receive the appropriate supply of irrigation water even during the rainy season alone, contributing mainly to the failures of paddy rice production; creating confusion, chaos and disappointment among farmers in the barrios.

With the introduction of improved water management practices, however, in the said area, 15 farmers planted their second crop on a trial basis during the dry season of 1970. Their first paddy rice crop after 44 years of farming frustrations, was satisfactorily served with enough water, thus the water management people were able to win back their confidence.

The watermaster and the 10 ditchtenders in the division were called to a conference. Details of the water management programme proposed for the area and the strategies of implementation were discussed.

Lateral D and its sub-laterals and farmditches were calibrated, to make sure that it can carry the peak water requirements, and can deliver the right amount of water to the service area on time.

It is of interest to mention in this connection, that there now exist an Operation and Maintenance Department in the NIA. Among its various functions are the implementation of improved water management on a system-wide/national in scope basis and systems developments.

Ditchtenders were required to close all gaps and attend religiously to their work. Turnouts were gated. Ditchtenders were taught to read and record water discharge measurements. Strict adherence to the rules and strategies of implementation were carried out.

Indoctrination Campaign

Meetings with farmer-clientele in the area were held, supplemented with farm and home visits and personal calls.

Water supply had been assured. Water is coming. A second crop of rice can be raised profitably. These were assured to the farmers. Despite these assurances, however, the farmers are still reluctant to plant a second crop of rice. They had several bad experiences in previous years.

During one of the campaign meetings with farmers, various remarks heard were: "That is not true." "It's only a gimmick." "We are fed up with similar promises."

The team, upon gauging the "we are fed up" attitudes of the farmers, intensified and conducted a series of educational and change-of-attitude campaigns, to ward off their beliefs and bad impressions, that the irrigation system cannot supply the needed amount of water to sustain continuously the water requirement for the vegetative and reproductive growth phases of their rice plants so that profitable level of production could be obtained.

Through existing barrio associations and organized interest groups, the idea of improved farming practices as a corollary to improved water management had gradually and steadily gained a foothold among farmers – the pillars of the agriculturally-based Philippine economy.

The farmers feel secured in their farming ventures later on. The idea of improved water management have swept the barrios and spread like wild fire among farmers. The chain of fear for lack of water to sustain the crop growth requirements had been broken by the silent and peaceful revolution in the field of water management that creep gradually into the minds of the farmers.

Their beliefs and attitudes had been changed-via the audio-visual principles of education by using the 5 senses: hearing, seeing, feeling, smelling, and testing. The farmers are now happy. They now have water for the first time in 44 years, and more so, during the summer months of March and April. Investment in farming can now be surely repaid; and the gain per peso invested can surely be used for the comfort of their families.

Crop failures had been avoided. The average production obtained per hectare is 2.64 tons (60 cavans), where the farmers harvested none before. The role played by the water management team coupled with the spirit of cooperation and eagerness on the part of the farmers to improve their standard of livelihood have provided a very encouraging atmosphere to all concerned.

Good Harvest, Despite Tungro Infestation

Timing is an indispensable factor considered in water management implementation, in relation to water application, weeding, plant protection, fertilizer application, and the adoption of proper care and management techniques in rice production.

Despite the widespread tungro infestation, it is of interest to mention, that farmers in the ARIS Pilot Area got a highly profitable harvest. Water management, therefore, is one of the insurance factors against crop failures.

Results of the rice production contest, jointly sponsored by the Irrigators-Seed Growers' Association, Inc., and the NIA Water Management Project, show that the First Prize Winner, Nonilo Katipunan got an average yield of 6.82 tons (155 cavans) per ha; Second Prize Winner, Alberto Paulino harvested 5.41 tons (123 cavans) per ha, and Third Prize Winner, Ricardo Fernandez, got 5.10 tons (116 cavans) per ha. Majority of the farmers got at least 3.08 tons (70 cavans) per ha. Good harvest can be assured through strict adherence to the time element in water application, use of the right amount and kind of fertilizers and adoption of good cultural and management practices.

Water management, therefore, can be literally considered as an effective insurance for improved agricultural production and a sure deterrent factor against crop failures.

Follow-up Activities

The Water Management Team sustained the operation and the continuously increasing demand for irrigation water, due to increase in the number of farmers that wanted to plant their second crop of rice and its corresponding increase in area irrigated.

Precautionary measures to minimize tungro infestation had been given to the farmers. Popularly written instruction in Philippines, to control the deadly effects of the disease had been prepared and distributed to farmers.

Signs of Rejoicings

Farmers all over the area show signs of rejoicings. Idleness on their part had been a thing of the past.

A 2 rice crop production pattern had gained a strong adherence among farmers in the area, increase, therefore in their rice production is more than 100 per cent, by considering that production per crop per unit area has increased two-fold, from 1.32 tons (30 cavans) to 2.64 tons (60 cavans) per ha.

It is lamentable to note, that their single rice crop before the introduction of water management does not give a profitable level of production, to guarantee a decent level of livelihood for them and their families.

Out of the 15 ha planted with paddy rice in 1970 by 17 farmers in the previously mentioned barrios it has now increased geometrically to 150 ha (up to this writing) which is equivalent to 900% dramatic increase in hectarage plants

A directive from the NIA Administrator, Alfredo L. Juinio, to implement water management to all NIA operated and maintained irrigation systems had been sent to all systems in-charge, for their proper guidance in the manner of undertaking improved water management operation in their respective systems.

Water Control Innovations

Innovative programme for improved water management is not usually and easily accepted by the end-users, especially so, during the initial stages of implementation.

However, with proper dialogue among farmers and NIA personnel, water control and distribution innovation are now becoming a regular pattern of an established institution, happily accepted in areas where the water management programme had been introduced.

Continuing Search for New Direction

To be able to introduce innovative undertaking in water management, a continuing research and establishment of trials and demonstration plots, are a regular part of the programme, i.e. basic and applied researches.

The impact of improved water management practices can be strongly felt in collaboration with the use of proper production inputs such as, fertilizers and farm chemicals and proper care and management practices, including the use of properly selected seeds from high yielding varieties (HYV) highly suitable for planting for profitable income in the area.

TRAINING OF TECHNICIANS

To enhance the technical capability and efficiency of the NIA professional staff in the field of improved water management operation, 4 training courses, considered extremely significant in attaining the long-term objectives of water management implementation in the Philippines were conducted at the headquarters of the NIA-ADB Water Management Project in San Rafael, Bulacan, while the Technical Assistance was in force.

Technically trained manpower in the field of water management implementation are the "Catalyzers" of innovation in the revolutionary introduction of a change that will totally improved Philippine farms.

A total of 64 participants were taught the techniques of water management at the San Rafael Project Office during the three in-service training courses conducted by the NIA-ADB team. The fourth training courses conducted by the NIA-ADB team in May 1970 was for watermasters and ditchtenders and irrigation technical personnel, who would be designated later on as water management trainers in their respective areas of operation.

In addition to the training programme in the Philippines, 4 NIA engineers were sent abroad, 2 to the Republic of China and 2 to Japan, to observe advanced management of irrigation systems for a period of 4 months each.

It is hoped that the radiation coverage and influence of water management can be felt through these nucleus of trained manpower in the whole country.

Special classes for ditchtenders are also being conducted.

BASIC AND APPLIED RESEARCH

The Philippine Water Management Project has conducted some basic and applied researches on water use in conjunction with improved cultural practices.

Summaries of some of these studies and other observations are hereby presented. Results of these studies had been published in a pamphlet form, for the information and guidance of all field technical personnel of the National Irrigation Administration, in implementing improved water management in their respective systems.

Soil Moisture Stress Study – Paddy Field
(Direct Measurement of soil cracks in relation with soil moisture content)

Results of the study showed that the mean yield as affected by the treatments did not reach the significant level. Treatment D1 (Panicle initiation to heading-continuous submergence) gave the highest mean yield of 4.18 tons (95.17 cavans) per ha while treatment D3 (Panicle initiation to heading soil crack is about 1/4 inch wide) gave the lowest mean yield of 3.62 tons (82.36 cavans) per ha.

The soil moisture depleted daily ranged from 0.51 mm to 14.21 mm. The results obtained show an irregular pattern of depletion. As the average moisture content decreases size of cracks increase.

Moisture Stress Effect on Plant Growth and Yield

It is a well known fact that plants wilt as the moisture content of the soil is depleted to a point known as the permanent wilting point. Baver stated that the addition of water to dry soils results in increased plant growth and greater yields. Generally, plant growth and yield are affected as the soil moisture content is decreased.

Analysis of the data shows that the mean yield as affected by the treatment did not reach the significant level. Treatment D1 or control plot gave the highest mean yield of 4.18 tons (95.17 cavans) per ha, while treatment D3 or 1/4 inch crack gave the lowest mean yield of 3.62 tons (82.36 cavans) per ha. The result of the study is in consonance with the previous findings of a study on the effects of drainage on rice yield conducted within the ARIS Project Area.

Determination of Effective Rainfall

Two conditions of paddy dikes, improved or mud-lined and ordinary or unlined were tried to determine the rainfall efficiency and total water use and its effect on the yield of paddy rice. Results of the study showed that Lot I (improved dike) yielded an average of 3.98 tons (90.58 cavans) per ha and required less irrigation water, 414.30 mm in depth and retained 127.98 mm of rainfall (78.11% of the actual) or a total paddy water requirement of 542.28 mm, while Lot II (ordinary dike) produced 3.46 tons (78.80 cavans) per ha and needed 443.50 mm depth of irrigation water and retained 124.07 mm of rainfall (75.72% of the actual) or a total water requirement of 567.57 mm.

Comparative Study on Methods of Transplanting

Two methods of transplanting, ordinary or random planting and straight planting were tried to determine its effect on the yield of IR22 rice variety. Results of the study revealed that straight planting out-yielded significantly ordinary or random planting. However, significant difference in yield was observed between 20 x 15 cm and 20 x 20 cm spacings, (See Table I).

The total plant population per hectare at 20 x 15 cm is 320,750 hills, while at the distance of 20 x 20 cm, plant population is 240.563 hills. These figures have been arrived at, after deducting 12,583 and 9,437 hills respectively, in an area of 377.5 m² of paddy dike. (Average length of paddy dikes in an irrigated area is 755 lineal metres per ha).

With the mean yield of 4.63 tons (105.45 cavans) per ha for the 20 x 15 cm distance and 4.05 tons (92.26 cavans) for the 20 x 20 cm, there is a yield difference of 0.58 ton (13.18 cavans) in favor of the 20 x 15 cm distance. This difference can be attributed to the greater number of plant population per ha for the 20 x 15 cm distance.

As per yield component analysis, both treatments exhibited a high percentage of good grains, with insignificant difference in the number of productive tillers.

With the 20 x 15 cm distance, 3,040.80 hills can produce a cavan of palay, while in the 20 x 20 cm distance, a cavan can be produced from 2,607.44 hills.

Continuous Submergence vs. Intermittent Irrigation

Continuous submergence and intermittent irrigation were used to find out its effect on the growth and yield of IR20 rice variety. The result of the study showed that there was no significant difference in yield between the two irrigation methods. Continuous submergence gave an average yield of 4.15 tons (94.53 cavans) per ha while intermittent irrigation gave a mean yield of 3.87 tons (87.96 cavans) per ha.

Twenty-three day-old IR20 rice seedlings were transplanted in straight rows, 15 x 15 cm with 2 to 4 seedlings per hill. The rate of fertilizer applications was 90-30-30 kg NPK/ha. Basal application of 40-30-30 kg NPK/ha was done on Nov. 5, 1970 First top dressing of 30 kg N/ha was done on Nov. 18, 1970, and second top dressing was done on Jan. 12, 1971 at the rate of 20 kg.

Methods of Planting	Sample Number 1	2	3	4	5	Total	Mean
T1 – Ordinary	62.13	75.25	73.22	68.68	63.93	345.71	69.14
T2 – 20 x 15 cm.	125.13	102.47	93.13	104.86	101.68	527.27	105.45
T3 – 20 x 20 cm.	105.25	102.70	83.95	80.34	89.06	461.30	92.26
Total	292.51	282.92	250.30	253.88	254.67	1334.67	

Table 1. Computed Yield Per Hectare in Cavans (44 kg per cavan)

N/ha. Gamma BHC was applied to the plants on Nov. 18 and Dec. 23, 1970 at the rate of 25 kg/ha, per application. The plants were also sprayed with insecticides like Diazinon 20E, Fosferno 50 and Folidol M50 at recommended dosages. Weedicide was also used to control the growth of weeds.

Grain Yield in Cavans

Analysis of the data shows that the mean yield as affected by the two irrigation methods did not reach the significant level. Continuous submergence gave an average yield of 4.15 tons (94.53 cavans) per ha while intermittent irrigation gave a mean yield of 3.87 tons (87.96 cavans) per ha.

Soil Moisture Stress Study – Lysimeter
(Direct measurement of soil cracks in relation with soil moisture content)

Three treatments, TA(continuous submergence), TB (two weeks stress at booting) and TC (3 weeks stress at booting) were used to determine its effect on the growth and yield of IR5 rice variety. Results of the study showed that there were no significant difference in yield as affected by the treatments. The control plot TA gave the highest computed yield of 8.22 tons (187 cavans) per ha followed by TB, 7.89 tons (179.5 cavans) per ha and TC, 7.33 tons (166.6 cavans) per ha.

Methods and Procedures

Three lysimeter tanks measuring 2 x 2 metres each, were thoroughly prepared and transplanted using IR5 seedlings on October 6, 1970, 3 seedlings per hill, 20 x 20 cm distance. The rate of fertilizer application was 150-50-50 kg per ha basis. Plant protection and weeding were uniformly given to the rice plants.

TB and TC were drained on December 21, 1970. Soil samples from TB were collected daily from December 22, 1970 to January 4, 1971; soil samples from TC were also collected daily from December 22, 1970 to January 11, 1971. Average size of soil cracks were also measured daily during the stress period.

The weight of soil samples fresh and oven dried were taken. The moisture content was determined by using the formula:

$$\%\text{M. C.} = \frac{\text{weight of wet soil} - \text{weight of oven dried soil}}{\text{weight of oven dried soil}} \times 100$$

The plants were harvested on February 26, 1971.

Size of Soil Cracks

Slight cracking of the soil was observed 3 days after water was drained. At the 14th day of observation or stress period of 2 weeks, the average size of cracks was 14.0 mm and 28.0 mm on the 21st day.

It can also be seen from the same table that the size of cracks increases as the soil moisture content decreases.

Water-Use Study

	Non-Pilot Area	Pilot Area
Irrigation Water Applied	1,125 mm	427 mm
Effective Rainfall	534 mm	534 mm
Total	1,659 mm	961 mm

This comparative water-use observation was done in the ARIS Pilot Area of 140 ha and within the non-pilot service area of the Angat River Irrigation System during the first crop in 1969.

The total irrigation water applied for the non-pilot area was 1,125 mm while only 427 mm was used in the pilot area. Total rainfall recorded for both the pilot and the non-pilot area is 890 mm. Effective rainfall considered is 60% of the total rainfall that fell in the area which is equivalent to 534 mm.

Total water-use for the non-pilot area was 1,659 mm, while the pilot area had a total water-use of only 961 mm. Considering that the total number of days of irrigation period is 100 days, more or less, water-use would be 16.59 mm/day for the non-pilot area and 9.61 mm/day for the pilot area.

On a crop-hectare basis, savings in water was 698 mm or 6,980 m^3 in favour of the pilot area, which is equivalent to 72.6 percent of the total water-use under the pilot scheme basis.

Effects of Drainage on the Growth and Yield of IR5 Rice Variety

Summary

Analysis of the data shows that there is no significant difference among treatments A, B, C, and D. Treatment A obtained an average yield of 5.93 tons (134.9 cavans) per ha, while treatment B and C yielded 4.56 tons (103.7 cavans) and 4.16 tons (94.6 cavans) per ha, respectively, as against 3.94 tons (89.5 cavans) for Treatment D (control).

Treatment A out-yielded the control plots by as much as 1.99 tons (45.4 cavans).

Experimental Procedures

An area of 4,000 m² was selected within Rotation Area A. Soil type is silty clay loam. The farmditch serving the area was concrete-lined. Four treatments were designated, with 2 replications each, Treatment A (10 days drainage at tillering); Treatment B (10 days drainage at booting); Treatment C (10 days drainage at heading time) and Treatment D (control or continuous submergence).

The paddies were thoroughly prepared and 50-30-30 kg each of NPK fertilizer was applied before the final harrowing.

Twenty-day old IR5 rice seedlings was transplanted on June 1, 1970, in straight rows spaced at 20 x 20 cm at 2-4 seedlings per hill.

The regular irrgation interval used was 7 days at 42 mm water depth per application.

The pattern, however of water application was interrupted for 10 days as called for in the design of the study.

The additional nitrogen requirement of 20 kg each was top dressed at 30 DAT respectively.

Gamma BHC was applied at the rate of 30 kg per ha per application at 18th, 31st and 66th DAT to control common rice pests.

Supplemental spraying of Sevin 85 WP was done at 23rd DAT and Folidol M-50 at 51st DAT.

Results and Discussions

Grain yield in cavans

The average yield as affected by the 4 treatments is shown in Table 2. Analysis of the data shows that the average yield as affected by the 4 treatments did not reach the significant level. However, Treatment A (10 days drainage at tillering) gave the highest average yield of 5.93 tons (134.9 cavans) per ha and Treatment D (control) gave the lowest mean yield of 3.94 tons (89.5 cavans) per ha.

Agronomic Characteristics

Other observations such as number of productive tillers, height of plants, length of panicles, and percentage of empty grains showed that there were no significant differences as affected by the four treatments, (See Table 2).

Treatments (10 days Drainage)	Average Yield Per Hectare, Cav. (44 kg/cav.)	Average Height at Maturity (cm)	Average No. of Prod. Tillers/Hill	Average Length of Panicles (cm)	Average Percentage Chaff per Treatment
A) Tillering	134.9	125.47	15.5	24.52	30.28
B) Booting	103.7.	123.67	14.9	24.02	22.27
C) Heading	94.6	123.60	13.9	23.65	21.26
D) Control	89.5	116.55	14.5	23.82	26.74

Table 2. Computed Yield Per Hectare and Other Agronomic Characteristics

Effects of Drainage on the Growth and Yield of IR22 Rice Variety Lysimeter

Variety IR22

Date Planted .... June 10, 1970

Date Harvested .... September 29, 1970

Date of Seedlings .... 10 days

Spacing .... 20 x 25 cm

Type of Soil .... Silty clay loam

Rate of Fertilizer .... 90-30-30 kg NPK per ha

Basal Application .... 50-30-30 kg NPK

Top Dressing

(1) 20 kg N at 45 days after transplanting
(2) 20 kg N at 80 days after transplanting

Plant Protection

(1) 25 kg/ha, Gamma BHC per application at 10, 45, and 70 days after transplanting.
(2) Supplemental spraying of Sevin 85 WP at 28 and 50 days after transplanting.

	Treatments (10 days drainage)	Grain Yield per plot (grammes)	Computed Yield per ha. (cavans)
(a)	At Tillering	3,351.3	182.10
(b)	At Booting	2,773.0	150.70
(c)	At Heading	2,721.7	147.90

Rooting Habits of Rice Plants in the ARIS Pilot Area

Observations were made from representative areas during the 1970-1971 wet season crop. The varieties planted were IR5, Binato, IR8, Intan and C4-63. A hectare was planted to a glutinous variety.

It can be noted in Table 3 that root lateral ramification for Rotation Areas I and B are wider in circumference at 26.3 cm. Soil textural class in both Rotation Areas is silty clay.

On the other hand, downward penetration are highest within Rotation Areas I and II at 27.3 cm followed by Rotation Area B at 27.2 cm in depth.

In Rotation Areas II and III, rice plants exhibited a lateral ramification of 23.9 cm and 25.2 cm respectively. Root penetration of rice plants in Rotation Area III was observed to be 26.6 cm in depth, (Table 3).

It may be observed that rice plants in Rotation Area A, exhibited an average root ramification of only 17.8 cm and root penetration of 18.7 cm, which is the lowest average among the 5 rotation areas under consideration.

All rotation areas have a soil textural class of silty clay except Rotation Area A which has a silty clay loam textural class. Paddy fields in Rotation Area A are always submerged due to lack of drainage facilities. Rain water that fell on the access road at the right embankment of the lateral canal, usually flow towards the paddies of the area.

In a latter observation, IR20 planted at a distance of 20 x 15 cm has a downward root penetration of 28.3 cm and a lateral root ramification of 18.2 cm; while IR22, on the other hand, exhibited a downward penetration of 26.7 cm and lateral ramification of 16.4 cm Variety C4-63

Rotation Area	Average Values		Soil Texture
	Lateral (cm)	Downward (cm)	
I	26.3	27.3	Silty clay
II	23.9	27.3	Silty clay
III	25.2	26.2	Silty clay
A	17.8	18.7	Silty clay loam
B	26.3	27.2	Silty clay

Table 3. Rooting Habits of Rice Plants Wet Season Crop 1970-1971

(broadcast method) exhibited 28.9 cm downward movements of the roots and 17.0 cm ramification laterally.

Research findings shows that 80% of the roots of the rice plants are within the 10 cm depth of soil in irrigated areas, while in the non-irrigated areas, 90% of the root systems are within the 15 cm stratum depth.

For efficient plant nutrition utilization, a mud depth of 30 cm but not more than 45 cm is considered ideal. Beyond this range, it will be detrimental to the rice plants.

Knowing the depth of root penetration and the rage of soil moisture depleted daily within the 30 cm stratum depth of soil, is a good guide for determining the proper date of next water application, especially in areas where water is at the minimum, without interferring with the yield potential of the rice plant.

In a study conducted by the NIA Assistant Administrator, Conrado G. Mercado, average production cost per cavan was P13.26 for irrigated areas, for two agricultural years (2-first crops and 2-second crops) while under the non-irrigated areas, cost was P14.98 per cavan. For the NIA Pilot Area, cost of production per cavan was found to be P14.14.

SUPPORTING EXTENSION SERVICES

As mentioned earlier the implementation of improved water management practices in the Philippines was carried on the basis of a unified team approach.

The innovative processes in the introduction of

A Case Study on the Cost of Production for a Cavan of Palay in the ARIS Pilot Area

Items of Work/Expense	Ordinary Method	Improved Method
Seedbed preparation and sowing	P20.00	P20.00
Land preparation	100.00	100.00
Transplanting (pulling, bundling and hauling of seedlings)	67.00	92.00
Care of transplanted paddy	18.00	196.00
Harvesting and threshing	207.00	318.40
Hauling	P15.00	P33.60
Irrigation fee	35.00	35.00
Land tax	6.00	6.00
Seeds	30.00	30.00
Fertilizers	None	221.00
Farm chemicals	None	46.00
Interest on production loans	P29.89	65.88
Total production cost	528.09	1,163.88
Yield in cavans (44 kg)	37	83
Cost of producing a cavan	P14.27	P14.02
Difference in cost of production	0.25	
Total value of production	1,036.00	2,324.00
Net profit	507.91	1,160.12
Difference in net profit		652.21

water management on the farm level in the Philippines needs such supporting services from the agricultural sector. The programme itself. involves changes in approaches in the engineering and agricultural aspects.

The manner of improved water management implementation, can be well understood by the farmers, if done in an approach that considers their level of education, beliefs and traditions, and attacks the problem on an "as-is-where-is" principles in community development and adult education; where the programme intended for the farmers are started from where the farmers are.

All possible avenues were tested and tried by the the NIA Water Management Team, in order to strengthen the extension work of the group, on a grassroot democratic approach via the printing of popular literatures about the project and its objectives; leaflets on modern farming practices, preparation and showing of slides, use of the radio, public meetings and barrio forums.

Local officials such as barrio and municipal officials were contacted; and their assistance solicited for the proper promotion of the NIA programme on improved water management, for the good of their constituents.

Home visits, farms calls, individual contacts and other personalized calls were done by the project staff.

In some instances, the team worked through the existing/organized associations in the barrio where the dissemination of useful and technical informations can be easily done.

PROJECTED PROGRAMMES

Based on the successful experience of the Philippine Water Management Team, the approach practice has been radiated/diffused on division level scheme. Three watermasters' division, with a combined approximate area of 5,000 ha, more or less, had been pre-selected for division level approaches in improved water management, preparatory to an intensified system-wide integrated operation.

As tried in Division II, southside of the Angat River Irrigation System (ARIS), the practice can be successfully radiated to all the NIA operated-systems.

Division office of the respective watermasters are new in preparatory construction to bring the management of the system closer to the end-users/farmers.

Construction of necessary turnouts and farm-ditches in the whole service area of the ARIS, has been given a high priority for funding.

To facilitate closer supervision and inspection, posting of ditchtenders' whereabouts had been strictly required. A day of the week had been set-aside to thresh out problems and difficulties encountered during the previous week of operation and be discussed thoroughly so that proper solution can be formulated.

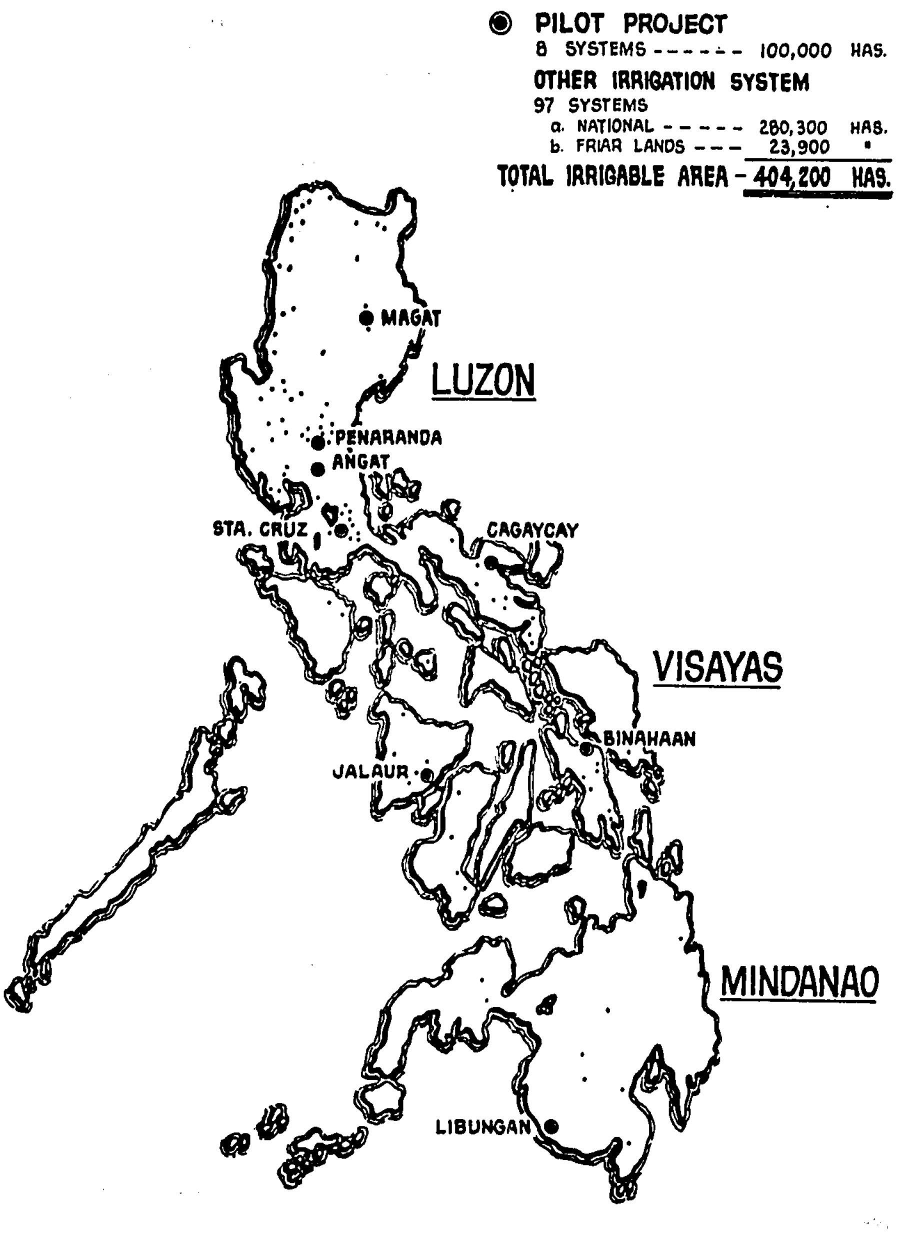
The success of improved water management services has some contributory factors, such as good seeds from a high yielding variety, appropriate fertilizers and farm chemicals and other modern farming practices in the increase in yield per unit area. A programme of adult-farmers' re-education campaign is a continuing part of the undertaking.

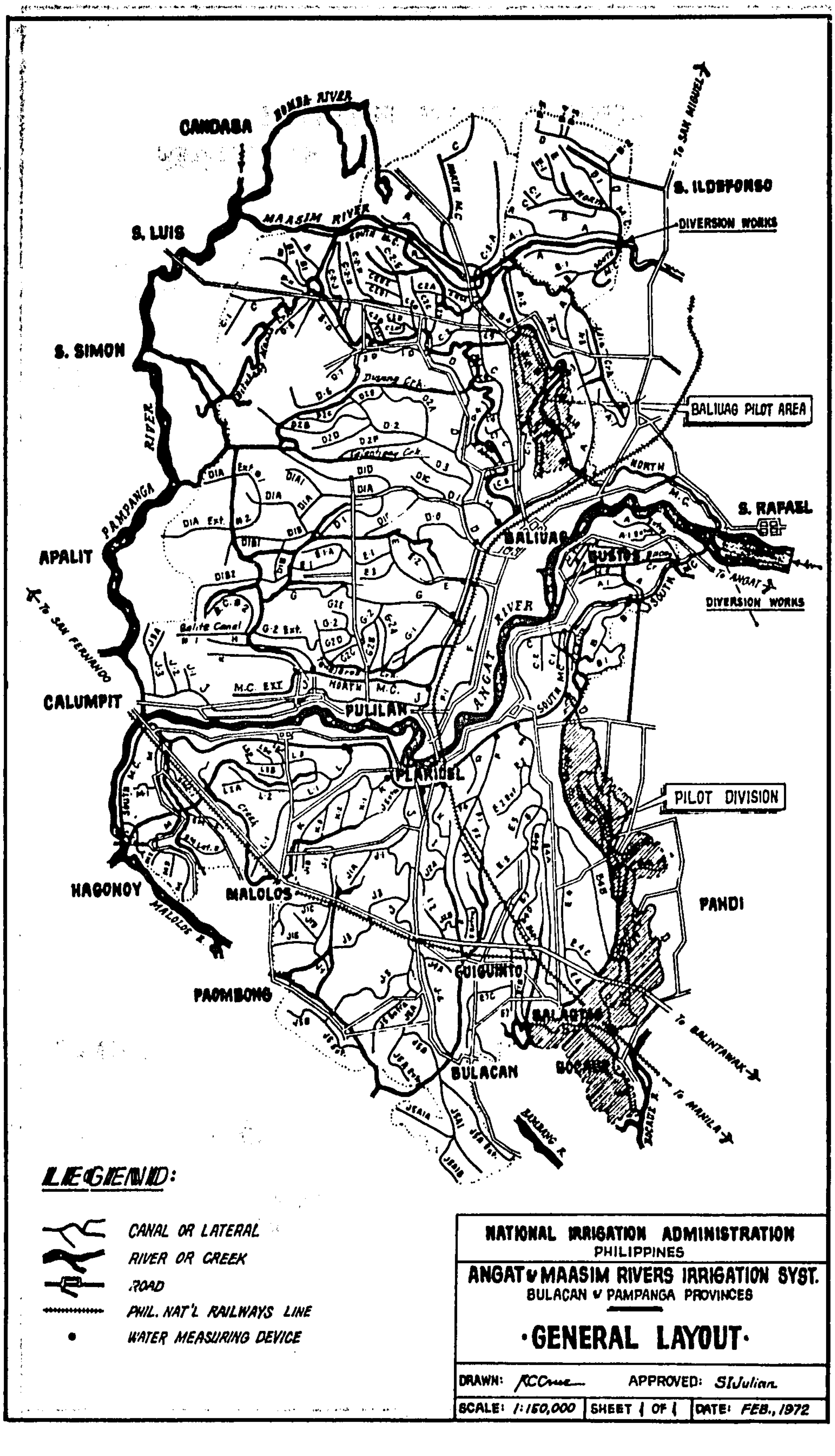
A two-paddy rice crop regular pattern of production is a common eyesight within the service area of the Angat River Irrigation System. The NIA Water Management Team, however, has prepared a cropping programme, to raise 5 crops of rice within 2 years. This scheme of the proposed cropping programme, will undoubtedly and correspondingly increase the level of farm income of all farm families, whose land area is being served with water by the Angat River Irrigation System in the Provinces of Bulacan and Pampanga, and possibly to all systems in the Philippines.

Demographic Data of the ARIS Pilot Area
(As of June 30, 1971)

Location	Sabang, Baliuag, Bulacan
Elevation	11.30 metres above sea le
Average length of sunshine hours:	
May, 1970	8.16 hrs/day
June, 1970	4.32 hrs/day
July, 1970	5.60 hrs/day
August, 1970	2.60 hrs/day
Average solar radiation:	
June, 1970	230 grammes calorie/day
July, 1970	350 grammes calorie/day
August, 1970	178 grammes calorie/day
Total irrigated area	139.25 ha
Number of lots served	77
Number of landowners	47
Number of farmers	67
Average size of lots	1.80 ha
Average landholdings	2.96 ha
Farmditch density	63.3 m/ha
Supplementary drainage ditch	17.0 m/ha
Average paddy dike length	755 m/ha
Total area planted to HYV	138.25 ha
Other varieties (Glutinous)	1.00 ha
Area planted to HYV in per cent	99.28%
Other varieties (Glutinous)	0.72%

REPUBLIC OF THE PHILIPPINES
NIA IRRIGATION SYSTEMS




CANDABA
S. ILDEFONSO
DIVERSION WORKS
S. LUIS
MAASIM RIVER
S. SIMON
BALIUAG PILOT AREA
PAMPANGA RIVER
S. RAFAEL
APALIT
BALIUAG
BUSTOS
DIVERSION WORKS
ANGAT RIVER
CALUMPIT
PULILAN
PLARIDEL
PILOT DIVISION
HAGONOY
MALOLOS
PANDI
PAOMBONG
GUIGUINTO
BALAGTAS
BULACAN
BOCAUE
LEGEND:
CANAL OR LATERAL
RIVER OR CREEK
ROAD
PHIL. NAT'L RAILWAYS LINE
WATER MEASURING DEVICE
NATIONAL IRRIGATION ADMINISTRATION
PHILIPPINES
ANGAT & MAASIM RIVERS IRRIGATION SYST.
BULACAN & PAMPANGA PROVINCES
·GENERAL LAYOUT·
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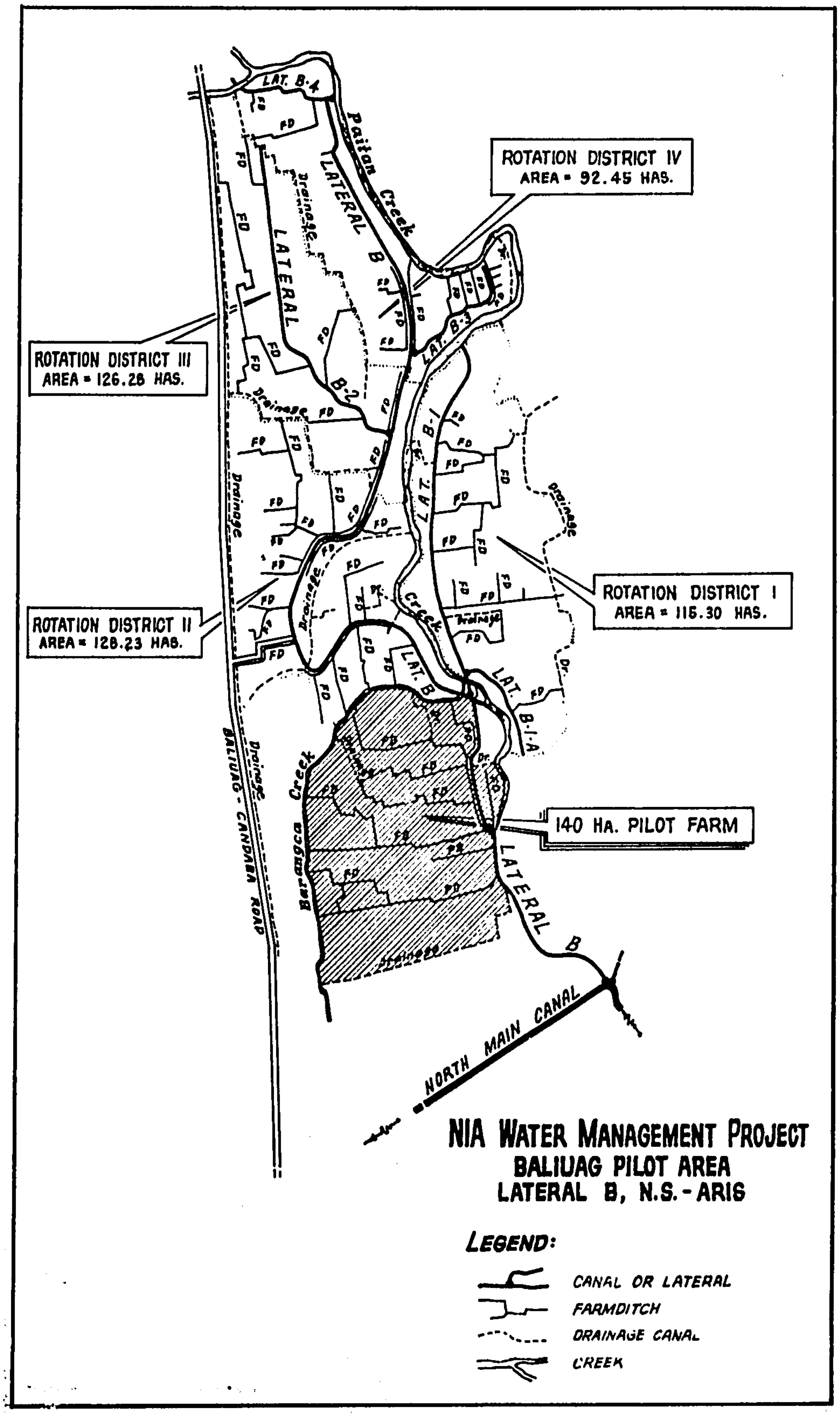
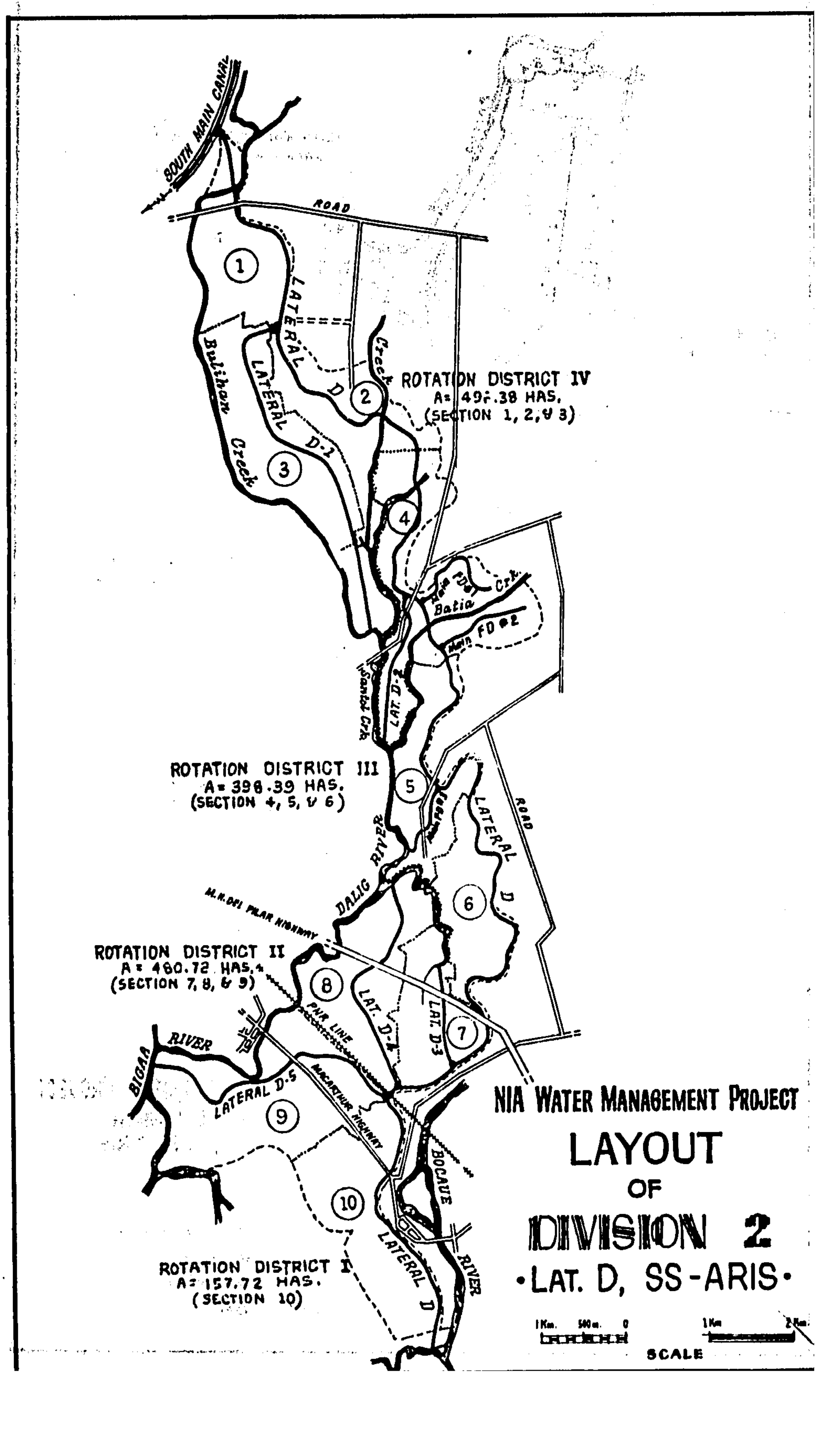
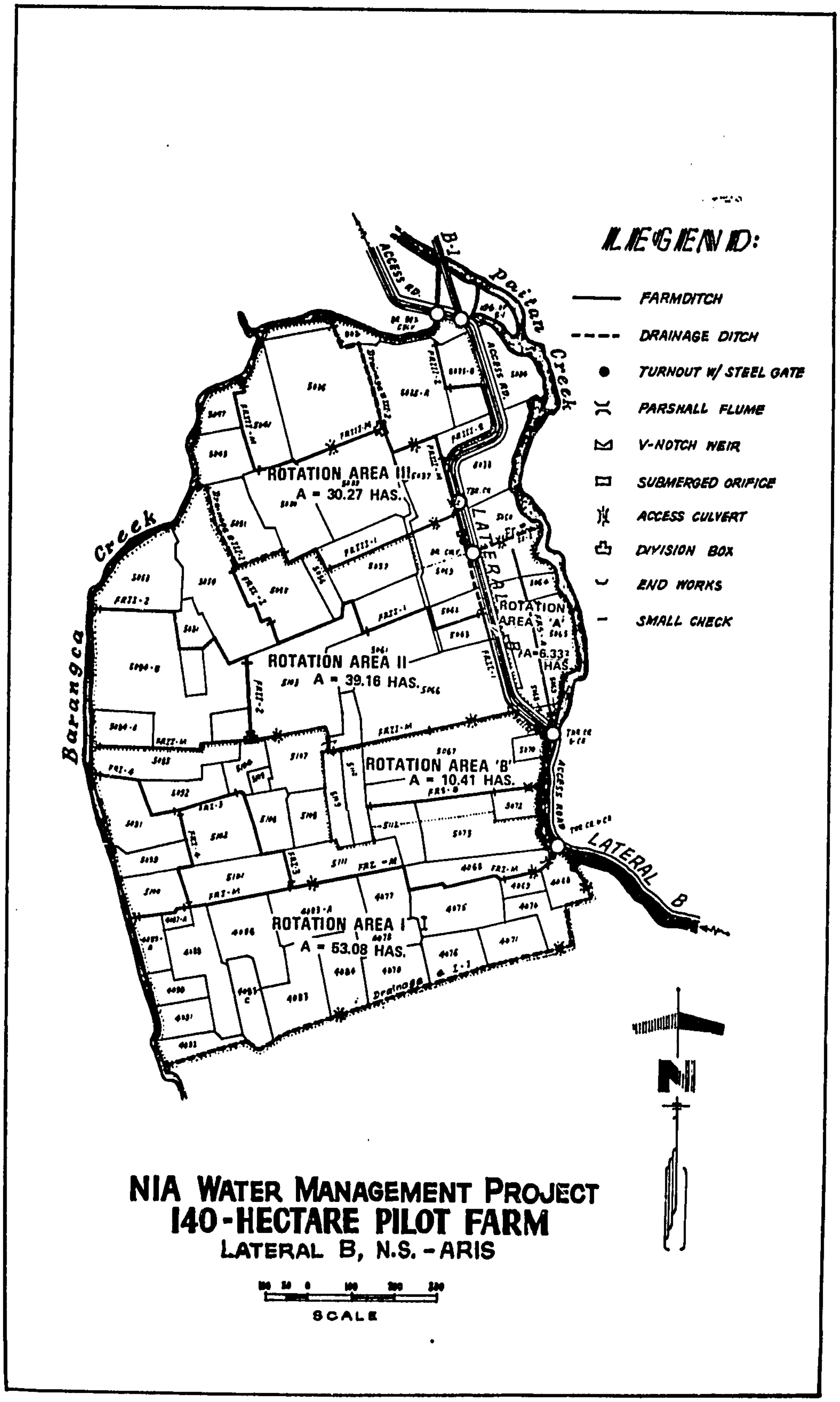
APPROVED: SIJulian
SCALE: 1:150,000
SHEET 1 OF 1
DATE: FEB., 1972

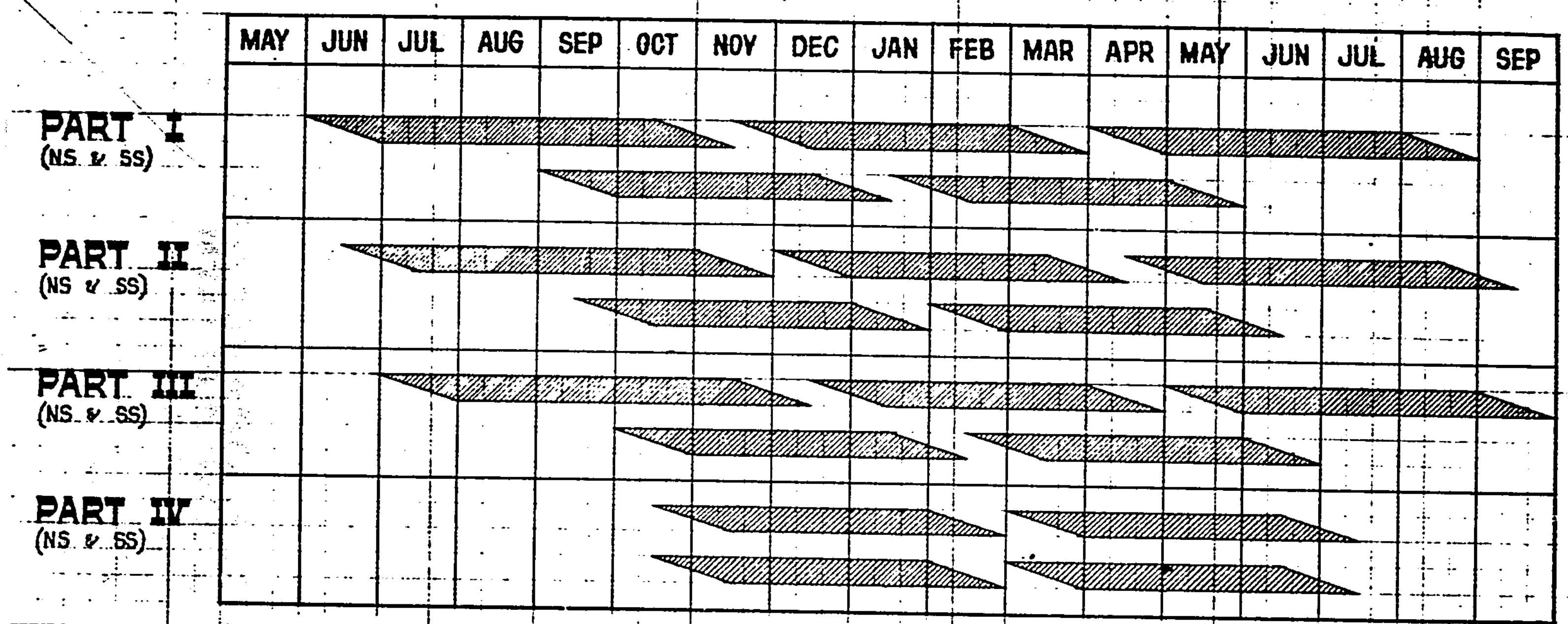

ROTATION DISTRICT IV
AREA = 92.45 HAS.
ROTATION DISTRICT III
AREA = 126.28 HAS.
ROTATION DISTRICT II
AREA = 128.23 HAS.
ROTATION DISTRICT I
AREA = 115.30 HAS.
140 HA. PILOT FARM
LAT. B-4
Paitan Creek
LATERAL B
LATERAL B-2
LAT. B-3
LAT. B-1
LAT. B-1-A
LATERAL B
NORTH MAIN CANAL
BALIUAG - CANDABA ROAD
Drainage
NIA WATER MANAGEMENT PROJECT
BALIUAG PILOT AREA
LATERAL B, N.S.-ARIS
LEGEND:
CANAL OR LATERAL
FARMDITCH
DRAINAGE CANAL
CREEK


SOUTH MAIN CANAL
ROAD
LATERAL D
LATERAL D-1
Bulihan Creek
Creek
ROTATION DISTRICT IV
A= 49?.38 HAS.
(SECTION 1, 2, & 3)
Batia Crk.
Main FD #2
LAT. D-2
Santol Crk.
ROTATION DISTRICT III
A= 398.39 HAS.
(SECTION 4, 5, & 6)
DALIG RIVER
ROAD
LATERAL D
M.H. DEL PILAR HIGHWAY
ROTATION DISTRICT II
A= 480.72 HAS.
(SECTION 7, 8, & 9)
LAT. D-4
LAT. D-3
PNR LINE
BIGAA RIVER
LATERAL D-5
MACARTHUR HIGHWAY
BOCAUE RIVER
LATERAL D
ROTATION DISTRICT I
A= 157.72 HAS.
(SECTION 10)
NIA WATER MANAGEMENT PROJECT
LAYOUT
OF
DIVISION 2
•LAT. D, SS-ARIS•
SCALE


LEGEND:
FARMDITCH
DRAINAGE DITCH
TURNOUT W/ STEEL GATE
PARSHALL FLUME
V-NOTCH WEIR
SUBMERGED ORIFICE
ACCESS CULVERT
DIVISION BOX
END WORKS
SMALL CHECK
Paitan Creek
Barangca Creek
ACCESS RD.
LATERAL B
ROTATION AREA III
A = 30.27 HAS.
ROTATION AREA II
A = 39.16 HAS.
ROTATION AREA 'A'
A=6.33 HAS.
ROTATION AREA 'B'
A = 10.41 HAS.
ROTATION AREA I
A = 53.08 HAS.
N
NIA WATER MANAGEMENT PROJECT
140-HECTARE PILOT FARM
LATERAL B, N.S. - ARIS
SCALE

RICE CROPPING SCHEDULE

FOR THE ARIS, PHILIPPINES



AREA IN HAS.

	NORTH SIDE	SOUTH SIDE
PART I	3,435.82	4,111.28
PART II	2,963.15	2,155.92
PART III	4,540.73	4,087.12
PART IV	4,031.54	982.70
TOTAL	14,971.24	11,337.02

NOTE:

A TWO (2) YEAR RECOMMENDED RICE CROPPING SCHEDULE FOR THE **ARIS**, PHILIPPINES, BASED ON THE RIVER HYDROGRAPH AND WATER DISTRIBUTION BY ROTATIONAL IRRIGATION IN THE SECTIONS OF LATERAL. RECOMMENDED VARIETIES ARE C4-63, C4-137 & IR-20 WHICH POSSESS A CERTAIN DEGREE OF RESISTANCE AGAINST TUNGRO VIRUS TRANSMITTED BY THE GREENLEAPHOPPERS IR8-68, IR-22 & BPI-76 (NS) CAN BE PLANTED, PROVIDED A THOROUGH PLANT PROTECTION SCHEME CAN BE IMPLEMENTED. AVOID THE PLANTING OF IR8-68 DURING THE RAINY SEASON.

PLANNING FOR WATER REUSE

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ABSTRACT

Urbanization and industrialization throughout the world are exerting great pressures on limited water resources. Although nature renews the volume of pure fresh water available annually, we have been wasteful of it and have often had to use highly polluted sources for public water supplies. In virtually all urban areas where sources of naturally pure waters are being exhausted, these limited supplies are being squandered on uses that can be met with waters of much lower quality, such as waters from polluted rivers or waters reclaimed from wastewaters directly.

Reclaiming wastewaters for non-potable purposes, such as for urban irrigation, industry, and toilet flushing, in a planned water resource programme:

(1) relieves the pressure on limited resources of high quality water, so that these can serve larger populations;

(2) reduces the cost of water for non-potable purposes, as reclaiming wastewater is likely to be much less costly than developing additional high quality fresh water sources;

(3) reduces pollution of the receiving bodies of water; and

(4) reduces the risk to the population of ingesting contaminants present in polluted waters that would be used for drinking if such a water reclamation programme was not instituted.

The use of polluted waters or wastewaters for potable public water supplies poses many problems:

(1) water and wastewater treatment plants do not assure the removal of chemical contaminants that that are likely to be present in the urban wastewaters;

(2) the operation of wastewater treatment facilities is always below the design intention;

(3) the technology for routine monitoring of potable waters is not available to assure their safety whe the water is drawn from contaminated sources; and

(4) fail-safe technology to guarantee a high quality of water, suitable for drinking, from polluted sourc is not available.

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A hierarchy of water quality is proposed, whereby high quality fresh waters would be reserved for high quality uses such as drinking and cooking, while polluted waters and reclaimed wastewaters would be used for non-potable purposes.

Rapidly growing population and increasing rates of urbanisation and industrialization throughout the world are exerting greater and greater pressures on limited water resources. Although nature renews the volume of fresh water available, we have been profligate in its use so that in many areas of the world, particularly in urban centres, communities have had to turn to polluted sources to meet their needs. In the United States, for example, about one-third of the total population uses water that in part is made up of wastewaters that only hours earlier had been discharged from municipal or industrial sewers.

This indirect reuse of wastewaters for municipal water supplies is largely unplanned. Because it is unplanned, the practice is beset with serious problems. Where water hygiene practices are poor as in many countries of Asia, Africa, and Latin America, water-borne diseases exert a heavy toll on the population, particularly children. Death rates from enteric diseases, most of which are water-borne, are more than 100-fold greater than in the industrialized countries of Europe and America.

Even in industrialized countries, where modern hygienic water supply practices are observed, the use of polluted waters for public supplies poses many threats:

(1)A breakdown in water treatment facilities may serve to carry contaminated water to users in great number. If raw waters are polluted, treatment facilities must be adequate in capacity, be properly designed, and must be properly operated, with highly qualified chemists and bacteriologists in close supervision, to assure that breakdowns in the treatment barrier do not occur.

(2)Even where conventional treatment is provided, the fate of viruses, particularly those of infectious hepatitis, is uncertain. Only a few virus particles need be ingested for infection to result. Most who are infected may not become visibly ill, but subclinical infections cannot be considered innocuous. Their effects may be delayed, or may be camouflaged amongst other illnesses, or may, by increasing the incidence of the disease in the population, promote the spread of infectious disease through other routes.

(3)Hundreds of new chemical compounds are being introduced into our environment daily. The likelihood of ingesting such chemicals increases many fold when contaminated waters are used as sources for municipal supply, as conventional water treatment is ineffective in removing these chemicals. Some of these chemicals, either alone or in concert with others, have been demonstrated to cause cancer, genetic damages, or birth malformations [30] [31] Because the effects of such chemicals ingested in low concentrations over long periods are insidious, and are likely to be similar to those manifested by aging their significance is hard to establish. To quote Rene' Dubos [6]. "In the case of environmental pollution, the situation may well become unmanageable if the accumulation of convincing epidemiological evidence is made a prerequisite of social action." In other words, we have to learn to live with these chemicals while protecting ourselves from them.

Despite the fact that reuse of water is beset with many hazards, the need for reuse of water is upon us. How, then, may we *plan* for economical water reuse without submitting ourselves to the threats from bacteria, viruses, and chemicals?

A HIERARCHY OF WATER QUALITY

A theme for planned water reuse was stated by the United Nations Economic and Social Council [42]. "No higher quality water, unless there is a surplus of it, should be used for a purpose that can tolerate a lower grade."

In virtually all urban areas where sources of naturally pure waters are being exhausted, these limited supplies are being squandered on uses that can be met with waters of much lower quality, such as waters from polluted rivers, or waters reclaimed from wastewaters directly. In New York City - waters from mountain areas of the upper Delaware Basin and the Catskills, in Bangkok - high-quality ground waters, in Singapore - waters from the reservoir system, and high-quality natural waters serving many other major metropolises are being wasted on lawn, park, and other urban irrigation, in industry on toilet flushing, and on many other uses that do not require the high quality that is necessary for a drinking water supply.

On the other hand, using reclaimed wastewaters for non-potable purposes in a planned water resource programme can provide the following benefits:

(1) Wastewater reuse for non-potable purposes relieves the pressure on limited high-quality water sources, so that these can serve larger populations.

(2)The cost of providing reclaimed wastewater for non-potable purposes would be far less, in many instances, than the cost of developing additional high-quality fresh water sources.

(3) Wastewater reuse reduces the burden of pollution on the receiving body of water, thus reducing water pollution control costs and environmental damage.

(4) The risk to the population of ingesting the contaminants present in polluted waters is reduced.

One ancillary benefit from such reuse is the elimination of the necessity for phosphate removal where wastewaters are used for irrigation. At current prices in the United States for ammonium nitrate, triple superphosphate, and potassium chloride, the value of the nutrients in reclaimed wastewater amounts to more than 5 cents per 100 gallons (1.4 cents per m^3), a not insubstantial increment to the value of the water itself.

A development in the United States that indicates the value of this approach is that in Colorado Springs, Colorado [32], where about one-third of the biologically treated wastewater is passed through rapid sand filters, disinfected, and then stored and distributed through an extensive second distribution system for sale as irrigation water to colleges campuses, cemeteries, golf courses, and other large users. Part of this reclaimed wastewater is coagulated and settled with lime for phosphate removal and then passed through rapid sand filters and carbon beds for removal of organic chemicals and sold as industrial water. Supply of this reclaimed wastewater is limited to customers using more than 10,000 gallons per day (about 40 m^3 per day). The reclaimed wastewater sells for two-thirds the price of the high-quality potable water that is served in the city. By 1980, 90% of the wastewater is expected to be reclaimed, thus putting off, perhaps permanently, major investments that would otherwise be required for additional water supply which would have to be obtained by tunnelling through the Continental Divide at extremely high cost.

Another excellent example is the water reclamation plant for the Jurong Industrial Estate, in Singapore. Effluent from the Ulu Pandan Wastewater Treatment Plant is treated at a filtration plant and disinfected prior to being pumped to an industrial water supply system for use through the Jurong Town Council area. In water-short Singapore, the utilization of the full capacity of this reclamation plant, 10 mgd, over a six-month drought period, would save storage equivalent to the capacity of the MacRitchie and Peirce Reservoirs, important elements in the Singapore water supply system.

Perhaps the oldest such reuse system is the direct sale of treated Baltimore wastewaters to the Bethlehem Steel Company for industrial use.

An extensive literature has already been developed describing the technology involved and experiences with reuse of wastewaters for a wide variety of industrial applications, for irrigation and for recreation. Selected references are appended.

REUSE OF WASTEWATERS FOR POTABLE PURPOSES

If using polluted sources is hazardous, direct reuse of wastewaters for drinking is even more dangerous. The benefits and protection afforded by (1) time in transit between the point of discharge of the wastewaters and the point of recovery from the stream for water supply. (2) the dilution afforded by fresh water in the stream, and (3) the disinfection by sunlight, sedimentation, and natural biochemical degradation that take place in natural water courses are not available where direct reuse of wastewaters is practised.

Direct reuse of wastewaters for potable water supplies poses other problems:

(a) Water and wastewater treatment plants that are now available or that are likely to be economical in the foreseeable future do not assure the removal or significant reduction of chemical contaminants that are likely to be present in wastewaters from urban centers.

(b) The operation of these facilities is almost always below the design intention, even in industrialized countries. Often the quality of the operators, the supervision by regulatory agencies, and the lack of investment in maintenance preclude efficient performance of treatment plants. In developing countries, moreover, the capacity of most plants is often exceeded before new facilities are constructed, so that efficiency of operation is threatened.

(c) The technology for analysis and routine monitoring of potable waters is just not available to assure their safety when they are drawn from contaminated sources.

(d) "Fail-safe" technology is not yet available.

(e) The public is understandably reluctant to ingest its own wastes.

The American Water Works Association [1], in a Policy Statement in 1971, indicated that "The Association encourages an increase in the use of reclaimed wastewaters for beneficial purposes, such as industrial cooling and processing, irrigation of crops, recreation, and . . . . groundwater recharge . . . . The Association is of the opinion, however, that current scientific knowledge and technology in the field of wastewater treatment are not advanced sufficiently to permit direct use of treated wastewaters as a source of public water supply, and it notes with concern current proposals to increase significantly both indirect and direct use of treated wastewaters for such (potable) purposes." This policy is the same in both Britain [26] and Germany [27].

The only planned direct reuse of wastewater for public water supplies intended for drinking is at Windhoek, South-West Africa. During favourable periods, effluent is recycled after complex advanced wastewater treatment is a one mgd plant for re-use as one-third of the potable supply for the city. During other periods, when the chlorine demand cannot always be met, the wastewaters are not recycled. In order to make this experimental demonstration system operating, a considerable investment in highly qualified supervisory personnel is required. The cost of extending this to other communities would be prohibitive, even if the personnel were available. Furthermore, the wastewaters in Windhoek carry no significant industrial wastes, so that the threat of chemical contamination is less than it would be in industrialized communities.

The water quality parameters of Drinking Water Standard were never intended to be applied to waters derived directly from wastewaters. It is assumed that the source is properly protected as revealed by a sanitary survey. Most of the chemical contaminants and viruses of concern today are not even mentioned in such standards. To sum up, "supplies should be drawn from the best available source" [8].

DUAL WATER SUPPLIES

How then can we meet the increasing demand for water for municipalities if reuse of wastewaters, either planned or unplanned, is highly undesirable where the water is to be used for drinking? One approach that deserves considerable study is the dual supply system. A relatively small portion of the total public water supply is required for drinking, cooking and other uses that demand high purity. In industrialized cities, this portion is only about 10% the remainder being used for industrial purposes, as well as for toilet and street flushing, lawn and park watering, laundering, fire fighting, public fountains, and the like. Dual systems are not new. Large industries have been utilizing many different water supply streams for as many purposes within a single plant: raw water cooling for a higher quality for process, a demineralized water for boiler feed, and a bacteriologically safe water for drinking.

Where fresh water is in extremely short supply, as in the Bahama Islands, and in Grand Canyon Village, where the drinking water is pumped from springs a kilometre below near the bottom of the canyon, dual systems have long been used [11]. The efficiency of such a dual system was well demonstrated in Hong Kong during the severe drought of the summer of 1963. Water was so short that the water service area was divided into sectors with each sector receiving water service four hours every fourth day. This meant that many water uses, such as toilet flushing, were sharply curtailed. Only in the high-rise government housing on Hong Kong Island, where a dual system was in use with sea water for toilet flushing, were the sanitary needs being met throughout the drought.

Two main objections, cross connections and cost, are cited when dual systems are proposed [30] Conventional dual water supply systems, where one system delivers potable water and the other generally furnishes untreated water for emergency use only, has led to very serious water-borne disease outbreaks throughout the world. However, in the dual water supply system here proposed, the non-potable supply would be adequately disinfected, and could be of a quality that many communities are now providing for their potable systems. Occasional inadvertent ingestion should create no problem even if not discovered for weeks and months. The health hazard that results from continuous ingestion of potentially toxic substances over a period of years would not be present. However, proper plumbing codes and supervision of construction would avoid this danger.

Another approach is through a discriminating pricing policy, with a much higher unit price for the high quality drinking water and a lower price for the second supply, as in Colorado Springs. In the Soviet Union, it has been suggested that, because 43% of the pure water supplied to cities is used by industries that do not require pure water, the drinking water should be priced beyond the reach of those who would misuse it.

The cost of dual systems does warrant study. If an existing system is to be replaced in its entirety by a dual system, the cost might well be unreasonable. However, a dual water supply for new communities, or for new sections or renewal areas of existing urban centers need not be costly. Studies of the cost of such distribution systems indicate that they would be only about 20% higher than conventional systems. Where the new construction comprises high-rise multi-family dwellings with high density, the cost increment would be considerably less. It is easy to visualize the use of reclaimed wastewaters for toilet flushing in the mammoth housing developments that increasingly dominate the sky lines of modern cities. Offsetting this increased cost are the savings that result from eliminating the need for developing new pure water resources and, above all, the assurance of high-quality drinking water for public consumption.

If only 10% of a high-quality public supply is now used for potable purposes, with a dual system this source could serve a population ten-fold greater. All other water uses would be served from reclaimed wastewaters or from polluted streams or other waters of lesser quality.

The technology for such dual systems now exists. Because the potable water system would not be used for fire protection, it would not need to withstand the high pressures that are otherwise required. Plastic pipes would be entirely appropriate. Water quality surveillance would be far simpler where water planned for potable purposes is drawn from unpolluted sources.

Perhaps the best recourse for the future is to plan the management of polluted waters and wastewaters so that they would not be required as a source for drinking water supplies. Rather they would serve the wide variety of other beneficial uses to which water is put.

REGIONALIZATION AND INTEGRATION

Wastewater is a resource, and as has been mentioned, out of necessity, economy, and safety, reuse must be planned. This requires close cooperation between water resource and water pollution control authorities. Slowly, this integration of interests is beginning to be institutionalized. Again, this is now new. A close community of interests, extended to joint management of water and wastewater enterprises, has been going on in the Ruhr area of Germany for sixty-five years. Nevertheless, there has been reluctance to initiate such joint enterprise elsewhere.

Water supply and water pullution control have been characterized since their initiation as municipal responsibilities. This has begun to change because the economies of scale of construction and operation virtually demand regional solutions. Larger facilities make possible the employment of qualified managers, engineers, and laboratory personnel who can assure efficient water supply and wastewater disposal service at lowest cost without objectionable impact on the environment or threat to the public health.

Regionalization offers another major benefit. In place of the strictly municipal approach to water supply and wastewater disposal, regionalization offers an opportunity for serving outlying areas where this would otherwise not be economical. Often small communities in the vicinity of large metropolitan areas are without the resources to develop their own facilities. A regional programme would stimulate the development of these services that are so necessary to maintain health and to spur proper housing and the prospects for economic development. Regionalization of water supply in Great Britain has provided more than 99% of the total population, including people in rural areas, with water from public systems. In the metropolitan areas in developing countries, such as Bangkok and Djakarta, often only the central city is served adequately, with the outlying areas being served by water carriers at a high cost with poor service and the continual threat of contamination.

A regional approach and integration of water and wastewater management is further justified by the recognition that the wastewater of one community is often the water resource of another. Common enterprise in the development of water sources and in the discharge or reuse of wastewaters would serve both communities better than if the water supply and pollution control operations are independent of one another.

The science and technology for water supply and pollution control are much the same. Only our professional and governmental institutions are separate. Educational institutions have begun to recognize the unity of water quality management. Hopefully government, too, will soon eliminate this unfortunate dichotomy.

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Paper No. I/18

RATIONAL USE OF WATER

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ABSTRACT

In the densely populated islands of Java, Bali and Lombok water use is becoming very intensive, not only for drinking and domestic purposes, but also for irrigation, industry and town water. Besides, flood problems need to be solved. Therefore, the use of water should be rationalized which could be achieved by sound integrated planning.

Transmigration could not effectively solve the population problem of the densely populated islands of Indonesia, but should be seen as a measure of labour supply for the development of the less populated areas, with abundant soil and water resources.

Indonesia has no problem of shortage of water resources, but has an unequal rainfall distribution over the year. The problem of Singapore is different; it has a real shortage of water resources. Even so, water is is wasted; surface run-off is flowing unused into the sea. Estuarial storage, in creeks along the coast has been proposed as the only way to store all available water, and could be a cheaper solution than recycling of very dirty town water or desalinisation of sea-water.

INTRODUCTION

In Indonesia, especially in Djawa, Bali and Lombok, landuse is becoming more intense due to population growth. Many forests on steep slopes have been destroyed for food cultivation without any conservation methods, which has caused land deterioration and sediment problems.

Since about 70% of the population live on farming, agricultural development is essential to raise their living standards. This requires rehabilitation of existing irrigation systems and flood control as well as intensification of farming and double cropping. The dry season discharge of the rivers is small, therefore, storage is needed which could be combined with flood control. At places where storage is impossible, ground water resources could be used for supplementary irrigation. Besides more water is needed for domestic purposes, for flushing of water disposals and for growing industries.

For these reasons, the use of water in the densely populated islands should be rationalized, which could be achieved by integrated planning before starting with the development.

The other islands are very thinly populated and have many potential land and water resources suitable for agricultural development. Transmigration could not effectively solve the population problem of the densely populated islands. It should be seen more as a method of labour supply for the development of the other islands.

The problems of Singapore are very different to the problems faced by Indonesia. It does have enough water resources. But they are not always available at the time when needed. Singapore on the other hand has a shortage of water resources. For non-consumptive uses, recycling of used water is possible, but for consumptive uses, new resources should be found. As stated by the Singapore Government, for the recycling of used water, the most important problem would be pollution control of the environment.

The biggest problem in the densely populated areas of Indonesia is to find places to store damaging flood water of the wet season so that it can be used in the dry season. The second is the reforestation of badly eroded slopes which causes floods and sediment problems. The third is volcanic debris and channel control of rivers affected by volcanic eruptions, which are only specific cases, but very difficult to solve and form an increasing problem for the basins involved.

Pollution is not a critical problem yet, but in the near future when industries have been growing, it will become worse. Since prevention is better than cure, it would be better to have pollution control measures now, before it becomes a problem.

To be able to solve these problems, sound planning is essential, which need hydrologic data. A systematic inventory should be arranged not only of hydrologic data but also of the damage caused by floods and droughts. As a good beginning, the Indonesian Government already started with the building up and strengthening of the Institute of Hydraulic Engineering with its hydrologic division, and with the installation of river gauging stations on important rivers.

Integrated planning of water resources development has got an important place in the 5 year development plan. The basins of all the big rivers in Java and the 2 densely populated islands of Bali and Lombok are under study, as well as some important parts of the other islands A National Water Resources Development Plan will be drawn up from all these study reports.

BACKGROUND INFORMATION

Indonesia consists of thousands of islands lying along the equator. It has 2 distinguished monsoons, the wet and the dry monsoon. In the wet season, the rainfall is abundant and excess water flows unused into the sea. In the dry seasons there is hardly any rain, and there is a resultant shortage of water. Droughts cause much damage to agriculture and there is not enough water for other purposes.

The situation of hydrology and water usage in Indonesia is as follows :

Hydrology

Rainfall and Evaporation

The rainfall is very high in the West and gets less to the East. The mean yearly rainfall in about 2,500 mm; in some places it is over the 5,000 mm. The evaporation is about 4 mm/day or approximately 1,5000 mm/year.

Surface and Ground Water

The biggest streams are found on the large islands of Sumatra, Kalimantan and Irian. The maximum discharge in the rainy season is over a thousand cubic metres per second, while the minimum in the dry season is only some tens of cubic metres. Many of the big rivers are navigable up to more than one hundred kilometres inland.

There are some lakes but all unexploited. The crater lakes are especially not worthy to be exploited, because of their small catchment areas.

Extensive parts of the alluvial plains of Sumatra, Kalimantan and West Irian, a total area of more than 5,000,000 ha are covered with swamps. The tidal effect extends far inland especially along the rivers.

The best water bearing formation in Indonesia are the Quaternary deposits. Yields in lava formations are also good, yields over 2,000 l/sec have been recorded. Most of the alluvial plains along the coast as well as along the rivers are good water bearing formations. Many towns and thousands of villages get their water supply entirely from those formations.

Denudation and Erosion

The tropical climate with high and concentrated rainfalls combined with young volcanic soil bring about rapid denudation of about 1 mm a year. Inadequate land use, deforestation and cultivation without soil conservation methods are particularly disastrous, many basins have been recorded to have a denudation of 4 mm a year which indicates a critical erosion rate.

Volcanic eruptions have created more problems. In the first 3 years after an eruption, floods with large concentrations of debris flow down the mountain rivers. Million cubic metres of debris spread out on the foot of the mountain and cause damages to towns, villages, roads and farmlands. A portion of the debris flows in the main river causing sediment problems and aggradation.

Floods and Drainage

Floods as well as bad drainage can cause inundations. Every year thousands hectares of low areas of the plains are flooded. For the densely populated island of Java, the flood damages form a big problem.

Water Use in Indonesia

The largest water consumer in Indonesia is irrigation. Domestic and industrial water supply are very limited. Hydro-power is a non-consumptive water-user.

Irrigation

Rice cultivation is the most extended agricultural activity. The quantity of irrigation water for rice is the largest namely 10,000 to 12,000 m^3/ha/crop, or about 33,000,000,000/year. The yield without any fertilizer is approximately 2.8 ton/ha, which is 3 times the yield of non-irrigated rice.

The rice cultivation in the dry season covers only 25 to 30% of the irrigated rice fields because of limited amount of water. To have more water in the dry season, reservoirs have been built and some are under construction. Most are less than 100,000, 000 m^3.

The two biggest reservoirs are:
The Djatiluhur reservoir which has been completed in 1969 with an effective capacity of 3,000, 000,000 m^3 and could irrigate 3000.000 ha rice fields. The Karangkates reservoir, which is nearly completed, and has an effective capacity of 253,000, 000 m^3. The Djatiluhur as well as the Karangkates reservoirs are multipurpose. Many others are under study and will be constructed in the second five-year development period.

In certain areas in East Java, groundwater has been used for irrigation, but only at a limited scale. To promote groundwater irrigation, the government has done some exploration and has established some pilot projects. An area of 19,000ha has been explored and another 282,000ha is under exploration with technical assistance from the British Government. An area of 250,000ha will be explored with I.D.A. technical assistance as a preparation for a loan for construction. At present, the irrigated rice fields in Indonesia are as follows:

technically irrigated	1,852,000 ha
semi tech. irrigated	900,000 ha
non tech. irrigated	1,785,000 ha
	4,537,000 ha

Domestic Water Supply

Only about 140 cities and towns throughout Indonesia have piped water supply, mostly from springs and a small part from artesian water. Some large cities get their water supply from river water with special treatments. The total daily production at the beginning of the 5-year development period was approximately 150 million cubic metres. The Government has completed new water supply systems from river water for the following cities: Djakarta 2,000 l/sec, Palembang 300 l/sec, Menado 125 l/sec, Padang 250 l/sec, Tandjung Uban 40 l/sec, Purbolinggo 20 l/sec, Kendari 10 l/sec. Some other cities such as Den Pasar 400 l/sec and Udjung Pandang 500 l/sec are under construction.

Many towns and thousands of villages receive their domestic water entirely from dug wells, while about 85% of the Indonesian population use surface water for domestic uses without any treatment. This should be improved.

Industrial Water Supply

Factories need water for processing and cooling, and obtain their water mostly from rivers, while ground water is only used if not much water is needed.

Flushing Water

Only very few cities have a centralized water disposal system with a treatment plant. These systems need water for flushing, which is obtained from rivers. In most of the cities and towns, waste is disposed off in septic tanks installed in every house. But in many small towns and villages, people dispose their waste directly in open waters.

It is urgently felt that serious attention should be paid to the increasing pollution of public waters from human as well as from increasing industrial waste.

Hydro-Power

Hydro-power is a non-consumptive water user, but even so the operation schedule could be against the interest of other users. Therefore the operation plan of a multi-purpose dam should be studied thoroughly. Besides, hydro-power could not be determined in a water resources development plan plan only, but also as a unit in the overall power development plan for the region concerned.

New hydro-electric power plants which are nearly completed are Riam Kanan 20 MW in South Kalimantan, Karangkates 70 MW and Seloredjo 4, 5 MW both in Java. Others are under study. There are many hydro-power potentials which should not be exploited because it is more expensive than other power sources. Or it is not to be combined with other purposes, for example with irrigation, which has no substitute and has therefore a higher priority.

The present situation of the hydro-power potentials are as follows:

already exploited	–	312,000 KW
under construction/ study	–	615,000 KW
already surveyed	–	9,100,000 KW
total	–	10,027,000 KW

The firm installed capacity of electric power is as follows :

hydro-power	–	311,943 KW
diesel power	–	202,155 KW
thermal power	–	142,832 KW
total		655,930 KW

The effective power supply is only about 5 watts per capita.

PROBLEM AND POSSIBLE SOLUTIONS

Generally speaking, there is sufficient rainfall, but it is concentrated in the wet season. Especially in the densely populated islands. there is a shortage of water in the dry season, because the water demand is very large, while the hydrologic conditions are very bad due to inefficient land use. A solution might be to store excess water of the wet seasons for use in the dry season. But damsite possibilities are limited in quantity as well as in capacity, so that not all available water could be stored. Therefore, the limited amount of stored water should be used effectively to meet the various water demands. A sound plan of the integrated use of the available water resources is therefore essential.

To reach this goal, the following steps are necessary:

(1) Coordination in planning and programming the development, to get the maximum output from the available resources and the maximum benefit from the invested capital.

(2) More intensive and systematic inventory of hydrologic and other data necessary for planning Water Resources Development which is at present inadequate and in many hands.

(3) Upgrading of personnel for planning and programming the Water Resources Development, since there is lack of experienced personnel acquainted with theories and methods.

Coordination of Planning and Programming

How would the coordination be carried out, as the responsibility for the various subjects is in the hands of so many departments.

For example the irrigation project of the Luwu area in South Sulawesi.

What is the main objective of the development?

(1) Is it to develop the less developed parts of Indonesia to reach an equal level of development?

(2) Is it to receive transmigrants from the densely populated parts of Indonesia?

(3) Is it to reach the food target especially to supply the eastern part of Indonesia?

If it is the first question, then transmigration should be seen as labour supply for the development, which means that, there should be a suitable selection of the kind of labours needed. The crop need not be necessarily rice, but could be cash crops for export. For these kinds of crops, it might not be necessary to build irrigation systems, since the rainfall is spread over the whole year with only two or three weeks of dry days.

If it is the second question, then we have to look for labour intensive work for unskilled labour, who have the experience only in rice cultivation. For other kinds of work, an upgrading centre should be established to train the transmigrants for their new jobs. Crops for export other than rice could be of more economical value. This should be studied more thoroughly.

If it is the third question, then the crop should be rice and irrigation is then essential. Or could it not be combined with other kinds of crops? Rice in the wet season and other crops for the second planting. Is then irrigation still necessary? It is an alternative worth to be studied. Here, transmigration is again for labour supply.

What ever it will be, it is certain that the road system and the harbour should be improved to be able to transport the produce from this remote area to the consuming centres.

This is an example of an irrigation project in the scarcely populated islands. If we consider one of densely populated islands, for example Java, then the social problem of irrigation development is how to protect the farmers from black market banking for the expenses of tilling their fields and living before the harvest. Because then the black market bankers would become rich while the farmers would stay poor as they were previously.

It is clear than an irrigation project could not be planned separately, but should be studied together. with related subjects such as transmigration, agriculture, transportation, etc.

A second example is the 3 storage dams in East Semarang on 3 small rivers, the Djragung, Dolok and Pengaron. Each storage capacity is just enough to give supplementary irrigation water to the rice fields in their respective basins the whole year round. But flood control is essential although this will reduce the effective storage. Besides the area badly needs electricity. But again the storage would decrease, because hydro-power needs enough head.

There is no substitute for irrigation water, but there might be a possibility to supply water from a neighbouring river. An alternative for flood control could be a shortcut and improvement of the downstream reaches. Hydropower should be studied in the Central Java overall power plan, where diesel or thermal power would be studied as alternatives.

It is clear that the programme to have a second crop from the existing irrigated fields in East Semarang could not be studied as an irrigation project independently, but should be studied integrated with other aspects as a social economic project of a bigger region.

A third example is the Water Resources Development in the Brantas Basin. (See Fig. 1).

The river has a serious problem of an extraordinary sediment transport coming from erupted materials of a very active volcano in the Basin. Increasing problems of aggradation floods, bad drainage, and sedimentation in the irrigation systems are all caused by the excessive sediment load which deposits in the river channel. A development programme which does not solve the sediment problem has not much use, more so, if the programme would cause a deterioration of the river.

A programme to arrest debris/sand on the slope of the Kelud and in the sand carrying tributaries has been planned and partly executed.

There are many dam possibilities suited for multipurpose storage. Because of the aggradation, the capacity of the river is decreasing and cannot discharge the yearly floods, so that flood control is the most essential step. To solve the sand problem, the River Department asks for water to flush the sand into the sea. It needs the maximum discharge tolerated by the decreased cross-section of the river, which is in contrary with the much lower discharge required for other purposes. (See Fig. 2).

If all the stored water would be used for sand flushing, nothing would be left for other purposes, while irrigation is also essential for the 70% of the population of the basin who live on agriculture. Besides, Surabaja city with its 2 million population needs domestic and industrial water supply and water for town flushing. The state electrical company is also eager to exploit the existing hydropower potentials.

The two multipurpose dams already constructed control the floods and store the excess water, so that only low flows come down the river. The tractive force is decreased and would decrease more when the other dams, already planned, would be constructed. The more dams the worse the regime of the Brantas would be, and the faster the aggradation. (See Fig. 3).

The situation also worsens at the time that the tunnel of South Tulungagung, to divert flood water of the Ngasinan/Ngrowo tributary into the ocean, has been completed. This is an example of a solution without considering the effect of the sand problem in the main river, so that the repercussion is felt within a few years. Another part, already developed, is now under permanent inundation. The whole basin should be cut off from the Brantas and drained fully into the ocean. A better solution would be diversion of floodwater from the sand carrying main river into the ocean, and to use the relatively clean water of the Ngasinan/Ngrowo tributary for flushing the sand, flowing in the main river into the sea. (See Fig. 3).

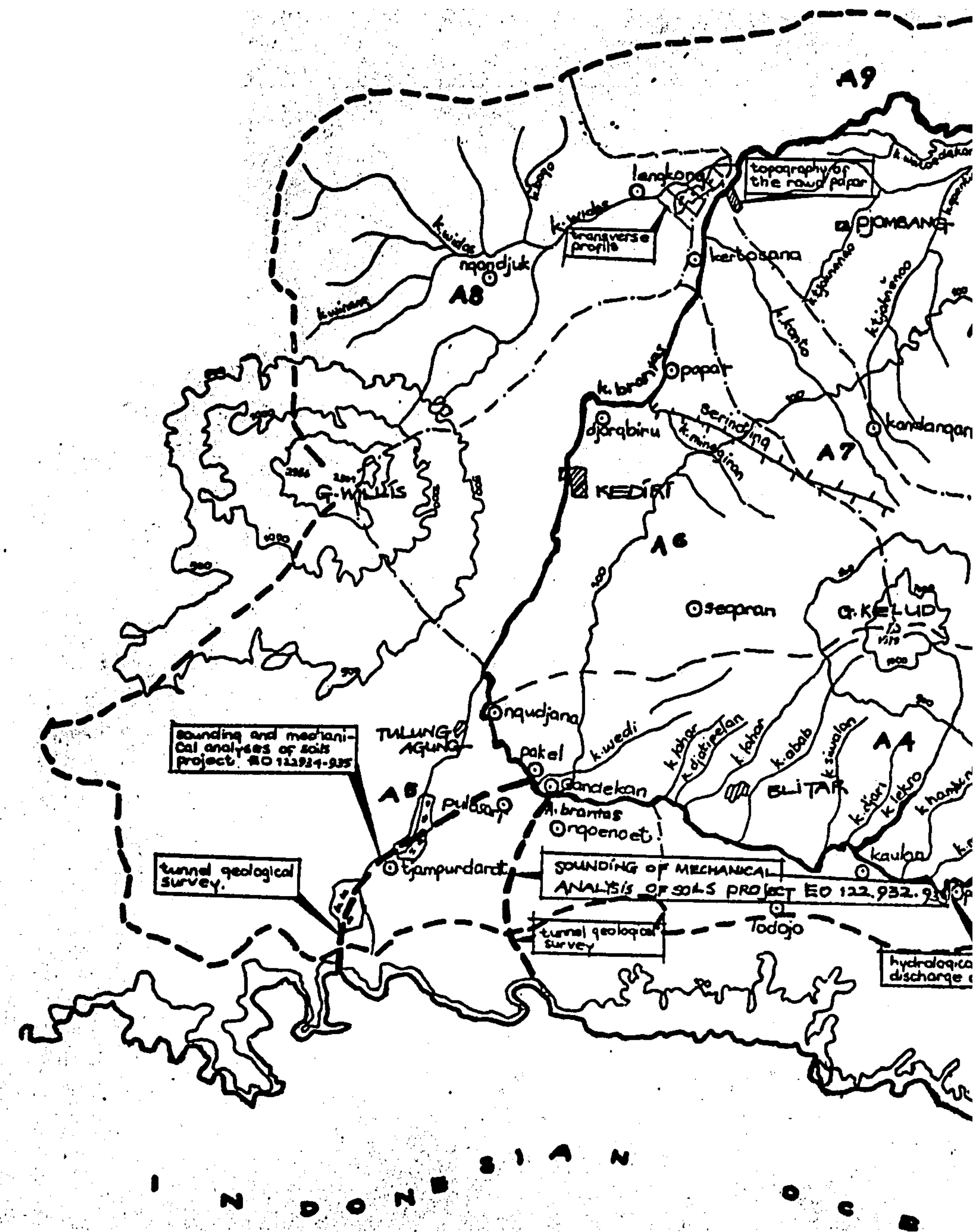
Another example of an uncoordinated planning is the rehabilitation of the two branches of the Brantas. Since they intend to renew the barrage, dredge the river bed, and heighten the dikes, the flood discharge distribution should be rearranged. If the floods would be diverted into the main branch only, the siltation would not increase. See Fig. 4. The smaller branch should be used as a supply canal for Surabaja city and for emergency floodway during extraordinary floods only.

It is clear that a sound overall water resources development programme should be planned, to be able to make the best use of the damsites, to get the most rational use of the Brantas water and at the same time to solve the sand problem.

When the overall plan and programme have been completed, the coordination of the various fields of development would be safe guarded. The execution could then be undertaken by the departments concerned, provided that it would be executed in accordance with the accepted plan and programme.

The problem is, who will do the integrated study and the overall planning and programming, where the responsibility of the various subjects are in so many hands?

The best way could be to create a temporary study group for every basin study, (could be a firm), which is responsible to a special study team consisting of people from the various departments responsible. After approval of the overall plan and programme, the detailed planning and programming of each subject could be done by the departments concerned.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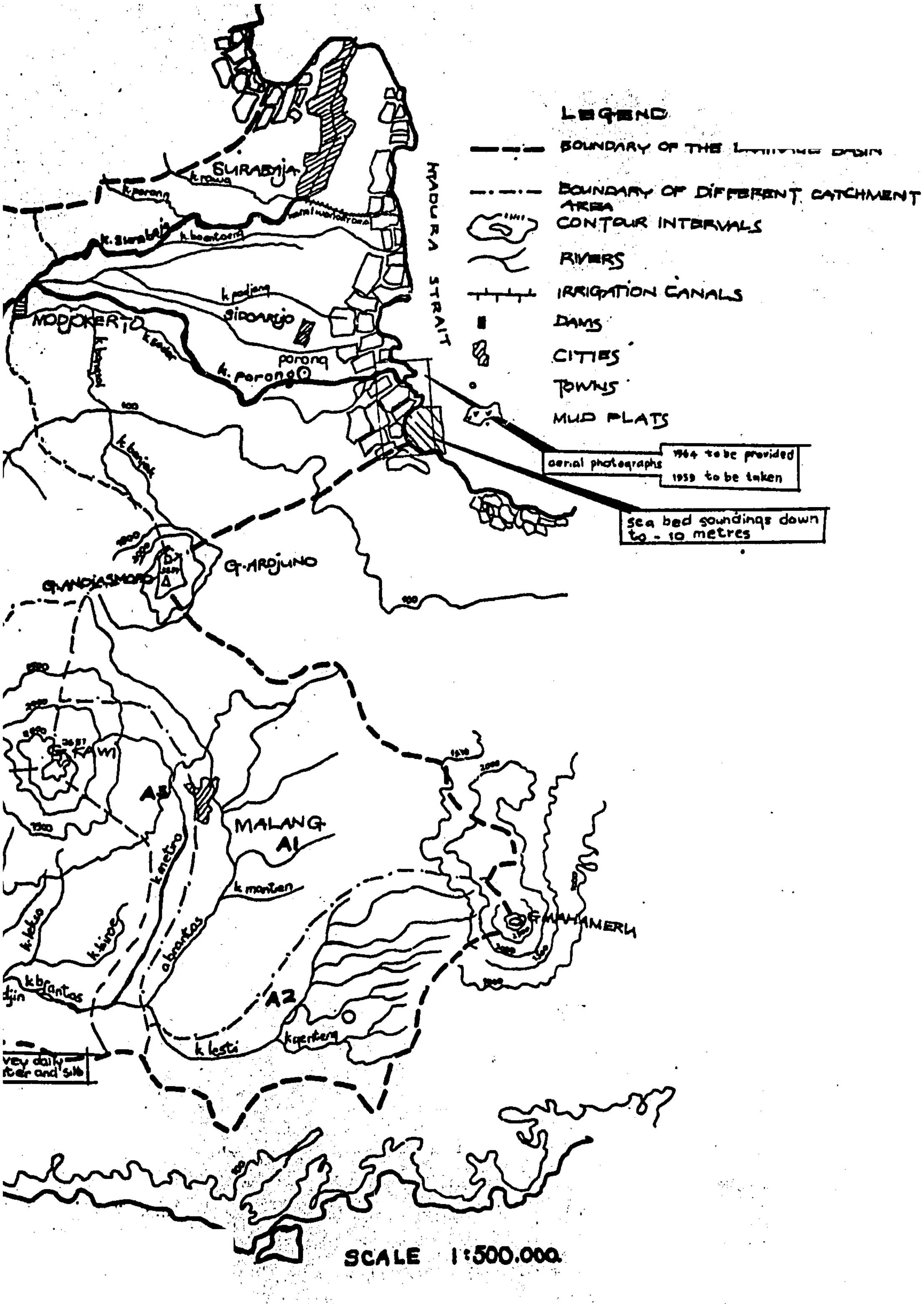

River Basin (East Java)

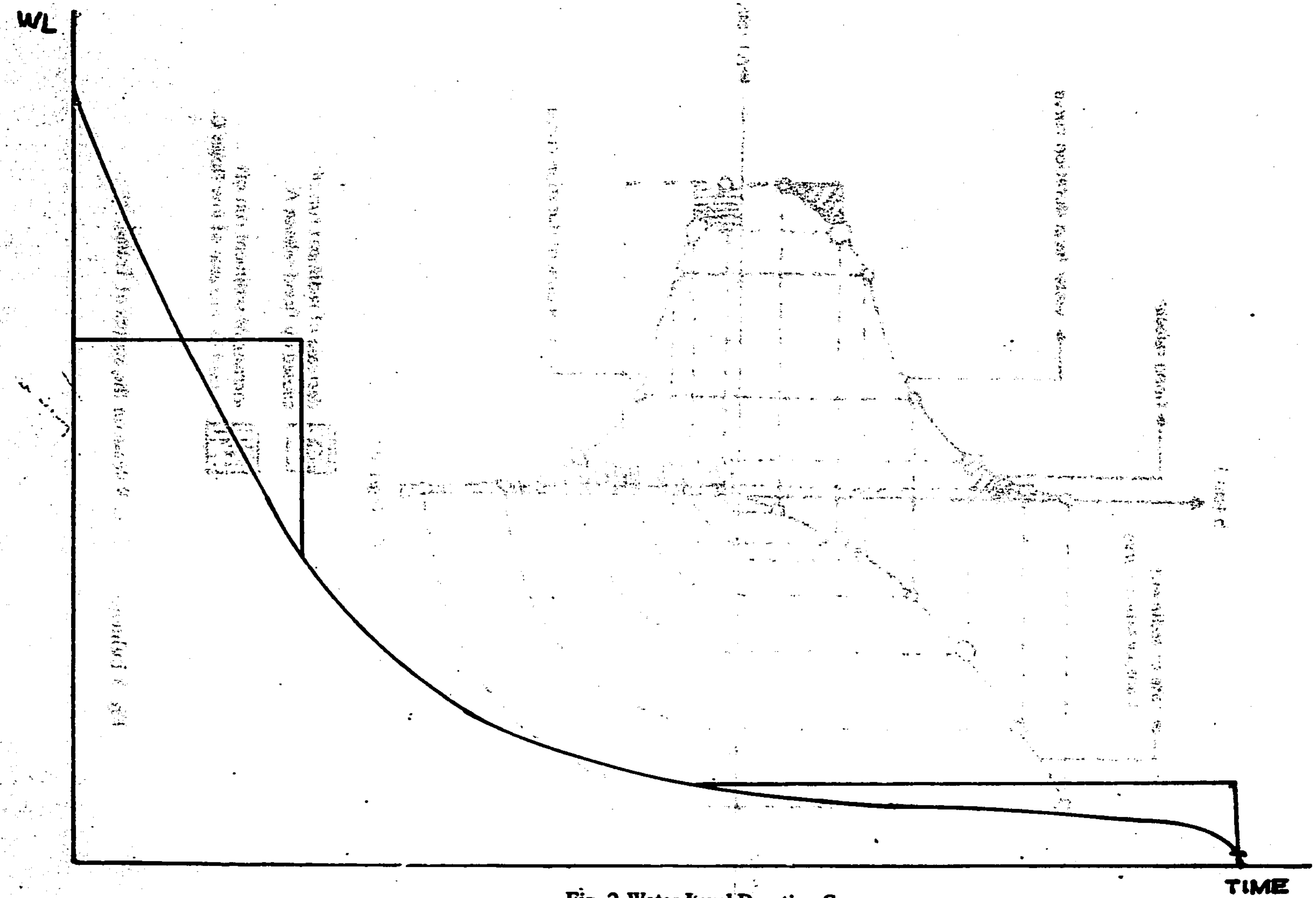

Fig. 2. Water Level Duration Curve

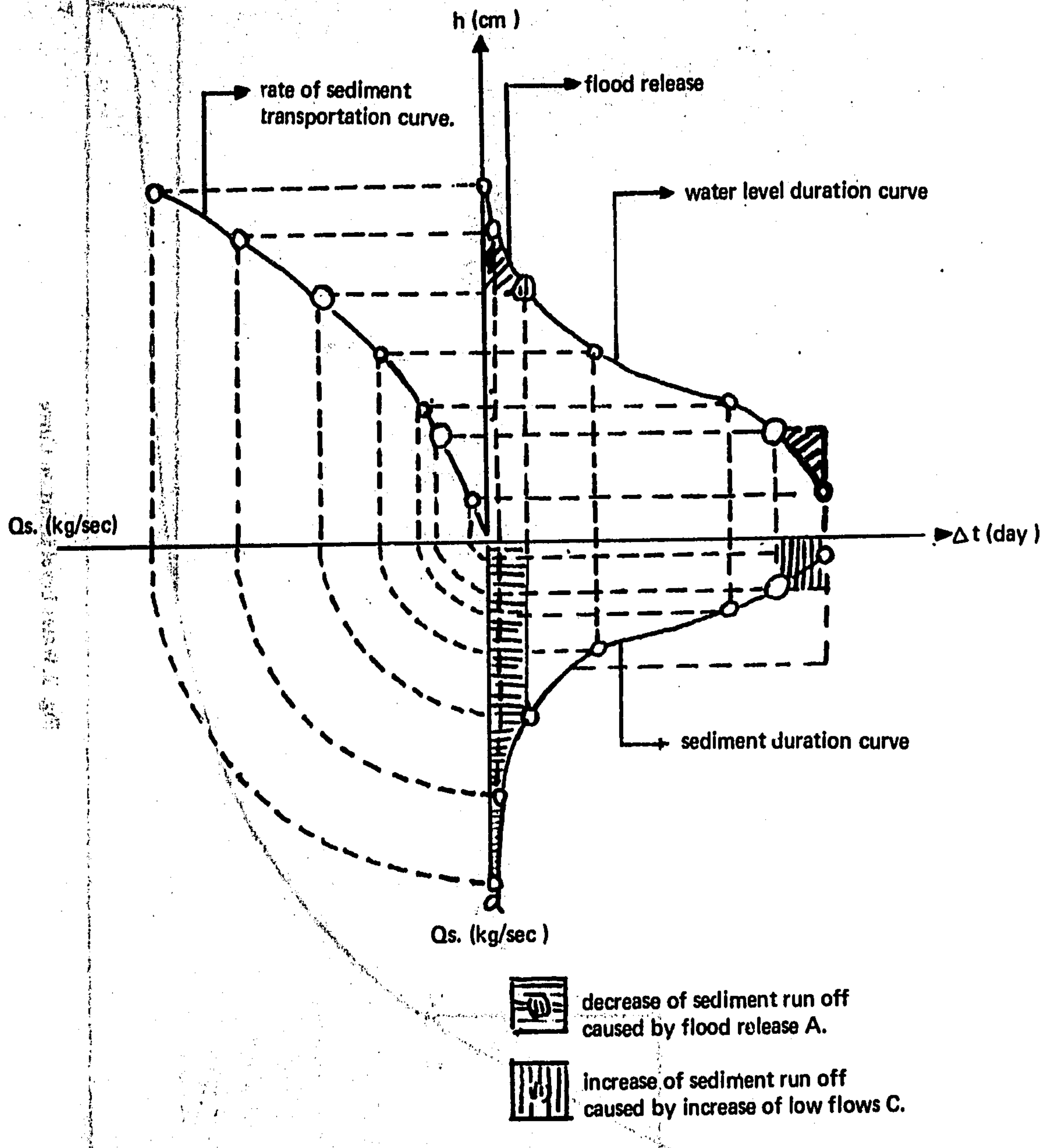

Fig. 3 Influence of Flood Release on the Sediment Transport

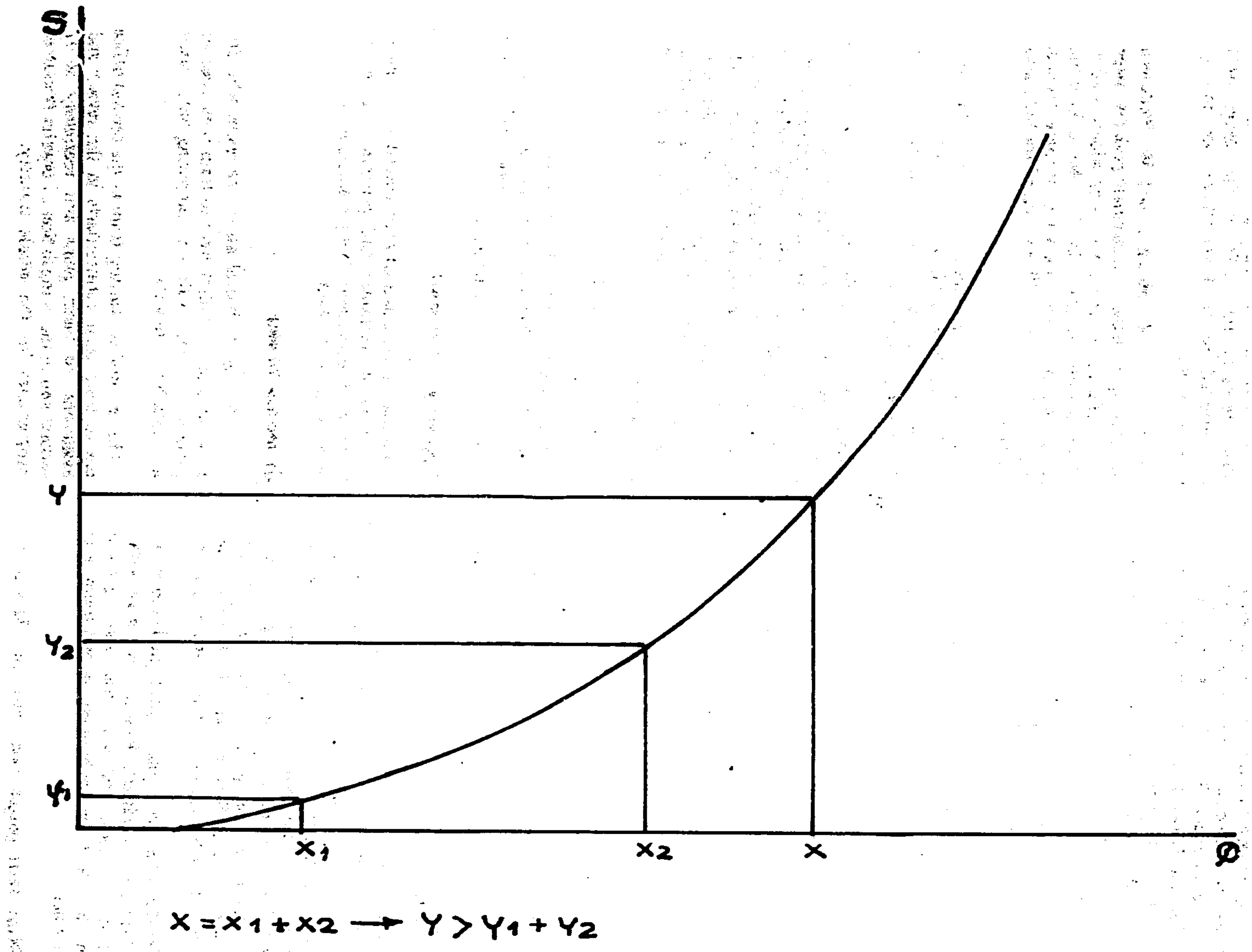

Fig. 4. Rate of Sediment Transportation Curve

The Indonesian Government has already started with the studies of many basins. Technical assistance has been obtained from many countries, each for a special basin, a group of small basins or even a whole island.

The Progo Basin Study has been completed with British technical assistance. Tjimanuk, Tjitanduy, Seraju, Djratunseluna, Solo, Brantas, and Barito basin, Bali and Lombok islands, Lampung, South Sumatra and . ·iwu areas are under study with technical assistance from various countries and the Tjitarum basin will be studied with a World Bank loan starting this year.

A general consulting team from th' British technical assistance programme is attached to the Planning Directorate of .he Directorate General of Water Resources. Together with their counterparts their task is to review and evaluate all the reports and to draw up a National Water Resources Development Plan and Programme from all those plans.

Inventory of Data

Data on hydrology, on damages by floods and droughts and on yields and demands are inadequate. The collection of hydrologic data is done by special bodies, which also do the processing, analysing and storage The collection of data on damage, demands and yield have been done by the Public Works and other offices in the Provinces.

Hydrologic Data

In Indonesia, the inventory of rainfall and other meteorological data is done by the Meteorological Service, surface water hydrology by the Institute of Hydraulic Engineering and ground water by the Geologic Service, but nobody is responsible for the water balance studies.

Old rainfall records from ordinary rain gauges are available. Most of the records are more than 30 years old, which is adequate for hydrologic studies. Meteorological data, from the whole Indonesia has been systematically processed, analysed and published. For more detailed studies of special projects, automatic rain gauges should be installed. The Meteorological Service is an established organisation, but needs improvement and modernization.

On the other hand, the Hydrologic Division of the Institute of Hydraulic Research is not yet established. Technical assistance has been received from the UNDP for the building up and training of personnel.

Many staff gauges exist, but the old records were never systematically processed or analysed, and are not centrally inventoried by the Institute. They are kept scattered in the various local offices who have installed the gauges. It is the task of the Institute to collect all these data and to process, analyse and then publish them systematically To get more up to date and more detailed information for special studies, recording gauges should be installed. Recently about 100 recording gauges have been installed by the River Directorate and by different projects.

Before 1945, Mr. Melchior and Mr. Weduwen have developed methods to calculate peak discharge from rainfall data, which have been widely used in Indonesia until nowadays. In 1952, Mr. Bakker has studied the hydrologic characters of some rivers in Java and his report is still very useful for Indonesia hydrologists.

Data on ground water are very few. The Geohydrologic Division of the Geologic Service should be developed to be able to do systematic studies on ground water resources

As already stated in the chapter on ground water uses, the Water Resources Directorate General of the Public Works Department has started with the exploration of ground water for irrigation purposes. at a place where surface storage is inadequate for supplementary irrigation in the dry season. The study is project oriented, therefore the Geohydrologic Division of the Geologic Service will do some additional study to make a systematic recording of the data.

Inventory of Other Data

The inventory of other data has been done by the local offices concerned. It should be done more systematically, and the processing, analysis and storage should be standardised.

Upgrading of Personnel

Indonesia has a lack of experienced and trained personnel in planning and programming water resources development. Many training programmes have been established.

On the job training

The foreign technical assistance teams who do the various basin studies, have to train their counterparts in the field offices in preparing basin plans and feasibility reports.

The general consulting team in the central office has to train their counterparts in the review and evaluation of basin plans and feasibility study reports and in the compilation of a water resources programmes for the whole country.

Courses

Regular upgrading courses have been organized by the Public Works Department for its personnel, carried out by a special Institute of the Public Works Department. The courses last for two or three months. The lecturers are experienced people, scientists and university professors.

Study Abroad

Many officials have been sent abroad to follow special courses or to study at universities

CONCLUSIONS

The Problems in Indonesia Are as Follows:

(1) Not a shortage of water, but an unequal distribution over the year, with damaging floods in the rainy season and nearly dry rivers in the dry season.

(2) The control of volcanic debris and the river channels affected by sand coming from volcanic materials and erosion of waste land.

(3) Coordination in developing the water resources, since the various units of a multipurpose development and the related subjects are the responsibilities of many departments.

(4) Inadequate and unreliable data, because the institutes who have to collect, analyse and store the data are not yet adequately established.

(5) Lack of experienced and trained personnel to do basin planning and to draw up programmes.

Possible Solutions Are as Follows:

(1) Building multipurpose dams to control the floods and to store excess water, to have enough discharge in the dry season for the various purposes.

(2) Regulation and prevention of sand flowing into the main rivers, or diverting them directly into the sea. Besides, developments in the basin should not worsen the regime of the river.

(3) Creating a coordinating team for each project or for a group of projects, consisting of personnel from the departments concerned.

(4) Upgrading, strengthening and modernization of the various institutes responsible for hydrology.

(5) Establishment of programmes for:
   * on the job training by foreign teams to do the basin planning and feasibility studies.
   * regular training courses.
   * sending people abroad to follow courses or to study at Universities.

The problems faced by Indonesia are of a very different character compared to Singapore. Therefore, experience of the Indonesian people on water resources development would probably not be of much value, especially for the planning of pollution control, recycling methods and desalination of sea water as needed by Singapore.

PROPOSALS

It is at this moment impossible for Indonesia to propose solutions for the water problems of Singapore, because of a lack of knowledge on the potentials and demands, and on the present situation.

It might be possible, however, to use the entire surface run-off of the island, since groundwater storage is not available. Storage of water in creeks along the coast might be of some use and could be cheaper than recycling or desalinisation. Therefore, it should be included as an alternative which can be studied, if it has not been done before.

Experience in solving problems in developing countries could be more valuable for ASEAN countries than knowledge of the latest inventions. Therefore, close cooperation to promote exchange of experience would be very useful, for which a permanent contact should be established between the water resources planners of the ASEAN countries.

WORKING GROUP II

WATER POLLUTION

Paper No. II/2

SEWERAGE, SEWAGE TREATMENT AND DISPOSAL IN SINGAPORE

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ABSTRACT

The paper deals in brief with the history of the sewerage system in Singapore from the time of its first inception up to the present day.

It then deals in greater detail with the methods of nightsoil and sewage treatment and disposal starting with the collection and disposal of nightsoil, the first sewage treatment works at Alexandra Road, the early Kim Chuan Sewage Treatment Works and its attendant Sludge Treatment Works at Serangoon, the development of the Ulu Pandan Sewage Treatment Works, which replaced the Alexandra Road Sewage Treatment Works, and the later phases of the Kim Chuan Sewage Treatment Works including the new Kim Chuan East Works, the Ulu Pandan Sewage Treatment Works extensions and the Serangoon Sludge Works extensions. It also deals with the smaller sewage treatment plants including septic tanks and cesspits.

In the discussions on the works, the method of treatment and modus operandi are discussed in some detail; capital and operating costs are also discussed. The paper also discusses the future of the existing works, the need for additional treatment works to cater for the future and thoughts on the types of works for the future.

The discussions are supplemented with various appendices, flow diagrams, maps and photographs.

INTRODUCTION

The aim of this paper is to present in brief the development of sewerage, sewage treatment and sewage disposal in Singapore from the time the first sewers were laid up to the present day. It is not surprising how little the general public knows or wants to know how the wastes of the community, insofar as they manifest themselves as domestic sewage and industrial effluents, are collected, treated and safely disposed off. However, in the current clamour for clean air, clean water and a clean or cleaner environment, there appears to be a general desire now to know more about pollution and pollution control and in particular water pollution control.

Singapore lies 80 miles north of the equator at the southern tip of the Malay Peninsula. It is a modern city of some 224 square miles and has no distinct seasons. The average annual rainfall is 98 inches, distributed fairly evenly throughout the year. The mean shade temperature is 27°C and the diurnal range rarely exceeds 8°C. The population at census night (22/23 June 1971) was 2,074,507 people.

Regional Workshop on Water Resources, Environment and National Development
Singapore, March 13-17, 1972.

In an urban society like Singapore, it is both prudent if not imperative that wastes which contribute directly or otherwise towards water pollution should be channelled away expeditiously to a place where they can be treated and rendered innocuous. Obviously this need was not necessary when the population of Singapore was small and the corresponding quantity of wastes also small and easily disposed off by burial or dumping.

With the passage of time, it became obvious to the city fathers that a more effective and safer method of collection and disposal of wastes should be investigated if epidemics of the dreaded diseases of cholera and plague were to be avoided. Already legislation was being effected in England, whereby it was an offence to discharge sewage into inland rivers and water-courses without first treating it (Rivers Pollution Prevention Act, 1876). Local interest in a better system for the treatment and disposal of sewage in Singapore was aroused and this was rightly so considering that the population had grown from about 10,000 as estimated by Sir Stamford Raffles in 1823 to about 200,000 in 1890. Singapore was moving towards an era of water-borne sewage disposal.

HISTORICAL BACKGROUND OF THE SEWERAGE SYSTEM (1890 - 1930)

The first report on sewage disposal was presented in 1890 by a Mr. MacRitchie, the then Municipal Engineer. The most common method of sewage disposal at that time was by collecting the nightsoil in buckets, the disposal of the nightsoil being a matter of private arrangement. Some of the nightsoil was used by small plantation holders as a fertiliser, but the bulk of it was either buried or found its way into the ever convenient monsoon drains. MacRitchie proposed a nightsoil collection service by the bucket system for disposal by dumping into the sea at Pasir Panjang. The proposal of sea disposal was not implemented as results of current and tidal observations were not in favour of this. He submitted a later report in 1893 following which an experimental plant for dessicating nightsoil was erected in Tanjong Pagar. In this installation, the collected nightsoil was boiled by means of coal fires to produce a powder residue termed "poudrette". The plant proved very expensive to operate, the market gardeners did not take kindly to the "poudrette" as a substitute for fertilisers and not surprisingly the plant was offensive. In 1904, this experiment was abandoned and so also was a scheme put forward by Mr. Peirce, who had become the Municipal Engineer proposed that nightsoil be dumped at sea from barges.

Two years later, in 1906, the Municipal Commissioners engaged Professor Simpson (a medical professor) to report on the sanitation of Singapore. He recommended that the nightsoil collection be carried out as a temporary measure and that a water-carriage system be developed. Simpson being a medical professor did not touch on the engineering aspects of his proposals. The Municipal Commissioners then engaged Mr. G. Midgley Taylor of Messrs. John Taylor & Sons to report on a scheme for the provision of sewerage facilities. Mr. Taylor presented his report in 1910 and its main recommendations were for the continuance of nightsoil service to serve those premises which could not be readily provided with the water-borne system and the construction of main sewers and a sewage disposal works. The nightsoil so collected should be discharged into the sewerage system at special depots.

The sewer network would have started on the west side of Kallang Bridge and would have traversed the town via Victoria Street, Hill Street and New Bridge Road to a single pumping station at the junction of Keppel Road and Cantonment Road. Subsidiary sewers were proposed leading to a disposal works on the hillside above Pasir Panjang Road near South Buona Vista Road. The disposal works was to consist of settling tanks, percolating filters with sludge presses or centrifuges for dewatering of sludge. The effluent from the works was to be discharged through a pipe to a point 1,000 feet off-shore at Pasir Panjang.

The proposal was not adopted on account of the high cost, estimated at S$5,000,000.00 – a large sum indeed in those days, the time required to complete the scheme and the proposal to lay deep sewers in what was considered "liquid mud" subsoil conditions. The Municipal Commissioners instructed the Municipal Engineer, Mr. Peirce, to prepare an alternative scheme and in 1911 Mr. Peirce put forward a modified scheme. The modified scheme comprised shallower sewers and separate pumping areas, each pumping station discharging to a sewage disposal works. This scheme after reference to the Consulting Engineer, Mr. Taylor, was adopted and outlined what is in effect the main sewerage system in Singapore today. The estimated cost in 1911 was S$4,200,000.00 and had the advantage of flexibility in that the construction could be carried out in phases, the first of which was estimated at S$1,300,000.00.

In this scheme, the main town area was divided into three zones for sewerage. The southern zone draining to the Park Road Pumping Station, northern zone No. 1 draining to River Valley

Road Pumping Station and northern zone No. 2 draining to Albert Street Pumping Station. Thus the area served was similar to that proposed by Taylor except that instead of a single pumping station served by a single trunk sewer running roughly north-east to south-west, the modified scheme included three trunk sewers system all running north-west from the sea. All the three pumping stations pumped the sewage to Alexandra Road where a disposal works was constructed on much the same lines as had been put up in previous reports. After consultation with Mr. Taylor, humus tanks were included in the works to prevent solids discharged from the filters settling in the Singapore River.

Following the adoption of the scheme, construction work began in 1912 and by 1915 the first phase was completed. The Park Road Pumping Station was commissioned in 1915, followed by the River Valley Road Pumping Station in 1917. The Albert Street Pumping Station was not commissioned until 1927 as a result of the outbreak of the World War I.

The exact dates of the development of the sewerage system are not known but it can be safely deduced that after 1917 most of the "Peirce" proposals were completed and a progressive extension of the system carried out year by year mainly by direct labour. In this progressive development, other pumping stations and sewers were constructed such as Kampong Bahru to serve the progressive expansion of Singapore. The population served in early 1930 was 100,000 with another 165,000 persons served by the nightsoil service. The nightsoil was dumped at two special depots, Albert Street Pumping Station and Park Road Pumping Station and conveyed to the Alexandra Works for treatment. This made the sewage hard to treat as is still the case today.

EXPANSION AND DEVELOPMENT OF THE SYSTEM (1931–1965)

Although various extensions and improvements were made to the Alexandra Disposal Works, with the extension of the sewerage network and the increase in flow, the Works was often overloaded resulting in aerial nuisance. This was particularly objectionable because of building development in the neighbourhood. At about this time, various proposals were put forward for the sewerage of the north and east of the town and these included schemes for disposal at sea at several points along the coast. Extensive float observations were made and experiments were carried out to show that the nightsoil could be taken to the disposal works separately and treated by sludge digestion processes.

These proposals were compiled as a report and was sent to Mr. J.D. Watson of M/s. J.D. & D.M. Watson, Consulting Engineers, and he in turn, after a visit to Singapore in 1934, submitted a report commenting on and supporting the Municipal Engineer's report. On the basis of this report and the Watson recommendations, the sewerage system and disposal works for the eastern sector of the Island was formulated. Following these lines the Rangoon Road and Paya Lebar Pumping Stations, the Kim Chuan Sewage Treatment Works (Phase I) and the Serangoon Sludge Works were designed and constructed in the closing years of the thirties.

Salient Points of the Watson Report and Recommendations

Nightsoil which had previously been dumped into sewers would be kept separate and pumped to the Paya Lebar Disposal Works, now better known as the Kim Chuan Sewage Treatment Works, where it should be mixed with sewage sludge and digested before being passed onto the Serangoon Sludge Works for disposal. The nightsoil problem was stressed as being a temporary one which would be resolved by redevelopment of those areas which could not be sewered so that sewerage facilities could be provided, thus progressively eliminating the problem. It is surprising to note that forty years later the problem has yet to be fully resolved. Out of a population of 2.1 million people no less than 700,000 or 33% are still served by the nightsoil system today.

The position and future of the Alexandra Works was considered at length and it was concluded that with the exclusion of nightsoil from the works, its effective life would be extended for many years although it became obvious then that with the development mushrooming around the works its future abolition was inevitable, the Kim Chuan Works being made to cater for these flows when the time arose. It is interesting to note that Watson recommended the retention of the Works "until the Singapore River can afford to do without the clear oxygenated effluent which they can be made capable of discharging, but no longer." Unfortunately that day has yet to come, still the Works had to make way for the rapid development fast encircling it. The population in 1933 served by the Alexandra Works was 100,000 persons of which 25,000 were in the northern area later transferred to the Kim Chuan Works.

Proposals were put forward for new sewers and pumping stations designed to serve the areas in the northern and eastern parts of the town and the sewage previously pumped from the Albert Street Pumping Station to Alexandra Road was to be diverted to the new pumping station at Rangoon Road. The eastern area not previously served was to be provided with sewers draining to a pumping station off Paya Lebar Road. Both pumping stations would then pass the sewage onto the Kim Chuan Sewage Treatment Works.

Watson recommended originally that the Works comprise sedimentation and the discharge of the partially treated sewage into the Johore Straits some distance off-shore near Pasir Ris. However, if the cost of this proposal proved to be too high, he recommended an alternative outfall terminating at the Serangoon River as a temporary measure. The latter proposal was implemented together with the introduction of units for the partial treatment of the sewage in the activated sludge method to reduce pollution.

It is interesting to note that the original intention was to site the works at Serangoon. This was changed to the present site in order to limit the retention in the pumping mains to reduce septicity which had already proved to be a problem then. The present site was chosen as being suitable partly because that area was at that time zoned by planners for noxious industries.

The forecast for the future based on 1934 statistics was remarkably accurate. At that time, about 100,000 persons were served by the water-carriage system out of a population of 500,000 (20%), while the Alexandra works was believed to be capable of serving up to 270,000 persons and the proposed works at Kim Chuan Road designed for 150,000 persons. It was predicted that the population which could be served by 1965 would be 650,000 persons. This was a remarkably close estimate as time has since proved. The total quantity of sewage treated in 1934 was 3.25 mgd (DWF) and provisions were made for its increase to 15 mgd. The estimated cost of the scheme excluding sewers and rising mains was $ 4.5 million.

Unfortunately the start of the construction work of the Works was delayed until 1936, due to the depression resulting from the world slump, and later the outbreak of war in Europe affected deliveries of plant and materials so that it was not until 1941 that the new scheme and the Kim Chuan Sewage Treatment Works began to operate.

Singapore was occupied by the Japanese between 1942 and 1945 and the works and the new sewerage system were therefore under utilised and neglected. After the War, relatively few connections had been made to the 60 miles of sewer draining to Kim Chuan Sewage Treatment Works and the population served by the water-borne system by both works was only 210,000 persons or 30% of the population of the municipal area. Many years were required to rehabilitate the sewerage system and the works but by the early fifties it became possible to rapidly increase the sewered population. At the same time, the population of the town had increased at a greater rate than anticipated and the projected population which could be served by 1965 of 650,000 was revised to 715,000.

It became very obvious that the old Alexandra Works would have to be abandoned as it was too near to the centre of the town. Earlier thinking on the matter was that should this take place then all the flows would be diverted to the Kim Chuan Works. However, development in the Island had increased so rapidly it became apparent that satellite towns would definitely be built in the then rural areas and that new works would ultimately be required in the western part of the Island, the works at Kim Chuan Road being reserved for development on the eastern side.

The broad outline of the sewerage system having been laid out before the two World Wars, it then became a matter of extending the system to cater for the needs of the town which attained city status in 1951. After the Second World War, the expansion of the town was such that the sewerage system became overloaded and the time had come to replace the old Alexandra Works as its position in relation to the development around it became untenable. Resulting from this, the City Council in 1955 acting on a report prepared by M/s. J.D. & D.M. Watson instructed them to prepare designs for a new treatment work and the demolition of the Alexandra Works.

The new Watson scheme included the re-routing of sewage from the Alexandra Works to a new pumping station at Tanglin, situated off Alexandra Road, from whence the sewage would be delivered by pumping mains to a discharge chamber at North Buona Vista Road. From there, the sewage is finally conveyed by a 72-inch diameter gravity sewer a distance of some 3 miles to the site of the Ulu Pandan Sewage Treatment Works. This works was constructed on a completely new site well clear of the city's ever reaching development and was designed to give full treatment to the sewage before its discharge to the Jurong River. The whole scheme cost some $40 million and was completed and commissioned in July 1961.

Concurrently with overload conditions at Alexandra and the need for a new works at Ulu Pandan, the Kim Chuan Works was also being overloaded by expansion of the city northwards and rapid development in the east. In order to cater for these additional flows, it was proposed to extend the Kim Chuan Works by phases each designed to treat sewage from 150,000 persons. Thus with the completion of the fourth phase, the works would have had enough capacity to treat sewage from a population of 600,000 people. Two phases of these proposal (Phase II & III), commissioned in 1959 and 1963 respectively were realised before the Toa Payoh development necessitated a complete change in the planning of future facilities.

At the same time as the sewage treatment and disposal facilities were being expanded so also was the sewerage network. Sewers were extended and additional pumping stations constructed.

Fig. 1 shows the sewered areas in the period 1915 – 1968.

THE PRESENT SYSTEM (FROM 1966)

With the rapid development of Singapore, a new approach to the planning of sewerage facilities is required for reasons stated below. It should be remembered that whereas in the past plans were made for a population of 200,000, the population of Singapore as at June 1971 was some 2,07 0,000 people. Moreover sewerage facilities in the past were confined within the municipal area and then the city area planning now is the responsibility of the Public Works Department and is for the whole island.

The development of highrise flats by the Housing and Development Board, the setting up of industries at the Jurong Industrial Estate and the redevelopment of the central city area under the Urban Renewal Programme have all necessitated a rapid expansion of the sewerage network, the relaying and re-routing of existing services and the expansion of the sewage treatment works. The development of the Queenstown Satellite Town fortunately coincided with the development of the Ulu Pandan Sewage Treatment Works and was thus provided with sewerage facilities without too much trouble. However, the development of the Toa Payoh Satellite Town resulted in a complete rethinking on the development of the Kim Chuan Sewage Treatment Works. The projected population of 250,000 to 300,000 for Toa Payoh necessitated the development of an almost entirely separate works at Kim Chuan. Messrs. J.D. & D.M. Watson, who planned and designed the sewerage and works extensions to cater for Toa Payoh Township, included in their planning the provision of sewers from the area draining to a main pumping station at Braddell Road where provision is also made to cater for flows from adjoining areas. From Braddell Road the sewage is pumped through a second pumping station at Bartley Road to Kim Chuan Sewage Treatment Works (East Works), the other three phases of the old works being designated the West Works. With the extension to the Kim Chuan Sewage Treatment Works, the capacity of the works is raised to 750,000 persons and it can be further extended to serve an ultimate population of 1,150,000 people.

In order to keep pace with the extension to the Kim Chuan Sewage Treatment Works, the Sludge Treatment Works at Serangoon is at present undergoing extensions at a cost of S$7.8 million and when completed will meet the full capacity of the Kim Chuan Sewage Treatment Works, provision being made for future extensions should the need arise. Concurrently with development in the east, the Ulu Pandan Sewage Treatment Works, which is at present working under overloaded conditions, is also undergoing extensions and when completed in 1973 will cater for a population of 600,000.

THE FUTURE SYSTEM

In line with the present emphasis on a clean and wholesome environment, the introduction of anti-pollution legislations, water pollution control in particular, and the proposed development of new towns such as Telok Blangah, Woodlands, and other areas where there are no existing sewerage networks, the planning and design of sewerage facilities to cater for these areas would have to be decentralised. New treatment works with their separate network of sewers would have to be worked out with the guide-line that the sewers planned today should cater for the ultimate needs of the future.

It is now obvious that the Ulu Pandan Sewage Treatment Works would have to be duplicated to cater for the combined flows of the Bukit Timah, Telok Blangah and the Queenstown Neighbourhood VII and adjoining areas. Similarly the Kim Chuan Sewage Treatment Works will have to be further expanded to cope up with the rapid development in the east. A feasibility study is now under way in the east and north-east with a view to the ultimate provision of sewerage facilities in this area.

It is predicted that the next 5 years will see the construction of 3 new sewage treatment works at Jurong, Woodlands and the East Coast, the duplication of Ulu Pandan Sewage Treatment Works and the further extension of Kim Chuan Sewage Treatment Works. The building of many more pumping stations and the laying of new sewerage networks and extensions to the existing systems.

Fig. 2 depicts the sewered areas existing at the moment as well as sewerage area schemes currently in progress or planned for the next five years. Figs. 3 and 4 indicate the areas served by treatment plants and nightsoil collection. It should be noted that each of the areas depicted on Fig. 1 to 3 appear to overlap the other, this is on account of the fact that within sewered areas are so called "pockets" which cannot be served. This is because they are mainly squatter settlements, therefore subject to redevelopment, uneconomic to serve or demarcated for urban renewal development. The sewered area as at 1971 is some 31 square miles and the total population served by main drainage and treatment plants is 1,180,000 persons or 57% of the total population. A further 340,000 people are served by the nightsoil collection system, 360,000 persons have some form of outdoor latrines and the balance some form or other of sewage disposal. As a result of improved sanitation over the years, the crude death rate has steadily plunged from a high 40 per 1,000 in 1934 to about 5 per 1,000 in 1971.

THE SEWAGE AND SLUDGE TREATMENT WORKS

Having dealt with the sewerage system in some detail, the sewage treatment works and sludge treatment works in brief we now look into greater detail the design, operation and maintenance of the works of both past and present, and a peep into the works of the future. In the discussion on sewage works included will be the smaller treatment plants that serve both individual housing units as well as large housing estates where main drainage is at present not available. Cesspits, used in an effort to control the pollution of water catchment areas, will also be discussed in passing.

Alexandra Road Sewage Disposal Works

The Works was designed to provide secondary treatment to the sewage and biological filter beds were employed to achieve this end. The units incorporated in the Works comprised screens, detritus channels, sedimentation tanks, filter beds, humus tanks, humus drying beds, primary sludge digestion tanks with concrete gas-collecting covers and top water settling tanks.

Screens

Hand raked bar screens and simple hand cleaned detritus channels incorporated in the Works removed only a small amount of screenings and detritus and these were collected daily and disposed off by dumping.

Sedimentation Tanks (Imhoff Tanks)

The sedimentation tanks used were of the Imhoff type and were constructed in pairs on account of poor ground conditions. They had the advantage of flexibility in that they could and were converted to upward flow tanks and separate digestion tanks. The sludge digestion tanks were used in conjunction with square Dorr Clarifiers. Short periods of sedimentation of about two hours at the average rate of flow resulted in a 55% suspended solids removal. Under those conditions, it was reported that upward flow tanks gave slightly better results than mechanically scraped tanks and required less maintenance. The quantity of sludge produced was about 0.8% of the average flow (6.5 mgd in 1951) with a moisture content of between 95% to 96%.

Filter Beds

Altogether there were 55 filter beds but 10 were destroyed during the war. The beds were each 100 feet in diameter with 6 feet media and dosing of the settled sewage was by means of rotary distributors. After some experimentation it was decided to use coral as media since it was cheap, had a large surface area, rough surface and light in weight thus reducing foundation costs. Loading on the filter was 50 gallons per cubic yard (11 gpd/sq ft) prior to the discharge of nightsoil being re-routed to the Kim Chuan Sewage

Treatment Works and 100 gallons per cubic yard (22 gpd/sq. ft) after the cessation of nightsoil discharges into the Works.

Some smell nuisance was experienced when treating an admixture of sewage and nightsoil and this was minimised by dosing 2 ppm of chlorine to the settled sewage, except in times of heavy rain. The smell appeared to be caused by a gelatinous film growing on the surface of the beds and was most noticeable at night due to the lower rate of flow. The beds were prone to ponding and in order to maintain a good effluent it was necessary to wash the top media of the beds about once a year by raking and housing with returned effluent at high pressure. Smell nuisance and ponding of the beds became less frequent when only sewage was treated after 1941 and beds required less frequent raking and housing. Filter-bed flies *(psychoda)* were never a real nuisance although present on the filters. A small spider was observed in great numbers around the beds and was thought to have some effect in controlling the flies, but climatic conditions are probably of greater consequence.

Humus Tanks

The humus tanks were rectangular in shape and were cleaned manually once a week. The retention times of the filtrate in the tanks were 3.7 hours and 2.2 hours at average flow as different blocks of filter beds were fed to a different set of humus tanks. It was discovered that the shorter retention time resulted in a poorer final effluent. Small upward flow filters (Bank's filters) of broken granite were incorporated at the ends of all the tanks and these proved very effective in reducing the suspended solids in the final effluent. These filters were washed down each time the tanks were cleaned to prevent them from being clogged up.

Humus Drying Beds

The humus was pumped to drying beds, where it dried readily in the sun and after about 22 days was lifted and used as a soil conditioner in the the Works and some were given to the public. About 2,750 tons were lifted annually and the moisture content of the dried sludge was about 70%. The sludge was periodically examined for the presence of live hookworm ova, etc and these tests were normally negative. At times the results were positive and it was decided to use the gas produced from the digestion of crude sludge for sterilising the humus sludge.

Sludge Digestion Tanks

Crude sludge from the sedimentation tanks was "seeded" with about one-third its volume of recirculated sludge and fed into sludge digestion tanks where it was digested for about 30 days. The top-water from these tanks was settled and returned to the inlet of the Works. The digested sludge was incinerated and dumped at the Works. After 1941, it was pumped across the town for further treatment and disposal at the Serangoon Works, the volume pumped being half the volume of the crude sludge. The sludge gas was collected in floating concrete covers and used for lighting of the Works as well as to heat the humus sludge as mentioned earlier. The final effluent was discharged into the Singapore River at a point somewhere near the Kim Seng Road Bridge and found its way ultimately to sea.

Kim Chuan Sewage Treatment Works

The Kim Chuan Sewage Treatment Works is in actual fact two separate works generally known as the West Works and the East Works or the Toa Payoh Sewage Treatment Works. The West Works comprising three phases, I to III, were designed as Partial-Treatment Activated Sludge Plants to produce an effluent standard of 50 mg/BOD and 50 mg/l suspended solids. Mr. J.D. Watson's recommendation was to use primary treatment only, possibly in conjunction with a sea outfall in the future, but for various reasons the municipal engineers favoured biological treatment and a short period diffused air activated sludge plant was selected and constituted Phase I of the West Works. The other phases, II and III, were designed with little change in basic ideas and improvements were mainly in points of comparative detail. Basically the improvements were the introduction of machine scraping of tanks with a consequent revision of shape, more efficient and intense air diffusion, increased return sludge capacity and a more sophisticated arrangement of the aeration tank feeds, etc. Shortly modifications will be made to the West Works in order that it may produce a final effluent of 20 mg/l BOD and 30 mg/l suspended solids.

Phase I

A summary of the treatment units and their designed capacities are as shown in Table I. It should be noted that modifications and improvements have been carried out over the years and the details set out are for treatment units at present existing in the West Works.

Screens

Hand-raked fine screens were originally used and a small amount of screenings removed. These were passed into the sludge digestion tanks after disintegration. These were later replaced with comminutors. Originally no grit channels were incorporated since full length channels were provided at the Rangoon Road and Paya Lebar Road Pumping Stations. As a result of this much heavy silt was deposited in the pre-aeration channels and grit channels were then incorporated in the Phase II design of the Works.

Pre-aeration units

Although included in the design no evidence could be found of any significant benefit from the use of these units. It was reported that the sewage was septic throughout the unit and did not appear to respond better to sedimentation or bio-flocculation and the perforated pipes in the diffuser system were constantly blocked as a result of the settlement of grit in the channels. It was decided that these units should be abandoned when Phase II was constructed since the benefit derived was too small to justify the considerable quantities of air used.

Primary sedimentation tanks

The primary sedimentation units are upward flow radial tanks and are designed to give a retention period of 3 hours at average rate of flow and an upward velocity of 17 ft/hour at 3 DWF. No scum removal mechanism is incorporated and removal is effected manually by skimming.

Aeration units

The aeration units are of the flat bottom type and are 12 feet deep, the total capacity being about 820,000 gallons. Aeration time at DWF is about 3.5 hours and about 3.0 hours at average flow. Activated sludge is returned from the final settling tanks through adjustable telescopic valves and axial flow sludge pumps.

Final sedimentation tanks

The final sedimentation tanks are in four rectangular sections, each of which has a conical hopper bottom, no mechanical scrapers are incorporated. The total volume of the tanks is about 1,925,000 gallons and the average retention time is 5.5 hours with a corresponding upward flow velocity of 6.5 ft/hour.

Phases II and III

Grit channels and comminutors

Four grit channels of the spiral flow type having a total capacity of 195,000 gallons were introduced in the Phase II & III development of the Works and are to this day still in use. Two suction dredgers extract the grit from the channels and pass it through the Atkins classifiers (using a spiral screw in an inclined trough) to dewater it, the dewatered grit then drops into hoppers. Four Nos. 36 R Jones & Attwood Comminuters are installed after the grit channels with bar screens added as an additional precaution in case of breakdowns of the comminutors.

Primary sedimentation tanks

These are circular tanks each 70 feet in diameter, four to each phase designed for a retention period of 3 hours at DWF and a maximum upward flow velocity of 7.8 ft/hour.

Aeration units

These are identical units comprising 2 units each with 407 feet of 15 ft x 12 ft channel and dome diffusers set in the bottom of the tanks. The retention time in the units is about 4 hours at DWF. Activated sludge is returned from the final separating tanks by means of axial flow sludge pumps.

Final separating tanks

These are similar to the primary sedimentation tanks with 30 degree slope on the floor and a light chain-type scraper installed. V-notch aluminium weir plates are incorporated to give a higher overflow rate.

Sludge digestion tanks

Four primary sludge digestion tanks with floating gas-holder roofs equipped for gas recirculation and sludge recirculation pumps were in use till early 1971 when the East Works digesters obviated the need to use the old digesters. The future of these digesters will have to be resolved shortly.

Compressor house

Prior to the commissioning of the East Works, the air supply to the West Works was derived from dual-fuel engines driving Rootes-type air compressors housed in the old compressor house. When the East Works became operational in 1965, all the air supply to both Works is now derived from air blowers driven by English Electric & CSRKD dual-fuel engines housed in the new compressor house.

Kim Chuan East Works

The orginal planning as mentioned earlier was to design the Kim Chuan Sewage Treatment Works by phased development in 4 phases, each serving a population of 150,000 persons and a dry weather flow of 6 mgd. However, as a result of the decision to develop Toa Payoh into a satellite town of 250,000 to 300,000 people, it beame necessary to change the development of the Kim Chuan Sewage Treatment Works. Messrs. J.D. & D.M. Watson recommended the development of a separate works which will give full treatment to the sewage to produce an effluent complying with the Royal Commission Standard of 30 mg/l suspended solids and 20 mg/l BOD. However, flexibility was incorporated in the design and some links with the West Works are maintained. The construction of the Works started in 1963 and the Works was commissioned in 1969. The cost of the Works was S$13.0 million. The Works has a very pleasing outlook.

Description

The Works is situated on a 12-acre site east of the West Works and receives its flow of sewage via a new inlet channel. An East-West link enables flows from the West Works Inlet Works, previously described, to be diverted to the East Works for treatment. No grit channels or communitors are installed as all pretreatment is carried out at the 2 pumping stations at Braddell Road and Bartley Road.

Treatment Units – Primary sedimentation tanks

There are 4 primary sedimentation tanks each 87.5 feet in diameter, mechanically scraped and equipped with scum removal mechanism. Details of the design of the units are as shown in Table 1. The settled sewage flows into a common chamber and from there via the common settled sewage channel is fed into the aeration units.

Aeration Units

The aeration units are divided into 2 units each served by 4 final separating tanks. The channels have flat bottoms with air pipes running through them. Porous (Alundum) domes fitted to these pipes permit fine diffused air bubbles to pass through them and the total capacity of air which is available is up to 18 million cu ft/day. The capacity of the tank is 4 million gallons and the average retention time is 7 hours.

Final Separating Tanks

The MLSS from the aeration units are then channelled to the final separating tanks where the activated sludge is settled out and returned to the aeration units. There are 8 final separating tanks These tanks are circular in shape, upward flow type and are fitted with scrapers. The final effluent flows over V-notches and activated sludge is returned to the aeration units by means of axial flow sludge pumps – two to each unit.

Primary Sludge Digestion Tanks

The crude sludge from the primary sedimentation tanks are fed to a bank of 6 fixed roof concrete digestion tanks, only 4 digesters are at the moment in use. Heatamix units are installed in the digesters and provision for some and digested sludge withdrawal have been incorporated. High and low level alarms in the form of EL Control Units are also installed. The digested sludge flows by gravity to the Serangoon Sludge Treatment Works for further treatment.

The sludge gas is piped to a gas holder which incorporates a piston and gas is delivered under a pressure of 10 inches water gauge to dual-fuel engines of the 8 CSRKD English Electric type housed in a compressor house. These engines drive airblowers which supply air to the aeration units in both the East and West Works. Surplus gas produced can be disposed off by burning it at the waste gas-burner.

Wash-water Tower

A wash-water tower and a sump below the compressor house equipped with pumps deliver final effluent for general use on the Works and engine cooling. Ram pumps are installed in both the Works Pumping Station and under the wash-water tower for cleaning of choked pipe-lines, etc. The Works Pumping Station houses drainage and S. A. S. pumps.

Administration Building

The Administration Building houses the office of the manager, offices of the maintenance and operation staff, a store as well as a modern laboratory where all the works samples are analysed.

The flows into and through all the unit processes in the works are fully metered. The meters installed are of varied makes and types as these were put in over a period of 30 years. Malfunctioning of the meters is a common day occurrence for reasons explained later.

Serangoon Sludge Works

The Serangoon Sludge Works located at the northern-eastern part of the Island was developed at the same time as the first phase development was initiated. Its function was and still is to further treat the admixture of sludge and nightsoil from the K .a Chuan Sewage Treatment Works. Development of the Works has not kept pace with development at Kim Chuan Road. Although some extensions were carried out between 1962 and 1964 these were inadequate. Messrs. J.D. & D.M. Watson were instructed to look into the extensions of the Works in 1967 and presented a report later that year. They were further asked to look into the treatment and disposal of sludge liquors from the Works in 1968 and reported on the matter in 1969. Extension work to the Works began in 1970 and is scheduled for completion in 1973.

Old Works

The old Works is made up of 2 circular concrete sludge digester, one being an open digester and the other is fitted with a floating roof gas holder with a total capacity of 1.2 m.g. Sludge together with nightsoil is fed into the digesters and the gas produced is used to drive two dual fuel engines coupled to an alternator which generates electricity for general lighting at the Works.

The digested sludge is withdrawn and fed into secondary digestion lagoons rectangular in shape. There are 3 lagoons with a total capacity of 8.7 m.g. The scum and the sludge are then fed into the sludge drying beds by gravity as and when empty beds are available.

The sludge drying beds are rectangular in shape, there being 21 in number and the under drainage is made up of field drains laid with open joints and topped with granite media and sand. The total capacity of the beds is 14,000 square yards.

Top-water from the lagoons are withdrawn into two circular top-water settling tanks with a total capacity of 200,000 gallons. The settled top-water and the drying bed filtrate together being discharged into the Sungei Blukar, a tributary of the Serangoon River.

The New Extensions

The present extensions to the Works comprise the construction of additional and very much larger sludge drying beds, secondary digestion lagoons, a top-water settling tank, new quarters for both staff and labourers, an administration office equipped with a modern laboratory, and attendant pumping stations.

Secondary sludge digestion lagoons

The secondary sludge digestion lagoons (4 Nos.) will have a capacity of 8.2 million gallons and will be used in conjunction with the existing units. A new top-water settling tank of capacity 50,000 gallons will be incorporated and the existing tanks will be abandoned. Similarly when the extensions are completed the existing primary digestion tanks will also be abandoned as Public Utilities Board electricity supply will be used for the operation of the whole Works.

Sludge drying beds

The sludge drying beds, 50 in number each having an area of about 2,200 square yards have concrete floors sloping towards collecting channels. Granite media is used throughout the bed and the bed filtrate drains towards a pumping station where together with the top-water from the lagoons are pumped out to the Serangoon Harbour via a short PVC pipe outfail. The existing sludge drying beds may be renovated and used in conjunction with the new beds or demolished to make way for the construction of new beds.

Administration building

The Administration Building will house the the office of the manager, a general office, offices for the Works personnel and a modern laboratory for the analysis of works samples. At the moment, samples are collected and transported to Kim Chuan Sewage Treatment Works for analysis.

Staff quarters

The tied quarters provide housing for both staff and labourers as the Works is located at rather remote area. The whole of the Works is sited in pleasant surroundings and when completed and properly landscaped can be quite attractive.

Ulu Pandan Sewage Treatment Works and Sludge Treatment Works

Stage I

The Ulu Pandan Works is located in the north-western part of the Island at the end of Toh Tuck

Road. It was designed to treat sewage from a contributory population of 400,000 (24 mgd dwf) persons and was commissioned in 1961. The whole scheme, including the Tanglin Pumping Station and its attendant rising mains, gravity outfall sewer and effluent outfall cost S$40 million. The Works is currently being extended and when completed will serve a total population of 600,000 persons. The first stage of the extensions, the sludge drying beds and secondary sludge digestion lagoons were completed in 1970 and 1971 respectively and are now in use.

Inlet works

Sewage from Tanglin Pumping Station is received at the Works by the Works Pumping Station. Here vertical spindle centrifugal pumps (9 Nos.) driven by 100 hp electrical motors deliver the sewage directly to a discharge basin which distributes the flow to the rest of the Works. Venturi flumes measure the flows.

Primary sedimentation tanks

There are eight mechanically scraped sedimentation tanks of 98 feet diameter having 7½ sloped floors with central sludge hoppers. Each tank has a capacity of 437,000 gallons with a designed retention time of 3.5 hours at DWF.

Aeration units

Four aeration units (eight half-units) with a total capacity of 9,960,000 gallons designed for a detention period of 10 hours at DWF have ridged and furrowed floors. Two half-units each consisting of seven channels share a common return channel and diffused air is fed through porous (Alundum) dome diffusers located in the furrows. Provision is made for incremental feed. Eight 15-inch diameter vertical spindle axial flow return sludge pumps are arranged in pairs with variable speed control to pump varying flows to the units.

Final separating tanks

There are sixteen final separating tanks of 70 feet diameter with 30° conical floors mechanically swept by chain scraper. Each tank has a capacity of 260,000 gallons designed for a retention period of 4 hours at DWF. The tanks have concrete peripheral weirs over which the final effluent flows.

Primary sludge digestion tanks

Four primary sludge-digestion tanks of 70 feet internal diameter with a total capacity of 465,000 cubic feet equivalent to 1.55 cu ft /head are equipped with floating gasholders and gas and sludge recirculation arrangements. An external heat exchanger at one of the tanks which when in use heats the sludge to a temperature of 95°F. Heated sludge from one tank is transferred to the other tanks and a temperature of 90°F can be maintained.

Secondary sludge digestion lagoons

The two rectangular earth-banked secondary sludge digestion lagoons are lined with 4 ins in-situ concrete. Their base area is approximately 196 ft x 96 ft and their average depth is 12 ft with 1 to 1½ sloping sides. Their total capacity is 503,000 cu ft equivalent to 1.67 cu ft/head.

Sludge drying beds

Altogether there are twenty sludge drying beds each 150 ft x 80 ft giving a total area of 26,500 square yard or the equivalent of 11.3 persons/square yard. Provision is made for the lifting of sludge using light-alloy portable sludge conveyors each approximately 30 ft long, 5 of them being operated together in series across one bed.

Power house

This is a concrete framed building and it houses the dual-fuel engines, alternator sets, air blowers and other auxillary equipment. There are three dual-fuel English Electric 7RLD engines which are each coupled to an alternator set having an output of 770 KW, 962.5 KVA at 0.8 power factor capacity of giving a supply of 3,300 volts, 3-phase

Three two-stage air blower sets each capable of delivering 12,500 cu ft/minute of free air at a pressure of 6.5 lb/sq in supply the air required by the aeration units.

A ram pump is incorporated in the Works for clearing chokes on any pipe-line, as a booster on the sludge pipe-line to the drying beds and as a standby to the other pumps.

The Works is fully metered and almost all of the meters are of the Kent type.

Administration building

This is a concrete framed structure and houses the manager's office, a general office, offices for the maintenance and operation personnel, stores, workshops and a modern laboratory where all the works samples are analysed.

Effluent outfall

This is a 72-inch diameter reinforced concrete spigot and socket pipe-line with rubber ring joints some 6,950 feet in length. Some sections are laid in heading and these are of in-situ Portland cement concrete with precast invert. The point of discharge is at the Jurong River off Jalan Ahmad Ibrahim via three effluent dispersion steel pipes each 43-inch diameter fitted with diffuser outlets.

Stage II — New Extensions

The new extensions to the Works comprise units which are similar to those in existence with the incorporation of modifications and improvements derived from experience in the operation and maintenance of the existing units. The new units are made up of 30 additional sludge drying beds which are already in use, two half-units aeration tanks, four final separating tanks, two secondary sludge digestion lagoons also now in use, two covered primary sludge digestion tanks with floating roofs, extension to the sludge pumping station and the installation of an additional air blower. No additional engine or alternator set are added as the new blower will be fed from the Public Utilities Board's power supply. The 30 new sludge drying beds bring the total number of beds to 50 and a total drying area of 600,000 sq ft or 9 persons/sq yd.

Works on the extensions started in 1968 and it is scheduled for completion by 1973. The estimated cost is S$7.0 million and when completed will bring the capacity of the Works to 500,000 persons or 30 mgd DWF.

MODE OF OPERATION OF THE WORKS

Kim Chuan and Serangoon Treatment Works

Hydraulic Loading

As described earlier the Kim Chuan Sewage Treatment Works consists of three phases making up the West Works and the East Works Stage I. Together the Works is designed to treat 30 mgd of sewage at DWF or 90 mgd at WWF. The West Works receives sewage from the Rangoon Road and Paya Lebar Pumping Station but a east-west link permits sewage from this West Works to be diverted to the East Works. The East Works receives sewage from the Toa Payoh area via a separate inlet cha[illegible] The general distribution of flow to the various West Works Phases and the East Works are as follows :—

Units	Average Flow 0800 hrs. to 0000 hrs. mgd	Average Flow 0000 hrs. to 0800 hrs. mgd	Daily Average mgd
Phase I	7.0	3.7	6
Phase II	4.5	3.0	3.5
Phase III	5.5	3.5	5.0
East Works	16.2	9.5	12.5
	33.2	19.7	27.0

In the author's opinion it is more appropriate to consider an average rate of flow rather than the DWF. On this assumption, calculations of population served is therefore based on a factor of 1.0 for average flow and 0.8 for DWF, the maximun flow of 30 DWF is therefore in reality only 2.4 average flow. On this basis, the population served by Kim Chuan Sewage Treatment Works assuming a flow contribution of 40 gcpd at an average flow of 27 mgd is

$$\frac{27 \times 10^6}{40} \times 0.8 = 540{,}000 \text{ persons.}$$

West Works Unit Processes

Primary sedimentation tanks

There are 4 primary sedimentation tanks in each phase having a total capacity of 1,032,000 gallons, 768,000 gallons and 768,000 gallons respectively. In Phase I between 8 a.m. and midnight three tanks only are in use and between midnight and 8 a.m. only two tanks are in use. This results in retention periods of 2.65 hours and 3.36 hours at average flow as against a designed retention time of 4.1 hours at DWF. Withdrawal of crude sludge is carried out at 0800 hours, 1500 hours and 2330 hours. Retention periods referred to in the following text are all based on average flows at (8 a.m. to midnight) and (midnight to 8 a.m.).

In Phase II only one tank is used daily and it is desludged three times a day at 0800 hours, 1515 hours and 2330 hours. The retention times are 1.02 hours and 1.54 hours as against a designed [illegible]ention time of 3.06 hours at DWF.

Of the 4 primary sedimentation tanks in Phase III only two are used between 8 a.m. and midnight and only one is used between midnight and 8 a.m. This results in retention periods of 1.68 hours and

1.32 hours as against a designed retention period of 3.06 hours. The desludging times are the same as for Phase II.

The reasons for keeping the detention times shorter than the designed times is on account of the septicity of the sewage. Sewage normally arrives at the Works in an already septic condition and it is observed that long retention periods in the primary tanks result in emission of odours and possible overflowing of sludge. Efficiency of the units are not adversely affected as the suspended solids and BOD removals are 60% and 30% respectively on the average.

Aeration units

The Phase I units differ from the other two phases in that the returned activated sludge is not distributed to all aeration channels as about 50% of the capacity is used for re-aeration.

Aeration times are 2.65 hours and 3.36 hours respectively whereas the designed aeration time is 3.8 hours at DWF. Two axial flow return sludge pumps are used with one pump cutting out for 8 hours between midnight and 8 a.m. The return sludge as a percentage of the crude sewage is 45% and 86% respectively. The air supply is about 0.8 cu ft gallon of crude sewage.

The Phase II units have a total capacity of 895,000 gallons and step-aeration is practised here. Two R.A.S. pumps operate continuously over a 24-hour period resulting in percentage returns of 88% and 133%. The detention periods are 4.77 hours and 7.15 hours against a designed aeration time of 3.4 hours at DWF. The air supply is about 1.25 cu ft gallon of crude sewage.

In Phase III all channels of the aeration units are in use and step-aeration is also practised here. Two R.A.S. pumps operate 24 hours continuously resulting in percentage returns of 79% and 114% respectively. Retention periods are 3.9 and 6.1 hours as compared with a designed retention time of 3.4 hours at DWF.

Final separating tanks

All the final separating tanks, four per phase, are in use. The resulting retention periods are 6 hours and 11.4 hours for Phase I, 5.5 hours and 8.2 hours for Phase II and 4.5 hours and 7.0 hours for Phase III as against designed retention periods of 7.7 hours, 4 hours and 4 hours at DWF respectively.

Primary sludge digestion tanks

Since 1971 with the commissioning of four primary sludge digestion tanks in the East Works no crude sludge is now fed into the Western Digesters. The future of these digesters will have to be resolved, although for the time being one of them may be used in an experiment on the digestion of an admixture of crude sludge and nightsoil. In the meantime, they are used as balancing tanks when the Serangoon Sludge Treatment Works is unable to cope with the primary digested sludge, nightsoil and top-water from the Kim Chuan Sewage Treatment Works.

East Works

The East Works treats sewage received from the Braddell Road-Bartley Road Pumping Stations via the Toa Payoh Inlet Channel with a flow variation of from 1 mgd to 7 mgd. The rest of the flow is from the West Works received via the east-west link.

Primary sedimentation tanks

Altogether there are four primary sedimentation tanks with a total volume of 1,000,000 gallons. All four tanks are in use between 8 a.m. and midnight, one tank being taken out of stream after midnight following the last desludging operation. In contrast with the West Works these tanks are desludged four times as against three times a day, the hours of desludging are 0830 hours, 1300 hours, 1730 hours and 2330 hours. The retention periods : 1.6 hours and 1.9 hours as against a designed retention time of 2 hours. Here again the reason for using less tanks at night is the same as that for the West Works, that is a matter of alleviating septicity in the sewage. The efficiency of the units are as follows: BOD removal 30% and suspended solids removal 50%.

Aeration units

There are two aeration units, E1 and E2, and these are further divided into two half-units each (A & B), each half-unit comprising 7 aeration channels. The total capacity is 4,200,000 gallons. A common settled sewage channel delivers the flow to the units and the flow distribution is effected by means of penstocks which distribute the flow into the first and second channels. Two variable speed R.A.S. pumps running at maximum speed are in operation at each unit between 8 a.m. and midnight and one of these is taken off stream after midnight. The MLSS loading is in the region of

3,000 mg/l and 3,500 mg/l and the RASSS is between 6,000 mg/l and 6,500 mg/l. The rate of return of R.A.S. as a percentage of crude sewage is 86% and 74% respectively. The air supply is approximately 1.48 cu ft/gallon crude sewage or 1,200 cu ft/lb BOD applied. It is to be noted that high solids loading is practised, this is so in order to prevent the units from foaming since the synthetic detergents currently in use are "hard".

Final separating tanks

There are 8 final separating tanks with a total capacity of 2,035,000 gallons. Four F.S.T. serve each aeration unit and all 8 tanks are in use at all times. The resulting retention periods are 3.00 hours and 5.2 hours as against a designed retention time of 4.0 hours at DWF.

Primary sludge digestion tanks

There are 6 digestion tanks with a total capacity of 5,310,000 gallons. Only 4 are at the moment in operation viz. No. 2,3,4 and 5. Heatamix units incorporated in each digestion tank enable gas recirculation to be effected. Each Heatamix unit is operated on an 8-hour basis over 24 hours, there being 2 units to each digestion tank. The daily operation of the tanks are as follows :

Digestion Tank No :	2	3	4	5
Gas recirculation :	24 hours	24 hours	24 hours	24 hours
Top-water and digested sludge withdrawal: (6 times a day)	40,000 g	40,000 g	40,000 g	40,000 g
Crude sludge fed : (6 times a day)	40,000 g	40,000 g	40,000 g	40,000 g

The system is based on a draw-feed operation. The top-water and the digested sludge are discharged to the Serangoon Sludge Treatment Works for further treatment. The detention period in the digestion tanks is about 22 days.

The digestion process is carried out at the Mesophilic Range (90°F) and the sludge-gas produced, mainly methane, is piped to a gas-holder which feeds the dual-fuel engines, that drives the blowers coupled to them.

Compressor house

There are 3 English Electric 8CSRKD dual-fuel engines (670 hp and 533 rpm) which are coupled to Brayan Donkin air blowers that supplies the necessary air to the aeration units in both the East and West Works. Two of the 3 engines and air blowers run 24 hours continuously with the third on standby. About 11,000 cu ft/min of air at a pressure of 7 psi is supplied to the West Works by one blower while the other supplies 15,000 cu ft/min. of air at a pressure of 5.2 psi to the East Works. About 6,000 to 8,000 cubic feet of sludge gas and 7 gallons of high speed diesel is required per hour to operate the engines. On straight diesel alone about 300 gallons are required per 24-hour day. Final effluent from the works is used for engine cooling. Electrical energy for the Works is taken from the Public Utilities Board's supply.

Laboratory

Daily analysis of Works samples are carried out in the laboratory. Composite samples made up of 2-hour samples form the basis of samples analysed. Generally BOD and SS levels are monitored daily but once a week a complete analysis is carried out. Results of average analyses are as shown in Table 2.

Serangoon Sludge Works

This Works has been dealt with in some detail previously. The Works as it stands at the moment is overloaded and the mode of operation subject to variation depending upon the Kim Chuan Sewage Treatment Works. However, basically all the units operate on a draw-feed basis. The digested sludge is continuously discharged to the lagoons from the primary digestion tanks. Top-water is withdrawn twice a day on the average to the top-water settling tanks. Sludge and scum are fed to the sludge drying beds as and when empty beds are available.

Ulu Pandan Sewage Treatment Works

The Works serves the south and south-western parts of the Island as well as the Jurong Industrial Estate. It receives most of the sewage from the south via the Tanglin Pumping Station and the balance comes via the Jalan Peng Kang Pumping Station at the Jurong Industrial Estate and some large housing estates. The Works was designed to serve 400,000 persons (24 mgd at DWF) and is at present being extended to serve a total population of 500,000 persons (30 mgd at DWF).

Hydraulic Loading

The daily average flow received at the Works is in the the region of 25.6 mgd, this is inclusive of all return flows. This works out to a population equivalent of 470,000 persons (return flow averaging 2.1 mgd). There are no grit removal or comminution of the sewage at the Works. The flow is distributed to the treatment units by centrifugal pumps housed in an annexe to the power house. Two-peak flows are experienced at the Works each day. The morning peak is at about 1000 hours falling off at around 1800 hours. The second and shorter peak is between 2000 hours and 2300 hours. A period of very low flow is recorded between 0300 hours and 0600 hours.

Average flow (0900 to 2300 hours): 29.2 mgd
Average flow (2300 to 0900 hours): 20.7 mgd

Primary Sedimentation Tanks

There are 8 mechanically scraped tanks each designed to have a detention period of 3.5 hours at 24 mgd. Seven tanks are in use between 0900 and 2300 hours while 2 tanks are drained every night after 2300 hours. The flow is distributed equally to all tanks. Withdrawal of crude sludge is carried out at 0800 hours, 1400 hours, 2100 hours and 0300 hours and about 326,000 gallons of sludge are drawn daily. The average detention periods of the tanks are 2.5 hours (0900 to 2300 hours) and 2.6 hours (2300 to 0900 hours). The efficiency of the tanks in terms of BOD and suspended solids removals are 47% and 66% respectively.

Aeration Units

The aeration units (4 in number) are made up of 8 half-units each having a capacity of 1.245m.g. designed for a detention period of 10 hours at 24 mgd. Two half-units each comprising 7 channels share a common return sludge channel and fine bubble diffused air is fed through porous dome (Alundum) diffusers located in furrows on the channel floors. Return activated sludge is returned continuously by means of variable speed axial flow pumps, 2 to each unit, which run at maximum speed throughout the day. Surplus activated sludge is returned to the inlet and mixes with the influent.

Seven half-units are normally in use and flow is distributed equally to the 7 tanks. Settled sewage is fed into each half-unit through penstocks which distribute the flow into the first and second channels. The following data are representive of normal operating conditions :

Average detention period (0900 to 2300 hours) : 7.2 hours
Average detention period (2300 to 0900 hours) : 10.0 hours
Air supply : 20,000 cu ft/ min or 1.0 cu ft/g of crude sewage
Average return activated sludge (0900 to 2300 hours) (% of crude sewage) 70%
Average return activated sludge (2300 to 0900 hours) (% of crude sewage) 84%
Total surplus activated sludge 2.0% to 3.0% of crude sewage
Average MLSS : 3500 mg/l
Average RASS : 6000 mg/l

Final Separating Tanks

Of the 16 final separating tanks, 14 are normally in use and activated sludge is withdrawn continuously. Each tank has a capacity of 259,375 gallons, is mechanically scraped and is designed for a retention period of 4 hours at 24 mgd. Under operating conditions the detention periods are : 3.0 hours (0900 to 2300 hours) and 4.2 hours (2300 to 0900 hours).

Primary Sludge Digestion Tanks

Four digestion tanks each with a capacity of 968,750 gallons are equipped with floating gas holders capable of holding 10,000 cu ft sludge gas each. All 4 tanks are operated in parallel and crude sludge is fed to the tanks by means of 3 vertical spindle sludge pumps. Sludge recirculation is carried out by means of 2 horizontal spindle sludge pumps. Gas recirculation is carried out by means of 3 gas compressors. An external heat exchanger is coupled to one of the primary digestion tanks and heat the sludge to a temperature of 95°F. Heated sludge from this tank is transferred to other tanks thus maintaining the temperature of the sludge between 90°F and 95°F in all the tanks.

The following data are representative of normal operating conditions :

Digestion Tank :	1	2	3	4	Total
Gas recirculation	2 hrs	2 hrs	2 hrs	2 hrs	
Sludge recirculation	6 hrs	6 hrs	6 hrs	6 hrs	
Digested sludge withdrawn: (0715,1230,2000&0100hrs)	– 4,000 gallons each –				64,000 gallons
Top-water withdrawn: (0715, 1230, 2000, & 0300 hrs)	– ditto –				64,000 gallons
Top-water overflowing: (0800, 1400, 2100 & 0300 hrs)	Average 14,400 gallons each				198,400 gallons
Crude sludge fed in: (0800, 1400, 2100 & 0300 hrs)	Average 20,400 gallons each				326,400 gallons

The volume of crude sludge fed in is rather high; this is partly on account of nightsoil from the Toh Tuck Road Nightsoil Station, about 20, 000 gallons and sludge from cesspits, about 10,000 gallons. As a result of this, the detention period in the digesters is only about 12 days as against a designed detention period of 12 days.

Secondary Sludge Digestion Lagoons

These are open tanks each having a capacity of 1,860,000 gallons. All 4 are in use of which 2 are operated in parallel and 2 in series. On the average a detention period of 24 days is attained. The supernatant from these tanks (average 190,000 gall/day) is withdrawn continuously between 0800 to 1900 hours to the inlet of the Works. Digested sludge is fed to the drying beds whenever em ty beds are available and the average volume withdrawn amounts to 80,000 gall/day.

Sludge Drying Beds

Altogether there are 50 drying beds each having an area of 12,000 sq ft. Sludge is fed to a depth ranging from 9 to 12 ins and depending on weather conditions the dried sludge is normally lifted after about 35 days of drying. The bed filtrate is returned to the Works inlet. Sludge lifting is carried out by contract labour and the dried sludge is sold to the public, given away free of charge to schools and Government bodies or dumped in low lying areas in the Works. About 150 cu yd. of dried sludge is lifted per day.

Power House

Three generating sets, each comprising an English Electric 7RLD dual-fuel engine (110 bhp at 428 rpm) coupled to an alternator are capable of generating 3.3 KV, 3-phase, 50 cycles electricity. The total power generated, averaging 27,000 KWH per day, supplies the whole requirement of the Works and the tied quarters. Under normal conditions 2 of the 3 engines run continuously throughout 24 hours while the third is on standby or under maintenance. High speed diesel and sludge gas are used as fuel for the engines. Final effluent from the Works is used for cooling the engines and air compressors.

There are 3 two-stage 500 hp air blowers, each capable of delivering 12,000 cu ft of free air per minute at a pressure of 6.5 lbs/sq in. Two of the 3 air blowers are operated continuously for 24 hours of the day and together they deliver 23,000 cu ft /min of air. In an annexe to the power house is housed nine 100 hp centrifugal raw sewage pumps. Each pump is capable of delivering 6,250 gpm against a head of 31 ft. They lift the sewage from the wet well into the discharge basin outside the power house. The number of pumps in use at any one time is such as to match the incoming flows as closely as possible.

Laboratory

Daily analysis of Works samples are carried out in the laboratory. Composite samples made up of 2-hour samples form the basis of samples analysed. Generally BOD and suspended solids levels are monitored daily, but once a week a complete analysis is carried out. Results of average analyses are as shown in Table II.

Operational Difficulties

Septicity

Septicity appears to be the most apparent difficulty in the treatment of sewage at both the Kim Chuan and Ulu Pandan Treatment Works. The causes of septicity are mainly two-fold:-

(1) The repeated pumping of sewage resulting in long retention period in the rising mains and the high sewage temperature 90^0F; and

(2) The incorrigible methods adopted by the pumping station attendants in the manned pumping stations.

Poor Activated Sludge Quality

As a result of septicity, which is more pronounced at the Kim Chuan Works than at Ulu Pandan, it is suspected that the presence of high levels of volatile acids and sulphides adversely affect the quality of the activated sludge. Smell normally emanates from the primary sedimentation tanks in the early hours of the day. The sludge density index, the ratio of its mixed liquor solids concentration, to its volume is very low, less than 0.7, particularly for the Kim Chuan Sewage Treatment Works. Readily settleable sludges have high SDI, above about 0.8. The low SDI shows very poor quality activated sludge and this is so at both works where the activated sludge is light and flocculant. Both works are subjected to high sludge blankets in the final separating tanks and fairly regular overflowing of activated sludge from these tanks at peak flows. This is particularly so in the FST of the Kim Chuan East Works. It was suspected that due to uneven weir levels the overflow rate of the tanks were different. Upon investigation, this proved to be so but despite correcting this high sludge blankets continue to occur with consequent overflowing of solids.

Although it is conceded that septicity could be the cause of the above problems, it is the opinion of the author that the composition of Singapore sewage, which by most standards is generally weak, is another contributary factor. Since the staple food of Singaporeans, like the majority of Asians, is rice the substrate is therefore predominantly carbonaceous in nature, with low amino acid levels. This coupled with septicity, limited air supply (1200 cu ft/lb BOD applied) and relatively long retention time at high ambient temperatures favour the growth of filamentous bacteria resulting in light activated sludge flocs, which are easily sheared at high upward flow velocities during peak flows. Further investigations will have to be carried out before any positive conclusions can be reached and remedial action taken.

Effects of Synthetic Detergents

The effects of synthetic detergents manifest themselves mainly as foam in the aeration units, collecting chambers and in the effluent outfalls. The synthetic detergents in use in Singapore are mainly "hard" (non-biodegradable) detergents. At best the reduction in the concentration of the detergent level in the influent and effluent is 75%. As a result of this and in order to suppress foaming in the aeration units high MLSS concentrations, between 3,000 mg/l and 3,500 mg/l are maintained. Because of the loss of solids from the FST it is sometimes difficult to maintain the solids level in the aeration units and should the quality of the activated sludge deteriorate profuse foaming will result, but this is normally overcome in a matter of days. So far the synthetic detergents have had no significant effect on sludge digestion as no failure in sludge digestion tanks directly attributed to the presence of synthetic detergents has been experienced. With the move towards the total replacement of "hard" detergents with "soft" (bio-degradable) ones it will then be possible to operate MLSS concentrations at a much lower level of 2,000 mg/l say.

Nightsoil and Cesspit Sludges

Nightsoil as previously mentioned is treated at both the Serangoon Sludge Treatment Works and at the Ulu Pandan Sewage Treatment Works. No significant problems in the digestion of nightsoil at Serangoon has been reported mainly because it is fed to the digestion tanks in admixture with primary digested sludge from Kim Chuan Sewage Treatment Works and also any significant drop in gas production is not easily observed. However, the sludge is difficult to dewater and the sludge cake has a moisture content of 78% and 67% volatile matter. Drying normally takes about 40 to 50 days. At the Ulu Pandan Sewage Treatment Works the situation is quite different. Nightsoil is not fed directly to the digestion tanks, for operational reasons, but is discharged at the head of the Works. Because of the high moisture content of the nightsoil the resulting crude sludge has a much higher moisture content of 97%, low solids less than 2.5% and high volatile organic matter. About 20,000 gallons of nightsoil are discharged into the Works daily.

As a result of anti-pollution measures in the Seletar Reservoir Catchment Areas, cesspits for treating piggery wastes have been installed. Altogether there are some 2,440 such cesspits located in the eight catchment areas within the Seletar Reservoir Catchment Area. About 10,000 gallons of cesspit sludges are fed to the Ulu Pandan Sewage Treatment Works digestion tanks daily. These sludges have low solids content, less than 2%, very high (98%) moisture content and high volatile organic matter. The mixture of sludges fed to the digestion tanks is thus one of high moisture content, low solid concentration and high volatile organic matter. Since the Ulu Pandan Sewage Treatment Works is already working under overload conditions the recent discharge of nightsoil and cesspit sludges has made sewage treatment at the Works ever more difficult and resulted in a very short retention period in the tanks. The calculated retention period in the tanks at present is less than 15 days and as to be expected there has been a tremendous drop in gas production. Until the additional sludge digestion tanks are completed, it may be necessary to digest the sludges in the thermophilic range or discharge the cesspit sludges, which are semi-digested, into the secondary sludge digestion lagoons. As a consequence of the poor quality of the primary digested sludge with its high volatile matter concentration (61%) sludge drying is now proving to be a problem. Whereas the sludge could be lifted within 3 to 4 weeks in the past a period of 4 to 5 weeks is now required and the sludge cake has a high moisture content (75%).

Scum

Scum formation in the secondary slude digestion lagoons is a perennial problem. If left unattended a scum depth of 18-inch thickness can develop within a matter of weeks. Daily removal of scum by dragging bamboo poles across the lagoons is the only present means of keeping the the scum down. It may become necessary shortly to apply additives, such as enzymes, to dissolve the scum and cause it to settle with the sludge for discharge to the sludge drying beds.

Crystal Deposits

Crystal deposits are to be found in the top-water withdrawal pipe-line at both Ulu Pandan Sewage Treatment Works and Serangoon Sludge Treatment Works. An analysis made of the crystals showed that they probably have a chemical composition of this nature: $MgNH_4PO_4 \cdot 6H_2O$. These deposits are a nuisance as they tend to reduce the pipes' carrying capacity and cause them to be choked. The crystals can be used as a fertiliser.

SEWAGE TREATMENT PLANTS

These come in a variety of sizes, ranging from plants serving individual houses to those serving whole housing estates. In past designs most of the plants serving individual houses were true septic tanks, primary treatment only being effected and the settled sewage is either allowed to soak away into the sub-soil or discharge directly into a stream or open drain. The newer plants now have secondary treatment in the form of percolating filters and the final effluent is discharged into the drain.

The larger plants, generally incorporate an Imhoff Tank (comprising sedimentation compartment and sludge digestion tank) with biological filters, the media being granite and coral, and humus tanks incorporating upward flow filters at the discharge weir end. Sludge drying beds are provided and pumping arrangements can be incorporated together with screens. The filter beds are either rectangular or circular in shape and the settled sewage is applied to them either by means of perforated chutes and channels fed by a tipping arrangement in the case of the rectangular beds and rotary distributor arms with dosing syphon arrangements in the latter case. Provision is made for the recirculation of final effluent and bed filtrate from sludge drying beds can also be returned to the inlet in the larger plants.

The plants are generally designed to produce a final effluent of 30 mg/l SS and 20 mg/l BOD at best. In general a 50/50 effluent is achieved without too much difficulty. In some cases an effluent better than the 20/30 standard set is possible. The large plants serving more than 2,000 persons are designed on the same basis as sewage treatment works. There are altogether about 1,650 such plants and works scattered all over the Island and for the purpose of maintenance and operation of these plants, the Island is divided into 4 districts viz. City, Serangoon, Katong and Bukit Panjang/Jurong. Fig. 3 shows the areas served by these treatment plants. Removal of screenings are carried out daily and general maintenance to the plants in the form of desludging, lifting of sludge, cleaning of chutes and channels and maintenance of the grounds is carried out to each tank once a month on the average. Cleaning of filter media is carried out as and when necessary seldom but frequently more than once a year. The typical analytical results of some of the plants are as shown in Table 3A. Fig. 10 shows a typical layout and section of one of these plants.

Design Parameters of the Plants

Primary Sedimentation Tank:

(1)	Settling rate	:	4 ft/hour
(2)	Overflow rate	:	600 gpd/sq ft at 3 x DWF
(3)	Retention time	:	3.75 hours @ DWF
(4)	Rectangular tanks	:	Length – width ratio 3 to 1 Depth – width ratio 1½ to

Imhoff Tank

(1) Sedimentation compartment : Minimum slope 1½ times vertical to 1 horizontal

(2) Scum compartment : Minimum width 12 inches. Area 25% of sedimentation compartment.

(3) Sludge digestion compartment : Capacity 1½ cu ft per capita minimun bottom slopes 1 vertical to 4 horizontal.

Humus Tank

(1)	Settling rate	: 5 ft/hour
(2)	Overflow rate	: 750 g/d/sq ft at 3 DWF
(3)	Retention time	: 3 hours @ DWF
(4)	Rectangular tanks	: Length – width ratio : 3 to 1 Depth – width ratio : 1½ to 1
(5)	Min. bottom slope	: 1 vertical to 4 horizontal
(6)	Weir loading	: 15,000 gpd/lin ft (maximum)

Sludge Drying Bed

(1) Up to 400-person plant : 0.25 sq ft per capita

(2) Plant not exceeding 2,000 persons : 0.50 sq ft per capita

(3) Plant larger than 2,000 persons : 1.00 sq ft per capita

Biological Filter

(1) Less than 400-person plant : Rectangular beds with tippers, chutes and channels distribution system

(2) 400-person and above : Circular beds with dosing syphon and rotary type distributors.

(3) Hydraulic loading : 20 -80 g/d/sq ft

(4) BOD loading : Up to 6 lb/d/100 cu ft

(5) Capacity of filter bed : 12 cu ft per capita

(6) Average depth of filter : 4 ft and 6 ft

(7) Media : Coral or granite single size (4 inches and 2 inches sizes).

NIGHTSOIL COLLECTION

The nightsoil collection system covers a fairly large area as shown in Fig. 4. Most of the nightsoil are collected by the Public Health Division of the Ministry of Health and the balance is collected by private contractors. The average number of buckets collected by the PHD per month is about 740,000. These are dumped into nightsoil pumping stations, there being three viz. Albert Street Nightsoil Pumping Station and Paya Lebar Pumping Station which pumps the nightsoil to the Kim Chuan Sewage Treatment Works and from there to Serangoon Sludge Treatment Works for treatment and disposal; and the Toh Tuck Road Nightsoil Pumping Station which pumps the nightsoil to Ulu Pandan Sewage Treatment Works for treatment and disposal. The nightsoil has an extremely high moisture content about 98.0% and a great deal of paper is present. It is estimated that about 700,000 persons are served by the nightsoil collection system (both PHD and private).

FUTURE TREATMENT WORKS

In view of the rapid development currently taking place in the island, the creation of new satellite towns in the rural areas and the expansion of the Jurong Industrial Estate, the establishment of new treatment works, and the extension, even duplication, of existing Works will have to be realised within the next five years if sewerage facilities to keep pace with development.

It is evident that the new works and the proposed extensions to existing Works will have to be designed to cater for the future. In the light of present legislation on trade effluent discharges and anti-pollution laws, tertiary treatment will have to be incorporated if higher standards of effluent discharges are to be met. Works will have to be designed to treat an admixture of domestic sewage and rapidly increasing industrial wastes. Scarcity of land will necessitate the use of other methods of sludge dewatering such as centrifuging, filter presses or even wet oxidation, in place of conventional sludge drying beds. Air supply to activated sludge plants will have to be reassessed in the light of present operating difficulties. At least a 50% increase to 1,700 cu ft/lb BOD applied will be necessary.

The switch from hard to soft detergents will play a significant role in the treatment of sewage. The more wide-spread use of automatic samplers, analysers and recorders will become a necessity as the Works become more sophisticated. Experimentation and research on sewage treatment in Singapore will provide basic parameters for treatment works design and operation in South-East

Asia. Such valuable information is at present sadly lacking.

FINANCING OF MAINTENANCE, OPERATION AND DEVELOPMENT

In Singapore, sewerage services form part of the functions of the Public Works Department, while water supply comes under the ambit of the Public Utilities Board. Until recently, the provision of sewerage facilities was regarded as a social service, hence the planning and development of the service was not assessed on the grounds of their economic viability.

Since the provision of sewerage facilities is a function of a Government agency, the financing of operations and maintenance is subject to existing Governmental financial procedure. In brief, Governmental financial procedures require that all revenue be brought into consolidated funds and all expenditure be paid out of voted funds. Each year funds are appropriated out of Government development funds to meet the planned or budgetted capital expenditure programme for the year. Similarly funds are also provided out of Government's annual recurrent expenditure to meet the cost of operations and maintenance. In short, the financing of development, operations and maintenance of sewerage facilities depend on the annual appropriation in the development and ordinary expenditure budgets for such services.

However, in 1968 the Government obtained a S$18 million loan, spread over a five-year period from June 1968 to July 1973, from the International Bank for Reconstruction and Development (IBRD) to help finance the foreign exchange element of the cost of sewerage projects. One of the conditions of the loan is to make sewerage operations an economically viable undertaking. Additional sewerage fees based on the volume of water consumption were introduced in March 1970 and a separate accounting system was also implemented to enable management to assess the operations. With the revision of water-borne removal fees, which accounts for over 90% of the total revenue, it has been possible to change the results of the operations from an accumulated, operating deficit of S$ 1.7 million up to the financial year ended 31.3.1970 to an operating surplus of some S$11 million in the financial year ending 31.3.1971. Following the change in the operating results, the mode of financing capital expenditure has also changed. It has been possible by the Third quarter ended 31.12.71 to finance all sewerage projects exclusively from operating surplus and IBRD loan.

CONCLUSION

Water-borne sewerage facilities were first introduced in Singapore in 1915 and the first sewage works was established at about the same time. Following this start the sewerage system was further expanded and the Kim Chuan Sewage Treatment Works, designed for the partial treatment of the sewage, and the Serangoon Sludge Works were commissioned in 1941 to cater for the development of the northern and eastern parts of the city. Rapid development of the Island after the War necessitated the closing down of the Alexandra Road Works and the establishment of the Ulu Pandan Sewage Treatment Works. At the same time, the Kim Chuan Sewage Treatment Works was further extended by two phases before the development of the Toa Payoh Satellite Town necessitated the setting up of a new works, to cater for the flow from this development and the areas adjoining it.

The sewerage network is undergoing further extensive expansion and new sewerage area schemes to serve areas such as Jurong Industrial Estate, Thomson Road, Serangoon, Urban Renewal North and South, Telok Blangah, Queenstown, Bukit Timah and Woodlands are either in progress or will be implemented shortly. The Ulu Pandan Sewage Treatment Works and the Serangoon Sludge Treatment Works are at present undergoing extensions. New treatment works at Woodlands, Jurong, East Coast and Seletar will be established within the next five years, further extensions to the Kim Chuan Sewage Treatment Works and the duplication of the Ulu Pandan Sewage Treatment Works will be required.

Treatment plants serving individual houses and whole housing estates and nightsoil collection of unsewered areas will be progressively eliminated as the sewerage network is extended and new networks established. Tertiary treatment of sewage will become a necessity as higher standards of effluent are required. Due to the scarcity of land new methods of sludge dewatering in place of conventional sludge drying beds will have to be implemented. Basic research on the treatment and operation of sewage treatment works under local conditions for the design and operation of works in this part of the world should be initiated and will prove invaluable to the developing countries in this region that are contemplating establishing sewage treatment works.

Until recently, the provision of sewerage facilities was regarded as a social service hence the planning and development of the service was not assessed on the grounds of their economic viability, However, the foreign exchange element of the cost of sewerage projects is now financed by an IBRD loan and one of the conditions of the loan is to make sewerage operations an economically viable undertaking. In compliance with this additional sewerage fees based on the volume of water consumption were introduced in March 1970 and coupled with revenue derived from water-borne removal fees, it had been possible to change the results of operations from an accumulated operating deficit of S$1.7 million to an operating surplus of some S$11.0 million. Because of this it is now possible to finance all sewerage projects exclusively from operating surplus and IBRD Loan.

ACKNOWLEDGEMENT

The author is grateful to the Director of Public Works, Mr. Hiew Siew Nam, for permission to present this paper and the Senior Executive Engineer, Sewerage Branch, Mr. L.D.J. Chelliah, for his encouragement during the preparation of the paper. My thanks also go to the Managers of the Treatment Works for their cooperation and the other staff of the Sewerage Branch who have helped to make the writing of this paper possible.

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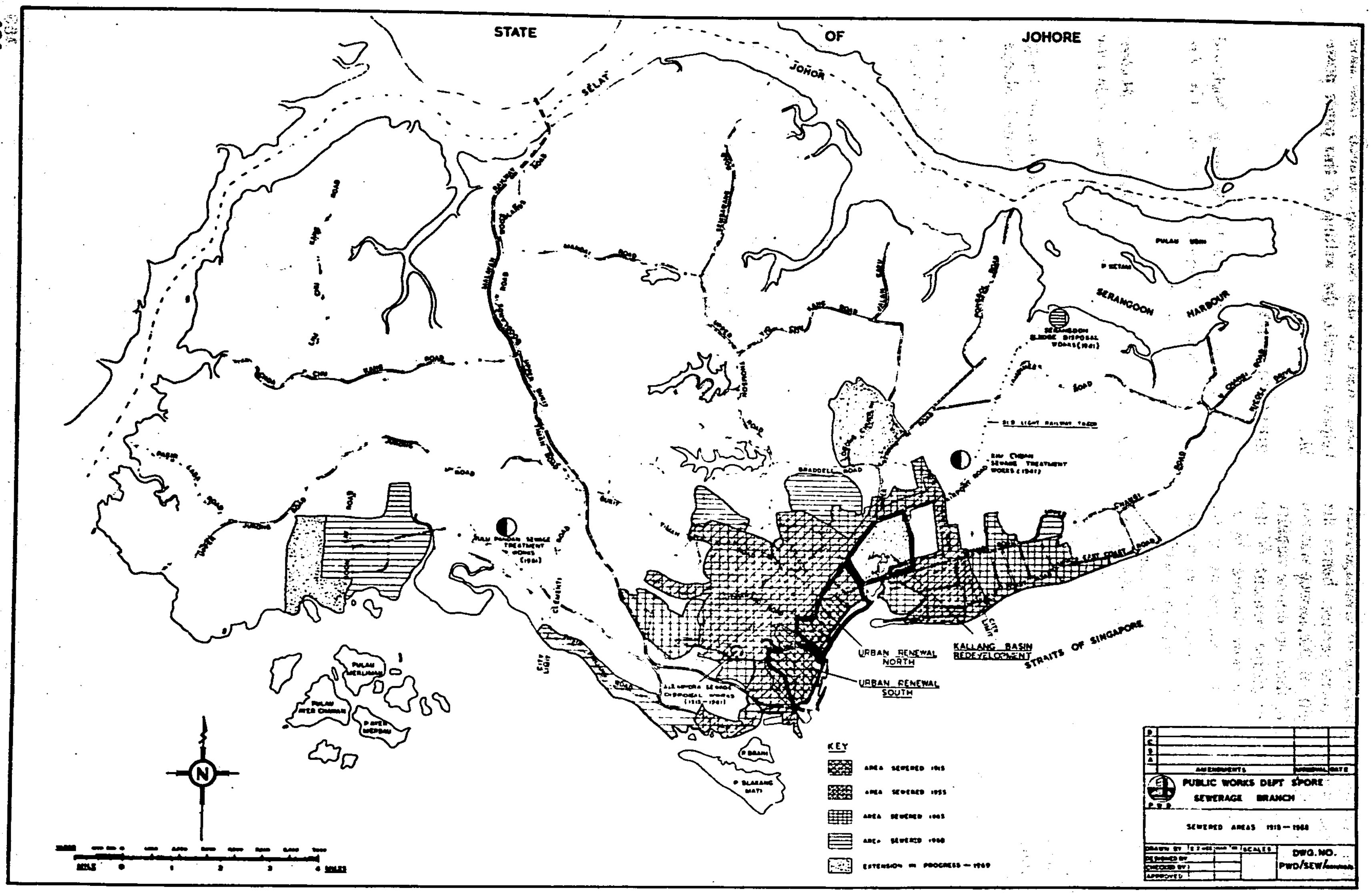


Fig. 1. Sewered Areas 1915 – 1968

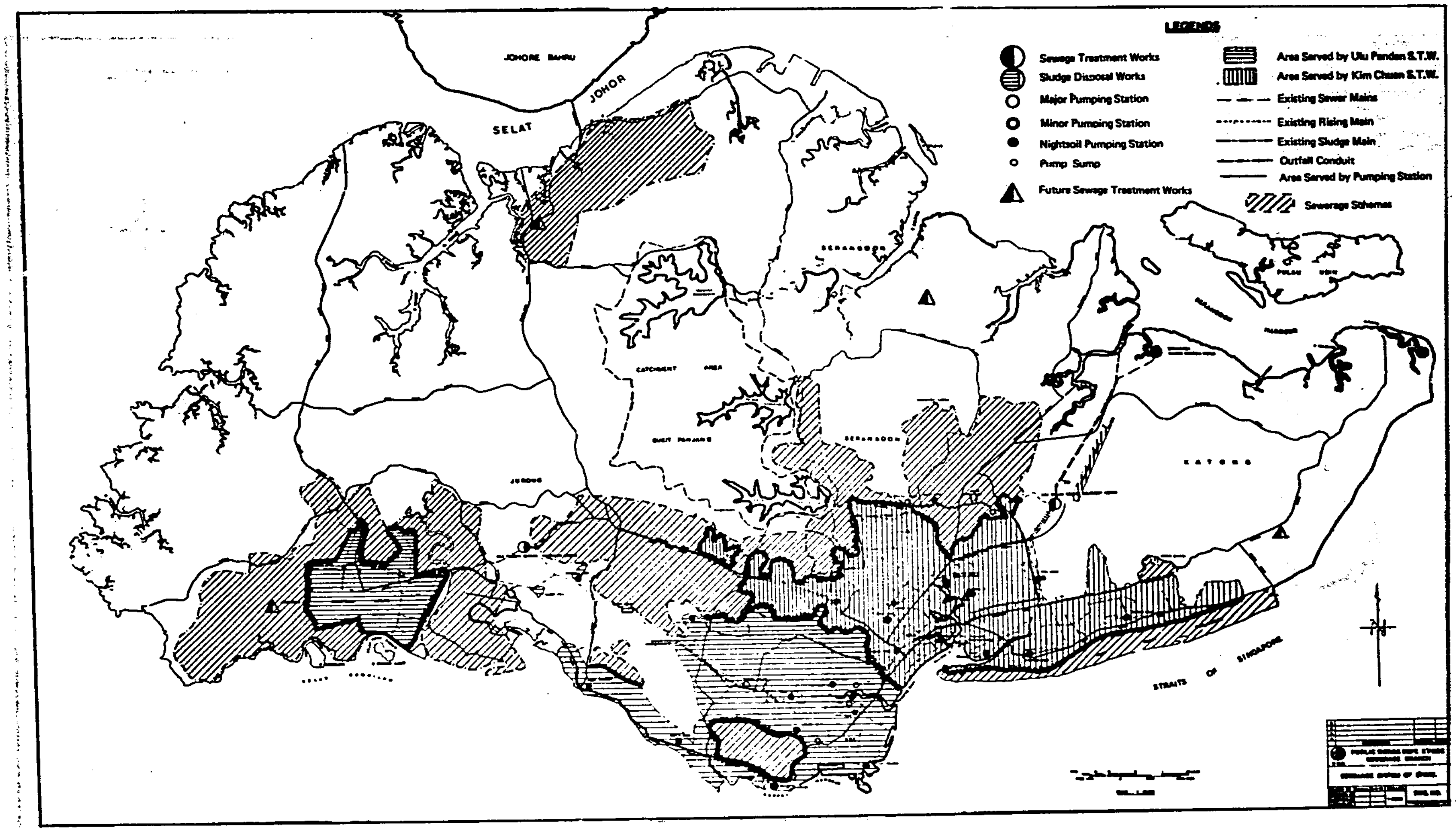


Fig. 2. Sewered System

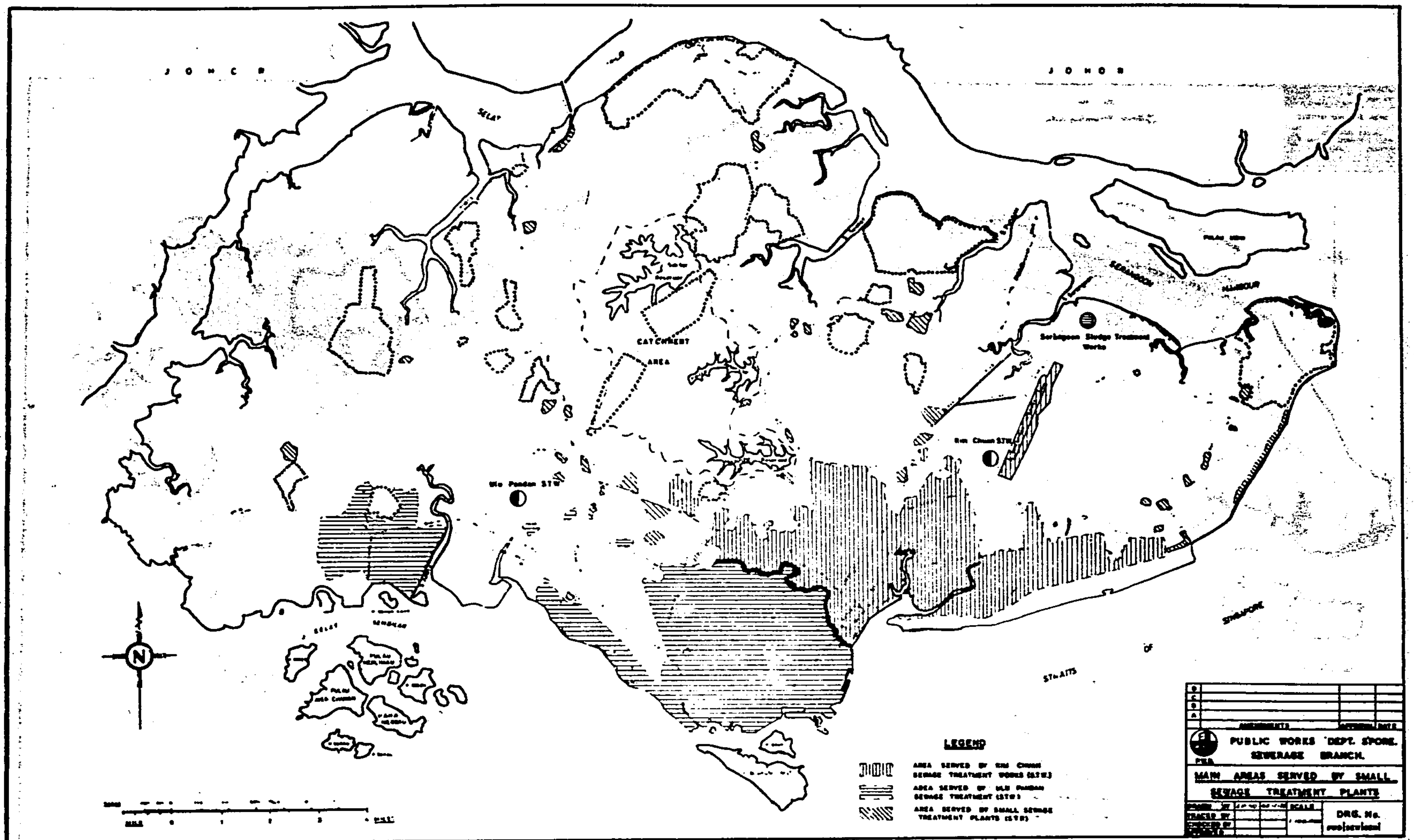


Fig. 3. Main Areas Served by Small Sewage Treatment Plants

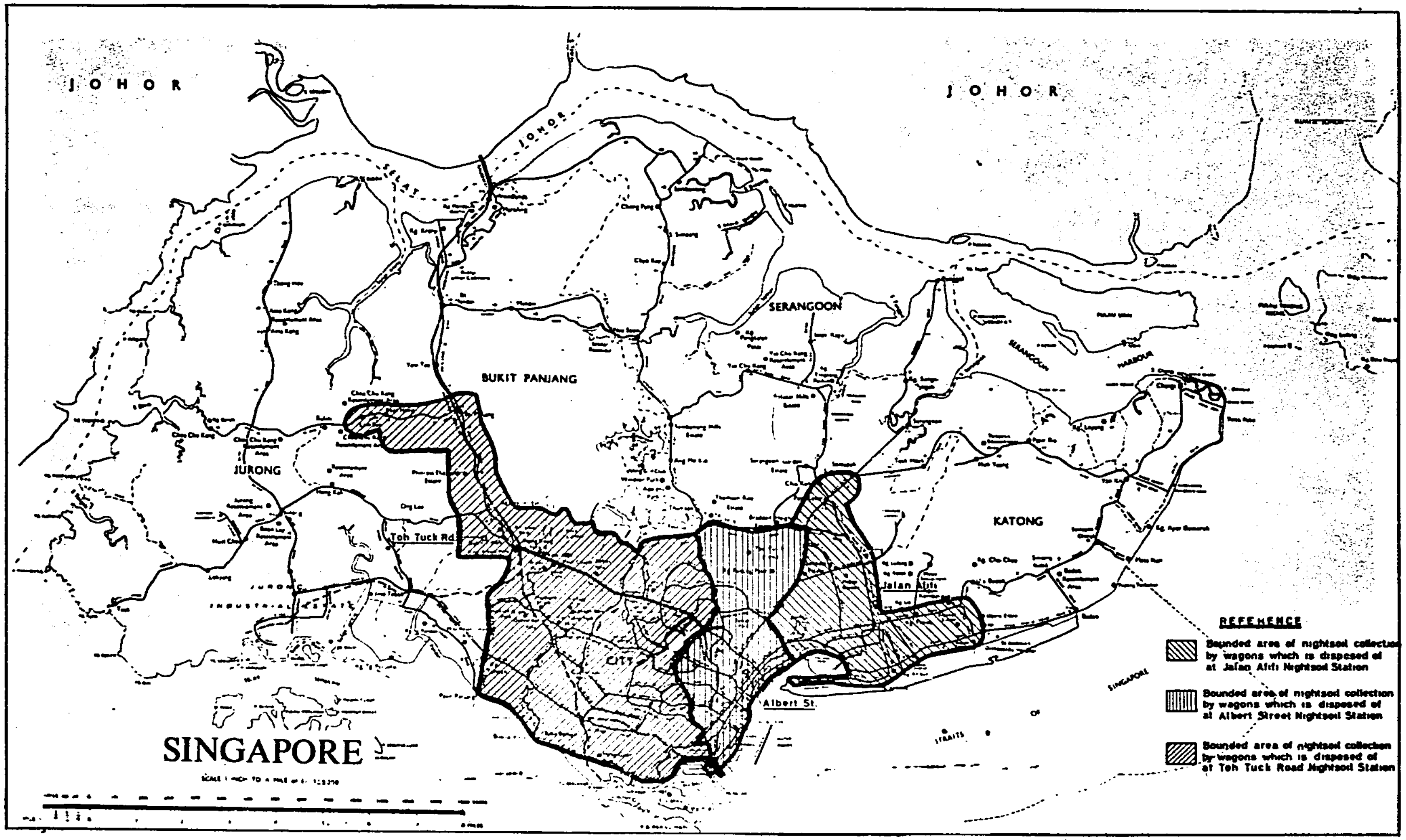


Fig. 4. Nightsoil Collection System

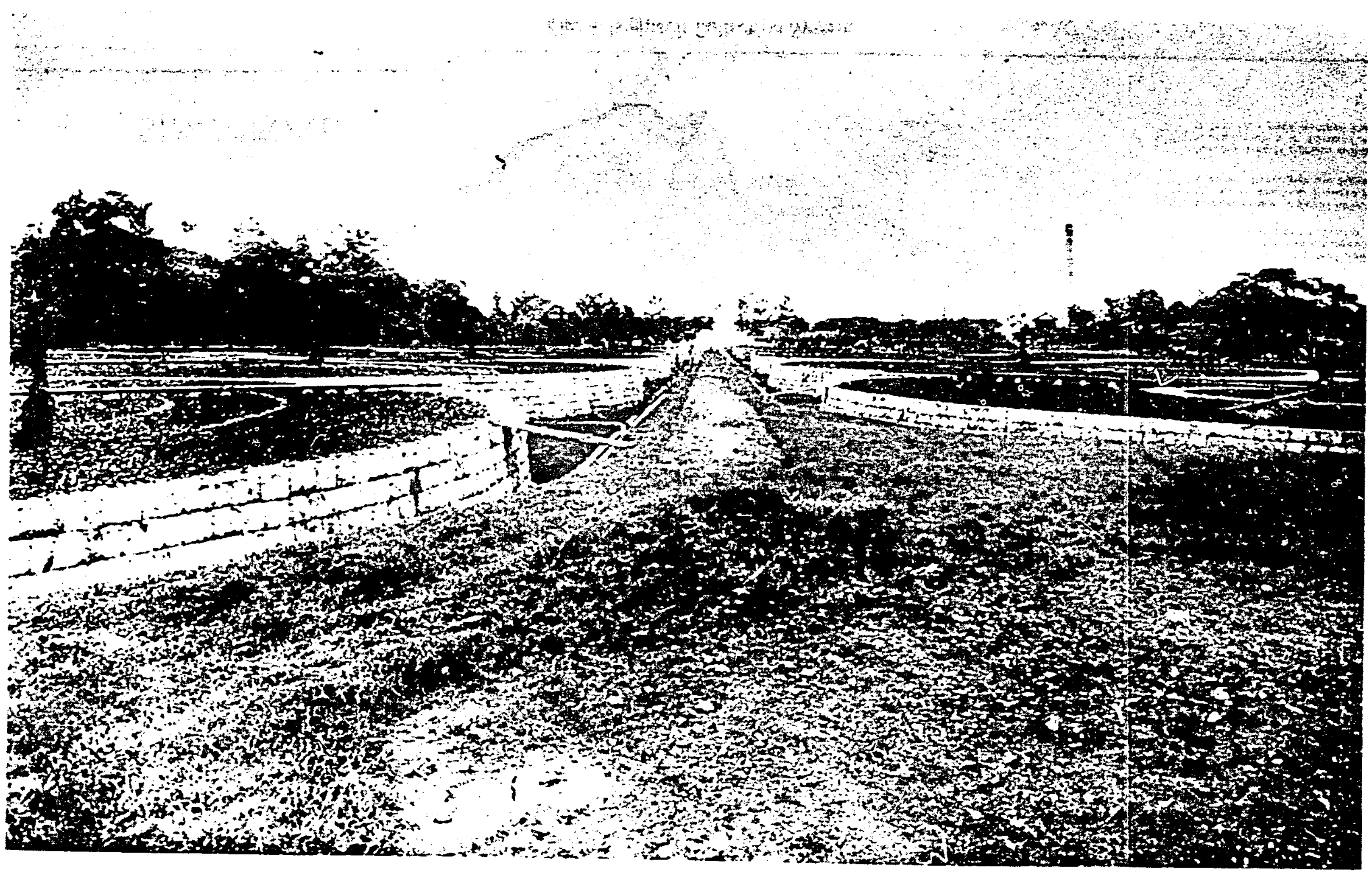


Fig. 5A. Sewage Disposal Works, Alexandra Road, 21 New Filter Beds (Blocks C & D) in Operation. Taken 9-1-30.

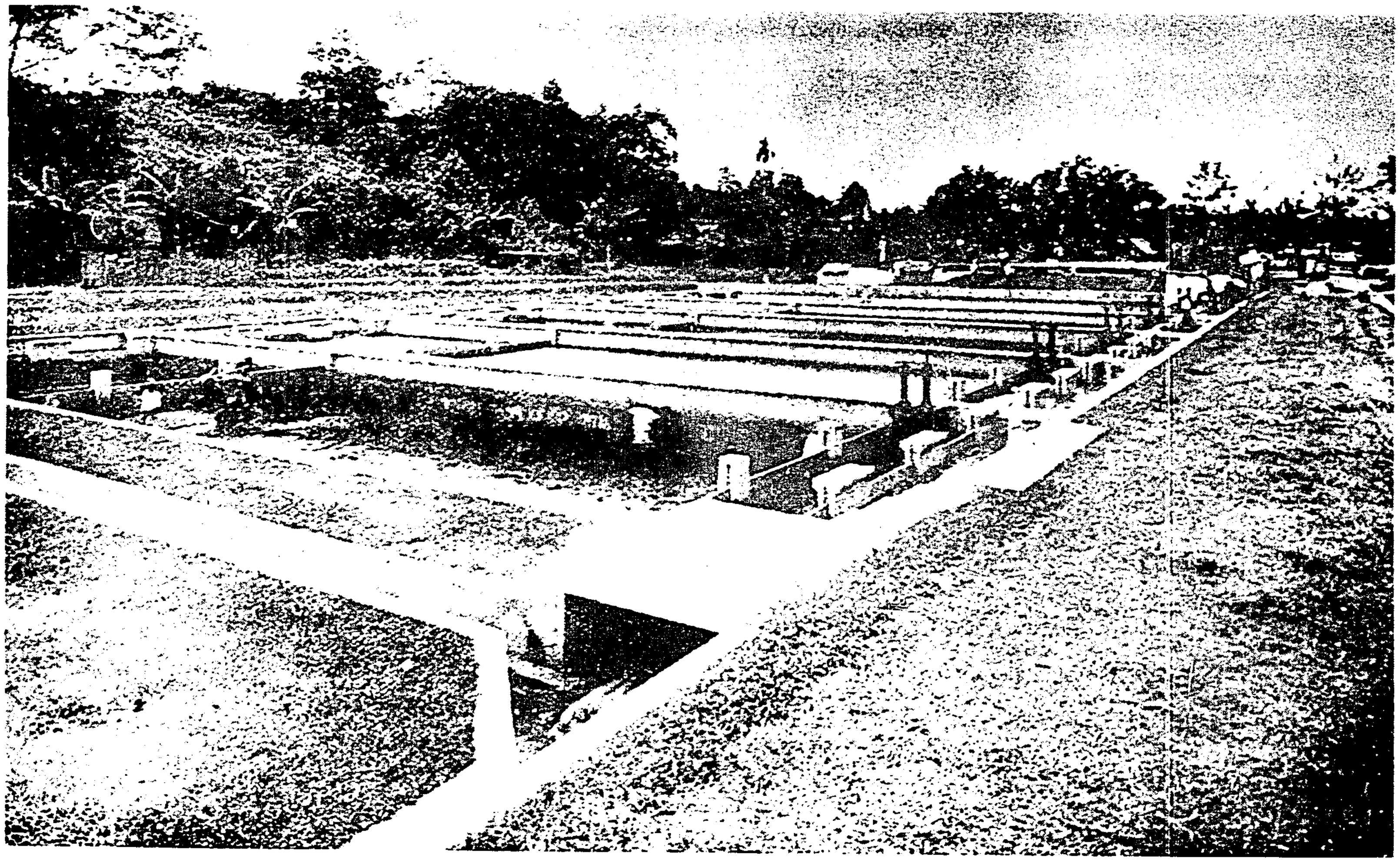


Fig. 5B. Sewage Disposal Works, Alexandra Road. New Humus Tanks (From Filter Beds Blocks C & D). Humus Sludge Drying Beds and Pump House. (Under Construction) Taken 9-1-30.

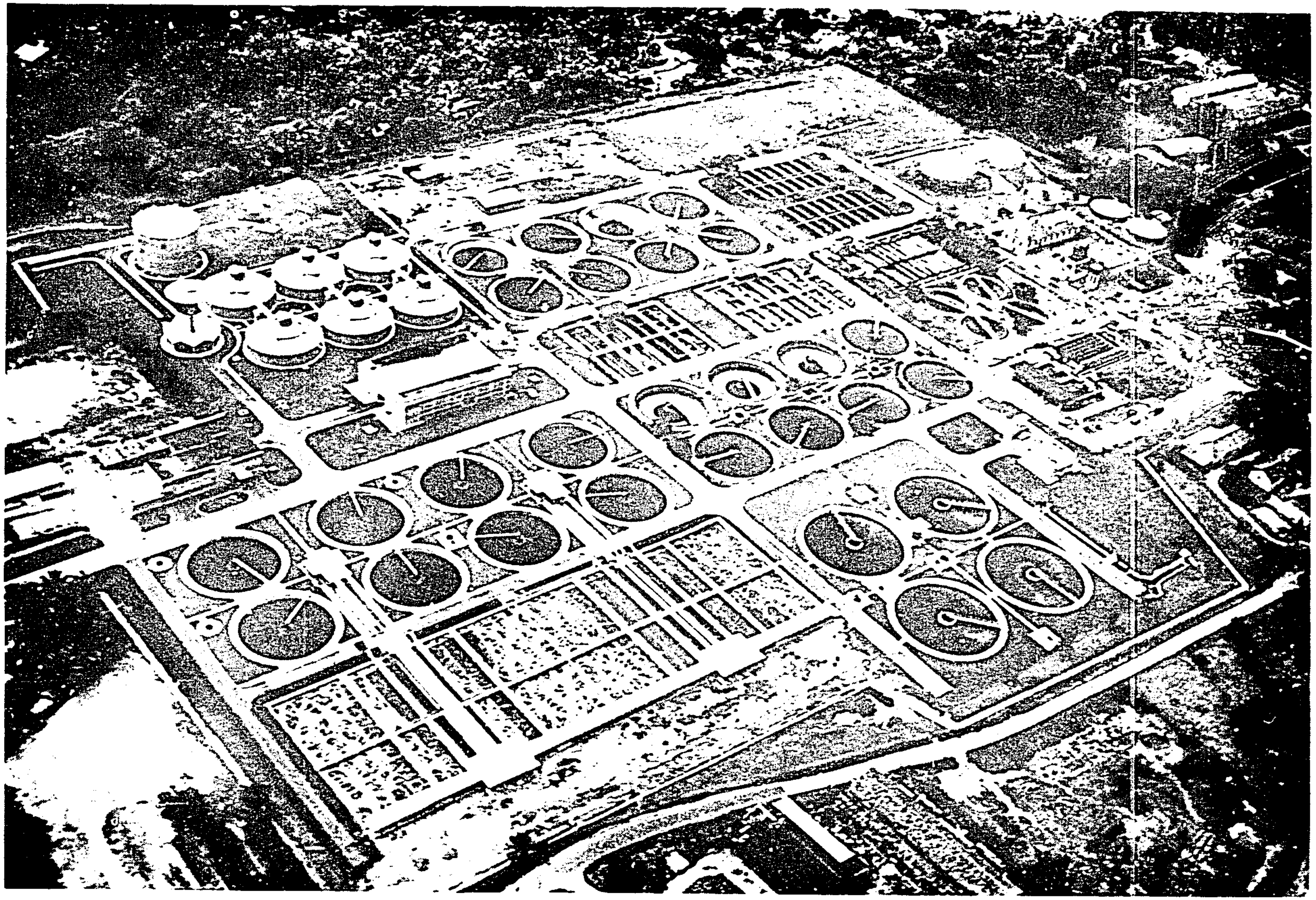


Fig. 6A. Kim Chuan Sewage Treatment Works.

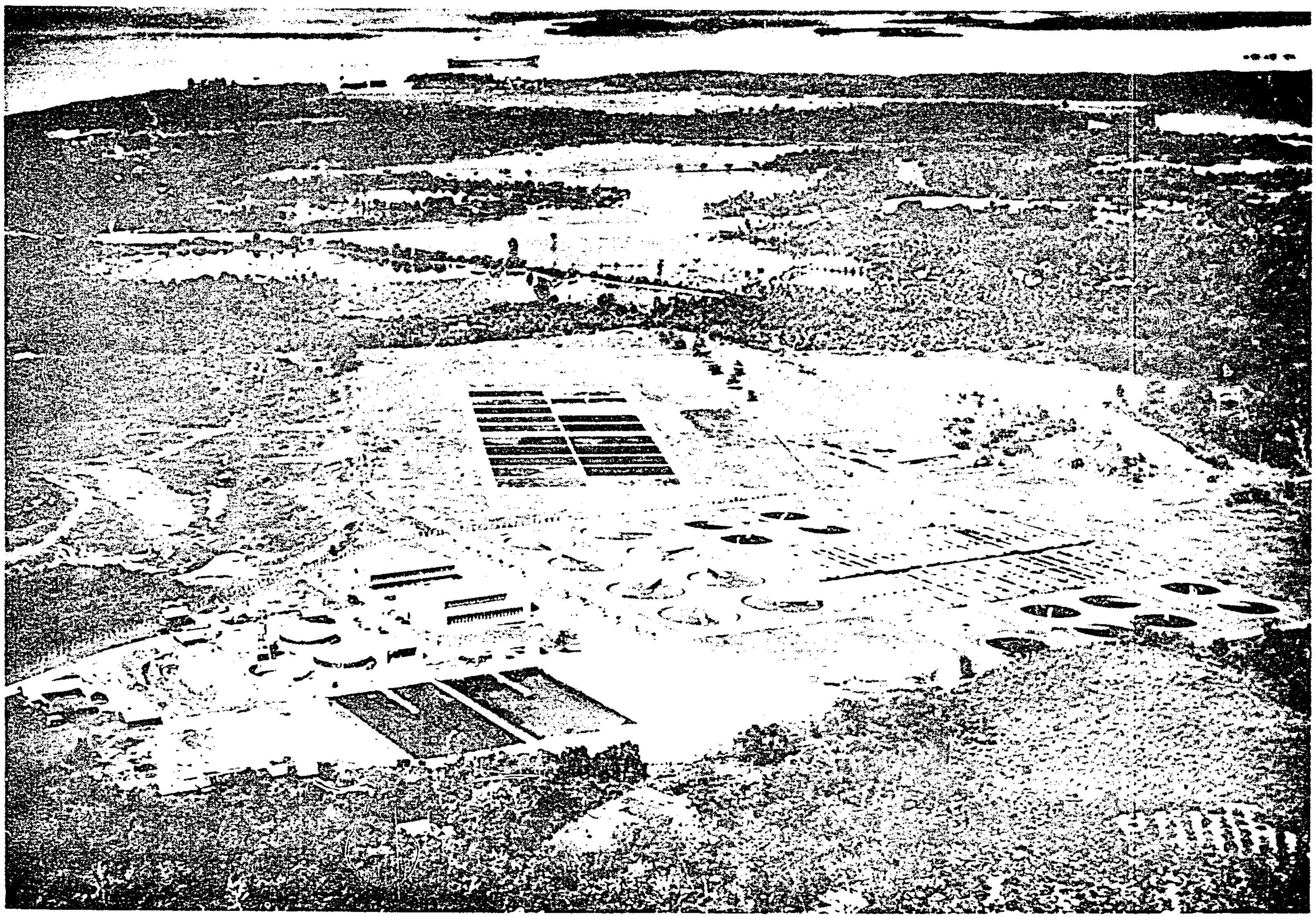


Fig. 6B. Ulu Pandan Sewage Treatment Works.

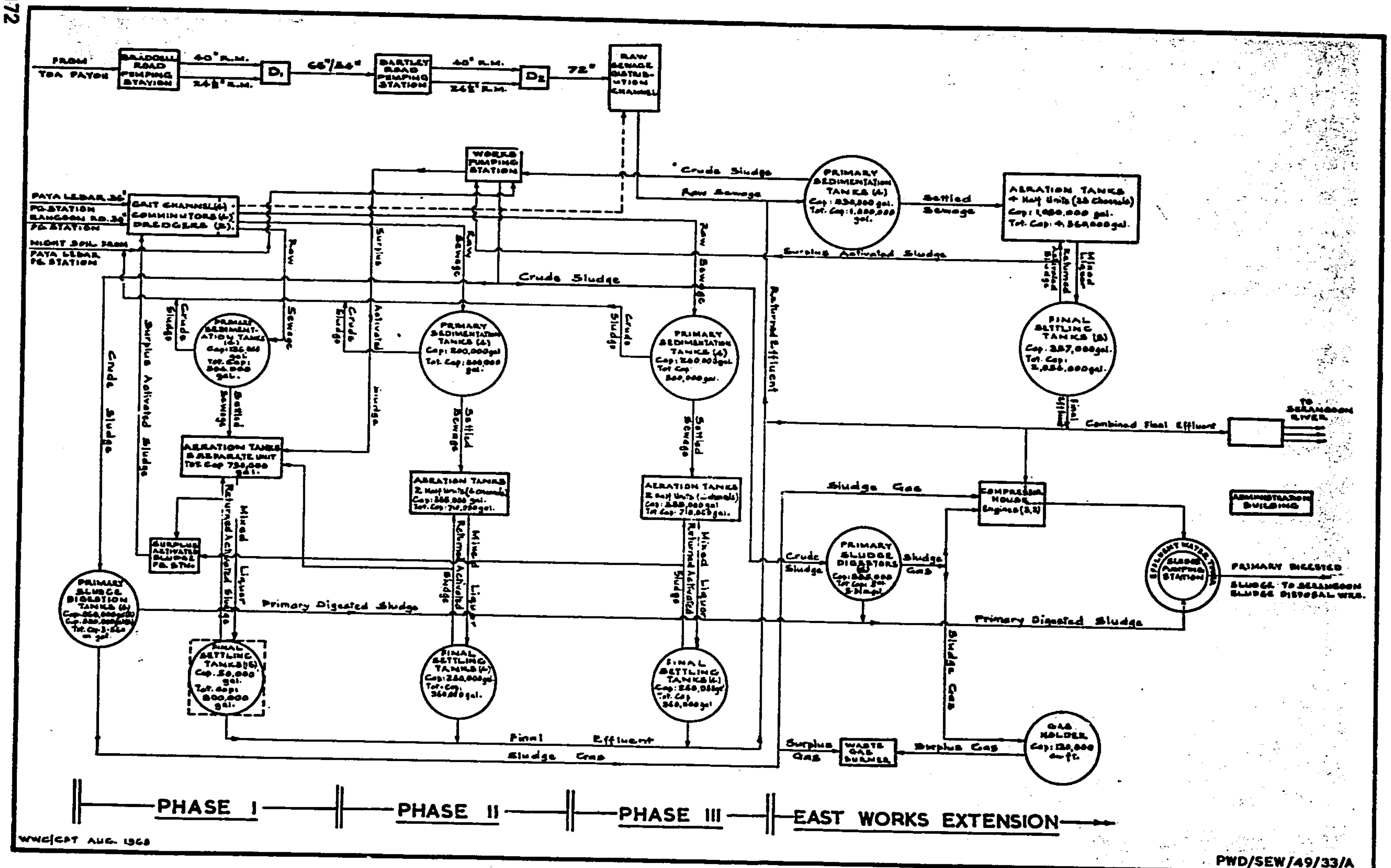


Fig. 7. Kim Chuan Sewage Treatment Works

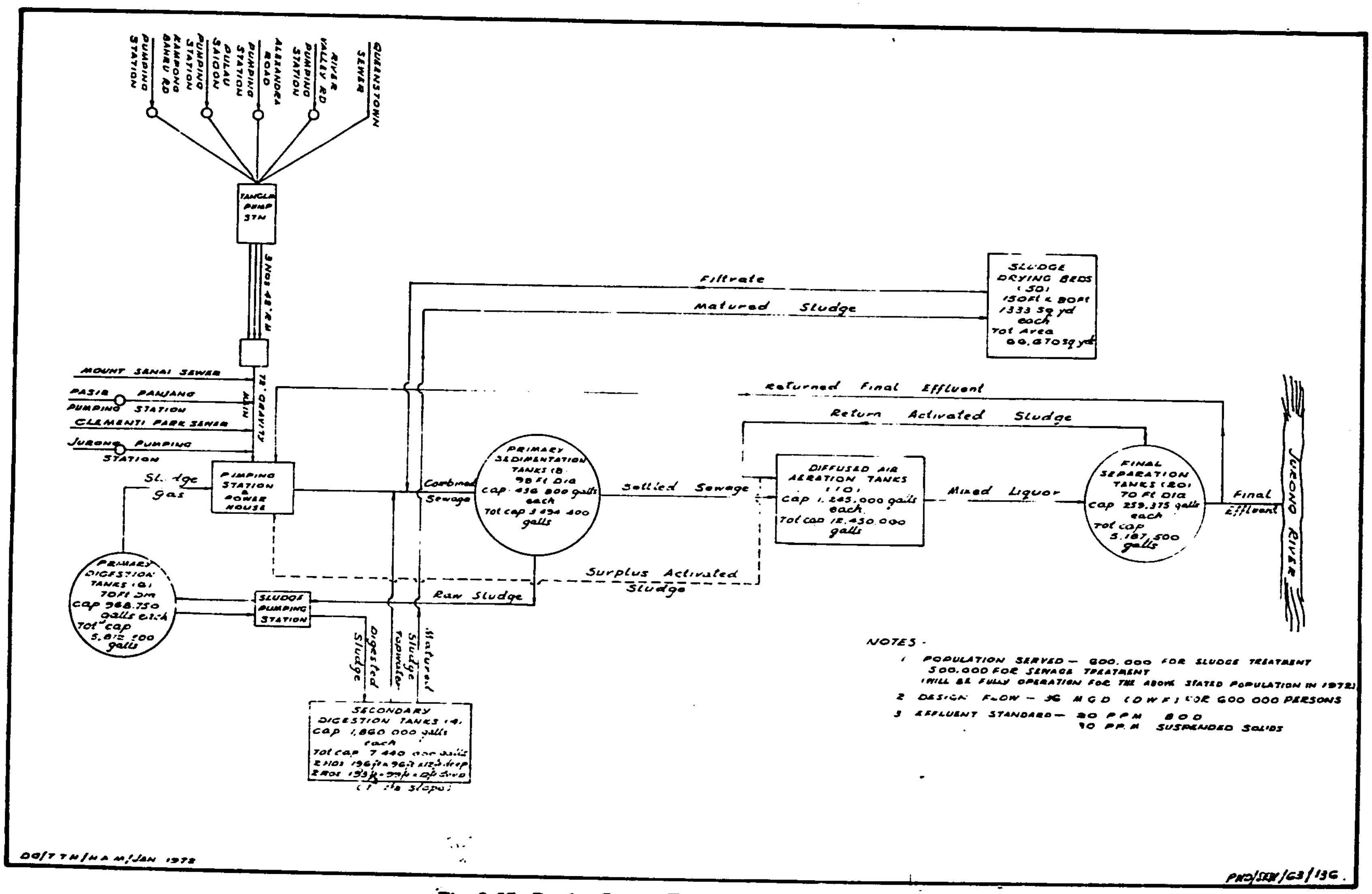


Fig. 8. Ulu Pandan Sewage Treatment Works Flow Diagram

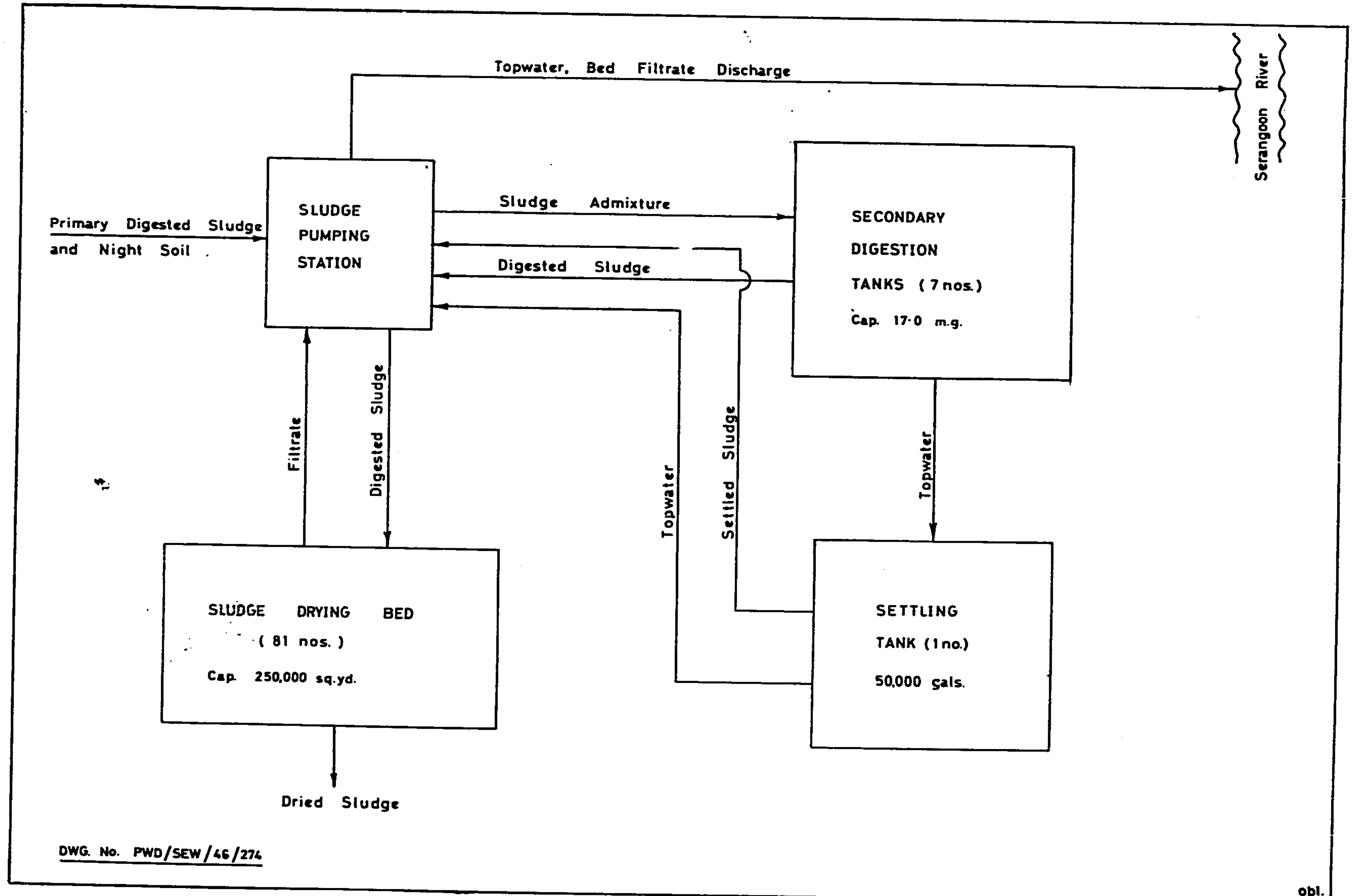
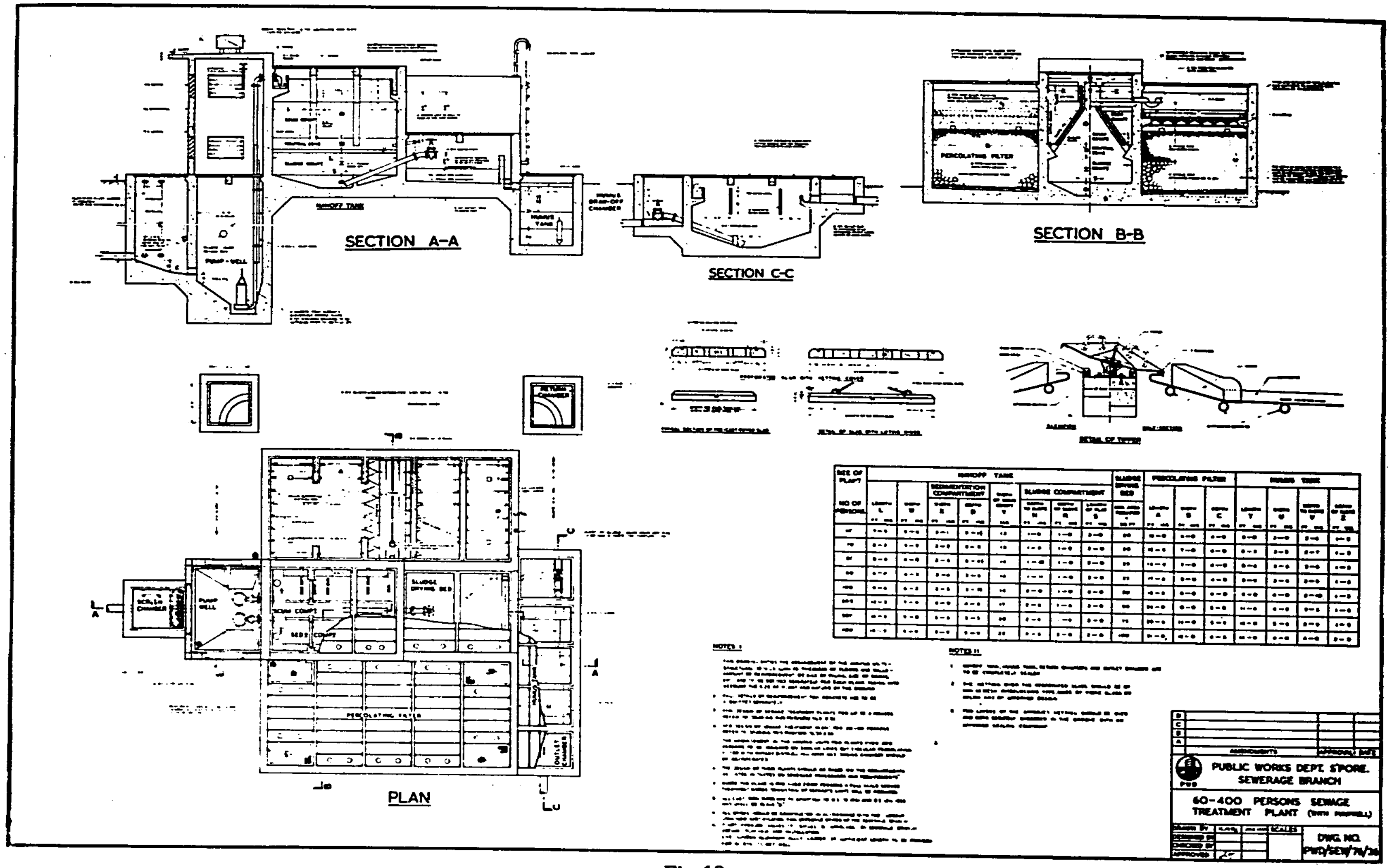


Fig. 9B. Serangoon Sludge Treatment Works Extension



SECTION A-A
SECTION C-C
SECTION B-B
PLAN
PUBLIC WORKS DEPT. S'PORE.
SEWERAGE BRANCH
60-400 PERSONS SEWAGE TREATMENT PLANT
DWG. NO.

Fig. 10.

DESCRIPTION	KIM CHUAN WEST WORKS			KIM CHUAN EAST WORKS	ULU PANDAN		SERANGOON SLUDGE WORKS		REMARKS
	PHASE I	PHASE II	PHASE III		STAGE I	STAGE II	EXISTING	EXTENSIONS	
COMPLETION	1941	1959	1963	1969	1961	1973	1941	1973	
Design Bases									
(i) DWF – S. A. S. Ignored	6.0 mgd			12.0 mgd	24.0 mgd	12.0 mgd			
(ii) Max. Flow = 3 x DWF.	18.0 mgd			36.0 mgd	72.0 mgd	36.0 mgd			
(iii) Population Served	150,000 persons	As for Phase I		300,000 persons	400,000 persons	200,000 persons			
(iv) Treatment	Partial		As for Phase I	Full	Full	Full			
(v) Final Effluent Standard	50mg/1 B.O.D., 50 mg/1 S. S.			20 mg/l B.O.D., 30 mg/1 S.S.	20 mg/1 B.O.D., 30 mg/1S.S.	20 mg/1 B.O.D.,30 mg/1S.S.			
(vi) Flow Per Capita	40 gphd			40 gphd	60 gphd	60 gphd			
Primary Sedimentation Tanks									
(i) Internal Diameter	48 ft	70 ft		87.5 ft	98 ft				
(ii) Slope	1 : 1½	1 : 9.3		7½°	7½°	Nil			* Using 8 tanks for 500,000 persons retention period = 2.8 hrs @ 30 mgd (DWF)
(iii) Total No. of Tanks	4	4		4	8				
(iv) Total Capacity	1,032,000 g	768, 000 g		1,000,000 g	3,494,400 g				
(v) Retention Period @ DWF	4.1 hrs	3.06 hrs	As for Phase II	2 hrs	3½ hrs	* See Remarks			
(vi) Overflow Rate @ 3 DWF	2,500 gpd/sq ft	1,170 gpd/sq ft		1,500 gpd/sq ft	1,200 gpd/sq ft				
(vii) Upward Flow Velocity @ 3 DWF	16.7 ft /hr	7.8 ft /hr		10 ft /hr	8 ft /hr				
(viii) Capacity / Person	1.1 cu ft/person	0.82 cu ft /person		0.53 cu ft /person	1.4 cu ft /person				
Aeration Units									
(i) Rectangular Tanks – Sizes	94.5' x 20' x 12.3' (4 Nos.) 94.5' x 10' x 12.3' (4 Nos.)	100.3' x 15' x 11.3' (8 Nos.) 125.8' x 5' x 11.3' (8 Nos.)	As for Phase II	14.2' x 107' x 11.3' (4 Nos.)	914' x 15' x 12' (8 Half-Units)	914' x 15' x 12' (2 Half-Units)			* Using 10 half-units for 500,000 persons retention period = 10 hrs @ 30 mgd (DWF)
(ii) Total Capacity	870,000 g	895,000 g		4,200,000 g	9,960,000 g	2,490,000 g			
(iii) Type	Flat Floor – Dome Diffu.	Ridge & Furrow – Dowe Diffu.	Flat Floor – Dome Diffu.	Flat Floor – Dome Diffu.	Ridge & Furrow – Dome Diffu.	Flat Floor – Dome Diffu.			
(iv) Aeration Time @ DWF	3.48 hrs	3.58 hrs	As for Phase II	7.5 hrs	10 hrs	* See Remarks			
(v) Air Design Basis @ DWF	0.2 cfm/sq ft 0.54 cf /g	0.2 cfm/sq ft 0.61 cf /g		0.3 cfm/sq ft 2.17 cf/g	0.23 cfm /sq ft 1.52 cf/g				1.55 cf/g
Final Separating Tanks									
(i) Internal Diameter	34 ft	70 ft		70 ft	70 ft	70 ft			
(ii) Slope	1 : 1.4	1 : 1.75		30°	30°	30°			
(iii) Total No. of Tanks	16	4		8	16	4			
(iv) Total Capacity	1,754,000 g	1,025,000 g	As for Phase II	2,035,000 g	4,150,000 g	1,037.500 g			
(v) Retention Period @ DWF	7 hrs	4.1 hrs		4.0 hrs	4.0 hrs				
(vi) Overflow Rate @ 3 DWF	1240 gpd/sq ft	1,170 gpd/sq ft		1,170 gpd/sq ft	1,170 gpd/sq ft	* See Remarks			* Using 20 tanks for 500,000 persons gives same parameters as for Stage I
(vii) Upward Flow Velocity @ 3 DWF	8.26 ft /hr	7.8 ft /hr		7.8 ft /hr	7.8 ft /hr				
(viii) Capacity / Persons	1.88 cu ft/person	1.1 cu ft /person		1.08 cu ft /person	1.66 cu ft /person				
Primary Sludge Digestion Tanks									
(i) Internal Diameter	51 ft (Floating Roof)	70 ft (Floating Roof)		70 ft (Fixed Roof)	70 ft (Floating Roof)		1 No. 70 ft (Floating Roof) 1 No. 70 ft (Open Tank)		
(ii) Slope	2 : 1	1 : 1.6		30°	30°		30°		
(iii) Side Water Depth	40 ft	31.8 ft	Nil	30 ft	33 ft	As for Stage I	49 ft & 16 ft	Nil	
(iv) Full Water Depth	52' – 4"	52' – 4"		50' – 6"	52' – 6"				
(v) Total No. of Tanks	2	2		6	4	2	Total Capacity		
(vi) Total Capacity	1,054,000 g	1,900,000 g		5,310,000 g	2,900,000 g	1,450,000 g	1,2000,000 g		
(vii) Capacity / Person	1.12 cu ft /person	2.03 cu ft /person		1.15 cu ft /person	1.55 cu ft /person for 300,000 persons	* See Remarks			* Using 6 tanks for 600,000 persons capacity/person = 1.15 cu ft
Secondary Sludge Digestion Tanks									
(i) Rectangular Earth Banks					196' x 96' x 12' (2 Nos.)		169' x 106' x 26' (3 Nos.)	220' x 135' x 14' (4 Nos.)	
(ii) Slope					1 : 1½	As for Stage I	1 : 1½	1 : 1½	
(iii) Total Capacity					502,800 cu ft		1,392,600 cu ft	1,312, 000 cu ft	
(iv) Capacity / Person		See Serangoon Sludge Treatment Works			1.67 cu ft /person for 300,000 persons		3.5 cu ft /person for 450,000 persons	* See Remarks	* 7 Lagoons – 2.2 cu ft per person for 1,250,000 persons including nightsoil
Sludge Drying Beds									
(i) Size & No. of Beds					150' x 80 (20 Nos.)	150' x 80 (30 Nos.)	210' x 25' (16 Nos.) 210' x 48' (5 Nos.)	240' x 147' (60 Nos.)	
(ii) Capacity					26,500 sq yd	39,750 sq yd	14,000 sq yd	235, 200 sq yd	
(iii) Persons / sq yd					11.3 persons/sq yd for 300,000 persons	* See Remarks	40 persons/sq yd for 450,000 persons	5.4 persons/sq yd for 1,250,000 persons including nightsoil	* 9 persons/sq yd (50 Beds)

Table 1. Designs Bases, Capacities & Dimensions of Treatment Units

Treatment Works	FLOW: Total Works Flow	FLOW: Ret. Act. Slge.	FLOW: Wste. Act. Slge.	FLOW: Air	SUSPENDED SOLIDS: Sewage Crude	SUSPENDED SOLIDS: Sewage Comb.	SUSPENDED SOLIDS: Settd. Sew.	SUSPENDED SOLIDS: Mix. Liq.	SUSPENDED SOLIDS: Ret. Act. Slge.	SUSPENDED SOLIDS: Final Effl.	TOTAL SOLIDS: Sewage Crude	TOTAL SOLIDS: Sewage Comb.	TOTAL SOLIDS: Settd. Sew.	TOTAL SOLIDS: Mix. Liq.	TOTAL SOLIDS: Ret. Act. Slge.	TOTAL SOLIDS: Final Effl.	B.O.D. (5 DAYS): Sewage Crude	B.O.D. (5 DAYS): Sewage Comb.	B.O.D. (5 DAYS): Settd. Sew.	B.O.D. (5 DAYS): Final Effl.	C.O.D.: Sewage Crude	C.O.D.: Sewage Comb.	C.O.D.: Settd. Sew.	C.O.D.: Final Effl.	pH: Sewage Crude	pH: Sewage Comb.	pH: Final Effl.
	mgd	mgd	mgd	mcf/day	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l			
Kim Chuan	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Phase I	5.7	3.2	0.10	4.8	208	–	82	1997	4500	21	699	–	525	2305	5030	401	194	–	130	22					7.0	–	7.3
Phase II	3.6	4.0	0.09	4.1	20[illegible]	–	92	2866	4660	13	699	–	545	3217	5330	380	194	–	131	15	}528	–	}383	122	7.0	–	7.3
Phase III	5.2	4.0	0.87	4.1	208	–	93	2738	4650	13	699	–	561	3140	5290	405	194	–	133	14					7.0	–	7.3
East Works	12.9	11.7	0.43	18.4	265	–	137	3410	6380	36	709	–	590	4070	6860	443	219	–	157	30	553	–	421	124	7.2	–	7.3
Ulu Pandan	25.8	17.3	0.46	30.1	234	522	181	3860	5700	21	1364	1666	1240	4400	6100	994	211	326	172	16	553	925	400	110	7.0	7.0	7.3

Treatment Works	NITROGEN: Sewage Crude NH_3	NITROGEN: Sewage Comb. NH_3	NITROGEN: Settd. Sew. NH_3	NITROGEN: Final Effluent NH_3	NITROGEN: Final Effluent NO_2	NITROGEN: Final Effluent NO_3	AERATION UNITS: Air Cu ft per Gal.	AERATION UNITS: Air Cu ft per lb B.O.D. Rem.	AERATION UNITS: D.O. Ret. Act. Slge.	AERATION UNITS: D.O. Mix Liq.	SLUDGE DRYING BEDS: Slge. Fed	SLUDGE DRYING BEDS: Slge. Lifted	SLUDGE DRYING BEDS: Slge. Sold/Given	S.D.I.: Ret. Act. Slge.	S.D.I.: Mix. Liq.	ENERGY: Gas Prod.	ENERGY: H.S.D. Used	ENERGY: K.W.H. Gen./Used	PHOSPHATE PO_4: Sewage Crude	PHOSPHATE PO_4: Sewage Comb.	PHOSPHATE PO_4: Settd. Sew.	PHOSPHATE PO_4: Final Effl.	SYNDETS Manoxol: Sewage Crude	SYNDETS Manoxol: Sewage Comb.	SYNDETS O.T.: Settd. Sew.	SYNDETS O.T.: Final Effl.	RAINFALL
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l			mg/l	mg/l	gal	cu yd	cu yd	gm/100 cc	gm/100 cc	cu ft	gal	kwh	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ins
Kim Chuan	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Phase I	42	–	45.5	35.5	0.06	0.2	0.87	757	2.2	1.9				0.50	0.33												
Phase II	42	–	43.3	31.6	0.23	0.3	1.28	1082	1.6	1.9	See East Works Sludge Fed at Serangoon Limited by Capacity of the Sludge Drying Beds			0.51	0.41	} See East Works			}10.0	–	8.7	5.0	}16.1	–	14.3	6.0	}See East Works
Phase III	42	–	43.3	38.4	0.20	0.7	0.88	717	1.8	2.0				0.54	0.42												
East Works	50	–	44.6	28.5	0.30	0.7	1.42	1044	1.6	1.9	9.25×10^6	16.68×10^3	4.89×10^3	0.69	0.47	63.15×10^6	217×10^3	1.5×10^6	14.1	–	11.6	4.8	19.6	–	16.8	4.8	63.6
Ulu Pandan	47	49	46	32	0.18	0.03	1.17	788	1.0	1.5	30.82×10^6	56.88×10^3	16.23×10^3	0.69	0.59	120.85×10^6	226×10^3	955×10^6	19.5	27.8	24.5	7.6	15.7	18.2	14.9	4.7	53.8

Remarks

Abbreviation:
- Comb. – Combined Sewage (Crude Sewage + Top Water + Bed Filtrate + Nightsoil)
- Slge. – Sludge
- Rem. – Removed
- H. S. D. – High Speed Diesel
- Mix. Liq. – Mixed Liquor

Kim Chuan Overall Performance
- B. O. D. : 20.3 mg/l
- S. S. : 20.8 mg/l

Table 2. Sewage & Sludge Treatment Works Summary of Operation for 1971

Description	CRUDE SLUDGE		DIGESTING SLUDGE		DIGESTED SLUDGE	
	Kim Chuan	Ulu Pandan	Kim Chuan	Ulu Pandan	Kim Chuan	Ulu Pandan
Moisture Content	95.0%	97.1%	93.5%	97.5%	96.9%	96.5%
Organic Matter	84.9%	78.0%	65.5%	71.0%	67.5%	67.1%
Volatile Acid As Acetic Acid	900 mg/1	960 mg/l	48 mg/l	168 mg/l	54 mg/l	108 mg/l
Alkalinity As $CaCO_3$	625 mg/1	700 mg/l	1969 mg/l	1700 mg/l	1626 mg/l	1900 mg/l
pH	6.5	6.2	8.3	7.0	8.0	7.2
Total Solids	41840 mg/1	28310 mg/l	60150 mg/l	26160 mg/l	23370 mg/l	35230 mg/l
Suspended Solids	40760 mg/1	26730 mg/l	54948 mg/l	23610 mg/l	20498 mg/l	32900 mg/l
Dried Sludge						
Moisture Content	77.0%	71.0%				
Volatile Organic Matter	67.0%	61.0%				

Table 3.

ANALYSIS	TREATMENT PLANT C.649 CAPACITY : 25 PERS.		TREATMENT PLANT K. CAPACITY: 50 PERS.		TREATMENT PLANT C.C.28 CAPACITY : 350 PERS.		TREATMENT PLANT C.C. 127 CAPACITY : 1,700 PERS.	
	Crude Sewage	Final Effluent	Crude Sewage	Final Effluent	Crude Sewage	Final Effluent	Crude Sewage	Final Effluent
Description	T.W.S.	C.W.S.	T.W.S.	C.W.S.	T.W.S.	C.W.S.	T.W.S.	C.W.S.
Oxygen Absorbed From KMnO4 (4hrs.)	41.8	7.4	16.9	3.05	25.8	10.65	29.9	7.25
Suspended Solids	45	12	40	16	44	18	57	22
Free Ammonia (expressed as N)	123.5	3.7	36.6	2.05	34.55	15.6	23.85	4.1
Albuminoid Ammonia (expressed as N)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Chlorides (expressed as C1)	50	41	58	51	29	26	35	35
Nitrates (expressed as N)		Nil		Nil		Nil		Nil
pH	6.9	7.7	6.7	7.2	6.55	7.05	6.7	7.3

Table 3A – Average Analysis of Treatment Plants
(Results in mg/1 where applicable)

Paper No. II/3

DISPOSAL OF INDUSTRIAL TRADE EFFLUENTS FROM THE FOOD INDUSTRIES

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ABSTRACT

The paper outlines the problems of trade effluent disposal faced by the food industries in Singapore.

It attempts to define water pollution and discusses the question of disposal of effluents into the public sewers and water courses.

It illustrates the types of effluent presently disposed by the different types of food industry, including those which manufacture meat, vegetable, dairy, oil and fermented products. Partly because of the character of the trade effluents, it may be possible to channel such wastes direct into sewers subject to a levy imposed by the relevant authority.

INTRODUCTION

In Singapore, where there is a high population density and a lack of catchment areas, it is important that the quality of surface and underground water resources be well preserved. However, it is only in the late sixties that legislation was enacted, empowering two authorities to ensure that the industrial effluents which are presently discharged into the sewers/water courses to conform to the specifications for the disposal of effluents as set out by the authorities concerned. The authorities are the Ministry of Health which administers the Environmental Public Health Regulations, 1971, prohibiting the disposal of trade effluents into water courses; and the Public Works Department of the Ministry of National Development, which is responsible for administering the Local Government Regulations, 1970, governing the disposal of trade effluents into public sewers.

As at 1970, there were no less than 1,855 manufacturing establishments* which are engaged in manufacturing a wide variety of goods, including *inter alia* food, beverages, tobacco, textile, footwear, packaging material, furniture, paper products, machinery, transport equipment, etc. Almost all the industries mentioned require water at some stages of their production and correspondingly discharge wastes from some stages of their manufacturing processes. Due to the diversified nature of the manufacturing sector, the nature, type and level of the pollutants in the effluents are very varied. It includes, for example such waste as spent-solution from the electro-plating industry which consists basically of heavy metals and the mother liquor from the manufacture of wine which contains substantial quantity of organic matter either in solution or in colloidal suspension.

DEFINITION OF POLLUTION

What is pollution?

One of the most comprehensive definitions

*Employing more than 10 persons

of pollution is that due to Klassen. "Water pollution may be defined as any change in the physical, chemical or biological properties of any expanse of water whatsoever, or any discharge of liquor, gaseous or solid substances into such an expanse of water, liable to create a harmful effect or make the water dangerous or detrimental from the point of view of public health, safety and well being of its legitimate uses for domestic, agricultural, industrial, recreative and other purposes or of wild and aquatic fauna livestock, etc."

Broadly speaking, pollution could be divided into two categories:

Physical Pollution – Due to heat or solid matter. Heat pollution from cooling water or condensate may kill aquatic and other organisms directly or by reducing oxygen concentration due to increase in metabolic rate. Solid matter in effluents may blanket the bed of the river, kill fish or prevent sufficient light penetration into the water to enable plants to undergo the process of photosynthesis.

Chemical Pollution – Either by direct toxicity or due to putrefactive organic matter. Putrefactive, carbonaceous and nitrogenous matter increase the oxygen demand of the river water and in extreme cases by overcoming the natural re-aeration of the river, thereby creating an anaerobic condition with its accompanying foul odour. Surface active materials, like detergent may also hinder the regenerative capacity of the water courses. Toxic materials like heavy metal, chlorine, cyanide, phenol can kill the flora and fauna and render the water unfit for human consumption.

DISPOSAL OF EFFLUENTS INTO WATER COURSES

As we understand, there are about 900 factories which are presently served by the public sewerage system, (the definition of a factory here is different from that of the CIP's definition of a manufacturing establishment, as the criteria here is on the type of effluents rather than the number of people employed). In addition, we understand that only a small proportion of the factories concerned discharge all their wastes into sewers. In fact, the majority of them discharge their effluents into the water courses. Recently legislation has been enacted to curb such anti-social practices and potential polluters are required to meet the standard imposed by the Ministry of Health on discharge of trade effluents into water courses. Allowable limits for the different contaminants are spelled out in Table 1. These standards are presumably based upon the potential effect effluents may have on the water courses, taking into consideration the volume and nature of the effluents, the capacity and regenerating characteristics of the receiving water, as well as the subsequent use of such water courses. If such water courses were to serve as a source of potable water, then the standards will necessarily be strict. As a comparison, a guideline on permitted limits for contaminants laid down for industrial effluents by the Mersey and Weaver River Authority for fishing and non-fishing streams are shown in Table 2. It must be emphasized here that different river authorities in U. K. have different guidelines and standards and these depend considerably on the down streams users. It is evident that quite a few industrial effluents must be treated before they can comply with the Ministry of Health's requirements.

DISPOSAL OF EFFLUENTS INTO THE PUBLIC SEWERS

As mentioned earlier, the public sewerage system caters for a number of factories, and in addition serves more than a million people. It is anticipated that with the enforcement of the Ministry of Health's requirements a great number of factories which are presently in the sewered areas and who are engaged in dumping their effluents into the water courses will necessarily switch their disposal into the sewers. Nonetheless, many of the factories concerned may require some form of pretreatment for their wastes before discharging into the sewers. The question is whether there will be any treatment problem, if all the industries concerned were to dump their wastes into the sewers. It is known that certain high concentration of metal ions may impair the operation of the treatment works or if not will most certainly lower the efficiency of the bio-degrading process in the works.

Nishimura, [12] reported (experiments on biological treatment on sewage which contains large quantity of industrial waste) that industrial waste which will be discharged into the Japanese municipal sewerage system, is estimated to be 70% of the total flow and 90% of sources of pollution. Apparently, after pH treatment with lime and by sedimentation, the compounded sewage when treated with the activated sludge process (retention time 1½ hours) has its soluble solids reduced by

Item of Analysis		* Public Works Dept.'s Requirements — Allowable limits for the discharge of trade effluents into sewers	** Ministry of Health's Requirements — Allowable limits for the discharge of trade effluents into the water courses
1. Temperature of discharge		110°F (43°C)	43°C
2. pH value		6 – 9	6 – 9
3. BOD (5 days at 20°C)	mg/l	400	50
4. COd	mg/l	1,000	100
5. 4-hour PV	mg/l	200	40
6. Total suspended solids	mg/l	400	50
7. Total dissolved solids	mg/l	1,000 – 3,000 (Max.)	1,000
8. Alkalinity as CaCO3	mg/l	2,000	–
9. Chloride (Cl)	mg/l	1,000	400
10. Sulphide (S)	mg/l	1.0	0.2
11. Sulphate (SO_4)	mg/l	600	50
12. Detergent as Manoxol O. T.	mg/l	30	15
13. Grease and oil	mg/l	30	5
14. Simple soluble cyanide	mg/l	1.0	0.1
15. Complex cyanide	mg/l	1.0	–
16. Ferro-cyanide	mg/l	3.0	–
17. Barium, selenium, tin	mg/l	10	–
18. Iron (Fe)	mg/l	50	5
19. Arsenic	mg/l	5	0.5
20. Beryllium	mg/l	5	0.5
21. Boron	mg/l	5	0.5
22. Cadmium	mg/l	10	0.1
23. Chromium (trivalent or hexavalent)	mg/l	10	0.1
24. Copper	mg/l	5	0.1
25. Lead	mg/l	5	0.1
26. Mercury	mg/l	10	0.1
27. Nickel	mg/l	10	0.1
28. Silver	mg/l	5	0.1
29. Zinc	mg/l	10	0.1
(items 22–29)		Individual as shown collectively 10 maximum	Individual as shown collectively 0.5 maximum
30. Chlorine (free)	mg/l	–	1.0
31. Colour (7 Lovibond)		–	7
32. Phenol	mg/l	–	Nil
33. Pesticides, insecticides	mg/l	–	Nil
34. Fumigant	mg/l	–	Nil

Notes: * L. G. I. O (Disposal of Trade Effluents) Regulations 1970
** The Environmental Public Health (Prohibition on Discharge of Trade Effluents into Water Courses) Regulations 1971

Table 1

	Non-fishing streams	
(1)	pH value	≮ 5 or ≯ 9
(2)	Suspended solids content (dried at 105°C)	≯ 40 mg/litre
(3)	Suspended solids content + dissolved metals*	≯ 40 mg/litre
(4)	Permanganate value (4 hr at 27°C)	≯ 60 mg/litre
(5)	Biochemical oxygen demand (five days at 20°C)	≯ 40 mg/litre
(6)	Sulphide (as S)	≯ 1 mg/litre
(7)	Cyanide (as CN)	≯ 0.2 mg/litre
(8)	Oils and grease	≯ 10 mg/litre
(9)	Formaldehyde	≯ 1 mg/litre
(10)	Phenols (as cresols)	≯ 1 mg/litre
(11)	Free chlorine	≯ 1 mg/litre
(12)	Tar	None
(13)	Arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc.	Individually or in total ≯ 1 mg/litre
(14)	Soluble solids (dried at 105°C)	≯ 7,500 mg/litre
(15)	Temperature	≯ 32.5°C
	Fishing streams	
(1)	Biochemical O_2 demand (five days at 20°C)	≯ 20 mg/litre
(2)	Permanganate value (4 hr at 27°C)	≯ 20 mg/litre
(3)	Suspended solids content (dissolved metals) *	≯ 30 mg/litre
(4)	pH value	≯ 5 or 9
(5)	Sulphides (as S)	≯ 1 mg/litre
(6)	Cyanide (as CN)	≯ 0.1 mg/litre
(7)	Oils and grease	≯ 10 mg/litre
(8)	Temperature	≯ 30°C
(9)	The effluent shall not contain any other matter which would cause the stream to be poisonous or indurious to fish and other aquatic life.	

* Applies to relatively non-toxic metals in solution (e.g. iron, aluminium) which could give precipitates with the natural alkalinity of the river water.

Table 2. General Standards of Quality for Trade Effluents Discharge to River

84%, 4-hour permanganate value reduced by 40% and COD reduced by 73%. Adequate presence of active micro-organisms was observed in the activated sludge which proved that it is efficient to treat domestic sewage mixed with industrial waste.

The diversity of the nature of effluents connected to the sewerage system, coupled with the fact that further intensive treatment to be given at the sewerage works, makes the Public Works Department authority accept concentration of certain pollutants 5 to 10 times higher than those acceptable to the Ministry of Health. Nonetheless, pH value will require fairly rigid control (pH 6 – 9) because of potential damage to sewerage fabrics, liberation of obnoxious gases in the sewers and interference with the biological treatment processes at the sewerage works.

INDUSTRIAL EFFLUENTS FROM THE FOOD AND ALLIED INDUSTRIES

There are no less than 250 establishments engaged in the manufacture of food and beverage products. The range of manufacture includes the canning and preserving of meat, fish, fruits and vegetable products, sausages, manufacture of milk, biscuits and baking products, cocoa, chocolate and sugar confectionery, noodles, coffee powder, spices, distilling of spirit and wines, vegetable oil production, etc. In most of the food processing factories the rate and strength of the effluents discharged vary considerably over a working day and for certain categories of food products they also vary with the festive season. All the results of analysis given in this note are based on random samples of the effluents taken and though they may not reflect the true average quality of the effluents, nonetheless, they are a guide to the types of effluent presently discharged by the industries concerned. Methods of treatment for the effluents have been suggested. Although it is only a cure, it is proposed that for most of the factories concerned better house-keeping methods will invariably reduce both the volume and level of contaminants of the trade effluents discharged.

Canning of Meat Products

The effluents from the canning of meat and fish products are characterised by a high dissolved and suspended organic matter, protein and fats. The following values of the contaminants have been recorded: BOD (5 days) 700 – 1500 ppm, pH 5.5 – 6.4, grease and oil varying from 80 – 120 ppm. In the processing of canned curry chicken, apparently about 60 – 70% of the meat is derived from frozen chicken and the remaining 30 – 40% from live birds. The waste from the latter consists of faeces, urine, blood, washings from carcasses, floor and utensils, undigestable food from the paunch and sometimes liquor from the rendering of offal. Blood is one of the most important sources of pollution as it contains 20% of the total solids and has a high BOD of 100,000 ppm. All the wastes are largely organic in character and normally highly putrescent. Initial treatment usually consists of screening which removes feathers, intestines and large particles. In one particular meat process plant screening alone could lower the BOD to 300 – 400 ppm and suspended solids to 150 – 200 ppm. Sedimentation removes faeces and undigestable food and grease and oil is normally removed by using an oil trap. Biological methods may be required to reduce the level of BOD to an acceptable level of 50 ppm before discharging into the water courses. We are presently conducting experiments on the waste from a cannery plant using a pilot plant trickling filter.

Canning of Vegetable Products

Normally the factories which are engaged in meat canning are also involved in the canning of vegetables, and such products include bamboo shoot, bean sprouts, salted beans, vegetables, etc. When salted vegetables are used as raw materials, the washings from the process contain a high suspended solids, in the region of 150 ppm and dissolved solid concentration can go up to as high as 10%, consisting basically of salt solution. Screening can remove a substantial quantity of discarded vegetables and fruits from being washed into the works effluents. Other forms of treatment include the disposal of cannery wastes by impounding in lagoons, provided there is available land. In lagooning, the waste undergoes a measure of purification and is subsequently discharged intermittently or continuously to surface water. It is usually in such treatment that sodium nitrate is added in order to prevent an anaerobic condition. Apparently considerable success has been reported and result of BOD reduction from 650 – 45 ppm over a 60-day period has been achieved [15]. Experiment in our laboratory with a mixed canning waste from the meat and vegetable lines shows that the COD could be reduced considerably with the addition of alum (200 ppm) from 1400 ppm to 400 ppm.

Manufacture of Milk and Milk Products

In the dairy industry most of the factories consist of several operations and the types of waste may be variable, depending on the process involved, e.g. bottling, creameries, ice-cream production, milk manufacture, etc. In one plant, bottling reconstituted milk, the waste consists of a very high BOD, approximately 9,000 ppm and dissolved solids of 3,000 ppm. This may be due to the spillage in the bottling process and in particular the spillage due to the breakage of bottles when they are subjected to sterilising. (BOD of whole milk is 110,000 ppm). On the other hand, the quality of the waste from the plant manufacturing condensed milk is less severe. BOD level of 200 – 300 ppm has been reported and although in another similar plant the level has been recorded at 3,000 ppm. Presumably the use of tin containers are subjected to less breakage and normally the processing of sweetened condensed milk does not involve high temperature sterilisation. The level of grease and oil is about 100 ppm. Effluents from a plant compounding butter give a BOD level of 200 – 400 ppm, and grease and oil content of 100 ppm. Reports from the Water Pollution Research Laboratory show that milk loss in washing as a percentage of milk handled varies from 0.2 – 1% and a BOD ranging from 600 – 1000 ppm. Under controlled conditions, the polluting of wastewater containing milk and milk products could be reduced by chemical coagulants. Results of some experiments in the Water Pollution Research Laboratory on the mixture of milk and water are given as follows:

Coagulants Used (ppm)	BOD	Percent Purification Based on BOD
$Ca(OH)_2 + Fe\,Cl_3$ (400 ppm)	104	65
$Ca(OH)_2$ 300 ppm + $Fe\,SO_4$ (400 ppm)	49	84
None	30.0	0

Other methods have been tried with partial success, e.g. activated sludge process. However, milk washings and whey washings after sedimentation and dilution where necessary in order to bring the BOD level to within 200 ppm has been successfully treated by using alternative double filtration technique.

Fermentation Industry

Waste from such industry includes the effluents from the manufacture of wines, samsu, beer and monosodium glutamate. The waste from the fermentation of wines has a high BOD level of approximately 1,500 – 3,000 ppm and a high level of suspended solids due to the presence of microorganisms and organic nutrients. In a sample of mother liquor from the fermentation of wines a BOD level of 25,000 ppm and COD 38,000 ppm has been recorded. Experiments in our laboratory indicate that the BOD could be reduced substantially from 25,000 – 3,000 ppm by dilution (2 : 1) and aeration in presence of activated sludge for two days. Apparently, such wastes when mixed with sewage can be treated by biological methods. We are now working on lagooning the waste from one factory fermenting sugar molasses.

Manufacture of Soft Drinks

The effluents are derived from washings of the bottles, floor and equipment, syrup storage tanks and drains. The characteristics of such wastes include a high pH 9 – 10, BOD 600 – 2000 ppm, total dissolved solids 100 – 900 and a suspended solids of 200 – 700 ppm. Some form of biological treatment may be required to reduce the BOD to a level of 400 ppm before it could be discharged into the sewers.

Manufacture of Vegetable Oil

Basically there are two types of waste in such a factory. One is the washings from the drums, floors and the plant. BOD is normally in the region of 300 – 800 ppm and suspended solids 50 – 400 ppm, grease and oil 100 – 800 ppm. Methods of treatment usually include an oil trap to remove the grease and oil and this correspondingly reduces the BOD. The other washing is from the soap stock and this is characterised with a high BOD level, somewhere in the region of 20,000 – 40,000 ppm and the total dissolved solids of 20,000 – 100,000 ppm, depending on the process used. Some effluents may contain a high dissolved chloride due to the liberal use of salt in the de-emulsification process. Treatment will include some form of biological process.

So far we have mentioned that preliminary treatment be conducted by the respective factories in order to bring the level of trade effluents to that allowable by the Public Works Department before discharge into the sewers. On the other hand, there is another school of thinking which is of the opinion that the proper place to deal with trade effluents is at the local sewerage works and not at the traders' premises. Assuming that this principle is accepted, namely that the trade wastes should be treated at the sewerage works we must now examine the practical problems associated in dealing with such wastes, the possible effects on the purification process and the conditions and limitations which must be imposed on the acceptance of such wastes.

In Singapore the sewerage works consist of the following process:

(1) Screening, where heavy particles and objects are removed.

(2) Sedimentation tanks, where the bulk of the solid materials is settled in the form of sludge.

(3) Activated sludge process, where by means of aeration, organic matter is largely oxidised.

(4) Some form of sludge treatment, often an anaerobic process.

There are a number of factors which will affect one way or another the working of the different processes at the sewerage plant and such factors which make the trade waste unacceptable or difficult to handle in the sewerage system or on the works dealing with domestic sewerage are as follows:

(a) **The temperature must not be too high.** The main objection is that hot liquid discharged into the sewers is a danger to the men working in the sewers. Additionally, they are more corrosive in their attack on concrete brick works and metal in the sewers.

(b) **The discharge must be as uniform as possible, both in the rate as well as its composition.** Whilst it is possible for biological system to deal with consistently heavy load, difficulties may be encountered with intermittent and uneven flows. The activated sludge process is perhaps particularly sensitive to fluctuations in the load.

(c) **The waste must not be overloaded with suspended matter.** This is liable to cause silting in the sewers, and in addition to having a destructive effect on sewers, may also impair the proper functioning of the biological activities in the activated sludge process.

(d) **Wastes which are positively toxic to life in the biological processes,** e.g. phenol, heavy metals, copper, arsenic, zinc, chromium, sulphite, if not treated will have a devastating effect on the biological plant. Waste containing high concentration of oil, soap and grease will require a pre-treatment before discharging into the sewers.

However, other wastes, possibly those from certain food industries could be discharged directly into the sewers provided industries concerned pay a charge to the Sewerage Authority for the treatment which would, otherwise be undertaken by the industries themselves. Apparently this has been practised by a number of Sewerage Authorities in the U.K. and the manner of computing is based on the Mogden formula. The computation takes into account the overall cost of sewerage treatment and this is split into three elements, representing the basic operations to which the sewerage and the trade effluents are subjected, during the period when it is received into the sewers to the time when it is discharged into the water courses. These are:

(i) Operations dependent upon the volume, irrespective of strength.

(ii) Operations dealing with solid matter to be removed from the sewage.

(iii) Operations dealing with the oxidation of the organic matter and other oxidisable matter which is still present in the liquid fraction after preliminary settlement.

This type of charging could be expressed as follows:

$$Ct = Cv + \frac{St}{Sm}Cs + \frac{Ot}{Om}Co$$

where

C_t = total cost of treating 100 m^3 trade effluent

C_v = cost of treatment operations related to volume only for 100 m^3 mixed sewage

C_s = cost of solids disposal from 100 m^3 mixed sewage

C_o = cost of oxidation of 100 m^3 mixed sewage after settlement

S_t, S_m are suspended solid contents of trade waste and mixed effluent

O_t, O_m are oxygen demand of settled trade waste and settled mixed sewage.

For apportioning cost between the various manufacturers, it seemed reasonable to use volume of flow and amount of suspended solids as directly determined but BOD values do not sufficiently reflect the relative costs that are incurred, since some trade wastes with relatively high BOD are readily amendable to treatment and the reverse can be true in other cases. So in New Zealand they introduce a "Treatability Factor" into their calculations. Such basis of charging seems fair to both sides and provides a financial incentive to manufacturers to limit the volumes of water he uses and to reduce the strength and solids content.

We are not advocating that we should copy this system *in toto*, nonetheless, it deserves some attention especially when effluents from the food industries which are characterised with a high BOD, and with little or no toxic material could be discharged directly into the sewerage works.

In conclusion, I would like to thank my colleagues in the Ministry of Health and Public Works Department for useful discussion and Chairman, SISIR for permission to publish this paper.

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POLLUTION CONTROL OF DISCHARGES INTO RIVERS, STREAMS AND SEA

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ABSTRACT

Legislation is necessary in order to provide a uniform code on pollution control for industries to conform to. The technical solutions to pollution problems are generally known, as are also the costs of overcoming or avoiding such problems. In an industrially competitive society the additional costs of achieving pollution control are eventually passed to the consumer. Realistic control limits are therefore needed. This paper is confined to effluents likely from the petroleum industry.

INTRODUCTION

This paper is confined to some aspects of water pollution control which are employed by the petroleum industry. Points considered are:

(1) Need for investigation
(2) Setting of realistic standards
(3) Refinery treatment facilities
(4) Need for regulations by properly informed government

NEED OF INVESTIGATION

Curiously the oil industry seems to bear the brunt of criticism levied against side effects from the use of its products. Complaints against trash from food and drink containers, are hardly sheeted home to the manufacturers of these products in the same way that any pollution by petroleum products is charged to the oil industry.

Before taking action against pollution problems which could require a large expenditure of money, it is necessary to measure the extent of the pollution and its effect on the environment. Pollution levels set for good reasons in one locality should not be adopted blindly in another place, where there is a requirement for a different set of standards. The following table shows control limits that have been applied in various locations.

	Singapore Inland Watercourses & Foreshore	Canada Seaboard Refinery	Continental Europe Inland Refinery	UK Royal Commission "Standard"
Oil ppm	5	15	2	20
Phenols ppm	nil	1	0.1	–
pH	6 to 9	5.5 to 10.5	6.5 to 8.5	–
BOD (5day) Max.	50	15	20	20
Suspended Solids ppm	50	15	20	30
Temperature °C	43	–	30	–

In Singapore it would appear that the regulations have been framed to conserve water from inland courses with a view to its recovery to supplement domestic supplies. The levels set are realistic for this objective. However, the Act also extends these limits to discharges into estuaries and the foreshore. It is not realistic to apply the same standards to both situations. Limits are necessary for the disposal of effluents to the sea, but, is there need to make these limits as stringent as those required for inland watercourses. It could well require that the quality of the water discharged from a refinery is required to be more pure than that taken in from the sea.

SETTING OF REALISTIC STANDARDS

Refineries

The older seaboard refineries made extensive use of salt water for cooling purposes and the quantity could amount to as much as 20 tons of water for every ton of crude oil processed. The newer refineries and particularly those on inland rivers have made maximum use of air cooling. Here the water effluent has been reduced to as low as one quarter of a ton of water per ton of crude oil processed. What maximum concentration of oil pollutant should be allowed in these two cases?

For a 100,000 Barrels Per Stream Day (BPSD) refinery employing extensive use of salt cooling water, the total oil discharged (at a permissible limit of 5 ppm oil in effluent water) would be:

$$\frac{100{,}000}{7.5} \times \frac{5}{1{,}000{,}000} \times \frac{20}{1} = 1.3 \text{ tons/day}$$

For a modern refinery employing maximum air cooling (but allowed 20 ppm oil in effluent water) the total oil discharged would be:

$$\frac{100{,}000}{7.5} \times \frac{20}{1{,}000{,}000} \times \frac{1}{4} = 0.07 \text{ tons/day}$$

or 18 galls/day

Pollution By Shipping

The 1954 International Convention For Prevention Of Pollution Of The Sea By Oil established zones where it was prohibited to discharge persistent oils and water containing more than 100 ppm of oil. The Convention was amended in 1962, but outside the prohibited zones it was still legal to discharge tank washings which from a crude carrier can equal 0.3 to 0.5 per cent of the cargo. To overcome this pollution the oil industry has adopted a procedure known as LOT (Load-On-Top). Here sea water used for washing is retained on the ship until the slop oil has separated. This oil then pumped into one compartment and the wash water now essentially free of oil is returned to the sea. On arrival at the loading terminal, the crude oil cargo is then loaded on top of the oil that has been retained in the slop compartment. With LOT it has been estimated that the amount of oil discharged to the sea from tanker washings in 1970 would have been less than one million tons and of this, some 75 per cent would have come from the 20 per cent of the free world tankers who are not observing LOT.

REFINERY TREATMENT FACILITIES

Oil Removal

Within a refinery the following processes have been used for treatment of aqueous effluent for oil removal.

	Oil Content of Treated Effluent ppm	REMOVERS		
		Suspended Oil	Emulsified Oil	Soluble Oil
API separator	30 to 50	YES	NO	NO
Parallel plate interceptors	20 to 25	"	"	"
Dissolved air flotation	20 to 25	"	"	"
Dissolved air flotation with flocculation	15	"	YES	"
Flocculation and sedimentation	5 to 10	"	"	"
Sand filtration	About 5	"	NO	"
Biological treatment	About 3	"	YES	YES

Pollutants Originating From Oil

Apart from oil, refinery operations can produce other chemicals and pollutants. Steam condensate from stripping operations on crude distillation units can contain sulphides and phenols. Similar condensate from catalytic crackers can also contain cyanides, ammonia salts and higher concentrations of phenols. The effluent water from desalters (used to remove salt and salt water from crude oil before further treatment in crude distillation units) which have become necessary in refineries with the advent of LOT, contains sulphides, phenols and naphthenic acids. These above contaminants can be oxidised by biological treatment.

Spent Chemicals

Spent caustic soda and sulphuric acid are the chemicals used in largest quantities and techniques are available for their neutralization, stripping and if necessary incineration of oily components. The older refining processing routes which depended on these chemicals are in modern refineries being supplanted by catalytic hydrogenation.

Solutions to the problems of disposal or neutralisation of pollutants from petroleum refinery and maximum operations are known, as is also the cost of building and operating treatment facilities. There is no cash flow or profit from expenditure on such treatment facilities.

The magnitude of the additional cost of providing pollution abatement equipment for a 100,000 BPSD refinery, could be as high as 2½ to 3 million pounds sterling or 6 to 7 per cent of the total refinery cost.

NEED FOR REGULATIONS

Pollution must not be allowed to go unchecked and there is a need for control through legislation by a well-informed government. The public is unlikely to buy the higher-priced product from a lone manufacturer pursuing a voluntary and costly pollution control programme and facing competition from a less public-spirited competitor.

The benefits to be gained from setting pollution control levels need to be weighted against the increased cost of manufacture, as in a competitive industry the increased manufacturing cost must eventually be borne by the consumer. In this field of pollution control, industry has special knowledge and expertise. There is a need to bring together the various interests and industry should be encouraged to participate in advisory panels and provide purely technical advice in optimising expenditure on pollution control.

Paper No. II/6

AIMS OF WATER POLLUTION CONTROL

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ABSTRACT

Ideally the aims of water pollution control are to ensure the availability of water for public supply, to eliminate health risks and to preserve amenities. The paper discusses the way in which economic considerations often dictate the extent to which these aims can be achieved in practice.

INTRODUCTION

The basic aims of water pollution control are the minimising of health risks and the preservation of amenities. Closely allied to these aims is the need to conserve water, particularly in areas where resources are scarce in relation to demands for domestic supply, industry and irrigation.

It is rarely possible to attain all of these aims completely because the competing claims of other services essential to the community such as medicine, education, housing and transport all have to be taken into account by Governments when allocating funds to water pollution control out of the total budget. The work of the sanitary engineer is therefore directed largely towards informing the responsible authorities of the consequences which will result from their decisions and towards ensuring that funds devoted to the control of water pollution are used to best advantage.

It is convenient in this paper to discuss the aims of water pollution control under separate headings, but it is evident that in many cases they are closely inter-related. For instance, measures designed to reduce health risks by improving the quality of streams passing through developed areas will usually improve their amenity value at the same time. On the other hand, the provision of a piped water supply and water-borne sanitation for one community can, unless adequate treatment is provided, adversely affect the amenity value of a watercourse and/or the quality of water abstracted by other communities further downstream. The optimum use of scarce resources is of such fundamental importance that it will also be discussed briefly under the section dealing with economic considerations.

HEALTH

The provision of an adequate supply of piped potable water is probably the most important single factor in safeguarding the health of a community. The installation of public sewers to convey the used water to a satisfactory disposal point is the next priority; indeed in densely populated urban areas it is desirable if not essential for sewerage to proceed simultaneously with the provision of piped water. Failure to provide adequate drainage facilities for all water supplied, including subsequent augmentation, can result in a deterioration of sanitary conditions in a large urbanisation.

Diseases associated with the drinking of polluted water and with transmission by flies and direct bodily contact generally show a marked reduction

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when public water supplies and sewers have been provided; one of the most significant indications is the incidence rate of typhoid. Urban areas lacking either of these facilities, such as existed in Europe during the nineteenth century and are still to be found in a few parts of the world today, show annual case rates of several hundred per 100,000. After the provision of basic sanitary services, the case rate falls drastically to a figure of the order of 10 per 100,000.

With further improvements in sanitary conditions, not only connected with water but also with food, the annual case rate for typhoid can be reduced to about 1 per 100,000, but even at this low level the disease does not cease to be significant. It remains a constant threat and outbreaks are liable to occur whenever the sanitary services are disrupted by flood, drought, earthquake or other emergencies. This was clearly evidenced by the return of typhoid in epidemic form to parts of Central Europe in the aftermath of the Second World War, resulting in 50,000 deaths in the years 1945-46. Outbreaks of cholera are also likely to follow any breakdown or disruption in the sanitary services involving the efficient disposal of liquid wastes..

However strenuous are the efforts made to provide public water supplies and sewerage systems there always inevitably remains some proportion of the population which cannot be served; this is due to the relatively high cost of providing long lengths of water mains and sewers conveying small flows, particularly in scattered rural communities. The significance of this to public health depends entirely on the local conditions, and can vary widely from place to place; usually the liquid wastes from small communities can be disposed of without serious risk due to their limited volume and the dilution available.

Where local water supplies are drawn from wells in granular soils they may be quite satisfactory, and in any case they can readily be monitored for contamination by faecal bacteria, but where local supplies are taken from surface streams their quality is more likely to be subject to a varying amount of pollution. There is much to be said for extending piped potable water supplies to small communities even if it is economically possible only to install standpipes.

The personal habits of the population also have a marked bearing on the significance of water pollution to public health. In some parts of South East Asia the population invariably boil all water before use and also cook almost all their food. The general state of health may then be remarkably good, with infant mortality rates less than 20 per 1,000, even though sections of the population live in conditions which appear grossly insanitary.

In assessing the likely impact of proposed water supply, sewerage and sewage disposal schemes on public health, much depends on the availability of comprehensive and detailed statistics of morbidity and mortality rates. Where the figures are broken down between different areas, age-groups and also by race (as in Singapore) they are of maximum usefulness.

AMENITY

In almost every part of the world, domestic sewage and industrial wastes—treated and untreated—have been permitted to foul streams, rivers and the inshore coastal waters. Concern about these developments was at first concentrated on public health aspects but there is now growing realisation that amenity considerations cannot lightly be ignored.

Two particular forms of river pollution which detract from amenity values without necessarily posing a threat to health may be mentioned as examples. Strong organic wastes, such as those produced by food processing factories, intensive livestock units and the palm oil and rubber industries may, if discharged untreated to rivers, give rise to anaerobic conditions resulting in foul smells, due largely to the evolution of hydrogen sulphide, to the elimination of fish and most other forms of life and also to progressive discolouration of the water until it eventually becomes black. Wastes from many mineral processing industries, such as tin dredging and the production of china clay may contain a very high content of fine suspended solids which are virtually unsettleable and which cause greatly increased turbidity and discolouration of rivers.

The significance of these effects depends to a large extent on local conditions such as the natural state of the rivers, the character of the surrounding area and the general living standards of the community. Discolouration of rivers in remote rural areas may be of little importance whereas dark coloured, evil-smelling streams in densely populated areas may be very objectionable. One factor which is of growing importance in some countries is the impact on tourism; visitors unaccustomed to unpleasant conditions tend not to accept them so readily as the local inhabitants who have probably grown to regard them as inevitable.

Where river pollution is caused by the activities of industry it is often argued that the provision of effective measures to abate the nuisance is either impracticable or would be so expensive as to render the industrial process totally uneconomical. Such claims need careful and expert scrutiny. Where they are found to be true, a decision may be required at Government level as to whether the benefit to the community as a whole of permitting the industry to continue outweigh the disbenefits of the pollution caused; these decisions are amongst the most difficult which have to be made in this field, and it is better if such matters can be covered by comprehensive legislation so that industrial concerns can evaluate the cost at the outset.

WATER CONSERVATION

The separation of administrative arrangements has in the past often meant that the disposal of sewage and industrial effluent has been considered quite independently from the supply of water. In many cases, proposals for major increases in water supply have been put in hand long before any thought has been given to the necessity for corresponding augmentation of the sewerage and sewage disposal facilities. This separation of responsibilities has often proved unfortunate and it is now widely recognised that it is essential to consider the cycle of water usage as a whole, at least for planning and financing purposes.

In areas where rainfall is relatively small and development is dense, it may be impossible to meet the growing demands for water without recourse to reuse in one form or another. The commonest form of reuse is that where purified effluents from sewage works are discharged into a river which is used as a source of water further downstream. Provided that proper attention is paid to sewage treatment, to the control of industries producing or handling potentially toxic materials, and to the treatment of the water abstracted, this can be a perfectly satisfactory arrangement. Indeed, under some circumstances it can provide additional water very economically; as an example, the discharge of high quality sewage effluents into a river in England is expected to increase the yield of an existing water supply scheme from 37 million gallons per day (mgd) in 1965 to 73 mgd by the end of the century merely by reason of the increase in the steady base flow of the river and without the need for any additional capital expenditure on storage. In this case, it is envisaged that all major effluent discharges will be treated to a standard of 10 mg/l biochemical oxygen demand and 15 mg/l suspended solids or better.

Direct and regular reuse of sewage effluent for potable supply has only been instituted, so fas as the author is aware, at Windhoek in South West Africa. Most authorities are understandably cautious in their approach to this radical method of water conservation, but in many cases it is feasible to reuse sewage effluents for secondary purposes, such as industrial use, cooling or irrigation, without the same misgivings on either aesthetic or public health grounds. As an example, proposals have recently been drawn up for the city of Lima in Peru which would permit the reuse of up to 300 mgd of treated sewage effluent for irrigating desert areas within 50 miles of the city.

A different aspect of water conservation by pollution control was illustrated by a study recently carried out on pollution in the tidal reaches of a river in England. The upper reaches of this river are used as a source of water supply, but the amount which can be abstracted is limited by the need to provide a flushing flow at all times into the head of the estuary. From the results of water quality surveys carried out along the length of the estuary at different rates of fresh water flow, it was possible to predict the effects of (1) reducing the fresh water flow and (2) providing waste treatment at a large food processing factory which discharged the bulk of the polluting load entering the estuary. The investigation showed that the provision of biological treatment at the factory would permit the abstraction of up to 20 mgd of additional water from the non-tidal river at about a quarter of the cost of any alternative source of supply.

ECONOMY

Mention has already been made in the introductory section of the need for sanitary engineers to ensure that funds allocated to water pollution control are used to best advantage. There are two requirements to be satisfied in this connection. The first is by careful consideration to decide upon the essential objectives which have to be achieved; the second is the selection of the most suitable methods for achieving those objectives.

The objectives can be defined only after study of existing conditions and this may necessitate stream pollution surveys, sampling and measurement of existing pollution loads, and prediction of future conditions. The value of these steps may be illustrated by reference to a recent case where the discharge of about 12 mgd of sewage effluent to an estuary was proposed and the regulating authority initially stated that if partial treatment only was provided it would require effluent holding tanks of sufficient capacity to ensure that no flow would be discharged during the period when the tide in the estuary was rising. Examination of this proposal showed, firstly, that it would be more effective to discharge when the river level was above mid-tide, irrespective of whether it was rising or falling, and secondly that the provision of holding tanks sufficient to accommodate the normal flows instead of the maximum possible flow during the necessary period would not significantly increase the pollution load discharged. After discussion and verification, the regulating authority agreed to amend their requirements and a saving of some S $ 1.5 million was made on the holding tank capacity provided.

In selecting the least costly methods of controlling water pollution it is essential to take account of all relevant local conditions including the characteristics of the receiving water, climate, the availability of land, constructional materials and operational factors.

For communities located on the coast there is often a choice between sewage treatment at an inland works or discharge to the sea through long submarine outfalls with the minimum of treatment required to meet aesthetic requirements. In some cases a combination of the two methods is preferred; a study recently carried out for the disposal of sewage for the Bombay Municipal Corporation in India showed that the most effective and economical scheme (assuming sewage effluent to be required for irrigation purposes) would comprise two submarine outfalls of 2.8 m and 3.0 m diameter serving about two thirds of the total present population of nearly six million, and four inland treatment works serving the remainder of the city. In the selection of sites for submarine outfall discharge points comprehensive hydrographic investigations are, of course, vital not only to determine the way in which the sewage field will disperse but also to allow a reliable estimate to be made of construction costs which depend very largely on sea bed and oceanographic conditions.

Where full sewage treatment is indicated, the choice of biological method generally lies between trickling filters, activated sludge and oxidation ponds. The maintenance of mechanical and electrical plant proves troublesome in many countries and where spares are also difficult to obtain; there is much to be said for keeping the amount of such equipment to a minimum. In localities where there is adequate land available, oxidation ponds are often the selected form of treatment; they have the merit of being robust and reliable where climatic conditions are suitable.

CONCLUSIONS

It is unlikely that water pollution will, in the foreseeable future, be eliminated completely in any part of the world where there are towns and industries. It is, however, being reduced in many countries and the measures needed to bring it under control are well established. The cost is the limiting factor and is likely to continue to be so for many years hence-in England alone it is proposed to increase by over 50% the present outlay on new pollution control measures in the next five years resulting in much higher capital expenditure than is being allocated to new water supply projects.

The main requirement is to develop a practical programme in each case which will provide the maximum benefits for the expenditure of funds within the resources of the community. In drawing up schemes for water pollution control and presenting them to the responsible authorities, careful consideration and clear explanation of the aims to be achieved are of prime importance.

Paper No. II/7

THE SLOP OIL PROBLEM IN SINGAPORE

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ABSTRACT

Slop oil is the oil/water mixture resulting from tank cleaning operations from ocean-going tankers. At this moment over 3,300 tankers totalling 177 million deadweight tons are plying the "oil routes" of the world. In 1970 they carry over 1,200 million tons of oil. On an average of once a year to eighteen months, these tankers are docked for inspection and/or repairs. Sometimes they berth alongside for emergency repairs. Safety ordinances require their tanks to be cleaned, gas freed and the slop discharged before the tankers can be docked or berthed. If shore reception facilities do not exist, half a million tons of oil would be discharged into the seas from "repairing" tankers alone. Including "normal" tanker operations, accidents and the discharge from ships bilge the total oil spill (from ships) could come to over a million tons per year.

Oiled waters can and do cast numerous troubles ranging from dead sea birds to extermination of whole colonies of shellfish. Potentially, the most serious could be a reduction in the population of phytoplanktons which reside just below the ocean surface. Phytoplanktons are responsible for converting a major part of the carbon dioxide into oxygen and its wholesale annihilation could mean an irreversible change in the oxygen cycle. Also fishery resources would be affected by a decline in the population of marine organisms. In the decades to come, this could be a setback to a world hungry for protein.

The rationale for slop receiving facilities have been accepted by major ship repairing countries and who have put several into operations. The usage of such facilities have also been largely accepted by tanker owners despite the penalties incurred.

In the case of Singapore, the quantitative need for slop facilities has been assessed by the author in a technoeconomic study for the Port of Singapore Authority. Due to proprietary conditions only the technical part of the study is presented in this paper. The main conclusions are as follows: the economics of scale suggests a central depot to service the various ship repairers; forecasts of tanker repair turnover show that by 1975 Singapore will be repairing nearly 20% of the world's tankers and the total slop crude, heavy fuel oil or "white oil" slop. Findings show that crude will predominate. White slop has tetraethyl lead which is undesirable in refinery operations.

Reception facilities start with the provision of wharves suitable for berthing supertankers in ballast condition. Study of wharf facilities are carried out separately and not included in this paper. After re-

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ception in standard oil tanks, the oil is processed from the slop and stored for final disposal. Four methods of final disposal are given, the most promising being one where arrangements are made with oil refineries to accept the processed oil as a small part of their feed stock in the case of crude or for blending in the cases of fuel or white oil.

Coincident with the need for slop facilities, the oil depot at P. Sebarok is being vacated by an oil company, It was found that, this would be a suitable site for a slop centre. Some modifications to the existing pipes, tanks and other facilities are being carried out and slop reception is scheduled to commence from February 1972.

INTRODUCTION

This paper has its origin in a technoeconomic study performed by the author for the Port of Singapore Authority. The author wishes to thank the Port of Singapore Authority for permission to present this paper. For proprietary reasons only the technical part of the technoeconomic study is presented. The author is also indebted to Shell Company for their help in freely giving technical advice and for permission to use the slop treatment flow chart, and to Sembawang Shipyard Ltd. for the use of survey data on slop quantities.

Perhaps an explanation is in order here as to the usage of a slop reception facility. This facility is primarily intended to collect dirty oil and water from tanker vessels. It is not the intention to use it to dispose of dirty oil that originates from such land sources as garages and workshops.

THE PROBLEM: ENVIRONMENTAL QUALITY AND ECONOMIC RETURNS

In Singapore, the need for a slop reception centre was first felt when the major ship repairers found that their tanker repairing business could be seriously jeopardized once the clean seas policy is implemented.

Tankers when returning to their loading points sail under ballast and when this ballast water is pumped out the residual dirty oil goes out with it, or at least it used to be so. Today, however, 80% of tankers have adopted the Load-on-Top system. In this system, the procedure of which is described in the Appendix 1, the residual oil is separated from the ballast water and is put into a special slop tank or to be mixed again with the next oil load. The penalty here of course is that less cargo space is available and for this reason independent tanker owners operating on small profit margins and comprising the remaining 20% of the tanker fleet, are reluctant to operate the Load-on-Top procedure. This is one category of oil discharges from tankers.

The other category occurs when tankers have to be repaired. More often than not, hot work such as welding is required and safety ordinances throughout the world require tanks to be free of combustible vapour and oil. The tanks have therefore not only be cleaned but the slop oil must not be present when the tankers are being repaired. Where tankers are prohibited by their flag state in discharging oil they have three alternatives: either discharge to a specially provided on-board or onshore slop facility, or discharge to a refinery slop tank, or repair elsewhere where slop facilities exist. In 1971, several tankers have found it impossible to be repaired in Singapore because slop facilities are absent. The above two categories of oil discharges account for half a million tons of oil on the world's ocean surface.

In future years, it is not toodifficult to foresee a total ban on oil discharges into the seas. Public awareness of the need for quality of the total environment have reached the point, and probably rightly so, when even ships flying the flags of convenience will be prohibited from fouling the world's ocean. Even now the Japanese Seamen Union has asked its members not to discharge slop oil into the sea. Other indirect pressures could well be (1) from the oil companies which can instruct chartered tankers, beside their own, to comply to the clean seas policy and (2) from insurance companies which can refuse to insure tankers whose owners do not comply with clean seas regulations.

As a matter of fact, long before the public is aware of environmental problems attempts were made to restrict discharges. In 1924 the United States in an Oil Pollution Act prohibits the discharge of oil upon the navigable waters of the United States. In 1954 a Convention on the Prevention of Pollution of the Sea by Oil was drawn up and prohibits oil discharge within 50 miles of the coast. This was hardly sufficient and in 1962 the zones were extended and tankers over 20,000 dwt were advised to be equipped with facilities to eliminate discharges. This was the beginning of the Load-on-Top system. Again this was not satisfactory and in 1969 at a meeting in Brussels, the Intergovernmental Maritime Consultative Organisation (IMCO) in an amendment to the 1954 Convention, limit discharges to 20 gallons of oil per nautical mile on the high seas. Even if the 1969 convention were strictly adhered to it has been estimated that 60,000 tons of oil would still be discharged.

Ideally of course no oil whatsoever should be discharged or as one wit put it in the present environmental climate this would be casting troubles on oiled water. "Troubles" in fact were given a thorough airing when the US Senate in May 1971 conducted Hearings on Conventions and amendments relating to Pollution of the Sea by Oil. Oil is a toxic substance and its effect on the marine environment has, since the Falmouth spill in September 1969, been well documented by scientists from the nearby Woods Hole Oceanographic Institute. Previous to the Falmouth spill, it was still unclear whether the pollution effects of oil are minor or major, or whether they are of short or long duration. After Falmouth, it was determined beyond all doubts that the effects were major, that there was a massive and immediate kill of fish, worms, invertebrates and clams. The effects were also long-term: mussels that survived the spill as juveniles have a year later developed no eggs or sperm. Crops of shellfish harvested a year later were as heavily contaminated as the previous year's crop. Moreover crude oil contains carcinogen and can cause cancer in man when eating contaminated fish. Also in the long run the effect on phytoplankton could be damaging to the oxygen cycle, since phytoplankton plays a major part in renewing the oxygen supply of the atmosphere.

Such briefly is the damage caused to the marine environment by oil pollution. To prevent this would not only require mandatory prohibition of discharges but also the prerequisite shore reception facilities. It has been estimated that, world-wide, such facilities would cost US$1.6 billion to build and US$225 million a year to operate. These are large sums of money in anybody's language. Even major US ports such as New York, Los Angeles and San Francisco, as of May 1971, do not have slop reception facilities and we can congratulate ourselves that we in Singapore are almost ready to operate such facilites.

THE MAGNITUDES: TANKER REPAIR TURNOVER AND SLOP QUANTITIES

As in any investment project forecasts of certain critical parameters are required. Critical parameters in the case of a slop reception and treatment centre in Singapore catering primarily to repairing tankers are of course the tanker repair turnover and from this turnover the amount of slop expected. The slop expected are particularly sensitive to the economics equation as it not only influences the service charges to tanker owners but also may form an additional source of income from the sale of the treated oil. To jump the gun a bit and anticipate the findings of the next chapter, one may mention here that it is the normal practice in places where slop reception facilities are available (e.g. Malta, Japan, Holland, UK etc.) to process the slop to a state where it can fetch a price.

Tanker Repair Turnover

Forecasts of tanker repair turnover made here is not quite the same as forecasts of demands for tanker repairs. In the latter, one has to consider the "availability" factor: i.e. how many dead weight tons of tankers are operating in this region, for example in carrying oil from the Middle East to Japan. Moreover, one has also to consider the possibility of tankers not normally operating in this region but which may be available due to "spot chartering" for operation in this region. Furthermore, one has to consider the proportion of tankers whose flag states require them to be repaired in their own countries etc. These are the sort of factors one has to evaluate before building a repair dock. We, however, have sufficient information on the number and sizes of docks being planned or mooted in Singapore and it is therefore logical to use this information as the starting point in our forecasts. Thus if we could come up with an answer that indicates the tonnages repaired for a given size of dock at a given year then this should serve our purpose for this reason: that docks are not planned and vast sums of investment are not committed unless the planners have themselves made reasonable forecasts of their work load. Once repair turnovers are known the amount of slop expected can be calculated based on the experience of tanker operators. Methods and data are given later in this section.

With information on dock sizes and year of completion as initial inputs the estimates of tanker turnover proceed as shown in the Logical Diagram (Fig. 1). Firstly, the number of unscheduled repairs (i.e. collision, groundings, damages due to heavy weather etc.) are assumed, using present day experience at the three major shipyards (Keppel, Sembawang and Jurong) for guidance. These repairs will take a total dock time of about 60 days. The remaining 300 odd days of the year is then "free" for scheduled dockings (i.e. annual and survey dockings). The average time spent in dock of such a docking is a function of the size of the tankers (Table I). Average size of tankers that are likely to be repaired at a given dock is dependent on the size of that dock. For example, a superdock capable of taking a 300,000 dwt tanker is hardly to be used to service small 20,000 dwt tankers. On the other hand, it is likely to service tankers of about 225,000 dwt as there is a preponderance of such tankers. For a 300,000 dwt dock, the average size of tankers to be serviced have in fact been given by Japanese shipyard executives as 150,000 dwt. Thus to continue the example of a 300,000 dwt dock, the maximum capacity for scheduled dockings would be:

$$\text{average dwt (150,000 dwt)} \times \frac{\text{305 days}}{\text{average time spent in dock (3.4 days)}} = \text{13.5 million dwt}$$

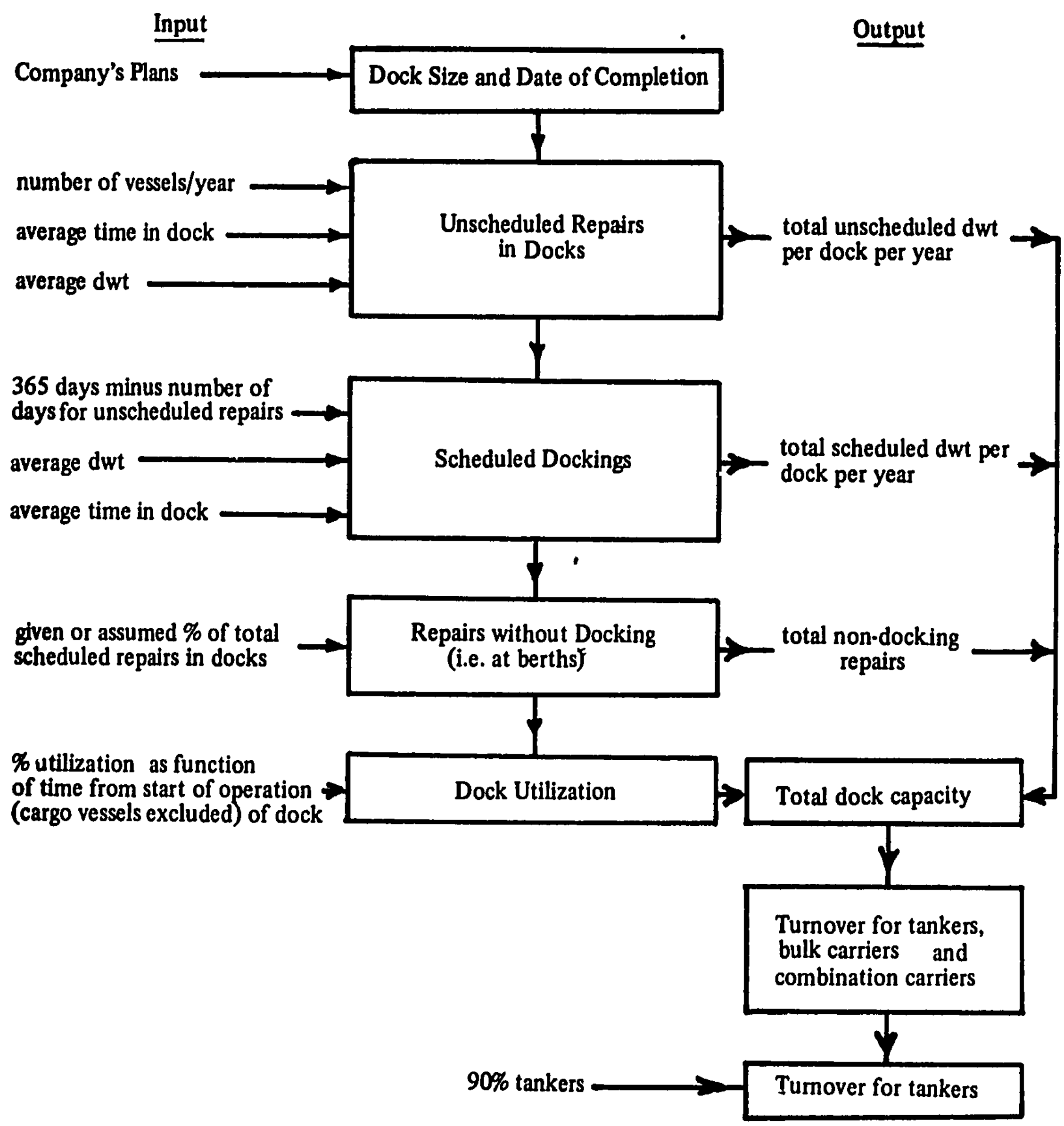


Fig. 1 Logical Diagram for Estimation of Tanker Repairs Turnover

Dock Size (dwt)	Number of Docks in S'pore by 1980	Unscheduled Repairs in Docks				Scheduled Repairs in Docks					Berthing Repairs		Grand Total
		Number of repairs	Average time in dock (days)	Average vessel size (dwt)	Total dwt (million)	Days "free" of unscheduled repairs	Number of repairs	Average time in dock (days)	Average vessel size (dwt)	Total dwt (million)	% of scheduled repairs in docks	Total dwt (million)	Repair capacity million dwt
40,000	1	11	5.0	25,000	0.28	310	103	3.0	25,000	2.6	30	0.78	3.5
100,000	3	8	7.5	20,000	0.40	305	100	3.0	50,000	5.0	20	1.00	6.4
150,000	1	6	10	80,000	0.48	305	100	3.0	80,000	8.0	10	0.80	9.3
300,000	4	4	15	150,000	0.60	305	90	3.4	150,000	13.5	10	1.35	15.5
400,000	1	3	15	200,000	0.60	320	84	3.8	200,000	16.8	10	1.68	19.1
500,000	1	3	15	250,000	0.75	320	80	4.0	250,000	20.0	10	2.00	22.8

Table I

Lastly, there is a category of repairs that do not require dockings. Here it should be explained that all repair yards have sufficient berthing space and moreover berthings can be double-banked. It should also be noted that berthings (for about 3-4 days) usually occur both before and after docking so that a large amount of berthing capacity is already taken up by docking tankers. On the basis of information provided by the shipyards, berthing capacities are taken as 10, 20 or 30% of the docking capacities. The results of the above calculations are summarized in Table I. These results represent the maximum dock capacity. Two other factors have to be considered (as shown in the logical diagram, Fig. 1) before the tankers' repair turnover can be obtained. These are the utilization of the dock and the proportion of vessels repaired that are tankers and not other types of vessels. Utilization is usually low, when a dock is first commissioned since "marketing" activities are not yet in top gear. For our purpose, we have assumed 40% utilization in the first year of service and increasing by 10% a year (till saturation at 80-90%) for established shipyards putting new docks into service. For new shipyards, we have assumed utilization factors of 30% in the first year, 50% in the second, 70% in the third, 80% in fourth and saturation again at 80-90%. The reason for the high growth of utilization is that the new shipyards have "built-in" marketing services through their parent companies and moreover one would expect the parent companies to recoup their investments as quickly as possible by channelling repair business to the new docks. Furthermore, to explain not only the meteoric increase in repair dock construction in Singapore but also the maintenance of a high level of utilization after the "break-in" period, 2 basic factors favourable to Singapore can be stated:

(1) Relatively lower labour costs than major ship-repair countries. Since ship repairing is highly labour intensive and there is no way in which to reduce this labour dependence this is an important advantage for Singapore vis-a-vis for example Japan.

(2) Time saved by tanker owner in tank cleaning operations. Tank cleaning is required by safety laws before repair work can be carried out. This usually takes 4-6 days depending on weather conditions and can be fitted in during the voyage between departure from the unloading port in Japan, for example, and arrival in Singapore, before proceeding to the Persian Gulf. For a 200,000 dwt tanker, a day lost could mean costs and loss of revenue of S$200,000 or even higher for voyage charter.

Finally to arrive at the turnover for tanker repairs as distinct from all types of repairs the % of tankers repaired must be known. On present performance this % is about 90 for the larger docks. For vessels over 100,000 dwt Lloyd's Register of Shipping gives the total number of vessels at 332 of which 72% (by number) are tankers and the remainder combination carriers (such as ore, bulk and oil carriers) and bulk carriers. By dwt the corresponding figure would be about 80%. Since Singapore has more tanker traffic than bulk carrier traffic, we shall assume that 90% of all repairs are tanker repairs.

Thus total tanker repair turnovers up to 1980 are obtained and shown in Table II and Fig. 2 with dock repair capacities and world's tanker repair potential. The latter is a conservative estimate based on actual construction orders up to 1974 and extrapolated to 1980, and on the assumption that a tanker is docked every one and a half year plus 25% for non-scheduled repairs.

The last row of Table II gives Singapore's share of tanker repairs as a % of world's tanker repair potential. Thus by 1975/76 we can expect that 20% of the world's tankers will be repaired in Singapore and representing a good 50 million deadweight tons. This is, indeed, no mean achievement. One would even hazard a guess that by 1980, Singapore would be the leading tanker repair nation.

Slop Quantities

There are 4 main categories of slop. They are: bilge oil, slop mixture, tank cleaning water and dirty ballast water. Dirty bilge oil is, of course, found in all motorised vessels. Last year (1971) 20,000 vessels of average 4,000 net registered tons entered Singapore port waters. If each vessel discharge ¼ ton of bilge oil into the harbour, which they sometimes do under cover of darkness, there will be 5,000 tons a year. This is in fact small beer compared to what is to come from tanker slop.

Slop mixtures, tank cleaning water and dirty ballast water have their origin in tanker operations. These terms are explained in Appendix 2. To add to the complexity there are various types of tankers classified by their cargo: such as crude oil, black oil, white oil, lubricating oil, liquid petroleum gas etc. In general, however, crude oil carriers will predominate but as Singapore is also a refining centre, "product" tankers will also be common. The type of slop expected from each type of tanker can best be seen in Fig 3.

An explanation of the above matrix is in order. Take crude carriers first: most crude carriers ply the route from Persian Gulf to Japan. They do not stop in Singapore and are therefore "passers". However, on the return voyage these tankers find it convenient, should it be necessary, to be repaired in Singapore. In such cases, there would be sufficient time for the tank cleaning water to separate out from the oily residues. Once separated

Calendar Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Major Repair Docks in Singapore (in existence or projected) Figures indicate size of dock in dwt	40,000 →										
	100,000 →										
	100,000 →			300,000 (enlarged) →							
	100,000 →										
					300,000 →						
						400,000 →					
						100,000 →					
						150,000 →					
						500,000 →					
							300,000 →				
								300,000 →			
Docks Repair Capacities in Singapore (million dwt)	22.7	22.7	22.7	31.8	47.3	103	103	118	134	134	134
Estimated Tanker Repair Turnover in Singapore (million dwt)	12.0	15.6	16.7	20.2	26.1	44.0	54.3	64.0	77.4	89.0	98.5
World's Tanker Repair Potential (million dwt)	124	143	163	187	206	231	253	282	307	332	359
Singapore's Share %	9.6	10.9	10.2	10.8	12.7	19.1	21.4	22.7	25.2	26.8	27.4

Table II

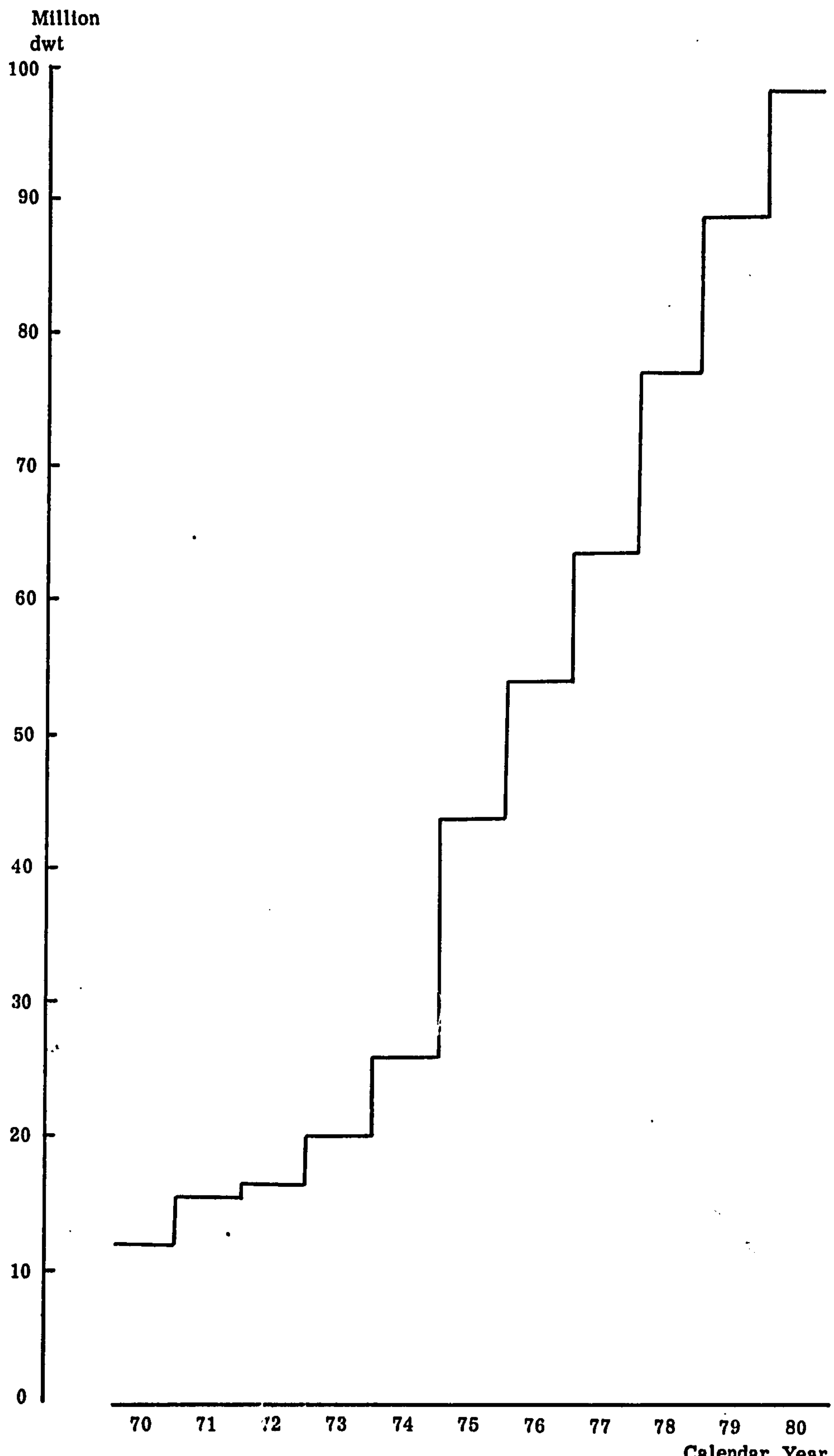


Fig. 2. Tankers' Repair Turnover in Singapore

Carrier Type \ Slop Type	Slop Mixture	Tank Cleaning Water	Dirty Ballast Water
Crude	Majority of cases from "passers"	Tankers delivering crude to local refineries	Few cases expected as crude carriers usually have slop tanks
Black	Tankers returning to local refineries for loading and also "passers"	Few cases	Some cases expected from older tankers not operating the LOT system
White			

Fig. 3 Matrix of Tanker/Slop Type Relationship for Singapore's Conditions

the clean water is discharged into the sea, the tanker retaining several hundred tons of slop mixture. For a 80,000 dwt tanker, there would be 400 tons of slop mixture of which 200 tons (0.25% of dwt) is slop oil. A survey made by Sembawang Shipyard indicates about the same percentage of slop oil, decreasing with tanker size. In fact, the slop quantities (Fig. 4) appear to be proportional to the two-thirds power of the dwt of the tankers i.e.

$$\text{Slop} \propto (\text{dwt})^{2/3}$$

and the reason for this seems to be that the slop originates from the surfaces of the tanks which is proportional to the square of a length whereas the dwt of a tanker (i.e. carrying capacity) varies as the volume of the tanks i.e. the cube of a length. For "slop oil" the constant of proportionality is about 0.108 (Fig. 4). The same relationship but with different constant (3.76) holds for tank cleaning water (also called tank washings).

Tank washings can be expected in Singapore from tankers delivering crude oil to local refineries since they have to clean out their tanks on the spot (before repairs). To do this would take one or two days and rather than waste more time allowing the water to separate out they may prefer to pump the washings into shore facilities.

Ballast water is usually uncontaminated if the tankers are operating the LOT system. The conversion to the LOT mode is not particularly difficult and it is anticipated that in a few years ballast water discharged at slop facilities will be small.

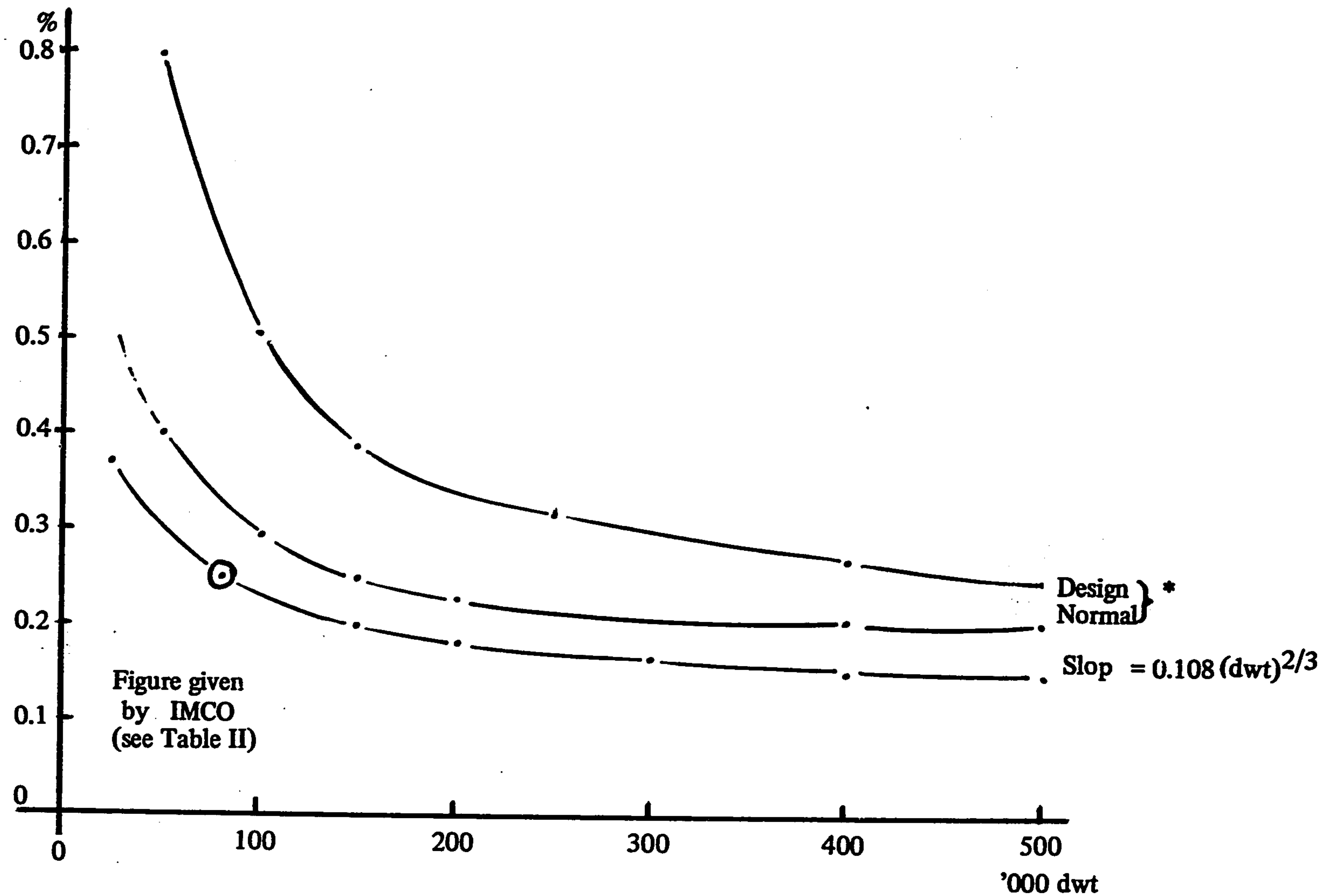
Product tankers normally constitute about 10% of the tanker fleet. Japan in fact do import product oil from Singapore and M. E. refineries and one must allow for such cases where the slop is mainly "slop mixture". Tank washings from product carriers are not generally expected since Singapore is not a major unloading point for product oil. The ballast water case is similar to the one mentioned above for crude carriers except that more dirty ballast may be expected since product carriers are smaller, older and more likely to be operated by smaller shipping companies.

Slop Oil and Slop Mixture

Quantities of slop oil are calculated using the "NORMAL" curve of Fig. 3 and turnover expected from each individual dock. Each dock has to be considered separately as the average size of tankers repaired (and hence % slop oil) in each dock varies. This average size is obtained in Table I. Turnovers of individual docks are not shown as they may reveal the performance of individual shipyards. The quantities of slop oil are shown in Table III. "Slop mixture" is typically twice the amount of "slop oil".

Washings from Slop Tanks

In the Load-on-Top procedure "slop mixtures" are separated from wash water andr transferred to a specially designated tank called the slop tank. In some VLCC there may be more than one slop tank. After the discharge of slop, the slop tanks itself must also be cleaned and gas freed. Since slop tanks are usually small (capacity of about 5,000 tons for a 200,000 dwt carrier) it is expected that washings would be of the same order of quantity as the initial slop mixture.



* Courtesy of Sembawang Shipyard

Fig. 4. Slop Oil as % of Tanker dwt

Tank Washings

In order to have some ideas of the amount of tank washings expected the output of local refineries must be projected. From the expansion plans of existing and projected refineries the capacities are shown in Table II. Since refineries do not usually operate at full capacity we have assumed 80% utilization which gives the crude oil deliveries. Most of this oil comes from the Middle East. This is expected to be the pattern in the future even if oil is found in the S. E. Asian region because (1) refineries are already set-up to process the M. E. type of oil and (2) S. E. Asian crude is more expensive and more likely to be exported direct to the major consumers such as Japan and the U. S. The number of round trips, a very large crude carrier can make per year from the Persian Gulf to Singapore is about 15.3, taking into account its service speed (about 15 knots), and the offcharter time (about 15 days per year) and the time-in-ports. Thus the total dwt. of tankers required are known and if 70% of these are repaired in Singapore the amount of tank washings can be calculated. These are shown in Table III.

Total Slop

Assuming that ballast water and tank washings from product carriers discharged at the slop reception centre are small, the total slop is then obtained from the above three cases viz. (1) slop mixture from crude and product tankers, (2) washings from slop tanks and (3) tank washings from crude carriers. In 1975, for example the total slop thus estimated is about 684,000 tons which, if it were all oil would represent half the turnover of a small refinery. By 1980 this quantity would be about doubled.

THE SOLUTION: RECEPTION FACILITIES AND DISPOSAL ROUTES

Needless to say the slop disposal route must be pollution free, or relatively so, or we will be cleaning one environment at the expense of another.

Looking at the "total disposal system" from the beginning we have tankers in "light" condition and drawing no more than 35-40 feet of water even for VLCC of 300,000 dwt, berthing at a specially provided or designated wharf. Discharge of slop is achieved by the tanker's own pumps and rates of discharge are usually limited by the diameter of the receiving pipes. Here an acceptable size would be 18 inches capable of handling 2,000 tons per hour. This rate would be sufficient for a VLCC of 200,000 dwt discharging 1-2,000 tons of slop mixture to complete the operation in about an hour or less. It may then have to clean the slop tank using its own cleaning system and discharge the "washings" perhaps in another hour or so.

On the basis of a discharge rate of 2,000 tons/hour the total discharge time of 684,000 tons of slop (1975) would be 342 hours or roughly an hour a day. Thus if there is no "bunching" wharf time should be more than adequate.

Systems f - dehydrating slop mixtures to a point where i an be recycled are well established in refinery r ..ations. Fig. 5 represents an effective system supplied through the courtesy of Shell Eastern Petroleum (Pte) Ltd. This is likely to be the process adopted. In such a system, dehydration takes place in 2 steps: firstly at the so-called "deballasting tank" where oil/water separation occurs by gravity action and secondly at the intermediate tank where separation may be further effected by thermal or chemical action. The oil/water interface at the "deballasting tank" is not a sharp one. In fact, an emulsion layer is likely to be formed between the oil and the water. A floating skimmer allow the oil and some emulsion to be transferred to the intermediate tank. Water content here is reduced to typically 1%. Oil-free water from the deballasting tank is drained away to the sea via a concrete-lined interceptor tank with vertical baffles to prevent accidental oil discharge. Water so purified should not contain more than 20 to 50 ppm of oil, much less than the 100 ppm allowed by law.

Oil from crude slop thus purified should in principle be acceptable by any refinery and to all intents and purposes are in fact crude oil. Oil from black and white slop can be blended into the much larger quantities of black and white oil produced by refineries. Because of the dilution factor detergent impurities should have little adverse effect. Thus recycling would be effected and would cause no trouble unless tetraethyl lead is present in the crude slop. Lead incorporated in organic molecules could be transported into fractionating columns and poison expensive platinum catalysts. Lead is present in "white oil" i.e. gasoline etc. where it is an additive to increase the octane number. Thus when a "white oil" carrier switches its cargo to crude, lead contamination of the crude can occur. VLCCs do not normally carry "products" and should be quite "safe". Smaller tankers are the ones to watch for contamination. "Watching" can take the form of looking at the ship's log book and on the spot chemical analysis for lead. If lead is present the crude slop may have to be burnt or disposed of in the following methods which are also alternative disposal routes:

Calendar Year	unit	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
			←	planned	→	←		linear	projections		→
1) Capacities of Refineries	million tons	20	28	37	44	52	60	68	76	84	92
2) Crude Oil deliveries assumed 80% of (1)	million tons	16.0	22.4	29.6	35.2	41.6	48.0	54.4	60.8	67.2	73.5
3) Tankers delivering Crude to Singapore (15.3 round trips/year)	million dwt	1.05	1.47	1.93	2.30	2.72	3.14	3.53	3.97	4.40	4.80
4) % of above Tankers repaired in Singapore: assume 70% of (3)	million dwt	0.74	1.03	1.35	1.61	1.90	2.20	2.48	2.78	3.08	3.36
5) Tank Washings*	thousand tons	53	74	97	115	136	157	177	198	220	240
6) Slop Oil+	thousand tons	60	69	71	87	137	167	195	228	261	287
7) Slop mixture 2 x (6)	"	120	138	142	174	274	334	390	456	522	574
8) Washings from slop tanks taken as = (7)	"	120	138	142	174	274	334	390	456	522	574
9) Total Slop = (5) + (7) + (8)	"	293	350	381	463	684	825	957	1110	1264	1388

* assume average size of tankers = 150,000 dwt. Hence 10,700 tons of washings i.e. 7.15% of dwt.

\+ calculated from the "Normal" curve of Fig. 3, average sizes of tankers repaired in Table I, and tankers turnover for each dock.

Table III Slop Oil and Tank Washing Quantities

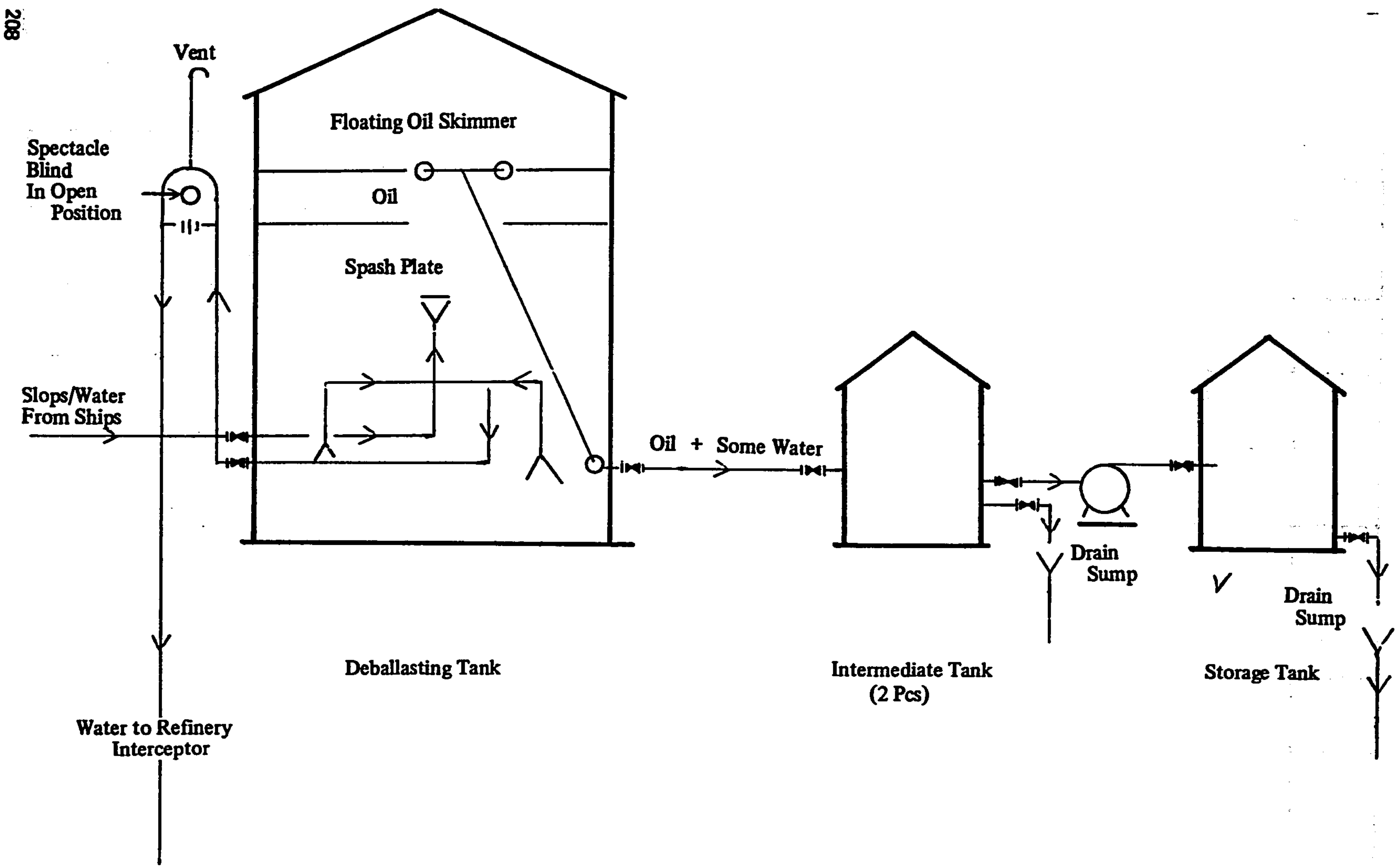


Fig. 5 Dehydration System for Slops (Courtesy of Shell Eastern Petroleum Ltd.)

	Suitable for	Economic by-products
(1) Return slop to tankers after completion of repairs	all slops	nil
(2) Return slop to tankers designed to burn slop in boilers	crude and black only	propulsive power
(3) To power station for direct burning in boilers	crude and black only	electricity

Some U. S. owned tankers have been modified to burn slop oil for propulsion. Crude oil burning in power stations has been recently established in Japan (to reduce sulphur-doixide pollution by burning Indonesian crude). There is no technical reason why crude or black slop properly processed, cannot meet the requirements of power stations. Safety-wise, however, it is not advisable to burn crude oil or slop due to its low flash point. In Singapore where electric power is generated in only two major power stations safety considerations must be paramount.

Postscript

As of 24.1.72 the Port of Singapore Authority is in the process of taking over the existing tank farm at P. Sebarok, an island 6 miles south of Singapore for use as a slop centre. The tank farm was originally used for storage and bunkering purposes and the capacities of the tanks, pipes etc. are more than adequate for slop reception.

The Load-on-Top System **APPENDIX 1**

The important factor in the LOT system is that oily residues are always kept on board for mixing with the next cargo. A recent development permits these residues to be pumped into a separate tank (the slop tank) so that mixing does not take place. The slop oil is discharged into refineries slop facilities at the next unloading point so as to free the slop tanks for the next cycle.

When a tanker completed its discharge of cargo ballast water must be taken in to give the vessel stability. In the LOT procedure only certain tanks are ballasted. The remaining tanks are then cleaned, the free water drained and the residues transferred to a separate tank (slop tank) which can be one of the cargo tanks. The cleaned tanks are then filled with clean sea water while the original ballast tanks are subjected to the same cleaning, draining and residue transfer operations. The cleaning operations are necessary in both cases when tankers return to loading points (so that only clean ballast water is discharged at loading ports) and when tankers go into repair docks (so that tanks are free of gas).

Definition of Terms

APPENDIX 2

Slop oil:	the oil component of "slop mixture".
Slop mixture:	the residual mixture of oil and water in tanker vessels after tank cleaning and after the separation of "tank cleaning water".
Tank cleaning water:	the substantially pure water component after tank cleaning operations. This water is purified by gravity settling and usually discharged into the sea.
Ballast Water:	the water required for ballasting the tanker. For older vessels this water is mixed with slop oil. For newer vessels and those operating the "Load-on-Top" (LOT) system this water is usually clean.
Load-on-Top System:	this system was devised to carry the slop oil with the tanker after tank cleaning operations. Previously slop oil is discharged into the sea together with the tank cleaning water. The procedure is described in Appendix 1.

Paper No. II/8 ✕ЛСКИЭ'ЦА

THE CONTROL OF WASTEWATER AND OIL DISCHARGES TO THE SEA WITH PARTICULAR REGARD TO STUDIES RECENTLY CARRIED OUT IN SINGAPORE'S SOUTHERN COASTAL WATERS

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ABSTRACT

The paper discusses the characteristics by which pollution in wastewater can be described and quantified; they include suspended solids, biochemical oxygen demand, coliform bacteria, oils and greases, heavy metals and other toxics and nutrient concentrations. It reviews the standards commonly associated with wastewater discharges into inland waterways; and compares them with standards which might be upheld for marine discharges, taking health, amenity, fishing and shipping into account. The difficulties in quantifying ecological factors and the importance of such factors in enclosed waterways are mentioned. Dilution and dispersion mechanics from marine outfalls are recounted and hydrographic and hydrological techniques summarised. The engineering feasibility of outfall construction is reviewed, and methods are described. Marine investigations recently carried out in Singapore's southern waters are summarised and related to the general parameters discussed earlier in the paper. The principal conclusion of the investigations are set down.

Lastly, the problems associated with pollution from oil handling and from accidental oil spillages are stated and precautions and remedies are suggested, with particular reference to Singapore's position as a major oil port.

INTRODUCTION

In times almost unremembered by contemporary urban society, water was there for the taking. It could be raised from a river or lake, sullied, and returned to the source without concern being felt by the user, either for his own health and welfare, or for that of others. This situation still holds in the remoter regions of the world where relatively small and scattered groups of people have the exclusive use of large water sources. It can hold in the rural parts of advanced countries, but pressure against the indiscriminate fouling and disposal of water increases in the rural areas to match the pressure already active where urban communities have had to face facts. The facts are that, if we are to survive and prosper, we must maintain control over the situations and forces and material things contrived by Man which are potential destroyers of mankind if they remain unchecked. In three words, very well published words these days, we must PROTECT OUR ENVIRONMENT.

Individuals who find the grime of an urban existence not to their liking, can withdraw and take to the country. Many do, and vast numbers of town workers travel daily from country to town and back again in pursuit of similar ideals allied to economic necessity. This may be a rational and possible solution for individuals now, but time will come and has come in many places, where the immensely spread communities thus created swallow up the reasonably available countryside. Informed contemporary thought has turned, therefore, to controlling urban sprawls and developing self-contained communities whose individuals have tolerable access to their daily work and to the preserved countryside.

The lessons of polluting air and water have been similarly expensively learned. The planning of new communities includes well ordered arrangements to ensure that air and water are not despoiled, but there is a legacy of pollution which stemmed from poorly informed and profit motivated acts and behaviour, and which must be tackled, along with the new planning.

The inventors of the first motor-cars could hardly have been expected to foresee that the exhaust gases from the engines of hundreds of thousands of cars in a big city would combine to foul atmospheres and lungs to the extent that they do. The first settlers on the banks of many large rivers would be astonished if they now could see the devastation along the banks and the foulness of the water which populations and their attendant industries have caused. But if those originators and their successors had each in turn taken steps to protect their fellow men, the consequences would have been less dismaying. This is not to say that nothing has been done; much has, but comparatively recent, and retrospectively rather than prospectively. Modern technology makes sound forward planning feasible and, in pollution matters, detection instrumentation permits reliable monitoring of predictions.

It is, on the other hand, unrealistic to suppose that we can plan and order our existence to satisfy ultimate circumstances. We would have to be very well informed to predict them; the cost of long-term objectives would be out of all proportion to contemporary resources and there are limits of durability for the constructions and manufactured devices of man. Methods and measures must therefore evolve as existence itself does, keeping a few steps ahead to accord with predictable circumstances.

Pollution is, by and large, local. That is to say, it is most intense close to its source and cannot be detected at a distance. Some sources are, of course, very large, such as to make the pollution seem endless, but the pollution is nevertheless still local. Most of you will have taken a flight through and out of the dirty overcast of a large city, or seen the distinct change of colour at the boundary of a polluted area of water. Nature has enormous capacity to absorb pollution as long as means can be found to delocalise it. One of the purposes of this paper is to discuss the available means and the practicability of coping with water-borne pollution by making the best use of natural resources with particular regard to disposal to the sea.

Water quality can be gauged by its appearance and its smell. Clean water has clarity becauseofthe absence of suspended solids, and its quality is high because it is saturated with dissolved oxygen. Clarity and smell deteriorate the more polluted the water becomes, and the pollution degree can by quantified more often than not by measuring the suspended solids (SS) and the biochemical oxygen demand (BOD). If heavy metals and other toxic substances are present they can also be measured and their inhibitory characteristics to biological degradation gauged.

An increasing number of waste substances are completely toxic and they have either to be massively diluted to make them safe or be safely buried or be sealed in containers and disposed of by dumping. It is these latter substances which cause most concern in modern life and which give most reason for planned monitoring and disposal. However, matter which stabilises naturally is still the large part of polluting matter.

The more commonplace municipal wastes in which toxic constituents are present in insufficient degree to inhibit biodegradation carry nutrients and bacteria evidencing their domestic origin. The bacteria vary and develop according to the nature of the waste and can be broadly classified as aerobic or anaerobic. Their remarkable and very convenient ability to consume and stabilise the organic polluting matter in a waste stream is well-known and widely ultilised. Biological treatment is aided and complemented by preliminary treatment which includes the screening of grosser solids which can be completely removed by burying or incinerating or macerated and returned to the flow, and the settling of grit; by primary sedimentation in which readily settleable solids are removed; and by final settling to remove the converted colloidal matter released by bacterial activity. The end-product of these treatment processes is a water with diminished BOD and SS according to the degree of treatment and a sludge requiring further treatment depending on the method of final disposal, land availability, etc.

When waste matter or partially treated waste matter is discharged directly to rivers and other bodies of water, reliance is placed on natural resources to cope with the pollution and to remove it from its source. This occurs by the receiving water diluting the waste initially and dispersing it away from the source where riverine receiving waters are available. Settleable solids proceed to settle over a greater or lesser area depending on the extent to which they are dispersed, and their settling characteristics relative to the stream velocities into which they are discharged. Biochemical processes play their part and colloidal suspensions are converted to settleable matter which in turn sinks. Oxygen mechanics work towards correcting deficiencies in the water, and subtle changes take place in the flora and fauna on the bed of the river or lake all to the end of purifying and stabilising the settling matter. Breakdown of the abilities of the receiving water occurs, when oxygen demand exceeds oxygen availability and when settled sludge blankets bottom fauna and even the lower forms of life are overcome.

STANDARDS

As treatment technology developed, the parallel need arose to set treatment standards. This was done in Britain by a Royal Commission which carried out its original work at the beginning of this century and eventually prescribed a two reference standard for treated waters disposed of to inland waterways. The recommendation was that treated effluents should contain no more than 30 mg/l of suspended solids and should have a biochemical oxygen demand measured at 20°C over five days of not more than 20 mg/l. This compares with average raw sewage values of 200 to 300 mg/l for suspended solids and five-day BOD and indicates the considerable measure of improvement thought necessary. The recommendations assumed that at least 8 to 1 dilutions of effluent into receiving waters could be achieved, noting that natural waters could develop BOD's of between 2 and 4 mg/l without danger of continuing debasement. These early recommendations still hold good in Britain and in many other parts of the world but they are rapidly becoming displaced by more stringent standards as conurbations swell and spread into each other and pressures on water resources increase. Other standards are also applicable, particularly where toxic substances and metals are involved.

Although control over the fouling of inland waterways was evolving, seaside and estuary communities were hardly affected because the pressing need had not yet touched them. Their wastes could be discharged into the sea or at the mouth of a river, often a large river, and the action of wind and tides and the larger masses of diluting water available acted miraculously to remove the fouling matter from their doorsteps.

But that was before seaside communities grew sufficiently for the sea to be overcome as the rivers had been, and while sufficient dispersive conditions could still be reached by short outfalls to low water mark. Moreover, the sea was then watched and wondered at by the fortunate few who could reach it and not enter into and assaulted by armies of swimmers and skiers and boaters as it now is. Very soon the same lessons came to be learned and shoreside pollution became as problematical as inland pollution.

Methods of dealing with pollution at the seaside in Britain varied. Some municipalities lengthened their outfalls as far as construction technology permitted, some built treatment plants like the inland ones, some adopted partial treatment combined with lengthened outfalls, and many did nothing. In the ensuing years, a major development affecting such considerations was the advancement of construction technology enabling pipelines to be laid at or under the sea bed for long distances from the shore. The means was now available to make so much better use of natural pollution absorbing capacity, provided the use was sensible and well-planned.

Concurrently with the improvement of construction techniques the science of oceanography was blossoming. The science, as applied to pollution control, has advanced rapidly during the past ten to fifteen years and much useful knowledge has been gained. Much more is being done and has to be done, particularly in studying ecological matters as related to the behaviour and effect of dumped chemicals and metals. Oil pollution is very much in the news these days and forms almost a separate science.

There has been much controversy and discussion over appropriate standards for the disposal of sewage to sea. The primary objectives and their connected standards are four-fold: health, amenity, fishing and shipping. They can be summarised as follows:

(1) Dangers to public health arise from amenity use of beaches and sea and from the consumption of raw or partly cooked shellfish. In either circumstance the danger is that pathogenic bacteria and viruses might be ingested. Bacteria exist in multitudes in domestic sewage and direct evidence and extent of faecal pollution is assessable by measuring the bacteria known generally as the faecal coliform group. In each 100 ml of raw sewage some twenty million coliform bacteria exist. Pathogenic bacteria, if they exist at all in a water or sewage sample, occur in relatively small concentrations and are consequently much more difficult and costly to isolate than are the faecal group as a whole. The commonly adopted measurement of faecal pollution is therefore the coliform count.

Notwithstanding that there is an accepted approach to determining faecal pollution, views vary widely on the standard applicable, and the general British attitude is that the faecal coliform count provides no more than a rough grading of the degree of sewage pollution. If figures are to be nominated at all they would be in the range 2,500 to 10,000 per 100 ml.

A committee of the U.K. Public Health Laboratory Service said in 1959 that a survey of of bathers and beaches had caused them to conclude that bathing in sewage polluted sea water carries negligible risk to health even on beaches where the water is aesthetically revolting and that the risk is probably associated with chance contact with intact faeces that happen to have come from infected person. Public health requirements could therefore be reasonably met by a general policy of improving grossly insanitary bathing waters and preventing the pollution of bathing beaches with intact faecal matter.

The dangers arise from the consumption of raw filter feeding shellfish are more real. Pollution of shellfish beds should be avoided as far as possible and strict measures should be adopted for cleansing shellfish exposed to possible pollution. High standards are imposed in Britain, with effluents being stored in maturation ponds for periods in excess of fifteen days and fish being cleaned by clean water filtering and ultra-violet irradiation treatment.

(2) The setting of standards for the recreational and amenity use of water becomes a matter of aesthetics in the absence of definable health standards. Such qualitative standards can normally only be described in general terms and one such attempt given recently by the U.S. National Technical Advisory Committee on Water Quality Criteria states:-

"That waters having aesthetic and recreational use should be capable of supporting life forms of aesthetic value and should be free of substances attributable to discharges or wastes, such as materials which will settle to give objectionable deposits, or those giving floating debris, oil scum or other matter or giving rise to objectionable colour, odour, taste, or turbidity."

The importance of seeking quantitative standards is being increasingly recognised and the U.K. Water Pollution Control Laboratory is attempting to relate the presence or absence of smell to diluted sewage. First indications suggest that very faint odours persist with dilutions over 1 in 1000 and a distinct sewage smell is discernible with dilutions less than 1 in 100.

(3) The need for standards concerning fishing arises as already described from the dangers inherent in consuming polluted fish, and in more general terms, insofar as pollution might affect the general ecology of the area.

There is a major difficulty in drafting ecological standards in the lack of information on eco-system changes which would make it possible to classify an environment as polluted. Study of the complex effects of pollution on marine life is difficult and ideally requires the collection of much information on marine populations before and after the onset of pollution. General contemporary thought is that, although discharge of sewage into the sea will have ecological effects, these will not be serious from an economic or nuisance view-point if outfalls are sited away from fisheries and shellfish beds and in regions where a high degree of dilution can be rapidly achieved so that sewage or its breakdown products do not persist.

Ecological factors are those most earnestly under consideration currently, particularly where toxic discharges are concerned. Ecological considerations are also of great importance in enclosed waterways where benthic fauna and flora can be reduced or eliminated by deposits and where algal blooming caused by an abundance of nutrients can cause eutrophication of the waters. An additional hazard from nutrient build up is the encouragement of dense seaweed growths which cause seasonal nuisance value when they decay.

(4) Standards affecting shipping are concerned with physical hazards presented by the diffuser sections of marine outfalls, with the possible obstruction of ships' seawater intakes by solid matter and with the fouling of ships' bottoms.

These overall requirements might be reasonably met by the following criteria:
(a) Discharges should be free from gross solids above 6 mm in size and floating solids adjacent to an outfall should be limited to 50 mg/l in the top 100 mm with a grease content not above 1 mg/l.

(b) The discharge field immediately after initial dilution should not be toxic to fish and should even under the worst conditions for dispersion maintain a minimum dissolved oxygen content of 50% saturation being the level normally recognised as critical for maintaining fish life disregarding other complicating factors.

(c) The minimum dilution at beaches or other water contact sport areas should be not less than 1 in 100.

(d) The faecal coliform content of sewage polluted sea water should generally be less than 2,500 per 100 ml with not more than 5% of single samples in any tide cycle exceeding 10,000 per 100 ml. This still sounds a lot but it compares well with a 30 mg/l suspended solids effluent discharged into a river giving 8 to 1 dilution. The coliform content of the mixture would probably be ten times the figure given above.

(e) It is less easy to quantify limits for toxic concentrations. Any estimate of a long-term safe concentration in an aquatic toxin should be based on threshold concentration (i.e. the concentration which just borders on toxicity). Threshold concentration is a function of time as well as actual toxin concentration. The speed at which poisoned fish die decreases as the toxin concentration is reduced, to a point where they will probably not die, and this is the threshold concentration. Long-term tests are difficult to perform and most work in this field has been based on shorter term estimates. An additional difficulty is that the survival time of individuals of the same species can differ by a factor of more than ten, which makes determination even from long-term tests less precise than one would wish.

In general terms it can be said that heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc etc.) and cyanides, phenols, sulphides, detergents, chlorines, are most quoted and that sewage field concentrations range between 0.01 and 0.05 mg/l, metals being aggregated. In particular cases, if fisheries are of vital economic importance, it would be appropriate to submit indigenous species to toxicity tests with the toxics known to be present or in prospect.

WASTE ASSIMILATION IN THE MARINE ENVIRONMENT

Given standards as a starting point, it is possible with fairly reliable accuracy to assess the degree of pollution which any body of marine water is likely to be able to tolerate, and the way in which pollutants should be dispersed into it. The choice lies basically between pretreating the polluting discharge and achieving the maximum possible dilution and dispersion into the receiving water. Very often a combination of these alternatives is proved to be most appropriate. However efficient is dispersion, the reduction of gross solids will not be reliably achieved. Screening should be practised and floatable material should be removed as completely as possible.

Dilution and dispersion mechanics rely on a number of factors, the most important of which are the initial dilution achievable by proper design of the outlet and the way in which the receiving water behaves subsequently and carries the polluted water away.

When sewage, containing liquid and suspended solid fractions, is discharged to the sea through submarine outfalls, the two elements behave differently. At first, the less saline and usually warmer sewage will have marked buoyancy and will rise toward the upper levels of the sea. The rate and extent of the rise will depend on the relative densities of sewage and receiving water.

The differential diminishes as the rising sewage plume shears through the receiving water and mixes with it by eddy diffusion at the sewage/sea water boundary, and it can also be significantly affected if the surface layers of the sea are appreciably warmer or less saline than the deeper layers. In circumstances of deep water with pronounced temperature and/or salinity gradients from sea bed to sea surface, the rise can be stalled below the surface. More often, however, a diluted mixture reaches the surface layers and comes under the influence of surface layer movements. Currents and remaining density differences then act together to disperse the mixture until the differentials are so little that mass turbulence becomes the major influence and the behaviour of the mixture is at one with the receiving water. Mass turbulence takes effect sooner or later according to the rate of initial dispersion.

Whilst this main sequence of events is taking place, the suspended solids fraction of the discharge behaves differently by virtue of the greater density of the suspended particles. The solids separate from the main stream according to their size. The heavier particles will settle towards the sea bed relatively quickly and the lighter portions later. Many will be carried to the surface with the main flow to settle much later, and some will continue to float and disperse at the surface or be oxidised and broken down so as to be indiscernible. The solids which do settle will be influenced by the deeper currents rather than the near surface ones and may consequently move away from the source in a different direction to that of the main stream. In some situations bottom currents are insufficient to disperse the solids and the sea bottom becomes blanketed with sludge deposits.

Given unidirectional currents of good strength, dispersion of sewage and removal of deposits are at their best. More usually currents are reciprocatory and variable in strength, particularly in neap tide conditions. In these circumstances, dilution and dispersion are diminished andcomplicated by slack water and by already polluted water passing and repassing over the sewage source.

Oceanographic factors affecting the dispersion of sewage field are currents, tides, wind, rain and temperature, all of them inter-related to some extent.

Imposed on prevailing or oceanic currents are local currents developed by topographic features, peninsulas and embayments and the like; wind induced currents and tidal currents. Most often the local wind-induced, and tidal currents are of importance for initial dispersion, and the prevailing current in long-term behaviour.

The main tide generating force is the moon, but the sun's influence is also felt in spite of its great distance from the earth. When the earth, moon and sun are in line (at new or full moon) a tide of maximum range (spring) occurs, and when the moon and sun form a right angle with the earth a minimum (neap) tide results. In an "ideal" ocean covering the entire earth the water facing the moon would be attracted to it and form a bulge. On the opposite side where there was least attraction a similar bulge would occur and as the earth rotated, each point on its surface would have two high waters and two low waters each lunar day. These tides would be called semi-diurnal. The ideal situation is complicated by the inertia of the ocean water, the irregularity of coastlines and the depths of ocean basins so that tides only occur once a day in some parts of the world and both diurnal and semi-diurnal effects vary greatly from place to place. The tides in coastal seas are secondary effects and the more the coastal sea is land-locked, as is the Mediterranean, the smaller the tides. With complete separation the tides would be imperceptible as they are in freshwater lakes. The gradients formed by the tides cause currents to flow from high tide to low tide areas. The current in any location will flow in one direction when high tide is approaching it and will reverse as high tide passes it, creating ebbs and floods. The strengths of these currents are a function of the range of the tide.

Wind blowing over the sea raises waves and there is a transference of energy from air to water causing the water to move under the wind's influence. The effect is greatest at the surface of the sea but diminishes with depths as the transferred energy is dissipated.

Superimposed on these actions are the effects of geotrophic force due to the rotation of the earth. The effect known as coriolis force can be ignored on land but assumes importance in the sea because the current creating forces are so weak. It varies with latitude, being zero at the equator and a maximum at the poles. The result is that currents set up by tides and winds do not react directly to those forces but are deflected to the right in northern hemisphere and to the left in the south.

The two factors affecting the density of the sea are salinity and temperature. The last factor, rainfall, is also of importance in density considerations, particularly close to large freshwater sources such as rivers.

It can readily be appreciated that the interplay of all these factors is complex but that it must be understood before reliable predictions of water behaviour can be attempted.

INVESTIGATORY REQUIREMENTS

The committing of large funds to the building of sea outfall works should not, therefore, be countenanced without full investigation of the facts. This should be done by engaging in a hydrographic and hydrological survey for each intended outfall or groups of outfalls. The aim of such a survey is to estimate the optimum outfall sizes and length required to satisfy the prescribed standards and to examine the engineering feasibility of a sea outfall. These determinations permit cost estimates to be drawn up whereby comparisons can be drawn with the alternative of treating the discharge before releasing it to the sea through a short outfall. Between those extremes there is the possibility of partial treatment to varying degree with consequent variance in outfall length. Very often it proves most economic to separate sludge by settling and to discharge it through a long but small diameter pipeline whilst the liquid fraction is put into a shorter large diameter pipe. Another alternative is to tanker sludge into deep water. The sludge itself may be pretreated by digestion or discharged raw according to survey findings.

An investigation should take account of seasonal changes and should therefore be as lengthy as reasonably possible. Its cost with respect to the capital cost being investigated is small, perhaps ½% or 1% including borehole and diver investigation.

The tools of such hydrographic investigation are numerous. The basic requirement is of course a survey vessel which should be reasonably large, seagoing, with sleeping accommodation to allow for relatively long trips. Navigation and positioning is by normal methods of sextant or radio based fixing. Wind strength and direction is measured with the aid of anemometers both ship and shore based. Temperature, salinity, dissolved oxygen, and current direction and speed can all be measured in-situ with direct reading battery-operated meters on long cables which allow the meters to be lowered to considerable depths. Path tracing can be carried out with the assistance of simple canvas covered kite-like drogues which can be suspended on floats at varying depths and be left to drift, their paths being followed and traced. Potential sludge movements can be similarly traced by the recovery of bottom drifters released at strategic positions. Sea water samples can be taken with specially designed apparatus engineered to open and close at depth to ensure representative and untainted sampling. Finally, indicators of dispersion such as fluorescent dyes or specially cultured bacterial traces can be released in admixture with water, and their behaviour monitored and quantified. In some instances hydraulic modelling of the prototype assists in predictions and in most cases the application of mathematical models is relevant, whereby the results of grid surveys are assembled in mathematical order such that they can be reviewed by computer techniques according to programmes determined by the various dilution and dispersion formulae which are available.

ENGINEERING FEASIBILITY

Engineering feasibility takes types of outfall and methods of outfall construction into account. Pipe materials are very varied, but the most durable and common are concrete and appropriately protected steel. There are four methods of laying: lay barge, pipe pulling, immersed tube, and tunnelling. The first two are restricted to smaller diameter pipes and the last two to the larger sizes.

Lay-barging consists of laying pipes by suspending them in a catenary from an angled ladder on a barge. The pipe lengths are joined together on the barge as it moves seawards. Small pipes (say 1-metre diameter) and relatively small sea depths (say 30 metres) are the limits attempted by this method.

Pipe-pulling involves pulling long strings of prefabricated pipe into a prepared trench by means of an anchored winch moored beyond the end of the final outfall position. Continuous kilometre pulls are not uncommon with three or four strings being joined together as the pulling progresses. 1½-metre diameter lines can be pulled with ease.

With immersed tube and tunnel techniques, very large diameter (up to 4 or 5 metres) are quite feasible. Tunnels are driven in suitable strata below the sea bed, often with the use of compressed air to control percolation into the tunnel, and vertical breakthroughs are made at predetermined off-shore locations. Immersed tubes are laid with the aid of sea bed mounted platforms and divers. It is common for strings as long as 60 metres to be pre-assembled on land, floated to sea and lowered by flooding attached ballast tanks.

In most cases shoreward sections of the pipelines are best buried as a protection against wave action and damage by ships and ships' anchors. Diffuser sections comprising multiple port outlets are usually long and must be laid on or no more than half buried in the sea bed. To these ends investigations must include a thorough examination of the sea bed along the lines of prospective outfalls by diver and sometimes by borehole survey.

It will be appreciated that it is difficult to be precise about costs of sea outfall prospects, until studies of the sort prescribed have been carried out. The cost of full treatment of sewage in Singapore is about S$100 per head of population treated for populations of upwards of 100,000 and annual running costs S$5 per head. The object of sea outfall disposal is to achieve equivalent ends at less cost. This is often proved possible but equally often the initial capital cost is more and the outfall alternative pays off because of the low annual costs involved.

THE SINGAPORE STUDIES

Introduction

Singapore island is diamond-shaped with its long axis running east/west. The main land masses of Indonesia and Malaysia, with their numerous offshore islands, surround the Republic. There is a stretch of open water off the southeast coast of the island but the sea to the south and west is dotted with the groups of islands, many of which are surrounded by reefs. The southwest coast contains large port and oil refinery installations and major offshore shipping anchorage. Singapore city is situated near the southern point but there are urban conurbations, existing and planned, along the whole of the southern shores. Fig. 1 illustrates the study area and its leading features.

Most of Singapore's city sewerage is pumped inland to two full treatment works but prospective development made advisable consideration of marine discharge of additional sewage flows as an alternative to continuing to pump them for treatment. The three major development centres and their ultimate contributory populations are also shown on Fig. 1, and ultimate predicted sewage flows arising are:

Area	Ultimate Population	Dry Weather Flow (DWF) @ 60 g h d.	Peak Flow 3 x D W F
Bedok-Changi	460,000	27.6 mgd	82 mgd
Telok Blangah	250,000	15.0	45
Jurong	600,000	36.0	108
	1,310,000	78.6 mgd	235 mgd

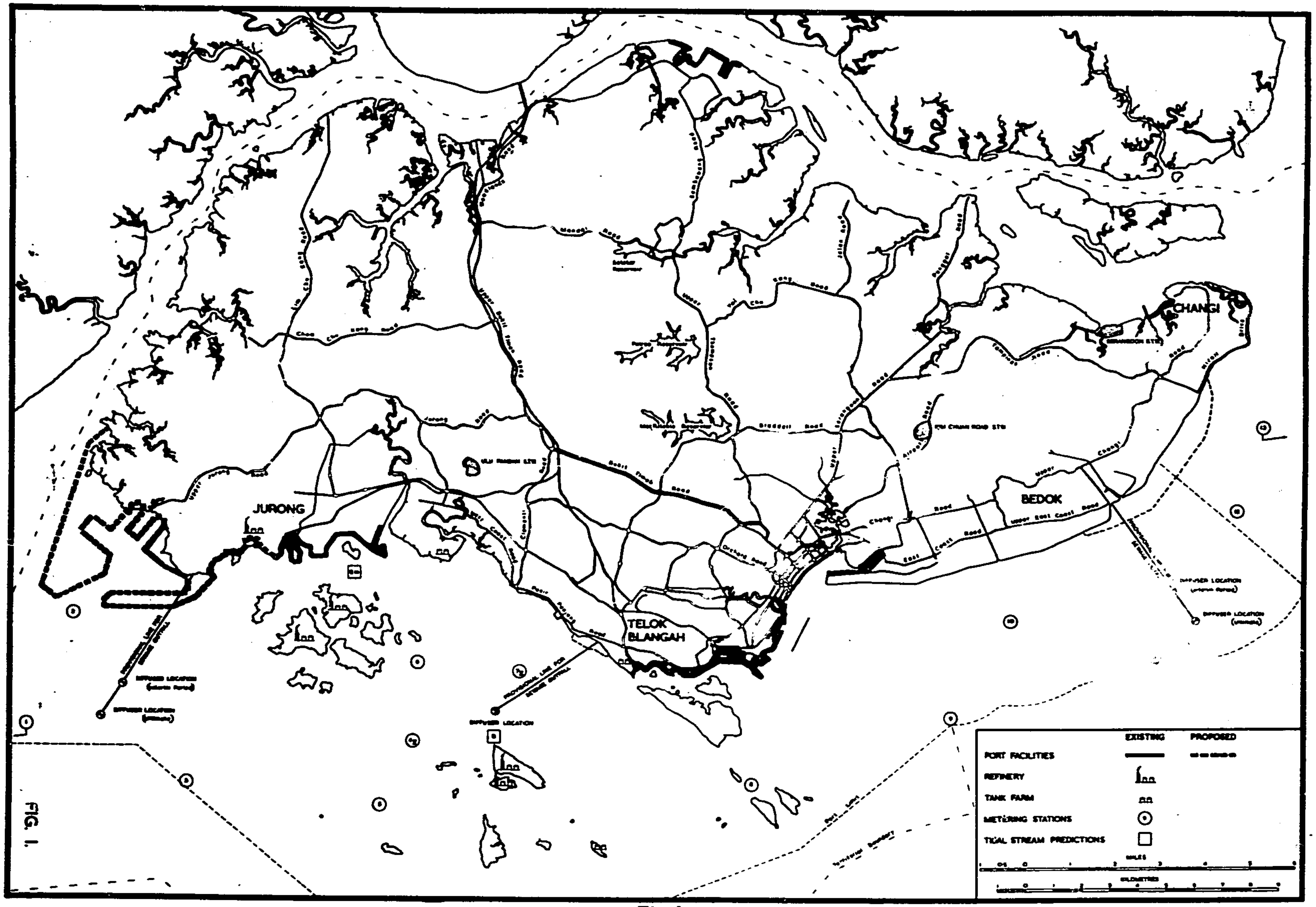
JURONG
TELOK BLANGAH
BEDOK
CHANGI
EXISTING
PROPOSED
PORT FACILITIES
REFINERY
TANK FARM
METERING STATIONS
TIDAL STREAM PREDICTIONS
FIG. 1.

Fig. 1.

Sewage strength was taken as 250 mg/l BOD and 300 mg/l SS with a faecal coliform count of 20 x 10^6 per 100 ml.

The Bedok-Changi area is devoted to residential and amenity use and is considered "sensitive". Jurong is industrial and not so critical, and Telok Blangah is intermediate.

CURRENTS, TIDES AND WINDS

Fig. 2 shows the overall drift of surface waters around the Malay Peninsula in the two monsoonal seasons (July - SW monsoon and December-NE monsoon)as illustrated in the "Malacca Straits Pilot". It will be noted that the general direction of the overall drift through Singapore Strait is shown as westward throughout the year.

The tidal regime in the Strait is a complex modified diurnal pattern,verging on semi-diurnal at neap periods. The behaviour of South China Sea and Indian Ocean waters are governing factors but there is interference through the Malacca Straits and by the island patterns south of Singapore.

The winds off Singapore are generally light and often variable with occasional squalls.

INVESTIGATORY APPROACH

Water movement was expected to be relatively uncomplicated, of a mainly reciprocatory nature, and it was therefore decided to base dispersion studies mainly on current metering, using drogue tracking for prediction proving purposes. Thirteen current metering stations were established as indicated on Fig. 1 and measurements were taken at near surface, near bottom and at one or two intermediate depths. These results were analysed to eliminate wind effect and to establish the net drift in each tidal cycle. Maximum and minimum cycles were grouped and separate appraisals were made for the two-monsoon periods and for the the transitions. Average curves for the major and minor components of velocity were also produced, the major component being given an east-west orientation. It had also been intended to meter mid-depth currents continuously (for two or three-week periods) by mooring recording meters at two strategic points. In spite of elaborate precautions, the first such experiment ended with the meter being lost and the work was therefore abandoned.

During current measuring and drogue tracking experiments, dissolved oxygen, temperature and salinity were measured with in-situ meters.

Coliforms were not assessed, partly because discharge of crude domestic sewage to the study waters is on a small scale, and partly because previous work elsewhere in Singapore and in Hong Kong had demonstrated that die-off was extremely rapid (T90 probably less than 1 hour) and the trouble and expense involved was not thought justifiable.

Nutrient and plankton experiments were also not mounted because the southern waters are open and eutrophication was not expected to be a problem. It was recognised, however, that local waters are rich in algal life as most tropical waters are, and that coliform die-off might be attributable to bacteriocidal effects from algae.

Radio-active tracer techniques were used to estimate dispersion rates.

The analytical procedure was to develop simulated water movement paths from points along the pre-selected outfall lines in each area mathematically and "fit" the simulations to prototype drogue tracks. The matched formulae were then applied to produce predictions of discharge behaviour from the three outfalls with various rates of flow. Dispersion rate estimates were then superimposed on paths and dilution assessments were established.

PRINCIPAL FINDINGS

The indications are that there is a net westerly movement of near surface waters during the Northeast Monsoon, reversed during the Southwest Monsoon. Sub-surface movements are fundamentally the same, the differences being in scale rather than sense. Local wind is a relatively unimportant factor in water movement except in its effect on floating matter.

Temperature and salinity measurements show no evidence of stratification and good vertical mixing can therefore be expected.

The information available on the character and behaviour of bottom sediments suggests that fine solids from sewage or sludge would be dispersed upon discharge, eventually reaching the waters off the western end of Singapore where fine silts and organic solids from river discharges already accumulate. Sea bed drifter experiments are currently being conducted to support the existing evidence.

The receiving waters were generally found to be saturated or slightly supersaturated with dissolved oxygen.

Current regime, water depths and water quality were all found to be suitable for the discharge of sewage after preliminary treatment (screening and grit removal) only, but it was thought that space provision should be made for the addition

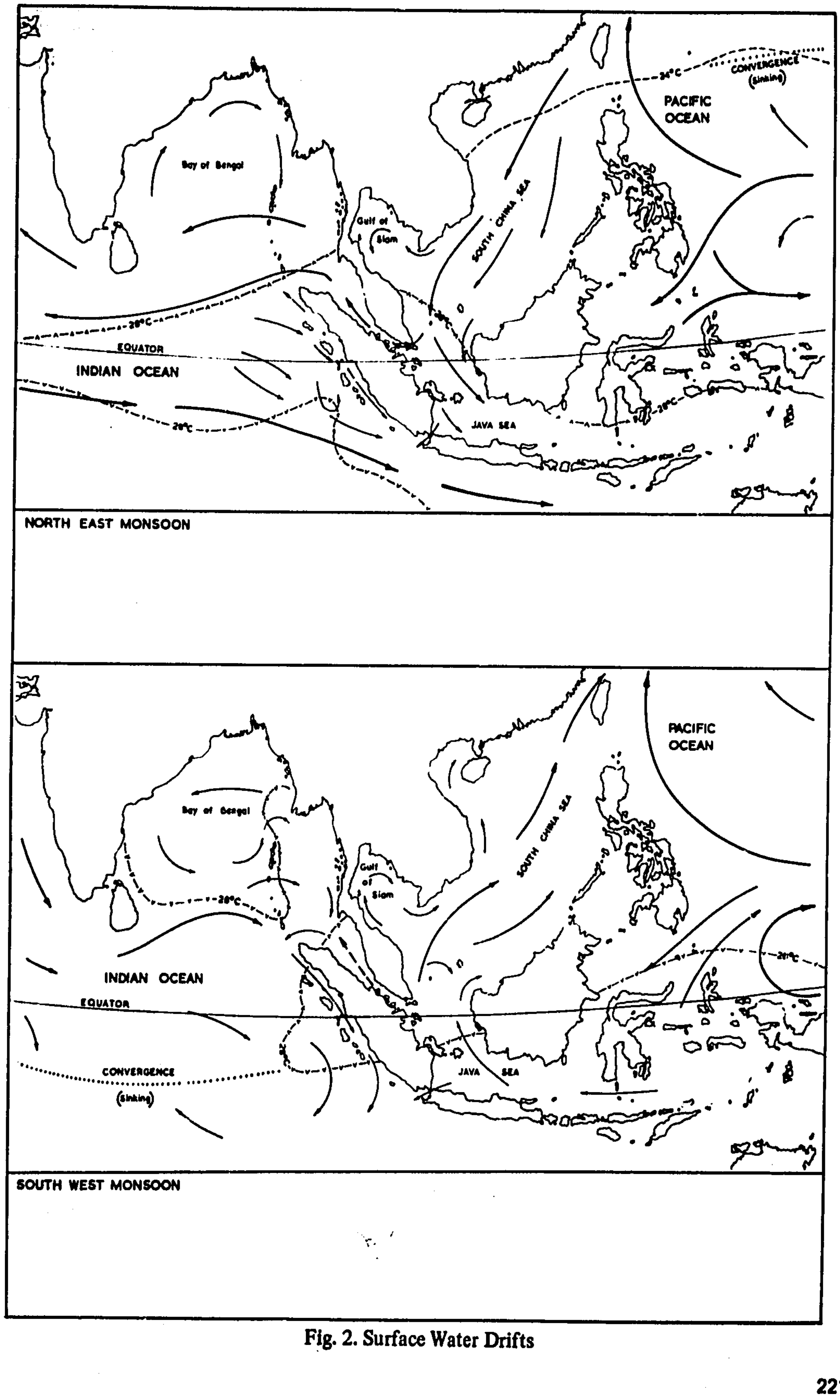

Fig. 2. Surface Water Drifts

of primary settling tanks or other partial treatment facilities if and when unforseen flow increases or the adoption of higher receiving water quality standards made such facilities desirable.

SPECIFIC FINDINGS

From the largest prospective community at Jurong 1.7 m outfall, 6 km long, was thought appropriate for the ultimate flow. The initial dilution achieved would be 60 to 1 which was considered sufficient for an industrial waterway.

From the Bedok area a 1.45 m outfall, 4 km long, would be necessary, achieving an initial dilution of 110 to 1 and, at Telok Blangah, a 1.2 m pipe, 4.3 km long, giving an initial dilution of 65 to 1.

It is likely that, although use of the outfalls would not necessarily be restricted to the listed development, achievement of ultimate conditions would probably take many years. Predictions were therefore made for half populations and half loads per capita, with the following results:-

Outfall	Length (km)		Diameter (m)		Initial Dilution (1 in:-)	
	Ultimate	"Half"	Ultimate	"Half"	Ultimate	"Half"
Jurong	6.0	4.8	1.7	1.0	60	55
Bedok	4.0	3.0	1.45	0.84	110	100
Telok Blangah	4.3	4.3	1.2	0.76	65	65

Detailed site investigation and feasibility studies would be needed to determine most suitable methods of construction, but it was reckoned that immersed tube or tunnelling techniques would be applicable at Jurong, immersed tube or pulled pipe methods at Bedok, and tunnelling at Telok Blangah.

Estimated costs were:

Outfall	Order of Cost (S$ millions)		Cost (S$ per capital)	
	Ultimate	"Half"	Ultimate	"Half"
Jurong	48	31	80	103
Bedok	35	20	76	87
Telok Blangah	29	22	116	176

In the event that primary sludges are removed in the future, the indications are that disposal to sea in the raw state by long submarine outfall or by tanker would be feasible.

OIL POLLUTION

Four refineries are located off the Jurong area and a fifth is under construction. The annual handled tonnage of bulk petroleum is expected to top the million mark in 1975. There are about 20 tanker movements in or out of Singapore daily and about 8 passages in each direction daily through the Singapore Strait. The freighter/tanker shipping movement ratio is about 4 to 1 so that, in an average day, there are between 150 and 200 ship movements in the vicinity of Singapore. This is a formidable number and the risks of collision and consequent oil spillage are very real, particularly when it is realised that over a distance of 19 km Singapore Strait is only 2.4 km wide and a 40° turn is required at Raffles Lighthouse.

The basic requirements against the hazards of oil pollution are good control over shipping movements and oil handling facilities, and a well conceived and understood plan for tackling major disasters.

The most serious consequences of pollution are on pelagic sea birds, i.e. those spending much of their time on the water and diving for their food, and from the stranding of oil along the coast lines and particularly on beaches.

The toxic constituents of crude oil are chiefly in the light fractions which are lost by evaporation quite rapidly in tropical waters. No material damage to plankton, fishes, of marine mammals was observed off Santa Barbara recently, nor off south-west England following the Torrey Canyon spill. At both places sea temperature is within the range 10°C to 15°C. Although direct damage to commercial fishes is not much in evidence, indirect damage can be caused from the fouling of lines, nets, and fishing gear. Filter feeding shellfish can be contaminated by minute oil particles which have been dispersed in the water and, although there is no risk of poisoning to the consumer, the shellfish are completely uneatable.

Most of the major oil companies forbid the discharge of any oil into the sea either in or outside territorial water, and tankers are fitted with slop tanks into which the residue from tank cleaning operations and other oily residue is pumped for onward transfer to the refinery. It is likely that 80% of tankers at sea conform to these rules. Where freighters are concerned, if the country of registration of a ship has ratified the recent Inter-Governmental Maritime Consultative Organisation (I.M.C.O.) recommendations, no oil from any ship is permitted to be pumped into the sea inside a prohibited zone. This includes fifty miles from any land which covers all the waters adjacent to Singapore. However, not every country has ratified these recommendations, and freighters are generally suspected where the pumping out of dirty bilge water is concerned as they are very seldom fitted with slop tanks. There is always the possibility that a ship may discharge oil into the sea during the night while at anchor and when detection and conviction are difficult.

It has been recommended, and the Singapore Government is effecting the recommendations, that one government appointed department or body should have overall authority in all matters of policy and technical developments regarding oil pollution. Its responsibility would be the day to day prevention of oil pollution and the marshalling of emergency measures to deal with catastrophes.

Once oil is stranded, different problems arise and it is usually in the interests of all for the domestic authority local to the centre of the stranding to deal with beached oils. The centrally appointed agency would develop its own departmental establishment, and would be broadly headed by oil pollution committees in executive and policy making roles. There would also be a beach committee to advise local authorities. The policy committee would deal with legislative matters; the executive committee with surveillance, enforcement of legislation, and spillages: and the beach committee, as its name implies, with the fouling of beaches. All committees would include a common chairman and oil pollution officer and all should have representation from the oil industry and the ship owners' associations. Working emergency and beach organisations would include representatives from the fire brigade, the police, and the health authorities and an oil pollution enforcement subcommittee would be served largely by marine police, port authority officials, port pilots, civil and military aircraft, and by specially appointed survey vessels.

The major efforts of the organisation would be directed towards the regularisation of navigational movement through and near the port to avoid collisions, twenty-four-hour surveillance, and law enforcement with appropriate fines for offenders, and to effect emergency arrangements to combat major spillages. In the matter of fines it is important that the maximum sum should be a sufficient deterrent and a figure in the order of S$10,000 is appropriate.

It is most important that if freighters are precluded from discharging oil or oily water, there should be harbour based facilities for collecting such wastes, carrying them to the shore, and dealing with them in a controlled manner by incineration.

It is important that the central organisation has the support and cooperation of the oil companies, particularly with regard to the siting and maintenance of submarine oil pipelines. Although such cooperation can be expected voluntarily, it should be backed by legislation.

Singapore has an efficient concern for dealing with emergency spills under "An Emergency Plan to Combat a Major Oil Pollution Disaster". Its principal responsibility is to ensure that sufficient stocks of floating booms, skimming devices, and detergents are available in the Republic, and that they can be brought quickly into use in the event of an emergency. These basic stocks should be supported by pooled equipment and stores held by the oil companies and should include spraying craft and fire floats, pumping equipment for transferring oil from damaged tankers, and equipment for repairing submerged pipelines.

Paper No. II/9

PETROLEUM REFINERY EFFLUENT QUALITY CONTROL

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ABSTRACT

The protection of our water environment is of continuing concern to the petroleum industry. Further, population growth, greater energy demand and urbanization will promptly increase regulation of industrial discharges. Effective and economical long range planning and implementation of pollution control facilities require that responsible authorities use a reasonable, scientific approach when setting allowable contaminant levels. The magnitude and characteristics of typical refinery unit effluents are covered. Principal potential pollutants are described, and their effect on the environment is discussed. The state of the art in equipment available for minimizing or removing contaminants is reviewed. The separation of oil and water by the classic American Petroleum Institute (API) separator is covered, as well as newer techniques, i.e. dissolved air flotation, mixed media filtration, chemical flocculation. The capabilities and limitations of secondary treatment facilities are reviewed, e.g. biological treatment, activated carbon. Pollution control requirements are having greater influence upon the design of refining facilities. Typical refinery water pollution control systems for salt and fresh water environments are presented.

Industry is not something separate and apart from the community in which it exists. Intelligent use of the natural resources, particularly air and water, is the responsibility of every progressive manufacturer. The petroleum industry, recognizing its obligations to society, has invested much effort and capital in the planning, design and operation of facilities that will conserve the quality of the atmosphere and the natural waters of the surrounding areas. This pollution abatement policy has resulted in significant progress being made in controlling and minimizing the impact of refining operations upon the environment.

This paper will describe the parameters, in refinery wastewaters, that are of principal concern to the water pollution control engineer. The potential effect of these material will be discussed and typical allowable discharge concentrations reviewed. The design philosophy for pollution prevention and abatement will then be covered. Equipment and techniques for reducing or eliminating potential pollutants shall be analyzed. Finally, some typical wastewater treatment systems will be presented that discharge into different types of water environments and logically require different degrees of cleanup.

In order to understand and effectively solve a problem, it is necessary to properly define it. Pollution is defined as the presence of substances, in our environment, put there by the acts of man or nature, in concentrations sufficient to interfere with the comfort, safety or health of man, or with the full use and enjoyment of his property. Pollution, therefore, is not the very presence of a substance in an effluent stream but rather an excess over the amount that can be assimilated and controlled by natural self-purification.

Now what are the substances or pollutants in water that are of concern to the environmental control engineer ? Let us start with oil.

From a practical point of view, the presence of small amounts of oil, on or in water, will not

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necessarily have a detrimental effect on humans or aquatic life. The objections that have been raised are influenced by the end uses of the receiving water and can be grouped as follows :-

Fresh water / domestic water supply

(1) Hazardous to health. However, tolerable concentrations are usually much higher than the limits of taste and odour. Oil polluted waters will become esthetically objectionable at levels far below the chronic toxicity level.

(2) Production of tastes and odours.

(3) Presence of unsightly films, turbidity, or iridescense.

(4) Increased difficulty with water treatment processes. Oily water can complicate the coagulation, flocculation and sedimentation unit operations.

Salt water / aquatic life

(1) Interference with respiration caused by adhering to fish gills.

(2) Coating and destroying algae and other plankton, thereby removing a food source.

(3) Interference with spawning areas by coating the bottom and destroying benthal organisms (fish food).

(4) Deoxygenating waters and reducing oxygen availability.

(5) Tainting the taste through ingestion of soluble and emulsified fractions.

(6) Interfering with the natural processes of reaeration and photosynthesis.

(7) Toxic effect of water soluble fractions on fish or fish food organisms.

In their efforts to control the potential adverse effects of excessive oil, authorities have specified that the effluent discharged shall not

Produce oily films or floating oil in quantities great enough to cause iridescence of the surface of the receiving waters.

Coat the bottom or shoreline in the vicinity of the waste discharge.

Contain in excess of a specified concentration of oil. This value varies from location to location with values ranging from 5 to 100 parts per million by weight (ppm). The lower values are generally applied to effluents discharging into fresh waters.

Phenol is another potential pollutant of concern in refining operations. It is not likely that harmful concentrations of phenol will be consumed in drinking water. Such concentrations are much higher than taste considerations would allow. Appreciable concentrations (up to 5,000 ppm) appear to have no deleterious physiological effects on animals. However, since phenol can cause obnoxious tastes and odours, it is considered deleterious in many food and beverage industries.

Phenolic compounds may affect fish in two ways: (a) by a direct toxic action, (b) by imparting taste to fish flesh. Since it takes considerably higher concentrations to produce toxic reactions in fish life, the taste tainting concentration is usually the controlling factor for this parameter.

In most regulations, the phenol levels are indirectly covered by statements prohibiting the discharge of materials producing taste and odour in fish flesh or toxic to fish. In fresh water locations, where dilution potential is small and drinking water is extracted; direct references range from nil amounts allowable to requirements that "phenol concentrations shall not exceed 0.1 mg/l in the receiving waters."

pH is a term used to express the intensity of the acid or alkaline condition of a solution. It is defined as the logarithm (base 10) of the reciprocal of the hydrogen-ion concentration. pH ranges from 1 to 14 with 7 being neutral.

The ability of fish to extract dissolved oxygen from the aquatic environment is adversely affected by a decrease in pH. An inter-relationship of the toxicity of substances found in petroleum industry wastes and the pH of the water, has been noted:

Sulphides - the lower the pH, the greater the toxic effects; and
Ammonia - the higher the pH, the greater the toxicity

Most regulations will specify that the waste discharge shall not cause the pH value of the receiving waters to be less than 5.5 – 6.5 or greater than 8.5 – 9.5.

Another important parameter is the sulphide concentration. Owing to the unpleasant taste and odour which result when sulphides occur in water, it is unlikely that any person or animals will consume a harmful dose. The degree of toxicity of aquatic life is based on the concentration of the undissociated (unionized) hydrogen sulphide molecule in the receiving water. It is directly related to the pH; the lower the pH, the greater the number of undissociated molecules and the greater the toxicity.

Regulations usually cover sulphide concentrations indirectly by statements prohibiting the discharge of toxic materials or those producing taste and odours in fish flesh. Direct references range from nil amounts allowable to requirements that "undissociated hydrogen sulphide concentrations shall not exceed 0.1 mg/l in the receiving waters".

One of the principal objectives of water pollution control must be the maintenance of an dissolved oxygen content in the receiving water. To sustain healthy aquatic life, especially fish, and to assist bacteria oxidising discharged organic matter, there can be no deficiency or complete absence of oxygen. The temperature and salinity of the water determine the dissolved oxygen content at equilibrium with the environment. This balance can be upset if the wastewater makes a significant demand upon the dissolved oxygen content of the receiving water body. This is generally not a problem with coastal refineries since the oxygen demand of the wastewater, even when untreated, is equivalent to dilute municipal sewage and can easily be assimilated because the volume of flow is comparatively small. In inland locations, particularly where receiving waters are of limited capacity, and other industrial and municipal wastes are introduced, control of Biochemical Oxygen Demand may be mandatory.

Biochemical Oxygen Demand (BOD) is a measure of the amount of oxygen required for the complete decompostion of organic matter by bacteria which grow and oxidise the organic aerobically. A high BOD waste will require greater amounts of oxygen and by reducing the available dissolved oxygen in a stream produce an entirely different ecological system. Lack of oxygen could deplete the fish populations, promote slimes and other noxious growths and cause offensive odours due to anaerobic decomposition.

Regulations for protecting the dissolved oxygen content fall into two categories. The first involves the monitoring of the dissolved oxygen concentration in the receiving water body. Here, specifications require that the waste discharge shall not cause the dissolved oxygen content to be less than a fixed amount at existing water temperature and salinity. There is no consistency in specified limits with values dependent upon specific location and end use of the receiving water body. Some require D.O. levels to be no less than 40% of saturation, while others require daily minimum of 3–4 mg/1. Extremely restrictive regulations will demand D.O. contents of at least 85% of saturation of 5 mg/1, whichever value is greater. The second method of dissolved oxygen management involves the setting of BOD discharge limits on the effluent stream. Where finite limits have been applied values range from 10 to 200 mg/1. Such restrictions have normally been confined to river locations rather than coastal areas.

A coordinated effort by government and industry is needed to develop water quality criteria and regulations that are scientifically reasonable and economically realistic. It is essential that there be a careful evaluation of (i) the local situation, (ii) the control technology available and its limitations, (iii) the technical feasibility of monitoring exceptionally low limits, (iv) the manpower requirements of enforcement and (v) the overall economic implications involved. Pollution control is a subject that cannot be generalized. Nearly every refinery has its individual problems, dependent upon the types and number of crude oils to be processed, the degree of processing complexity, local environmental conditions and the types of treatment techniques used. Effluent quality legislation should reflect these facts and make initial provisions to protect the more immediate future end uses of the water environment. Ultimate requirements would be determined by further population growth, greater energy demand and urbanization. Should more stringent regulations be necessary, industry should be given sufficient time to develop optimum treatment systems that would effectively handle local problems and incorporate expected technological developments.

A refinery is a complex of integrated unit operations. Every operation produces waste materials in varying amounts and forms. However, as a basis for this discussion we will focus attention upon a generalized list of potential water contaminants. This list includes the following:

Oil	Bases
Dissolved Solids	Soluble Organics
Suspended Solids	Phenol
Hydrogen Sulphide	Metallic Ions
Acid	Ammonia

These may be contained in the following liquid waste streams:

Oil Wastewaters	Spent Regenerants
Chemical Wastewaters	Spent Catalysts
Boiler Blowdown	Surface Runoff
Cooling Water	Sanitary Sewage

Our normal approach to the control of potential contaminants is a frontal assault. The basic principal of pollution control is to attack the source. In the design of new refining facilities, it is necessary to pinpoint all waste stream and identify and quantify the pollutants therein. We determine whether these sources can be eliminated or whether the pollutants can be minimized or eliminated. This may be accomplished by process selection, where a process producing a relatively easy-to-treat waste would be preferred over one that creates an expensive treatment problem. Design modifications may also be implemented, e.g. multiple use of pipe-lines, surface rather than barometric condensers, closed water drawoff systems. The reuse of streams is encouraged. A hierarchy is developed where water streams after initial use, where high quality is required are recycled into lower quality service. Another method of water economy is to substitute a contaminated stream for fresh water as the feed to boilers producing process steam. Of course, the reused water may have to be stripped of volatile substances that would contaminate the steam, or treated to reduce its corrosivity. It may also be productive to recover the pollutants as useful products or to sell them to others.

Stream segregation generally simplified the overall treating problem. It is usually more effective and less expensive to treat a small concentrated waste stream rather than one that is large and dilute.

Technological developments over the last decade have dramatically reduced refinery water consumption. This is reflected in the change in average waste flows. Older refineries discharged an average of 250 gallons of water per barrel of throughput while new refineries have effluents in the range of 30 gallons per barrel of throughput. Instead of using once-through water for cooling purposes, recirculating cooling towers are applied. The use of air fin coolers further reduce water consumption by eliminating evaporative losses. Refinery cooling now, under favourable atmospheric conditions, is the combination of maximum application of air cooling with trim cooling requirements satisfied by recirculating systems. It is not meant to imply that once-through cooling water is not acceptable from a pollution control point of view. But rather that where high quality effluents are required, the cost of treatment facilities is reduced significantly by minimizing wastewater volumes.

There are several alternative techniques available for the control of each specific refinery pollutant (Fig. 1). Oil and suspended solids removal can be accomplished in the classic American Petroleum Institute separator or by a skim point, chemical flocculation or dissolved air flotation. For oxygen demand reduction, various biological treatment processes are available including stabilization lagoons, trickling filters and activated sludge. Chemical oxidation, using sodium peroxide or chlorine, is known but rarely used. Adsorption on carbon is also possible.

PURPOSE	TECHNIQUE
OIL WATER/SOLIDS SEPARATION	API SEPARATOR, SKIM POND, CHEM FLOC, DISSOLVED AIR FLOTATION' FILTRATION
OXYGEN DEMAND REDUCTION	BIOLOGICAL TREATMENT, CHEMICAL OXIDATION, CARBON ADSORPTION
HYDROGEN SULPHIDES	STRIPPING, FRACTIONATION
AMMONIA	HI-TEMP STRIPPING, FRACTIONATION, BIOLOGICAL TREATMENT
PHENOL REDUCTION	BIOLOGICAL TREATMENT, DESALTER INJECTION, CARBON ADSORPTION

Fig. 1. The Potential Pollutants

Hydrogen sulphide may be removed by steam, air and flue gas stripping or fractionation. Ammonia may be reduced by high temperature stripping, fractionation or biological treatment. Biological treatment is also effective for phenol removal as are adsorption on carbon and injection into refinery desalters. pH adjustment is accomplished by neutralization with fresh or spent acids and bases.

Gravity oil/water separators are employed in all refineries as a primary step in waste treatment. The oil water is passed horizontally through a sedimentation tank or natural basin at a velocity that will allow oil globules to rise to the surface before they are carried out. Modern, well maintained separators are capable of reducing oil contents down to about 25 – 50 ppm. An 80% reduction in suspended solids is also accomplished. Filtration, coagulation or dissolved air flotation (DAF) units can further reduce these parameters, if necessary.

The traditional filters, of graded material with the finest media on top, do not make effective use of the bed depth. Therefore, a trend has developed to use mixed media that filter from coarse to fine and thereby reduce the frequency of cleaning by utilizing more of the pore spaces before washing is required.

In the DAF system, air is dissolved in water, which is usually clarified flotation effuent and known as recycle water. Air is injected into a pump capable of pumping an air/water mixture. The mixture is retained briefly in a pressure tank to enhance stabilization and to disengage excess air. Minute air bubbles are formed when the mixture is subsequently introduced into the tank and pressure is released. The air bubbles scavenge oil globules and particulate matter from the wastewater way or further treatment.

Chemical flocculation is a well known technique which promotes particle agglomeration to change size and settling rate. The oil/particulate/floc mixture settles in the clarifier and is removed by bottom scrapers.

Another conventional anti-pollution process, used principally in inland locations, is biological oxidation. Where land is readily available, lagoons and ponds can provide the proper environment for the biological stabilization of organic wastes. Since we generally have not had the luxury of large acreage, the activated sludge process has been widely adopted. It is a system in which active, flocculated biological growths are continuously contacted with organic wastewater in the presence of oxygen. The aeration step results in a rapid adsorption and flocculation of suspended colloidal and soluble organics by sludge which has been recycled from the subsequent sedimentation step. There then ensues a progressive oxidation and synthesis of the adsorbed organics and they are continuously removed from solution.

The aforementioned treatment processes, when operated with care, may be expected to effect the percentage removals of oil, phenol and biochemical oxygen demand shown on the bar graph (Fig. 2). The numbers at the top of the columns show order of magnitude residual concentration for oil achievable by each process. The data in Fig. 2 are generalized and may not accurately predict results in specific situations. For example, we have found that biological oxidation is often capable of giving better removals of oil and phenolic compounds than are indicated here.

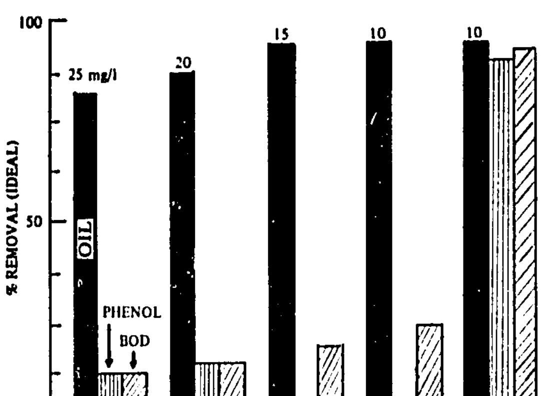

Fig. 2. Conventional Anti-Pollution Processes

These individual process units are then fashioned into systems that are tailor-made to fit the local water pollution control requirements. To show the effect of local environmental conditions, three refinery flow plans will be shown. The Esso Refinery near Castellon, Spain, discharges into sea water where the end use of the water is primarily for fishing. The refinery was started up in 1967. Cooling is effected by the combination of air fin coolers and recirculating water cooling towers. The treatment facilities consist of sour water strippers, an API gravity oil/water separator, and ballast water treatment tanks (Fig. 3). The authorities have been satisfied with the quality of the effluent.

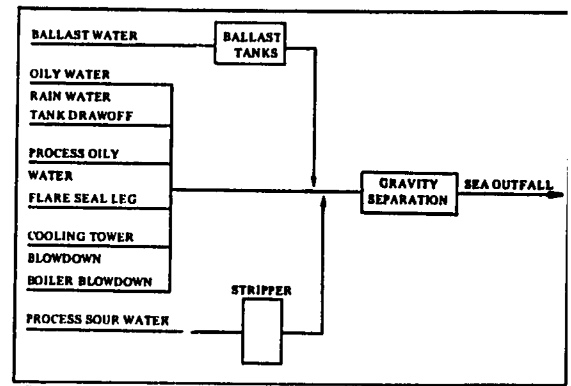

Fig. 3. Castellon Wastewater Treating Facilities

Humble Oil's new refinery at Benicia, California, began operations in 1969. Located about 30 miles above San Francisco, the refinery discharges into the bay system which ultimately passes the city and goes out into the Pacific. The relatively stringent water quality standards require that the receiving waters in the vicinity of the refinery outfall must have a dissolved oxygen of at least 5 mg/l (Fig. 4). In the receiving water, the total sulphides must be below 0.1 mg/l and the undissociated ammonium hydroxide no greater than 0.25 mg/l. The effluent itself is not allowed to contain more than 15 mg/l of total oil. The treatment facilities provided are shown in Fig. 5 All requirements are being met.

RECEIVING WATER	
DISSOLVED OXYGEN, mg/l	5.0 MINIMUM
pH	7.0 - 8.5
TOTAL SULPHIDES mg/l	0.1 MAXIMUM
AMMONIA NITROGEN, mg/l (UNDISSOCIATED)	0.25 MAX. AVGE.
TOXICITY	NONE
EFFLUENT	
TOTAL OIL, mg/l	15 MAXIMUM

Fig. 4 Benicia Water Quality Limits

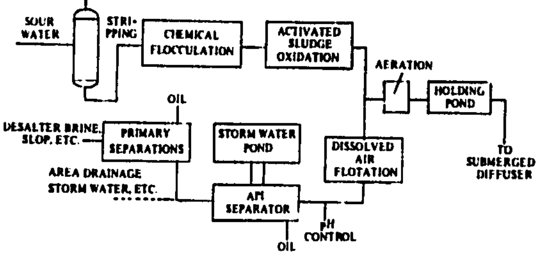

Fig. 5. Schematic of Wastewater Treating at Benicia Refinery

Let us turn now from the salt and estuarine environment to a fresh water location, in particular, to an installation in Central Europe where controls are among the most stringent in the world. The Esso A.G. Refinery at Ingolstadt, Germany, is situated by the head waters of the Danube River. Effluent water quality requirements are as follows (Fig. 6):

	SPECIFICATION (mg/l)
OIL	<3
PHENOLS	<0.2
BOD	<25
pH	6.5 - 8.5
IRON	<0.5
MERCAPTANS AND SULPHIDES	NONE
AMMONIA AND HEAVY METALS	NO TOXIC CONC.
SOLIDS	<0.3 ml/l
TEMPERATURE	<30°C
EFFLUENT RATE	$<100\ m^3/hr$

Fig. 6 Ingolstadt Effluent Water Quality

At Ingolstadt (Fig. 7), all wastewater streams, with the exception of sanitary sewage, pass through a grit chamber for solids reduction, an oil/water separator and a settling tank. In the chemical flocculation -biological treatment plant, coagulating chemicals are added and the resultant flocs absorb the remaining traces of oil. Activated sludge microorganisms convert the phenols and other organic pollutants to carbon dioxide and water.

A final aeration basin with a retention time of 2–3 days further polishes the water. The aeration basin effluent is normally completely discharged to a decarbonization unit and fed after chlorination to the cooling water circuit. Only surplus water is sent to the Danube.

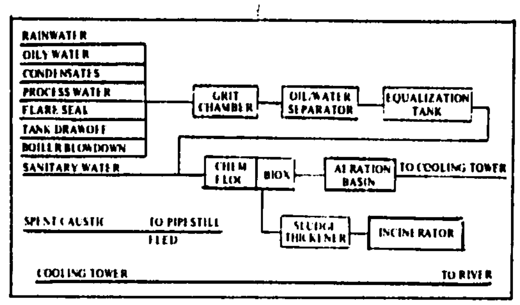

Fig. 7. Ingolstadt Wastewater Treatment Facilities

In addition to the reuse of treated wastewater as cooling tower makeup, specific contaminated waters containing phenol, mercaptans and hydrogen sulphide are vaporized and used as stripping and atomizing steam.

All applicable standards are being met.

To meet future needs, there are "advanced" treating processes, now in the research and development stage, which it is hoped can be successfully applied to large scale industrial use. Several which are the most promising or which offer the most needed capabilities are shown in Fig. 8. The numbers cited indicate the expected levels, expressed as mg/l or ppm, to which some troublesome pollution parameters can be reduced. An "X" entry denotes that a particular technique is applicable but that a definite performance number cannot yet be stated.

	BOD	COD	TDS	SS	ODOUR & COLOUR	TOXICITY
ION EXCHANGE	-	<50	0.5	<1	x	REDUCED
ACTIVATED CARBON	<15	<40	-	<1	G. REDUCED	REDUCED
MEMBRANE PROCESSES	10-20	<50	G.REDUCED			REDUCED
OXIDATION	x	x	-	-	x	x
PRECIPITATION	-	-	x	x	-	x
FLASH EVAPORATION	-	-	G.REDUCED	<1	-	x

Fig. 8. "Advanced" Treatment

Ion exchange, for example, can be used to reduce chemical oxygen demand (COD), total dissolved solids (TDS) and suspended solids. At the same time, odour and colour producing contaminants and some toxic substances are substantially removed.

Filtration through beds of activated, high surface area carbon is capable of removing many parameters of water pollution to quite low levels. The carbon surface can be cleaned and reused in repeated adsorption cycles.

Promising membrane processes include reverse osmosis and electrodialysis. These processes and others are frequently described in the technical literature and sales brochures.

Since economics are also a design consideration, the relative capital costs of some of these waste water treatment methods are depicted in Fig. 9. These data cover the treatment of ten million gallons per day of wastewater with the indicated impurity levels. At the bottom of the chart, the progressive reduction of three impurities is shown.

It is quite apparent that the specialized, sophisticated techniques required to solve pollution problems in the future will have tremendous economic impact. This emphasizes the great responsibility that water authorities have when setting standards. It is of major importance that the main attack on pollutants be carried out where the amounts and need to remove them is greatest. The arbitrary adoption of ultra-low pollutant levels, without an orderly, scientific determination of their necessity, should be avoided. A coordinated effort by industry and government is needed to develop regulations and quality standards that are reasonable and realistic. It would be wasteful to all concerned if the vast experience of industry were not utilized in these determinations.

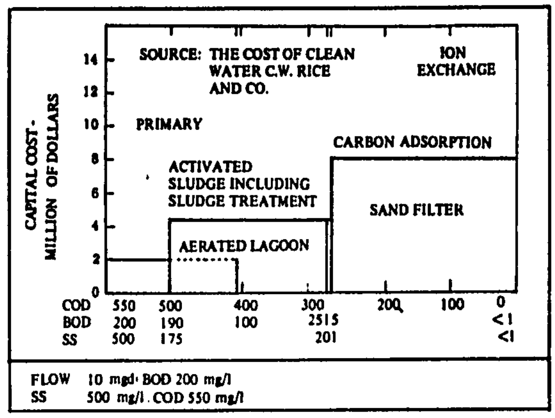

Fig. 9. Capital Cost of Treatment Plant vs. Substrate Removal

THE HANDLING OF OIL SPILLS

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ABSTRACT

The effectiveness of oil spill cleanup is significantly influenced by environmental conditions at the spill area and the degree of preparedness that has been achieved. Anticipated problems are first defined, based on historical data from past incidents, in terms of spill size, location, type of oil involved and wind/sea conditions. The characteristics of the oil spilled, the location and extent of the spill and existing environmental factors, will influence the decisions on how an oil spill should be handled. Containment, confinement, removal and disposal are commonly-used methods for control and recovery of spilled oil. The various cleanup alternatives are explored. Current state of the art involving equipment and materials, for removing oil from the surface of water, is reviewed. Included in the discussion are booms, sorbent materials, chemicals and skimming devices. The basic requirements of preplanning and subsequent development of effective contingency plans are discussed. In the event containment and removal are not feasible, the role that chemical dispersion can play in minimizing and/or mitigating the harmful effect of the spilled oil will be outlined.

It is considered sound, standard operating procedure to begin a presentation with some attention gathering statistics. Therefore, to impress you with the importance of effective oil spill handling, let me acquaint you with some basic facts. There are more than 3,000 ocean-going tankers in the world today and thousands of terminals, barges and off-shore wells. On an average day, the entire petroleum industry has some 500 million barrels of oil afloat. The magnitude of the production and transportation operations is enough to suggest the need for an equally large scale effort to avoid spills and to improve cleanup procedures and techniques.

The American Petroleum Institute in 1969 sponsored a study to determine the conditions that existed when significant oil spills happened. Information was compiled covering 38 major spills which occurred during 1956-1969. Although the emphasis was on spills of 1,000 barrels or more, information was also collected on various other incidents including (1) large spills in open and coastal water. (2) spills less than 2,000 barrels where the incident received wide public attention. (3) several spills in inland waters.

Fig. 1 shows the source of the spill. Three out of four spills were associated with vessels. Of these, over 90% involved tankers and half of these

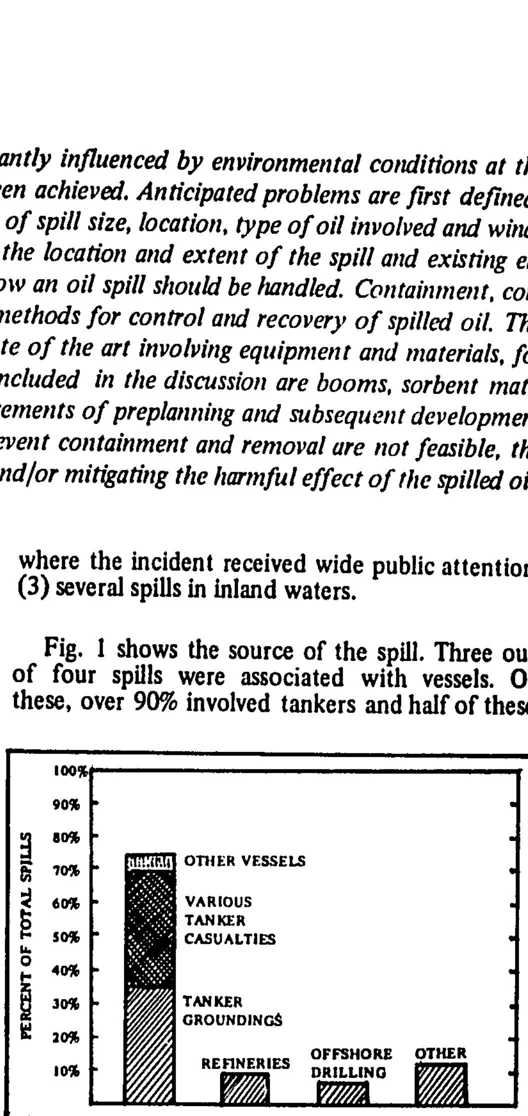

Fig. 1 Source of Spill (Data from 36 incidents).

were by grounding. This implies that future spills are likely to be caused by vessels, most likely tankers.

Fig. 2 indicates that the composition of the 2.2 million barrels spilled was 80% crude, 19% light oil, and 1% residual oil. The crude oil was also the material involved in most incidents. Residual oils were involved in the next largest number of spills; these, however, involved only 34,000 barrels. Future spills, therefore, would appear most likely to be of crude or residual oils.

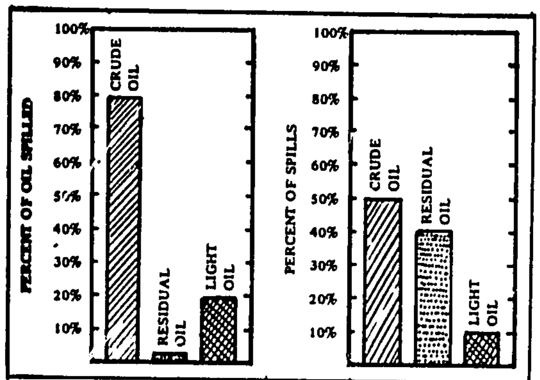

Fig. 2 Composition of Material Spilled (Data from 35 incidents).

The median volume of spill, Fig. 3, is approximately 25,000 barrels. Fifty percent lie between 5,000 and 100,000 barrels. Fig. 4 covers the distance of the incident from the shore.

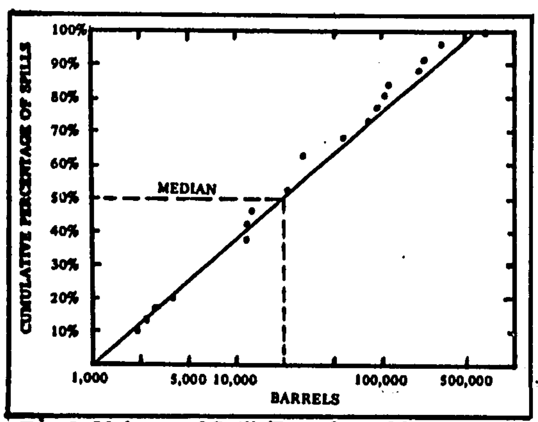

Fig. 3 Volume of Spill (Data from 23 incidents).

Half are less than one mile off-shore and 80% are within 10 miles of shore. This gives an indication of the time available for mobilizing shoreline protection before the oil may reach the shore. Since oil appears to drift at 3.3% of the wind speed, with an assumed 15 knot wind, the slick

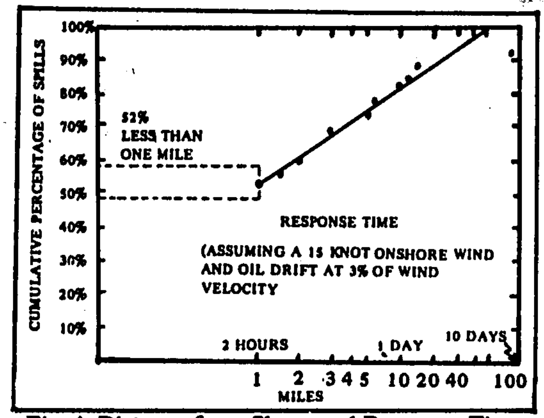

Fig. 4 Distance from Shore and Response Time Available for Shoreline Protection

would drift at 0.3 knots. Thus, with 50% less than 1 mile from shore, a wind toward land could move oil onto the shore in 2 hours, and in 80% of the incidents in less than a day.

Fig. 5 will show that logistic support is likely to be required over a period of several weeks in a future spill incident. Data on the extent of coastal contamination (Fig. 6) is not too well documented. In half of the 18 past spills noted, less than 7 miles of coastline were involved. In 80% of the incidents, less than 20 miles were affected. The median value for all the incidents is 3–4 miles. There is a tendency to class as recreational any shoreline which is accessible to the public. Eighty-five percent of the spills affected recreational coastline. Residential and industrial areas were affected in 45% of the spills. The total is more than 100% since most incidents reported shorelines with multiple uses (Fig. 7).

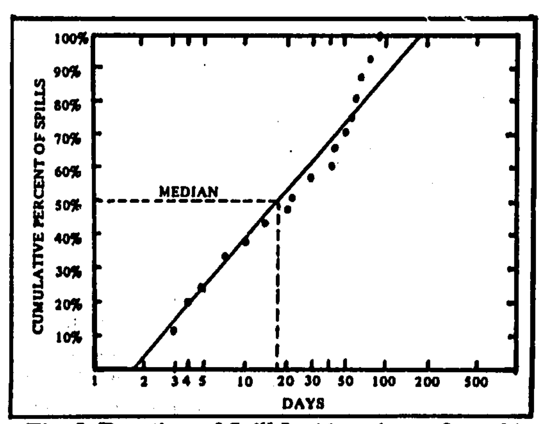

Fig. 5 Duration of Spill Incident (Data from 21 incidents).

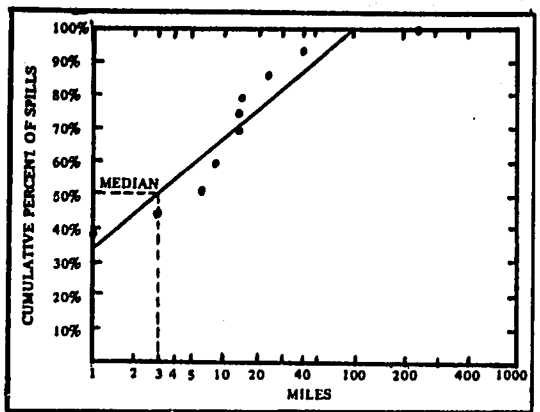

Fig. 6 Distance of Spill Incident (Data from 18 incidents).

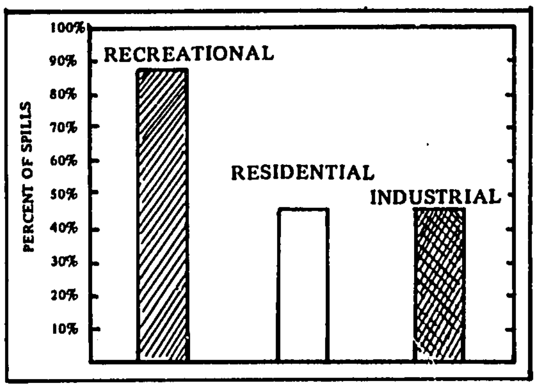

Fig. 7 Coastline Utilization (Data from 23 incidents).

The data in Fig. 8 is significant for planning actions to control spills and for developing the logistic support arrangement. Seventy-five percent of the incidents were within 25 miles of port and 85% were within 50 miles.

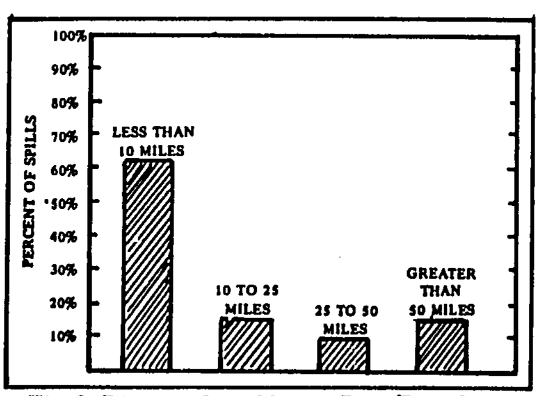

Fig. 8 Distance from Nearest Port (Data from 21 incidents).

Information covering wave height and wind velocities (Fig. 9 and 10) are of prime importance. The environmental conditions will establish what techniques should be used.

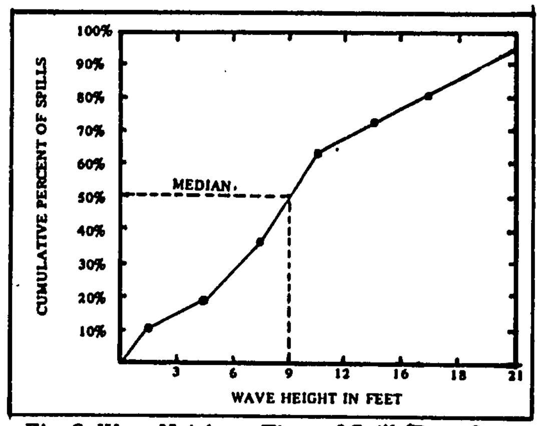

Fig. 9 Wave Height at Time of Spill (Data from 11 incidents).

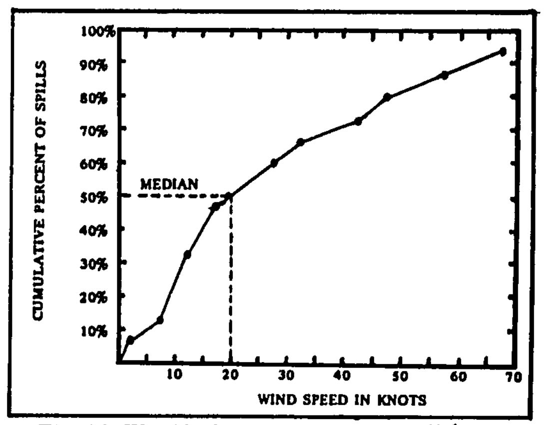

Fig. 10 Wind Velocity at Time of Spill (Data from 15 incidents).

It should be noted that the bulk of oil entering the sea is the result of routine escape from tanker ballast water, refinery operation and off-shore production. Dry cargo, passenger, fishing, and coastal vessels also contribute significant volumes amounting to about one-third of the total. Accidental spills are not a major source of oil in the sea but have the potential to cause significant pollution. Much progress is being made in preventing or minimizing the routine escape of oil into the sea. Simultaneously, there are sizable efforts underway to eliminate or reduce the possibility of accidents. Discussion of these subjects are beyond the scope of this paper. We will cover the preplanning required and the handling of an incident once oil has reached the surface of the water.

The characteristics of the oil spilled, the location and extent of the spill, and existing environmental factors will influence the decisions on how the incident should be handled. Naturally, the first consideration will be to stop or minimize the source of oil. It would be possible, under certain favourable conditions, i.e., off-shore winds and currents, remote locations, etc., that no specific cleanup action is warranted and that natural forces could be allowed to take effect. However, the increasing public anxiety over pollution and new proposed legislation, have materially reduced the chances of permitting this to happen. Therefore, some form of abatement will usually be necessary, and Fig. 11 shows some of the techniques that are frequently used.

• CONTAINMENT	- USING MATERIALS OR CHEMICALS TO TRAP THE OIL OR CHANGE ITS FORM SO THAT ITS SPREAD IS MINIMIZED AND COLLECTION IS SIMPLER
• CONFINEMENT	- USING PHYSICAL AND PNEUMATIC BARRIERS TO LIMIT THE SPREAD OF OIL
• REMOVAL	- USING VARIOUS TECHNIQUES TO EITHER PHYSICALLY RECOVER THE OIL OR DESTROY IT
• DISPOSAL	- USING SURFACE ACTIVE AGENTS FOR DISPERSAL; SINKING AGENTS; BURNING AGENTS

Fig. 11 Techniques for Control and Recovery of Oil Spills

Containment involves the using of materials or chemicals to trap the oil or change its form so that spreading is minimized and collection is simplified. In this classification are the sorbent materials, both natural and manufactured, and the gellants. We will discuss these further later on.

Confinement is accomplished by using physical and pneumatic barriers to limit the spread of the spilled oil. Booms and air curtain barriers fall into this category.

Removal includes the various methods available to either physically recover the oil or to destroy it. The skimming devices and burning agents fall into this category.

Finally, we come to disposal, in which surface active agents are used for dispersal or sinking agents are applied to deposit the oil on the bottom of the water body.

There is no standard procedure for handling an oil spill. Any of the above-mentioned methods may be applicable. Containment or confinement, followed by physical removal, are usually the first steps tried. This is obviously the most complete solution to the problem. However, there are all too frequent instances wherein weather conditions, sea state, local geography, etc., are beyond the current effective operating limits for containment booms and recovery devices. In this situation, two courses of action are available either (1) take no action and possibly permit the oil slick to reach shore where subsequent cleanup would take place or (2) treat the surface oil. The treatment is essentially directed toward removing the oil from the surface and enhancing its ultimate removal from the environment. This may be accomplished by burning, sinking or dispersing. Of these techniques, dispersion is probably the most versatile. Therefore, in discussing this "last resort" situation, we shall consider the relative merits of either permitting the oil to remain as an intact cohesive slick versus dispersing it into fine droplets.

One must realize that in dealing with this subject we are faced with a "state of the art" that is changing rapidly. New equipment and chemicals are appearing on the market with increasing frequency. This activity has been prompted by a series of mishaps starting with the massive *Torrey Canyon* incident. The many substantial research and development projects being sponsored by governments and private industry should hopefully add significant new weapons to our arsenal for the fight against pollution of the sea by oil.

Let us return now to containment. The range of fluids capable of being absorbed efficiently is limited to the less viscous refined petroleum products and crude oils. The rate of oil absorption depends on the viscosity of the oil.

In handling a spill of light and heavy components, rapid deployment of sorbent materials is necessary. Prompt action will contain the oil before the volatile fractions evaporate and the viscosity increases. Quick recovery is also important because an oil-in-water emulsion will form due to wave agitation. Once the oil has formed this emulsion, it is difficult to absorb but easier to recover by manual techniques.

The use of absorbent materials has generally been limited to small spills because of the amount required and also the relatively high cost of the manufactured product. A disadvantage of such materials is their susceptibility to wind action and the tendency to drift easily. This makes distribution and collection difficult unless adequate confinement is provided. Sorbents will find their greatest applicability in confined areas and handling small spills where potential damage to property and the ecology from other methods exists.

Fig. 12 shows some popular oil absorbent materials. The absorbed oil can be recovered from some materials by squeezing. Some can be reused once the oil is burned away. Others require disposal by burying or burning. Although some of the synthetic materials show superior sorbent qualities, natural substances are generally used due to their availability and low cost. These naturally occurring substances could include rice straw, sugar cane, peat moss and hay.

PRODUCT	DESCRIPTION	RATIO OIL/ SORBENT	QUANTITY CF/BBL	COST $/BBL OIL
STRAW	VARIOUS	5/1	5	2.50
E KOPERL	EXPANDED PERLITE	2/1	10	13.50
MISTRON	Zn STEARATE COATED TALCUM	1/3	1	4.00
SOSOL	SHREDDED POLYURETHANE	1/2 (VOL)	5	22.00
SORBENT C	FIBRE	6/1	11	12.00

Fig. 12 Oil Sorbent Materials

Chemicals have been developed which will convert oil slicks into gelled masses. Once the oil has been congealed, it can be harvested from the water surface and burned or processed to reclaim the the oil. In their present stage of development, such techniques require a significant amount of chemical and are expensive.

By treating the periphery of a spill with a chemical gelling agent, or a polymerizing agent, a chemical boom could be created to retard the spreading of oil. However, chemical booms will be severely limited by their mechanical properties (strength, flexibility and elasticity) and the height (above or below the surface) that they present to the spreading oil. The potential toxicity effects of chemicals which function by gelation or some other technique for creating a semi-solid mass, must be carefully considered. Complete gellation of ship's cargoes is under active research.

An oil spill boom generally consists of a weighted fin which extends both above and below the water surface and is kept afloat by some type of buoyancy device.

A boom may be used to encircle an oil slick in an open area or be stretched across a river and anchored, for the protection of either the upstream or downstream area. To be effective, booms should be readily available to permit quick placement, light enough to easily be handled, yet substantial enough to contain oil in the area while considering current strength and rough water.

Experience has shown that these presently available booms (Fig. 13) are satisfactory where current, wind and wave conditions are relatively mild. Approximate environmental limits are 1.5 knot currents and 2-3 foot waves. However, much research effort is presently being expended to develop rugged sea-worthy booms capable of withstanding the forces.

BARRIER	FT/UNIT	$/FT	DIAMETER (INCHES)	FIN DEPTH (INCHES)
BENNETT OFFSHORE	50-100	15-25	6	24
KEPNER SEA CURTAIN	20	15-40	13-30	24
T-T COASTAL	20-164	7-20	3	24
SLICKBAR	10	6-15	4-6	24
SEALDBOOM	30	12		
WARNE TYPE T	25	35	16	24
SPILLGUARD	100	20		24

Fig. 13 Barriers for Oil Confinement

Excessive current causes the skirt of a boom to lift which enables the confined oil to flow under. Excessive wave action results in oil washing over the top of the fin. Both current and wave action cause twisting and stress at the boom joints and anchors. These factors continue to cause problems with all booms.

Underwater bubble barriers are a relatively recent development. This type of barrier appears to have considerable merit for fixed installations in sheltered waters and has the advantage that entry and egress of ships is unimpaired. Portable systems are in the development stage.

Compressed air emitted from a submerged pipe causes local upwelling with a resultant surface current flowing in both directions perpendicular to the bubble curtain. As long as this flow toward the oil is not exceeded by the current or overcome by the wind force on the oil, the barrier will contain a spill. The rising air plume is affected by the stream current which causes it to tilt. If the movement is more than 30 degrees from the vertical, the plume will break up and adversely affect the overall effectiveness. In general, this technique has proven to be effective in currents of up to 0.7 knots.

Many different mechanical devices are presently being routinely used to recover oil from the surface of water. Several of these are shown in Fig. 14. Generally, their operation is limited to harbours and waterways that are only mildly agitated by waves and/or currents, and their recovery rates are low. Again, much effort is being expended to develop units which overcome these basic limitations.

TYPE	DEVELOPED BY	RECOVERY PRINCIPLE	RECOVERY RATE (B/HR)	COST $
• SUCTION				
DRACONE BARGE	DUNLOP	SUCTION	-	20-60 M
UNIVAC PUMP	HENRY SYKES LTD	SUCTION	120/pump	NA
SLICK SKIM	INDUSTRIAL PLASTICS	VACCUUM	-	3.8-7.5
• CYCLING ELEMENT				
MOP CAT	WORTHINGTON	SELECTIVE SEP	50	50
RECLAMATOR	AMOCO	FOAM COATED ROTATING DRUM	50	11
• WEIR				
T-T OIL REFINERY	TRUGVE THUNE	WEIR	75	30
RHEINWEA		WEIR	10-125	5 - 30
MEDUSA	REYNOLDS SUBMARINE	WEIR		6 -7
SEA SWEEP	SPILLTROL	WEIR		55

Fig. 14 Collection Devices

Mechanical devices or skimmers to recover floating oil are of three general types:

Suction – which employs pumps or vacuum devices to pick up oil/water mixtures and transfer them to separation tanks.

Cycling Element – which employs a cycling belt or rotating cylinder for contacting oil.

Weir – which recovers oil by drawing it over a weir by the forward motion of the device or the movement of the water due to current.

Suction skimmers require calm water and an oil thickness over ¼ inch. Waves up to 6 inches can be tolerated. Cycling elements can operate in 1-2 foot waves. They are not as effective on oil emulsified with water or on weathered oil. Weir skimmers require calm water and large oil thicknesses. For these devices to be effective, the oil pickup mechanism must closely follow the movement of the surface of the water so that the liquid recovered is primarily oil with little accompanied water. Recovery devices may only be useful in assisting in the cleanup of an oil spill in calm waters such as harbours and bays.

Burning techniques have not been too successful to date and have limited applicability. The slick must be small and thick. The water must be calm. Locations must be such that fire cannot damage nearby structures or forests or other vegetation. There should be no danger of the fire spreading to the source itself. In certain locations, the possibility of air pollution must be considered.

Once oil is on the water, burning becomes increasingly more difficult due to evaporation of the more volatile components. There is also a rapid transfer of heat to the water which decreases the oil temperature to below the flash point. Heavy smoke formation is possible since there is a general lack of oxygen supply to all but the edges of the slick.

When the materials and equipment necessary to physically contain and remove the oil spill from the water cannot be rapidly deployed or would be ineffective under existing environmental conditions, use of chemical dispersants should be considered. The other alternative is to await more favourable conditions and this action has disadvantages. Spilled oil left unattended on the surface may be detrimental for the following reasons:

Shore contamination
Marine fowl destruction
Surface plankton affected
Persistent tarry lumps are formed

Chemical dispersion of the oil can prevent these problems but has limitations of its own. For example, in certain locations, particularly in fresh water, many factors should be considered before deciding on chemical treatment. Effective dispersion requires a freely moving body of water. In confined waters having low dissolved oxygen contents, the degradation of dispersed oil and dispersing chemical may deplete the oxygen content below the required level for maintaining a specified water quality. Dispersion near intakes can cause oil to be drawn into municipal or industrial water distribution systems.

The function of a dispersant is to accelerate the natural tendency of an oil slick to spread. The intact film tends to break up into minute, dispersed droplets when mixed with the chemical.

The required energy and turbulence may be provided by wind, waves, work boats or high velocity fire hose. The dispersant, therefore, eliminates the unsightly oil slick and assists in the ultimate decomposition of the oil by bacterial action and other natural forces.

The original objections to the application of chemicals on coastal waters stemmed from the toxic effects that these chemicals have on fish and marine life. This property is not an inherent characteristic of surfactants and essentially non-toxic dispersants are now in use.

A sinking agent is a powder or fine granular material of high true density which admixes with the oil, adheres to it and sinks it. Several substantial problems with the use of sinking agents are evident. First, the logistics of supply and dispersal of the agent is difficult, particularly in the case of large spills. Secondly, the sunken oil may have substantial adverse effect on marine life. Thirdly, resurfacing also poses a considerable problem.

Let us now briefly consider the cleanup of land areas after the oil has reached the shore. The basic techniques available are (1) bulldozing and physical removal of the contaminated sand, (2) chemical cleaning, (3) adsorption of the oil by straw, fiber, etc. High viscosity oils and heavy crudes tend to lie on the surface of beaches. For them the preferred method of cleanup is physical excavation and removal. Earthmoving equipment can make rapid progress on uninterrupted stretches of beach. Oil soaked pebbles can be buried above the high water mark.

Where chemicals are to be used to clean a sandy beach, it is recommended that a non-toxic dispersant be applied as a dilute solution.

The use of absorbents on beaches requires high manpower. Reports on the Santa Barbara incident indicated that 100 men per mile were required to handle the straw used.

In restoring rocky coastlines, physical removal is not usually possible and absorbents are marginal. Simple water washing should first be tried. However, the removed oil may redeposit.

For viscous, tarlike oil clingage on solid shore surfaces, a fast acting cleaning agent is required. The agent must posses some degree of solvency to cut the oil film and apply the surface active agent. We are recommending use of low toxicity dispersants. Where there is no regard for chemical toxicity, one of the heavy aromatic naphtha or special detergent products can be quite effective.

Burning oil off using flame throwers is unsatisfactory because of the slowness of the method, excessive quantity of fuel used and the damage to the walls which might occur.

"Be prepared," the Boy Scout motto, is most applicable here. The rapid mobilization of equipment, material and manpower should be planned and developed long before an incident occurs. In every region where the traffic of oil occurs, actions should be taken to determine potential spill areas and the environmental conditions at such sites. Decisions should be made to define the types of oil that might be spilled and the maximum size of spill to be treated. Inventories should be compiled of equipment, chemicals and manpower available, (1) at local terminals, (2) through co-operative programmes and (3) through contract services and from the government. In addition, the official attitude toward the use of chemicals should be explored.

Predominant environmental conditions will determine which handling techniques should be emphasized. Where confinement is considered feasible, boom availability should be established. Consideration should be given to the various types of collection equipment that are available and needed.

The stockpiling of sorbent materials and/or dispersant chemicals will vary with the anticipated type and size of spill. Estimates should be made of the quantities required for some base case spill. With proper stock replenishment, this will always provide for immediate reaction to smaller spills. The provision of additional stockpiles for larger spills involves many judgement decisions. For exa[illegible] the chances of a disaster, the added amoun[illegible] under such a condition, the rates at which these materials could be applied even if available, the time required to receive additional materials from other stockpiles or a manufacturing site, the cost of emergency shipments, etc.

A working organization should exist, with personnel awareness of their responsibilities and preferably trained in the discharge of their duties.

The development of oil spill cleanup capability involves significant expenditures, particularly if they are borne by individual companies. The advantages of promoting cooperative action with governmental and industry groups is quite apparent.

In conclusion, it should be stressed that prevention of oil spills is the first consideration. In this regard, there is extensive ongoing research that will help to minimize the amount of oil reaching the water, e.g., improved collision avoidance techniques and training, revised vessels designs, cargo gellation. Concurrently, technological advances are expected to improve our capabilities for containment, confinement and removal of spilled oil during adverse weather. These will be welcome, since the present state of the art limits us to relatively calm water conditions. In cases where chemicals must be used reliance should be placed primarily on the non-toxic dispersants. Lastly, the cleanup operation is in reality the final few days or hours that reflect the months of contingency planning that have gone before. The value of dedicated preplanning cannot be over emphasized.

Paper No. II/11

SEA POLLUTION IN SINGAPORE

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ABSTRACT

The sea pollution problem in Singapore is broadly two-fold, i.e. pollution that emanates directly from a variety of sources within the territory of Singapore and the constant threat posed by the international shipping, particularly the tankers.

To a satisfactory extent surveillance is maintained against minor forms of pollution and also constant remedial action is taken to ensure that the sea around theRepublic is clean.The difficulty at the moment is effective surveillance during the hours of darkness when pollution detection is not possible except by means spot checks.

However, these problems may be considered insignificant when compared with the disastrous effects that ocean-going ships and tankers could bring about as a result of collision and grounding. Such a threat is greater now than ever before owing to the general increase in the world shipping tonnage and the continuing increase in the size and draft of tankers. The other factor which has a detrimental influence on the general situation is the configuration of the waterway around the Republic where bottle necks exist on the west, south and east. These three locations, off Tanjong Piat, off Raffles Lighthouse and at the approaches to Horsburgh Lighthouse, besides being narrow and shallow are also bends where ships have to alter their course which introduces a further element of risk of collision or grounding.

The remedy against a major pollution threat may be two-fold, i.e. by creating a national anti-sea pollution organisation which is properly equipped, organised and conducted, and secondly by promoting international understanding and cooperation and drawing up an international scheme to combat any pollution disaster that may occur in the region.

It is also vital that those industries which deal in bulk quantities of oil or in the transportation of such oil exercise greater awareness of the threat and accept responsibility and liability for a major oil pollution however caused.

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AIM

The aim of this paper is to outline the day to day pollution problem of the waters of Singapore and to indicate the constant threat of a major pollution risk that exists around the Island.

PRESENT SITUATION

The sea pollution problem in Singapore is broadly two-fold, i.e.

(1) Pollution that emanates directly from a variety of sources within the territory of Singapore and

(2) The constant threat that is posed by the movement of shipping along the main shipping lanes virtually all round the southern half of the Island of Singapore.

First of all to examine the dimension of the problem, I wish to outline the sources that predominantlycontribute towards the volume of solid and liquid waste that is discharged into the sea. These are the shipyards along the foreshores of Kallang Basin, Jurong, Sembawang and the rivers of Geylang, Kallang and Rochore. The solid waste is mainly composed of timber debris, polythene bags and garbage; and the liquid waste is mainly of sludgy mixture of bilge oil and other forms of industrial effluent. Both equipment and human failure in the operation of discharging, loading or transferring petroleum between ships and between ship and shore is a constant source of pollution. Indiscriminate jettisoning of solid waste and the pumping out of the bilges particularly during the hours of darkness by ships and craft in harbour are considered to be the main contributors to the day to day problem. The concentration of oil refineries and terminals within the western region of the port and the ships that call at these centres to load or unload petroleum besides being a potential source of major oil pollution hazard also contribute to the pollution of the sea from time to time as a result of human or equipment failure.

The Port of Singapore Authority which has the responsibility of ensuring the cleanliness of Singapore waters maintains continuous surveillance against all these sources of pollution during the daylight hours; but sustaining the effort during the hours of darkness has not been very fruitful owing to the impracticability of detection. The Anti-Sea Pollution Unit of the Authority is the only organisation in Singapore which has a reasonable capability and operational flexibility to deploy and combat an oil spill at short notice. For the year ending 1971, the Authority's Anti-Sea Pollution Unit attended to 132 cases of sea pollution and used 202, 415 litres (44,526 gallons) of detergent and the operational cost was more than a million dollars. It also collected 107.5 tons of debris. For the same period, 94 cases were taken to court and hitherto 49 cases have been convicted.

The cumulative effort however of all these foregoing sources of pollution does not pose as great a threat as a maritime accident, which could occur either at the number of oil refineries that exist around Singapore or in the navigable waterway, as a result of collision or even by grounding on the vast number of shallow patches that are found within and without the waters of Singapore. To give an indication of operational and cost involvement in a medium marine incident, the ' EVERGRAND ' case absorbed 300 men, 20 crafts and 10,000 gallons of dispersant to combat continuously for more than 180 hours. The amount of oil that was spilt was approximately 400 tons as a result of the barge sinking while loading slop from a tanker.

In comparison to the above, a marine mishap involving a fully laden tanker could have the most disastrous and costly consequence and a study of the chart of this region would give some indication of the high probability of such an event taking place. To examine first of all the constraints to navigation in the waters around Singapore, there are three bottlenecks along the main shipping lane around the Island in the west, south and east. The western bottleneck is between Tanjong Piat and the Karimun Island at the southern end of Malacca Straits, where the aids to navigation are not particularly adequate to ensure a high degree of accuracy of a ship's position especially when it is the course alteration zone for both the east and west bound ships. Though not firmly established, this could well have been the reason for many a ship stranding from time to time on the island of Nipa which is approximately six miles south of Sultan Shoal Light. Most ships navigating through the Main Strait confine themselves to within approximately two-mile width lane nearer the west Malaysian coast. The tidal current pattern around Singapore is such that in a monthly cycle the current flow is easterly for one third of the period and westerly for the remaining period. Therefore, the probability of flotsam and oil spillage in the western bottleneck being carried into the port waters though not very high but still there is good chance owing to the close proximity to the port limit.

The closest and the worst of the bottlenecks is between Raffles Lighthouse, Peak Island and the surrounding Indonesian Islands. The Phillip Channel and the Main Strait in the vicinity of Raffles Lighthouse are narrow and the bend relatively sharp for east and west bound ships. A fully laden super tanker navigating through these channels has very little alternative to take bold avoiding action against collision or for that matter grounding should a navigational error or error in judgement be realised at any point within about six miles radius of Raffles Lighthouse. Although super tankers intending to navigate through this area send navigational warning signals to the shipping community at large to keep clear of them in this particular region, this is by no means a full proof method of minimising the probability of an accident. Any spillage of oil into the waters between Raffles Lighthouse and St. John's Island would partly find its way on to the beaches of the Southern Island of Singapore because of their proximity to the shipping lane. And any cleaning up operation in this area will be particularly difficult because of shoals and general navigational hazards.

The eastern bottlenecks are at the approaches to the Horsburg Lighthouse between the south eastern coast of Johore Strait and the Bintan Island of Indonesia. Although the waterway in this region appears to be wide, the normal navigational lane for most ships is only of about 2-mile width. A major accident in this area would inflict serious damage to the southern coast of Johore and the eastern approaches to Singapore. As it often does any scale of oil spillage in this area would effect the popular recreational beaches on the east coast. The situation is further aggravated by the longer period and stronger west flowing current.

With almost one hundred per cent increase in the world shipping tonnage in the last ten years, with approximately ninety per cent of Japanese tankers with increasing capacity transiting through this region and with general increase in sea borne trade in the Far East and South East Asia, it is only logical to state that the probability of marine accident would proportionately be higher. Despite the many modern technological innovations to minimise marine accidents, analysis of accidents at sea has always revealed the element of human error as the fundamental cause. Therefore, the threat of pollution by oil resulting from marine accidents in this region is a matter of great concern to Singapore. In the light of two recent incidences in the Phillip Channel and the Main Strait in the vicinity of Batu Berhenti, it can be said that we have come quite close to a major oil pollution disaster. One 200,000 ton fully laden and east bound struck a submerged object in the Phillip Channel and sustained damage to the hull. Within an interval of about two days, another 200,000 ton tanker also fully laden and east bound also struck a submerged object off Batu Berhenti and sustained damage to the hull. The same day the Port of Singapore Authority received an aerial report of a few miles long oil slick in the vicinity of Horsburg Lighthouse. Fortunately, the tidal current was favourable enough to carry the oil out to the South China Sea.

REMEDIAL ACTIONS

The remedial actions against the menace of sea pollution can broadly be categorised into two i.e. one which is within the statutory control of Singapore and the other which is only possible with the understanding and cooperation of the countries in the region.

Prior to coming into force of the Prevention of the Sea Pollution Act, 1971 in 1st February, 1972 the Port of Singapore Authority with the powers vested in it by the Port of Singapore Authority Ordinance 1963 (now Port of Singapore Authority Amendment Act 1971) made regulations to control pollution of the waters of Singapore. Regulation 101(2) of the Singapore Port Regulation 1970 states the following : -

" If any person discharges, throws or deposits into the water of the Port or causes or permits to escape or be discharged, thrown or deposited thereinto, any oil, dirt, rubbish, corpse or carcase otherwise than in persuance of written permission in the behalf granted by th Port Master such person shall be guilty of an offence under these regulations "

Extensive surveillance of the waters of Singapore is achieved by authorising all PSA staff afloat to board any vessel seen to commit a pollution offence and to execute preliminary investigation procedure in order that the culprit may be prosecuted. The cooperation of other statutory bodies and government departments which have their staff afloat in execution of their day to day functions has also been sought to maintain vigilance and to report any case of pollution that may be sighted. This system has met with reasonable success in apprehending and convicting the culprits. Fines imposed on those convicted is not in itself adequate deterrent but the liability to pay for the cleaning up operation is often the greatest deterrent factor.

In terms of equipment, the Anti-Pollution Organisation of the Authority is equipped basically with detergent spraying system and craft to agitate after treatment. Currently, it is not equipped with oil skimmers to carry out large scale effective oil collection which of course is a better method to spraying great quantities of toxic substance which might be harmful to marine life. One of the greatest difficulties in cleaning up operation in the waters of Singapore is that owing to its configuration, unless prompt and speedy action is initiated the oil slick lands on the beaches and creates a more tedious task involving a great deal of manpower and time. A very recent example of such a situation was the "Petra" case in which the ship caused to spill over the side a few tons of oil during transfer operation thereby polluting approximately one and a half miles of beach in the Sembawang area. It involved hundreds of manhours from PSA, Public Health and the Ministry of Defence literally digging out the beach to attain some measure of cleanliness.

All oil refineries and some shipyards have basic items of spraying equipment and slick booms which are used for their own purpose. However in the event of an emergency, there is a contingency plan for voluntary contribution of all available resources from all sectors for a mop up operation. This plan is called the Emergency Action Procedure against Major Oil Pollution - code name MOP. The main objective of the plan is to muster all available resources and effectively deploy them with the PSA coordinating and controlling all activities. The plan being relatively new and having not been subject to test it is not possible at this stage to state whether it is either effective or complete. One of the possible drawbacks or a weak link in the existing working arrangement is that it is voluntary and therefore the participants are not compelled to provide prompt and maximum contribution.

It will be in the interest of all concerned if this anomaly is removed by legal obligation to ensure that prompt and efficient service is provided at all times. This is of vital importance particularly in Singapore waters to minimise damage to property and pollution of the beaches.

Now the governments all over the world are being pressurised by the problem of oil pollution the trend is to introduce legislation in keeping with the principles of International Convention for the Prevention of Pollution of the Sea by Oil 1954 (amended 1962) and Brussel's 1969 Convention on Civil Liability for Oil Pollution Damage. The latter Convention provides that tanker owners are liable irrespective of fault except act of war, sabotage or an irresistable natural phenomenon. The liability if limited to US$140 per grt or US$14 million whichever is the lesser. Except for Canada a number of countries out of a total of thirty four backed the Convention on the understanding that IMCO brought about a scheme to ensure victims are fully compensated and a compensation fund is created to relieve shipowners of the additional financial burden imposed by the Convention. Towards this end, the IMCO has already formulated a scheme known as the International Compensation Fund which requires oil importers to provide US$ 30 million over and above the US$ 14 million limit required by the 1969 Convention. A conference in December last year was held to adapt the Compensation Fund Convention at which Singapore was represented.

Repugnant to these Conventions was the creation of TOVALOP (Tanker Owner's Voluntary Agreement Concerning Liability for Oil Pollution) and CRISTAL (Contract Regarding Interim Supplement to Tanker Liability). It is said that the object of creating these voluntary insurance schemes was to discourage governments from enacting legislations for additional liability. There is a likelihood of these schemes of voluntary liability being completely replaced by when the world at large introduces legislation for legal liability.

The provisions of international conventions and local legislations besides inculcating intense awareness and providing financial security it does not necessarily guarantee protection against pollution problem. What is really required is international or regional cooperation in formulating practical schemes to minimise probability of maritime disasters or eliminating other sources of sea pollution. Therefore, the sooner, we examine our needs and establish a workable scheme the better our chance against the menace of sea pollution.

Paper No. II/13

INDICATIONS OF THE RELATIONSHIP BETWEEN PHYTO-PLANKTON DISTRIBUTION AND PHOSPHATE LEVELS

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ABSTRACT

Phosphates and nitrates are known to cause algal 'bloom' in impounding reservoirs if they are present in appreciable quantities in the water. From an earlier study, these radicals are known to be present in varying quantities in our streams. However, in the Republic no tolerance levels have been set either for running streams or for stored water in the reservoirs. A project was initiated in December, 1971 to study phyto-plankton distribution in relation to levels of these radicals in our reservoirs, which it is hoped, eventually will help formulate raw water standards for these two radicals.

This report deals with some preliminary findings on phosphate values and phyto-plankton distribution. Water samples were collected at various depths from Seletar Reservoir (280 ha), Peirce Reservoir (110 ha) and MacRitchie Reservoir (102 ha). A total of 11 stations were sampled in Seletar Reservoir and 4 each in Peirce and MacRitchie Reservoirs.

The phosphate values (expressed as elemental P) at various depths in MacRitchie Reservoir range from 0.26 μg-atom/l to 0.78 μg-atom/l (mean = 0.45 μg-atom/l); those of Peirce Reservoir from 0.05 to 0.50 μg-atom/l (mean = 0.28 μg-atom/l); and those of Seletar Reservoir from 0.31 to 1.46 μg-atom/l (mean = 0.88 μg-atom/l).

Although from this preliminary analysis, it is not possible to state the exact phosphate level at which undesirable algae begin to proliferate in the water, there is clear indication that the higher phosphate levels of Seletar Reservoir have given rise to an algal population commonly found in highly eutrophic waters and consisting predominantly of genera such as Dictyosphaerium, Scenedesmus, Coelastrum (Chlorophyta), Microcystis, Oscillaforia, Phormidium, Aphanocapsa and Merismopedia (Cyanophyta).

Contrasting, one notes a high proportion of innocuous algae such as Cosmarium and Staurastrum (Chlorophyta) in Peirce and MacRitchie Reservoirs in which phosphate values are lower. These 2 genera constitute 80% of the algae in Peirce Reservoir and 96% of the algae in MacRitchie Reservoir.

Growth of pure culture of Scenedesmus species were observed in filtered water collected from the 3 reservoirs and the best growth was observed in the Seletar water indicating once again possible correlation with the phosphate values.

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INTRODUCTION

One of the major problems of water resource management is the eutrophication of impounded waters. The eutrophication normally sets in when nutrients, particularly phosphates and nitrates, have reached an appreciable level, thereby increasing primary productivity and causing algal blooms. This in turn can influence the economics of water treatment for potable purposes.

In general, as nutrient level of a body of water increases, species composition of phyto-plankton shifts in dominance usually in the order: diatoms, green algae and finally blue-green algae and flagellates, the last group occurring in water with high organic matter.

Algal blooms are usually dominated by the blue-green species of algae and it has been frequently reported that succession of blue-green algae in this phenomenon produces toxins which are fatal to fish and animals and they constitute a health hazard to man [6] [3].

Certain organisms such as *Microcystis* and *Oscillatoria* can serve as indicators of eutrophic waters. However, these organisms can only indicate eutrophic conditions existing in a body of water but fail to provide an early warning system to implement measures to prevent further deterioration. Quantitative methods of assessing the degree of eutrophication such as regular determination of oxygen, rates of oxygen consumption, biological productivity, transparency and nutrients levels can be used. Bio-assay such as the pure algal culture techniques in the assessment of growth promoting properties of these can also be used.

Although eutrophication is a universal phenomenon attributable to phosphates and nitrates in the raw water yet little has been done in any country to determine levels of chemicals which would lead to the phenomenon. No reliable information is available in Singapore concerning this phenomenon. A project was therefore initiated in December 1971 to study the species composition and distribution of phyto-plankton in relation to different levels of these radicals in our reservoirs. It is hoped that this study will eventually help to formulate raw water standards for these two radicals in Singapore. This report deals with some preliminary findings on phosphate values and phyto-plankton distribution in the reservoirs with special reference to Seletar Reservoir.

THE INVESTIGATIONAL SITES

The three reservoirs from which water samples were taken viz. Seletar Reservoir (280 ha), Peirce Reservoir (110 ha) and MacRitchie Reservoir (102 ha) has catchment areas totalling 2,717 ha. Reference to a map will show that in fact the catchment areas form a continuous piece of land. The vegetation cover of the catchment areas, however, varies from place to place, and together forms a mosaic of near-primary high forests to open shrubland. The streams draining into MacRitchie and Peirce carry high quality raw water by virtue of the fact that the catchment areas are practically uninhabited while certain streams feeding Seletar flow through some farming areas and have been observed to carry appreciable amounts of organic materials.

Water from Seletar Reservoir is pumped into Peirce Reservoir, from which water in turn overflows into MacRitchie Reservoir.

SAMPLING METHODS

Altogether there were 19 sampling stations with 14 located in Seletar Reservoir and 4 each in Peirce and MacRitchie Reservoirs. The positions of the sampling stations are indicated in Figure 1.

Water samples were collected at various depths by the Kitahara water sampler for the determination of dissolved oxygen concentration, temperature, density and species composition of plankton. Plankton samples were preserved in 4% neutralised formalin, later to be concentrated by centrifuge in the laboratory. Transparency was determined by Secchi disc. Dissolved oxygen concentration was determined by Winker's method. Phosphate-phosphours (PO_4-P) concentration was determined by Deniges method [1] using the spectronic 20 spectrophotometer set at 700 $m\mu$ wave length. The values of the element P was expressed in μg-atom/l.

Growth of pure culture of *Scenedesmus* sp., a common species of green alga in Singapore waters, was used to indicate the relative fertility of the water sampled in different localities and at different depths, the water having been first properly filtered. Five drops of a suspension of *Scenedesmus*, cultured in Matsudaira medium [4] were innoculated into a 50 ml of sample water. The culture was allowed to grow for four days under laboratory conditions with constant lighting after which *Scenedesmus* density was determined by reference to a pre-calibrated density curve at wave length of 507.5 $m\mu$. In this way, densities of *Scenedesmus* of different water samples can be compared.

The depths of sampling stations varied from 3.8 to 15 m at Seletar, 1.0 to 5.5 m at Peirce and 3.0 to 7.0 m at MacRitchie.

RESULTS

The temperature for all 3 reservoirs ranged from 26.0°C to 28.5°C, depending on depths. No thermocline was observed.

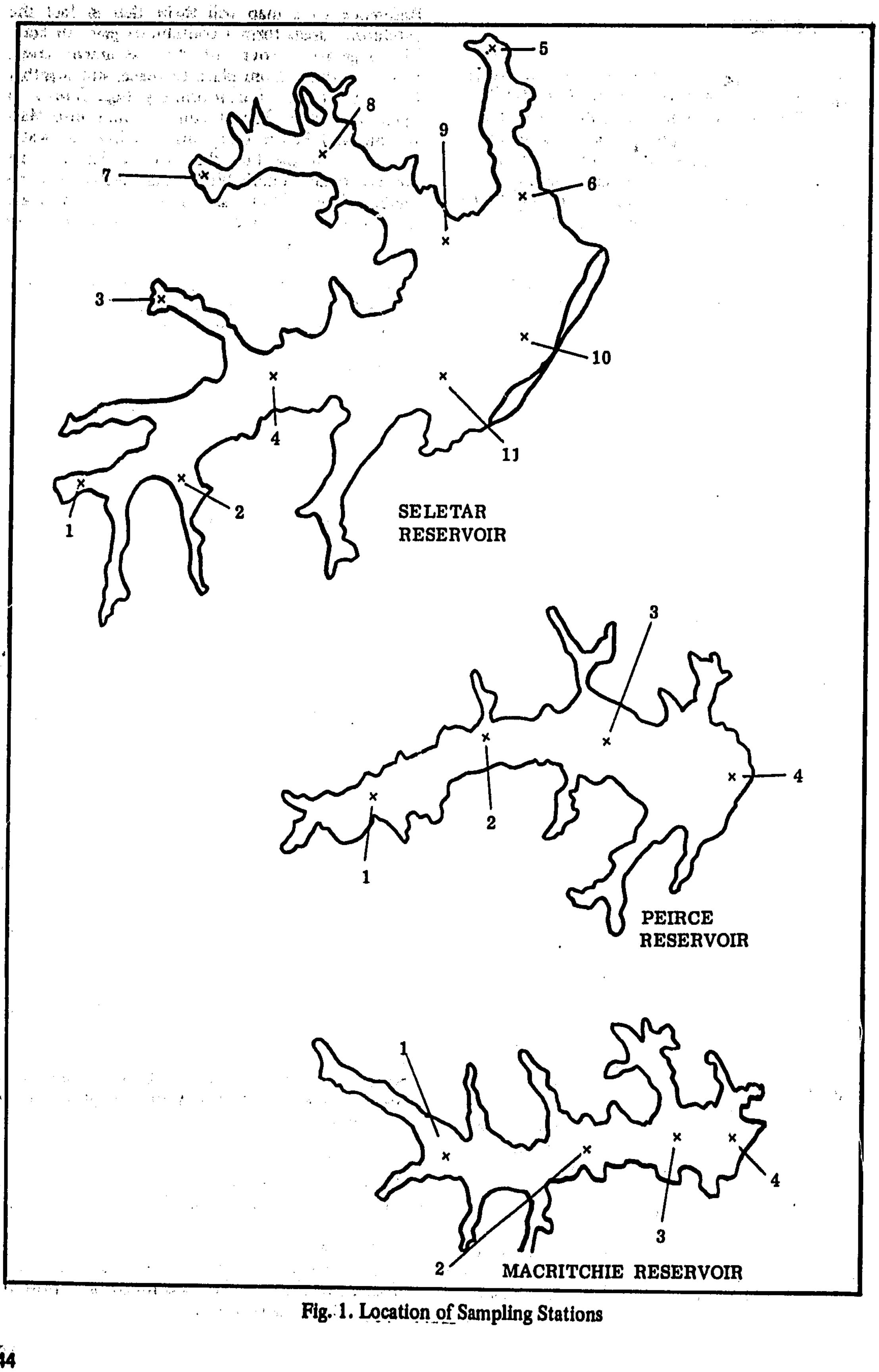

Fig. 1. Location of Sampling Stations

Table 1 illustrates the dissolved oxygen concentration at various depths for three reservoirs. It varied from 0.43 to 5.52 ppm in Seletar, 4.00 to 6.48 ppm in Peirce and 3.48 to 6.50 ppm in MacRitchie.

Table 2 illustrates the phosphate-phopshorus contents at various depths for all reservoirs. It can be seen that the phosphate values expressed as elemental P in Seletar Reservoir ranged from 0.31 to 1.46 μg-atom/l (mean = 0.88 μg-atom/l); those of Peirce Reservoir from 0.05 to 0.50 μg-atom/l, (mean = 0.28 μg-atom/l); and those of MacRitchie Reservoir from 0.26 μg-atom/l to 0.78 μg-atom/l (mean = 0.45 μg-atom/l).

Plankton composition in the MacRitchie Reservoir was markedly different from that of Seletar Reservoir. However, because Peirce Reservoir is connected to both MacRitchie and Seletar Reservoirs in a manner as described earlier, its plankton composition has some species common to the other two reservoirs (Table 3).

Cosmarium and *Staurastrum*, rare in Seletar Reservoir, were the dominant groups of green algae in MacRitchie and Peirce Reservoirs. These two genera constituted 96% and 80% respectively of the algae present in the samples. Some *Dictyosphaerium, Microcystis* and the flagellate *Trachelomonas*, present in great abundance in Seletar Reservoir, were also found in appreciable amount in Peirce Reservoir.

In Seletar Reservoir, the dominant groups of phytoplankton were *Dictyosphaerium, Colastrum* and *Scenedesmus* of the green algae (about 55%) and Oscillatoria, *Microcystis, Phormidium, Aphanocapsa* and *Merismopedia* of the blue-green algae (about 30%). Some rotifers and *Trachelomonas* were also present in appreciable quantity.

The bio-assay experiment on the growth of pure culture *Scenedesmus* in water collected from the three reservoirs showed that the best growth was attained in the Seletar water (Table 4). In the other two reservoirs with much lower phosphate values, the growth of the green alga was less prolific. It appears that there is some correlation between growth of the alga and phosphate values.

DISCUSSIONS

From the above preliminary observations, although it is not possible to state the exact phosphate level at which nuisance blooms of algae begin to establish in the water, there is clear indication that the higher phosphate levels of Seletar Reservoir have given rise to an algal population commonly found in eutrophic water.

Water with high nutrient contents are often accompanied by low dissolved oxygen. This has been clearly shown in certain areas of Seletar Reservoir.

In terms of phosphate loads, there is no doubt that the water in the Seletar Reservoir is of a lower quality than that in both the Peirce and MacRitchie Reservoirs. One can mention several possible contributing factors responsible for the high phosphate contents of the Seletar water. Since water for the Seletar Reservoir is abstracted from streams draining rural areas with various densities of human population and different intensities of agricultural activities, one can say that the phosphate could have come from water closets, animal wastes, pisciculture (some making use of animal wastes), synthetic detergents and possibly fertilizers. However, since no quantitative study has been made it is difficult to say with certainty which particular factor is the more serious one. When the Seletar scheme was launched people living within the catchment areas were required to install water-sealed latrines and pig farms were required to build cesspits to contain pig-wastes. Although most of the farmers complied with this measure some of the cesspits were observed to have suffered from overloading and some pig wastes must have found their way into the water courses; therefore pig wastes could have contributed to the phosphate load of the water.

It is often thought that the agronomic practice of using pig wastes to fertilise fish ponds, such as some farmers are doing in Singapore, is contributing much to pollution of the streams into which pond water is discharged periodically. This, however, is controversial and may indeed be a misconception. It is known that phyto-plankton and zooplankton can concentrate large quantities of phosphates in their cells. Thus, phytoplanktons and certain aquatic weeds have 250 times and zooplankton 20,000 times, more phosphorus in their systems than is found in the surrounding water [7]. This being the case, harvesting of fish feeding on such plankton in ponds fertilized with pig waste would in fact be removing large quantities of phosphate from the water which otherwise would have found their way into the impounding reservoirs. Viewed from this angle, we can say that fish culture such as rearing of carps, which are known to be voracious plankton and weed feeders, is an efficient way of biological control of eutrophication.

Manuring of crops using chemical fertilizers has been one of the major causes of water pollution in agricultural countries especially where aerial application is widely practised. But in Singapore, little chemical fertilizers are used and it is unlikely that horticultural practice contributes much to phosphate contamination of our streams.

Depth (m) \ Stn.	Seletar Reservoir											Peirce Reservoir				MacRitchie Reservoir			
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	1	2	3	4
0	4.1	4.7	4.1	4.1	2.2	3.3	5.5.				4.1	6.5	5.9					6.2	6.5
1.5	4.1	4.6					5.5												
2			3.3	3.9	1.5	2.6							2.2	6.1			6.3		
2.5									0.4						5.0	6.0		5.0	
3	3.3	3.7					4.1			4.0	4.1			5.9				5.0	6.0
4			2.6	3.5	0.5	1.8											5.2		
4.5		3.4																	
5							2.1		1.4		2.9			4.1				3.5	
6		2.5		1.2		1.1		0.6		2.0									4.9
7									1.3										
8				0.3		1.0		0.3			0.5								
9									1.0										
10				0.9		1.0				1.6	0.5								
11									0.9										

Table 1. Dissolved Oxygen Concentration (ml/l) at Various Depths for All Three Reservoirs

Stn. / Depth (m)	Seletar Reservoir											Peirce Reservoir				MacRitchie Reservoir			
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	1	2	3	4
0	0.8	0.8	0.6	0.6	1.0	0.8	0.3	0.4	0.5	1.0	0.5	0.3	0.1	0.5	0.3	0.5	0.5	0.3	0.4
1																0.3			
1.5	0.8						0.8												
2			0.6	0.9	1.0	1.1		0.3					0.1	0.3			0.5		
2.5									1.5						0.3	0.5		0.4	
3	0.8	0.8					1.0			1.3	1.5			0.4				0.4	0.3
4			0.6	0.8	1.0	1.3		1.0									0.6		
4.5		0.8																	
5							0.8		1.4		1.0				0.3			0.8	
6		0.8		2.0		1.0		0.9		1.1									0.5
7									1.0										
8				0.6		0.9		0.8			0.8								
9									0.8										
10				0.7		1.0				1.1									
11									0.8										
12																			
13																			
14										1.0	1.0								
15																			

Table 2. Phosphate - Phosphorus Contents (μg - atoms/l) at Various Depths of All Reservoirs

Main Group of Plankton	Seletar Reservoir		Peirce Reservoir		MacRitchie Reservoir	
	Dominant Plantkon	%	Dominant Plankton	%	Dominant Plankton	%
Green algae	*Dictyosphaerium* *Coelastrum* *Micractinium* *Scenedesmus* *Selenastrum*	55	*Cosmarium* *Staurastrum* *Dictyosphaerium*	80	*Cosmarium* *Staurastrum*	96
Blue-green algae	*Oscillatoria* *Microcystis* *Aphanocapsa* *Merismopedia* *Phormidium*	30	*Microcystis*	7		
Flagellate	*Trachelomonas*	10	*Trachelomonas*	8		
Others	*Rotifer*	5		5		4

Table 3. Relative Abundance (%) of the Main Plankton Groups Occurring in the Three Reservoirs

Depth (m) \ Stn.	Seletar Reservoir											Peirce Reservoir				MacRitchie Reservoir			
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	1	2	3	4
0	12.0	9.6	26.0	9.6	14.0	22.0	8.6	13.0	16.0	12.0	7.9-	6.9	8.0	5.0	5.3	5.7	6.1	5.8	6.9
1																5.6			
1.5	7.6	6.8																	
2			14.0	9.8	14.0	22.0	14.0	14.0					7.2	6.4			5.5		
2.5									18.0						5.0	5.5			
3	18.0	21.0					16.0			15.0	6.5			5.8				4.9	4.7
4			8.8	9.8	19.0	88.0		10.0									6.2		
5		13.0					10.0		15.0		17.0				6.8			6.3	
6		12.0		12.0		11.0		18.0		12.0									5.7
7									9.6										
8				9.8		16.0		18.0			13.0								
9									14.0										
10				22.0		19.0				22.0									
11									12.0										
14										14.0									

Table 4. The Growth of Pure Culture *Scenedesmus* in Water Collected from Various Depths of the Three Reservoirs (Colony numbers in 1000 units per litre)

The role of synthetic detergents in stream pollution and subsequent eutrophication of impounding reservoirs has not received much attention in the Republic. Detergents are freely used for daily household purposes and it is a fair assumption that much of the phosphates of Seletar Reservoir could have come from this source. Fosberg [2] states that some detergents contain up to 10% by weight of phosphorus in the form of polyphosphate. Owens and Wood [5] basing their estimate on a report by the Committee on Synthetic Detergents in Britain, estimated that about 50% of the phosphorus in sewage effluent was derived from detergents, the contribution in absolute terms being 3.5 mg of elemental P/l of water. In Europe and America it is estimated that 20-50% of all phosphorus entering surface waters is of detergent origin (Abstract No. 624, Water Pollution Abstr. 1969).

From the foregoing, it is obvious that apart from our present attempt to discover tolerance levels of chemical radicals in the raw water in a general effort to minimise eutrophication, it is also essential to initiate researches to discover the relative roles of the various contributing factors in the various localities so that efficient control measures can be meted out. In this connection, it is envisaged that numerous monitoring stations have to be set up to gather such information.

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Paper No. II/14

RESEARCH ON THE CULTURE OF CERTAIN COMMON MARINE ORGANISMS IN SINGAPORE WATERS

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ABSTRACT

Singapore is an island and it is only natural that some research effort should be devoted to the study of the biology of the more common marine organisms. Among some of the problems presented by the trade in marine resources is that of the diminishing supply of oysters, mussels, certain seaweeds, marine prawns, exotic marine aquarium fish and certain species of marine food fish used for the restaurant trade.

The experimental cultivation of Eucheuma spinosum, a local red alga, which is being harvested by fishermen in increasing quantities and exported to the USA, Europe and other developed countries is described. The experimental cultivation of the local green mussel, Mytilus viridis, a local oyster, Crassostrea cucullata and certain marine prawns as well as a marine copepod, Paracalanus crassirostris is also described. The main problems encountered in this type of mariculture are also briefly described.

INTRODUCTION

Singapore is an island and it is only natural that some research effort should be devoted to the study of the biology of the more common marine organisms. Among some of the problems presented by the trade in marine resources is that of the diminishing supply of oysters, mussels, certain seaweeds, marine prawns, exotic marine aquarium fish and certain species of marine food fish used for the restaurant trade.

Eucheuma spinosum, a local red alga, is being harvested by fishermen in increasing quantities and exported to the USA, Europe and other developed countries. The trade in this seaweed in Singapore has reached $1.5 million per annum. As the seaweed is found abundantly only in the inshore waters of Singapore, Indonesia and the Philippines, the continued harvesting of the natural stocks in increasing quantities raised fears of depletion and a method of cultivation had to be formulated. The preliminary experiments in growing this seaweed in Singapore waters are extremely encouraging.

The local edible oyster, *Crassostrea cucullata,* is very popular with local consumers in spite of its small size. Stocks have dwindled so much that many of the 'oh luak' or oyster omelette sellers do not have oysters to ply their trade on some days of the week. The main difficulty in the culture of this oyster is the heavy settlement of barnacles on the oyster spat collectors thus making it uneconomic to collect young oysters for cultivation. The preliminary experiments have shown how this difficulty can be overcome.

The local feed mills have to import over $5,000,000 worth of fish meal for compounding the balanced feeds for pigs and poultry. Tan [2] found that the local green mussel, *Mytilus viridis,* has an amino acid composition comparable to high quality fish meal and should be very suitable for use as a feedstuff especially in pig rations. This green mussel grows well in Johore Straits. The nutrient content of the water in Johore Straits is increasing rapidly and it is considered that the cultivation of a filter feeder such as the green mussel on a large scale would help to remove a fairly large portion of the plankton blooms, thus restoring the natural balance in the water. Experiments on the culture of this mussel were therefore started.

With the rapid increase in the intensity of prawn trawling in the South China Sea, it may be expected that, before long, we should be very short of wild prawns as in Japan and prawn culture would be a lucrative undertaking. Experiments on the culture of two of the most highly priced prawns were therefore started.

The trade in marine exotic aquarium fish is increasing and it may be expected that before very long, there will be a need to culture such species. A study of the biology of a local inshore marine fish was carried out to elucidate some of the more important problems in the culture of marine fish in this part of the world. At the same time, the experimental culture of a marine copepod, *Paracalanus crassirostris,* a typical food for larval and juvenile marine fish, was also started.

EXPERIMENTAL CULTIVATION OF A RED ALGA, *EUCHEUMA SPINOSUM*

This red alga is collected along the coasts of Singapore, Indonesia and the Philippines. It has a very good market in the sun-dried form in USA, Europe and several other countries and is used, inter alia, as a base for face cream. Experiments carried out in Johore Straits showed that this alga could grow very fast. Its weight could be doubled in about 40 to 50 days. The water in which this growth rate has been observed has a temperature varying from $28^{0}C$ to $31^{0}C$, a dissolved inorganic phosphate content of 60 mg P_2O_5/m^3 to 150 mg P_2O_5/m^3, a nitrate nitrogen content of 45 mg/m^3 to 85 mg/m^3 and a salinity varying from 28^{0}/oo to 30^{0}/oo.The light intensity at the depth at which this alga was grown was between 2,000 lux to 15,000 lux.There was a fairly strong current during 16 out of the 24 hours of the day. The water was fairly clear. Further details of this preliminary study are given by Tham [4].

EXPERIMENTAL CULTIVATION OF THE LOCAL OYSTER, *CRASSOSTREA CUCULLATA*

The local oyster, *Crassostrea cucullata,* is much relished by the local consumers, especially when cooked as oyster omelette (Oh Luak). In recent years, the supply of local oysters has declined. Oysters imported from Japan and Australia are costly and local 'Oh Luak' consumers appear to prefer the local oyster. Attempts to collect oyster seed by conventional methods using tiles and other materials coated with lime were not successfu[illegible]inly because of the heavy settlement o[illegible]les which eventually crowded out the oyste[illegible] was accidentally found that with nylon rope as a collector the settlement of oyster spat was satisfactory and settlement of barnacles was at a minimum.

It was also observed, that nylon rope was superior to other collectors including ropes of other materials. Among nylon ropes of different colours, it was found that the best collection was obtained by dark green nylon rope under shade and by blue nylon rope when partly exposed to direct sunlight during low tide. White and yellow nylon ropes obtained the poorest catches.

Oyster spat could be collected throughout the year but they were most abundant during January/February and May/June. They settle in a zone between 3 ft and 15 ft below the water surface at the highest high water spring tide, the densest settlement being between 4 ft and 8 ft below the water surface at the highest high water spring tide. Settlement of spat was also more intense on collectors placed under shade.

The growth of *Crassostrea cucullata* was slow, of the order of 0.096 mm per day. They attained a mean size of 26.96 mm in 10 months. They were found to be mature at around 20 mm. The growth of another species of oyster, *Crassostrea rivularis,* was also studied and its growth rate appeared to be much faster varying from 0.18 mm per day to 0.89 mm per day. The mean daily growth rate was found to be 0.34 mm per day and in 6 months it reached an average length of nearly 63 mm.

Artificial fertilisation of *C. cucullata* was tried and found to be successful. The period of development from the time of fertilisation to the early umbonal stage is between 10 and 18 days. Cross fertilisation between four local species of *Crassostrea* was tried and fertilised eggs were obtained. In most cases, the fertilised eggs developed to the swimming or rotating stage. In a few cases the straight-hinged stage was reached. However, high mortality of oyster larvae was encountered during these studies and this was apparently caused by the large number of ciliates in the culture medium. Full details of this study are given by Yang [6] in his thesis for the degree of Master of Science.

LABORATORY CULTURE OF A LOCAL MARINE COPEPOD, *PARACALANUS CRASSIROSTRIS*

For the successful culture of certain species of marine fish and the larval and young stages of almost all species of marine fish, it is necessary to have an adequate supply of planktonic food, of which copepods must form a fairly large proportion. For example, young seahorse cannot be reared successfully in aquaria mainly because of the lack of zooplankton food.

An attempt was therefore made to cultivate

Paracalanus crassirostris, one of the most common local marine copepod in coastal waters, in the laboratory. Active and mature females with dark spermathecae were picked out from freshly collected plankton samples and transferred to rectangular plastic tanks, each of about 7 litres capacity and containing 4 litres of freshly collected and filtered sea water. About 200 females were placed in each tank. The temperature of the tanks were maintained at 26°C 28°C and they were all well aerated.

The nauplii started to hatch out about 2 days later. Usually it took the males 9 -12 days to pass through the 6 naupliar and 6 copepodid stages, whilst the females took 10-15 days. The life span of the females was found to be about 23 days and that of the males about 15 days. They were fed with cultured diatoms belonging to the species *Nitzschia closterium*.

It was found that *P. crassirostris* could survive and breed under laboratory conditions for about 3 to 6 generations and live for about 30 to 73 days. When the culture medium was changed, say, once a week, the least number of generations and the shortest surviving periods were obtained. But when the water was left unchanged, then the number of ciliates (*Carchesium* species) would increase considerably and cover the bodies of the copepods, thus killing them.

Whilst the culture of *P. crassirostris* could be carried out in the laboratory, mass production is not yet possible in the laboratory. Full details of this study are given by To [5] in her thesis for the degree of Master of Science.

LABORATORY CULTURE OF TWO LOCAL PENAEID PRAWNS

This study was carried by Teng [3] and forms part of his thesis for the degree of Master of Science. The two species studied are *Penaeus merguiensis* and *Metapenaeus brevicornis* which are among the most highly priced marine market prawns in this region.

Live mature females of *M. brevicornis* and *P. merguiensis* were caught at sea and transferred to an aquarium tank. While the mature females of *M. brevicornis* had white conjugal pads, those of *P. merguiensis* did not seem to possess these conjugal pads but had sperm packets attached to the external genitalia.

Before spawning, the mature female swims rapidly up and down as well as to and fro in the tank, with its pereiopods moving vigorously sideways and its pleopods moving forwards and backwards. This activity continues for one to two hours, after which it sinks to the bottom, resting quietly for about 15 minutes. Then it floats up with the posterior part of the body bent slightly forwards and the pleopods moving rapidly. At the same time two streams of eggs are ejected from the genital openings on the coxa of the third pair of pereiopods, passing between the fifth pair of pereiopods and then outwards near the first pair of pleopods. This continues for 2 to 3 minutes after which it sinks to the bottom of the tank to rest for about 1 minute. After this rest period, it floats up again and spawning is resumed.

In the case of *M. brevicornis*, the number of spawned eggs is estimated to be of the order of 150,000 for a mature female of 4 inches total length. In the case of *P. merguiensis* the spawning behaviour pattern is similar to that of *M. brevicornis* but the spawned eggs have a larger diameter In both cases the nauplius hatches out in about 11 to 12 hours at 26°C-28°C. In the case of *M. brevicornis*, 6 naupliar, 3 protozoeal, 3 mysis and 12 postlarval stages were observed, whilst in the case of *P. merguiensis*, there were 6 naupliar, 3 protozoeal, 3 mysis and 15 postlarval stages.

Both protozoeal and early mysis stages fed voraciously on yeast cells. The later mysis and early postlarval stages fed on both yeast cells and newly hatched nauplii of *Artemia* and copepods. The later stages of postlarvae fed voraciously on the flesh of a sea snail, *Telescopium telescopium*. High mortality of the naupliar and protozoeal stages were experienced because of the presence of large numbers of ciliates. Mortality after the mysis stages was much less.

LABORATORY CULTURE OF A LOCAL MARINE FISH, *CHANDA KOPSII*

In the study of the biology of marine fish one cannot help but be impressed with the very high mortality of the larval and juvenile stages, due to predation and adverse environmental factors. Although certain species have a high fecundity of over one million eggs per individual, comparatively small numbers survive at the commercially fishable stage. With the increasing exploitation of the world stocks of marine fish, fisheries scientists all over the world have focussed their attention on the feasibility of cultivating marine fish species. Marine fish culture is a comparatively new undertaking and it is felt that the study of the biology of a local coastal species would throw light on the problems which may be encountered in the mass culture of fish. It was thought that the local glassfish, *Chanda kopsii*, which has been found to mature throughout the year, could be used with advantage because it is cheap and the cost of the experiment will thus be low.

It was found that both sexes of this species could be stripped and the eggs fertilised. The young fish hatched out in 12-14 hours. At the age of 5 days, the yolk sac was fully absorbed and the length of the larva was about 2.6 mm. At the age of 50 days, the juvenile stage (9 mm in total length) was reached.The fish matured at a length of 60-70 mm, the age being about 7 - 9 months.

The results of this study indicated that the inshore areas of Singapore form an ideal nursery ground for marine fish. High mortality was encountered beyond the yolk sac stage. It is thought that with an open sea water circulation mortality might have been lower. If juveniles were captured from the sea the problem of high mortality beyond the yolk sac stage would be eliminated. Full details of these studies are given by Chua [1] in his thesis for the degree of Doctor of Philosophy.

EXPERIMENTAL CULTIVATION OF THE GREEN MUSSEL, *MYTILUS VIRIDIS*

This study is being carried out by Leo Tan Wee Hin in Johore Straits and Singapore Straits. The green mussel has been observed to settle at almost any depth from below the halfway level between High Water Spring Tide (HWST) and Low Water Spring Tide (LWST). The tidal range during spring tide is about 3.5 m in Johore Straits. The densest setting was found to be within the range of 2.45 m (8ft) to 4.57 m(15 ft) below HWST. The population density of mussels (av. length = 1 cm) has been estimated to be as high as 200,000 per m^2. This falls off drastically, as the mussels grow to a level of 7,000 to 9,000 when the specimens are 3-5 cm in length. Field experiments carried out to determine the survival of mussels at different depths above LWST showed that the period of exposure to the air tolerable to the animal was the determining factor.

Mytilus viridis in Johore Straits matures at a length of about 2.5 to 3.0 cm. Spawning occurs throughout the year. Fertilisation is external. Induced spawning has been tried in the laboratory with limited success. The pattern of development of the local green mussel is similar to that of *Mytilus viridis* observed in USA except for the time factor. The transition from fertilised eggs to the straight-hinged stage larva takes less than 24 hours. Larval mortality is high under laboratory conditions, the larvae usually dying in the late straight-hinged stage although a few pass into the early umbonal phase. The factors causing the mortality of the larvae have not been fully investigated. It was observed that bacteria and ciliates thrive well in the larval culture medium and they could be the cause of the high mortality. The developing eggs and larvae are not very tolerant to salinities outside the usual range found in Johore Straits (26°/oo - 29°/oo), whilst adult mussels show a considerable degree of tolerance (10°/oo - 3[illegible]o).

Mytilus viridis in Johore Straits siphon actively throughout the 24 hours of the day, so long as it is submerged. The gut is never empty. Seasonal observations revealed that more than half of the stomach contents of the mussels examined consisted of detrital material. Planktonic organisms, mainly diatoms and tintinnids made up the rest. Dinoflagellates, which are regarded as a principal food of other species of *Mytilus* studied in other parts of the world, were frequently found in the gut of *M. viridis* but never in large quantities even during dinoflagellate blooms. Diatoms seemed to be preferred by the local species.

The growth rate of natural population on kelong poles as well as those cultivated on coconut fibre ropes and in experimental plastic trays over periods of 3 to 6 months have been observed to be about 0.89 cm to 1.29 cm per month. These mussels were placed about 1 m above LWST. Further experimental studies on growth rate have shown that there is negative correlation between growth rate and the period of exposure. The most significant finding of the present study is that even at 1.5 m above LWST, *M. viridis* grew much faster in Johore Straits than its European commercial counterpart, *Mytilus edulis*. For example, *M. edulis* in Spanish waters requires 14 months from the time of settlement to grow to a length of 7.6 cm (3ins), whilst *M. viridis* in Johore Straits requires only about half this time. The study is continuing.

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Paper No. II/15

DEVELOPMENT OF BLUE-GREEN ALGAL BLOOMS IN NON-ALKALINE WATERS

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ABSTRACT

On the basis of temperate experience, it has been generally believed that blooms of blue-green algae are unlikely to be a problem in freshwaters unless these are calcium-rich, with high alkalinity, and with high basic pH. Thus the occasional reports of blue-green algal blooms in reservoirs in Malaysia and of incipient blooms (fortunately not developing further) in Singapore reservoirs are unexpected since the majority of these habitats are calcium-poor, low alkalinity, low pH habitats which are generally low in dissolved minerals. Further, our general investigations have shown that a number of fishponds in Singapore with well-developed blue-green blooms were not excessively rich in calcium. Usually, indeed the calcium was high by local standards yet low enough for the ponds to be classed as calcium-poor on a world scale.

During the last two years, we have been investigating the primary production of an experimental pond at Sembawang as part of a contract under the International Atomic Energy Agency. This has given us the opportunity to examine the development of blue-green blooms in an acid water pond. The pond is extremely calcium-poor on world standards (3.0 - 4.5 parts per million). At the start of the survey, the mid-day pH varied from 6.3 to 7.0 with still lower levels at night; the alkalinity ranged from 0.14 to 0.29 meq/l and the phytoplankton was a diversified soft-water assemblage dominated by green algae and with an abundance of desmids. These conditions had probably persisted for some time as the pond had been out of use. It was stocked with fish and these were given supplemental feeding, carefully controlled so as not to pollute the water. No other fertilization was used but the incidental fertilization was sufficient to initiate a spectacular blue-green bloom which finally rose to over 51,000 organisms per litre before partially collapsing during the dull, rainy weather of December-January.

The pond was drained, refilled, and restocked in early 1971 and we have been able to follow the subsequent succession leading to a blue-green bloom which later collapsed to yield a moderately rich, persistent plankton assemblage still dominated by blue-green algae. During this latter period, it has been possible to show clearly the fall in plankton levels associated with the development of the blue-green bloom. Whilst there is thus a definite connection between phosphate and blue-green blooms, we have found correlations to be less clear at other times and agree with a number of workers in temperate zones in finding that bloom collapse occurs before phosphate exhaustion, suggesting ultimate control by other factors. It is also note-worthy that the phosphate levels involved, though high compared to those of local unproductive waters, are nonetheless lower than are common in bloom-forming waters in temperate areas.

We conclude that blue-green blooms develop much more readily in equatorial climates than in temperate climates. They are likely to develop in waters in which they would not occur in temperate

areas, at relatively low levels of fertilization, and at any period of the year, where there is no long-continued dull weather. Thus more stringent control is necessary to avoid eutrophication than would be required in temperate areas.

INTRODUCTION

It is scarcely necessary to emphasize the importance of water blooms of blue-green algae. These blooms are usually unsightly and commonly give the water unpleasant odours and tastes; the floating masses create filtration problems for water supply engineers; many of the component algae are scarcely or not at all digested by plankton-feeding organisms including fish so that much of the primary production of the habitat is wasted; at high temperature with their concomitant low oxygen capacity of the water, the algal respiration can lead to undesirably low oxygen concentrations during the night; storms which churn up bottom debris and plankton crashes can cause sudden oxygen depletion with associated fish mortality [1]; excessive photosynthesis can lead to carbon dioxide depletion and the rise of pH values to deleterious levels in the region of 10.0.

Toxic blooms are more immediately deleterious to man. Species of *Anabaena, Aphanizomenon,* and *Microcystis* all possess strains which are toxic both to fish and mammals, including man [21] [2] [11] [12] [28] [35] [39] [41]. The problem is complicated by the existence of toxic and non-toxic strains which cannot be differentiated morphologically. Toxic blooms are probably more widespread than published information indicates. They are doubtless often unrecognized and even where they are recognized the information may be supressed because of misguided official secrecy. They certainly occur in S. E. Asia and I know of instances very close to Singapore though not so far in Singapore itself.

It is very difficult to control or prevent the development of water blooms once bloom conditions are established although a variety of control methods are available or under consideration.

CONTROL OF BLOOMS

Assumption of the importance of phosphate (see below) lies behind methods of reducing the phosphate content of the water such as treatment with ferricyanide [28] or restriction of recycling from bottom muds [16]. Artificial circulation of the water may work by reducing photosynthesis or growth though the mechanism is not yet clear [23] [10] [49]. Naturally produced growth inhibitors might similarly be used but there is no satisfactory work as yet in this field. Herbicides have been tried in blue-green control [4] [28], but they are only effective at concentrations likely to be prohibitively expensive and may well themselves be harmful to man and fish.

In special circumstances, concentrations of grazing zooplankters such as rotifers [5] or cladocerans [46] may exert some control but it is not easy to see how this method can be used economically and with certainty of results. Plankton feeding fish are helpful in preventing the build-up of water blooms [35] but are themselves sensitive to toxic blooms. Some interest has attached to the possible use of the virus-like cyanophages [26] [28] [37] [44], but the method has not developed beyond the experimental stage and suffers from the high specificity of these parasites. The occurrence of cyanophage resistant strains [25] [42] may pose a further limitation. Possibly more promising is the broad-spectrum, lytic bacterium *Myxobacter* species [45] [40] [42].

All there methods are limited in their applicability and have disadvantages which commonly include relatively high cost. Most workers in the field would thus agree with Singer [43] that ecological control is the approach of choice. Where possible it is better to prevent the development of conditions favourable to bloom formation than to try and control or prevent bloom formation once bloom conditions have become established.

If we are to control environmental conditions in this way and to do so as effectively and economically as possible we need to have some understanding of what conditions are associated with bloom development. Failing this, we must continue to rely on ad-hoc, empirical methods with all their inefficiency and uncertainty.

CONDITIONS FOR BLOOM FORMATION

Water blooms first attracted attention in Europe where the summer-long blooms characterizing many water bodies of the North European Plain are very obstrusive.

It is over fifty years since such water bodies were recognized as a distinctive class whose predominant features formed the core of the concept of eutrophic waters. Since then these waters have been the centre of such research not merely in Europe but also in other temperate areas such as N. America and sub-tropical areas such as Israel [38] [30] [1] and India [6]. Relatively few studies have been made in the tropics but recent studies have been made on the shallow L. George in Uganda [7] [47] and blooms have also been studied in connection with the recent development of large reservoirs in Africa [3]. Much general information is available from the experience of workers in the field of pond-fish cultivation [32]

[33] [35].

We are still far from a full understanding of the factors involved in eutrophication and the formation of blue-green blooms even in temperate areas [48] [10] [18]. Much of the disagreement is about details or refers to the interpretation of peculiar sets of data and most workers would agree on the general nature of environments where blue-green blooms are likely to develop.

Water blooms are absent in winter in temperate climates even in otherwise suitable habitats and decay at the approach of winter. It is usually concluded that relatively high temperatures are required for bloom development and this receives support from correlations established between temperature and algal density [14] though other factors may well be involved in the seasonality shown in temperate areas. Water blooms characteristically develop in hard waters which are calcium rich or at least not calcium poor, which have moderate to high alkalinity, and in which the pH is above 7.0 even at night and during algal minima. No one expects to find blue-green blooms developing in soft, calcium poor waters in which the pH, in the absence of intense photosynthesis, is below 7.0. Massive blooms can occur in intensely fertilized, hypereutrophic urban waters such as those investigated by Casper [5] and are indeed a familiar feature of such waters on the North European Plain. It is now becoming generally realised that even in other waters such blooms are seldom fully natural. Usually habitats which exhibit intense water blooms are culturally modified and subject to over fertilization from sewage or other sources [14] [43] [22]. This phenomenon of eutrophication has become much more widespread in recent years so that it has been possible to demonstrate it with comparative historical studies such as those of Mathiesen on Danish lakes.

Fertilization leading to eutrophication usually involves the addition of a complex variety of substances including organic carbon, phosphate, and nitrate and it is not always easy to disentangle their effects.

Organic matter is not necessary for the growth of blue-green algae [21] [14]. However, as early as 1932, Pearsall [27] suggested that organic matter could favour the growth of algal blooms and Fogg and Walsby [10] state of blooms in shallow, non-stratified waters. 'It seems characteristic of all such water-bodies that they receive large amounts of organic matter either through pollution or intense primary production'. Nitrate is nowadays seldom invoked as an important factor in bloom formation. Independence of nitrate levels is perhaps to be expected in blooms dominated by heterocyst bearing algae at least where conditions allow them to fix nitrogen, a property which appears to be associated with the possession of heterocysts [8] [9]. However, some associations have recently been claimed between bloom formation and nitrate levels in circumstances where phosphate effects seem to be ruled out [1].

Most workers regard phosphate as being important for bloom formation [14] [24] [35] [48] though there are dissenting voices and it has commonly proved difficult to establish detailed correlations between phosphate levels and phytoplankton development [1] [15] [22]. Such failure may result from superabundance of phosphate with other factors influencing algal growth so that, though detailed correlations are not established, it can be shown that the habitats concerned are rich in phosphate or, as in the ponds studied by Abeliovich, phosphate is at least readily available. Blooms can certainly be maintained in circumstances where most of the phosphate is stored in algal cells and the free phosphate in solution is thus very low [36] [29] [1] [14]. Some blue-green algae appear to be adversely affected by really high phosphate levels [14] and these include *Anabaena flos-aquae* which figures in S. E. Asian blooms. Pearsall [27] found maximum summer growth rates when nutrient levels, including phosphate, were minimal. Fogg and Walsby [10] suggest a possible explanation for this somewhat surprising record which does not involve any contradiction with the accepted belief in the role of phosphate in the multiplication of algal populations.

Despite these complications, it can be stated as generally true that blue-green blooms are associated with high phosphate supply to warm waters which have plenty of calcium, a high alkalinity and pH levels which are above 7.0 even in the absence of blooms. The association of blooms with calcium-rich, alkaline waters is so marked that it has seldom been questioned and is generally taken for granted by workers concerned with bloom formation.

LOCAL EXPERIENCE

Work at the Batu Berendam station had shown that blue-green blooms could be developed in previously acidic waters with high levels of phosphate fertilization [35] but here the water had been previously limed to neutrality and [32] it could be maintained that the conditions to produce a blue-green bloom in fishponds were the application of inorganic fertilizer to alkaline waters. The occurrence of water blooms in Malaysian reservoirs in situations removed from limestone areas [34] is however sufficient to raise queries concerning this accepted association of blooms with calcium-rich, alkaline, hard waters. There are insufficient chemical data available to interpret these records but the majority of Malaysian reservoirs are calcium poor habitats, ' in alkalinity and with pH often below 7.0 [2. . Even such apparently eutrophic habitats as L· Chonderoh are calcium poor, soft waters.

Even in the very mineral poor, slightly acidic reservoirs of Singapore known bloom-forming species have at times appeared in some numbers though fortunately never approaching bloom levels. Nonetheless, the balance appear to be rather delicate and one that could easily be tipped in the direction of bloom formation. In recent years, blue-green blooms have become not uncommon in fishponds. This partly reflects changes in methods of management. In the traditional fishponds fertilization by organic matter was intense and dense populations of euglenoids developed. Increase in numbers of ponds showing blue-green blooms corresponds with change to other methods of culture or to other uses (such as use for angling ponds). Whilst some of these ponds, especially those near the sea show alkalinities and calcium content which are high by local standards, I have seen inland ponds in both Singapore and Sarawak with dense blue-green blooms where there was no reason to believe that either calcium or alkalinity were unusually high.

The Sembawang Pond

Such casual observations suggest strongly that in the humid equatorial climate blooms can develop even in calcium poor, low alkalinity waters but clearly more concrete data are needed to establish this conclusion. Fortunately we are in a position to provide this as an outcome of observations made for a different purpose on a pond at the Sembawang research station. This pond has been under observation for two years as part of a programme of studies on primary production in equatorial ponds.

When first examined, the pond had been disused for some time and had characteristics comparable to those of other unfertilized ponds. It was, and is, a very calcium-poor pond with concentrations varying from 3.0 to 12.0 ppm. The alkalinity was somewhat less than 0.3 meq/l, a figure which is quite high by local standards but low and indicative of a soft water on world standards. The quantity was to fall still lower and even to less than 0.1 meq/l during the year. The daytime pH at the period of maximum photosynthetic activity varied from 6.3 to 7.1 according to day and depth of sample. Night-time pH values were not obtained during this period but 24-hour surveys at a later date showed that even when the daytime pH was 7.4, the night-time pH could fall to the region of 6.5 - 6.6. It is probable that the night-time pH in the original period was thus somewhat lower than the measured day-time values. The pond was then generally slightly acidic and definitely non-alkaline.

The phytoplankton was abundant in terms of individuals (Figure 1) but not in terms of biomass since most of the algae were nannoplanktonic species with the minute flagellate *Pedinomonas minor* especially abundant. Desmids were both abundant and varied. They accounted for above 25% of the plankton by weight and because of their relatively large size would make an even greater contribution to the biomass. Blue-green algae formed less than 10% of the plankton.

At this stage, the pond was stocked with fish, mainly crucian carps, and these were given supplemental food. The pond was neither limed nor fertilized. Apart from incidental fertilization as a by-product of supplemental feeding the only exogenous source of nutrients was from very occasional 'topping-up' using water from the nearby stream. This water is somewhat polluted because of drainage from neighbouring pigsty. Such topping up has been kept to a minimum in the pond and it is believed that the supplemental feeding was more important as a source of nutrients. During the first period of observations in 1970, the level of feeding was relatively high. Since there was some evidence of 'fouling' the feeding level was reduced during the second year. The lower level of feeding has corresponded with lower algal maxima which tends to confirm that this is the main source of nutrients.

The most obvious initial changes were a decline in total plankton numbers and an especially rapid decline in the numbers of *Pedinomonas* (Volvocales) and desmids (Fig. 1 and 2). This was followed by a short-lived and very moderate bloom dominated by *Anabaena* species. After another decline, numbers gradually built up to yield an algal bloom of very unusual composition. The species of *Lyngbya* accounted for over 90% by numbers of the plankton.

Especially important was *L. limnetica* and what appears to be a more slender strain of the same species but *L. contorta* was also present in some numbers. At its peak, the bloom gave individual counts (not cells but colonies, filaments etc.) of 51,000 per ml.

Early in 1971, the pond was drained, left fallow, and then restocked with fish following standard fish pond practise in S. E. Asia. An anabaenoid bloom developed rapidly but not immediately (Fig. 3). Initially after refilling, there was a rapid build up of 'weed' algae, mainly belonging to the Chlorophyceae, and photosynthetic flagellates. This peak soon collapsed and only then did the blue-green algae build up really get under way. After the initial peak of the blue-green bloom, which was lower than the maximum attained in the previous year, numbers declined to moderate levels but the plankton has remained blue-green dominated.

CORRELATED VARIATIONS

A full analysis of all factors involved will take time and we hope to produce this elsewhere.

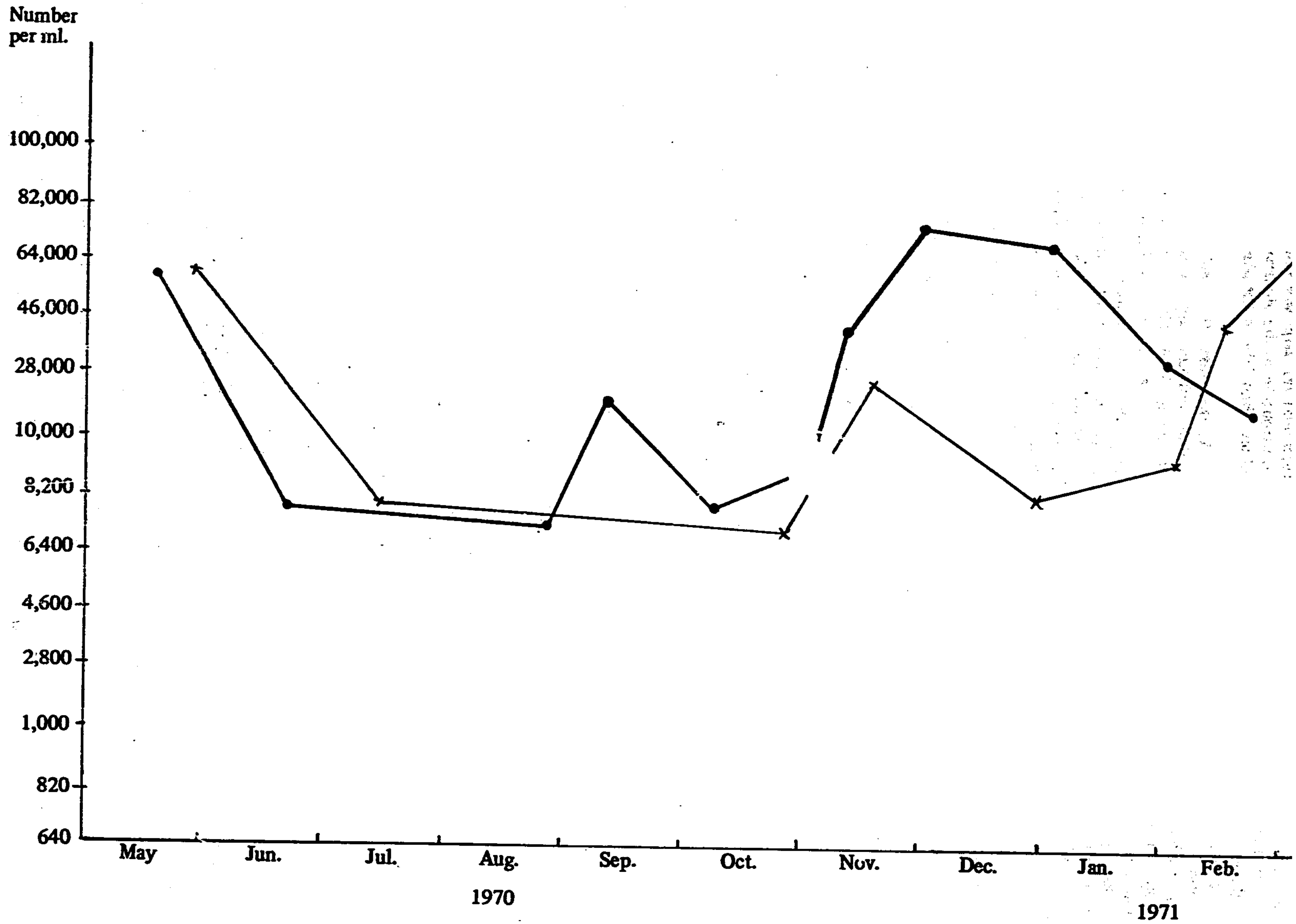


Fig. 1 Changes in Total Numbers of Planktonic Algae in Sembawang Pond 1970/71

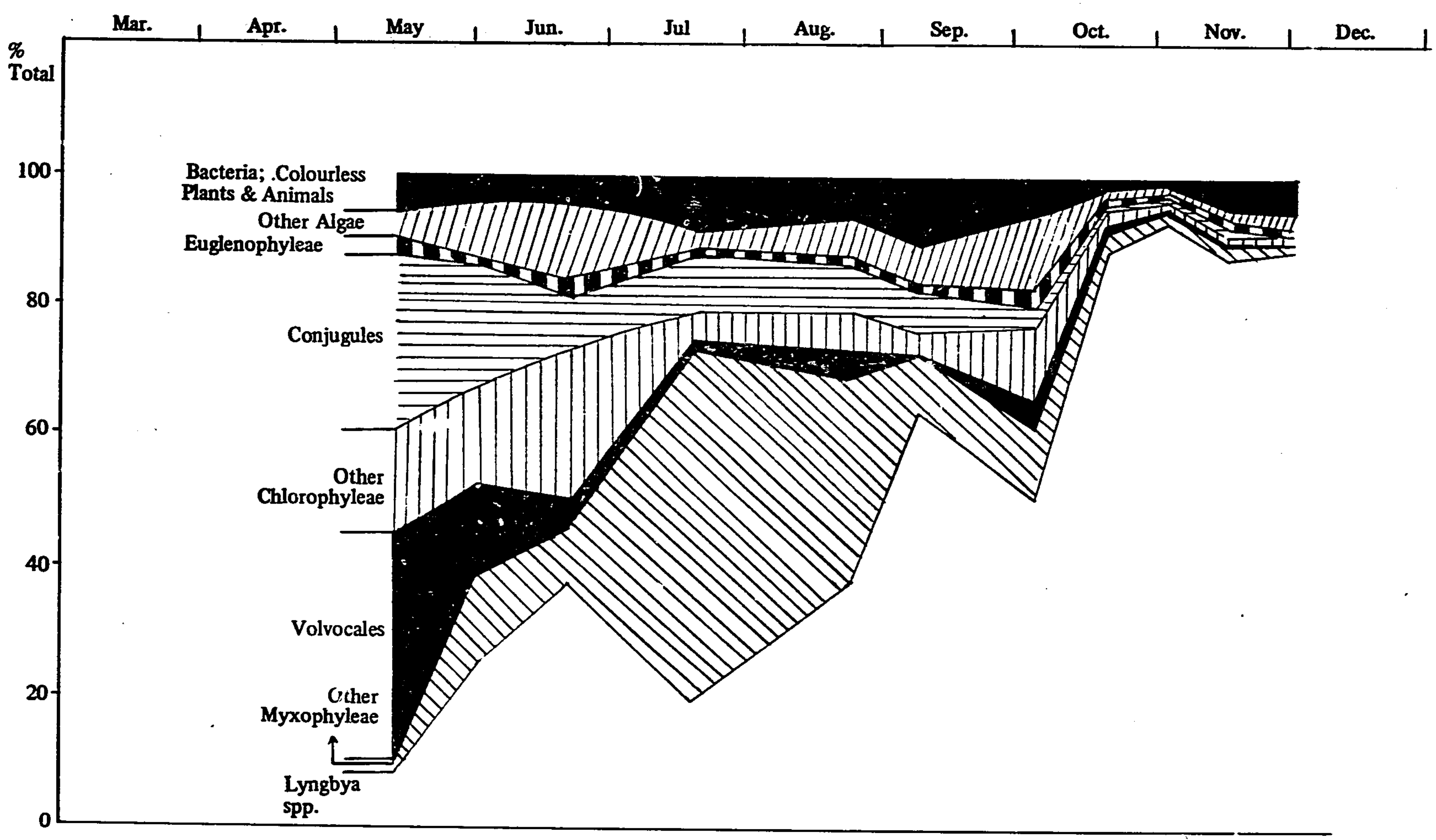
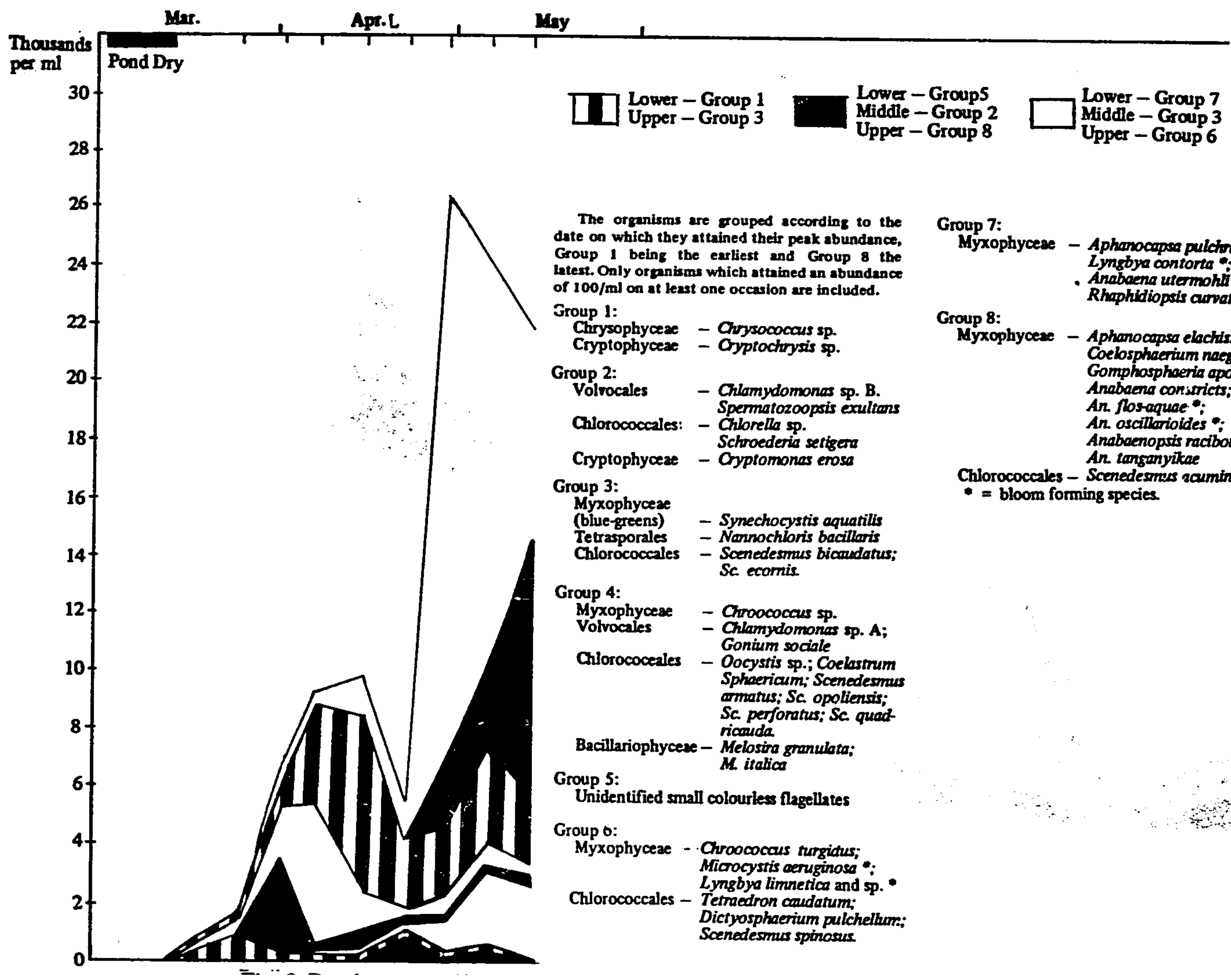


Fig. 2. Changes in Composition of Algal Plankton in Sembawang Pond during 1970



The organisms are grouped according to the date on which they attained their peak abundance, Group 1 being the earliest and Group 8 the latest. Only organisms which attained an abundance of 100/ml on at least one occasion are included.

Group 1:
- Chrysophyceae – *Chrysococcus* sp.
- Cryptophyceae – *Cryptochrysis* sp.

Group 2:
- Volvocales – *Chlamydomonas* sp. B. *Spermatozoopsis exultans*
- Chlorococcales: – *Chlorella* sp. *Schroederia setigera*
- Cryptophyceae – *Cryptomonas erosa*

Group 3:
- Myxophyceae (blue-greens) – *Synechocystis aquatilis*
- Tetrasporales – *Nannochloris bacillaris*
- Chlorococcales – *Scenedesmus bicaudatus; Sc. ecornis.*

Group 4:
- Myxophyceae – *Chroococcus* sp.
- Volvocales – *Chlamydomonas* sp. A; *Gonium sociale*
- Chlorococcales – *Oocystis* sp.; *Coelastrum Sphaericum; Scenedesmus armatus; Sc. opoliensis; Sc. perforatus; Sc. quadricauda.*
- Bacillariophyceae – *Melosira granulata; M. italica*

Group 5:
- Unidentified small colourless flagellates

Group 6:
- Myxophyceae – *Chroococcus turgidus; Microcystis aeruginosa* *; *Lyngbya limnetica* and sp. *
- Chlorococcales – *Tetraedron caudatum; Dictyosphaerium pulchellum; Scenedesmus spinosus.*

Group 7:
- Myxophyceae – *Aphanocapsa pulchra; Lyngbya contorta* *; *Anabaena utermohli* *; *Rhaphidiopsis curvata*

Group 8:
- Myxophyceae – *Aphanocapsa elachista* *; *Coelosphaerium naegelianum; Gomphosphaeria aponina; Anabaena constricts; An. flos-aquae* *; *An. oscillarioides* *; *Anabaenopsis raciborskii* *; *An. tanganyikae*
- Chlorococcales – *Scenedesmus acuminatus*

* = bloom forming species.

For present purposes, only a few points need be noted.

After the initial period, pH has shown considerable variation determined in part by photosynthetic activity and in part by products of algal decay. Over most of the period, diurnal pH has usually been a little above 7.0 with the nocturnal pH, when measured, tending to be below 7.0. The general range of diurnal pH records has been from about 6.5 to about 7.6. No correlation has been possible with the algal fluctuations and even the marked *Lyngbya* maximum was not associated with high pH values. However the 1970 anabaenoid peak did correspond with an unusually high diurnal pH in the region of 8.5 and no doubt determined by photosynthetic activity. Values for pH have never approached the 'danger' level of 9.5 to 10.0 in this pond.

Phosphate levels were initially very low, in the region of 0.005 ppm but rose fairly rapidly to 0.04 ppm. The rise corresponded with the initial fall in algal population but its large value suggests that the additional phosphate came at least in part from external sources (Fig. 4). The anabaenoid peak corresponded with a small but definite fall in phosphate with recovery after the peak had passed. The build up of the *Lyngbya* bloom corresponded with a reduction in phosphate to the original low levels and it is difficult to avoid the conclusion that storage in the algae was the cause of this fall. Breakdown of the algal bloom and a period of low photosynthetic activity corresponded with a rise in phosphate to 0.05 ppm.

Immediately after refilling phosphate values were quite high, approaching those found in European bloom-forming habitats at the beginning of the spring growth period. The value of 0.096 ppm is one of the highest we have seen in this area, though it is of course far from high by world standards. The initial algal build-up was associated with a rapid fall to less than 0.02 ppm. Renewed build up of phosphate was interrupted at the period of the anabaenoid bloom but ultimately the value returned to 0.04 ppm only to fall again to low levels with a future increase in algal population.

The general correlation between algal numbers and phosphate levels shown in this pond is remarkably good and leaves little doubt that phosphate is an important regulating factor.

During the first year, alkalinity fluctuated from just below 0.1 meq/l to just above 0.3 meq/l. No correlations are apparent between the alkalinity and algal numbers. Even the highest value corresponds to a soft water on world standards. Immediately after refilling, the alkalinity was much higher and exceeded 0.7 meq/l, a level which is approaching accepted definitions for hard waters. The value was not retained and fell rapidly to previous levels. A slight rise to values between 0.35 and 0.50 corresponded with the anabaenoid maximum but it is not easy to see a casual connection even though values once more fell below 0.30 after this maximum had passed.

COMPARISONS

As has already been noted, it is most unusual for dense blue-green blooms to be found in soft waters where the pH not uncommonly falls below 7.0, at least in well worked temperate areas. The range in our pond from less than 0.1 meq/l to 0.5 (in very special circumstances, 0.7 meq/l can be compared with some recent published figures of typical alkalinity values for bloom-forming and similar habitats:

Locality	Alkalinity in meq/l	Source
Czechoslovakia	0.5 to over 2.0	[15]
L. Soro, Denmark	1.55 to 2.89	[19]
L. Pederborg, Den.	0.86 to 3.42	[19]
L. Lyngby etc. Den.	1.31 to 3.14	[19]
Saskatchewan lakes	3.96 to 6.46	[14]
L. George, Africa	1.5 to 2.0	[7]
L. George, Africa	1.25 to 2.0	[47]
Sembawang, normal	0.15 to 0.30	(this paper)
Sembawang, extreme	below 0.10 to 0.75	(this paper)

The phosphate values for this pond were also low compared to those given for most temperate ponds. However, some records from tropical and subtropical bloom-forming habitats agree better with our figures. (See next page)

It should be noted that Viner reports values for insoluble particulate phosphate of 0.24 and that in Abeliovich's ponds, there was an abundant supply of phosphate in the bottom mud.

In warm water areas, it would appear that phosphorus turnover is high so that the levels of phosphate needed to intiate bloom formation may be much lower than is normally true for temperate climates.

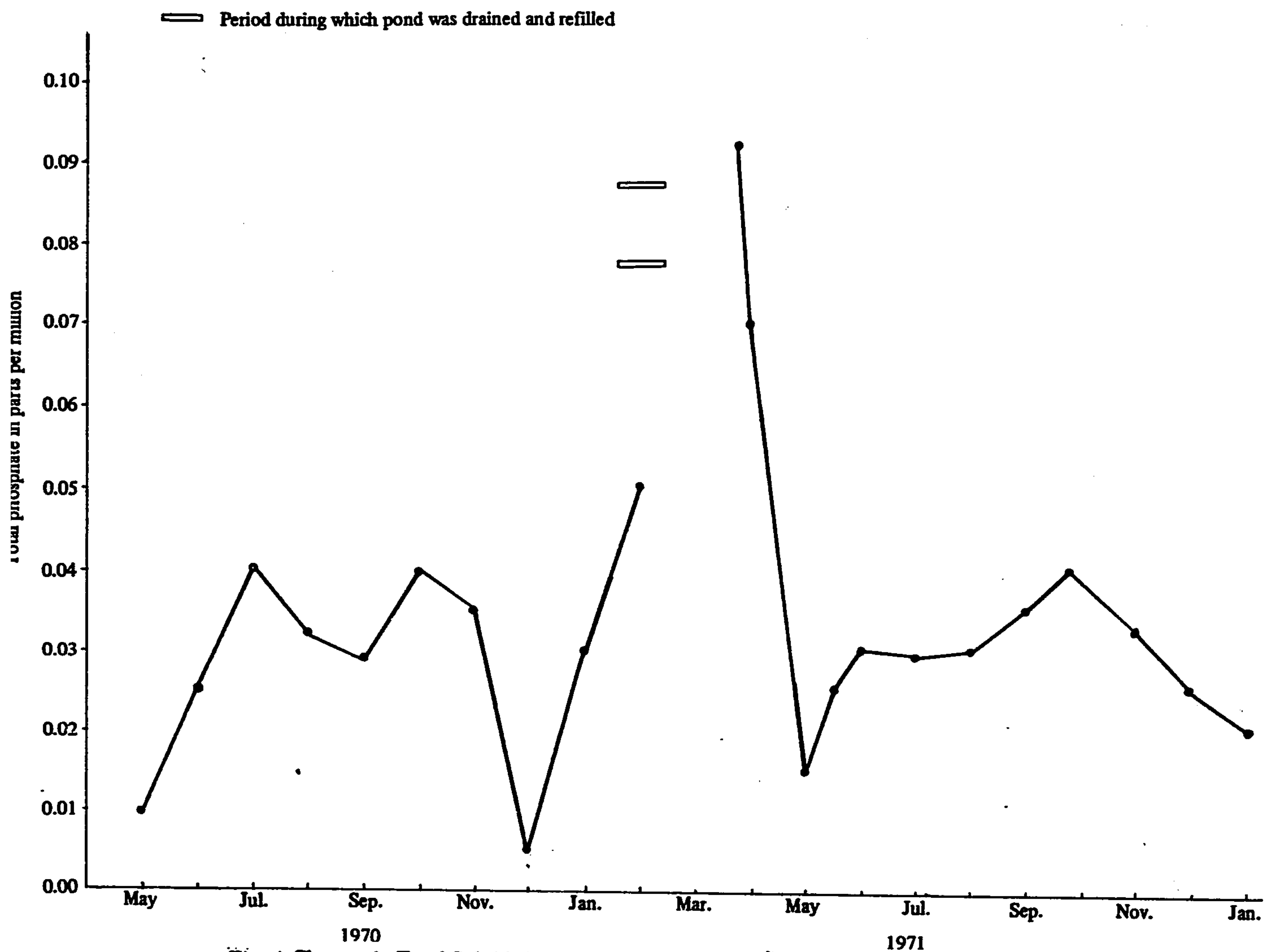


Fig. 4. Changes in Total Soluble Phosphate in the Sembawang Pond during the period 1970–1971

Locality	Maximum soluble phosphate in mg/l	Source
Czechoslovakia	0.25 to over 0.50	[15]
Denmark	0.20 to 0.44	[22]
Saskatchewan	0.32 to 2.16 *	[14]
L. George, Uganda	0.042	[47]
Israel, fishponds	0.02	[1]
Sembawang before		
Sembawang treatment	0.005	Our records
Sembawang normal	0.05	Our records
Sembawang immediately after refill	0.096	Our records

* Orthophosphate values

The more typical Sembawang blooms, as indeed most blooms which I have seen in this area were dominated by anabaenoids rather than by *Microcystis* and kindred forms. *Aphanizomenon* which is generally thought of as favouring very high nutrient levels never appeared and is in general very rare in this area. Anabaenoid dominance agrees with the views of Hammer [14] who believes that *Anabaena* is favoured by relatively low phosphate and inhibited by really high concentrations. Hammer [13] also found that *Anabaena* blooms only developed after initial spring phosphate concentrations had fallen to 0.3 mg/l or less. A similar factor operating at still lower concentrations may be involved in the delayed development of the anabaenoid bloom at Sembawang in 1971. However, other factors such as the availability of external metabolites may have been involved.

CONCLUSIONS

These observations are important in drawing attention to features in which equatorial freshwaters may be prone to eutrophication and blue-green bloom formation than most temperate waters.

Soft, slightly acidic waters which can usually be ignored in temperate studies may develop dense blooms in the equatorial tropics. Tropical blooms appear also to develop at relatively low levels of fertilization, especially phosphate fertilization. Thus control of phosphate inflows should probably be more stringent than is necessary in temperate areas, especially if small amounts of organic matter are also added to the water. The Sembawang pond received no treatment by lime and no intentional fertilization. Increase in phosphate appears to have been mainly if not entirely the result of supplemental feeding of the fish.

Unfertilized waters in this part of the world are almost invariably very unproductive. If they are to be used for fish production it is thus necessary to add some fertilizer or to give supplementary feeding to the fish. If fertilization is organic then phosphates are to be preferred [32] since nitrates and other fertilizers make little difference to production levels. The apparent rapidity and sensitivity of the bloom-forming response to such fertilization indicates that there is very little safe margin between adequate fertilization or feeding levels and levels which will initiate blue-green blooms. Thus multipurpose usage of water-bodies is likely to be much more difficult to manage effectively than it would be in temperate areas.

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Paper No. II/16

WATER POLLUTION AND ENVIRONMENTAL HEALTH

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ABSTRACT

Urbanisation, industrialisation and land development in West Malaysia have been growing at a rapid rate. Existing legislation to cope with pollution problems is reviewed. It is clear that existing legislation was designed to cope with special problems as they have arisen and have been designed on the basis of expediency to try to eliminate some of the gross and obvious nuisance problems. This legislation has failed to control pollution and this has been due to inability to recruit and train adequate technical staff to carry out knowledgeable implementation.

The paper calls for comprehensive water quality control legislation coordinated with an overall environmental quality control enabling act. Such legislation must include provision for recruitment and training of adequate staff and other factors relating to implementation.

(Abstracted by Chin Kee Kean)

THE EVOLVING NEED FOR WATER POLLUTION CONTROL

Under primitive conditions, man lived in dispersed low density environments and so avoided for the most part the damaging effects of his waste products upon his health. Water pollution by human wastes was rarely sufficiently concentrated that his health was endangered by using natural waters as a source of drinking water. As he has attempted to draw together into larger communities and as density of population tended to increase surface water and streams were more heavily polluted and became a danger to health. Epidemics and high death rates reduced populations. Cities and towns depended upon immigration to maintain population as deaths exceeded births in some urban areas. It was not until the advent of safe piped and treated water supplies in the nineteenth century that cities became self sustaining in relation to population. Soon thereafter the necessity for removing contaminated wastewater was recognised and the modern sewerage system was evolved. However, even in rural areas the increase in population density and the discharge of wastes from cities and towns have made surface waters unsafe for use without treatment and/or disinfection in most locations and upstream towns have contaminated the water sources for downstream supplies. Treatment of urban sewage and the provision of improved disposal methods in rural areas have thus become necessary to control pollution of surface and even ground waters.

Added to the problems of disease causing human sewage and wastes are the newer problems of organic and chemical pollution by manufacturing industries, the products they introduce into society with intensified agricultural development and land usage. The effects of these new polluting materials are often little understood and normal methods of wastewater treatment are inadequate or ineffective in removing them.

In West Malaysia urbanisation, industrialisation and land development are proceeding at a constantly accelerated rate and serious problems have already developed. Surface water is now almost unsafe to use without treatment and disinfection, silt loads from land development and mining are high and are increasing, and industrial wastes are beginning to be introduced in significant quantities. Other factors, such as enrichment of wasters by sewage, agricultural fertilizers, and industrial wastes have already caused damage to water users. The extent of introduction of persistent pesticides and chemicals has not been evaluated to a significant degree.

THE PUBLIC HEALTH ASPECTS

The public health engineer is concerned with a wide range of aspects of environmental development, control and protection many of which relate directly or indirectly to water pollution control. The principal areas of concern relating to water pollution control are:

(1) General Patterns of Settlement and Development
- (a) Recreation and open space
- (b) Housing and the home environment
- (c) The need for planned urban development

(2) Domestic and Industrial Water Supply
- (a) The effects of pollution upon water sources treatment processes and treated water
- (b) The effects of pollution on food processing etc.

(3) Sewerage and Sewage Treatment and Disposal - Planning, Construction and Operation
- (a) Promotion of sewerage system and treatment
- (b) Ensuring adequate design, construction methods and organisation to protect health and ensure attainment of health objectives
- (c) Coordination with overall city sanitation

(4) Urban and Rural Drainage and Land Preparation
- (a) To ensure optimum sanitation
- (b) To control disease vectors, eliminate vector food sources and prevent contamination of breeding places etc.

(5) Agricultural Practices with Particular Emphasis upon Use of Pesticides, Weedicides and Fertilizers and Effects upon the Nutritional Value and Safety of Foods.

(6) Industrial Plant Location
- (a) Relationship to downstream water uses
- (b) Costs of treatment

(7) Industrial Waste Prevention, Recovery and Control
- (a) Effects upon domestic and industrial water supply
- (b) Biological effects and effects upon wild life and recreation
- (c) General effects upon the ecology of man

(8) Design and Operation of Public Eating Establishments, Schools, Hospitals and other Public Facilities
- (a) To ensure optimum sanitation
- (b) To reduce or eliminate health hazards
- (c) To reduce or eliminate waste production

(9) Air Pollution Control
- (a) Fallout, rainout to land and water
- (b) Diversion of wastes to water resources

(10) Solid Waste Collection and Disposal
- (a) Relationship to sewerage
- (b) Seepage from disposal sites
- (c) Indirect effects of burning through air polution

It is not possible to go into details of all the above areas of interest which are presented to illustrate the wide range of the health aspects of the problem of water pollution control.

HEALTH AGENCY INVOLVEMENT

In most countries, it has been the Public Health Administration that has taken the initiative in developing water pollution control activities and in many cases it has retained full responsibility for the operation for water pollution control programme. In other cases, the responsibiltiy has been transferred to independent W.P.C. agencies or to agencies concerned with water resources. In all cases, the Health Agency has played a prominent role in this field of work.

Malaysia is no exception and here also we find the Ministry of Health through its newly established Environmental Health and Engineering Section taking the initiative in promotion of basic legislation and supporting activities. As an interim measure, an amendment to the Water Enactment has been prepared and is in process of being adopted by the State Governments. Proposed water quality criteria are also in process of development and action is being taken to promote the installation of central water carried sewerage systems in major towns and cities. The new section is also attending to urgent aspects of the other matters listed above. Efforts are also being made to expand the section's capabilities by developing supporting national and State Committee structure and recruiting and training of additional public health engineering staff.

There is still much to be done if the significant national savings that accrue from timely planning and preventive measures are to be realised, and the public health is to be adequately protected from the damaging effects of water pollution.

PRESENT STATUS OF WATER QUALITY MANAGEMENT IN MALAYSIA

Water is a state subject under the constitution of Malaysia. This has somewhat slowed progress in establishing a National Water Resources Authority on a statutory basis. There is however a Water Resources Subcommittee which has existed on an ad-hoc basis since 1961 and in its present form, was constituted as a subcommittee of the Technical Committee for land capability classification. The committee functions as a liaison and coordinating body dealing with common problems concerned with water resources evaluation and uses at national level.

WATERS ENACTMENT

The existing Waters Enactment provide for the control and protection of river banks. The Drainage & Irrigation Department is the government authority that is concerned with the enforcement of the legislation through the collectors of land revenue. The executive responsibility still lies with the collector of land revenue and the present system is not always successful.

An amendment to this water enactment has been prepared to take into consideration the element of water pollution control. This is considered as an interim measure designed to control effluent discharges into streams and waterways until such time as authority is established for the overall control of pollution due to other complex diverse sources and the necessary specialised technical personnel can be trained to implement control activities.

The Drainage & Irrigation Department of the Ministry of Agriculture & Lands presently functions under the Irrigation Areas Ordinance 1953 and the Drainage Works Ordinance 1954 and is largely responsible for irrigation and river diversion works. The Irrigation Areas Ordinance provides for the declaration of irrigation areas and is meant for rice cultivation with the provisions for industry and other cultivation. It also provides for the removal of trees or refuse likely to damage the irrigation works or harbours, and the control of pollution of waters by bathing, washing of articles or in any other way. The Drainage Works Ordinance 1954 refers to the declaration of drainage areas but has no reference to pollution.

MINING ENACTMENTS

The extensive mining operations that have been carried out in the country during the last 4 to 5 decades have had a significant effect on our rivers and streams. Large land areas still bear witness of the damage done by mining operations and the waterways that have been choked by sediment load.

The spoilation of land by mining operations is somewhat better controlled today. However, due to large scale mining operations and the lack or shortage of supervisory staff, enforcement has not been as effective as could be desired.

The existing legislation provides a limitation to effluent discharge containing a solid content up to a maximum of 800 grammes/gallon. This varies in different areas and in some areas no sediment is permitted - a requirement which cannot be enforced.

FORESTRY ENACTMENT

The existing state forest enactment and rules have no provisions for soil and water conservation. Any measures for the control relating to soil and water conservation is done on an ad-hoc basis and is left to the individual state forest departments by incorporating conditions when issuing licences for logging.

AGRICULTURAL ENACTMENT – LAND CONSERVATION ACT

The government, conscious of the need for the protection of lands from misuse and to give protection to developed lands and streams from the effects of erosion, brought about the Land Conservation Act of 1960. This is the most important existing legislation for the conservation of soil and water but like the amendment to the Water Enactment, it is not known as to the number of states that have adopted this piece of legislation. Enforcement is somewhat poor and there is need for trained personnel and a separate agency to implement its provisions.

LOCAL GOVERNMENT AREAS

The 1970 census revealed that about 35% of the population live in the urban areas of over 10,000 population. This percentage has been steadily increasing and is expected to grow rapidly in the next decade or so as more and more people in the rural areas move towards urban centres.

The wastes generated by the urban centres are causing serious problems. Much of the wastes generated find their way into the ground and surface waters. The existing Town Boards Enactment allows for the control of discharge of effluents into waterways in a limited way i.e. they provide for powers against public nuisance arising out of community and trade wastes. These laws are inadequate in the present day context for controlling water pollution as it is not possible to clearly define "public nuisance", in such a way as to *specifically establish default and responsibility.*

FACTORIES AND MACHINERY ACT 1967

The Factories & Machinery Act, 1967 is recent in origin and provides for the control of effluents from factories purely as a health measure.

The Factories & Machinery Department is about the only authority in Government that is to date trying to enforce effluent control through its inspectorate service. This is however only one of the many functions carried out by the Inspectorate and due to lack of sufficient trained manpower and professional and technical assistance from appropriate government agencies to establish criteria and assess and evaluate the problem of each industry, water pollution control has not been effective. Control must be based upon a river drainage basin unit with appropriate study of the whole basin as a unit and of individual effluents as they affect the downstream waters.

SUMMARY AND CONCLUSIONS

It is clear that existing legislation was designed to cope with special problems as they have arisen and has been designed on the basis of expediency to try to eliminate some of the gross and obvious nuisance problems. It is also equally clear that such legislation has failed to control pollution and that this has been due to inability to recruit and train adequate technical staff to carry out knowledgeable implementation.

What is needed now is comprehensive water quality control legislation coordinated with an overall environmental quality control enabling Act. Such legislation must include provision for recruitment and training of adequate staff and other factors relating to implementation.

Paper No. II/17

TOXICITY CONTROL OF INDUSTRIAL WASTEWATERS AND PESTICIDE- POLLUTED WATERS IN VIETNAM

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ABSTRACT

A bioassay evaluating the acute toxicity to Carassius auratus, has been used to test the toxicity of industrial wastewaters and pesticide-polluted waters in Vietnam.

In Vietnam toxicity control of industrial wastewaters and pesticide-polluted waters is carried out on a daily basis as a matter of routine. A bioassay method is employed in evaluating waters for acute toxicity to fish.

METHOD OF DOUDOROFF ET AL [3][4][5]

The method used is derived from the standard method proposed by the American Public Health Association [1]. A few slight changes have been incorporated in the procedure so as to take into account of local conditions. They are listed below:

Choice of Test Animal

Goldfish, *Carassius auratus,* (Cyprinidae)

- Length 3 – 4 cm.
- Weight 2.5 – 3.5 g.
- Fed once a day (9.00 a.m.) on mosquito larvae.
- 1 week acclimatization before use.
- 10 fishes per test.

Diluent Water

The water used as control or diluent has the following mean characteristics:

– pH	7.1
– Total alkalinity	2 meq/l
– Bicarbonate	170 ppm
– Total hardness	140 ppm ($CaCO_3$)
– Free CO_2	20 ppm
– Dissolved oxygen	4 ppm

Experimental Procedure

- Test container: Cylindrical jar, diameter 20 cm, height 17 cm.
- Depth of liquid in test container 12.5 cm.
- Volume of liquid in test container 5,000 ml.
- 1,000 ml of tested water per fish.
- Aeration by bubbling with a membrane pump to 5 ppm of dissolved oxygen in tested water.
- Dilution of sample with diluent stored at 28±1°C.
- Control test with diluent.
- Duration of test 24 hr, 48 hr, 96 hr.
- End point. Test animals surviving (percent). Calculation of TLm, median lethal dose or LD 50, 50 percent lethal dose.

EXPERIMENT WITH INDUSTRIAL WASTEWATERS

A few examples are listed below concerning the most usual industrial wastewaters in Vietnam.

Concentration (% wastewaters by volume)	*Carassius auratus* surviving (percent)		
	24 hr	48 hr	96 hr
100	100	0	0
50	100	100	0
25	100	100	50
TLm		70.5%	25%

Table 1. Toxicity of Wastewaters from Chemical Manufacturing Plants (Vietnam, 1970).

Concentration (% wastewaters by volume)	*Carassius auratus* surviving (percent)		
	24 hr	48 hr	96 hr
100	0	0	0
50	50	0	0
25	100	100	50
TLm	50%	36%	25%

Table 2. Toxicity of Wastewaters from Galvanized Sheet Metal Manufacturing Plants (Vietnam, 1970).

Concentration (% wastewaters by volume)	*Carassius auratus* surviving (percent)		
	24 hr	48 hr	96 hr
100	0	0	0
50	0	0	0
25	100	100	100
TLm	36%	36%	36%

Table 3. Toxicity of Wastewaters from Textile Dyeing Plants (Vietnam, 1970).

The wastewaters coming from hydrochloric acid and alkali manufacturing plants (no 24 hr TLm), are found usually less toxic than those coming from galvanized sheet-metal manufacturing plants (24hr TLm = 50%) or from textile dyeing plants (24hr TLm = 36%). These results fit quite well with BOD values determined for these same water.

EXPERIMENTS WITH PESTICIDE-POLLUTED WATERS

Some typical examples of toxicity control of lake waters in the Vietnam Southern Highlands (Dalat) are given below.

Concentration (% water by volume)	*Carassius auratus* surviving (percent)		
	24 hr	48 hr	96 hr
100	0	0	0
60	60	30	30
30	100	50	30
10	100	100	100
TLm	70.5%	30%	24.5%

Table 4. Toxicity of Water from Xuan Huong Lake (Dalat, July 1968).

Concentration (% water by volume)	*Carassius auratus* surviving (percent)		
	24 hr	48 hr	96 hr
100	0	0	0
60	80	60	60
30	100	100	100
10	100	100	100
TLm	72%	70.5%	70.5%

Table 5. Toxicity of Water from Xuan Huong Lake (Dalat, December 1968).

Concentration (% water by volume)	*Carassius auratus* surviving (percent)		
	24 hr	48 hr	96 hr
100	0	0	0
50	75	50	30
25	100	100	100
TLm	62%	50%	41.5%

Table 6. Toxicity of Shore Area Water from Xuan Huong Lake (Dalat, September 1968).

Concentration (% water by volume)	*Carassius auratus* surviving (percent)		
	24 hr	48 hr	96 hr
100	100	50	30
50	100	100	100
25	100	100	100
TLm		100%	81%

Table 7. Toxicity of Water from Centre Area, Xuan Huong Lake (Dalat, September 1968).

Concentration (% water by volume)	*Carassius auratus* surviving (percent)		
	24 hr	48 hr	96 hr
100	0	0	0
60	100	80	80
30	100	100	100
TLm	77%	72%	72%

Table 8. Toxicity of Water from Than Tho Lake (Dalat, July 1968).

Concentration (% water by volume)	*Carassius auratus* surviving (percent)		
	24 hr	48 hr	96 hr
100	60	0	0
60	100	100	100
30	100	100	100
TLm		77%	77%

Table 9. Toxicity of Water from Than Tho Lake (Dalat, December 1968).

Variation of Toxicity with Season [2]

The toxicity of waters from Xuan Huong Lake is greater in July (48hr TLm = 30%) than in December (48hr TLm = 70.5%). The height of the rainy season comes in July (Rainfall: 205mm), while December (Rainfall: 28mm) is a dry month. Precipitation washes away the pesticides sprayed on the vegetable crops grown on the slopes surrounding Xuan Huong Lake and make these waters more toxic in the rainy season.

Variation of Toxicity with Distance to the Shore

However, another experiment carried out during the rainy season (September, Rainfall: 279mm) shows a decrease in toxicity as one moves from the shore area (48hr TLm = 50%) towards the centre (48hr TLm = 100%) of the Lake.

Control Experiment with Waters from Than Tho Lake

Another experiment with waters from Than Tho Lake where there is no farming on the slopes shows low toxicity both during the rainy and dry seasons. The level of toxicity in Xuan Huong Lake during the dry season (when toxicity is lowest) is similar to the year-round low level of Than Tho Lake.

Efforts are now being made to apply the Doudoroff method to the study of toxicity of defoliant-polluted waters.

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Paper No. II/18

IMPROVEMENT OF SOIL COVER FOR WATER CONSERVATION, PREVENTION OF SEDIMENTATION AND POLLUTION CONTROL IN THE PHILIPPINES

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ABSTRACT

Surface water resources such as rivers, streams and lakes which abound in the Philippines are slowly being clogged with sediments and soil deposits or are heavily polluted to the extent that only a few of the not-so-delicate species of fish remains. Places which used to be the haven for recreation become murky and quicksandy. Water turbidity caused by suspended fine patricles carried by runoff water diminishes the population of phytoplankton which serve as food for fish. Suspended fine particles also suffocate fish by clogging their gills. Rivers and streams which used to be the source of potable water in the rural areas are slowly becoming useless for such purpose.

One activity being given impetus by the Philippine Government which may help alleviate the worsening condition of surface water resources is the improvement of the soil cover designed to minimize water erosion, sedimentation and pollution. This is being accomplished through:

(1) improvement of agricultural practices in the field of soil and water conservation,
(2) engineering measures, and
(3) forest protection and reforestation.

This paper discusses present practices and researches being undertaken to achieve this objective. Researches on planting of cover crops, pasture improvement and selection of fast-growing reforestation tree species which are also utilizable for pulp and paper manufacture are described.

INTRODUCTION

Water is a principal resource of the Philippines which affects considerably the national development. It is the source of both good and evil. Properly controlled and managed, it furnishes power, irrigation, domestic water supply, and recreation. Uncontrolled, it can destory agricultural lands through soil erosion, kill living things and destroy roads, bridges and other infrastructure through floods, impregnate reservoirs, lakes, rivers and recreation areas with sediment, etc.

Water comprises the major portion of the Philippines Archipelago. Composed of 7,100 islands, the Philippines has one of the longest coastline in the world consisting of 17,460 kilometres or about as long as that of the United States. Its territorial waters with an aggregate spatial coverage of about 167,930,000 hectares is more than six times its land area. It has 85 lakes with an aggregate total of about 199,400 hectares and 1,100 rivers and creeks.

The Climate of the Philippines

Since temperature variations in the archipelago are really very slight and since rainfall differences are on the contrary important and decidedly variant due to the combined influence of topography and air stream direction, the classification of Philippine climate is based upon the types of rainfall (Figure 1). In other words, the four types of climate were classified based upon the presence or absence of a dry season and of a maximum rain period, to wit:

First Type
Two pronounced seasons; one dry, from November to April, the other wet, during the rest of the year. All the regions on the western part of the islands of Luzon, Mindoro, Negros and Palawan are of this types. The controlling factor is topography. The localities of this types are shielded from the northers and even in good part from the trade winds by decided mountain ranges, but are open only to the Southwest Monsoon and cyclonic storms.

Second Type
No dry season; with a very pronounced maximum rain from November to January. In this class fall Catanduanes, Sorsogon, the eastern part of Albay, the eastern and northern parts of Camarines Norte and Camarines Sur, a great portion of the eastern part of Quezon, Samar, the eastern part of Leyte, and a large portion of eastern Mindanao. These regions are along or very near the eastern coast and sheltered neither from the northers and trade winds nor from cyclonic storms.

Third Type
Seasons not very pronounced; relatively dry from November to April and wet during the rest of the year. The maximum rain periods are not very pronounced, with the short dry season lasting only from one to three months. Regions with this types of climate are the western part of Cagayan (Luzon), Isabela, Nueva Vizcaya, the eastern portion of the Mountain Province, south Quezon, Masbate, Romblon, northeast Panay, eastern Negros, central and southern Cebu, part of northern Mindanao, and most of eastern Palawan. These localities are only partly sheltered from the northers and trade winds and open to the South-west Monsoon or at least to frequent cyclonic storms.

Fourth Type
Rainfall more or less evenly distributed throughout the year. The regions affected by this type are the Batanes Province, north-eastern Luzon, the Southwestern part of Camarines Sur and Albay, Bondoc Peninsula, eastern Mindoro, Marinduque, western Leyte, northern Cebu, Bohol and most of central, eastern and southern-Mindanao.

Mountain climates might reasonably form another type of climate. However, they can be reduced to some of the above types as far as some climatological elements are concerned, except as to temperature which decreases with a gain in altitude, and rainfall, which generally increases with height.

The average annual rainfall of the entire archipelago is 99.61 inches and the average number of rainy days is 176 (Appendix)

THE PROBLEM

As far back as in the late 30's and early 40's, the Philippines abounds with rivers and streams with crystal clear running waters which teems with fish and other forms of aquatic wildlife. People in the rural areas get their drinking water direct from the streams which also supply in abundance their protein needs in the form of fish in their meals. The lakes were likewise full of edible fishes. Flocks of wildlife such as ducks and other water-loving birds are attractive sceneries in lakes and mouths of rivers. The guerrilla soldiers during World War II were able to resist the Japanese invaders for more than three years because in their hiding places they could easily scrounge for food from wildlife sources such as fish from rivers, streams and creeks.

Presently, except for a few isolated areas, all these benefits from nature are things of the past. Most of the creeks, streams and rivers are either clogged with sediments and soil deposits or are now heavily polluted to the extent that only a few of the not-so-delicate species of fish remains. Famous fish species which abound in certain lakes like the *banak* or mullet (*Muqil* sp.) of Lake Naujan in the island of Mindoro and the *palos* or eel (*Anquilla* sp.) of Laguna Lake in the island of Luzon are now becoming scarce due to pollution.

Water turbidity caused by suspended particles carried by runoff water to streams, rivers and lakes diminishes the population of phytoplankton which serves as food for fish. Suspended fine sand or clay particles also directly cause suffocation to fish because their gills could be clogged. Places which used to be the haven for recreation become murky and quicksandy.

People who used to get their water supply direct from rivers and streams now resort to digging shallow and deep wells. But even these sources are beginning to show tell-tales of pollution in some places and signs of extinction in other areas due to poor recharge of aquifers and competition on the part of users.

With a population increase of about 3.2% annually, which is one of the highest in the World, the aforementioned problems are bound to be aggravated if remedies are not instituted. The present population is about 38 million.

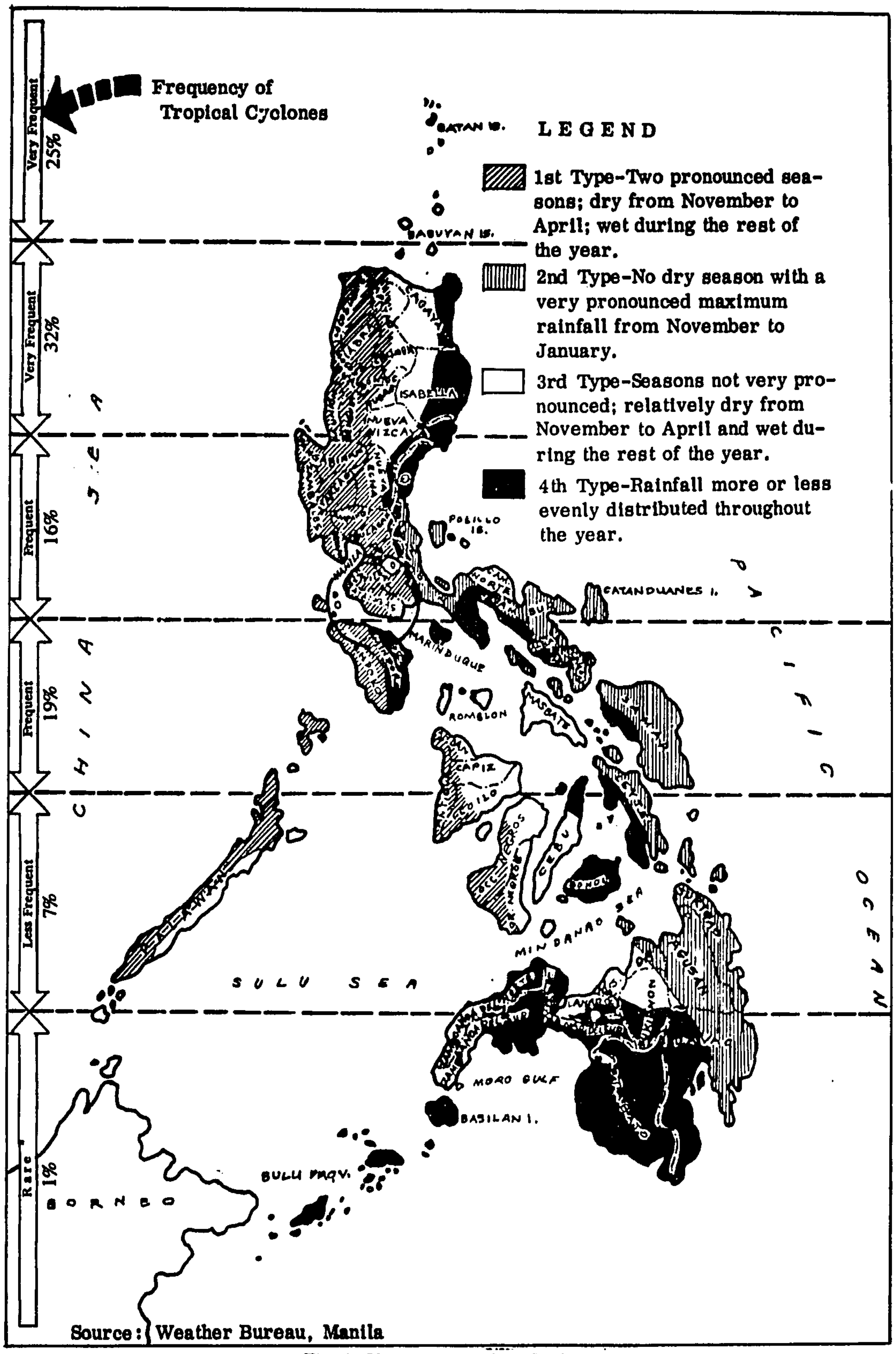

Fig. 1. Climate Map of the Philippines

MEASURES CURRENTLY UNDERTAKEN

To minimize the worsening of the problems mentioned above, the Philippine Government has adopted long-range programmes which may be grouped as follows:

Improvement of Agricultural Practices

Seven government agencies are directly and indirectly involved in programmes designed to minimize water erosion, sedimentation and pollution through improved agricultural practices. These are the following:

(1) Agricultural Productivity Commission
(2) Bureau of Animal Industry
(3) Bureau of Forestry
(4) Bureau of Plant Industry
(5) Bureau of Soils
(6) National Irrigation Administration
(7) Philippine Fisheries Commission

Through education, actual demonstration and other known extension methods, these government agencies aim to improve the soil cover to conserve soil and water, prevent sedimentation and control pollution. Practices such as cover cropping, strip cropping,ploughing along contours, deep plowing, farm terracing, pasture improvement water impounding, etc. are introduced. Application of proper kinds and amount of manures and fertilizers are also given impetus not only to supply vital plant nutrients but to improve cohesiveness of soil particles and strengthen them to be less susceptible to erosion.

Engineering Measures

The Bureau of Public Works sets standards for gutters and drainage channels in land development projects to maximize collection of surface runoff. The use of engineering principles in terrace designs is one of the functions of the Bureau of Soils. The National Water and Air Pollution Control Commission assists factories in designing devices to prevent their wastes from polluting the natural waterways.

Forest protection and reforestation

Whenever floods occur, a phenomena which is becoming more frequent in the Philippines, the loggers always get the blame. Clogged rivers and streams, quicksandy beaches and lakeshores are also attributed to them. The real culprit, however, in the denudation of forests in the Philippines is the *kainginero*. A *kainginero* is one who practises shifting agriculture. He follows the logger through the logging roads and cuts all the trees left by the loggers and then burns it to evolve a *kaingin* plot. The *kainginero* plants this plot with one crop of upland rice or other crops and after harvesting, he moves on to other areas and does the same, leaving behind him a desolate and bare land. When the annual torrential rains come, the top soil is washed away and eventually deposited in streams, rivers, lakes, etc.

The *kainginero* is a worse enemy of the forest than forest fires. The Bureau of Forestry takes charge of protecting the forests from unscrupulous loggers, from forest fires and from the *kaingineros*. It is claimed that the hardest to control is the *kainginero* because, being a voter, he easily finds protection from a local politician.

The Reforestation Administration is the government entity that is charged with the function of reforesting the denuded areas that are classified to be non-agricultural.

IMPROVEMENT OF SOIL COVER

The progress of the Philippines hinges a great deal on its water resources. With a national average annual rainfall of 99.61 inches over a surface area of 29,741,290 hectares, it seems that the water balance is favourable. On the other hand, such a tremendous volume of water could do a lot of damage considering that the rainfall could go as high as 34.64 inches in one day (Appendix) In fact, the country now suffers heavy damage from floods annually during the rainy months but lack of water is experienced in many areas during the dry months. Heavy deposition of sediment in natural streams raises the stream beds, thus causing higher water stages and more frequent flooding of unprotected land. The expected life and efficiency of dams, reservoirs, navigable rivers, irrigation and drainage canals are diminished due to sedimentation.

Barring the climatic and geologic factors which are hard to control, men can influence the soil cover which plays a great deal in water conservation and prevention of sedimentation. With respect to vegetation, one can easily discern that water erosion is promoted under the following conditions:

(1) overcutting natural forest
(2) overgrazing grassland by livestock
(3) planting crops unsuited to the terrain
(4) leaving the soil bare as in *kaingin* agriculture.

The beneficial effect of vegetation in preventing erosion can be analyzed as follows:

(a) The vegetal cover protects the soil surface from the impact of raindrops which otherwise would enhance closing of soil pores,
(b) The roots provide binding effect on the soil,
(c) Vegetation retards the overland flow, thus reducing its transporting capacity.
(d) Vegetation increases the infiltration ca-

pacity of the soil, thus reducing the overland flow and conserves water in the root zones and underneath.

In addition, vegetation uses broken-down organic substances which when allowed to deteriorate under anaerobic conditions in rivers and lakes would constitute bad smelling pollutants.

It was reported in 1961 [10] that the total soil cover of the Philippines consists of the following:

	Area in hectares	Percent
Commercial forest	9,329,280	31.37
Non-commercial forest	3,842,120	12.92
Swamps and marshes	716,260	2.41
Brushland	2,077,230	6.98
Open land vegetation	3,402,860	11.44
Cultivated crops & others	10,373,540	34.88
TOTAL	29,741,290	100.00%

By this time, the commercial forest must have been greatly diminished since it is estimated that 172,000 hectares of forest annually are being destroyed or denuded. Likewise, some of the non-commercial forest, the brushland and open land vegetation areas have been turned into pasture lands. About 3,000,000 hectares of the area devoted to cultivated crops are now planted with rice and only 10% of these are irrigated. The irrigated ricelands are generally in the lowlands and are well-protected from erosion by means of levees. It could be gleaned from the above data, therefore, that major part of the Philippine land area is exposed to the danger of water erosion particularly during the torrential rains common to all places in the Archipelago.

Researches on the Improvement of Soil Cover

Knowing the problem as mentioned above, several researches have been undertaken in the Philippines aimed at solving such problems. We would like to mention here some results of studies directed towards the improvement of soil cover to minimize floods and sedimentation and to conserve soil and water.

Planting of cover crops

It is advisable that critical areas are covered with a thick canopy of vegetation, preferably grasses and legumes which are suitable for planting on such critical areas: (1) Guinea grass, (2) tropical Kudzu, (3) Bermuda grass, (4) Para grass and (5) Centrosema. In plantations such as coconut and citrus where raising of animals is not intended, the growing of *Calopogonium* as cover is recommended.

Pasture improvement

The Bureau of Forestry, which is the government agency charged with the administration of our range and pasture lands, established a Pilot Range Project with the cooperation of the United Nations Development Programme (UNDP), at the Valbueco Ranch owned by Mr. Valeriano C. Bueno, one of the few bigtime ranchers in the Philippines, located at Carranglan, Nueva Ecija, in the island of Luzon. The objective is to conduct forage and pasture research and to demonstrate to ranchers how to scientifically increase beef production from the range lands to its optimum level consistent with the principles of conservation of soil and water. The area was formerly covered with the grass *Themeda triandra*, Porsk. (local name is *samsamong)*. The area is moderately hilly. Here exotic grass species viz.: Alabang X (*Dichantium aristatum* C. E. Hubbarb), coastal Bermuda grass (*Cynadon dactylon* Pers., guinea grass (*Panicum maximum* Jacq.), misamis grass (*Capillipedium assimile* A. Camus), and Napier grass(*Pennisetum pupureum* Schumach.) were introduced. It was found that soil fertility is a greater limiting factor than soil moisture. Fertilized plots produced more foliage and subsequently increased rainfall interception and minimized surface runoff and erosion. Fertilized coastal Bermuda grass was observed to be a good soil stabilizer.

Researches undertaken by the Bureau of Animal Industry pointed out the advantages of combining grasses with legumes, such as Guinea grass - Centrosema and Para grass - Kudzu combinations for the improvement of pastures. Legume-grass culture facilitated increase infiltration and protection from erosion.

In the 1960's pasture improvement work was intensified. An area of 600 hectares was set aside in 1963 at the NAWASA (National Waterworks and Sewerage Authority) reservation near the La Mesa Dam, for the establishment of improved pastures by the Bureau of Animal Industry primarily to serve as a seed bank and source of planting materials for distribution to any interested livestock raiser. In the same year, the Dairy Training and Research Institute, a cooperative project between the Bureau of Animal Industry and the U. P. College of Agriculture and assisted by the United Nations Special Fund, began operation, and by 1969, the Forage Husbandry Division of the Institute has worked on about 400 pasture species and cultivars. Among those found very productive were the three common grasses-Guinea, Napier, Para and the legumes - centro, glycine and siratro. A recently introduced grass, which is very resistant to drought and is now becoming popular among the graziers is *African* star grass. It is very aggressive and will send out young shoots even during the dry season.

The Bureau of Soils reported that contour planting with the use of *ipil-ipil* (*Leucaena glauca*) buffers and addition of organic matter to the soil on a 25 percent slope, effectively reduced soil and water losses.

Reforestation

Reforestation is the biggest single effort being undertaken by the Philippine government to offset the adverse effects of floods, sedimentation and lack of water. While the Reforestation Administration takes charge of actual reforestation projects, other government agencies like the Bureau of Forestry, College of Forestry of the University of the Philippines, the Forest Products Research and Industries Development Commission under the National Science Development Board and the private sector also conduct research to support the reforestation effort of the government. The most significant breakthrough attained in these researches is the selection and identification of fast-growing reforestation tree species which are also utilizable for pulp and paper manufacture. For such species which are considered exceptional are as follows:

	Common Name	Scientific Name	Ave. Yield * cu m/ha/year
1.	Moluccan - sau	*Albizzia falcata*	43
2.	Kaatoan Bangkal	*Anthocephalus chinensis*	36
3.	Yemane	*Gmelina arborea*	36
4.	Umbrella tree	*Musanga cecropioides*	28

* Under Mindanao conditions

Moluccan-sau, more popularly known as *Albizzia falcata* in the Philippines was introduced from Indonesia in 1938. The ability of this tree to adapt favourably to Philippine conditions has been observed after World War II. It produces viable seeds at 2½ years old. Survival of potted seedlings is high. In 2 years the mean diameter was 14 ± 2.03 cm and the mean height was 10.63 metres.

Kaatoan Bangkal is indigenous to India, Burma, Vietnam, Indonesia, Malaysia, Sarawak, Brunei and Sabah. The Forest Products Research and Industries Development Commission (FORPRIDECOM) of the NSDB has made an intensive study on this species embracing seeding habits, seed extraction, germination, vegetative growth rate and size attained, structure of the wood, mechanical properties of wood, durability, treatability and seasoning. It was reported that the average diameter increment is 2.76 cm to 2.81 cm with corresponding average annual height increment of about 1.73 metres. It has also an excellent wood quality. It has been dubbed the "miracle' tree" because aside from being a fast grower, it is also suitable for a variety of uses.

Yemane is indigenous to India, Pakistan, Northern Rhodesia and Malaysia. It thrives well in sites with elevations up to 1,750 ft above sea level. It has a straight bole and attains heights of up to 20 metres. The tree is deciduous and the timber is similar to teak because they belong to the same family. Survival of the potted seedlings was 97%. The average diameter of 3-year old trees was 31 cm.

The Umbrella tree is indigenous to West Africa. Being a fast grower at an early age, it initially forms the upper layer of the forest. It matures in 10-20 years. Its rate of growth varies considerably from place to place. In Bislig, Surigao del Sur, the trees averaged 5.18 - 0.46 cm in diameter in 2 years.

Other promising fast-growing species of trees for reforestation are the Earpod (*Enterolobium cyclocarpium* Griseb.), Benguet pine (*Pinus Insularis* Endl.), Agoho (*Casuarina equisetifolia* Forst.), Mindoro pine (*Pinus merkusii* Jungh.), African tulip (*Spathodea campanulata* Bereav.), Gubas (*Endospernum peltatum* Merr.) and the Fire tree (*Delonix regia* Ref.).

Aware of the ever-increasing rate of demand for pulp due to the stepped-up educational programme and industrial development in the Philippines, reforestation is now being eyed not as a government and civic duty alone but also as a major industry and occupation of the people. A big paper company in the Philippines has started an agro-forestry project wherein a farmer is given 10 ha to reforest and to take care as a full-time occupation. The net income derived from this area out of the trees harvested and bought by the pulp and paper company was comparable, if not better than the net income normally derived from some common agricultural crops. Recently, some banks in the Philippines signified their intention to extend long-term loans to similar agro-forestry projects.

Other Soil Conservation Practices

The Bureau of Soils reported accomplishments in soil and water practices, as follows:

I. Land Capability Classification	1,971,240 ha		
II. Soil Erosion Control Measures:			
1. Mechanical measures:			
Contour planting, furrowing, ridging	3,532 ha		
Broad-base terracing	632		
Bench-type terracing	378		
		4,542 ha	
2. Vegetative measures:			
Strip cropping, field stripping	212 ha		
Cover cropping	3,082		
Contour buffers on steep slopes	568		
Planting pastures	1,135		
Planting orchard trees in contour	1,920		
Grassed waterways	160		
		7,077 ha	
III. Other soil water conservation practices:			
1. Deep plowing	350,000 ha		
2. Green manuring and crop rotation	5,900		
3. Removal of excess water	4,064		
4. Water conservation - (farm ponds)	142		
5. Others	8,477		
		368,583 ha	
TOTAL		2,351,442 ha	

These developments which give income incentives to people to put back on the denuded lands the necessary soil cover to promote soil and water conservation and prevent floods and sedimentation augur well for the Philippines. It is hoped that in the future some of the benefits of nature now lost may be enjoyed once more by our succeeding generations.

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REPUBLIC OF THE PHILIPPINES
Department of Commerce and Industry

WEATHER BUREAU
Manila

AVERAGE MONTHLY RAINFALL IN INCHES

Region	Jan.	Feb.	Mar.	Apr.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
LUZON	4.95	3.50	3.45	3.58	6.97	9.88	14.42	15.84	13.33	11.52	11.02	8.87	107.34
VISAYAS	7.17	4.58	4.03	3.48	6.26	8.58	9.72	9.16	9.23	10.99	11.03	9.94	94.17
MINDANAO	7.90	5.58	5.81	5.32 :	7.61	8.25	8.32	7.56	7.80	9.03	8.84	9.70	91.72
PHILIPPINES	6.33	4.32	4.18	3.94	6.89	9.10	11.54	11.83	10.77	10.78	10.53	9.40	99.61

AVERAGE RAINY DAYS

Region	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
LUZON	11	8	8	8	13	16	19	19	19	17	15	14	167
VISAYAS	15	11	11	9	13	17	18	17	17	19	17	17	181
MINDANAO	14	11	11	12	15	17	17	16	16	17	17	16	180
PHILIPPINES	13	10	10	9	14	17	18	18	18	18	16	15	176

GREATEST AMOUNT OF RAINFALL EVER RECORDED

Region	Greatest Daily	Greatest Monthly	Greatest Annual
LUZON	34.64 in., July 14, 1911, Baguio City	136.30 in., Aug. 1919, Baguio City	355.84 in., 1911 Baguio City
VISAYAS	22.48 in., Nov. 23, 1928, Borongan, Samar	86.27 in., Jan. 1918 Borongan, Samar	267.32 in., 1934, Borongan, Samar
MINDANAO	18.71 in., Dec. 13, ? Surigao, Surigao	58.27 in., Dec. 1924, Surigao, Surigao	237.73 in., 1934, Surigao Surigao

Note: *Above data were based on the reports of Synoptic Stations operating at present (1960) and do not include the records of cooperative stations and other stations which are already inactive. The years of records range from 6 to 90 years.*

* *The amount was collected from 6 a.m. at Baguio City. 45.99 inches was collected from 12 noon to 12 noon (see Weather Bureau Publication-Monthly Bulletin, 1911). Twenty-four (24) hour rainfalls are collected normally from 8 a.m. to 8.00 a.m.*

POLLUTION CONTROL OF DISCHARGE INTO RIVERS, LAKES AND COASTAL WATERS IN THE PHILIPPINES

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ABSTRACT

Pollution has been and will continue to be an environmental problem as a consequence of industrialization, urbanization, increasing number of vehicles and the use of pesticides in agriculture. It is an economic as well as a social problem directly affecting many industries, urban and regional development, and patterns of land use.

Pollutants which are entering our water courses are industrial wastes, toxic chemicals, domestic sewage, mine tailings, detergents and pesticides. Steps taken by industry for the abatement of these pollutants are:

1. *reduction of wastewater volume*
2. *process changes*
3. *equipment modification*
4. *segregation of wastes*
5. *by-product recovery*

After applying the above preventive measures, the concentrated wastewater has still to be treated. Wastewater treatment may consist of one or a combination of the following:

1. *neutralization*
2. *sedimentation*
3. *flotation*
4. *coagulation*
5. *lagooning*
6. *activated sludge process*
7. *trickling filtration*

Pollution control of discharge into rivers, lakes and coastal waters in the Philippines is vested by law under the National Water and Air Pollution Control Commission. Pursuant to the pertinent provisions of the law it adopted water quality standards. Due to varied usage and location of different streams, lakes or other bodies of water, classification of bodies of water has to be based on their best usage. The

water quality standard for drinking and other domestic purposes is of a higher quality while that for navigation, agriculture and industry is of a lower quality. The water quality standard then adopted is the basis for determining the degree of wastewater treatment required for each firm.

The Commission recognizes the contribution of industry to the economic development of the country so that it has always sought cooperation and voluntary compliance rather than compelling industry under the threat of the penal provisions of the law.

INTRODUCTION

Pollution is an undesirable change in the physical, chemical or biological characteristics of the water, land and air that may or will harmfully affect human life or that of other desirable species, our industrial processes, living conditions, and cultural assets. Pollution increases not only because as people multiply, the space available to each person becomes smaller, but also because the demands per person are continually increasing.

Pollution has been and continues to be recognized and attacked as a public health problem. Much of our present knowledge of how to meet and cope with pollution stems from public health research and practice. It is also an economic problem intimately and directly affecting many industries and agriculture. It is a social problem creating constraints on the nature and direction of urban and regional development and patterns of land use.

The problem is growing faster than our present day solutions, both qualitatively and quantitatively. Therefore, present investment and effort for abatement and control must be increased substantially if we are to maintain the present pollution levels in and adjacent to our centres of pollution.

Water Pollution

Water pollution implies impairment of quality. When the effect is sufficient to render the river unacceptable for its best usage, it is said to be polluted. Best usage means just what the words imply: usage of water for drinking, bathing, fishing, agriculture, etc.

Rivers can assimilate a certain quality of waste before reaching a polluted state. Too much of any type of polluting material causes a nuisance and thus a polluted state exists. To call a river polluted therefore generally means that the river has been supersaturated with a specific pollutant.

Nature and Effects of Wastes on Bodies of Water

The pollutants which are entering the water courses are classified as follows:

Inorganic salts
Acids and/or alkalis
Organic matter
Suspended solids
Floating solids
Heated water
Colour
Toxic chemicals
Micro-organisms
Foam producing matter
Municipal sewage
Mine tailings

Inorganic Salts

The inorganic salts which are present in most industrial wastes as well as in nature itself cause water to be hard and make it undesirable for industrial, municipal and agricultural usage.

Salt-laden waters deposit scales on municipal water distribution pipelines, interfere with dyeing in textile industry. Magnesium sulphate has a cathartic effect on people. The chloride increases electrical conductance of insulating paper. Carbonates produce scales in boiler tubes which result to lower boiler efficiency and increased cost of operation. There is another facet of the problem worth noting: total absence of hardness in water result in corrosive and/or tasteless water.

Acids and/or Alkalis

The acids and/or alkalis make bodies of water unsuitable not only for recreational uses but also for propagating fish and other aquatic life. The toxicity of sulphuric acid for aquatic life is a function of the resulting pH. It is generally agreed that the pH of water must not be less than 4.5 if fish is to survive.

Sodium hydroxide appears in wastes of many industries including soap manufacturing, textile dyeing, leather tanning, rubber reclaiming, etc. Rivers containing sodium hydroxide as low as 25 ppm have been reported deadly to fish.

Organic Matter

The organic matter exhausts the oxygen resources of streams and creates unpleasant tastes, odours, and general septic conditions. Fish and most aquatic life are stifled by lack of oxygen. Oxygen level combined with other stream conditions determines the life or death of fish. It is generally conceded that the critical range for fish survival is 3 to 4 ppm dissolved oxygen.

Suspended Solids

The suspended solids settle to the bottom or wash up on the banks and decompose, causing odours and depleting oxygen in river water. Fish die because of sudden lowering of oxygen content. Solids that settle to the bottom tend to cover spawning grounds and inhibit propagation.

Visible sludge creates unsightly conditions and destroys the use of a river for recreational purposes. These solids increase the turbidity of river water.

Floating Solids

The floating solids like oil, grease, and other materials not only make the river unsightly but also abstract passage of light through the water retarding the growth of food plant. Objections to oil in water are (1) interferes with natural reaeration (2) toxic to certain species of fish and aquatic life (3) creates a fire hazard when present on the water surface in sufficient amounts (4) destroys vegetation along the shorelines (5) renders boiler-feed and cooling water unusable (6) causes trouble in conventional water treatment process by imparting tastes and odours, coating the sand filters with oil film and (7) creates an unsightly film on the surface of the water.

Heated Water

Heated water has decreased its value for industrial cooling. Since warm water is lighter than cold, stratification develops and this causes most fish life to retreat to stream bottoms. Since there will be less oxygen in warm water, aquatic life suffers, and any organic pollution discharge will have less oxygen available for natural biological degradation. Bacterial action increases in higher temperatures resulting in accelerated depletion of the stream's oxygen content.

Colour

Colour as contributed by textile and paper mills, tanneries, slaughterhouses, etc. is an indication of pollution. Colour interferes with the transmission of sunlight into the stream and therefore lessens photosynthetic action. It may also interfere with oxygen absorption from the atmosphere.Municipal and industrial water plants have great difficulty and scant success in removing colour from raw water..

Toxic Chemicals

Toxic chemicals, both organic and inorganic, even in low concentrations may be toxic to fish and other aquatic life. Insecticides used in agriculture have their maximum effect following a heavy rainfall, thus they are more lethal in solutions. Yet these substances are hard to detect in water.

Tanneries, slaughterhouses and food plants sometimes discharge wastes containing bacteria. These bacteria are generally of 2 types namely. bacteria which assist in the degradation of the organic matter and the pathogenic bacteria like *Anthrax bacillus* originating from tanneries.

Foam Producing Matter

Foam producing matter discharged by textile mills, pulp and paper mills and chemical plants is an indicator of pollution and sometimes more objectionable than lack of dissolved oxygen.

Municipal Sewage

Municipal sewage includes those waste from domestic, commercial, public, and industrial establishments discharged through sewer systems or septic tanks. Municipal sewage from urban areas are responsible for the principal public health hazards associated with pollution.

Mine Tailings

Mine tailings which are the rejects or waste materials in the milling operations result in the siltation of river beds and irrigation systems.

POLLUTION ABATEMENT PRACTICES

Pollution will never be an advantage to man and his environment. It will go on with its destructive activities unless controlled or abated. Rivers become polluted because pollutants are being dumped into them in quantities beyond the rivers' self-purifying capacity. The pollutant quantities should therefore be controlled and any of the following methods or combinations is usually practised.

Reduction of Wastewater Volume

Wastewater from factories does not come from only one source. There are wastes from manufacturing processes, wastes from cooling processes and wastes from sanitary facilities. Each wastewater has different characteristics. While others are polluted, others are clean enough to be discharged without undergoing any treatment. It is only the polluted water that needs to be treated.

Volume of wastewater could also be reduced by wastewater conservation. Relatively clean wastewater are recycled and used again. Treatment shall be done only after the water is no longer useful.

There are other methods of wastewater volume reduction like changing manufacturing processes to eliminate waste and reusing industrial and municipal effluents for raw water supplies. While both methods are feasible, their implication is expensive and probably intolerable to some extent. Hence, these methods are last resort to wastewater volume reduction.

Waste Strength Reduction

In the treatment of wastewater, the strength of the wastewater is most important to consider in the sizing of the plant needed. The stronger the waste is, the higher is the cost of treatment. To avoid high cost of waste treatment, the strength should therefore be reduced as low as possible. Methods of reducing the strength of wastewater include: (1) process changes (2) equipment modifications (3) segregation of waste (4) equalization of waste (5) by-product recovery.

Several industries are already employing the process changes as a means of waste strength reduction. The change from starch to cellulose compound as sizing agent in textile plants and the change from copper-cyanide plating solutions to acid-copper solutions are among the usual process changes.

Improving or changing the equipment used in a manufacturing process usually resulted in improved wastewater quality. This is effected by making the equipment work efficiently thereby ensuing smaller amounts of wastewater pollutants.

Segregations of wastes that are highly polluted from the less potent ones will reduce the strength of the bulk of the wastewater which makes it amenable to treatment. The concentrated part of the waste could then be hauled more easily because of the reduced volume.

Equalizing of waste applies to factories that produce several products from which different types of wastewater are discharged. A holding tank serves the purpose for which waste are collected per day or per working shift. Holding the waste for a certain period enables the acidic wastewater to neutralize, the highly alkaline ones hence stabilizes the pH and sometimes BOD. The effluent becomes stable and more consistent in its characteristics than when it is segregated.

By-product recovery may require an expensive and complicated process, however, some industries save in employing this process. Metal-plating industries for instance recover acids, copper, nickel, chromium, etc. by employing ion-exchangers; paper mills recover caustic soda from cooking liquors by using multiple-effect evaporators and dairy industry treats skim milk with dilute acid to produce casein. These are but few recovery processes which add income to the industry at the same time greatly lessen the strength of wastewater produced.

Wastewater Treatment

Wastewater treatment is the process of rendering the wastewater free from excessive levels of pollutants. Even after applying the previous preventive measures, reduction of wastewater volume and strength, the concentrated wastewater has still to be treated. Wastewater may consist of one or a combination of the following:

Neutralization

Waste with high or low pH is not allowed to be discharged into any body of water. The pH must be raised or lowered to near-neutral. Several methods of neutralization are:

(1) Mixing with alkaline and acidic wastes.
(2) Passing acid wastewater through limestone beds or mixing such wastewater with lime slurries, caustic soda or soda ash.
(3) Blowing waste boiler-flue gas through wastewater of high pH, or adding into such waste compressed carbon-dioxide or sulphuric acid.

Equalizing and Proportioning

Whenever variation of wastewater flows and characteristics exist, a process of holding and mixing the wastewater for a certain period is usually employed to make the effluent fairly uniform. Holding time usually depends on the operating cycle of the factory while mixing could be attained by proper distribution using baffles, mechanical agitation, aeration or a combination of the three.

Sedimentation

Sedimentation is mere settling of solids by gravity. This process is employed only in wastewater containing high percentage of settleable suspended solids. The velocity of flow is very much reduced by allowing the wastewater to flow through a sedimentation tank. Efficiency of sedimentation depends on the following factors: detention time, tank depth, floor surface area, temperature, particle size, velocity of particles, container wall effect, number of basins, sludge removal and flow fluctuations.

Flotation

Some suspended solids are difficult to settle, hence these could not be removed by sedimentation. Such solids could be made to float by the lifting power of the many minute air bubbles which attach to the suspended solids. Once floated, these solids agglomerate and are easily removed from the liquid surface by skimming.

Coagulation

Small sized, suspended solids do not settle by quantity. In order that sedimentation could be effected, the small particles must be combined together to form bigger particles heavy enough to settle down by gravity. The process of conglomerating the small particles by means of adding chemcials is called chemical coagulation.

Removal of Organic Dissolved Solids

The organic matter in wastewater constitutes the bulk of the pollution load. It is therefore necessary to employ means of removing it from the wastewater. The usual method is the biological process which involves the action of bacteria.

There are several processes of biological treatment, each one being adaptable to a specified wastewater quality. Among the biological processes commonly employed in sewage and industrial wastewater treatment are as follows: lagooning, activated sludge process, modified aeration, biosorption, high-rate aerobic process or total oxidation, trickling filter, spray irrigation and anaerobic digestion.

Lagooning (stabilization or oxidation in pond).

This process makes use of several self-purification phenomena. The settleable solids are deposited in the pond. Decomposition at the bottom takes place by the action of micro-organisms. The dissolved organic solids are likewise acted upon by bacteria in their metabolic processes giving off carbon dioxide that are needed by plants. There is therefore a completed cycle in which the micro-organisms use dissolved oxygen in the water, break down complex organic substances to produce waste products like carbon doixide, nitrates, sulphates and phosphates which the algae use in their photosynthesis giving off oxygen to supply the needs of the micro-organisms.

Activated sludge process

In this process, biological growths are produced which adsorb complex organic matter from the wastes and convert it by oxidation - enzyme systems into simple substances like carbon dioxide, water, nitrates and sulphates. Air is introduced in the system which maintains the oxygen requirements of the micro-organisms to form flocs which are actually living masses of organisms, food and slime material. These flocs are highly active from which the name activated sludge was named. A portion of the activated sludge is recycled and the rest are sent to a digester where it is further decomposed into stable substances.

Modified aeration process

This is a variation of the activated sludge process with the main purpose of supplying maximum volume of air to the sludge when it is in the optimum condition to oxidize adsorbed organic matter. The modification is done by varying the amount of air supplied at different points of the aeration tank - more at the point of entry of the wastewater and lesser as it goes farther from the influent.

Biosorption

This is again a modification of the activated sludge process. In this process, raw waste is mixed with previously formed activated sludge for a short time of about 15 to 20 minutes. The adsorbed organic matter together with the activated sludge is allowed to settle for about 2 hours. This settled floc will undergo intense biological oxidation in a stabilization-oxidation basin for at least one hour. Portion of the settled floc is returned to the raw waste effluent to adsorb again complex organic matter while the rest are subjected to anaerobic digestion into simple substances. Since the real aeration is made at the settled floc, this process needs less space than any of the other activated sludge process modification.

High rate aerobic treatment (total oxidation)

This is a modified activated sludge process where air is applied to the raw waste for a long period, from one to three days. In view of the long period of aeration, more air is required, however, no primary settling of the raw wastewater is needed. During the long period of aeration, the complex organic matter are broken down to simple substances.

Trickling filtration

This process makes use of a filter medium like stones where slime layer is allowed to grow. The slime growth which is actually bacterial growth absorbs and oxidizes the dissolved and colloidal matter from the raw wastewater. The process involves the formation of surface film on the stone or contact surface followed by the concentration of colloidal material and occurrence of organic matter. The absorbed substances are finally attacked and broken down by bacteria into simple substances.

Anaerobic digestion

Anaerobic digestion takes place in a closed tank or vessel where air is excluded. The micro-organism called anaerobic bacteria acts on the complex organic substances even without sunlight and oxygen.

QUALITY STANDARDS

In the implementation of pollution control programmes, standards are set by the regulatory agencies from which degree of wastewater treatment could be based. Due to varied usage and location of different streams, lakes or rivers, there could never be one set of standard for a certain country. The standard for streams used for drinking and other domestic purposes needs a high quality standard. For river used only for navigation, agricultural and industrial water supplies, a lower quality may be required.

Several factors should be considered in determining the usage of each river. The following may be used as a guide:

(1) The size, depth, surface area, volume, direction and rate of flow, stream gradient and temperature of the water.

(2) The character of the district bordering said water including any peculiar suitability such district may have on any dominant economic interest or developments which has become established in relation to or by reason of any peculiar use of such water.

(3) The uses which have been made, are being made or may in the future be made of such water for domestic water supply, navigation, aesthetic enjoyment, waste disposal or any other uses.

(4) The extent to which such water is already receiving sewage, industrial waste or other wastes as a result of present or past usage of the water and the relative economic values involved in improving or attempting to improve the condition of such water.

ADMINISTRATION

Normally, pollution control is under the administration of government authorities. In 1964, the Philippine Government cognizant of its duties and responsibilities to protect the health and welfare of the people from harm due to increasing pollution levels, passed and approved Republic Act 3931 known as the Pollution Control Law.

This law created an agency called the National Water and Air Pollution Control Commission. This agency is authorized to:

(1) Determine if pollution exists in any of the waters and/or atmospheric air of the Philippines. Findings of the Commission regarding the existence of pollution shall be filed on record in the office of the Commission.

(2) Adopt, prescribe, and promulgate rules and regulations governing the procedures of the Commission with respect to hearings; the methods and manner under which plans, specifications, designs, or other data relative thereto shall be submitted for sewage works and industrial wastes disposal systems or for addition or change to or extensions of such work; the filing of reports; the issuance of permits; and such other reasonable rules and regulations as may be necessary from time to time in the proper implementation and enforcement of this Act.

(3) Hold public hearings, receive pertinent and relevant proofs from any party in interest who appear before the Commission, make findings of facts and determinations, all with respect to the violations of this Act or orders issued by the Commission.

(4) Make, alter or modify orders requiring the discontinuance of pollution of the waters and/ or atmospheric air of the Philippines due to the discharge of sewage, industrial wastes or other wastes and specifying the conditions and the time within which such discontinuance must be accomplished.

(5) Institute or cause to be instituted in a court of competent jurisdiction legal proceedings to compel compliance with the provisions of this Act.

(6) Issue, renew, or deny permits, under such conditions as it may determine to be reasonable, for the prevention and abatement of pollution, for the discharge of sewage, industrial wastes or other wastes, or for the installation or operation of sewage works and industrial disposal system or parts therefore, except that no permits shall be required of any new sewage works or changes to or extensions of existing works that discharge on domestic or sanitary wastes from a single residential building/housing or occupied by twenty persons or less; provided, however, that applications for the issuance or renewal of permits required under this Act shall be filed with and decided by the city engineer or district engineer of the city or province from which the discharge of industrial or other wastes shall originate, in accordance with rules, regulations

and standards to be issued by the Commission. In case of doubt, the city or district engineer shall consult the Commission before issuing, renewing, or denying the permit applied for; and any decision of the city or district engineer may be appealed by the applicant or by any resident of the place who may be affected by the discharge of waste to the Commission, under such rules and regulations as the Commission shall issue for such appeals.

(7) After due notice and hearing, revoke, suspend or modify any permit issued under this Act, whenever modifications are necessary to prevent or abate pollution of any water and/ or atmospheric air of the Philippines.

(8) Cause such investigation to be made as it may deem advisable and necessary for the discharge of its duties under this Act.

(9) Settle or compromise any dispute arising out of the implementation and enforcement of the second paragraph of Section 10 of this Act as it may deem advantageous to the public interest.

(10) Perform such other duties as may be necessary to carry out effectively the duties and responsibilities prescribed in this Act.

The Commission shall have the following duties and responsibilities:

(1) To encourage voluntary cooperation by the people, municipalities, industries, associations, agriculture and representatives of other pursuits in the proper utilization and conservation of the waters and/or atmospheric air of the Philippines.

(2) To encourage the formation and organization of cooperative groups or associations in municipalities, industries, enterprises and other users of the waters who severally and jointly are or may be the source of pollution of the same water, the purpose of which shall be to provide a medium to discuss and formulate plans for the prevention and abatement of pollution.

(3) To serve as arbitrator for the determination of reparations involved in the damages and losses resulting from the pollution of the waters and/or air of the Philippines.

(4) To devise, consult, participate, cooperate and enter into agreements with other agencies of the government, and with affected political groups, political subdivisions and enterprises in the furtherance of the purposes of this Act. This particularly refers to such cooperative agreements with the various provincial and municipal governments in securing their assistance in carrying out the provisions of this Act.

(5) To prepare and develop a comprehensive plan for the abatement of existing pollution and prevention of new and/or imminent pollution of the waters and/or atmospheric air of the Philippines.

(6) To issue standards, rules and regulation to govern city and district engineers in the approval of plans and specifications for sewage works and industrial wastes disposal systems and in the issuance of permits in accordance with the provisions of this Act, and to inspect the construction and maintenance of sewage works and industrial wastes disposal system for compliance of the approved plans.

(7) To collect and disseminate information relating to water and atmosphere pollution and the prevention, abatement and control thereof.

(8) To authorise its representative to enter at all reasonable times in or upon any property of the public dominion and private property devoted to industrial, manufacturing, processing or commercial use without doing damage, for the purpose of inspecting and investigating conditions relating to pollution or the possible or imminent pollution of any waters or atmospheric air of the Philippines.

Rules and Regulations

The National Water and Air Pollution Control Commission adopted its rules and regulations to implement the provisions of the Pollution Control Law. Philippine rivers were classified on the basis of their best usage. It is left to each industry to decide the manner and extent of treatment it must give to its waste to meet water quality standards. Industry generally communicate directly with the Commission since this agency reviews the final construction plans, supervises the construction and issues the permit to operate after the finished treatment plant has met the requirements of the Commissions.

Public Hearings

Philippine Republic Act 3931 empowers the Commission to summon industry to a public hearing for non-compliance with the provisions of the Pollution Control Law. Order for compliance is immediately issued if in the hearing, it has been established that the liquid wastes of the firm contribute to the pollution of the receiving body of water. Court action is the last resort taken and this is resorted to only when there is complete defiance to the orders issued by the Commission.

Paper No. II/2(

WATER POLLUTION IN THAILAND

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ABSTRACT

Water pollution problems exist in various parts of Thailand with varying degrees of seriousness. The causes, nature, and extent of the water pollution are described in some detail. Legislative controls of water pollution such as industrial effluent standards are discussed. Various problems responsible for the unsatisfactory combat against water pollution are elaborated. Research activities on water pollution are briefly described.

INTRODUCTION

Water is the most valuable resource for economic development but unfortunately, it is also most vulnerable to pollution. Water pollution has long been a serious environmental problem in industrialised countries. But not until recently have developing countries come to realize the existence of water pollution in their countries and its detrimental effects on their economic progress and the health of their people.

Thailand is fortunate in its abundant water resources. There are many large rivers in the country as shown in Fig. 1 which are of utmost importance to agriculture, communication, transportation, fisheries, industrial development, and daily living of the people. The majority of people in Thailand especially those residing outside municipal areas, have not been provided with tap-water. Even in Greater Bangkok, only about 60 per cent of the total population have access to a piped water supply and the figure is as low as 30 per cent in Nonthaburi, a small town in the suburbs of Greater Bangkok. Consequently, a large percentage of Thai people still has to rely on surface waters for various domestic uses such as washing, cleaning, bathing, and even drinking when rain water or ground water is not obtainable.

Adverse effects of water pollution in Thailand then become obvious. Apart from being a potential health hazard, water pollution also endangers aquatic life, degrades aesthetic values of the water, and damages crop plantation. It is therefore, one of the gravest environmental problems facing this country and its solution is of top priority as far as the control of environmental pollution is concerned.

CAUSES OF WATER POLLUTION

The real root of water pollution and other environmental problems in a developing country like Thailand, is a high rate of population increase which for Thailand, is over 3 per cent per annum. Rapid population growth means increasing needs for industrialization, and higher agricultural productivity, in attempts to increase per capita income and the standard of living. In the course of these developments, their consequent impacts on the environment are usually ignored because of unawareness, and lack of financial resources and knowledge. The final outcome of this is the deterioration of environment especially the aquatic environment as evidenced by appalling conditions of many rivers in the developing countries.

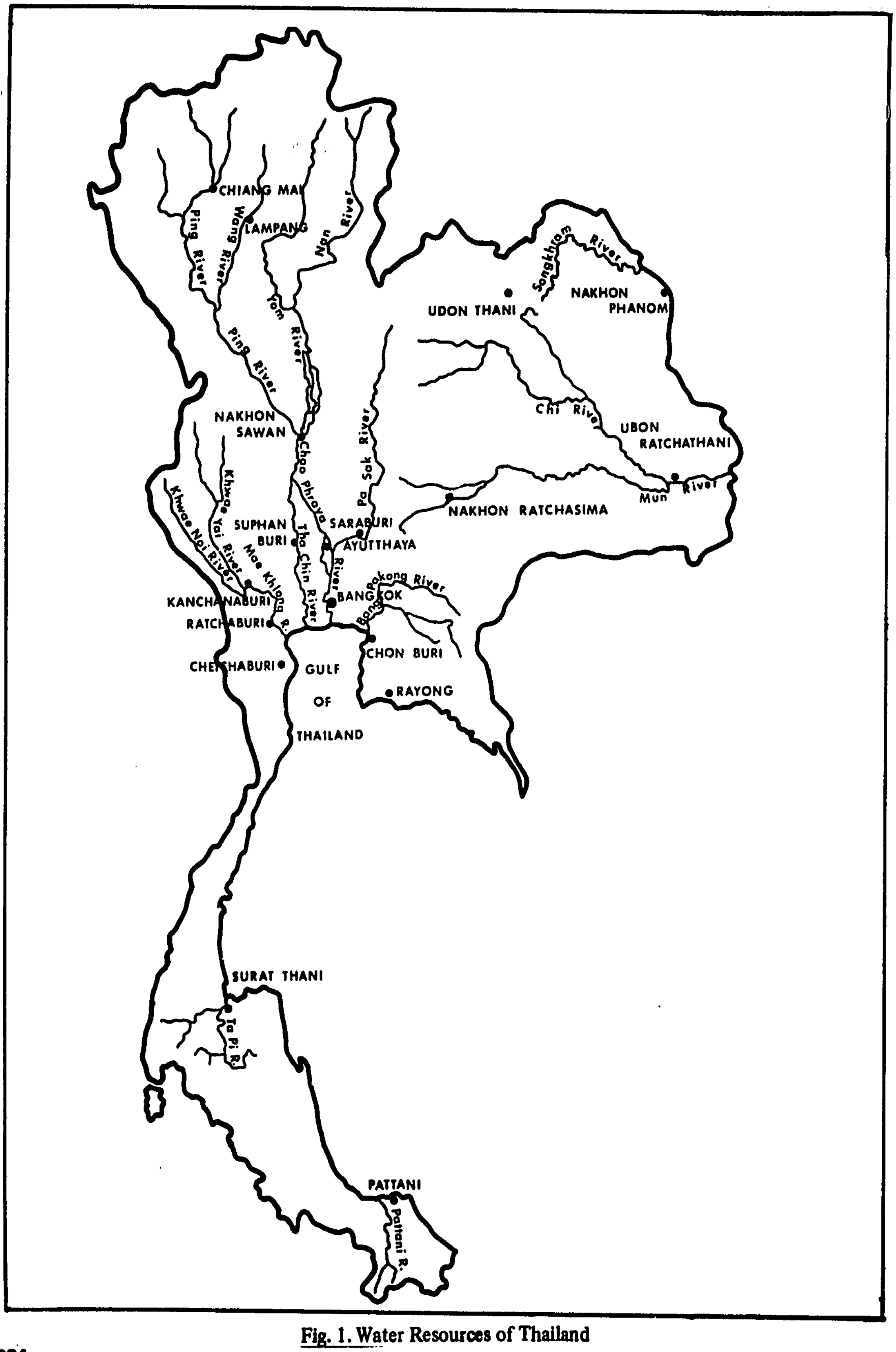

Fig. 1. Water Resources of Thailand

Pollution of surface waters in Thailand is caused by the disposal into the waters, liquid and solid wastes of domestic and industrial origins, and by polluted runoff from urban and agricultural areas. Evidence available at present indicates that domestic and industrial wastes are the main causes of water pollution in various parts of the country.

The process of urbanization in Thailand is uncontrolled, haphazard, and not according to plan, due to lax in enforcement of the urban planning laws. Industrial and residential areas are mingled and the municipalities usually fail to provide community facilities such as sewerage system at a fast-enough rate to cope with the rising demand. The final consequence is the aggravation of environmental quality in the urban areas.

Up to the present time, no major towns and cities in Thailand have had integrated sewerage system or sewage treatment systems. Household wastewaters arising from cooking, bathing and washing are discharged through street drains or sewers which are eventually drained into nearest receiving water bodies. Toilet wastes usually receive only rudimentary treatment in cesspits or septic tanks. The accumulated sludge is periodically removed and disposed off in a municipality's lagoon. The septic tank effluent seeps through the soil and should be rendered harmless before reaching underground water or a water course. However, this is not always the case especially in the areas in and around Greater Bangkok. These areas and alluvial plains and the ground water tables are high. Consequently, the septic tank effluent from houses contiguous to the water courses can still be a significant pollutional source.

Thailand is still regarded as an agricultural country in spite of a remarkable success in industrialization. The number of factories has considerably increased in the past decades with most of the industries concentrated in the areas in and around Greater Bangkok. Most of the factories are however, of small and medium sizes. Various industries located in the areas are textile, brewery, distillery, tannery, soap, detergent, soft-drink, dairy, paper, pharmaceutical, food, metal, etc.

At present, water pollution in Greater Bangkok area has reached a critical level. With a population of over 3 million persons and a great number of factories, Greater Bangkok becomes the most densely populated and heavily industrialised city in the country. Domestic and industrial wastes are taking equal shares in polluting many urban canals and the Chao Phraya River estuary.

In other parts of the country, industrial wastes are the most important source of pollution.

NATURE AND EXTENT OF WATER POLLUTION

The pollution of surface waters in Thailand is in most cases, organic in nature. One important effect of the organic pollution on the surface waters is the depletion of dissolved oxygen which is most vital to metabolic activities of aquatic life. If the level of dissolved oxygen is too low, most species of fish and other aquatic animals will not be able to survive. The exhaustion of dissolved oxygen will result in anaerobiosis and the water may become septic giving off unpleasant odours.

Toxic industrial wastes and pesticide residues in runoff from agricultural land, have not created serious problems of water pollution. Although, there have been occasional complaints of damages to fisheries, crop plantation, and domestic uses of the surface waters, caused by some toxic industrial wastes, the problems are on a small scale and can be regarded as minor ones compared with the problems of organic water pollution.

As previously mentioned, the most critical areas of water pollution are in Greater Bangkok. The city is situated on the banks of the estuarine reach of the Chao Phraya River which is the most important river in the country. The river supplies irrigation water for a vast area of rice fields and other crop plantation in the central alluvial plain. In is also a major mode of transport, a source of water supply, a fish and prawn culture resource, a recreational place, and a habitat for boatmen. Hence, it is always regarded as the main artery of the country's economy.

Branching out from the Chao Phraya River are many man-made canals which interconnect and form a complex network for communication and irrigation purposes. At present, almost all canals in the metropolitan area are so polluted that they remain septic for the greater part of the year. The estuary itself, becomes anaerobic near Bangkok Port during low flows, and the dissolved oxygen content on the average is far below a satisfactory level as shown in Fig. 2. It can be seen that the estuary condition has been steadily deteriorating since 1966 due to the increase in population and industries.

Industrial wastes are the most important source of pollution in the Mae Klong River and the Tachin River unlike the Chao Phraya River. Wastes from sugar and paper industries in Karnburi and Rachburi provinces reduce the dissolved oxygen level in the Mae Klong River to a minimum concentration of less than 1 mg/l in summer. Sugar factories in Supanburi province are responsible for depleting dissolved oxygen level in the Tachin River to less than 3 mg/l.

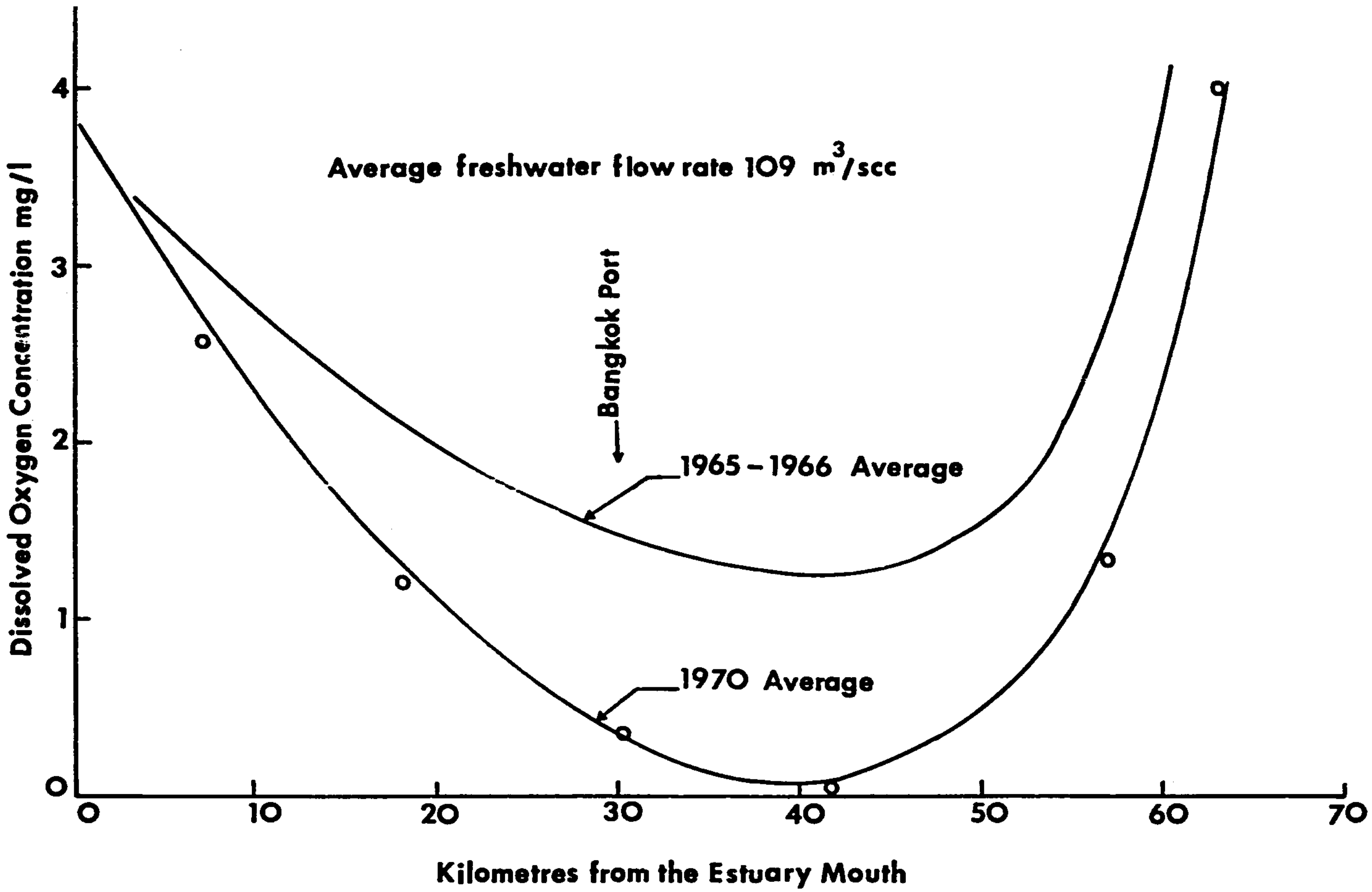

Fig. 2. Records of Dissolved Oxygen Condition of the Chao Phraya River

In the coastal areas of Chonburi and Rayong provinces, many streams are completely anaerobic due to wastewaters from sugar, tapioca, and fish meal factories. The septic streams drain into the sea which is at present, still capable of assimilating these pollutional leads without any significant deterioration of water quality.

There are 2 oil refineries in the Chonburi area. The refineries have treatment facilities to eliminate oil slicks from their spent cooling water before disposing into the sea. Although there are considerable activities of oil tankers in the waters, so far no significant case of oil pollution has been reported.

ECONOMIC IMPLICATIONS OF WATER POLLUTION

In view of the present state of the country's economy, one may justifiably ask whether water pollution control is necessary because more highways, schools, hospitals, and water supply are needed. To answer this question, damages of water pollution to fisheries, agriculture, public health, and aesthetic values of the water must be evaluated in monetary terms and balanced against the cost of pollution control. The estimation of the cost of pollution is however, difficult in practice since the damage in aesthetic terms is hard to measure in monetary values. In 1967 the economic cost of pollution to the United States of America was estimated at $12,000 million annually. Such a cost estimation in Thailand has not been made.

In Thailand, the damages of water pollution to fisheries, and public health are likely to be most significant. Fishing in the Chao Phraya River estuary and in the urban canals, has long ceased to be a lucrative business. No statistics of annual income from fisheries in the estuary and canals are available. In the Mae Klong River, an annual income from fisheries was estimated to be over $2.5 million.

Pescod [5] quoted from the data released by the Ministry of Public Health, that over the period from 1959 to 1963, the average number of deaths attributable to water-borne diseases made up 5.8% of the total number of deaths in Thailand. Wastage of working hours due to water-borne diseases must also be counted as a cost of pollution but information on this however, is not available.

ABATEMENT OF WATER POLLUTION

In any scheme of water pollution control, the objective should be clearly established preferably in terms of water quality standards taking into account all legitimate uses of the water. Up till now, no standards of water quality have officially been set up. It should be cautioned that the standards used in the developed countries might not be appropriate for the developing countries because of the great difference in environmental, technological and social conditions. Aesthetic benefits of the water usually, have much higher value in the developed countries than in the developing countries. It is essential that the developing countries establish their own water quality standards to suit their particular conditions.

Industrial Wastes Problems

Paradoxically, the primary aim of industrial water pollution control should be disposal without treatment, and treatment must only be the last resort. It is not in all cases that treatment is necessary from technical point of view. It is needed only when the waste-assimilation capacity of the receiving water body is not adequate to maintain the required water quality standards. The key to economic control of water pollution is full utilization of the waste-assimilation capacity of the receiving water body. The treatment cost may be considerably reduced if the degree of treatment can be made to vary with the waste-assimilation capacity. For instance, the treatment may not be necessary during high flows.

Before any decision on treatment is made, minimization of the treatment cost by in-plant reduction of volume and strength of the wastewaters should be investigated. Possible methods are improvement in manufacturing process, segregation of non-pollutant wastewaters such as spent cooling water, removal of pollutant in a dry state, reuse of the wastewaters, and recovery of valuable products in the wastewaters.

In Thailand, the disposal of untreated liquid industrial wastes into surface waters has created many serious cases of water pollution in various parts of the country. Although the industries are required by the Ministry of Industry to install waste treatment facilities, only a few of them have so far, complied with the requirement. The industries obviously have no incentive to treat their wastes since they do not suffer from pollution. An extra investment in waste treatment will undoubtedly, increase the cost of production and for some industries, the investment can put them out of business. In addition, the Ministry of Industry itself, has a lack of environmental or sanitary engineers specially trained in this field. The Ministry is therefore, in a dilemma and it always has to compromise. If it exercises all legal powers to compel the industries to meet its requirement, a number of industries will have to close down and country's economy will eventually suffer.

Domestic Wastewaters Problems

Ironically, while the industries are legally required to treat their wastewaters the municipalities are virtually free to discharge their wastewaters into the surface waters. At present, municipal wastewaters are the most important source of pollution in many canals in Greater Bangkok. The problem can be solved only through the treatment of the domestic wastewater.

The problem of drainage, sewerage, and sewage disposal for Greater Bangkok, has received attention from the previous governments. Various proposals on the project were put forward including those of Litchfield [4], Husband [3], Tholin [6], and Camp, Dresser, and McKee [2]. In the Master Plan Report of Camp, Dresser, and McKee, the cost of sewerage system was estimated at $188 million. So far, only a small part of the Master Plan costing $3 million has been implemented. In view of the country's economy, complete implementation of the plan would not be possible in foreseeable future.

Legislative Control of Water Pollution

Existing laws and regulations in Thailand concerning water pollution and wastewater discharges are neither clearly defined nor appropriate for the present situation. Their revision, amendment, and strong enforcement are indispensable for protecting the country's water resources.

At present, the drainage of buildings in Greater Bangkok is controlled by Municipal Bye-Laws, Section 8 of which deals with sanitation. This section states ambiguously that sewage should be treated to the satisfaction of the municipality before it is discharged to public waterway. This implies that human excreta or toilet wastes are not allowed to be discharged into the sewer or the water course, this is justified on public health and aesthetic grounds. At present septic tank is an acceptable form of treatment though the effluent can seep through the soil and pollute the water course.

Other types of domestic wastewaters such as kitchen wastewater, are at present, discharged directly or indirectly into the water courses. They are more important pollutional source than the septic tank effluent. However, the public cannot be held responsible for having polluted the water courses by their domestic wastewaters since it is the responsibility of the municipality to provide sewerage and waste treatment systems for the public.

Disposal of solid wastes into the water courses has been an illegal practice for a long time. Though they are not the important cause of dissolved oxygen depletion they are an aesthetic nuisance. In spite of a heavy fine imposed, garbage and other unsightful materials can still be seen in the urban canals. This is due to the inefficiency of the refuse collection system and sheer ignorance of the public.

Discharge of industrial wastes into the public waterway is controlled by the Factory Act. This legislation imposes the restriction that wastes discharged must not create nuisance to people using the waterways or people in the neighbourhood. Nuisance in this context can have a great number of implications thus it should have been specifically defined.

Recently, the Ministry of Industry has established working standards for effluent discharging into inland streams as shown in Table 1. The standards are expressed in terms of maximum allowable concentrations regardless of the waste-assimilation capacity of the receiving water body and the type of industry. Bachman and others [1] pointed out that these standards would not be practical for some industries. They therefore, proposed a new set of draft standards based on type of industry and the waste-assimilation capacity of the receiving water body expressed in terms of the degree of treatment. Some of the proposed standards are presented in Appendix 1. Appendix 2 presents the draft regulations on industrial effluent discharge and control recommended by Bachman and others [1]. The Ministry of Industry has also established rules and regulations for factory establishment and extension dealing with wastewater as presented in Appendix 3.

Problems in Water Pollution Control

Though the Thai authorities have long been aware of the problem of water pollution and the public is now very cautious of this matter, the control of water pollution has not satisfactorily progressed and there has been no significant improvement in water quality. Lack of cooperation among responsible authorities, financial resources and qualified environmental engineers are to be blamed for the ineffective pollution control. The municipality is legally responsible for pollution control of the public water courses but it has no authority over the control of industrial wastes which are a major source of pollution. In addition, the municipality itself, discharges untreated household wastewaters into the public watercourse. In Greater Bangkok, the water pollution will not be satisfactorily alleviated even if the industries fully treat their wastes, unless the municipality also follows suit.

The Ministry of Industry has a responsibility to control the discharge of industrial wastes. The Ministry's effort is however, hampered by lack of engineers trained in the field of wastewater engineering. The Sanitary Engineering Division, Ministry of Public Health has a duty to survey the extent of problems concerning industrial.

B O D (5days 20^{0}C) – maximum	20 ppm
Suspended solids – maximum	30 ppm
Dissolved solids – maximum	2000 ppm
pH value – between 5 and 9	
Permanganate value – maximum	60 ppm
Sulphide (as H_2S) – maximum	1 ppm
Cyanide (as HCN) – maximum	0.2 ppm
Oils and grease – none	
Tar – none	
Formaldehyde – maximum	1 ppm
Phenols and cresols – maximum	1 ppm
Free chlorine – maximum	1 ppm
Zinc, Chromium, Arsenic, Silver, Selenium, Lead, Nickel – individually or in total maximum 1 ppm	
Insecticides – none	
Radioactive materials – none	
Temperature – maximum	40 ^{0}C
Taste and odour – not disagreeable	

Table 1(a) Working Standards for Effluent Discharging into Inland Streams (Issued by Ministry of Industry).

Volumes of dilution	Maximum permitted suspended solids
8 – 150	30
150 – 300	60
300 – 500	150

Table 1(b) Standards for Sewage Effluents Discharging to Inland Streams of High Dilution Ratio waste disposal and water pollution, but it has no authority over the industries. Of the three organizations mentioned, the Sanitary Engineering Division is in the best position to perform the work of water pollution control in view of its facilities and manpower. It has a laboratory capable for general analysis of water and wastewaters, and a considerable number of engineers trained in the field of wastewater treatment.

The Applied Scientific Research Corporation of Thailand (ASRCT), has recently set up the Environmental Engineering Unit to undertake research on various aspects of environmental pollution which was formerly conducted by the Bio-Technology Group of the Corporation. Since ASRCT is essentially a research organization it has no authority over the control of water pollution. However, ASRCT can play an important role in the control by rendering useful information and proper technical advice to the control bodies. ASRCT's activities in water pollution research are still limited at present, due to lack of financial resources.

There is virtually no cooperation among the organizations involved. It is necessary that for efficient abatement of water pollution, cooperation and coordination among these organizations must be established. In addition, there should be an organization directly responsible for planning or making policy on pollution abatement. These conditions led to the official formation of the "Committee on Environmental Quality Control" in February, 1971. The Committee has the responsibility of making policy on environmental pollution control, and of encouraging and coordinating research on various aspects of environmental pollution conducted by various organizations. The committee is under the chairmanship of the Secretary-General of the National Research Council and 13 other members are representative from ministries and organizations involved in the economic development.

WATER POLLUTION RESEARCH IN THAILAND

Research on various aspects of water pollution is indispensable for efficient and economic control of water pollution. There are at present, few organizations in Thailand actively involved in water pollution research. Asian Institute of Technology (AIT), one of the most outstanding academic institutes in Asia has rendered a significant contribution to environmental pollution research in the country. AIT has compiled a large amount of information on various aspects of environmental pollution.

In conjunction with AIT, ASRCT has completed a study on photosynethetic oxygen production in the Chao Phraya River estuary and also a revision of various studies of oxygen balance of the estuary. A current research project which has been going on for over two years, is algal-protein production from sewage using high-rate oxidation ponds. Waste treatment can be regarded as an investment which can only result in intangible benefits. For a developing country like Thailand, it will be a heavy economic burden and is unlikely to be justified considering many other needs in the economic development. High-rate oxidation ponds seem to be the only treatment method of which the investment can be possibly offset through the sale of the algal-protein product. The research project therefore, aims at developing a method of profitable utilization and production of the algal-protein.

The Sanitary Engineering Division, Ministry of Public Health, has initiated a programme of periodic examination of water quality in various areas of the country. Though the programme is not strictly research, it is useful in assessing the extent of the pollution problem and in being a surveillance of the water quality.

Apart from these organizations, some universities are also conducting studies of water pollution problems.

CONCLUSIONS

Rapid increase in pollution is the root of environmental problems in the developing countries including Thailand. The impacts of various processes of the economic development, on the environment are usually ignored because of unawareness, and lack of technology and financial resources. The final consequence is the deterioration of environmental quality especially that of water.

Water pollution is the most serious environmental problem in Thailand since a great percentage of people rely on surface waters for their daily living. Water pollution is therefore, a potential health hazard and it also damages fisheries, agriculture, and aesthetic value of the water.

Serious problems of water pollution are experienced in Greater Bangkok and in a few areas of the country. Urban canals in Greater Bangkok, the Chao Phraya River, the Mae Klong River, and a number of streams in Chonburi are severely polluted. The condition of the Tachin River is also deteriorating.

In the Greater Bangkok area which is the most densely populated and heavily industrialized in the country, domestic wastes and industrial wastes are responsible for the water pollution. In other areas, industrial wastes are the main cause. Organic pollution with depletion of dissolved oxygen is the most common nature of water pollution.

Too little is known of the economic cost of water pollution. However,, the pollution control seems to be justified on the public health grounds alone. The pollution control has not satisfactorily succeeded due to many problems such as lack of cooperation and coordination among the authorities concerned, lack of financial resources and qualified personnel, and lack of appropriate laws concerning standards of water quality and effluent discharge.

Research activities, on water pollution are still limited. Research is solely needed to establish the levels of pollution control which will, on the one hand, provide a satisfactory environment and will yet, on the other, not hinder economic development.

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STANDARDS OF INDUSTRIAL EFFLUENTS DISCHARGE FOR SOME INDUSTRIES IN THAILAND RECOMMENDED BY BACHMAN AND OTHERS (1970).

Soap Factory Effluent

(1) *Primary Treatment*	
(a) settleable solids	0.3 ml/l
(b) floating matter	not perceptible
(c) pH value	6.0 – 8.5
(2) *Partly Biological Treatment*	
(a) settleable solids	0.3 ml/l
(b) undissolved matter	20 mg/l
(c) permanganate value (COD)	120 mg/l
(d) BOD_5	80 mg/l
(3) *Full Biological Treatment*	
(a) settleable solids	0.3 ml/l
(b) undissolved matter	20 mg/l
(c) permanganate value (COD)	80 mg/l
(d) BOD_5	25 mg/l

(4) *Special Notice*
- (a) oils and grease might affect treatment process, removal necessary
- (b) waste liquor must not be released in bulk
- (c) mind high salinity

Breweries Effluent

(1) *Primary Treatment*	
(a) settleable solids	0.3 ml/l
(b) floating matter	not perceptible
(2) *Partly Biological Treatment*	
(a) settleable solids	0.3 ml/l
(b) undissolved matter	20 mg/l
(c) permanganate value (COD)	150 mg/l
(d) BOD_5	80 mg/l
(3) *Full Biological Treatment*	
(a) settleable solids	0.3 ml/l
(b) undissolved matter	20 mg/l
(c) permanganate value (COD)	80 mg/l
(d) BOD_5	25 mg/l

(4) *Special Notice*
No discharge of yeast liquid.
Lye from bottle and barrel cleaning should be discharged continuously in small quantities.

Paper and Pulp Factories Effluent

With respect to the wastewater the production from the following raw materials must be distinguished:

(A) Paper and cardboard from chemical pulp
(B) Paper and cardboard from chemical pulp and wood pulp
(C) Paper and cardboard including mineral pigments
(D) Paper and cardboard with wastewater additives
(E) Paper and cardboard from chemically processed ragged clothes, wood straw and synthetic materials (bagasses from sugar cane production would fall under this grouping)

Standards of effluent quality must be based on the respective type of raw material used, see corresponding letters A, B, C, D, E as above.

	A	B	C	D	E
(1) *Primary Treatment*					
(a) settleable solids ml/l	(not practicable due to fibres)				
(b) undissolved matter mg/l	30	40	40	50	100
(c) pH value	------	5.5 to 9.0			-----
(d) bleaching agent		not detectible			
(2) *Chemical Treatment*					
(a) settleable solids ml/l (higher values permitted if value of undissolved matter maintained)	0.3	0.3	0.3	0.3	0.3
(b) undissolved matter mg/l	20	25	30	40	50
(c) pH value	--------	6.5 to 9.0			--------
(d) permanganate value (COD) mg/l	150	300	400	400	400
(e) BOD_5 mg/l	150	200	200	200	200
(f) bleaching agent		not detectible			
(3) *Biological Treatment*					
(a) settleable solids ml/l (higher values permitted if value of undissolved matter maintained)	0.3	0.3	0.3	0.3	0.3
(b) undissolved matter mg/l	20	20	20	–	30
(c) permanganate value (COD) mg/l	100	100	150	–	200
(d) BOD_5 mg/l	25	25	25	–	40

DRAFT REGULATIONS ON INDUSTRIAL EFFLUENT DISCHARGE AND CONTROL PROPOSED BY BACH... N AND OTHERS (1970).

Procedure

The control authority concerned issues the legal permission for the discharge of effluents with a validity of up to 20 years, however, revocable at any time. The application must be submitted formally, containing descriptions of the plant and its facilities, the method of treatment proposed, and plans of the sewerage and wastewater network pertaining to the system. The permission shall distinguish the discharge of

- storm water
- cooling water
- sanitary wastewater
- industrial wastewater

The permission relates to a well-defined point of effluent discharge along an open water stream and imposes the items in the following paragraphs for observance.The values and regulations given below are drafted for the Bangkok-Thonburi region in general but may be subject to variations under specific local conditions.

Quality Regulations

The discharge must not cause any nuisance in the river which might lead to damage on animals or plants living in water, or might affect the common use of the river water, the fishery and the use for water supply. The following values and quantities must be maintained.

(1)	temperature	not exceeding	$40^{o}C$
(2)	pH value	between	6.0 and 9.0
(3)	settleable solids in 2 hours	not exceeding	0.3 ml/l
(4)	floating solids	not visible	

Further limiting values may be imposed according to the type of industry and its effluents. On of the normal values to be maintained with organic polluted effluent is:

(5)	biological oxygen demand in 5 days (BOD_5)	not exceeding	25 mg/l

For inorganic pollution the values are imposed according to the degree and the feasibility of appropriate treatment processes. As for example, the metal-processing industries' effluents must not exceed the following values:

(6)	copper	1 mg/l
(7)	iron, chromium	2 mg/l
(8)	nickel, zinc, cadmium	3 mg/l

In case of pollutants fluctuating in concentration, their permissible total loads (per day, per month etc.) will be imposed.

Under special and difficult circumstances the possibility of adjusting the standard values should always be observed from the authorities concerned, viz. both to increase and to decrease the figures according to the local conditions.

General Regulations

(1) The applicant planning to erect and to operate a plant must observe the general rules and standards of technology. The regulations on accident prevention and safety must also be followed.

(2) The applicant must comply with all remarks or corrigenda shown on the application documents after their examination by the authority concerned.

(3) Storm water, non-polluted cooling water and sanitary sewage must be collected separately from the industrial wastewater, and discharged only after proper treatment.

(4) All changes within the factory involving changes of the wastewater conditions must be given on record to the authority concerned.

(5) Liquids on storage dangerous to the quality of open waters or ground water must be stored in such a way that they can be collected in tanks or pools for reuse, or otherwise be discharged without causing damage or danger. They must by no means enter the public sewerage network.

(6) In case of wastewaters that may affect the purification of the other wastewaters in a factory, those liquids must be subject to pre-treatment on the spot in so far that the normal wastewater treatment measures will not be affected.

(7) For the period of time during which the above conditions have not been fulfilled, an annual contribution will be levied supposed for public pollution control purposes. Permanent efforts must be made to reduce the wastewater effluent quantities of the applicant's factory.

(8) Once the permission has expired the outlet facility must be abandoned.

Self Control by the Applicant

(9) All drainage and sewerage facilities must be controlled, maintained in proper conditions and operated permanently.

(10) The applicant has to nominate a representative to his staff who will be responsible for the correct operation of all facilities concerning the collection, treatment and orderly discharge of all wastewaters.

(11) The applicant has to conduct the following measurements continuously, e.g. by use of self-recording control device:

(a) wastewater quantity
(b) temperature
(c) pH value
(d) settleable solids
(e) turbidity
(f) odour threshold value
(g) any other simplified examinations typical of the respective effluent.

The measurements must be made daily/weekly from grab-samples/ average samples and the results taken on record. Also any other occurrences, breakdowns etc. must be noticed in the record books. An annual report on all measurements conducted will be submitted to the authority concerned.

(12) The effluent outlet must be placed at a point suitable, well accessible and always open to representatives of the authority concerned.

Control by the Authority

(13) The effluent discharged from the applicant's factory must be analysed at least once a year, at his expense, by an expert or an institution authorized by the authority.

Solid Wastes

(14) Solid wastes must be disposed or discharged without causing damage or danger to open waters nor otherwise to the public.

Effects to Other River Water Users

(15) The effluent outlet and its maintenance must not affect the maintenance works along the open water, the river bed, the river banks nor the operations of naval traffic. Damages occurring at the applicant's expenses.

(16) The outlet pipe or conduit must have a minimum covering of 2.50 m at the point reaching the river banks.

(17) The applicant shall tolerate, without claim of indemnity, all measures of the authority concerned, caused by changes of the water course, the embankment, the water level or the water quality.

(18) As to the extraction and use of river water for water supply purposes, in particular for drinking water, any protective measures considered necessary by the authority concerned will be exerted by special procedure.

APPENDIX 3

RULES AND REGULATIONS FOR FACTORY ESTABLISHMENT AND EXTENSION DEALING WITH WASTEWATERS ISSUED BY MINISTRY OF INDUSTRY.

For the purpose of the prevention of nuisance caused by water pollution discharged by industrial factories, the factories are obligated to perform the following duties:

(1) Location and area of factory must be:-

(a) In suitable places for discharge of wastewater or in the places allocated by the government.
(b) Enough area for wastewater treatment or reservation.

(2) Treatment process

(a) Suspended solids must be separated from waste.
(b) Sludge separated from wastewater must be treated properly in order to avoid further nusiance.
(c) pH value and alkalinity must not be too high or too low.
(d) Any poisonous matter which may be dangerous to public health must not be discharged from the factory without proper treatment.
(e) Wastewater treatment process must be shown by drawing together with the plant layout.
(f) Wastewater must be treated properly, the method of treatment should be approved by government official.

Paper No. II/21

SUMMARY REPORT ON POLLUTION CONTROL IN INDONESIA

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ABSTRACT

The paper outlines the efforts made and problems encountered in pollution control in Indonesia. There are about 124 million population in Indonesia unevenly distributed over the Archipelago extending 3,200 miles west to east and 1,000 miles north to south. The islands of Java and Madura have 65% of the total population. Of the population about 100 million is rural. The size of the country and its large population constitutes a major problem for economic development, including water management and its pollution control.

Urbanization and industrialization have given rise to solid waste collection and disposal problems. Surveys in Bandung municipality in 1971 indicates an average 2 to 4 litres of solid waste per capita per day. The present disposal method is inadequate and the Central Government is providing technical and financial assistance to the locality to develop solid waste management systems. The ever-increasing rapid urbanization and industrialization in large cities are causing serious water pollution problems which result in major public health hazards and the general deterioration of natural water resources. In the city of Djakarta, a water pollution committee for the formulation of water pollution legislation was established in 1970 to cope with the problem. Steps have been taken in recent years through legislation, education, and research to deal with domestic trade and farm wastes. The problem has always been the lack of technical know-how and financial resources.

The paper calls for appropriate international assistance and close regional collaboration in dealing with these problems. In regions where people still struggle to obtain adequate drinking water supply, it is important to disseminate research, training, education and information programmes to create greater appreciation and awareness towards preservation of the environment.
(Abstracted by Chin Kee Kean)

INTRODUCTION

Pollution control has been identified as one of the main topics to be discussed and it is understood that recommendations on pollution control measures will be highly appreciated.

These findings attempt to cover main problems which are of national significance, however at present it is impossible to provide quantitative measures since many of these are relatively new to Indonesia. The thought given or actions taken to cope with these problems are still limited. Nevertheless, the Government of Indonesia is fully aware that the problems of environment should be given more consideration in the overall economic and and social development of the country.

Although this report has not covered all aspects of pollution, it is hoped that it will provide useful information to be discussed by the Workshop. It is also expected that action proposals for the formulation of national policies can be disseminated in the near future.

Regional Workshop on Water Resources, Environment and National Development
Singapore, March 13-17, 1972

GEOGRAPHICAL AND POPULATION ASPECTS

Indonesia is fifth in the world in population. The last census revealed the existence of about 124 million inhabitants and unevenly distributed over the Archipelago, which extends about 3,200 miles west to east and 1,100 miles north to south. Of the population, about 100 million are rural and 24 million urban residents, "rural" being loosely defined as settlements each with a population less than 5,000.

From the demographic perspective, the number of international migration to Indonesia being relatively low, therefore the future trends of the country's population growth will solely depend on the rate of natural increase. The average annual rate varies between 2 to 3 per cent, the cities showing higher rates than rural areas. It is obvious that the islands of Java and Madura have 65% of the total population, but only 7% of the land area, which gives a density of 1,300 persons per square mile and is probably the most densely populated island in the world. On the other hand, West Irian has only a population density of 4 people per square mile, whereas Sumatra, which is 4 times as large as Java, has only 16% of the total inhabitants, or about 90 people per square mile. Appendix 3 gives a list of large and small cities with its corresponding population number.

From the topographic view, the surface of the country consists generally of mountainous regions. In Sumatra, for example, the hills follow the west coast continuously; to the east the mountains level out to broad expanses of lowland. While in Java, the low coastal plains are to be found north of the island. The provincial capitals and large towns usually are situated in these lowland, suffering seriously from flood-threats and inundations during the rainy seasons.

Due to its mountainous and heavily forested land, Indonesia has abundant rainfall which is in most areas between 60 to 150 inches a year, the highest being registered in Kranggana (Central Java) with 320 inches/year and the lowest in Palu, a place in Sulawesi having only 22 inches a year.

Heavier rainfall occurs at higher elevations, therefore many springs emerge where the hills meet the coastal plains. Small and large rivers cross the islands but flows may be seasonal. Generally, these streams have average discharge ranging from 2,000 to 100,000 cfs. Water from these sources is intensively utilized for irrigation, municipal, industrial and public purposes. Appendix 3 shows some figures pertaining to municipal water supply.

The size of the country and its large population constitutes a major problem for the economic development, including the water management and its pollution control.

DISPOSAL OF SOLID WASTE

The rapid increase in the density of town population as a result of urbanization is making the collection and disposal of wastes, including refuse from the municipality and solids resulting from industrial wastes, a complicated problem of great magnitude. Failure to deal satisfactorily with the solid waste constitutes a serious threat to public health and contributes to the pollution of air, water and soil, as well as the propagation of flies, rodents and other vectors of diseases.

Traditionally, the Municipal Public Works have been responsible for the collection and disposal of these wastes. It is difficult to find out exactly, how much and what kind of wastes are produced and collected, because most communities do not measure or analyze the solid waste they collected.

From its survey conducted in the Bandung municipality during 1971, the Directorate of Sanitary Engineering revealed that an average 2 to 4 litres of waste is produced per capita per day. The market waste is the most troblesome, in view of collecting, due to its voluminous and wet nature and on the other hand due to lack of appropriate collecting facilities. The following figures have been obtained as an average for a fresh market waste:

pH	:	6.85
ash	:	29.39
total nitrogen	:	1.09%
total moisture	:	69.2%

Current methods for handling the town refuse are inadequate and are characterized by "minimum attention, minimum funding and public apathy". Permitting back-yard burning, the municipality provides provisional small storage stations, the refuse of which to be picked up daily or once within 3 days by the collectors.

Due to lack of equipment and proper maintenance, on the average only 50 percent of the total waste in the city could be collected and disposed off. The table on page 310 shows a rough estimate of production and disposal of solid waste in Djakarta, which has approximately 4,900,00 inhabitants.

Present disposal methods in the Indonesian scene include open dumping, sometimes sanitary landfill, primitive composting and incineration practices. Low wages reflect the low priority and status many communities assign to garbage collection, resulting in poor sanitation conditions.

Technical assistance and limited financial sub-

Source of Waste	Annual Production	Average Daily	Daily during Fruit & Wet Seasons
Inhabitants	2,200,000 m^3	5,000 m^3	7,550 m^3
Market places	840,000 m^3	2,000 m^3	3,000 m^3
Factories	55,000 m^3	150 m^3	150 m^3
Animals	55,000 m^3	150 m^3	150 m^3
Visitors	50,000 m^3	100 m^3	150 m^3
TOTAL	3,200,000 m^3	7,400 m^3	11,000 m^3
Collected and dumped by services	1,600,000 m^3	4,400 m^3	4,400 m^3
Collected & dumped by private enterprise	40,000 m^3	100 m^3	100 m^3
Burned privately	560,000 m^3	1,400 m^3	2,000 m^3
Left for wild disposal (ditches etc)	1,000,000 m^3	1,500 m^3	4,500 m^3
TOTAL	3,200,000 m^3	7,400 m^3	11,000 m^3

sidy from the Central Government is available to local officials to develop existing solid waste management systems and to encourage comprehensive planning, including the coordination of planning and training of local man-power.

DISPOSAL OF LIQUID WASTE

The ever increasing rapid urbanization and industrialization in some large towns, is causing an even more rapid rise in the pollution of water, which has resulted in major public health hazards, as well as in a general deterioration of natural water resources. In addition to water pollution due to chemicals disposed by local industry, recipient water bodies become evil smelling e.g. Tjiliwung River in Djakarta and Mas River in Surabaja, and become objectionable to the public due to pathogenic organisms from human waste. In Indonesia, this phenomenon is reflected by the prevalence of water-borne diseases.

Many cities in Indonesia are not provided with sewerage systems, therefore wastewater is disposed directly into water bodies. In a good residential area, each house has its own septic tank or closed pit privy. Though there is no evidence that ground water is polluted by seepage trenches of these septic tanks, the construction thereof are no longer recommended in preference to sewerage systems, such as practised within the cities of Bandung, Tjirebon and Jogjakarta. In rural areas or in the squatter areas of the towns, people discharge the nightsoil directly into water bodies, making the problem much more serious. To improve the situation, the simple and cheap water-seal latrine construction has been introduced.

Information on industrial waste discharge has been sparse and difficult to obtain because most companies have chosen to keep it confidential. Industrial wastes are significant in the larger cities, particularly in Java. In smaller cities, where only some home industries have developed, this kind of pollution has not been too serious.

Typical industries in some of the large cities in Indonesia are:

- dye industry
- tanneries
- beverages
- food canning
- paint industry
- pharmaceutical industry
- gas and coke plant
- textile industry
- oil industry

In the city of Djakarta, where these industrial wastes are considerable, the Governor authorized the establishment of water pollution committee for the formulation of water pollution legislation in 1970. Difficulties encountered among others, are the determination of industrial effluent quality and lack of experienced personnel and equipment. An effort will be made to adopt foreign effluent standards whenever applicable to local conditions.

PUBLIC HEALTH AND ECONOMICAL ASPECTS OF WATER POLLUTION

Some water pollution studies were conducted in recent years, but due to lack of funds available, this effort has not been continuously undertaken.

Last year, for example, the Directorate of Sanitary Engineering in collaboration with the Bandung Institute of Technology has investigated some domestic sewage characteristics in the cities of Bandung, Jogjakarta and Surabaja. The objective of the study undertaken was to provide comparative data in connection with a national project for sewage treatment methods and improvement works for the respective cities.

Water pollution studies within the Djakarta area are also undertaken through close collaboration between the Department of Public Works and Electrical Energy, the Department of Health and the Local Authorities.

As mentioned earlier, many provincial capital towns are situated in the coastal plains, with river-courses meandering through the heart of these cities. Therefore, inundations with all its consequences are common to these places during the rainy seasons, as witnessed during last January, while during the dry period the poor health situation is aggravated by the fact that river-flows are almost zero, giving rise to concentrations of septic conditions.

In countries such as Indonesia, the primary attention should be paid to biological pollutants, as the conditions are characterized by lack of protected water supplies, uncontrolled discharge of human wastes and the use of raw sewage for irrigation purposes.

In the average, only 30% of the urban population enjoy piped water supply, of which Appendix 3 shows the data available in this area. Available water works facilities known are inadequate and the present services are not satisfactory. This drawback together with the poor sanitation conditions and moreover, overcrowding in some areas were responsible for the incidence of cholera, typhoid, infectious hepatitis and other water-borne diseases.

Pollution by radioactive materials does not at the moment present a public health problem, though some indications have been reported.

The wide use of fertilizers and pesticides, especially if sprayed from the air might unintentionally contaminate open waters. This is quite harmful for Indonesia, where land fishery constitutes 40% of the total fish production in the entire country. It has been observed, on the other hand that even in certain rural areas insecticides are used intentionally for fishing purposes. This, again could lead to stimulate the growth of certain aquatic weeds which poses a threat to agricultural production potentials, such as the *alang-alang* (sabre grass) and *entjeng gondok* (*Eichornia crasipes*) as these compete with other plants for space, air and nutrient elements. Indonesia loses about one million tons of paddy for every harvest, which was caused by these varieties.

As the tourist industry, which has already developed in Indonesia, is a significant factor in the inflow of foreign currency, therefore it is of considerable economic importance to preserve the natural beauty of scenic resorts.

EDUCATION AND RESEARCH

Available educational institutions offering subjects in Sanitary Engineering are very limited. The Bandung Institute of Technology is a unique institution which produces graduate engineers in that field. On the other hand, the Department of Health has its own institution for sanitarians. With regard to post-graduate courses and local refreshment courses in Public Health, these are held from time to time either by the Department of Health or through the Department of Public Works and Electrical Energy, the participants of which in many cases come from municipal offices throughout the country.

Legislation is the basic foundation of an effective pollution control programme, therefore the General Water Rules and Regulations can be used as a basis for regulations on waterworks and water pollution control, but the complexity of related problems requires a more comprehensive legislation backed by research and experience.

The Directorate of Sanitary Engineering, therefore has initiated its Djakarta laboratory to undertake research and carry out the necessary sampling and investigations. This and other existing laboratories deserve more attention and assistance in view of financing and techniques involved. Until now these laboratories concentrate their activities in carrying out water quality examinations for potable water purposes or industrial water.

PROPOSED INTERNATIONAL AND REGIONAL MEASURES

The pressure of rapid population growth in a prevailing background of poverty within the vast and widespread area of the Archipelago makes it obvious that physical environment in Indonesia has deteriorated beyond manageable proportions, although the degree of pollution encountered has not reached an alarming scale.

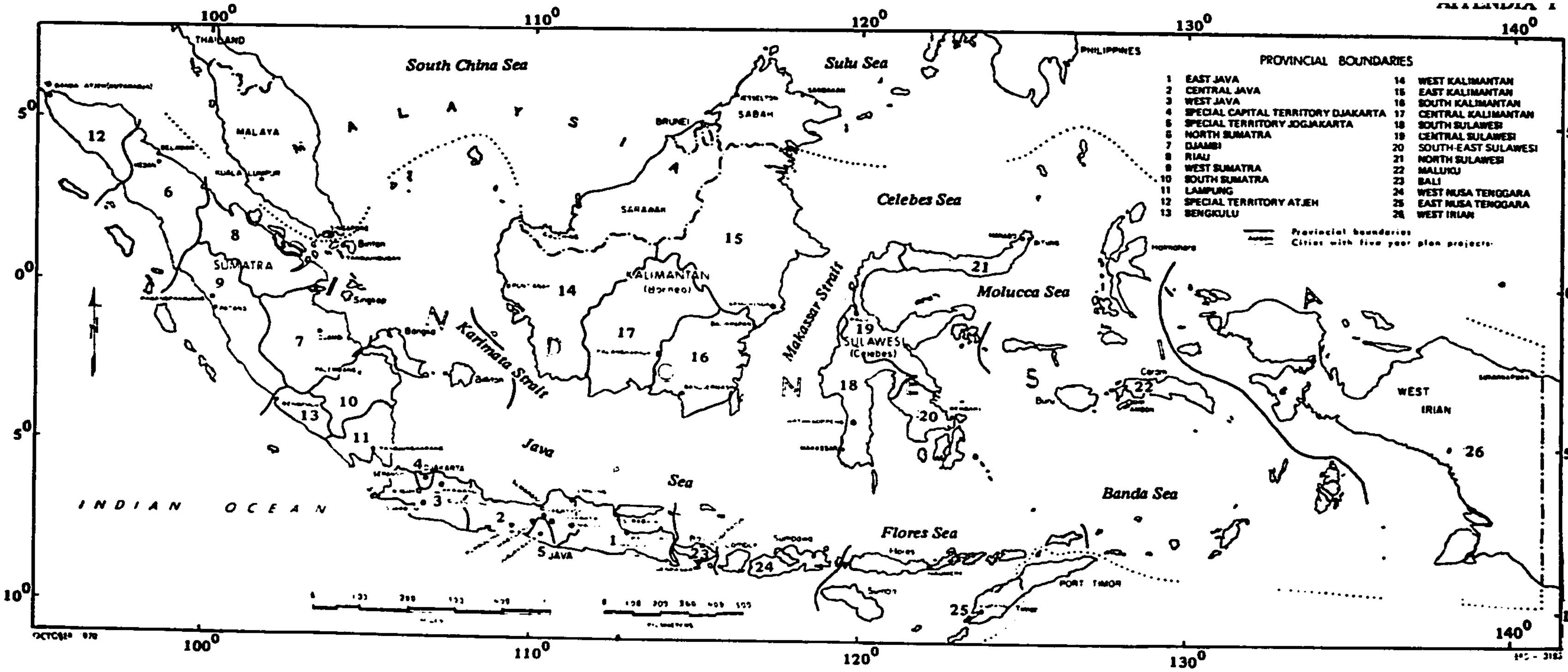
The basic problem is then how to utilize sophisticated technology in order to combat and prevent further deterioration of the environment.

Since Indonesia and most of the developing countries are lacking the technical know-how and cannot afford to waste their limited financial resources on costly remedial measures, it is therefore obvious that what they need most is approporiate international assistance and close regional collaboration, through which they could benefit, formulate and implement plans in the context of their overall development plans in dealing with pollution control problems.

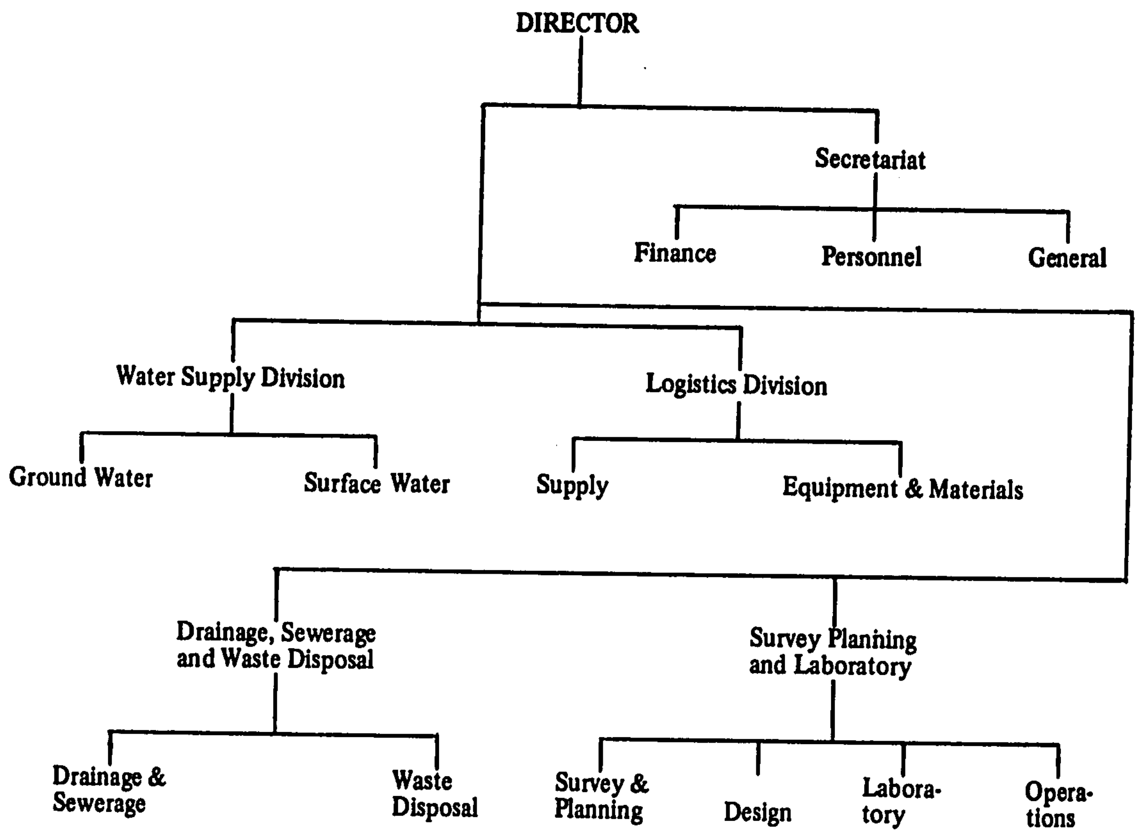
This Workshop could recommend certain measures in the above mentioned and other problem areas, such as technical assistance in specific fields, provisions for environmental education and training, the establishment of international information centres in the pollution control field and the establishment of regional pollution control centres.

CONCLUDING REMARKS

Water pollution and other pollution control programmes are comparatively new in Indonesia. We are still in the struggle to supply adequate drinking water for the people, so that it seems that problems of pollution are neglected. It is therefore important to disseminate research, training, education and information programmes in order to create greater appreciation and awareness towards the preservation of the environment.


South China Sea
Sulu Sea
Celebes Sea
Molucca Sea
Makassar Strait
Karimata Strait
Java Sea
Banda Sea
Flores Sea
INDIAN OCEAN
THAILAND
PHILIPPINES
MALAYA
SABAH
BRUNEI
SARAWAK
SUMATRA
KALIMANTAN (Borneo)
SULAWESI (Celebes)
JAVA
WEST IRIAN
PORT TIMOR
Halmahera
Ceram
Buru
Sumba
Flores
Timor
PROVINCIAL BOUNDARIES
1 EAST JAVA
2 CENTRAL JAVA
3 WEST JAVA
4 SPECIAL CAPITAL TERRITORY DJAKARTA
5 SPECIAL TERRITORY JOGJAKARTA
6 NORTH SUMATRA
7 DJAMBI
8 RIAU
9 WEST SUMATRA
10 SOUTH SUMATRA
11 LAMPUNG
12 SPECIAL TERRITORY ATJEH
13 BENGKULU
14 WEST KALIMANTAN
15 EAST KALIMANTAN
16 SOUTH KALIMANTAN
17 CENTRAL KALIMANTAN
18 SOUTH SULAWESI
19 CENTRAL SULAWESI
20 SOUTH-EAST SULAWESI
21 NORTH SULAWESI
22 MALUKU
23 BALI
24 WEST NUSA TENGGARA
25 EAST NUSA TENGGARA
26 WEST IRIAN
Provincial boundaries
Cities with five year plan projects
100°
110°
120°
130°
140°
5°
0°
10°

Indonesia



Organization of the Directorate of Sanitary Engineering
(Direktorat Tehnik Penjehatan)

SUMMARY OF DATA ON WATER SUPPLIES

ISLAND Province City (1)	Population (1,000s) (2)	Water Output (l/sec) (3)	Source (4)	City (1)	Population (1,000s) (2)	Water Output (l/sec) (3)	Source (4)
SUMATRA							
Atjeh Special Territory							
Banda Atjeh	46	16	Sp, Dw	Sabang	8.6	10	Sp
Sigli	54	10	S	Taningeun	25	10	S
Langsa	60	15	Aw, S				
North Sumatra							
Medan	554	–	Sp	Belawan	–	600	Sp
Bindjai	52	10	Sp	Tandjungpura	26.5	11	Aw
Pangkalanberan-dan	30.5	9.7	Aw	Pangkalansusu	18.5	2.8	Aw
Perbauangan	62	14	Aw	Tebingtinggi	30	–	Aw
Kisaran	61.9	4	S	Tandjungbalai	34	11	Sp
Bangun Purba	17	–	Sp	Pematangsiantar	133	20	Sp
Prapat	37	5	Sp	Seribudolok	36	15	Sp
Kabandjahe	28	17.7	Sp	Serbalawan	–	2.5	Sp
Berastagi	–	10	Aw	Tarutung	52.5	8	Sp
Sibolga	45	10	S	Panaitongah	–	–	Sp
Sipirok	37.6	–	S	Tigablata	25.9	0.8	Sp
Gunungsitoli	57	5	Sp	Lubukpakam	7.15	2.7	Aw

(2) Figures for population refer to the year 1967.
(3) Information on consumption is not available.
(4) For sources Sp denotes Spring; S = Surface; DW Drilled or bored well; Aw = Artesian well;
– denotes no data available.
(5) Under the heading "Others" appear the names of municipalities which have water supplies but for which no data are available from the Directorate.

ISLAND Province City (1)	Popu-Lation (1,000s) (2)	Water Output (l/sec) (3)	Source (4)	City (1)	Population (1,000s) (2)	Water Output (l/sec) (3)	Source (4)
West Sumatra							
Bukittinggi	59	42	Sp	Padang	250	250	Aw, S
Pandangpandjang	30	9	Sp	Solok	78.5	–	–
Sawahlunto	14	–	–	Batusangkar	–	20	Sp
Kotagedang	–	–	–	Talu	–	–	–
Murasiberut	55.6	–	–				
Djambi							
Djambi	131	30	S				
Riau							
Bagansiapi Api	67.5	5	S	Tandjungpinang	125.5	5.5	S
Tandjunguban	–	50	S	Pakanbaru	–	–	–
South Sumatra							
Palembang	550	600	S	Pangkalpinang	69	23	S
Lahat	33	17	S	Muntok	33	–	Sp
Bengkulu							
Bengkulu	29	14	S				
Lampung							
Kotabumi	85	2	S	Tandjungkarang	155	17	–
Telukbetung	–	–	Sp	Pandjang	–	5	Sp
JAVA							
Special Capital Territory							
Djakarta	4,900	2,547	Sp,s				
West Java							
Bogor	169	65	Sp	Sukabumi	88	40	Sp
Bandung	1,100	865	Sp, Aw, S	Serang	59	0.5	Aw
Pandeglang	31	5	Sp	Rangkasbitung	64	7	Sp
Tangerang	101	8	S	Tasikmalaja	126	13	Sp

ISLAND Province City (1)	Population (1,000s) (2)	Water Output (l/sec) (3)	Source (4)	City (1)	Population (1,000s) (2)	Water Output (l/sec) (3)	Source (4)
Tjiandjur	97	20	Sp	Tjiamis	113	13	Sp
Lembang	58	2.5	Sp	Garut	84	22	Sp
Tjirebon	174	105	Sp	Indramaju	70	7	S
Madjalengka	58	2	Sp	Tjijulang	51	2.5	–

Others: Padalarang; Purwakarta; Tjikotok; Genteng; Kuningan; Anjer; Tjiwidej; Krawang; Tjikajang; Basah; Bekasi; Sidangbarang; Labuan; Palabuhanratu ; Samedang; Pameungpeuk;

Central Java

Semarang	582	735	Sp,S	Kendal	29	8	Aw
Ungaran	47	2	Aw	Ambarawa	61	5	Sp
Salatiga	67	30	Sp	Banjubiru	30	–	Sp
Pekalongan	118	40	Sp	Bandar	42	20	Sp
Brebes	91	40	Sp	Tegal	103	40	Sp
Rembang	49	14	Sp	Pati	70	8	Sp
Djuwana	49.7	6	Sp	Lasem	28	–	Sp
Blora	61	5	Sp	Grobogan	37	24	Sp
Purwodadi	67.9	–	Sp	Surakarta (Solo)	426	150	Sp
Tawangmangu	25	–	Sp	Bojolali	39	1	Sp
Magelang	111	98	Sp	Bandungan	–	2	Sp
Wonosobo	42	11	Sp	Purworedjo	70	–	Sp
Kutoardjo	56	50	Sp	Prembun	35	–	Sp
Temanggung	77	–	Sp	Kebumen	80	23	Sp
Gombong	41	–	Sp	Banjumas	131	–	Sp
Purwokerto	141	82	Sp	Purobolinggo	39	–	Sp
Adjibarang	56	3	Sp	Wonogiri	57	2	Sp
Demak	23.6	–	–				

Others: Bandjarnegara; Pemalang; Tjilatjap; Batang; Kopeng; Sukoardjo; Kjepara; Kudus; Tawangmajo; Tugu.

ISLAND Province City (1)	Popu-lation (1,000s) (2)	Water Output (l/sec) (3)	Source (4)	City (1)	Popu-lation (1,000s) (2)	Water Output (l/sec) (3)	Source (4)
JAVA							
Jogjakarta - Special Territory							
Jogjakarata	362	200	Sp	Kaliurang	38	–	Sp
Others: Bantue; Kota Gede; Sleman; Wonosan; Klaten							
East Java (including Madura)							
Surabaja	1,200	1,500	Sp,S	Gresik	45	40	Sp,S
Sidoardjo	50	–	Sp	Lamongan	43	15	Sp
Djombang	71	41	Sp	Modjokerto	60	–	Sp,S
Kediri	184	24	Aw	Madiun	142	15	Aw
Ngawi	66	15	Sp	Magetan	67	–	–
Plaosan	46	20	Sp	Sarangan	58	–	Sp
Malang	395	225	Sp	Lawang	50	10	Sp
Kepandjen	61	30	Sp	Besuki	–	20	Sp
Sukapura	15	5	Sp	Probolinggo	80	40	Sp
Bangil	42	9	Sp	Pasuruan	73	5	Sp
Lumadjang	69	4	Sp	Banjuwangi	66	15	Sp
Djember	125	53	Aw	Situbondo	37	10	Aw
Bangkalan	37	10	Sp	Sumenep	42	10	Aw
Pamekasan	53	15	Sp	Sampang	59	10	Sp
Others: Tuban; Bodjonegoro; Ponorogo; Patjuitan; Sepandjang; Panarukan; Trenggalak; Tulungagung; Nganjuk; Bondowoso; Krian.							
BALI							
Singaradja	–	20	Sp	Denpasar	66	10	Sp
Tabanan	39	3	Sp	Klungkung	37	4	Sp
Karangasem	60	0.5	Sp				
WEST NUSA TENGGARA							
Ambang (Sumbawa)	54	3	Aw	Waikabubak	–	1	Sp

ISLAND Province City (1)	Population (1,000s) (2)	Water Output (l/sec) (3)	Source (4)	City (1)	Population (1,000s) (2)	Water Output (l/sec) (3)	Source (4)
EAST NUSA							
Flores							
Ruteng	–	–	Sp	Bedja	–	–	Sp
Ende	67	–	Sp	Lela	–	–	Sp
Lika	–	–	Sp	Maumere	–	–	Sp
Larantuka	0	2.5	Sp				
Timor							
Kupang	124	20	S	Soe	–	–	Sp
Kafanannu	–	–	Sp	Atapupu	–	–	Sp
Baa	–	–	Sp				
Alor							
Kalabahi	–	–	Sp				
KALIMANTAN (Borneo)							
West Kalimantan							
Pontianak	174	110	S	Pamangkat	–	5	S
Singkawang	78	8	S				
East Kalimantan							
Palangkaraja	8	10	S				
South Kalimantan							
Bandarmasin	248	30	S	Kotbaru	54	5	S
Balikpapan	106	10	S	Samarinda	81	9	S
SULAWESI (Celebes)							
North Sulawesi							
Menado	150	30	Sp,S	Mandar	87	1	Sp
Toli-toli	64	11	S	Tondano	38	14	Sp
Gorontalo	82	20	Sp				
Others: Bitung, Badjo							
Central Sulawesi							
Palu	26	7	Sp	Poso	52	3.5	Sp

ISLAND Province City (1)	Population (1,000s) (2)	Water Output (l/sec) (3)	Souce (4)	City (1)	Population (1,000s) (2)	Water Output (l/sec) (3)	Source (4)
Donggala	8	2	Sp	Luwuk	–	5	S
Ranggai	–	15	Sp				
South Sulawesi							
Makasar	444	150	S	Watansoppeng	–	5	Sp
Palopo	–	5	S	Watampone	75	3	Sp
Singkang	25	5	S	Pare-pare	79	29	Sp
Madjene	48	1	Sp				
Others: Sungguminasa ; Makele; Benteng; Bulukumba; Wadjo							
South-East Sulawesi							
Kendari	81	2	S	Bau-bau	88	2	Sp
Raha	55	20	Sp	Tombato	22	20	Sp
Sonder	–	20	Sp	Airmadidi	21	2*	Sp
MALUKU (Moluccas)							
Ambon (Ambon)	84	37	Sp	Ternate (Halmahera)	74	3	Sp
WEST IRIAN							
Djadjapura	–	–	Sp				

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SEA POLLUTION–SOME ASPECTS AND THE NEED TO FIGHT IT

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ABSTRACT

Industrial development and the significance of nature and the environment as vital resources for human needs are important for developing countries.

Estimating the significance of these two sectors combined, there are two aspects to be considered:

(1) The technological impact upon the environment, which in this particular case, concerns crude oil and its biological effects.

(2) The economical impact of the subsequent interaction of the latter. Petroleum industry circles in Indonesia are well aware of the danger of pollution. In view of this, it is therefore proposed to (a) secure the services of a bio-economist or an economic biologist for implementing an environmental management scheme and (b) to call for the closest cooperation between the neighbouring countries united in ASEAN and to establish an interim working committee or a permanent executive body for this purpose.

POLLUTION

Lately, technology and the environment have been frequently considered as two contradictory and competitive interests. The relation between technology and environment may actually represent an interaction or an impact created in the process of human endeavour, which in this particular case is in the form of technology or industry and their impact upon the environment.

This interaction is often represented in a negative sense, one particular example being the question of pollution.

There is the impression that industrial interests transcend those of the natural environment.

Under these circumstances, it is obvious that there is a conflict of opinion on the benefits of industry. According to some, industry brings speedy progress; others, being more nature-oriented, view industry as living off the natural riches of the soil (agriculture, fishery, forestry, tourism, recreation,etc.)

In my opinion and from the viewpoint of a developing country both are equally important. This represents a kind of coexistence and under the circumstances demands an attitude of give-and-take. Thus there should be a balance between industrial and environmental values.

In this context of analysis, I will devote a few words to some aspects which are considered fundamental in this problem. Namely the impact of industrial activities upon the environment in terms of biological effects. Another important aspect refers to economic values.

In this context, what we mean by environment is the surrounding landscape comprising the sea and offshore areas, including the coastal parts. By pollution we mean petroleum and petroleum products. On this occasion, we should like to present some record of what the Indonesian Study Group on Pollution has done in the way of surveying various aspects of oil pollution.

CRUDE OIL AS A POLLUTION ELEMENT

Crude oil consists of thousands of chemical components which can be grouped into nafthas, aromatics, or paraffinics, according to various characteristics. This grouping is simply to facilitate oil's characterization.

In relation to this fact, crude oil exists in various types (See table). Crude oil may represent a pollutant when found floating on the water surface. In this physical, chemical or other capacity crude represents a liability.

For example, because of its pourpoint character when the temperature is lower than that of seawater, crude oil will float on the water surface.

This liquid may easily spread and form a stratum which becomes wider and thinner. Its traject in condensation and which determines whether the oil be a light or heavy substance. The lighter the crude oil, the more of its fractions will vaporize and the less remains on the water surface.

Heavy fractions form a component emulsion which is rather persistent. Such an emulsion is difficult to clean up. Another fact of no less considerable character is the different acid content of crude oil.

PLACE OF ORIGIN

Indonesian waters generally are relatively clean, i.e. in comparison with, for example, the Baltic Sea. Areas with a relatively higher degree of hydrocarbon (according to random sampling are the southern areas of Banka/Billiton Island Group, the Bay of Djakarta, the northern coasts of Java, North Sulawesi, waters in the northern part of Lombok Island, Birdhead Bay of West Irian. Hydrocarbon, which partly origins form fossil oxygen as mentioned above, represents a danger.

The origins of those pollutants derived from crude oil are many.

Tankers

Before entering the harbour, tankers generally clean up their tanks. Not every harbour is fitted with tanks capable of taking the oil contained in their wastewater. An easy thing to do is to dispose of it in the open sea. Most of these big tankers now use the load-on-top method. Water is kept in the tanks until the oil is separated. The water is then disposed of. The water contains maximally 50 ppm hydrocarbon. As this disposal proceeds along, while the ship is moving, excessive hydrocarbon accumulation does not occur. Following the disposal of the water, new cargo is loaded on top again.

Collisions of Tankers

These are quite possible, especially in the Straits of Malacca, the Riau Archipelago, the area round Banka/Billiton Islands, in the Bay of Djakarta. These areas belong to the South East Asian waters, with abundant traffic of oil and oil-product transportation for domestic needs, for export as well as by innocent passengers from oil harbours, to and from Arabia, Africa, Japan, Taiwan, etc. In 1970 near Singapore there occurred two collisions between big tankers. Not all of these collisions are reported, as was the case of a chartered tanker with 190,000 tons of oil for Japan. This tanker was not allowed to enter Japan harbours because of the leakage it suffered following the accident in the Straits of Malacca. Along the way to Japan oil kept leaking out. The increase of oil production in Indonesia, onshore as well as offshore, and the increase in Japan's oil demand, 90% of which is imported, have to be taken into consideration, and it is not surprising that Indonesian waters especially in the western part are the most crowded in terms of tanker traffic. Add to this the fact of the increasing number of giant tankers of more than 250,000 dwt. An accident with these ships in these areas would be a great disaster. In 1970, Japan imported 3,574,900 bbl a day; the 1975 forecast amounts to 5,500,000 bbl a day, that of 1980 about 8,000,000 bbl a day. This means twice the original volume within 10 years. Another source of pollution are trading vessels or other motor-ships which go into the routine of disposing their wastewater in the open sea or in harbour waters. Assembling factories are also guilty of such practices in connection with rivers flowing through big coastal cities and through which all the dirt and waste reach the sea. An example is the Bay of Djakarta and the harbour of Pasar Ikan being very much polluted hydrocarbonically as well as bacteriologically. Dumping of city waste, including tar, residue, sola is a familiar scene in Djakarta rivers and canals.

Rivers south of Djakarta are still relatively clean, but when they pass the industrial area, they become insalubrious, in the sense that it does not contain adequate oxygen and is also atrophicated.

The purifying capacity of these rivers has lowered very much, so micro-organisms which do not require oxygen are flourishing there.

Sifat	Region/Country												
	Minas (Indonesia)	2) Pematang (Indonesia)	2) Java Sea E–1, Dst. 15	2) Java Sea IIAPCO Selatan – 1 Dst –4–6	2) Idem Dst–7	2) Idem Selatan 3	2) Java Sea PSI–1 K 1	2) Java Sea Cinta I Dst–3	2) Klamono	2) Bula	1) Kuwait	Zelten	Djatibarang
API Gravity (60^0F)	35.2	32.4	36.5	15.3 (4) 19.3 (6)	29.8	17.5	36.6	36.6	18.6	21.8	31.33	39.19	38.4
Viscosity (122^0F)	10.5			1785.60 (4) 814.80 (6)	40.67	955.05		21.35	38.21	10.91			1.97
Pour Point, ^0F	90.	95.0	75.	75 (4) 65 (6)	90	70	60	100	–5	–20	–25	45	70
S-Content, % wt	0.08	0.10	0.12	0.13 (4) 0.21 (6)	0.12	0.19	0.13	0.09	0.90	2.57	2.5.	0.21	0.2
Wax-Content, % wt (Holde meth)	16.1	19	7.3	9.1 (4) 6.2 (6)	19.4	7.44	10.3	26.	0.11		5.5.	11.4	5.6
Asphaltene Content, % wt	0.10	0.73	0.6	0.3	0.17	0.04	0.26	0.83	2.1	0.67	1.4	0.13	0.5
Total Acid	–	–	–	4.17 (4) 3.50 (6)	0.92	5.06	0.29	0.38	2.86	1.96	0.15	0.19	0.36
mg KOH per g										–	5	–	–
Vd-content ppm	–	–	–	–	–	–	–						

1) R. A. Dean "The Chemistry of Crude Oils" dalam the Biol. Effects of Oil Pollution on Littoral Communities, ed. by J. D. Carthy and Dan R. Arthur
2) Crude oil evaluation reports Lemigas.

Some Characteristics of Crudes from Various Regions & Countries

In view of this, there should be established some standards for waste-water. Concerning local standards of effluents, and of wastewater which contains crude components, related research work is now going on in Tejpu refinery and may possibly offer solutions to the problem. A man-made-pond is being examined and measurements of the impact of refinery waste on marine biota are taken.

MARINE ORGANISM

Indonesian waters are source of protein for a considerable part of the Indonesian people. Sea-fish production is about 750,000 to 1,000,000 tons a year. It is planned to increase this yield. Indonesian waters have a fishing production potential of 5.5 x 10^6 tons a year. Shrimp has become of considerable economic value recently. Primary productivity is a parameter to determine the fertility of the water in relation to the productivity potential of that area. The Straits of Malacca have high primary productivity, and may probably be classified as the highest in the archipelago of about 0.30g c/m^2 to more than 0.70 g c/m^2 a day. The Straits of Malacca have a fishing potential of 45 ton fish/km^2 a day. Fishing is not done far from the shore. The real potential productivity in other areas does not seem to be as great as in the Straits of Malacca. This fertility is related to coastal waters being closed-in, and also because there are so many rivers flowing into this strait. Primary productivity is measured by algae. This organism is the primary link of a food chain wherein the weak form a prey for the big (predator) fish.

Stable environmental conditions enable the organic system to continue undisturbed. In this system, all organisms are interconnected with one another together with natural features such as salinity, turbidity, presence or non-presence of inorganic nutrients, etc.

A disequilibrium will cause a labile situation, and may cause the disappearance of some species which cannot stand change. This disequilibrium and subsequent effects may be seen at the bottom of the sea where spontaneous oil-seepage occurs.

At Coal Oil Point in the U.S. for example, it was observed that the waters contain fewer species than further off the seep. In Indonesia, natural seeps occur off-shore of Big Masalembo Island, the northern part of Madura Island, etc. These phenomena have been under observation by SGP (Study Group for Pollution).

Another phenomenal example of disequilibrium is the change of temperature in Europe as registered in the last decennia and which effects fish migration. Disequilibrium of the environment of this sort is beyond human control.

Changes which have caused the disappearance of fish in the Thames River have resulted from the accumulation of industrial waste and have occurred since the 19th century.

Here the cause is human interference and it illustrates the degree of conflicting interests, where human productive efforts proceed without considering their negative effects upon the environment.

As mentioned earlier, the appraisal of the effects or impact of technology upon the environment in terms of biological evaluation is an important task.

BIOLOGICAL EFFECTS

The observation and examination of biological effects are done in laboratorial experiments which simulate natural conditions, and by surveys in some oil polluted areas, and with a view of studying definite organisms in their natural habitat.

Data about the effects of crude oil pollution are frequently contrary to what is believed. Enquiries have shown that the effects of the "Torrey Canyon" accident and the blow out of "Santa Barbara" are evidently not so serious as far as the biological effects are concerned. The amount spilled is respectively 117,000 tons and 12,000 tons. But the accident of the "Tampico Maru " tanker spoiling the sea with 8,000 diesel oil or the tanker accident in West Falmouth (USA) causing a spill of 650 tons resulted in large-scale death of marine organisms in that area. An analysis of accidents which cause oil spills with a view to biological effects and area conditions should be maintained constantly.

The biological effect of oil-spills are as follows:

Instant Death by Asphyxiation

This occurs with algae, swamp plants, shore vegetation plants, herbs, birds, fishes, shellfish, crawfish, etc. A good deal of these effects are found with respect to the "Tampico Maru" and "West Falmouth" cases and partly in that of "Torrey Canyon" and "Santa Barbara" blowout.

Instant Death by Poisoning

This phenomenon is effected particularly by light fractions (naftha/kerosene) of crude oil. In a laboratory experiment by a working group of SGP examining *Mudjair* fish *(Tilapia mossambica peters)* and kerosene as pollutant, it has been observed that death depends on the number of pollutants and may occur within 3 days. Death occurs particularly with fish which appears above the water surface. In experiments with young shrimps, young *bandengs* worked out by another group, it was shown that instant death does not occur. The long-term effects are still under investigation.

Instant Death Due to Poison or by Other Crude Oil Components which Dissolve in Water

Effects here usually occur far from the place of the accident. The components mentioned include acid and naftana. Crude oil in this respect may have quite different contents. The effects are particularly serious to young fish and fishing especially pelagics. Birds' eggs do not hatch.

It is also stated that contamination by crude oil can interfere in the reproduction of the phytoplankton cell and obstruct growth of certain marine algae.

Death of Juvenile Forms in General

These forms generally are very sensitive to environmental change. It depends on the type of crude oil, the physical conditions of the environment and on the presence of pollutants like DDT or other types of insecticides. Death can also be interpreted as a loss of the ability to lay eggs and to multiply. This is registered with respect to mussels in the waters near West Falmouth. Possibly this is one of the causes of the lowering of primary productivity level following an oil spill.

We can use larvae and pupae of *Culex* and *Aedes* which are sensitive to crude oil to record the presence of the crude oil fractions concerned.

Destruction of Nutrient Sources for Higher Level/ Bigger Species

It is stated that the disappearance of algae, which represented food for small fish brings about a loss of one link in the food chain. Disappearance of fish in the River Thames or in the Bay of Djakarta or in Bagan Siapi-api is a consequence of environmental change, i.e. alluvial deposits cause shallowness, coral picking, etc. which probably caused a decrease of food resources.

Death by Ecofisis

This happens with seagulls. Crude oil causes the isolative film covering the birds' feathers as a shield against low temperature hazards to dissolve.

Incorporation of Crude Oil and Petroleum Product Components in Sub - Lethal Proportions

Hydrocarbon infiltrates marine nutrients vis plankton, etc., and becomes stabilized in lipid fractions of that organism. These hydrocarbons may constitute 3, 6, 9, 12, 15, 18 heneikosa heksan (one olefin) [15] C_{11} - C_{12} isoprennoid hydrocarbon, [15a] etc. This type of hydrocarbon within an organism and originated from crude oil (fossiliferous carbon) differs from the hydrocarbon obtained in organisms which is biosynethetically formed. This difference is used by Blumer as a method to observe the presence of organisms in crude-polluted areas [16].

Lowering of Market Value by Oil Spill and by Infiltration of Hydrocarbon Elements which may Cause Skin Cancer

Mudjair fish *(Tilapia sp)* after 1-3 days in crude-infected environment (3 cc in 3 litres of water) would smell of oil. This frequently occurs in Bandung surroundings where fishponds are contaminated by diesel oil waste [17].

These phenomena may or not occur simultaneously. So far, literature on the subject clearly shows that reports and crude pollution effects are frequently contrary to one another. The difference in observation results with respect to biological effects and the latter consequences are indeed complicated matters and pertain to various factors:

Types of Crude Oil in the Case of Oil Spills

Light crude oil is lethal to organisms within 1-2 days after the incident. The longer the oil spill remains, the more lighter fractions will evaporate. Observation by our Study Group shows that young *bandeng* is not affected by paraffin crude oil such as Kawengan and Minas crude oil which contains relatively few light fractions.

Mudjair fish are found dead after one to three days in a contaminated area because of its carbon dioxide and oxygen content as determined by observation and by experiment.

Species of Organism

It is possible for fish to avoid oil spills, particularly those which occur in mid-sea.

Shore vegetation and sea-birds will be directly affected for they are bound by their position. Different restrictions can be observed with respect to fresh-water plants. *Salviam natams* and *Azo Ua (Paku Air)* will die in kerosene concentrations of 100 ppm, while *Lemia minor* and *Spirotela* persist in higher ppm concentrations [23].

Place and Location as a Function of Stream, Wind, Temperature.

An oil spill which occurs at mid-sea will not effect destruction. But if it washes ashore will cause water pollution in little bays where the current is slow, then it becomes a hazard to marine life. An oil spill in Bagan Siapi-api or Bengkalis will produce effects different from one which occurs in the South China Sea or the Java Sea. In the north of the Straits of Malacca ebb tide occurs twice in the period of 24 hours, which causes oil spills to reach the coast immediately, while in the Java Sea it takes several days. The accident of "Tampico Maru" in Baja (California) caused serious damage to marine life, while the "Santa Barbara" accident caused minor damage. The first accident occurred in a bay, the other in water with a heavy current. The impact of waves in their variety of strength and movement is also considerable. For example, in the "West Falmouth" accident oil was found 8 months after the accident occurred in sediments at a depth of 14 metres.

Sediment effects by hydrographical factors increase pollution of the sea-bottom, and caused pollution in places which were not affected by the the oil before.

Monsoons and Seasons

Periods of mating, growth, egg-laying and developing, all these periods are important in measuring the hazard resistance level of marine species, community and ecosystem. The accident of Santa Barbara occurred in the cold season (January). While experiments in England demonstrate that plants are affected by oil spills in their seed season, causing premature death.

Duration of Contamination

From the standpoint of the hazard resistance level of marine organism, it is generally held that the longer contamination lasts, the greater would be the negative effect of pollution.

Besides the effects upon marine organism, the behaviour of fish as predators will also be affected; a greater possibility of such an effect is the cause of damage to the fish; taste receptor function *vis-a-vis* their prey. So the longer the contamination lasts, the greater will be the possibility of hydrocarbonic incorporation which destroys the fish organism.

Other factors

Other factors are the state of the ecosystem, (labile or stable) supply of nutrients, presence of polluting elements such as DDT, heavy metal, etc.

RECOVERY

The environment has a pollution tolerance level, in particular with respect to oil contamination, the volume of oil spilled and the tolerance level of the environmental condition, the level to which pollution can be absorbed without degradation of the environment. It is difficult to find the criteria of recovery. Is there recovery when primary productivity is restored? Nine months after the West Falmouth accident, that area had not recovered, because dead organisms were still found (worms, mussels, etc.); while in the Santa Barbara blowout where the area had recovered after 6 months, no dead organisms were found. Experience shows that the tolerance level of species also varies.

But the environment of Baja Bay (USA) where the "Tampico Maru" accident occurred was declared normal within two years except for mussels, sea-stars and sea-urchins which were found considerably reduced 7 years later.

Frequently it is said that the situation is normal again when species of market value are found restored as of old. Evidently such a standard need not reflect actual conditions. It is generally said that technicians usually are optimistic and judge that conditions have recovered, while others are of the opinion that after an oil-spill recovery is not possible. One way for the environment to recover following oil pollution is by way of micro-organisms using hydrocarbon as a source of energy. But when crude oil infiltrates sediments the micro-organism can hardly oxidise the hydrocarbon. It is generally held that small oil spills are absorbed by the environment. A general estimate is that in tropical areas a concentration of micro-organisms occurs in a more extensive scale compared with the Arctic areas. But really voluminous oil spills cannot be overcome the natural way because of the limited capacity of these micro-organisms to consume the hydrocarbons. Witness day-to-day conditions in the Bay of Djakarta where rivers north of the imaginary line drawn parallel to the northern coastline have developed an acute H_2S stench and have an approximate zero oxygen content. Too much oxygen is already used up and still plenty of waste and refuse remains. These waters can be said to be in a sick state and can only be restored if disposal of polluting waste is limited or is cleaned up regularly. Attempts to that effect are made, if only insufficiently. Another way is by way of preventive measures, waste treatment, etc. which in the interest of the conservation of natural resources, that of industries using life material, of aesthetic and sanitary standards and that of tourism would be most beneficial.

CLEANING METHODS

One of the environment's self-cleaning methods is by means of micro-organisms. Some land resources may provide the way by means of isolating the former micro-organism (the *Pseudomonas* for instance) on which experiments using hydrocarbon have been made by the Institute of Oil and Natural Gas for purposes other than anti-pollution measures. But the example of West Falmouth. where the sea-bottom sediments are oil-polluted and do not contain micro-organisms, self-cleaning cannot proceed. Enormous oil-spills here may be the reason for the non-presence of such natural function. Whatever may be the case, the soil contains certain types of micro-organism| that can bring about change in the hydrocarbons so as to promote growth.

Nevertheless, large scale oil-spills cannot be left to nature to cope with, because of the very limited capacity available to nature. It is here that man must stand by and assist nature in overcoming the pollution problem. The latter can be accomplished by physical, chemical and biochemical methods or a combination of the two. Generally an oil-spill has first to be blocked off by means of a "boom". Depending on local conditions such as the strength of waves, etc. which are of a hydrological nature including local temperatures, these are decisive in whether to use biochemical or physical methods. Generally after the oil is blocked off, it can be salvaged for it is not economic to have the oil abandoned. These attempts can include the use of floating sucking pumps. Here again the height of the waves plays a prominent part. Sometimes an attempt is made to sink the oil by using a mixture of amino components. Here also talc powder and lime are useful. This method cannot be recommended in the case of demersal fishery such as shrimps etc.

In Indonesia where the shrimp industry is considerable the sinking method is not recommended.

For a small oil spill in the harbour or river hay, straw, etc. can be used because of the absorptive quality of these materials. After being scattered the straw can be recollected by means of nets, thereupon pressed free from oil and upon drying can be reused or used as fuel. The collected oil can be put into slop tanks and refined again. A more sophisticated method is by using plastic material.

Chemical methods using detergents (dispersants) are to disperse spills into small balls which can be more easily annihilated by micro-organism. But these dispersants must not contain poisonous elements. Recent tests by a working group of the Study Group on a variety of dispersant specimens may provide the solution to what type of dispersant to use so as not to be harmful to shrimps, young *bandeng,* plankton, etc. There are indeed less harmful dispersants that those which were used in the "Torrey Canyon" accident. There it appeared that the medicine was worse than the disease.

According to reports, biochemical methods use a mixture of micro-organisms (20 b.h. which is called Petrodog and Nutrears (N.P.) [18]. It is necessary to emphasize that blocking off and dispersing methods are best in the open sea. The use of detergents for off-shore oil-spills is also recommended.

But having washed ashore, the oil becomes really harmful. Cleaning of beaches takes place by removing the polluted sand.

QUANTITATIVE LOSS

Pollution and its biological effects are caused by the technological impact of industry upon environment, or a plant which is careless with respect to environmental conditions. Industrialisation is essential for the development of Indonesia as well as South East Asia in general. Industrial development will have an impact upon the environment if sufficient safety measures are taken, such as waste treatment, etc. But there will always be accidents, oil spills caused by tanker collision, or a tanker running ashore, oil pipes may explode, etc. Disturbance of the ecology will occur, whatever cleaning measures are taken. Full recovery cannot be expected. These negative effects should be accepted, however, as long as the environmental degradation does not assume large scale proportions, the risk can be taken. Under the present circumstances, evaluation of the loss already suffered is difficult. In the "Torrey Canyon" accident 117,000 tons of oil was spilled. Compensation money amounted to about $16,000 000. Here injury to the environment has not been calculated, although it is the state which suffered.

Economical loss caused by the "Santa Barbara" blowout amounted to $16,000,000 while the oil was only 12,000 tons [19].

But in the cost is included compensation for ecological injury even though the criteria used still very arbitrary:

Clean-up costs	$ 4,000,000
Recollecting the oil	$ 2,000,000
Loss sustained by the fishery	$ 804,000
Damage to birds	$ 1/piece
Destruction of organism in intertidal areas	$ 8400 – $ 32,400

Loss sustained by tourism, individuals, etc. and loss in terms of long-term destruction are not computed.

It is observed that primary productivity has not decreased remarkably. An oil spill in an area with high primary productivity like the Straits of Malacca will cause much greater losses. A 30% decrease in the primary productivity will cause fishing potential to drop more than 30% in that area. A market evaluation using real biological data and extrapolative interpretation of these data are important. For claiming purposes as well as to demonstrate a method to define the impact of the conflict of interests between technology and environmental health, such evaluation is of importance. This method may provide a solution and lead towards a balanced development as industrialisation proceeds without having to sacrifice too much of the ecological conditions necessaay for the society's well-being.

A bioeconomist or an economic ecobiologist should be a biologist who also is a master in economics and econometry, or an economist who is also an ecologist and at home with either petroleum chemistry, engineering or mathematics. Bioeconomics can perform task in the way of running a biomanagement scheme.

RECENT SITUATION

The oil industry, in general, is well aware of the negative aspects of oil spills.

The industry itself has developed many cleaning up systems, such as the use of dispersants, the sinking of oil, the use of load-on-top method for tankers, etc. In Indonesia which at present records an ever increasing oil production P.N. PERTAMINA with its contractors is well aware of the danger of oil spills. In governmental quarters this awareness is also spreading and has its starting point at the Department of Mining, and the Department of Agriculture. The Indonesia Petroleum Association in which all oil companies are united has a Committee on Sea Pollution which aims at full cooperation among all companies in fighting oil-spills, and not as a clearinghouse on oil pollution problem. The Institute for Oil and Natural Gas of the Department of Mining has established a Study Group on Pollution (SGP) which has adopted an integrated multidisciplinary approach to this complex problem of pollution and which is to be tackled together and from many points simultaneously

Besides ecological standards and those considering 'wastewater' for the oil refinery to be built in Java (Tjilatjap), SGP is also interested in drawing up legislative bills to promote healthy industrial development without endangering the environmental balance. Considering the importance of the country's seawaters linking us with our neighbouring states, we as nations evidently have to work together to overcome the dangers challenging our waters and our shores and all the riches contained therein.

In a recent ECAFE meeting in Bangkok, the Indonesian delegation in principle supported the establishment of an Asian Environmental Control Council. But we are also of the opinion that such purpose will be well served by starting regional committees to simplify the proceedings. For example an ASEAN committee may be established, which would comprise mostly the expertise of various disciplines to work out anti-pollution measures.

One important objective among others may be to build a monitoring system or a warning system network; another one is the training of expertise to manage a system of data-collecting, to design a contingency plan or an integrated plan to fight oil spills. This is no illusion. We feel certain that such a committee, of which the chairman will alternate periodically, will be most effective in bringing the people of ASEAN nearer to one another.

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WORKING GROUP III

ENVIRONMENTAL PROBLEMS

Paper No. III/2

PUBLIC HOUSING AND RESETTLEMENT IN SINGAPORE: AN OVERVIEW

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ABSTRACT

A brief review of the history of Singapore's public housing and an outline of the major policy developments in the last decade. Also an evaluation of the social and the economic consequences of the Government's low-cost housing efforts as well as an assessment of trends for the immediate future.

INTRODUCTION

The home together with its immediate environment is the single context in which the largest range of human needs are met and the greater part of human life is lived. Yet a substantial portion of the world's population is housed in unfit dwellings and unhealthy surroundings. The lack of adequate housing constitutes one of the most serious deficiencies in the living standard of the people in developing countries and directly contributes or aggravates a number of social and economic problems. Despite world-wide recognition of the magnitude of the shelter problem and efforts towards improvement on the part of the United Nations and some individual countries, housing shortage for many nations in Asia as well as elsewhere has been worsening, and the outlook for at least this decade is even more discouraging. So far the only countries in East and Southeast Asia where the Government has undertaken substantial remedial action in housing production are Hong Kong and Singapore.

Historically, the evolution of Singapore's housing problem was not unlike that of many other major urban centres in the region and could be directly ascribed to the interaction of heavy inflow of migrants and rapid natural population increase. Migration from China and India was the main reason for Singapore's population increase from the nineteenth century until World War II, after which the very high natural growth rate accounted for the bulk of the island's population inflation. In the last twenty five years the Singapore population has more than doubled itself, from 0.94 million in 1947 to approximately 2.2 million today. Despite substantial fertility reduction in the last ten years and the corresponding drop in natural growth rate, the picture cannot be overly optimistic since the postwar baby boom has resulted in a marriage boom which in turn implies greater demand for housing.

The growth of slums and the commercialization of Singapore came hand in hand during the late nineteenth century. As the island gained prominence as the main commercial centre of Southeast Asia, it attracted, mostly from China, thousands of migrants seeking employment in Singapore and its neighbouring territories. These early immigrants were largely poor males who had little intention of staying permanently. As a result, they overwhelmingly concentrated in the city proper where most business activities took place and where they could find substandard but cheap housing, thus further compounding the emerging housing problem. When the sex ratio improved with the arrival of large numbers of Chinese women in the 1930's, more and more temporary migrants turned into permanent settlers and all the characteristics of slum living became increasingly pronounced. As the population continued to expand rapidly after the War, Singapore had not only one of the most over-crowded slums in the world, but also large squatter settlements encircling the central city area. Before the start of the first public housing programme by the present

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Government in 1960, there were an estimated one-quarter of a million persons living in badly degenerated slums and at least another one third of a million people in squatter areas who urgently needed rehousing. These slum and squatter areas were - and some of them still are - breeding grounds of disease and crime. Many of the buildings in these areas had been nearly a hundred years' old. Since they were only two or three storeys high they constituted an uneconomic use of the valuable central area land today. Because of the age, type of materials used for construction, lack of modern sanitation and the absence of maintenance, many of these buildings are ripe for demolition and a danger to life. In fact, occurrence of fire in such areas have been common, and the roads planned then were never expected to cope with the present type and volume of traffic.

Slum formation is inevitable for any country undergoing rapid urbanization. However, the colonial administration in Singapore did very little to ease the housing shortage which multiplied with the population. Meanwhile, without relief from public housing and being unable to afford dwelling units built by private contractors, most of the low-income population either squeezed into the already crowded slum areas or joined the ranks of squatters. Extreme housing shortage led the colonial government into rent and eviction controls in 1947, which had the adverse effect of the landlords allowing their buildings to deteriorate and to subdivide rooms and cubicles to make space for more tenants.

The first official attempt to tackle housing shortage in Singapore dates back to 1927 with the formation of Singapore Improvement Trust (SIT), which was ineffective both before and after the war, having completed a total of 23,000 units. When the present government took office in 1959, a new Housing and Development Board (HDB) was created to replace SIT, with considerably more funds and legal powers to deal with public housing, urban renewal and other related problems. In 1960 HDB estimated that 147,000 dwelling units would have to be constructed in ten years in order to correct the existing deficiency of overcrowding and to keep up with demand due to population increase. To this end, HDB has completed two massive five-year Public Housing Programmes and is now in the process of implementing a third one. The first Programme(1961-65) saw the construction of 54,000 units, and the second Programme (1966-70) added another 56,000 public flats. The third Programme (1971-75) calls for the building of 95,000 units, at the end of which 45 to 50 per cent of Singapore population will be living in HDB flats. Including the units built by SIT, there are now a total of 133,000 public flats under HDB's management, housing some 760,000 persons or 35% of the total population. Meanwhile, complementary urban renewal and resettlement programmes have proceeded apace to revitalise Singapore's central area and to clear squatter colonies in the outlying areas for redevelopment.

In the light of such accomplishments, we shall provide a review of the major policy developments in Singapore's public housing efforts, together with an assessment of some of the socio-economic consequences and some observations on the prospects and problems in the immediate future. We shall also outline major trends in urban renewal and resettlement, and briefly comment on the role of public investment based on the Singapore experience.

POLICY DEVELOPMENTS

The basic assumption in the Government's endeavour into public housing is the recognition that the development process is at once social, economic, and political and that the linkage effects between the three are indeed profound. This being the case, Singapore has probably devoted more attention than most developing countries to those infrastructures or social overhead capital which carry a high consumption function but whose contribution to productivity and capital formation is less direct and more difficult to quantify. Investment in terms of financial and other resources in these infrastructures such as health, education, and public housing may or may not play an important role in the growth of national income; but these consumptions have value in themselves and are indispensable to higher standards of living or social development which in turn is an integral component of a balanced nation-building process. It is on this kind of fundamental development philosophy that all public housing policies in Singapore are based.

Since the inception of public housing programme by the present Government in 1961, there have been 3 major policy revisions worthy of note. The first has to do with physical design. When the backbone of the housing problem was broken upon the conclusion of the five Five-Year Programme in 1965, trends in both construction of public flats and the layout of their immediate environment have shown an improvement. From 1966 onwards, HDB has stopped building one-room emergency type of units, some of which had only communal toilet and cooking facilities and all or which shared a common corridor with flats facing each other. Because of the changing pattern of demand for public flats, even the two-room type of units are no longer in construction. Instead, emphasis in recent years is given to the building of more three, four, and five-room units with larger floor space and better internal arrangements for the kitchen, bathroom, and balcony as well as more generous provisions of common space and staircases. Although planning of the housing estates has continued along the neighbourhood principle, greater attention is being paid to make the concept of self-sufficiency more operational in terms of adequacy of various communal facilities. More open spaces are being provided between building which are becoming taller in order to maintain a maximum density of 100 units or 500 persons per acre. The trend of having a higher proportion of population living in larger and better HDB flats, is, indeed, an indicator of not only rising aspirations in physical living conditions but also the Government's ability to meet changes in the demand pattern for shelter of the lower income groups whose financial position has improved along with the economic growth of the nation.

The second major housing policy introduced during the last decade was the Home Ownership For The People Scheme. While this Scheme was first put into operation in 1964, the overwhelming demand to own a HDB flat did not gather its momentum until 1968, when the purchasers were permitted to use their Central Provident Fund (CPF) balance as down payment and monthly payment if they wish. The upper household income ceiling for purchase of flat was raised from $1,000 to $1,200 in 1970, and for those wishing to buy a five-room unit the income ceiling is now $1,500 (US$500) a month. Certain privileges in flat purchase are granted to "sitting" tenants who could have the option of buying their present flat without down payment or income restriction. To enable those in the civil service to participate, legislation was passed in 1970 so that these civil servants who do not contribute to CPF but who would otherwise qualify are permitted to register for purchase of flat without normal down payment. All of these conditions favourable to ownership of HDB flats are further augmented by a low interest rate of 6.25% coupled with a maximum of twenty years for loan repayment, reduced property tax and the option for resale at a profit under certain conditions. The sale prices of the public flats are indeed reasonable: a three-room unit costs $7,800 (US$2,800) and that for a four-room unit is $12,500 (US$4,400). The combined effect of all these policies have produced perhaps an unexpected flood of demand: waiting period for the purchase of a HDB flat is now two years. At the end of 1971, fully 30% of the public flats have been sold and this proportion is expected to increase in the immediate future.

Relaxation of qualifications for rental and sale of flats constitutes the third area of policy revision. From the colonial days of Singapore Improvement Trust (SIT) until 1967, the minimum qualification for obtaining a flat was five persons with the exception that in 1962 this number was reduced to three for those applying for one-room units. When the housing situation was drastically improved in the mid 1960's, HDB reduced the minimum requirement to two persons for any type of public housing unit. The effects of this new policy are essentially two-fold. On one hand, it encourages the splitting of households and generally increase the volume of demand for public housing. On the other hand, the reduction of household size in HDB flats means a decrease in density in the housing unit and in the estate, thus lessenging the population pressure on the use of amenities and communal facilities. There may also be a latent contribution to family planning: at least it could be argued that people no longer need to have more children in order to qualify for public housing.

SOCIAL AND ECONOMIC CONSEQUENCES

Knowledge of the consequences of Singapore's public housing efforts is not only of general interest but vital to the process of evaluation and planning for the future. It is, of course, not possible to assess anywhere near the full impact of the Republic's first two Five-Year Public Housing Programme (1961-65, 1966-70) on the economy and the society because much of it - especially the qualitative aspects and those with multiplying effects - is yet unknown. However, in the light of available evidence we can briefly describe some consequences of a decade's effort in public housing.

Cost-benefit analysis of any housing programme must be couched in social as well as economic terms, since public housing functions as social overhead capital in the overall development planning process and is intended to serve consumption as well as productive goals of the nation. Because of its greater relevance to consumption than production, the contribution of Singapore's public housing activities to the standard of living must first be taken into account. One gross indicator of the role of public housing in the improvement of physical living conditions is seen in the decline of household size in the public flats. Continuing high rate of construction, the infusion of smaller households and the general fertility reduction have all worked to bring down population density in the public housing units. Therefore, the average household size in HDB flats decreased by a substantial 13% from 6.4 persons in 1966 to 5.7 persons in 1970. This density reduction becomes even more meaningful if we take into account the simultaneous trend of constructing a higher proportion of larger public housing units to meet the demand, thus not only having less people but at the same time more living space in the housing unit.

We do not know the magnitude of density reduction in housing units for Singapore as a whole because of HDB's activities. However, if we consider the fact that in 1954 the average number of persons per housing unit was 10 as compared with the current figure of under 6 in HDB units, it is not difficult to imagine the extent to which the public flats, which now house more than one-third of Singapore's population, have brought improvement to the housing situation.

There are other indicators to denote the rising standards of housing. From a recent 10% sample survey of HDB tenants, several questions were directed to find out some aspects of their housing condition before re-location to the public flats. Results of the survey show that living space on the whole as measured by the number of rooms occupied has become larger by 20%. There has also been an improvement in amenities: while water, electricity, cooking, bathing and toilet facilities are standard in all HDB flats, in their previous private housing units some 25% of the tenant households surveyed did not have direct water and electricity supply, 45% had only a space for cooking, 50% had to share bathing facilities with other households, and only 33% had flush toilet available.

So far our evaluation of the impact of public housing takes the perspective of *looking in from outside*, that is from the position of the planner or interested layman. However, a more comprehensive assessment must also include the perspective of *looking out from the inside*, that is the views of those living in public housing units since they are the consumers of HDB's products. In this direction, a major portion of the questionnaire used in the survey mentioned earlier was devoted to seeking the HDB's tenants' views on their physical, social, and economic aspects of life. More specifically, tenants in the survey sample were asked 2 categories of questions: the first attempted to determine the degree of satisfaction regarding their present living conditions, and the second solicited response on the extent of change since relocation to public flats and how the tenants felt about it. Limitations of space prevents us from a full presentation and discussion of results, but the essence of the tenants' views could be summarized from the following 2 tables.

Item	Satisfactory	Acceptable	Unsatisfactory
Bus Service	57%	21%	22%
Taxi Service	63%	29%	8%
Nearness to City	49%	41%	10%
Nearness to Place of Work	40%	39%	21%
Nearness to Primary School	61%	24%	15%
Nearness to Secondary School	44%	35%	21%
Nearness to Market	81%	17%	2%
Availability of Goods	65%	28%	7%
Prices of Goods	16%	65%	19%
Nearness of Clinic	69%	24%	7%
Nearness to Police Station	37%	27%	36%
Public Security	65%	27%	8%
Playground for Children	33%	40%	27%
Parking Facilities	43%	28%	29%
Facilities for Rubbish Disposal	59%	28%	13%
Cleanliness of Building	41%	39%	20%
Efficiency of Lifts	14%	25%	61%
Opinion of Estate	72%	26%	2%
Opinion of Block	68%	27%	5%
Opinion of Floor	62%	25%	13%
Opinion of Flat	68%	24%	8%

Table 1

The overall picture, as suggested by the figures in Table 1, indicates a fairly high degree of satisfaction among the HDB tenants. However, closer inspection of the proportion expressing dissatisfaction in the items reveals several disquieting trends. The first is length of travel time to work or school. The second is transportation which is related to travel time and may have improved somewhat since the reorganization of bus services. The third is the felt distance to police station, although there is a high level of satisfaction with public security in the estate. The fourth has to do with inadequacy of communal facilities: playground, parking, cleanliness and lift efficiency. All of these problem areas have received attention from HDB in the planning of new estates, although some are beyond the control or Housing Board, such as the general increase in traffic and children prefer going to the school of their choice rather than the one nearer to their residence. Parking will continue to be a problem even though more carparks are being provided; the fact remains that ownership of vehicles is increasing rapidly with rising income and that maximum space for parking is limited in any estate. Priority in the allocation of parking space must compete with the demand for other communal facilities such as children's playground which is so overtaxed that 70% of the households interviewed reported that most of the time their children play inside the flat or along the corridors while only 18% regularly use the playground.

How the tenants felt about the changes that have taken place since moving into public housing (Table 2) is generally consistent with our other aggregate statistics, indicating an improvement. In the case of travel time to work and school, nearly an equal proportion reported changes for the better as that for the worse. The same could be said with respect to the amount of noise. While the majority of the respondents did not think that there has been a significant change in the people in the neighbourhood or the friendliness of the neighbours, among those who did the trend seems to be for the better. These findings taken together are not surprising; after all, life in an urban setting will always have some common feature and these could not be readily improved upon by mere relocation to the public flats. On the other hand, life in the densely populated highrise housing blocks do tend to aggravate cert[illegible] problems, such as the ease of movement up or down and the amount of noise. With respect to the latter, the survey discovered that the bulk of complaint is about children playing rather than the sound generated from musical instruments, conversations, mahjo[illegible] pounding of spices. There we have a good [illegible]ion of the interdependence of the problems: [illegible] children must play and some will always play in the flats or the corridors so that the parents can keep an eye on them. Improvement in playground facilities must compete with the demand for parking and other open areas so that blocks facing each other will be sufficiently far apart to ensure greater privacy and reduced noise level. All of these and many other physical and financial constraints consitute HDB planners' dilemma.

Item	No Significant Change	Changed for the Better	Changed for the Worse
Employment	87%	8%	5%
Travelling Time to Work	47%	28%	25%
Household Income	42%	45%	13%
Public Security	38%	56%	6%
Health of Household Members	29%	67%	4%
Marketing Facilities	38%	51%	11%
Primary School	65%	28%	7%
Secondary School	71%	18%	11%
Travelling Time to Primary School	38%	38%	24%
Travelling Time to Secondary School	46%	26%	28%
Friendliness of Neighbours	63%	28%	9%
Type of People	65%	27%	8%
Amount of Noise	28%	41%	31%
Cleanliness of Neighbourhood	15%	75%	10%

Table 2

In any event, there is a strong sentiment that life has changed for the better as a whole, as seen by the HDB tenants themselves: when asked to take everything into account, 26% of the sample said that life has become much better; 44% reported somewhat better; 18% mentioned that conditions have remained the same as before; 11% thought that life has become somewhat worse and 1% indicated that things have changed very much for the worse.

On the economic side, funds for capital development of low-cost housing are financed from State Development Funds in the form of loans to HDB. These loans are granted at the interest rate of 7.75% over 60 years in respect of rented properties, and at 6% repayable over 10 years in respect of properties under the Home Ownership For the People Scheme. Government expenditure on housing as a proportion of Development Expenditure has been rising, from 16.7% in 1961 to 20.5% in 1969. The proportion of capital expenditure for public housing of total State Development Fund over the 2 five-year periods of 1961-65 and 1966-70 are 27 and 26% respectively. HDB captial expenditure in housing construction between 1960 and 1970 was well over 500 million dollars. We estimate that, over the same two periods, an average of 1.3 and 1.6% of the GDP were induced by public housing development. Of course, the cost of Singapore's high rate of public housing construction cannot be appraised only in terms of financial investment by the Government; equally if not more important is the political will at the top and an efficient technical and administrative structure for implementation.

In the absence of any systematic analysis of public housing's impact on the Singapore economy, little can be said about the cost structure and returns to investment, employment creation, and impact on the demand for building materials. Without definitive knowledge in these and other related areas, we can only speculate on the periphery and make some generalisations.

The ratio of construction to GDP in Singapore has been increasing both absolutely and in proportion during the last decade. In fact, next only to the manufacturing and quarrying industrial sector, construction has been a leading sector in its contribution to GDP, between 1960-69, its average annual rate of growth was 45% while that of the GDP at factor cost was only 14%. In addition, more than 40% of Gross Domestic Fixed Capital Formation or total investment is contributed by the building and construction sector for each year in the last decade, of which a large proportion is by the construction of dwelling units. While we do not know the exact ramifications of HDB's role in the rapid growth of the construction industry as a whole, its importance cannot be minimized in terms of hundreds of millions of dollars that the Government has allocated for the 2 completed Five-Year Programmes and with more to come in the years ahead.

HDB must have generated a very substantial amount of employment during its 10-year operations. The building and construction industry is highly labour intensive with a capacity for labour absorption of both the skilled and unskilled labour force. The position of the building industry was particulary crucial in the early 1960's when unemployment was high; the industry employed an average of 10% of the total non-professional labour force for the period 1960-65, and about 7% for the period 1966-70. Direct employment of labour by HDB on sites average over 6,000 persons per day, and account must also be taken of the multiplier effect on employment generation in the primary and secondary building materials, transport and other related industries.

In order to provide employment opportunities within the public housing estates, provisions are made to include labour intensive industries within the vicinity of certain estates so as to provide jobs for the tenants, especially women. The plan for the Toa Payoh Estate, for example, has been amended to enable 50 acres of land to be set aside for industries and some 10,000 jobs are expected to be brought to the door steps of the tenants in the next few years. In this way, travel time and expenses can be saved, and indirectly income and productivity may increase. In locating these flatted, well-designed factories, it would also provide a welcome change to the skyline of the housing estates. There are now 300 industrial shops or factory units distributed among the HDB estates.

The fact that rent and conservancy charge for the same type of public housing units have never been raised contribute to the stability in the cost of living for the lower income groups. This is all the the more important since housing cost in the private sector has been rising appreciably. With such a large proportion of lower income population housed in HDB flats who pay an average of 15% of their income on rent and utilities, the maintenance of a constant rent is anti-inflationary and promote greater savings among the people.

PROBLEMS AND PROSPECTS IN PUBLIC HOUSING

Success in any aspect of national development, no matter how defined, is almost never a permanent condition. Moreover, success brings its own problems, and this applies to solutions to Singapore's housing problems. One crucial challenge facing HDB today and in the foreseeable future is meeting the continued demand for sale and rental of flats. Largely because of the Government's liberal policies in the promotion of higher standards of public housing on the one hand and the rising housing cost in the private sector on the other, volume of applications for purchase and rental of HDB units increased very rapidly during the last 2 years, resulting in a substantial backlog. The accumulation of this heavy backlog is purely due to the sharp rise in demand while the supply of HDB units has kept pace with the scheduled rate of construction in the Five-Year Programmes. The current status of demand for public housing serves to emphasize the essence of the problem: in order to bring further improvements in housing conditions in the lower and middle income groups and to promote all the social benefits associated with home ownership, the Government has brought upon itself a demand which calls for an even greater effort in public housing in this decade and beyond.

Needless to say, the substantial waiting list for public housing cannot be allowed to remain for too long without negative effects since there are yet no other alternatives to meet the housing needs of the lower income strata of the population. Until the private sector can effectively participate in the construction of low-cost housing, HDB will have the major responsibility alone. This is by no means an easy task; to increase the construction rate even further in the light of rising cost in admininstration, labour, land and materials, the Government will eventually be faced with a number of decisions, including the increase of subsidy to HDB and the raising of charges for purchase and rental of public housing units.

The question for the continued development in public housing is not only what per cent of the population that the Government can house or even how much housing conditions have improved but also what kind of life the people living in HDB flats have and will have. With more than one-third of the population already in public flats and the prospect of HDB providing shelter for half of the entire population, attention should be paid to both the qualitative as well as quantitative aspects of living in densely populated highrise flats - a trend that is becoming increasingly characteristic for the upper income groups in Singapore as well. Although the style of life, the community structure and many of the social problems in the public housing estates are inherently that of general urban environment in Singapore and may not be subject to direct Government control, there is nevertheless room for more understanding in depth of living environment in the public housing estates when seen as a web of interaction between the physical, social and economic components. There is a particular need to study the sociological aspects of life in the HDB flats and around the HDB estates so that knowledge of the present may give us a glance into the future. Given that problems such as neighbourliness and community cohesion are essentially a matter of *evolution* which cannot be provided by HDB in the same way that it brought forth a *revolution* in housing patterns, these are matters concerned with the overall nation-building process which both public and private sector should participate.

URBAN RENEWAL

From the land locational economics point of view, Singapore is unique in that the bulk of her commercial port, transportation, cultural, recreational and administrative activities take place within the central area of some 1,700 acres or 1.2% of the total land area of the Republic. Within this area lives about 15% of the total population. Within this area, too, are the city slums.

It is economically irrational to have a large piece of strategic and valuable land in the centre of the city occupied by slums which constitute a major obstacle to any comprehensive urban planning.

Socially, the city slums are a source of disease, crime and other forms of social disorganization. Physically, most of the buildings are too old, with grossly inadequate facilities and many internal subdivisions so that housing conditions are much below any minimum standard.

There are 3 ways by which the Government can undertake a revitalization and renewal programme in the central area. One is to emphasize on social objectives with minimum stress on economic projects. This would mean little or no private participation since social projects such as public housing, schools, recreational facilities and so on are non-revenue generating. This approach is beyond the financial capacity of the Singapore Government. The second approach is to give exclusive attention to economic projects which in turn will improve the tax base for the Government. However, purely economic projects such as office buildings, hotels, shopping centres would be undertaken by the private sector but would hardly benefit the whole community since the lower income groups are going to be left out. The Singapore approach to urban renewal, beginning in 1963, is one towards a more balanced development incorporating essential elements of the first 2 approaches whereby both the Government and a cross-section of the population would benefit. The private sector would concentrate on economically viable projects which in turn will provide employment opportunities. The Government would undertake social projects such as public housing, provision of infrastructure, the master planning and coordination.

This approach not only provides for a balanced community redevelopment but also helps the private sector to provide the scope variety necessary to make the central area more dynamic, functional viable, both in terms of living and working environment. Towards this end, the Government has provided the necessary suitable climate for investment by offering generous concessions to the private sector so that both are partners in the effort to revitalize the central area.

There are 3 basic considerations to a renewal programme aimed at revitalizing the central area. First, there is a conservation programme to preserve buildings, monuments and sites with historical or architectural interest. Secondly, there is a rehabilitation programme aimed at renovating, redecorating and improving buildings or sites which have architectural or historical value and where structures are sound enough to withstand repair works. This action would mean careful selection to tie in with the overall plan to improve the environment. Thirdly, there is the rebuilding of areas where the structures are ripe for demolition. Hence it would be wrong to assume that the urban renewal programme is one of wholesale demolition and rebuilding. In the renewal exercise, planning for the whole environment of the central area is emphasized. For example, all developers under the sale of sites programme are required to set aside 2% of the total project cost for general improvement of the site by way of land-scaping, provision of fountains, sculpture or murals.

In terms of urban renewal planning, the whole central area has been divided into a number of precincts according to the criteria of land availability, clearance feasibility and urgency for redevelopment. The strategy so far has been to the establishment of foot-holds at 2 ends of the central area to serve a demonstrative effect and gradually converge towards the centre.

Given the Singapore's experience in urban renewal during the last several years, a great deal more can still be learned from the past efforts for the planning of the future. Besides the need for a more systematic economic analysis of the urban renewal exercise, the social cost and benefits of families involved should also be taken into serious consideration. Inasmuch as all the households and commercial establishments affected by urban renewal are offered compensation and alternative accommodations, we do not know enough about the kind of change that has taken place in the life of the people affected. Of course, urban renewal in Singapore is not taken as a purely mechanical process: people are assumed to be happier and live better if they are moved from slums to new flats with low rental cost. Although relocation is inevitable in the exercise and that some adjustments necessarily have to be made by the families concerned to a new and often unfamiliar environment, the transition can be made easier with greater attention being directed to the changes taken place at the micro level. To this end, analysis of social organization in the slums and longitudinal studies of the families affected by clearance could provide additional insights for better programming.

RESETTLEMENT

Singapore's massive public housing programmes and, to a lesser extent, the accelerating urban renewal projects, all require areas of land for development. In addition to this, the priority given by the Government to rapid industrialization and the expansion of educational, commercial, social and other facilities have also generated heavy and often competing demand for available land. Most of the lands required for development have been heavily encumbered with squatters, small-scale farmers, tenants of dilapidated house and other occupiers. Before development could take place, the existing occupiers of the land required by Government for redevelopment purpose have to be resettled in acceptable alternative accommodation of one form or another. Therefore, the resettlement programme constitutes an indivisible link with public housing and urban renewal, all of which function in coordination within HDB.

The policy of resettlement takes into account the needs of the existing occupiers of the land for acceptable alternative accommodation, so that not only alternative shelter is provided but also their means of livelihood are not totally disrupted. For example, farmers have to be given agricultural land, industries are relocated into factories or sites, shopkeepers are allocated shops and residential dwellers are offered HDB units. Therefore, in the relocation process the public housing programme provides the alternative accommodations, the resettlement programme takes care of clearance, and the urban renewal programme undertakes to redevelop the central area.

Most of the land situated on the outskirts of Singapore's urban areas required for development are occupied by farmers or people leading a rural way of life. For the purpose of relocating these settlers, both squatters and legal occupiers, large areas of available and suitable land in the rural districts have been set aside into what are known as Resettlement Areas. A designated site is first developed with basic infrastructures such as roads, water, and electricity supply, the site then is cut into lots for allocation to the displaced farmers. However, owing to the limited supply of land, each lot has to be small in size, with a maximum of 2½ acres. Consequently, there has been a tendency for members of the resettled farming household to take on more non-farm jobs, which is in line with the Government's policy to encourage high proportion of industrial employment since many of the small farmers are not familiar with modern means of production and in any case cannot hope to achieve any economy of scale.

On resettlement, a farmer is paid compensation for the building structure, the crops and livestock, transport and disturbance allowances. More than 2,000 households have been relocated into the Resettlement Areas totalling more than 10,000 acres. Again, because of the grave shortage of land, the resettlement policy since 1964 has been to encourage the affected farmers to change to non-farm occupations. Therefore, for those settlers who do not insist on land allocation, additional payment in lieu of land allocation over and above the normal compensation is also paid.

Other land users such as factories, warehouses and shops affected by the resettlement programme are also relocated on the same principle. For example, a motor industry complex has been completed for the specific relocation of some motor workshops which proliferate in the urban areas. Similarly, a warehouse complex has been planned fot the eventual relocation of those warehouses found along the Singapore River where urban renewal is expected to take place in the next few years. Shopkeepers affected by resettlement are offered spaces in the various housing estates at concessional rents. So far, more than 2,000 shops have been relocated into the public housing estates.

The resettlement of residential settlers in the squatter or slum areas poses comparatively less problem. An overwhelming majority of them have accepted the alternative accommodation in the HDB estates. Preliminary research results have not indicated many substantial problems of adjustment, although more penetrating studies into the relocation process are necessary. In 1971, rates of compensation have been substantially improved from 50 to 100% to allow for less economic hardship. To date some 45,000 households have been relocated under HDB's resettlement programme.

PUBLIC INVESTMENT AND URBAN DEVELOPMENT

The Singapore experience makes a good case study for discussion among economists, town planners, housing experts and other urbanologists on the extent to which public resources should be allocated to housing development and other related programmes. For most countries in Asia, no aspect of public policy causes more frustration than housing; almost everywhere the gap between intention and achievement is great. Most economists would argue against any substantial public investment in housing, taking what may be called "the devil take housing" approach which asserts that housing is a durable form of investment requiring a heavy outlay to create it but paying off little each year. It generates no foreign exchange, competes with industries and agriculture for capital, draws off needed labour and materials, and might even be inflationary. A poor country, it is said, cannot spend much on assets for future consumption; instead, it should focus more on food production and on other assets with more direct and greater relevance to productivity such as factories, railroads and power plants. According to this line of reasoning, public housing and related programmes should be accorded low priority in the development plans and in the allocation of public funds.

It is difficult to argue with the contention that a country with limited resources should not spend "too much" on housing; indeed, it should not spend too much on anything. But using productivity analysis as the only major criterion to evaluate public expenditure on housing programmes must be rejected for the same reasons as we have stated earlier in this paper, that is, there cannot be a sharp distinction between economic and social change and between production and consumption standards. The development process is both social and economic, and the intricacies of their interdependence is often too complex to be divisible.

The "overheadness" of housing, be it in terms of economic or social services, takes on greater significance if we view it in the broader perspective of industrialization and urbanization. Although it is possible to have urbanization without industrialization, the reverse proposition does not hold. Since many of the developing countries have industrialization as one of their development objectives, this invariably involves urbanization which in turn means a demand for urban transport facilities, sanitation, expansion of public utilities, and housing. In fact, the growth of urbanization has preceded that of industrialization in most Asian countries. In any event, demands for housing and other facilities are directly related to industrialization and urbanization. Moreover, public housing programmes should include not just construction of dwellings for the low-income population which always constitutes the overwhelmingly majority in the developing countries; indeed, the building of public flats is only one of the many integral parts of the overall urban planning process which also includes slum clearance, urban renewal, improvement of the transport system, and a whole network of other social and economic services. Environment cannot be easily altered, especially in Asian countries where the pattern of urban growth has been haphazard, current housing shortage is extremely acute and squatter colonies abound. Therefore, a great deal of public investment is required to reorder and rationalize the established pattern in the interest of sound land use policy, economic growth, social improvement and political stability. Public investment in this context means not merely the allocation of funds but rather the mobilization of whatever resources that the Government has at its disposal, be it technical, administrative or the ability to generate participation from the public.

While the social and economic impact of housing cannot always be subject to precise quantitative measurement, some general arguments can be made in favour of both. First of all, the home together with its environment is the single context in which the largest range of human needs are met and the greater part of human life is lived. There is no doubt that housing must be acknowledged as a necessity of life and constitutes a major indicator of a country's standard of living. Substandard housing conditions manifest themselves in many forms such as slums or squatter settlements which not only promote social and psychological disorganizations but is also an impediment to public health. Moreover, these adverse social effects are capable of generating serious external diseconomies as well as creating political disorder. On the positive side, there is the desirability of having central control of town planning, which may promote social development and economic growth as an integrated whole.

The Singapore experience demonstrates that, although a country may first embark upon a housing programme simply to provide homes, its economy could benefit in many ways, such as the absorption of unemployment and the increase of local purchasing power stimulated by construction. A substantial public housing programme will encourage local material industries as well as many secondary industries. The new industries in turn will lessen a country's dependence on imports that may unnecessarily drain cash resources. Other advantages include the encouragement of industrial production and efficiency by convenient housing sites and the development of crafts and skills in an economy devoid of them. A good housing programme will contribute to the proper development or preservation of a country's physical environment and to the rationalization of the vast pool of public works, roads, schools, and other public improvements. It may stimulate savings and the organization of a mortgage system offering reasonable interest rates. Moreover, new and important sources of tax revenues may be created. Finally, such a programme helps to stabilize home and community life. Many of these general principles could be realized, as shown by the massive public housing, industrial estate development, and urban renewal programmes that are taking place in Singapore, But for the majority of Asian countries, the importance of housing in public investment allocations has yet to take root. Unless action is taken in this direction, more and more developing countries will be forced into housing programmes because of political if not socio-economic realities. Therefore, housing as a major item of social overhead capital or infrastructure should be seriously considered as an integral part of any development plan.

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Paper No. III/3

URBAN RENEWAL IN SINGAPORE AND ITS ASSOCIATED PROBLEMS

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ABSTRACT

This paper outlines the problems and achievements in urban renewal in Singapore. Launched in 1966, to date urban renewal in the Central Area has carried out the clearance of about 100 ha of slum and squatter ridden areas, re-housing the people in new public housing estates. Careful consideration is given towards achieving a satisfactory balance between the needs for easy access by cars to all parts of the central areas and the adverse effects created by cars. Plans are also programmed to maintain a large residential population in the Central Area. Through special incentives, private sectors also participate in the urban renewal programmes.

A special problem in re-development in the Central Area is the re-location and clearance of non-conforming uses such as backyard industries and warehousing. Resettling of identical and related cottage industries as a group within industrial sites in the fringes of the Central Area has been carried out with considerable success.

(Abstracted by Chin Kee Kean)

Singapore's Central Area shares many common features with most city centres. It is the strategic centre of Singapore's major functions in Government administration, civic, commercial, harbour and entertainment activities. It is also the oldest built-up area of Singapore with accumulated growth dating back to the beginning of urban development in Singapore in the early 19th century.

The bulk of the city comprises of structures which are over 100 years old, mainly of the two-storey traditional shophouses types. Crowded along narrow streets and blacklanes, they lack in the modern standards of light and open air ventilation. In addition, there are city sections which are not served by the modern sewerage system and are, therefore, entirely dependent on night-soil buckets for the removal of human wastes. Many of such structures are ill-maintained, especially aggravated by the Rent Control Act of 1947, and are in an advanced state of deterioration and dilapidation. Haphazard growth in the past had furthermore created an undesirable pattern of obnoxious, and incompatible uses of backyard industries and warehousing within the general mixed use Central Area fabric of residential and commercial developments. The inadequacy of the infrastructure is moreover especially felt in the prevailing obsolescence of the existing road system. There is also need for more open spaces as well as general social and recreational amenities for the Central Area.

This prevailing substandard environment of the Central Area was put under severe stress by the tremendous influx of immigrants during the immediate post-war period. Occupancy figures in many of the shophouses in Central Area had soared to over 20 times the original one family occupancy by successive subdivisions, with residential densities reaching over 2,500 persons to the ha. In addition, there was extensive squatting on vacant and marginal lands within the Centre, with people crowding in huts composed of largely inflammable material and devoid of sanitation, water or any of the elementary public health requirements.

The task of renewal faced within this deteriorating situation is, therefore, a formidable one. The Government has undertaken to tackle the problem comprehensively. The aim is the structural change of the Central Area environment and its transformation into an effective and efficient centre corresponding to the scale and tempo of the dynamic development forces within the Republic.

Launched in 1966, urban renewal under the Urban Renewal Department of the Housing & Development Board rapidly gained momentum, when the massive public housing programmes got underway and had convincingly succeeded in 1965 in breaking the back of Singapore's housing problem. The continuity of supply of suitable alternative accommodation, coupled with generous compensatory re-location terms, have paved the way for effective action in the clearance of slums and squatters from strategic Central Area sites for proper and speedy re-development purposes.

To date urban renewal in the Central Area has carried out the clearance of about 100 ha of slum and squatter ridden areas, re-housing the people in new public housing estates, of which approximately 30,000 persons were re-accommodated within Central Area sites. The latter include 1,000-shop units to re-locate shop cases in the affected areas.

The implementation of major roads and other infrastructure systems are comprehensively staged with the clearance and re-development of sites, within the framework of the re-distribution of residential and other activities for the new Central Area environment. Careful consideration is given towards achieving a satisfactory balance between the needs for easy access by car to all parts of the Central Area and the adverse effects created by cars on the environment through proper control in carparking and design of roads and elevated highways.

An important factor in the minimisation of demand for cars for journeys to work into the Central Area is the planned programme to maintain a large residential population in Central Area. Unlike many other city centres, Singapore's Central Area has a strong attraction for residence over a wide range of income groups. Another aspect of renewal is, therefore, the enhancement of the "new" Central Area, not only as an efficient environment for work but also as a desirable environment for living. Within this context, various schemes are being carried out towards the maximisation of existing natural features of the hills and sea front open spaces as well as the further development of new greenery and major open spaces and social and recreational amenities. An outstanding recreational feature soon to be undertaken, for example, is the over 50 ha reclamation of sea in front of the Central Area which is reserved for open space use. Together with the adjacent Kallang Sports Complex and the development of pedestrian promenades along Singapore River banks, they will become the focus of Singapore's Central Area park system in the near future. A segregated system of pedestrian walks is gradually being created to link all the major activity centres throughout this network of green and open space and other special features, such as areas to be preserved for their historical, religious or cultural values.

The above examples in transforming the Central Area environment are being realised with a significant participation of the private sector through special incentives. Their massive contribution in the re-development process covers a wide range of commercial and other projects, reaching a total of about $460 million investment capital within the brief period of 5 years since the start of the programme.

Rebuilding of Singapore's Central Area is, however, not without its specific constraints.

Singapore's limited land supply, for example, requires intensification of the use of the scarce land resources. For this reason, the principle of strata zoning is adopted in the re-development of the Central Area. Deliberate mixing of compatible uses at high densities has some other assets.

Singapore's Central Area, like many other city centres, has considerable areas which are deserted and lifeless after the working hours. Mixing of compatible uses, including residential uses, together with the planned development of a segregated pedestrian system within the area are expected to promote the extension of the levels of activities beyond these working hours.

A special problem in re-development in the Central Area is the re-location and clearance of non-conforming uses, such as backyard industries and warehousing which are distributed over large areas within the Central Area. Re-location of these incompatible and frequently obnoxious uses from Central Area require the development of new industrial and warehousing complexes suitable to the specific types and character of these activities.

Towards this end, the Government has undertaken to resettle identical and related cottage industries as a group within industrial sites on the fringes of the Central Area. Special consideration is hereby taken to promote the development of these small scale industries through the maximisation of the close links amongst and between identical and other related industries within the industrial sites. Steps are also being taken to promote the re-location of warehousing, presently occupying valuable land in Central Area, in suitable warehousing complexes outside the Central Area.

Similarly, the Government is undertaking to organise the re-distribution of hawkers and perishable food wholesalers into permanent hawker and market centres which meet the standards of health and cleanliness.

On a longer term basis, the re-organisation of the distribution of schools in Central Area is being planned in conjunction with the future composition and distribution of population within the Central Area.

These are some of the features, problems, constraints and opportunities which characterise the brief Singapore experience in urban renewal of the Central Area.

Paper No. III/4

JURONG TOWN – SINGAPORE'S EXPERIENCE IN THE PLANNING AND DEVELOPMENT OF AN INDUSTRIAL COMPLEX

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ABSTRACT

Industrialisation can be said to be a completely new venture and experiment to Singapore, which was started barely a decade ago. Among the numerous development strategies and priorities adopted by the Singapore Government, creating and providing a big scale industrial estate with all the necessary industrial facilities and infrastructure was one of the main tools used by the Singapore Government in its attempt to launch its industrialisation programme successfully. In the process of creating such an estate, countless problems of technical, social, economic, environmental nature were experienced.

This paper simply attempts to relate briefly the story of Jurong and some of the problems which were experienced during the implementation of the project.

HISTORICAL BACKGROUND

The idea of urbanizing the western region of Singapore Island dates back to the mid-fifties. At that time, the area was first envisaged as a possible outlet for the accelerating process of metropolitan extension and for the increasing congestion of the urban core. An extremely rapid rate of population growth was largely responsible for both these phenomena.

Much along the lines of the British "new town" approach, decentralized development was advocated in the form of isolated "satellite" centres as a possible solution. The 1955 Master Plan of Singapore Island resembled in fact a system of "self-contained" new towns, scattered around the coastal areas of the Island. One of the designated sites was "Bulim New Town", an area of about 500 acres at the north-eastern part of what was later to be known as Jurong Industrial Estate, and now, Jurong Town. However, ideas on how and when the new town was to be developed and for what specific purpose were not clearly defined at the time.

In the late fifties, a national drive towards industrialization was prompted by the growing awareness that Singapore's labour force was growing at a much faster pace than what the prospective expansion of the entrepot trade, on which the national economy had so heavily been dependent hitherto could cope with. Two basic tasks therefore presented themselves:

(1) To create the maximum number of jobs within the shortest possible time, in order to arrest rising unemployment. The growth of new industries must be nurtured at a sufficient rate to reduce the unemployment backlog.

(2) To achieve, within the shortest possible time, the diversification of the national economy. While Singapore will continue to do its best to foster close cooperation with its neighbouring countries, it must promote world-wide trade and those types of industries, as in the case of Japan, which can draw their raw materials from all parts of the world and supply the world markets on a competitive basis.

In carrying out these two tasks, one of the many recognised development strategies and priorities is the provision of the industrial facilities and infrastructure to attract the establishment of industries especially export-oriented industries. The Government also recognised that organised industrial estates are effective tools to induce manufacturing growth. A search for potential sites was then undertaken.

Thus, the two ideas, industrial promotion and urban decentralization (the former now very much over-shadowing the latter) converged on the selection of JURONG as the site for the development of an "Industrial New Town". Jurong offered itself as a good prospect mainly for the following reasons:

(1) The area was still largely rural in nature and sparsely settled.

(2) The area includes large tracts of land in public holdings; cumbersome and time-consuming land acquisition exercises can therefore be reduced considerably.

(3) More important, the water around the coasts in the area was generally deep, with a big group of sizable off-shore islands situated in even deeper water just south of the area. It thus offered a unique asset: the possibility of developing an industrial town, in conjunction with deep water berthing facilities in the form of a port.

In May 1960, at the req . . f the then Minister for Finance, Dr. Goh Keng Swee, an initial appraisal of its development possibilities was undertaken. A tentative layout plan was subsequently prepared covering an area of about 5,000 acres.

In the following year 1961, the overall industrialization policy for Singapore was the subject of a comprehensive analysis by a United Nations Industrial Survey Team headed by Dr. A. Winsemius and appointed under the United Nations Programme of Technical Assistance. Their recommendations included a programme of land acquisition and organisation of industrial estates, and they endorsed the Jurong Scheme. In the report, the Jurong Project was clearly envisaged as an integrated regional development, encompassing an area of 25,000 acres. Work on Jurong was undertaken immediately thereafter, under the responsibility of a newly-established Economic Development Board. The urgency to develop a first tract of land for industrial use dictated a largely empirical approach, since plans for comprehensive physical development of the area were far from finalized. In fact, the very mapping of the area had to be carried out in the following years. Thus, began a race between the strained capabilities of an initially scant technical staff and dazzling implementation activities on the site.

During this initial period of a frantic planning process, practically every agency involved in urban improvements in Singapore contributed different plans or proposals for Jurong. In early 1967, a Revised Master Plan for Jurong New Town, together with a written report was submitted by the Urban Renewal Department of the Housing and Development Board. Soon after, at the request of the Government of Singapore, the United Nations Bureau of Technical Assistance Operations assigned an expert to review and advise on the physical planning of Jurong Industrial Estate. A Comprehensive Plan for Jurong was the outcome and an Outline Programme for the phased development of the area was then embarked upon.

In 1967, a Canadian Consultant Team under the Colombo Plan undertook a Coastal Utilization Study of Jurong. This Team put forward a seaport concept for Jurong which proposed dredging a huge water basin 3 miles inland from the coastal deep water in the western part of Jurong to provide a few thousand acres of waterfront lands for marine and marine-oriented industries much along the lines of Europort. This proposal drastically changed all the early planning concepts hitherto conceived.

At about the same time in 1967, a special Planning Organisation known as the State & City Planning Office was established in Singapore under the United Nations Special Fund Programme to prepare a Comprehensive Plan for the whole of Singapore Island within a time period of 4 years. This is a specially-constituted planning body consisting of personnel from a Consultant Firm appointed by the U.N., and local counterparts from the Singapore Government.

Because Jurong, in the context of a small island State, is a very important component of Singapore, its planning was again reviewed, but this time, more systematically in a much broader context, and within the larger framework of the entire Island. The preparation of a Comprehensive Plan for Jurong has since been jointly carried out by the Planning Unit of Jurong Town Corporation and the State and City Planning Office.

It may be said that all the while, the physical plan of Jurong or what has been implemented of it at any one time, represent a compromise between immediate short-term economic requirements and what was regarded as long-term planning goals at each stage of its plan preparation development. Inevitably, issues were often settled by decision-makers as to which was deemed to be more important at the time.

PRESENT STAGE OF DEVELOPMENT IN JURONG

The Jurong Project, as Singapore's effort to industrialize, is now a success story, and the statistics on the Project's achievements speak for themselves. In the industrial promotion aspect of the Jurong Town Development, the foundation of providing industrial facilities and infrastructure can be said to have been firmly laid down. The economic development in Singapore has also progressed to such a stage that it has gathered enough momentum to keep new industries and investment coming in. The present task in this industrial sector, therefore, seems to be a relatively simple one of trying to develop more industrial land at a fast enough rate to keep up with the demand; to put the right industries in the right places and to prevent excessive pollution of all kinds from the factories.

The Jurong Town Corporation now sees one of its major tasks as that of devoting equal, if not greater, effort and energy to the development of a balanced community with proper facilities for the social as well as economic well-being of such a community. Considerable energy is now being applied to the provision of social amenities and recreational facilities which were sadly lacking in the early years.

GENERAL REVIEW OF THE PHYSICAL PLANNING PROCESS INVOLVED IN THE JURONG PROJECT

Because of the rapid speed at which development works were carried out and the limited manpower available for major mapping and design operations, planning activities could hardly catch up with implementation activities. Planners were confronted with the need to constantly revise and update plans as soon as they were drawn. Major earth movements and drainage works had to be decided expeditiously. Roads were laid out and land subdivided and allocated as soon as a finished grade was achieved. Wharves were piled and constructed on the basis of sketch layout in certain areas. (This refers of course to planning layout and not structural design.)

Another problem arose from the changing scope and character of the programme and the related difficulty in crystalizing agreement on the ultimate objectives of the Project. In the early 1950s when the Jurong Project was conceived, the first sketch plans anticipated development of only two or three thousand acres of industrial land. Later forecasts of future demand are of the order of several thousands. Educated guesses were made at different times as to the ultimate residential population of the area, ranging from sixty to six hundred thousand. The associated requirement of land for housing, recreational and community facilities fluctuated widely over time.

Layouts prepared for industrial sites were hastily prepared as they were subjected to constantly changing allocation requirements and policy. Alloation policy itself also suffered several limitations. Limited availability of prepared lots to satisfy applicants at any particular time and promotional considerations often determined what should be siting criteria. On the other hand, the apparently more sophisticated criteria introduced later, that of clustering industries manufacturing similar products, such as "food" or "chemical" industries, regardless of the specific process involved, imposed constant compromises since it restricted possibilities to accommodate prospective investors, while at the same time freezing tracts of perfectly suitable prepared land.

Achievement of a firm perspective on the ultimate land use within the area was also hampered by progressive knowledge of limitations not fully envisaged in early plans or by the sudden emergence of new factors. Only in the course of development did it become possible to appreciate the actual extent of problems associated with land clearance and resettlement of squatters, and with the exhumation of existing burial grounds. Further difficulties arose from clearance restrictions imposed by the flight pattern threshold of the military airfield situated just north of the area, and by the existing serial transmittal stations, the relocation of which turned out to be more financially difficult than originally anticipated.

A major challenge to the planner's imagination was imposed by the very scale of the undertaking. While some know-how had been gathered in Singapore from numerous small projects on other parts of the country, not sufficient experience was available on large-scale development. Many problems could be properly assessed only as they emerged in the very course of implementation. The planners' capacity of vision and their related tendency to press for long-term investments were not always easily reconciled with the short-term economic and social returns of the operation.

FACTORS CONTRIBUTING TO THE SUCCESS OF JURONG

As pointed out earlier, it was recognised, at the very outset, that to implement an industrialization programme successfully, the provision of industrial facilities and infrastructure is but only one of the many development strategies and priorities required.

In parallel with the physical development of Jurong Town the following development strategies and priorities adopted by the Government were as much responsible for Jurong being what it is today:

(1) Provision of necessary fiscal incentives to attract export-oriented industries,

(2) Launching of a national productivity drive to ensure good industrial relations, high productivity and low cost of production,

(3) Implementation of an active trade policy and export promotion programme in support of the industrial development,

(4) Launching of an intensive and extensive investment promotion campaign both at home and abroad,

(5) Modernisation and expansion of light industries with special emphasis on the promotion of labour-intensive industries,

(6) Establishment of prototype production and training centres to fill a vital gap—on - the - job training under actual production conditions — in the existing technical and vocational training programme,

(7) Development of industrial testing and research facilities and product design,

(8) Development of comprehensive manpower and training programme and organisation of specialised industrial teams for training at home and abroad with special emphasis on metal engineering, electronics, plastics and petrol-chemicials which offer good prospects for Singapore to specialise in future development.

RESIDENTIAL POPULATION AND ASSOCIATTED PROBLEMS IN JURONG TOWN

Jurong can certainly look back at ten years' achievement with pride. But how does Jurong fare as a new urban area, not only to work in, but also to live in, as envisaged and planned at the inception of the project?

Insofar as making provisions for live-in population is concerned, there was no lack of foresight or action. Over 4,000 units of low-cost flats were some of the first buildings to be constructed in Jurong to attract and house the workers to be employed in the new town. The planners were in no doubt, at the earliest stages, that to promote and successfully develop a large-scale industrial town, live-in population is essential.

However, during the first 2 or 3 years after the birth of the town, while the rate of industrial land allocation and the number of factories going into operation was progressing at a very heartening speed, the occupancy rate of the low-cost flats did not quite follow the same welcome trend.

The seasons for the workers' reluctance to move into Jurong in the initial stages are not difficult to understand. Apart from being put off by a new strange environment, there was the lack of entertainment facilities, social amenities, insufficient range of shopping facilities and difficulty in travelling between the new town and the existing urban core owing to the non-existence of a satisfactory public transport system. The remedies which were needed were fairly apparent. However, in the fact of the more important need then, to place greater priority on the development of more industrial land so as to attract the desired capital investment and to generate the urgently-needed jobs, the development and creation of better social amenities and recreational facilities during early stages received limited attention. The perennial "chicken and egg" problem also reared its ugly head for , to attract residents facilities must be provided, but to support these facilities and make them viable, a sufficient population was first required.

To date, in addition to providing social amenities and facilities for the local population such as cinema hall, community centre, hospital, government district dispensary, children's creche, etc., the Corporation is also currently completing or undertaking large scale, non-industrial projects which could also serve Singapore as a whole. Some of these projects are:

(1) A 700-acre Jurong Park which will cater for a wide range of active and passive recreational activities and which include a Japanese Garden, a Chinese Garden, boating, sailing, drive-in cinema, drive-in restaurant, motels, golf course, bowling centre, ice-skating, etc.

(2) A 50-acre Bird Park, which has among other things, a huge 5-acre flight-in aviary with a 100 feet artificial waterfall inside the avairy. A tram car system serving the visitors to the Bird Park is another novel feature.

(3) Development of open space and green areas, and reservation of vantage hills at strategic locations not only to provide relief to the monotony of the industrial area, but also to provide scenic spots and vantage lookout points for tourists and local visitors alike, to have an outing and commanding views of the town. Whenever possible, access to the seaside and pockets of seafront land will be reserved for the public. Seaside parklands and esplanades will also be provided at selected scenic locations. In some of the completed area, lookout towers with restaurants are provided.

4. Construction of a sports complex including a swimming pool and sports stadium.

Apart from building up the live-in population, one of the tasks in the planning and development of Jurong is to create a 'community' with a 'community spirit' and a sense of belonging in the area. And more ambitiously, it is hoped to create a socially 'balanced' community, through a fair cross-section of different socio-economic groups being represented as residents in Jurong.

In this respect, the Corporation is taking steps to provide better-class housing, ranging from lower-executive flats, middle-class housing estates to luxury apartments in high-rise blocks.

The provision of better-class houses is an important contribution to the full development of a socially balanced community in Jurong. It is desirable that proprietors, directors, executives and other leading workers in Jurong industries and businesses should live in the Town and take part in its life. A contribution is needed from every type and class of person to make Jurong a community richer in its social, cultural and recreational outlook and for this reason plans are in hand to attract and retain the higher-income groups in Jurong.

The dwellings built in the first years in Jurong are all low-cost flats of minimum standard. However good they may be, if some better-class dwellings are not provided now, Jurong will risk the danger of being stamped as a 'one-class' town and it may be difficult to redress the balance later.

NATIONAL ROLE OF OPEN SPACE, PARK LANDS AND RECREATIONAL AREAS IN JURONG TOWN

The development of the 50-acre Bird Park, the 700-acre Jurong Park, and other similar projects in Jurong, will not only provide amenities for the local residents in Jurong, but will also serve the whole population of Singapore, not to mention the attraction they will offer to tourists.

Although it may not be realised now, in the long run, open spaces like Jurong Park can and will play a very important role in helping to safeguard and maintain a good standard of mental health and hygiene in Singapore's population. As Singapore becomes more and more urbanised, more people have to live in high-rise flats. City living will become more crowded and the general mental health of the people may decline. While the rich and the middle class citizens can go abroad every now and then, this is not within the means of many a Singaporean for some time to come. It is therefore essential that sufficiently large tracts of rural-like open space or parkland should be reserved and developed, within easy reach of the average Singaporean. In this respect, the Jurong Park will no doubt be making a very important contribution.

As Singapore gets more urbanised and industrialised and because of its limited sea coast and waterfront lands, the seafront will be substantially requisitioned for port development and marine industries. Out of environmental considerations, seaside park reserves have been provided in Jurong at strategic locations to provide public access, recreational areas and "windows" to the sea, for the populace of Singapore in the future.

TRANSPORTATION AND JURONG

Among the deterrents for low-income workers to work or live in Jurong in the early stages of the Jurong Development is the lack of good public transport. However in 1969 six bus companies agreed to operate routes to Jurong after the worker and resident populations had increased sufficiently.

The present rapid growth of Jurong worker and resident populations clearly indicates not a reduction, but a positive increase in commuting traffic. The development of mass rapid transit facilities to and from the City Area should therefore be borne in mind in the long-term planning provisions for Jurong. Good road connection is already available. An expressway and major highways are now being planned as additional connections. During the interim period, frequent, economical and efficient bus services are probably the best solution.

CONCLUDING COMMENTS

In the physical planning of Jurong New Town, unique problems are faced. Clearly considerations of regional development patterns are basic requirements. During the next decade, the developments in Jurong will set off formidable centripetal forces. The early concern over achieving full occupancy of the First Residential Neighbourhood will probably give way to that of curbing landside urbanization pressure.

In spite of the several 'master plans' already prepared for Jurong, it is still difficult to adopt a 'final' plan, even at this stage, as development in Singapore is still in a state of flux, governed by a host of factors and considerations, many of which are still unknown. And although there is now available a firmer 'guide plan' than before, there is no doubt that the final shape of things to come in Jurong, at least for the parts yet to be developed, may yet be different from what is envisaged now. What is required now is therefore the development of predictive skills, so as to understand and anticipate the nature and requirements of the land users likely to settle in Jurong in the future.

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INDUSTRIAL DEVELOPMENT AND ENVIRONMENT IN SINGAPORE

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ABSTRACT

Rightly or wrongly, it has more or less been universally regarded as a natural order of things that industrial development, environmental pollution and disruption are inseparable cause and effect.

Without exception, Singapore, having launched its industrialisation programme out of necessity about a decade back, but not at all unaware of the inherent environmental problems that would arise from industrialisation, is confronted with the necessity to study the same problem.

This paper attempts to briefly examine the experiences that have been gathered from the industrial development during the past decade or so, and to touch upon some of the environmental issues which have or are going to become apparent.

INTRODUCTION

The aim of this paper is to relate to the delegates the experiences that have been gathered on the physical aspect of the industrial development in Singapore during the past decade or so, and also to touch upon some physical aspects of the human ecology in the industrially built environment in the Republic.

INDUSTRIAL DEVELOPMENT BEFORE 1960

To talk about industrialisation in Singapore, it would be convenient to differentiate it into 2 distinct periods, namely pre-1960 and post-1960.

Before 1960, except for some small factories, Singapore had hardly any industries of worthwhile scale to speak of, nor was there any conscientious or concerted efforts to industrialise the island. The national, or more appropriately, the island economy was then heavily dependent on the entrepot trade and also on the British military expenditure on the island, which at one stage, almost amounted to about 1/3 of the GDP.

During the pre-1960 period, the industrial sector was characterised by small manufacturing establishments, located mainly in the midst of population concentration or wherever cheap land was available. These industries grew spontaneously and sporadically as there was then no comprehensive planning for industrial areas. In fact, for that matter, there was no comprehensive planning of land uses for the whole island until 1955, when the first Master Plan for Singapore was completed. This Master Plan was approved in August 1958, and the first comprehensive planning legislation known as the Planning Ordinance was enacted only in 1959. Before then, in the absence of a proper development control, service industries were mainly attracted to the central area or along the fringes, and the manufacturing industries were often located in the outlying areas. Each type of these industrial activities created different environmental hazards and generated different problems of human ecology.

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The completion of the first Master Plan in 1955 was no doubt a "big leap forward" in the planning history of Singapore. It nevertheless and quite understandably, did no more than regularising and containing the development that had hitherto taken place, and preventing further execution of the *laisserfaire* types of development. The sum total effect of the approved Master Plan was that the existing industrial areas were, by virtue of the Plan, given proper and in some cases enlarged boundaries.

Since the location and the types of industries were not planned and rigidly controlled, the industrial activities often intruded into other land uses, creating environmental inbalances, which are often visually unpleasant and obstrusive. The industrial waste from these industries often created a consequential result of air, water and noise pollution. A good example is the Bukit Timah Canal, where the upstream water is usually clear but becomes murky and dirty after passing through some industries along the midstream.

Other problems also arise as time goes by. True to the classic pattern of urban growth experienced all over the world, and as Singapore became more urbanised, the suburban areas grew and extended outwards from the central core into the outlying areas. In many places, good-class housing estates were developed right alongside existing industries, the location of which should never have been allowed in the first place, had there been a comprehensive Master Plan earlier. As a result, it is not uncommon nowadays to find in Singapore good middle-class housing estates existing side-by-side with industries which often created nuisances by way of noise, smells, fumes, smokes, soots, etc. In fact, such examples are quite abound in Singapore. Because they were there before the housing estates, legal and economic considerations often compelled the authority to accept their *status quo.* The problem got serious, when obnoxious industries were involved and the population nearby was adversely affected.

In addition to the pollution problems, the sporadic structure of the industrial sector in the pre-1960 also created the problems of providing efficient industrial services and the adoption of properly planned waste disposal system.

The location of these industries also gave rise to undesirable home-workplace relationship. This is because their location, although often favoured the major roads which provided good accessibility, were seldom ideal. Employees working in these industries did not come from the population living in the surrounding areas, but usually from poorer areas quite some miles away.

Apart from the costly, time-consuming commuting and other problems, a new dimension of human ecological problem is also created as the physical environment in these areas is being transformed by new development. The situation presents a bad inter-relationship between man and his environment, because the surrounding community was not created to suit the industrial environment. Rather the existing industrial environment was, rightly or wrongly, already there to present a challenge to the newly moved-in residential community to adapt to this pre-existing environment now exerting influences on them.

The question now arises as to what would happen to this situation which is the legacy of the pre-1960 period.

Since human ecology is a rather relative science, and is studied to a large extent by the success or otherwise of man's adaptation to the environment he has created. I think the degree of adjustment and adaptation by the community to the spatial organisation of industrial development that can be achieved will vary from time to time depending on the stage of social and economic development, and degree of sophistication acquired by the community

In the case of Singapore, I think the human ecological problems resulting from the industries established during the pre-1960 period will become more apparent, acute and wanting for remedial actions. The reasons are many. In the initial stages, the relatively unsophisticated community, for many reasons, may find the existence of industries in or near their neighbourhood acceptable or tolerable. But as economic and social development advances in Singapore, and standard of living rises, new awareness of possible better environment resulting from better knowledge will come to life; new norms for living conditions will be established. The industries of the pre-1960 period in their neighbourhood will thus become more and more glaringly obtrusive and intolerable. Complaints and criticism on these industries will be increasingly voiced by the community. Happily, signs of this state of affairs are already apparent, as indicated by complaints in the articles and letters to the editors in the local newspapers.

Two remedial actions are possible, The first is to evict or to resite the industries. The second is to impose and rigidly enforce stringent remedial anti-pollution measures as a condition for the continued operation of the industries.

The first alternative would require drastic policy decision which could give rise to many possible economic and political consequences. The second is more practical but it would require certain stage of advancement in the economic development and technological know-how to be reached by the community, before meaningful and effective pressures can be put to bear on these industries. Happily again, I think Singapore is reaching that stage. This aspect will be elaborated in the later part of this paper.

POST-1960 INDUSTRIAL DEVELOPMENT

In the late 1950's, growing awareness that Singapore's labour force was increasing at a much faster pace than what the prospective expansion of the entrepot trade could cope with, gave rise to a national drive towards industrialisation, with the aim to create the maximum number of jobs required within the shortest possible time and to achieve the diversification of the national economy, also within the shortest possible time.

Quite timely with the national awareness of the need for comprehensive physical planning for the whole island, there was then also a concerted national effort to industrialise. The Master Plan prepared in 1955, therefore conveniently provided a timely and good general framework for the comprehensive planning of industrial estates in Singapore. Singapore is also very fortunate in that since the late 1950's, it had always been a planning and development-conscious state. Therefore, unlike the pre-1960 period, the post-1960 industrial development was implemented on a planned basis.

Apart from the existing industrial sites, which are the legacy of the pre-1960 period, there are essentially two forms of post-1960 industrial development, which create two distinct industrial environments and have generally different human ecological problems. The first form of industrial development of industrial estates are those planned and inplanted in the relatively remote or rural sectors of the island. The second are those planned and inplanted in or close to high-density housing estates on the fringe of the central area of Singapore.

The first type of post-1960 industrial estates are usually of big scale and covered a large tract of land, ranging from hundreds to thousands of acres. These estates are located in the relatively rural or undeveloped parts of Singapore to exploit the natural physical advantageous or the industrial potentials of the areas, and they are mainly meant for industries which require extensive land area, and which are comparatively pollution-prone. Jurong Town exemplifies this form to development. The site where the Jurong Town stands today was largely in State ownership, and has seafront with deep water which could be developed into a port or exploited to provide impetus to the growth of the marine or marine oriented industries.

The second form of post-1960 industrial development or industrial estate is oriented towards the labour resources and is therefore located within or close to high-density housing areas.

The industrial estates in Kallang Basin, Toa Payoh, Tiong Bahru, Redhill, etc. are examples of such industrial development. These estates are generally of much smaller scale than the first type located in the outlying areas. The industries located are generally clean and labour-intensive types, which require large number of relatively cheap and unskilled workers. Their close proximity to the high-density residential areas therefore facilitates easy recruitment of such workers from the potential pool of female and housewives in the area, who otherwise would not have worked in factories if they had to travel to factories elsewhere to do so.

PHYSICAL ASPECT OF HUMAN ECOLOGY IN THE LARGE-SCALE INDUSTRIAL ESTATES IN THE OUTLYING AREA

The large-scale industrial estates in the outlying areas created a completely new industrial environment unfamiliar to Singapore.

Both the workers and residents expected to work and live in these industrial towns and estates, whether they are originally from other parts of Singapore or from within the areas which are being transformed into industrial estates, are in fact, in the Singapore context, emigrants to a new world. One of the problem thus arises is the necessity to create congenial conditions in the new environment to facilitate the community to adjust and adapt itself to the new situation. The new industrial towns and estates therefore require careful planning and implementation, so as to re-orientate both the workers and residents to the new industrial environment, where they would spend all or a large portion of their time.

In the effort to do this, the Jurong Town for example is not planned to be used completely for industrial purposes, but with sufficient areas for residential development, which are provided in the form of neighbourhoods with adequate social amenities and recreational facilities, all within comfortable walking distances. Sports complex, open spaces, gardens and other facilities found in the older parts of Singapore are also introduced into Jurong Town to enable and help the new community to adjust and adapt to the new type of living in the new environment of a new industrial town.

Experiences in Jurong have shown that provision of adequate housing for workers is not only socially desirable, but is also essential in the successful development of a comprehensive industrial new town and implementation of an industrialisation programme. This is because lack of residential or associated facilities in or near the industrial estates would create labour shortage problem, at least initially, to the industries because of the time-consuming and costly commuting for the prospective workers, who could find jobs in or near the existing city core where they live. Housing also brings life to the industrial town and humanise the otherwise dull, industrialised environment. Possibly, another good thing about having housing in an industrial town is that its presence would make the Government, the responsible authorities, and also the public more conscious of keeping the industrial town clean and healthy for its workers and residents, and thus ensure greater effort on their part to take greater anti-pollution measures in the town.

Experiences in Jurong also show that provision of housing alone in the newly developed industrial towns will not be enough to attract resident workers. Apart from being put off by a new strange environment; the lack of entertainment, social amenities, insufficient range of shopping facilities, and the difficulty in travelling between Jurong and the existing urban core, etc. would deter many a prospective worker or resident from working or living in the new town. The provision of adequate and good-quality social amenities and recreational facilities will not only attract residents to the new town, but will also serve the whole population in Singapore, not to mention the attraction they might offer to tourist. In the long-run also, as Singapore become more industrialised and urbanised, and as more and more land are being used up and transformed by new development, social amenities, open spaces and recreational facilities provided in new industrial towns like Jurong, will play an important role in helping to safeguard and maintain good standard of mental health and hygiene of the workers and residents, as well as that of the population on other parts of the island.

POLLUTION AND ITS CONTROL PROBLEM IN SINGAPORE

In retrospect, it would not be untrue to say that in the initial stage of industrialisation in Singapore, more concern was focussed on the importance of creating new jobs and improving employment opportunity than on the inherent pollution problems that would come in the wake of industrialisation. This is, however, only understandable if the fear for unemployment, poverty and starvation which could lead to social and political unrest, was overshadowing the concern of the lesser evil of industrial pollution, which after all a community could learn to live with and combat, if they want to, at a later stage.

However, it would be untrue to say that while the creation of employment was upper most in our mind in those days, the pollution hazards of industrialisation were completely put aside and neglected. Among other things, means available by way of physical planning and development control to combat and minimise such possible industrial pollution were exploited to the full. For example, in the small industrial estates near the residential areas in town, only clean industries which do not create nuisance by way of noise, smells, soots, smoke, fumes, etc. were allowed.

In the outlying area like Jurong, attempts were made by way of zoning to separate each types of industries, generally the cleaner ones closer to residential areas and the dirtier ones farthest away.

Difficulties were of course encountered in the earlier stages of implementation. One of these difficulties was that because it was not possible to develop large tract of industrial land for the various types of industries all at once, or at a fast enough rate to enable each type of industries to be allocated in the appropriately designated area, limited availability of prepared lots to satisfy applicants at any one time and promotional considerations often become more important siting criteria than the general zoning. On certain occasions, because of the fear of losing potential capital investment and the jobs which could be created, threat, genuine or otherwise, from some prospective investors to go to other countries if they were not given the particular site of their own choice, succeeded in some pollution-wise undesirable industries being put up in areas where they should never have been allowed in the first place.

Other difficulties were also encountered in the attempts to prevent and minimise possible pollution from incoming industries. For example, at the very beginning, safeguarding clauses were included in the lease agreements and other legal documents, drafted and issued by the Economic Development Board as landlord, but these clauses were very general, weak and practically not enforceable. This is so, because it is all very well and easy to include a general clause to say that lessee should prevent any type of pollution from their factories but it is not so easy to define what constitutes pollution, how it is to be measured, to which limit they can be tolerated, and what penalties will be imposed in case of failure of compliance. In those early years, no definition was spelled out, no standard, rules and regulations were laid down upon which enforcing actions could be effectively taken.

This situation was not due to lack of foresight or willingness to impose restriction by the authorities concerned. Nor was it because of any unduly excessive fear that if too strict anti-pollution controls were exercised and requirements imposed at that early and crucial stage of industrialisation, prospective investors would be discouraged to come to Singapore.

An honest retrospective analysis would probably give the verdict that the lack of proper anti-pollution legislation and other legal means of control were, among other things mainly due to the lack of expertise, technological know-how and experiences of the matter in those early years.

As mentioned earlier, industrialisation in Singapore was actually only started in the early 1960's. Knowledges of industries, their manufacturing processes and by-products and all the other thousand and one things that are connected with them were quite lacking and simply wanting, let alone the technical know-how of controlling pollution resulting from these industries. It would be quite honestly impossible and unrealistic then to attempt drafting elaborate anti-pollution legislations and setting up a complicated back-up machinery of enforcement. In fact, few could predict with certainty as to what types of industries that would come to Singapore, if at all. There were even skeptics who greatly doubted the wisdom of industrialisation in Singapore, which they were quite convinced was an impossibility. This was clearly indicated by the fact that at the very beginning, Jurong was labelled as "Goh's folly" because it was mainly the brainchild of the then Finance Minister Dr. Goh Keng Swee.

For many years, controls, effective or otherwise, rested only with the existing Health Authorities and the Planning Department and a few other bodies, which were not quite adequately equipped and empowered to deal with the new industrial situation.

For many years, black smoke belched from factory chimneys, soots thrown into the air and sometimes settled on to nearby housing estates, fumes emitted from industrial machinery and vehicles, unsightly and sometimes harmful liquid waste were discharged into the open drains, river and sea, etc.

There were some reputable industrial firms which voluntarily attempted to prevent and minimise pollution from their factories and even installed expensive anti-pollution gadgets and devices on their own accord, but it would not be surprising if there were a few unscrupulous industrialists who were laughing in private at the helplessness of the authorities to take action on them in those initial years.

The Government and the various relevant Authorities were fully aware and conscious of the situation. Although keen and eager to do something about the situation, they were not really in a position to put remedial and preventive measures into immediate action. Time was required to evaluate comprehensively the overall situation, both on short-term and long-term basis; to study and adopt acceptable standards; to check and design the capacity of existing and future sewerage system to take on the extra load from the industrial liquid waste; to draft effective, meaningful, loop-hole free and yet realistic legislations; to assess the economic and other possible implication to both the public and the private investors when such legislations are put into force, etc.

Fortunately, the time taken was not too long. In keeping with the Government's policy to make Singapore into a healthy, clean, green and visually pleasing garden city, the constant pursuit of this objective by the Government with the support of the people has resulted, among other things, in the establishment of an anti-pollution unit in the Prime Minister's Office in 1970, with responsibility for formulating policies, drafting legislation and enforcement relating to pollution. This was the result of an intensive scheme to train local personnel to gather and acquire the necessary technological and legislative know-how and expertise in this particular field.

While many advanced nations can take pride in the fact that their countries were industrialised long before many others, including Singapore, were known to exist, Singapore can perhaps take consolation and be thankful for the blessing in disguise in that being the late comer, we are accorded the opportunity, which the advanced countries did not have, to observe and take lesson from the mistakes and sometimes disastrous aftermath of indiscrimate industrialisation in some of the advanced countries.

Singapore is also fortunately blessed with favourable geographical and meteorological conditions. Sited near the Equator, she is globally in the path of alternating trade winds. During the monsoon period near the end of the year, a strong prevailing wind blows from the north-east direction, and during the other monsoon period, a strong wind blows prevailingly from the south-west. Because physically Singapore is small and it is surrounded by sea in the tropics, localised air movement between land and sea and vice versa is also considerable. Although there are not many hills and mountains in Singapore and therefore not much orographical effects of wind movement, the sum total of the movement of air masses over Singapore is comparatively favourable in helping to cleanse and change the air over Singapore. There is less danger of air inversion problem as experienced in places like Los Angeles. Singapore also does not experience climatic conditions whereby poisonous or toxic gases and fumes could gather and settle especially at night in low-lying areas such as valleys, where they could be harmful and even fatal to human beings.

The climatic and soil conditions in Singapore also permit lushy and easy growth of plants and vegetation all year round. Trees, shrubs and flowers can be exploited to the full to soften the hardness and harshness of industrial estates; to add colour to the otherwise dull and lifeless factory setting; to help purify the area around the industries and to provide both visual and physical buffers for ugly sights and irritating sounds.

All these favourable geographical and meteorological conditions do not however mean that Singapore has far less problem to face than other countries. The threat from industrial pollution is just as real and as big as anywhere else. Over-polluted air could kill trees and shrubs, as can be seen from some young trees planted near the road, because of the excessive exhaust gas from the vehicles. If there were no proper control on the discharge and drainage of industrial liquid waste, immense volume of run-off from rainfall could magnify the dimensions of the pollution problem instead of helping it. To a great extent, the geographical and meteorological conditions are not necessarily the basic tool to prevent and cure all pollution ills, but can be exploited as advantages to enhance the industrial environment, provided the environment is also appropriately controlled and safeguarded by legislations and technological means.

PHILOSOPHY AND POLICY OF INDUSTRIALISATION AND THE CONSEQUENTIAL EFFECTS ON ENVIRONMENT

Physical planners are obliged to accept without question that the quality of life is not simply a thing of the mind but is partly created by the physical environment. The quality of the physical environment, however, depends to very large extent on the attitude, philosophy, and thus, in practical and non-abstract terms, the policy adopted by the community to control and shape the environment they live in.

Philosophy and mental attitudes are, to my mind, very much a thing of the mind, upon which policies and legislation are founded. It would, therefore, appear that to cultivate and adopt a correct state of mind, is most important to ensure the creation of a good physical environment. To put in non-abstract term and apply it in Singapore, it would mean that what sort of industrial environment Singapore would have in the future would depend on what is in the mind of the present generation of Singaporeans regarding such things as the types of industries to be allowed into Singapore now and in the future; the physical form of the industrial towns and estates to be planned and developed; the social and recreational facilities; open spaces and other non-industrial facilities to be provided in the new industrial towns and estates, etc.

One very important issue to deliberate at this stage of industrialisation in Singapore is the question of what types of industries should be allowed to come in now, as against the types of industries that Singapore should ultimately have, in terms of not only economic and technological advancements but also of social costs. This is so, partly because the physical land area in Singapore is very small to cater for the very many intensive and diversified types of land uses. Because of the intensity and close proximity of the various types of development; the types of industries to be established in Singapore would, therefore, have great consequential effects on the overall future environment.

It is now very clear that the types of industries best suited for Singapore are those clean, high-skill, high-pay, science and technology-based industries which are export-oriented to serve or supply the world market on a competitive basis.

Unfortunately, in deciding what types of industries should be allowed to come in at any one time, consideration has to be given to the economic position of the community at that time. Consideration also has to be given to the timing and opportunity factors. Singapore may desire to admit only capital-intensive, clean and high-skill industries ultimately, but these industries, due to a host of reasons, may not be willing or ready to come to Singapore for some time. Meanwhile, because of certain conditions in the advanced countries, such as production costs, labour and pollution problems etc, the environmentally not so desirable industries, such as steel and petrochemical complexes, oil refineries, etc, may be interested to come to Singapore now. Singapore could then be faced with the problem to decide whether these economically acceptable but environmentally undesirable industries are to be admitted, or to be rejected in preference to the cleaner industries, which are hopefully yet to come; and deciding at the same time whether the present economic position of the country can afford the second alternative to be adopted. The choice or decision would be difficult.

The steel and aluminium complex and other similar capital-intensive industries are very economically attractive indeed. Their large fixed investment totalling hundreds or even thousands of dollars; their direct and immediate impact on our economy in terms of employment of skill workers, revenue, foreign exchange gains etc; the attractiveness of having local and independent availability of raw materials, such as steel at internationally competitive prices to strengthen and upgrade our existing established ship-building, metal fabrication and other engineering industries etc. are all very relevant considerations and tempting opportunities at that. It would not be easy to resist such immediate opportunities in preference for something less certain in the future, When such difficult occasion arises, it could be made easier to certain extent, if Singapore has plenty of land spreading far and wide, in which case, physical planning could locate these economically attractive but environmentally undesirable industries in the relatively remote areas out of harm's way, and reserve industrial land close to the residential/commercial areas for cleaner industries, so as not to endanger the future environment. Unfortunately, land scarcity in Singapore has given rise to the situation, whereby the limited industrial land have to be either committed now to the less preferred industries or to be left vacant and safeguarded for those desired cleaner industries yet to come in the hopefully not so far future. If economic consideration override all others, the establishment of any environmentally undesirable types of industries is likely to have regrettable and even adverse effects on the future environmental well-being of the whole island, unless very strict and expensive anti-pollution measures are taken.

As mentioned earlier, the other very important factor which would influence and may in fact decide the quality of the future environment in Singapore, would be the attitude of the people towards the degree of rigid control and religious enforcement on pollution; their attitude towards the importance of social development on one end of the scale as against economic development on the other; their attitude towards the provision of the seemingly unnecessary social amenities, open spaces, green areas and other non-industrial facilities in the new industrial towns and estates, etc.

As an example or as a case for reflection, I, would now like to cite Japan. The marvellous success of the post-war economic development in Japan is by now a well-known and world-renown story, but it is perhaps also better known too that their great economic advancement was achieved at a considerable expense of their social development and environmental well-being. The reasons for this are of course many, and need not be elaborated here. But I think one of the major reasons is the attitude adopted by the Japanese towards the relative importance of the high rate of economic growth as against the penalty of environmental pollution and disruption. I had on one occasion, the opportunity in Tokyo to meet one of the top Japanese economist, who has played a very important role in the recovery of the post-war Japanese economy. When talking about economic development and pollutions, he quite decisively stated that no country should worry about pollution and its control until she has reached the per capital income of US$1,000. I gathered his statement or conviction was based on the belief that it would be far better for a country to become economically strong and wealthy first. Once she has reached that stage, she would or could be in the position to rectify or eliminate all pollution ills.

As a physical planner, I find it difficult to accept his thinking. In theory, it sounds workable put in practice, it may be a different story altogether. Whether rectification can be effected or not, a time factor, among other things, is involved. It may take a long time to reach the stated US$1,000 income level. Meanwhile, the community would suffer and the polluted environment may degenerate to an irreversible position. To my mind, environmental well-being must be upper-most in our mind, safeguarded and improved at all times, irrespective of the GNP level of the country.

I had also the opportunity to meet some of the top scientists from Tokyo University and other research institutes. When asked to comment on the pollution problem of their country, all said that they were not unduly worried, because they believed that in due course and when required, science and technology could be developed and used to improve or eradicate such problem. Other Japanese planners I met, including physical planners, also gave me the same impression of their attitude, i.e. they are all GNP oriented. One Japanese physical planner I met, even seemed to relate every aspect of physical planning to GNP.

This "GNP above all else" attitude, is in my mind, to no small extent, a contributory cause for the environmental problem in Japan. The Japanese themselves are now starting to realise it, as evidenced by the contents in their newspapers.

I think, we in Singapore, just as we are wary of the hippist culture in our youth development, should also be just as wary of the GNPist culture in our national development. Industrialisation should be a means to an end and not an end itself. We in Singapore can take a good lesson from the experiences in the already advanced countries in that success of economic development must not be judged by the growth rate of GNP alone, but also by the improvement of the quality of life and its environment. In this respect, efforts have been made towards that end in the industrial development in Singapore. Our roads in the industrial towns and estates are not just given enough width to accommodate carriageways and road-side drains, but are generally wide for planting of trees, shrubs, flowers, turfed median strips and side-tables. Quite commonly, the width of the main road and other minor road in Jurong are in excess of the normal road reserve requirements. Not all hills are cut and every square inch of land rented out for industrial purposes. Large tract of open land in Jurong [illegible] provided as open spaces, land-scape gardens, [illegible]eational areas, of which the 700 acre Jurong P[illegible] with a full range of social and recreational facilities is the main example, Even a Bird Park of 50 acres in area is incorporated in the Jurong development. Suitable hills at strategic locations are reserved and developed into additional open spaces and elevated lookout points. These hills are also to serve as relief for the otherwise flat and monotonous landscape. Together with the numerous smaller scale roadside gardens and parks scattered at the various parts of the industrial town, and in addition to the trees planted within the road reserve, trees of all species are planted both inside and outside the individual factory premises to soften and add colour to the otherwise harsh industrial scene. Factory owners are partly persuaded and partly compelled to beautify their premises with planting of shrubs and flowers. Strips of seafront land are reserved at strategic and scenic locations for development into seaside park la[illegible] to serve as public access or "window" to the sea.

It is being ensured that when the present intensive efforts in industrialisation and urbanisation in Singapore has brought the nation to an economically and technologically advanced stage, an average Singaporean, whenever he wants to, and without having to travel hundreds of miles to other countries, can still be able to find a tract of sizeable open land to experience the peace and quiet of open space, away from the maddening traffic and crowded buildings; or to climb a hill just to feel the wind in his face; or to stand on a strip of seafront land to reflect on the vastness of the sea and to taste the salty sea air in his face. Only when that is possible; only when we have achieved the so-called advanced status of national development and still not cut off completely from nature; only when the quality of life is improved and enhanced by industrial development and not degenerated by it; can we then claim success in our endeavours to advance our society; only then can we claim that all our efforts in the past decade and the years to come have not been made in vain. And in the process, we hope that we would have made a contribution to the world by way of our experience to be studied as an experiment if not a model by others.

Paper No. III/6

THE CHANGING CHARACTERISTICS OF SOLID WASTE IN SINGAPORE

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ABSTRACT

A refuse analysis was carried out in December 1971. The results are compared with similar analyses carried out in 1963, 1967 and 1970. Significant trends are seen in certain constituents and the factors responsible for influencing the changes are dealt with under each separate classification. The effects of some of these constituents, including paper and plastics, on the present and future methods of disposal are also indicated.

Refuse sampling was carried out recently (December 1971) in Singapore and the sampling areas included a Chinatown shopping area, a mixed shopping area, a private housing estate, an HDB estate of high-rise flats, a commercial area and a complex of multi-storeyed, flatted factories. These same areas formed the basis of previous analyses in 1967 and 1970. A much earlier exercise in 1963, although not carried out in the same areas, was also representative of a fair cross-section of the refuse producing areas in the Island and provides useful information for comparison with the more recent analyses.

Table 1 is a summary of the refuse analyses carried out in 1963, 1967, 1970 and 1971. The analysis in each case is the average for five years.

CHANGING CHARACTERISTICS

The total inorganic material shows a decrease over the years in spite of the gradual rise in the scrap metal (Item I 1). The decrease is mainly due to the fall in dust and sand sweepings (Item I 5), which may be attributed to a refinement in the method adopted in separating the sweepings from the rest of the sample rather than to any particular trend. The proportion of metal in refuse is likely to continue growing as this is associated with increasing demand and higher living standards. Glassware is tending to decrease as it loses out in the competition with metals and plastics.

There appears to be no significant trend in the total organic content although changes can be discerned in some of the individual components. The proportion of fruit and vegetable wastes (Item II 1) at 4.87% has declined significantly since 1963 when it was 14.5% and, together with the the increase in ferrous metal scrap, could possibly reflect an increase in the use of packaged (e.g. canned) foods at the expense of a decline in purchases from street market stalls. The falling trend in betel palm-leaf wrappings (Item II 6) from 1.09% in 1963 to 0.93% in 1967, 0.52% in 1970 and 0.3% in 1971 and in straw packings, feathers, etc. (Item II 5) from 7.77% in 1963 to 2.93% in 1967, 1.24% in 1970 and 2.77% in 1971 could be attributed to the greater use of plastic bags and plastic packing material respectively, while the greater quantities of discarded clothing in recent analyses, (Item II 8), 4.77% in 1967, 9.27% in 1970 and 7.78% in 1971 as compared with 3.23% in 1963 would be expected to accompany a rise in living standards. Garden refuse such as leaves, stumps, etc. 5.85% has begun to show a rise in recent years, from 2.92% in 1967 and 3.55% in 1970, reflecting the upsurge in tree-planting, gardening and development of parks in Singapore. The paper and cardboard content of 51.4%

TYPE OF REFUSE	Composition Weight Percent			
	Analysis June 1963	**Analysis November 1967**	**Analysis November 1970**	**Analysis November 1971**
I *INORGANIC MATTER*				
1. Ferrous metals: scrap iron, wire, tins and containers	1.37%	2.33%	2.84%	2.92%
2. Non-ferrous metals: copper alloys & aluminium scraps	Nil	0.02%	0.18%	0.42%
3. Glass: bottles and glass	1.02%	1.57%	1.29%	0.67%
4. Ceramic wares	0.73%	1.24%	0.50%	1.26%
5. Sweepings: dust, sand	13.00%	7.65%	6.43%	3.43%
Total Inorganic Matter:	16.12%	12.81%	11.24%	8.70%
II *ORGANIC MATTER*				
1. Fruit skins and vegetable scraps	14.59%	4.06%	3.25%	4.87%
2. Bread, rice & other waste food	0.43%	0.62%	1.33%	0.22%
3. Banana stalk, leaves, stumps	7.60%	2.92%	3.55%	5.85%
4. Coconut refuse (kernel & husks)	1.33%	0.85%	1.75%	0.23%
5. Wet straw packings, mats, feather, etc.	7.77%	2.93%	1.24%	2.77%
6. Betel palm-leaf wrappings	1.09%	0.93%	0.52%	0.03%
7. Paper (wrappings, newspaper, cardboard, etc.)	29.62%	53.63%	43.13%	51.47%
8. Old rags, bandages, old clothes	3.23%	4.77%	9.27%	7.78%
9. Miscellaneous (fine unsortable materials other than stones)	13.93%	9.45%	13.74%	7.32%
Total Organic Matter:	79.59%	80.16%	77.78%	80.54%
III *OTHER MATERIALS*				
1. Wood shaving, chips & bamboos	1.04%	1.85%	2.15%	2.30%
2. Old rubber articles & rubber strips	0.4[illegible]%	1.42%	0.61%	0.72%
3. Plastic materials, polythene and nylon	0.79%	2.48%	5.69%	7.19%
4. Old leather strips & shoes	0.98%	0.66%	0.78%	Nil
5. Shells, small stones, bones	1.06%	0.62%	1.75%	0.55%
Total Other Materials	4.29%	7.03%	10.98%	10.76%
Density (wt per cu ft in lbs)	8.8	7.95	10.95	11.14
Moisture (loss at 105°C)	54.35	–	44.5	37.20
Calorific Value (B T U /lb., on the dried sample)	–	–	3,730	7,283

Table 1. Analysis of Refuse in Singapore

in 1971 is much higher than the 29.62% in 1963, but in the last few years there had been no significant variation, which may be due to alternative materials (e.g. plastics) available. However, at around 50% of the total refuse it emphasizes a high weight and is responsible for great storage problems at premises, transport problems to tip, while representing a high volume of potential salvage.

The third category of materials shows the most significant growing trend due primarily to the noticeable increase in plastics and wood wastes. Plastics have been steadily rising from a comparatively insignificant 0.79% in 1963 to 2.48% in 1967, 5.69% in 1970 and now to an all-time high 7.19% which is an almost ten-fold increase in less than 10 years. Woodwastes have more than doubled in this period. From 1.04% in 1963 to 2.30% in 1971. These increases reflect the extensive use of plastics in the field of manufacture, as well as packaging and an expanding woodmill industry. Problems of storage, collection, transport and disposal follow in their wake.

Graphical representation of ferrous metal, paper and plastics content for period 1963-71 is given in Figure 1.

The density of refuse has gone up in the two more recent analyses which would be expected with the rise in scrap metal, woodwaste and garden refuse, although the increase in discarded plastics and plastic goods and other light-weight materials would tend to keep the overall density down. However, the density of mixed refuse is influenced by the prevailing weather to the extent that the sampled refuse is lighter or heavier according to its dryness or wetness.

The calorific value (c.v.) in the 1971 analysis is uncommonly high and may be ascribed to the fact that the standard laboratory method used to obtain the c.v. was not applicable to refuse. Laboratory work for c.v. of refuse was determined by bomb calorimeter after first shredding the refuse sample to a small size. The apparent error was due to the practical difficulties experienced in obtaining a small representative sample for the experimental determination of c.v. from a very large initial volume.

1980 FORECAST

The long-term and ultimate solution to the growing refuse problem and the depleting landfill areas in Singapore is to incinerate the bulk of its solid wastes through a system of central incineration, leaving only non-combustibles and ash residue to be tipped into the remaining small parcels of swampland. With this objective in mind, the Government engaged a firm of consultants to carry out feasibility studies and make recommendations on plant design and capacity for a long-term solution. The consultants considered it important that substantial operating margins should be allowed for in the plant design to prevent future changes having serious effect on the burning ability of the incinerator units. A projected refuse analysis was, therefore, prepared by the consultants so that the plant design and rating would enable it to deal with both present day refuse and the type of refuse anticipated in future.

The consultants based their projection on the 1963, 1967 and 1970 analyses. They did not have the benefit of the 1971 analysis. Table 2 gives their forecast for 1980.

The rising trend in the use of cans is likely to continue with the improvement in the standard of living. Bottles may increasingly be made from plastics.

The proportion of fruit skins and vegetable scraps will continue to decrease although the popularity of market purchases with a large sector of the middle and lower-income population, who will find fresh market produce cheaper than their canned counterparts, who will tend to steady this constituent. A generally better standard of living might continue to see more discarded clothing, The falling trend can be expected to continue in straw packing, feathers and betel palm-leaf wrappings as these give way more and more to plastics. Little change is anticipated in the paper and cardboard content.

In parallel with what is happening elsewhere, it can be expected that there will be an increase in the proportion of plastics, due to the greater use of plastic bottles and containers, plastic wrappers, foamed plastic materials etc., with corresponding decrease in the proportion of carboard cartons. Woodwaste will continue to grow, reflecting the local demand for timber products and the export market in timber.

In the case of calorific value, the consultants used an arithmetical means of considering each independent constituent, making due allowance for moisture content, in arriving at the 1980 figure of 3,930 BTU per lb, which is comparable with c.v's of mixed refuse in many other tropical countries.

EFFECTS OF CONSTITUENTS ON DISPOSAL

Present Disposal

The present method of refuse disposal in Singapore is a form of controlled tipping where the crude refuse is dumped into swamps, levelled and consolidated by bulldozers in heights of about 20 feet, and then covered over with a layer of earth at the end of each day's operations.

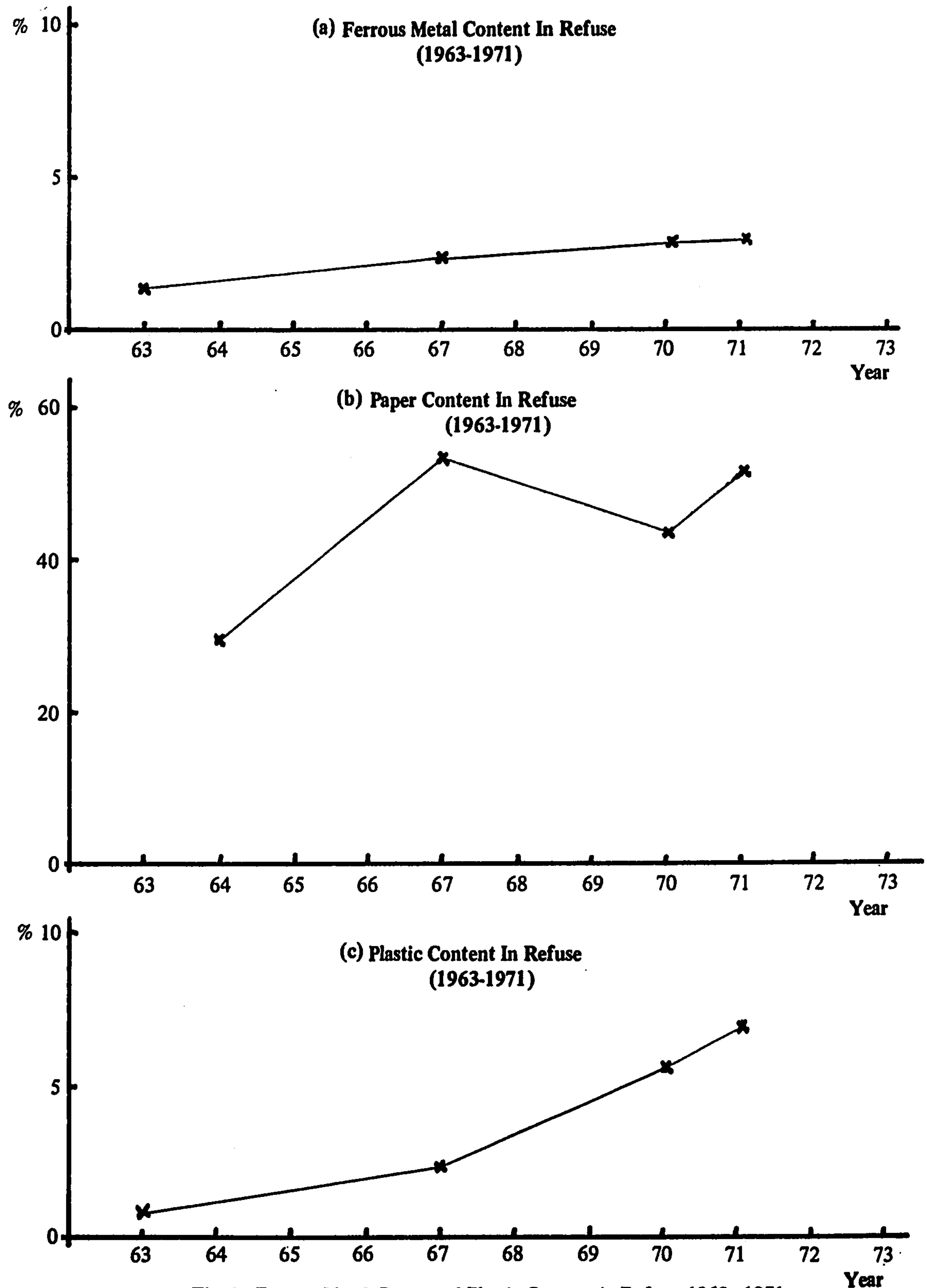

Fig. 1. Ferrous Metal, Paper and Plastic Content in Refuse, 1963–1971

TYPE OF REFUSE	Composition Weight Percent
I *INORGANIC MATTER*	
1. Ferrous metals: scrap iron, wire, tins and containers	3.1%
2. Non-ferrous metals: copper alloys and aluminium scraps	0.25%
3. Glass: bottles and glass	1.15%
4. Ceramic wares	0.6%
5. Sweepings: dust, sand	4.7%
Total Inorganic Matter:	9.8%
II *ORGANIC MATTER*	
1. Fruit skins and vegetable scraps	2.7%
2. Bread, rice and other waste food	1.9%
3. Banana stalk, leaves, stumps	3.0%
4. Coconut refuse (kernel & husks)	1.0%
5. Wet straw packings, mats, feathers, etc.	0.9%
6. Betel palm-leaf wrappings	0.3%
7. Paper (wrappings, newspaper, cardboard, etc.)	46.1%
8. Old rags, bandages, old clothes	10.45%
9. Miscellaneous (fine unsortable materials other than stones)	11.1%
Total Organic Matter:	77.5%
III *OTHER MATERIALS*	
1. Wood shaving, chips and bamboos	2.4%
2. Old rubber articles and rubber strips	0.65%
3. Plastic materials, polythene & nylon	7.30%
4. Old leather strips and shoes	0.95%
5. Shell, small stones, bones	1.40%
Total of Other Materials:	12.7%
Density (wt per cu ft in lbs)	9.5
Moisture (loss at 105°C)	45.0
Calorific Value (B T U /lb on the dried sample)	3,930

Table 2. 1980 Forecast of Refuse Characteristics

Under the first category of inorganic constituents, glass bottles and ceramic ware, which together constitute about 2% of the total load, are well suited to disposal by tipping. Even if unbroken, they have a high natural density and are completely inert. Their disadvantage is that in the mixed refuse that arrives at the tip, bottles are invariably present on the tip surface where they present a hazard to vehicle tyres.

Metal cans are also easily compacted by the action of a bulldozer, especially within the top few feet of the tip surface. However, their degradability by oxidation can vary from months to years.

Of the organic constituents in the second category, paper as a landfill material is easily compacted and will eventually break down due to biological and chemical action. However, it has disadvantages in that paper tends to be blown about over the tip area by wind, is not high in density even when compacted, is readily combustible, is known to have caused outbreaks of fire on the tip surface and it contributes to water pollution in the tidal estuaries.

The most difficult refuse constituent to deal with in landfill is plastics in their many forms. Apart from the proneness of thin plastic wrappers and bags to scattering by wind over a wide area, all types of plastics resist chemical and biological degrading to a high degree.

Future Disposal

In an incineration plant, the bottles will be affected only to the extent that if the furnace temperature is sufficiently high (about 2,000°F), the glass will liquefy and fuse with the ash or clinker from other materials in the refuse. At lower temperatures, the bottles will be shattered and appear in the furnace residue. Most incinerators have magnetic separators to recover metal either before or after burning. The advantage of incinerating first is that contaminants such as waste food are removed.

Paper and paper products will most effectively be disposed by incineration since they have a high c.v. and are readily combustible. Their heat value will be an aid to burning of the other less combustible materials.

Plastics which include polyethylene, polystyrene and polyvinyl chloride (P V C) incinerate easily, but fears have been expressed in some quarters of the effects of P V C on the metallic parts due to hydrochloric acid (HCl) released at low temperatures, of the possibility of melting plastics clogging fire bars and of dangerous air pollution through the release of hydrochloric acid (HCl) to atmosphere. However, there is no direct or conclusive evidence at present that in well-designed and operated refuse incinerators, hazards of air pollution or corrosion problems are caused by the burning of P V C in the proportion found in mixed domestic and commercial wastes. In fact, tests carried out in 1971 in New York have indicated that incinerator grates and furnaces of conventional municipal types will perform satisfactorily on normal refuse containing up to 6% or more of plastics. In the tests conducted there, was no evidence of plastics melting and dripping through the grates or causing abnormal clogging of grates openings, and by the use of gas scrubbers, fly ash and noxious acid gases were removed from the flue gas at high efficiency. Professor E.R. Kaiser of New York University, who conducted these studies has recently reiterated this conclusion and has gone on to state in his opinion, there would be no deleterious effect upon the operation of the incinerator even with the plastic content as high as 10% if well-mixed with other refuse.

CONCLUSION

As a conclusion to this paper, it must be pointed out that of the main constituents discussed, ferrous metal has a good and growing salvage potential, particularly where magnetic separation is to be employed in incineration plants. Glass, on the other hand, has no salvage value, but will form good inert material in the ash residue of an incineration plant.

The high proportion of paper and cardboard content makes salvage an attractive prospect except that on a tip this is impractical with the exception of a small proportion of the larger cardboard cartons. A better recovery rate may be achieved if appeals are made to the public to keep paper and cardboard separate from other refuse, and salvage compartments are available in refuse collection vehicles. As an effective means of volume reduction, incineration is undoubtedly the treatment for unsalvageable paper and cardboards as indeed it is for all other organic wastes.

Plastics recovery from mixed refuse is impracticable, so that plastics will continue to pose problems in both controlled tipping and incineration. Increased attention must, therefore, be given to improving the technology of plastics disposal or to changing the physical and chemical characteristics of plastics in order to reduce the problems they present at the disposal works.

A very high proportion of materials which might be salvaged is irrecoverable because it is mixed with other refuse, so that in the face of the growing refuse disposal loads, it would seem necessary to develop separation and recycling techniques that provide economic reuse of many salvageable materials.

ACKNOWLEDGEMENT

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Paper No. III/7

THE CONTROL OF THE LITTER PROBLEM IN SINGAPORE

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ABSTRACT

The multiple factors comprising high population density, humid climate and rapid urbanisation and industrialisation of Singapore have contributed to a pollution problem which includes among other things, the litter problem.

This litter problem is an acute and sensitive one and the task of solving this problem is enormous. This problem is being tackled through mass education and strict enforcement. The 'war' against litterbugs is a long and relentless one. With closer public cooperation and stricter enforcement. Singapore is now way ahead towards its goal of a cleaner and healthier environment.

The task of keeping Singapore clean has always been a gigantic and critical one. The uncontrolled pollution of Singapore would soon produce conditions that would be unsuitable for human habitation.

Many factors prevailing in Singapore magnify and make more acute the problem of pollution. Singapore's small area of 224 square miles and her population of slightly over two million people combine to give an extremely high concentration of people - about 8,000 people per square mile. In certain urban areas, this rises to some 25,000 people per square mile making it the most congested area in the world today.

The rapid urbanization and industrialisation of Singapore has also contributed greatly to the pollution problem. Further, the humid climatic condition encourages the rapid decomposition of refuse and the rapid breeding of disease bearing insects.

For these and various other reasons, strict measures against pollution must be and are being taken in Singapore.

Litter contributes one facet to this problem - that of solid waste pollution. It is the most expensive form of solid waste refuse to be removed for it involves the sweeping of roads, drains and the subsequent collection and removal of the litter for disposal. This brings the cost of litter removal to four times that the cost of domestic refuse removal. To economise, therefore, and to have maximum utilization of the resources available, littering should be stopped or minimized.

To achieve the goal of a litter free environment, both massive governmental efforts and public cooperation are essential. Without widespread public support, governmental efforts would prove futile and costly.

Public cooperation in litter control has to be solicited and developed. The public should have or should develop a sense of social responsibility and disciplines. Once the correct attitudes and habits in relation to cleanliness are inculcated, these self restraints would reduce the litter problem to a minimal.

The development of the public's civic consciousness was done in two stages - the first stage through education followed by the second, through deterrent action.

In the first stage efforts were directed towards obtaining public education. A massive month long nation-wide campaign to keep Singapore clean was launched in October 1968. In this campaign, both the public and private sectors were actively involved. All governmental and quasi governmental institutions participated as the ultimate objective was to motivate and stimulate the public's desire for a cleaner environment.

The school population of about a quarter million children were the prime target in this campaign. They are our future adult population and at this malleable age, there is a greater chance of the message filtering through to them.

Cleanliness competitions, essay competitions, poster design and slogan contests were organised. Lectures and demonstrations were given by doctors, health inspectors, principals and teachers.

The public was not neglected by the campaign. They were motivated through politicians, community and religious leaders. Inspection tours, mass rallies, film shows and other functions were organised to highlight the dangers of indiscriminate littering. Emphasis was placed on good housekeeping practices and cleanliness competitions organised by various bodies resulted in the sprucing up and 'spring cleaning' of offices, factories, and homes. Wide publicity to the campaign was given through posters, pamphlets, stamps, feature films and exhibitions. The newspapers, radio, television and even the cinema halls took up the campaign. The public was flooded daily with news of the campaign. Candid shots of dirty premises and litter bugs were taken and shown to the public.

This month long campaign in educating the public was a success. Its effectiveness was reflected in cleaner roads and highways; drains and water courses; parks and other scenic spots.

Such month long campaigns were organised, along the same lines, annually from 1968.

Although, all these annual campaigns were given different slants, the basic essential theme of keeping Singapore clean was maintained throughout.

Mainly through these campaigns public acceptance and cooperation for achieving and maintaining a high standard of cleanliness, was obtained. However, as anticipated, a few 'diehards' persisted. Despite all attempts of persuasion, this minority group failed to respond. Thus with them in mind, the second phase of education through deterrent action was put into gear.

In August 1968, legislation was passed to equip the Ministry of Health adequately in its battle against these litter bugs. This was the Environmental Public Health Act which embodies within its scope a more modern and realistic approach to the problem of environmental control in Singapore.

The Act in its fourteen parts covers all fields of environmental health. In particular, Part III (Public Cleansing) deals with the cleansing of streets, the collection and removal of refuse and the cleanliness of "public places". Comprehensive provision against littering and the depositing of refuse in public places were introduced. Under this Act, it becomes an offence to throw or leave behind any bottle, paper, food containers, food and cigarette butts. The spilling of noxious and offensive matter and the dropping or spilling of earth in public also became an offence.

All these offences rendered a person liable to be ticketted and even arrested if full and correct particulars are not forthcoming. Upon conviction a fine not exceeding S$500 may be imposed for the first conviction and a fine not exceeding S$2,000 for second and subsequent convictions. A more severe penalty is imposed on builders, developers and contractors who during the course of their work deposit or drop or leave building materials in public places; or who fail to take reasonable precautions to prevent people in public places from being injured by falling dust or building fragments.

This Act also requires the owners and/or developers of flats and industrial complexes to provide, at their own expense, proper methods of refuse collection and disposal. Bin centres are a requirement for such building complexes for they are a convenient point from which refuse may be removed by the refuse collecting vehicles.

Another step taken towards ensuring further improvements in keeping Singapore clean was the introduction of the Environmental Public Health (Public Cleansing) Regulations, 1970. Under these regulations, the public must take positive steps to keep the surroundings of their premises clean. The occupiers of houses and trade premises become responsible for the cleanliness of the footpath in front of their premises including the corridors and passageways of their flats.

They are also required to provide refuse bins and to ensure that all refuse is deposited in these bins. Any litter found in or around the building, regardless of whether it is in the drains or street, becomes the responsibility of the occupier unless it can be proved otherwise. As such, the occupier of the building becomes liable for prosecution under the regulations.

In keeping with the high standards of cleanliness demands by the public, these regulations also prohibit the sweeping of litter into any footway, drain or road. The people staging wayangs and fairs also came under scrutiny and were made responsible for sweeping and cleaning up the sites after the performances. It can be seen, therefore, that the Enviromental Public Health Act confers who wide ranging powers to the Health Ministry.

However, the best of legislation, without enforcement, is pointless. Legislation with partial enforcement is worthless. Legislation becomes effective only when it is stringently enforced. The type of people, their motivation, dedication and their commitment to duty ultimately determines the effectiveness of the legislation. The sword must be given an arm to strike effectively.

The officers of the Environmental Health Branch were given this task. Led by the Health Officers, the field staff enforced these laws strictly. It was the untiring efforts of these officers, particularly by the Senior Public Health Inspectors, which finally led to the success of anti-litter enforcement.

We in Singapore have to a large extent succeeded in our aims of keeping Singapore clean and litter free. This success has been achieved largely through the support and cooperation of the public at large. Annual keep clean campaigns, with school children being the prime target were responsible for this public support. Strict legislation was passed and this with vigilant enforcement action helped to break the back of the litter problem in Singapore.

Paper No. III/8

THE PROBLEM OF DUST IN GRANITE QUARRIES IN SINGAPORE

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ABSTRACT

There are 25 granite quarries operating in Singapore. These are of various sizes and employ methods of different degrees of sophistication but the basic processes involved are similar. A brief description is given of these processes.

A survey is described of a sample of these quarries. Dust counts were taken in relation to the various processes, comparing the dust concentrations between the different processes and between the various quarries. A brief discussion of the methods of dust control currently used is made.

INTRODUCTION

There are some 25 granite quarries in Singapore employing approximately 1,500 workers. With the construction boom going on for the past few years, the need to produce large quantities of granite to supply the demand for construction materials has somewhat aggravated the problem of dust in these quarries. The lack of dust control measures has given rise to a serious hazard in the form of workers contracting silicosis which is a chronic fibrosis of the lungs. Workers inhaling these granite dusts which contain a high percentage of free silica over a prolonged period of time from 5 to 10 years are exposed to a high risk of getting the disease. In 1965 a mass X-ray was conducted in most of the quarries and out of the 1,188 workers examined, some 7% had definite signs of silicosis. A five-year follow-up survey done in 1971 showed that out of 1,234 workers X-rayed, 15% had definite silicosis. This is a significant increase of 8% over the five-year period. The production of granite over the last five years had more than double, whereas the number of workers employed had only increased from 1,009 to 1,294, that is about 30% increase. It is therefore expected that the incidence of silicosis will also increase in view of the lack of effective control measures now present in these quarries. It is noteworthy that four major companies produced about 75% of the total output of granite in the State and the production per worker in the newer and more recognised quarries is about ten times that of its less sophisticated counterpart. This is a very significant matter when control measures are contemplated.

NATURE AND MAGNITUDE OF THE PROBLEM IN SINGAPORE

A survey of dust concentrations of the working environment was done on the quarries during late 1967 to early 1968. Results of the spot-samples clearly emphasised the magnitude of the problem. Table 1 gives a breakdown of the dust counts performed on 13 granite quarries. It is immediately evident that none of these had dust counts within the limits recommended by the American Conference of Governmental Industrial Hygienist (ACGIH).

The midget impinger was used to collect the samples which were taken over periods of one minute each. The M.S.A. microprojector was used

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Concentration in mppcf	No. of quarries at quarry face	No. of quarries at secondary crusher	No. of quarries (at silo)
0 – 49	1	1	1
50 – 99	7	2	4
100 – 149	2	3	4
150 – 199	2	1	4
200 – 249	0	3	0
250 – 299	1	2	0
300 – 349	0	0	0
350 – 399	0	0	0
More than 400	0	1	0
Total	13	13	13

Table 1. Results of Dust Survey in 13 Granite Quarries (1967)

to count dust particles. The percentage of free silica in the dust was about 30; this was obtained as outlined in the ILO Third International Report. Dust counts were performed for particles smaller than 5 μm size. The safe limit was then quoted to be 20 mppcf (ACGIH).

Table 2 is a breakdown of the dust suppression measures then used in the quarries. It is noteworthy that of the 25 quarries only almost ten units of dust control devices were used and of these none was used at the drilling operation.

In 1971 a series of spot tests on 3 quarries with dust control devices were taken and the results shown in Table 3 were obtained.

Locality	No. with suction system	No. with spraying system (water only)	No. with spraying system (wetting agents)	Total
Crusher Unit	1	3	1	5
Quarry Face	–	–	–	–
Silo	2	6	2	10

Table 2. Distribution of Dust Control Devices (1967)

Locality	Quarry 1	Quarry 2	Quarry 3
Quarry face	145 mppcf	67 mppcf	53 mppcf
Secondary Crusher	188	262	291
Silo	81	201	285
Free Silica	24.0%	4.9%	7.9%
	T.L.V. 9 mppcf	T.L.V. 20 mppcf	T.L.V. 17 mppcf

Table 3 Results of Spot - Samples (Taken 13.4.71)

Note: The T.L.V. (Threshold Limit Values) were calculated using the revised formula from the ACGIH, 1971.

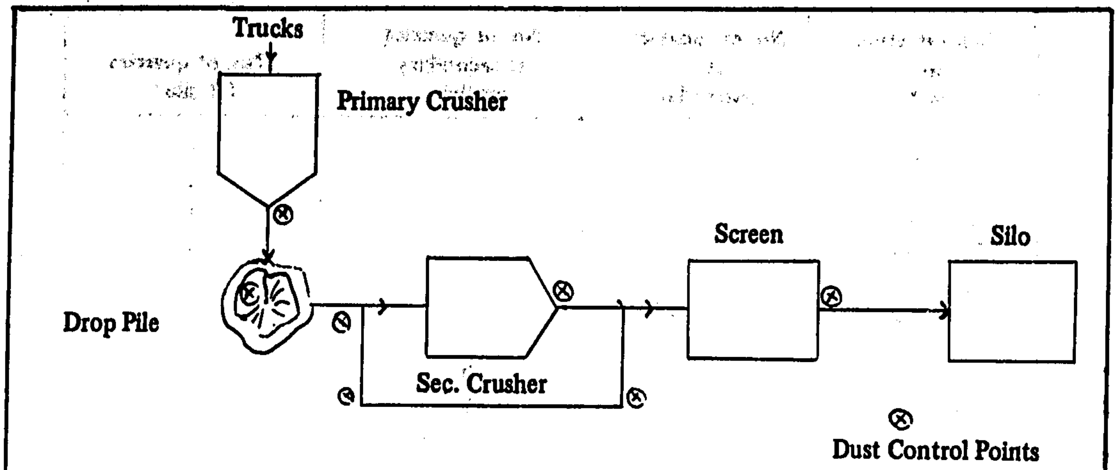

Fig. 1. Conveyor Belt Transfer Points

Presently, about 90% of the quarries have provision for some form of water-sprays—the only economic dust control measure employed at dust emission points – but the number actually using these is very small. This is largely due to the improper installation and use of water-sprays, resulting in over wetting of the aggregate and conveyor belts and hence clogged screens. This is all too common in the older quarries where in an attempt to save money, the installation is haphazard and practically useless.

CONTROL MEASURE

Control measures should be directed at processes which are responsible for dust generation and the dust control points should be carefully chosen (Fig. 1). Broadly speaking, dust control measures fall into two categories:

(1) Methods not employing exhaust air

(2) Methods employing exhaust air

And the operations and main areas to be controlled are:

(a) Drilling

(b) Blasting

(c) Crusher-unit (primary and secondary)

(d) Storage pile

(e) Network of conveyor and transfer points

(f) Loading and transport

While water spraying seemed ineffective in many quarries, there is at least one plant where this is used to some advantage. Here of course, this is part of the control measures of the whole plant and local exhaust ventilation is also employed. However, one drawback resulting from use of wetting agents is the increase in dust content in the granite - thus leading to a product of lower grade.

HIGH PRESSURE NOZZLES

In West Germany experiments on water-mist nozzles which atomised small quantities of water (10 - 20 l/hr) at high pressures (6 to 10 atmospheres) reduce dust at the discharge opening of a rotary crusher at transfer point of conveyors by more than half. In some cases the *mist nozzles by themselves* are sufficient to reduce the dust level to below hazard limit. In several gravel works, the combination of water mist nozzles/suction was shown to be effective and considerably reduce total cost [5].

METHOD EMPLOYING EXHAUST AIR

The object of installation of dust exhaust and collection is to prevent dust clouds at various points and this is usually achieved by placing hoods at the dust sources and evacuating the dust in air stream. The dust laden air is then drawn to a plant which separates the solid particles and allows the cleaned air to pass to atmosphere.

CONTROL AT SCREEN

Drilling, crushing and screening operations are the main areas of concern and the control measure for the latter seems to lie in provision of suitable hoods. To be effective each hood must have sufficient air passing through it to ensure capture of dust rising from the screen surface - a minimum surface velocity of 200 ft/min is required. So, for a screen of 10 ft x 5 ft (as used by some of the bigger plants here) hood face is 50 sq ft and the minimum extraction volume is 10,000 cu ft/min. This would involve a sizeable motor and fan, large ducts and dust collecting plant.

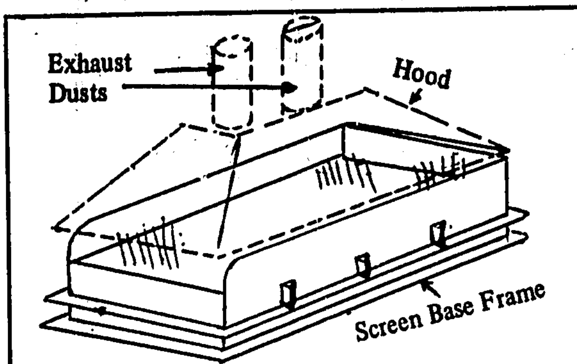

Fig. 2. Dust Control Hood for Screen

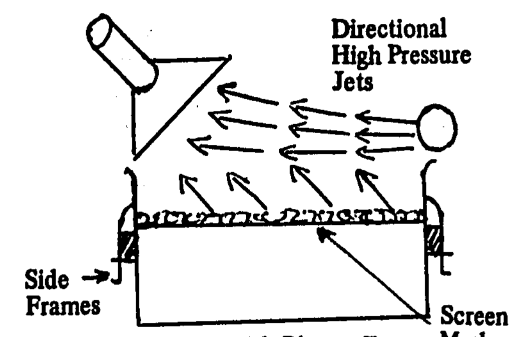

Fig. 3. Side Hood with Blower Fan

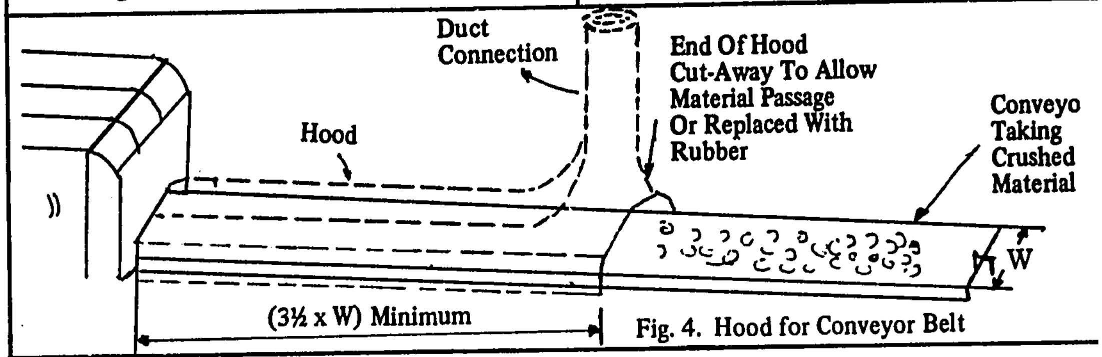

Fig. 4. Hood for Conveyor Belt

The hood must be fitted close to the screen to avoid drawing air from the general atmosphere of the screen, instead of exhausting the dust. The best methods of ensuring complete control is by covering over the entire screen (Fig. 2).

With this system, all that is required to prevent dust emission is to withdraw sufficient air to ensure that any dust generated is not permitted to billow out at the feed or discharge points. For a screen 5 ft x 10 ft only about 1,000 cu ft/min need be drawn through it.

Side hoods are sometimes used on screens of such width that sufficient air can be used to ensure that the air velocity over the same is high enough to carry rising dust away. With careful design and adjustment a blower fan can assist the passage of dust into the hood opening (Fig. 3).

With slight modifications the hood can be fitted 2 ins - 3 ins from the side members of the screen. Sufficient air is then exhausted to ensure sufficient air is drawn through the space at a velocity just high enough to prevent dust passing outwards.

CONTROL AT CRUSHER

In the case of some crushers, production of dust is so rapid that it is virtually impossible to introduce sufficient water in the form of finely divided droplets to exercise any noticeable control at all.

Since most impact breakers are fitted with a conveyor which removes the broken stone to the n process - normally a screening operation arran ment must be made to cope with dust discha along the conveyor belt. Much experimental w with various shapes and sizes of hoods and differ exhaust volumes was carried out before t "funnel" type of hood was found to be the m effective.

Fig. 4 shows a suggested arrangement, w sizes and proportions of hood required. It essential that adequate exhaust volumes are u to allow for the "induced volume" produced the flow of materials in the crusher.

CONTROL DURING DRILLING

To date, the only measure taken at drill operations at quarry face is personal protect by respirators. Even with considerably impro design, these are worn unwillingly and unfortun ly not regularly - as the local conditions are v trying.

The Swedes have developed a system of d abating - The Devaclon System - which is suction device with small air volume but high velocity.

This system is primarily used for hand to and can be provided with very long and slen hoses to facilitate easy handling of the tool. T Swedish Institute of Occupational Health tes the Devaclon separator over a period of 3 da The results are reproduced below, Table 4.

With dust removal	Mean daily concentration	–	0.4 mg/m³ Total dust
	Dust, concentration during effective drilling period	–	0.6 mg/m³ Total dust
Without dust removal	Mean daily concentration	–	12.5 mg/m³ Total dust
	Dust concentration during effective drilling period	–	22.0 mg/m³ Total dust

Table 4. Results of Rock Drilling

ıe results were obtained by portable filters attached to the workers' shoulders. The quartz content of the stones worked was 25%. According to Swedish recommendation the mean daily total dust concentration for the type of work should not exceed 3mg/m^3. In a regulation which came into force on 1st October 1970, the use of suction devices is prescribed during the winning and working of quartz containing stones.

Broadly speaking the granite quarries may be classified into two groups:

(1) Developing and capital investment intensive

(2) Low production and labour intensive

It is evident that any proposed measures to curb the dust problem should pay particular attention to the latter groups. Any high capital outlay is beyond their means and it seems that the only recourse is to employ the wet method, which can be very effective if properly designed and installed. The newer plants generally have provision for water-sprays, however, management can further improve control by adopting high pressure nozzles of approved design in conjunction with local suction at dust generation points.

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'aper No. III/10

EDUCATION, DEVELOPMENT AND RESEARCH

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ABSTRACT

There are two commonly accepted (concepts) about education which may bear examination. One is that education is implicit in schooling; the other is that the more institutionalised instruction which the individual receives, the better he is for such. These two concepts have led to the oversimplistic view that education and development are positively correlated when, in fact, such an outcome depends more specifically on the quality and relevance of the schooling received to development needs.

A changing environment with new challenges and new needs, with knowledge explosion and obsolescence does not require so much a content-oriented curriculum as a value-directed curriculum. The central study in schools should be principles of human action based on an understanding that in a shrunken world there has to be a "mutual coercion mutually agreed upon"

Mutual agreement implies mutually acceptable criteria which students may well do to understand as soon as they are capable of doing so. The study of all other subjects should be related to this central theme. In other words, the other disciplines should be presented from an interdisciplinary viewpoint rather than as isolates providing a great deal of detailed and unrelated data. Each subject studied should yield important basic principles for the building up of positive mental and emotional attitudes while affording those skills in thinking and doing which will enable the individual to develop such attitudes. This does not exclude the sciences nor even the technical education subjects which purport to teach specific manual skills.

The individual whom we prepare for the future will not be judged by how much of history or geography he has factually accrued, but how much of a glimpse he has caught of the good or ill consequences brought on through the struggles of man with environment, of man with man so that he may learn to avoid those paths which lead to costly destruction and insensitive unawareness of man's common destiny. Likewise, he will not be considered expert for having committed to memory the formulae of science and mathematics (the machine can do that for him), but he will need to know how to use science without consequential tears.

The problem of development stem essentially from a triad of lags - a perception lag, a value lag and an action lag.

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The trappings of technology – the machines, the consumer goods, modern transport and even the ubiquitous means media – do not necessarily imply an understanding of what technology means or does. Some suffer from a perception lag of the purpose and promise of technology.

A setting in of moral turpitude and a prevalent laissez faire about consequences of actions have resulted in a general lack of moral concern about the economic motive and the vested interests. Herein lies the the value lag.

There is also the lag of methods and ideas behind needs. This constitutes the action lag. Not that action is not swift enough. Packaged solutions are too readily available. Imported from affluent societies and designed for their cultures, they are frequently beyond the reach of majority needs. Underdevelopment, according to Illich signifies the "surrender of social consciousness to prepackaged solutions." One may impute much of the irrelevance too in education to this cause.

To understand more fully the proper relationship between education and development is, therefore, an important concern which needs to be supported by research. The following are basic problems associated with this concern : –

1. Basic assumptions about development need to be examined. Are the economic indices used for the measurement of development valid? Are we using development as a guise for ensuring a continuing loyalty to the producers who have both created and pandered to our wants? Does social and national development consist merely of economic growth and material affluence or is there now an urgent need to seek diligently the moral-spiritual component that we have not only overlooked, but in every underdeveloped country sought to remove as thing of superstition, a hindrance to modernisation?

2. Next, there is need to seek new alternatives to solutions. If mass education is required, how should it be orgainsed to produce the best results within the means available. Of what should it comprise? Concomitant with this is the need to evaluate alternatives. Too frequently in a given situation there is nothing entirely right or wrong. The control of environment, for example, is important, but the methods used must be assessed.

3. Thirdly, how do we deal with man himself? How to bring him to his senses lest he continues to destroy his own heritage?

4. Fourthly, there is need to select from the universe of values those most related to our well-being in the future; to find out what individual liberty would need to be sacrificed for the greater freedom of all, to decide on what values common consensus may rest for the good of the community.

5. Last, but not least, is the need for practical and concrete measures and alternatives to support solutions which are a result of studies made. A common failing is to leave mooted solutions at the word-level without practical demonstration of feasibility. On the part of the schools what form of responsibility should the teachers take? Teaching a course on environment and pollution control alone is not sufficient. How should parents and the community be actively involved? What forms of training must be given to change agents whose main problem will be the need to counter basic individualism and selfish unawareness of others?

It is obvious that in the approach to these needs, education cannot go it along. The research and the practical action have to come from interdisciplinary effort–from theorists and practitioners, from the particularly concerned and the man-in-the-street, from scientists, technologists and humanists – all will have to work together.

That education and development are somehow inextricably linked in a positive correlation has been an article of faith too frequently accepted without a closer look at the basis for belief. Further, in this connection, education is generally viewed as synonymous with schooling, that is, it is taken to mean that particular set of influences, organised either through the efforts of government or a determined group of persons for a stipulated part of the individual's life and, ostensibly, for his ultimate benefit as well as that of society.

About these concepts, two fallacies persist and have common currency in many countries to-day. The first is that the quality of education is measurable by the quantum received in terms of packaged knowledge and number of years spent in acquiring it; the second is that the dispensing of education, as understood in these terms, to as many as possible will cause certain influences to "take" and produce desirable outcomes which will correct many of the social and economic ills of contemporary man.

It needs little elaboration to show that the first is very much taken for granted. When a child enters school at the age of six he is considered raw material to be shaped. He is made to do sums and read texts which cram him with bits of information (whether relevant or irrelevant seems beside the point). As he laps up his various series of graded texts so he becomes increasingly educated. Naturally more bits of knowledge require more time to consume.

This volumetric approach to education suggests that an individual with a university honours degree is better than one with a pass degree, the distinction between them being the eligibility of the former for more specialised book-learning which the latter is deemed unworthy to receive by virtue of his inability to "produce" at examinations. For the same reason, a university degree is rated better than a school certificate and a secondary school education better than a primary school education. Out of this basic fallacy, therefore, arises the problem of educated unemployables; and these are not limited to any one level of education.

What is wrong here is that the quantum of education given may be entirely irrelevant to the needs of development. Besides, the number of years spent in consuming knowledge does not always imply that the right knowledge has been consumed. Those who leave at primary school level have been known to lapse into illiteracy and ignorance without supportive follow-up services; those who leave later may never have acquired the mental and other skills supposedly imparted, because an unimpeded escalation through the school years based on a continuous, automatic and mass promotion effort has long left them behind in the understanding of what they are supposed to have learnt.

There are suggestions that the curriculum should be made relevant to needs – that subjects such as health education, technical education, consumer education, population studies and the study of environment should have their place on the curriculum, inasmuch as they are more meaningful for our society to-day. But accretions tend to be advocated without an examination of what may be deleted from an already over-crowded time-table. The removal of hallowed traditional subjects raises a howl of public protest. Parents, while not admitting it, prefer the tried paths toward the examination and are generally suspicious of whatever is new. Their main preoccupation is not with the relevance of education but with the paper qualification which will admit their children to the next stage of the educational progression. Teachers are immediately insecure with new subjects, as traditional training has not made them perpetual, independent learners. New subjects imply the need for mass re-training of teachers. Then, there are the specialists who feel indirectly threatened by the removal of the spotlight from their traditional concerns.

With nothing to give and everything to take, for a schedule limited by time, the logical consequence is that children in schools learn more and more about less and less. They cannot see the trees for the wood. Schooling becomes a drudgery with much to cram and, whatever others may say of relevance, the victims of the schoolhouse see none.

The present malaise affecting schools, of which disenchanted and dissociated learners are common products, arises, therefore, out of society's mistaken concern for quantity and its strong tendency to conservatism. While the changing environment is pointing more and more to the need for a value-oriented curriculum, school-subject curricula are increasingly content-heavy. But, if any prediction may be made about the type of individual required for the society of the future (almost the immediate future as well), it is certainly not the bookworm. He will have to be an individual possessed of the art of self-education who does not consider his efforts at learning to have ceased at the point of leaving a formal institution of education; he will keep himself well-informed on the changing issues of life; he will have to be a good decision-maker, aware of the alternatives which multiply in a technological-consumer context, and be perceptive enough not to be dominated by the gimmickry and the mechanics of quick "sell".

As a case in point, let me cite what the Prime Minister said to Singapore Polytechnic students (1) :

> "At the end of it all, we have to ask ourselves: what is the optimum that you put into economic growth as against the social cost of economic growth?"

Elaborating upon the alternatives which are open for development, and the need for a cut-off point for the less desirable ones, he continued :

> "Well, I think we can only make part of these momentous decisions immediately. And perhaps by 1980 a younger generation with more data to decide what is in the best interest of the population, of the people, of the country, of the society, will decide whether they have reached cut-off point.
>
> Meanwhile, of course, there are certain things which we do not want to do. You know that the great thing now is pollution or what they call in Japan 'public nuisance'. So there are countries which would like to export all this industries which cause 'public nuisance' . . . .
>
> But I think some of these problems will be very difficult to resolve. The temptation, the thrill, the enthusiasm that you generate within a machine – whether it is the Economic Development Board and its promotion officers, whether it is the Finance Ministry to say: 'Well why shouldn't we have a real big iron and steel mill with five million tons capacity. Never mind the pollution. Sited at the eastern end of the island where the prevailing winds will blow it away and miss us. Or put it in Pulau Tekong. Why shouldn't we have an aluminium smelting industry? It will pollute, but it will miss us."
>
> Can Singapore citizens meet these problems in 1980?

In his much-vaunted technological progress, Man has created a vicious circle wherein obsolescence has immediately to be followed by new consumer wants which in turn have to be dampened out to give place to yet another phase of obsolescence and more wants. Increasing exposure to pollution of the environment, subjection to unscrupulous manipulations of consumer tastes, ignorance of the consequences of indiscriminate over-production, multiplication of the hazards to health – all these are derivatives of a vested interest in economic gain and output to the exclusion of other considerations. Man was told to be "fruitful and multiply and replenish the earth", but Man has been fruitful and multiplying, rapaciously despoiling earth, air and human spirit, not replenishing any part at all.

Taking note of this, the central study in schools should be principles of human action based on an understanding that in a shrunken world there has to be a "mutual coercion mutually agreed upon"(2). Mutual agreement implies mutually acceptable criteria which students may well do to understand as soon as they are capable of doing so. The study of all other subjects should be related to this central theme. In other words, the other disciplines should be presented from an interdisciplinary viewpoint rather than as isolates providing a great deal of detailed and unrelated data. Each subject studied should yield important basic principles for the building up of positive mental and emotional attitudes while affording those skills in thinking and doing which will enable the individual to develop such attitudes. This does not exclude the sciences nor even the technical education subjects which purport to teach specific manual skills.

In the light of this suggestion, the individual whom we prepare for the future will not be judged by how much of history or geography he has factually accrued, but how much of a glimpse he has caught of the good or ill consequences brought on through the struggles of Man with environment, of Man with Man so that he may learn to avoid those paths which lead to costly destruction and insensitive unawareness of Man's common destiny. Likewise, he will not be considered expert for having committed to memory the formulae of science and mathematics (the machine can do that for him), but he will need to know how to use science without consequential tears. Indeed, for him, choices are increasingly

(1) Lee Kuan Yew, "Education and Development in New Countries", an address delivered to Singapore Polytechnic students, January 1972.

difficult to make. For example, should he join in the continued war on pests by seeking to concoct yet stronger pesticides in support of farmers who are struggling to provide food for hungry millions, or should he desist, because he is indirectly helping to bring death to others, both Man and beast. He may need to look for alternatives in problem-solving, but the decreasing number of mutually exclusive options open to him makes his task more and more a heavy responsibility.

What of the second fallacy referred to above? Since the meeting of Ministers of Education in Karachi almost twenty years ago (3), most of the member countries of UNESCO in Asia have tried their level best to give six years of education to every child in their respective countries. Though a few like Singapore and Malaysia have outstripped the target set at that meeting and reaffirmed later in Tokyo, a number of others like Laos, Cambodia or South Vietnam would find themselves hard put to reach the goal by 1980. All, whether ahead or behind, are still frantically intent on expanding their school systems, spending on an average about a fifth or more of the total national budget on education. And still, there are many more yet to be educated and the development take-off not even in sight.

Meanwhile, obsolescence, which characteristically accompanies the constant evolution of technological refinements, also spreads its influence over education. Specific skills for which students are trained at any given time are liable to become irrelevant and inadequate within a matter of years. Teachers, who by preparation teach certain subjects, find themselves underprepared for the phenomenal gain in new knowledge made in every subject area; they have to be re-trained for higher levels of attainment and for new needs Planning in education which seeks, at its best, the attainment of certain specific objectives in a long-term perspective, finds itself corrected at almost every turn by rapid, situational changes which too often elude control. There is more that becomes unpredictable than otherwise in the race in which underdeveloped countries attempt to catch up with technologically advanced ones.

It thus happens that education, born of an egalitarian sentiment, in fact still favours the elite few. For the law of the survival of the fittest invariably operates on behalf of those who make it up the educational ladder. In the cause of technological progress, these finish their upward progression sometimes at such sophisticated levels that they become lost eventually to their home countries for lack of opportunity to practise their skills. The mediocre others receive such a thin slice of the educational pie that they wander to and fro on the misty flats, more often than not a drag on the economy, a large undertrained group, a pocket of discontent with heightened expectattions and nothing to substantiate their aspirations. Both over-training and under-training are not desirable. Where a country's development lags behind that of the individual, under-utilisation of skills and loss in terms of investment in human potential result. On the other hand, development can hardly begin if individuals with the right sort of skills are not around.

The problems of development stem essentially from a triad of lags – a perception lag, a value lag and an action lag.

The trappings of technology – the machines, the consumer goods, modern transport and even the ubiquitous mass media – do not necessarily imply an understanding of what technology means or does. Take, for example, the person who, having caught a cold, took a treble dose of a certain patent medicine because he thought the strengthening of the dosage would lead to three times as rapid a recovery as he would enjoy through a single dose at a time. Here is a simple case of perception lag. A person such as this one would be difficult to convince about technical prescriptions, do's and don'ts, except perhaps by ceaseless teaching, line upon line and precept upon precept. But so much care over one individual is time-consuming enough: how much more the education of many individuals. Thus in India, population control is extremely difficult to achieve, because many recognise neither the rationale for family-planning nor the techniques for bringing it about.

A setting in of moral turpitude and a prevalent *laissezfaire* about consequences of actions have resulted in a general lack of moral concern about the economic motive and the vested inter-

(2) An apt phrase used by G. Hardin in an article, "The Tragedy of the Commons" published in Environment [Ed. J.W.G. Ivany], Addison-Wesley Pub. Co. Inc. Philippines, 1972.

(3) UNESCO : Report of the Meeting of Ministers of Education of Asian Member States participating in the Karachi Plan, April 1962 p. 25.

ests. Herein lies the value lag.

"Economic 'needs' are among the most widely accepted rationalisations of human behaviour. Not only does alleged economic necessity cover otherwise indefensive projections of self-expression onto the environment; it also 'justifies' exploitive use of the environment in the name of progress, growth or public demand."(4)

There is also the lag of methods and ideas behind needs. This constitutes the action lag. Not that action is not swift enough. Packaged solutions are too readily available. Imported from affluent societies and designed for their cultures, they are frequently beyond the reach of majority needs. Take, for example, the expansion of schooling achieved through the rapid multiplication of buildings and equipment. In every underdeveloped country, there are new schools, new universities, new machines. What is offered with the new buildings reinforces the conditions of underdevelopment by introducing a state of mind inimical to development. Underdevelopment, according to Illich (5) signifies the "surrender of social consciousness to prepackaged solutions." One may impute much of the irrelevance too in education to this cause.

Spread schooling how widely you will, the results of schooling do not necessarily influence the course of development in desirable directions. There are too many variables which do not fit into the packaged solution. Education may be a necessary condition for development and for positive change : it is not, *per se*, a sufficient condition.

While this conference is specifically concerned over the pollution of the environment, a wider concern is how to bring about an avoidance of continuing pollution. This is, in its turn, but a subsidiary concern to the one of the proper relationship between education and development. To understand these concerns more fully, there is need for evaluation and research.

The following are needs which cannot be settled by quick answers. A thorough investigation of their problems would be useful.

(1) There is need to re-examine the basic assumptions about development. Are the economic indices used for the measurement of development valid – the number of house-holds per radio or T.V. set, the number of persons per car, amount of consumer goods, etc? Has industrial society converted us to the belief that man's needs were shaped by the Creator as demands for the products we have invented? Are we using development as a guise for ensuring a continuing loyalty to the producers who have both created and pandered to our wants? Does social and national development consist merely in economic growth and material affluence or is there now an urgent need to seek diligently the moralspiritual component that we have not only over-looked, but in every under-developed country sought to remove as a thing of superstition, a hindrance to modernisation. Perhaps we have not looked enough at the possibilities for harnessing this force on which man has relied for so many centuries before our own.

(2) Next, there is need to seek new alternatives to solutions. If mass education is required, how should it be organised to produce the best results within the means available. Of what should it comprise? Concomitant with this is the need to evaluate alternatives. Too frequently in a given situation there is nothing entirely right or wrong. The control of environment, for example, is important, but the methods used must be assessed.

(3) Thirdly, how do we deal with man himself? How do we bring him to his senses lest he continues to destroy his own heritage? Whilst psychology and sociology have made a study of human behaviours and needs, they have as yet few answers as to how basic attitudes may be changed, how decision-makers may be trained for intelligent action.

(4) Fourthly, there is need to select from the universe of values those most related to our well-being in the future; to find out what individual liberty would need to be sacrificed for the greater freedom of all, to decide on what values common consensus may rest for the good of the community. This is the most difficult exercise of them all in the slogan-prone world of to-day. We are constantly showered with brave new words which carry but a hollow ring.

(5) Last, but not least, is the need for practical and concrete measures and alternatives to support

(4) Caldwell L.K., *Environment - A Challenge to Modern Society,* Anchor Books, Doubleday & Co. Inc. N.Y., 1971, p.112.

(5) Illich, I., "Outwitting the Developed Countries", Church and Society, Nov.–Dec., 1970, p.64

solutions which are a result of studies made. A common failing is to leave mooted solutions at the word-level without practical demonstration of feasibility. Here, the help must come from all who are involved in the day-to-day routine of grappling with significant problems. For example, there are those who are required to attend to waste control. There are others who have to invent new devices for waste disposal, and so on, On the part of the schools what form of responsibility should the teachers take. Teaching a course on environment and pollution control alone is not sufficient. How should parents and the community be actively involved? What forms of training must be given to change agents whose main problem will be the need to counter basic individualism and selfish unawareness of others?

It is obvious that in the approach to these needs, education cannot do it alone. The research and the practical action have to come from interdisciplinary effort – from theorists and practitioners, from the particularly concerned and the man-in-the-street, from scientists, technologists and humanists – all will have to work together.

But, again, to leave my paper at this point is to leave it to a pious hope. For impact, something immediate has to be started – something specific. This may be in the form of an organisation – perhaps national and regional to begin with – which will have as its main concern the search for means which lead to the proper use of environment within varying contexts and situations in order to foster to the fullest man's potential and a life-style which has quality as a hallmark. With such an organisation, there will be firm ground for continued dialogue and concerted action within the region. Problems can be shared, advice put to the test, solutions adapted, controls jointly exercised and benefit disseminated over a wider area.

Already the ravages of ignorance are visible around us. Let us not be counted among those who wake up to find that action has come too late to serve any useful purpose.

Paper No. III/11

THE SUSCEPTIBILITY OF *CULEX PIPIENS FATIGANS* (WIED.) LARVAE TO INSECTICIDES IN SINGAPORE

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ABSTRACT

The susceptibility levels of C.p. fatigans larvae in Singapore to three chlorinated hydrocarbons and three organophosphorous compounds were studied and their toxicity was as follows: fenthion > diazinon malathion > dieldrin > gamma BHC. Results also showed that the larvae were susceptible to all the insecticides tested except DDT. Unpublished report from a previous study investigated by the first author revealed that the adults were also resistnt to DDT. Its usage was stopped completely since 1968 except under emergencies. Previous to that, DDT was not known to be used extensively and thus it is very likely that C. p. fatigans in Singapore is naturally refractory to DDT.

INTRODUCTION

C. p. fatigans in Singapore seems to be the main man-biting nuisance species on the basis of public complaints received by the Singapore Vector Control Unit. It is the dominant night biting species in all areas so far studied and maintains relatively high density levels throughout the year. Danaraj et al. [3] confirmed that it is a vector of Bancroftian Filariasis which is being maintained at a low level of endemicity. This species breeds profusely and rapidly under tropical conditions in polluted habitats such as drains, septic tanks and sullage pools. The only reference known to us which reports on the susceptibility of *C.p. fatigans* larvae to various insecticides in Singapore is Collins [2] which mentions the ineffectiveness of dieldrin for larval control after its use for 6 months. The present study was aimed at establishing baseline data of this species against the 6 insecticides available in the WHO test kit, for larvicidal control of *C.p. fatigans*. These include 3 chlorinated hydrocarbons namely DDT, dieldrin and gamma BHC, and 3 organophosphorous compounds (malathion, fenthion and diazinon) and tests were made on field larvae.

MATERIALS AND METHODS

Larvae were collected from roadside earth drains along Jalan Ubi which is densely populated area of mixed old suburban housing estate and rural ("kampong") houses with sparse vegetation and some chicken rearing. There is no covered sewerage and waste disposal is through earth drains and pit latrines. The drains form the main breeding places for *C.p.fatigans* and its population is extremely high throughout the year. Daily introduction of garbage, human waste and domestic wash water into these drains slows and pollutes water flow, and thus provides ideal breeding conditions. Regular oiling with Flit MLO which contains no insecticide was carried out once a week. Usually, larvae for testing were collected 1 or 2 days prior to oiling and at places where there was hardly any trace of oil. Only healthy and vigorous larvae were used. If many inactive, parasitized or otherwise abnormal larvae were present, the whole collection was discarded.

The method of determining the susceptibility of the larvae was essentially that described by the WHO Expert Committee on Insecticides [9]. The recommended preliminary test using 5-fold dilutions from 2.5 - 0.0008 ppm for organophosphorous compounds and 2.5 - 0.004 ppm for chlorinated hydrocarbons was first applied to indicate the general level of susceptibility. Based on these results, further batches of larvae were exposed to narrower dilution ranges including at least 4-5 concentrations within the 10-90% mortality range, so as to give precise regression lines. Actual dilutions are shown in Table 1. Thus lots of 25 third and early fourth instar larvae were picked out from the field larval collection and retained in petri-dishes for about one hour before testing. Any larvae which did not appear healthy were replaced by healthy ones. They were then transferred by means of a strainer into 500 ml beakers containing 249 ml of distilled water thoroughly mixed with 1 ml of the appropriate concentrate. No food was given during the test. After the 24-hour exposure period, dead and moribund larvae (as defined in the WHO standard method) were counted. For each insecticide 2 replicates at each concentration were set up together with 2 control replicates. The mortality in both replicates were combined and percentage mortality was calculated on the total of 50 larvae used. Tests with control mortality of 20% or more were discarded. When the control mortality was between 5 to 20%, the percentage mortality was corrected by Abbott's formula which is:

$$100 \times \frac{\%\ \text{test mortality} - \%\ \text{control mortality}}{100 - \%\ \text{control mortality}}$$

This was repeated 4 times on separate occasions in order to obtain adequate data for constructing a base-line susceptibility. In the case of malathion and DDT more than 5 concentrations each were used because the preliminary test suggested that the field population contained a mixture of susceptible and resistant individuals. The temperature of the water during the test ranged from 27.1°C to 28.7°C. The whole series of experiments were carried out from May to June 1969.

RESULTS AND DISCUSSIONS

The percentage mortality of *C.p.fatigans* larvae for each insecticide shown in Table 1 was plotted on log-dosage probit paper and the regression lines were fitted by eye (Fig. 1). The LC_{50} as read directly from these graphs are compared in Fig. 2. The levels of susceptibility of *C.p.fatigans* larvae in Singapore based on the LC_{50} to the insecticides tested were as follows: fenthion > diazinon > malathion > dieldrin > gamma BHC. DDT is not included in Fig. 2 because of its plateau response which makes the LC_{50} unreliable for comparison with the other insecticides. Four out of 6 insecticides namely fenthion, diazinon, dieldrin and gamma BHC showed the characteristic straight log dosage/probit mortality lines (Fig. 1). In the case of malathion the regression line differed slightly from the characteristic straight line response. All these insecticides with the exception of DDT have rather steep regression lines of more or less the same gradient. Results clearly show that organophosphorous compounds were more toxic than chlorinated hydrocarbons. Fenthion was the most toxic with an LC_{50} of 0.0022 ppm while diazinon has an LC_{50} of 0.017 ppm and malathion with LC_{50} of 0.032 ppm, followed by dieldrin and gamma BHC with LC_{50}'s of 0.22 ppm and 0.48 ppm respectively, The results of this study agree quite closely with those of Thomas [6] on the Malayan strain which are as follows: diazinon > fenthion > malathion > dieldrin > DDT > sevin. It is also observed that the susceptibility level for dieldrin is quite high. Collins [2] reported dieldrin as ineffective for larval control at H.M. Naval Base in Singapore.

The regression line for malathion shows a slight bending to the right as the concentration approaches higher levels. In February 1968, malathion was intensively used in Geylang and Geylang Serai (which are close to the larval collection site) in response to nuisance complaints against *C.p. fatigans*. Vector Control Unit records indicate that in May 1968, after 8 weeks of intensive larviciding with malathion, this species had developed 8-fold increase in resistance to the insecticide and its use was withdrawn immediately. The present results obtained one year later seem to indicate that in this period the species has still not lost all its acquired resistance to malathion.

With DDT, a plateau response is exhibited, the regression line being characterised by the failure of higher concentrations to produce a progressive straight line increase in mortality. Even the highest concentration of 2.5 ppm supplied by WHO did not kill all the larvae. This shows that the population is a heterogeneous one consisting of susceptible and resistant individuals, and the sharp inflection may indicate a simple genetic mechanism. It was also observed that among lower concentrations, i.e. from 0.02 to 0.1 there was no increase in mortality. According to our knowledge, DDT was not used anywhere near the larval collection site. According to Thomas [6] *C.p.fatigans* can revert to normal susceptibility level within 3-7 generations when selection pressure is lifted. Tests performed on the adults showed a nil mortality for DDT concentration of 4% and thus the adults were also resistant to

Insecticide	Insecticide concentration (ppm)	Corrected mortality rates (%)				Mean mortality (%)	LC_{50}
		Replicate 1	Replicate 2	Replicate 3	Replicate 4		
Fenthlor	0.001	2	0	4	6	3.0	0.0022
	0.002	28	58	40	54	45.0	
	0.0024	56	76	38	58	57.0	
	0.003	62	88	80	86	79.0	
	0.004	80	98	98	100	94.0	
	Control	0	0	4	2		
Diazinon	0.015	56	22	42	28	46.0	0.017
	0.02	70	72	78	74	73.5	
	0.025	92	64	80	98	86.0	
	0.035	98	96	98	100	98.0	
	0.06	100	100	100	100	100.0	
	Control	0	0	0	0		
Malathion	0.01	0	0	6	0	2.5	0.032
	0.02	0	6	2	2	3.5	
	0.025	12	56	28	46	28:5	
	0.03	30	64	68	76	45.5	
	0.035	50	98	90	79	68.5	
	0.04	56	96	100	88	78.5	
	0.05	92	92	90	94	92.5	
	0.06	90	96	98	96	95.0	
	0.07	94	96	98	98	96.5	
	0.08	98	98	100	96	98.5	
	0.09	96	94	100	98	95.0	
	0.1	98	98	100	100	99.0	
	Control	2	0	2	0		
Dieldrin	0.1	6	4	4	0	3.5	0.022
	0.25	60	46	88	50	61.0	
	0.3	82	64	94	62	75.5	
	0.375	94	88	98	76	89.0	
	0.5	100	100	100	92	98.0	
	Control	0	0	2	2		
DDT	0.02	4	0	4	0	2.0	
	0.1	4	0	2	4	2.5	
	0.25	62	18	24	46	37.5	
	0.5	94	70	52	88	76.0	
	0.75	92	88	52	86	79.5	
	1.25	94	96	56	96	85.5	
	2.5	100	94	66	98	89.5	
	Control	0	0	4	0	1.5	
Gamma BHC	0.25	4	14	2.1	14.6	8.7	0.048
	0.5	48	52	50.0	68.9	54.7	
	0.75	68	80	77.1	87.5	78.2	
	1.25	96	94	97.9	95.8	95.9	
	2.5	100	100	100.0	100.0	100.0	
	Control	0	0	4	2	1.5	

Table 1. Mortality Rates of 3rd and Early 4th Instar Larvae of *C. fatigans* to Various Insecticides

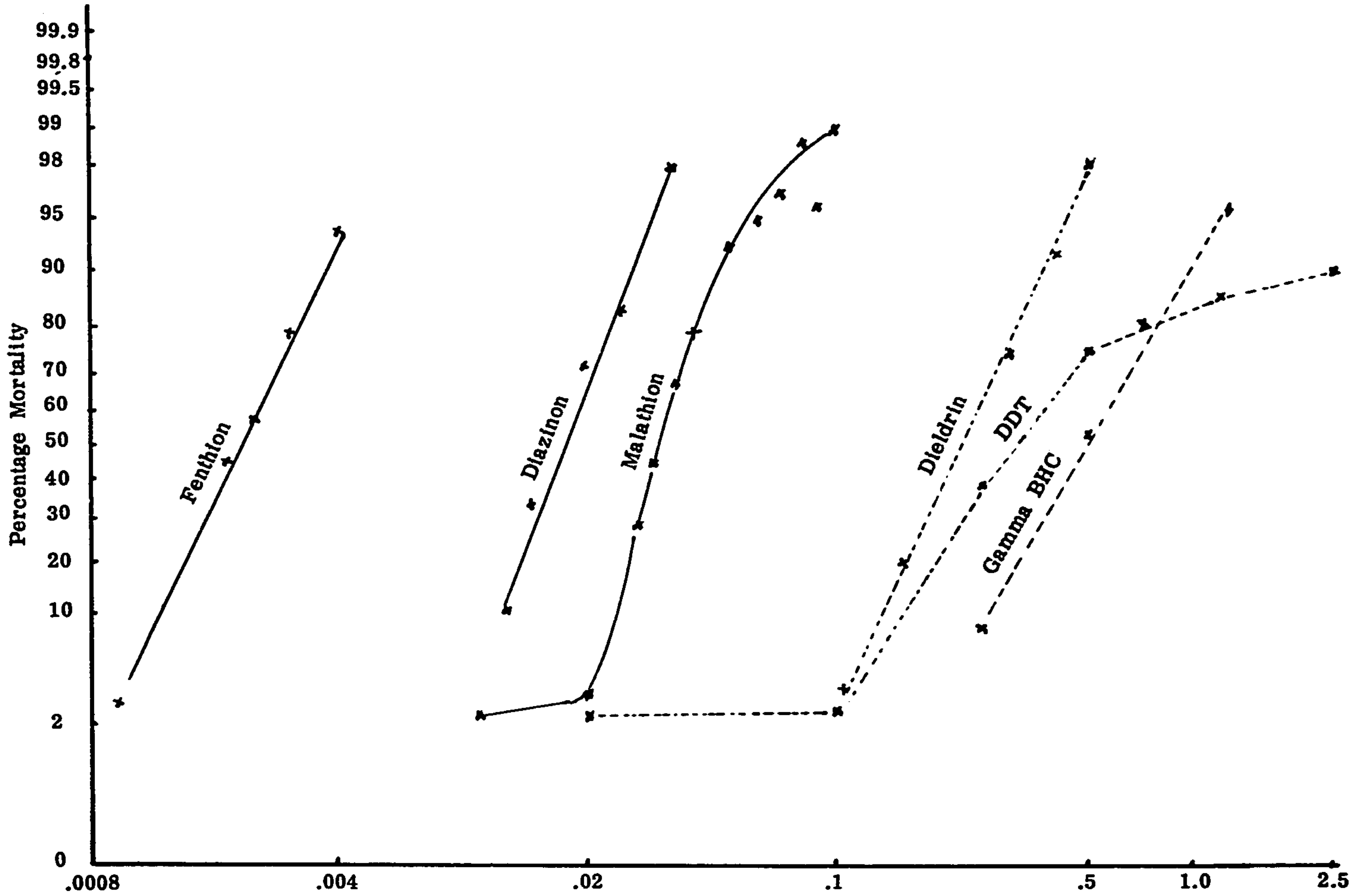

Fig. 1. Dosage Mortality Regression Lines of *Culex fatigans* to Insecticides in Singapore

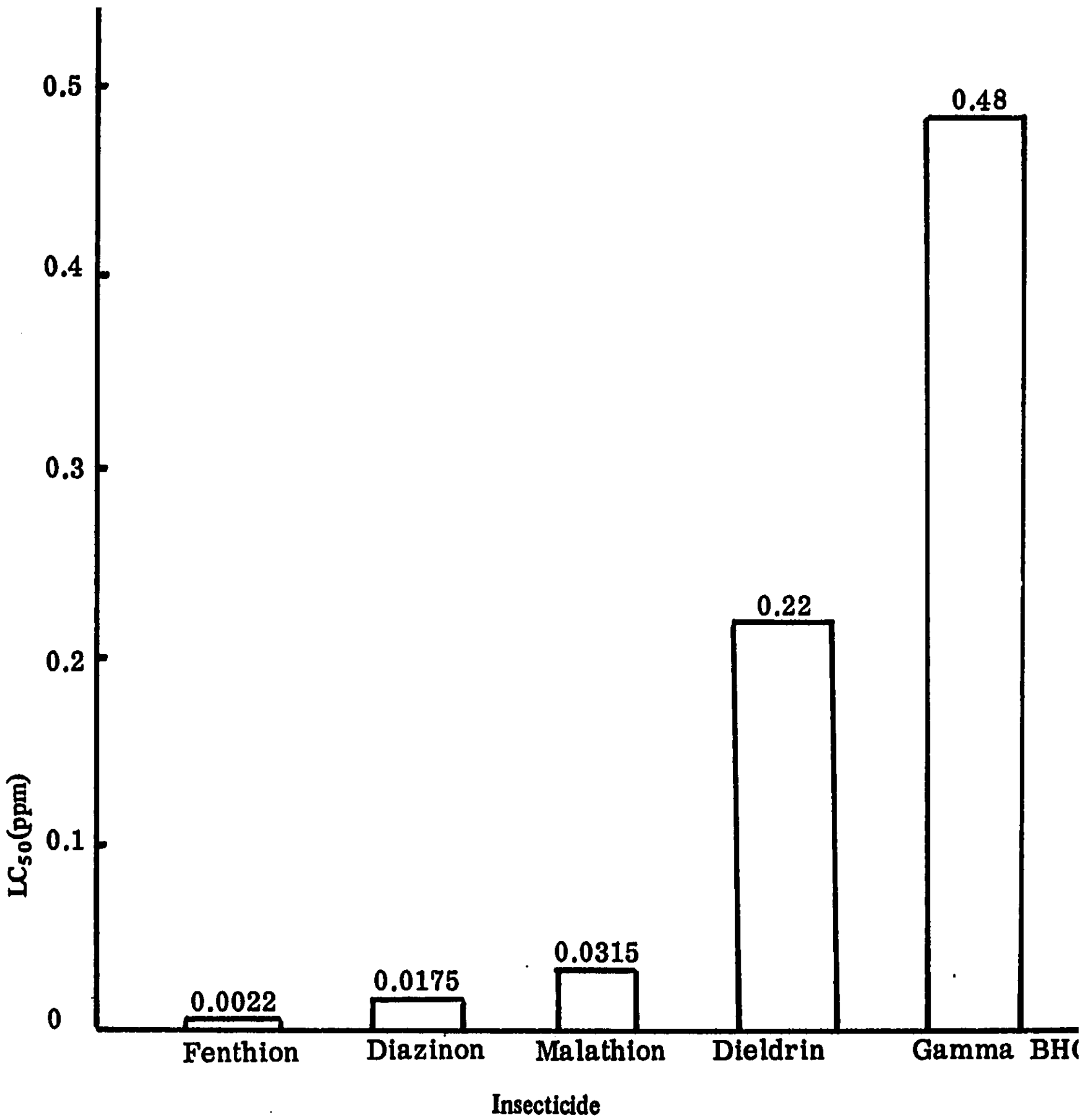

Fig. 2 LC_{50} Values of 3rd and Early 4th Instars of *Culex fatigans* in Singapore

DDT.

Reid [5], Wharton [8], Laird [4] and Brown [1] showed that a considerable degree of tolerance pre-exists in *C.p.fatigans.* Thus, it is likely that *C.p.fatigans* in Singapore has an innate lack of sensitivity to DDT.

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Paper No. III/12

SULPHUR CONTENT IN FUEL OIL AND ITS CONTRIBUTION TO AIR POLLUTION IN SINGAPORE

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ABSTRACT

High sulphur-bearing petroleum fuels are under scrutiny in a number of countries and limitation on permissible sulphur contents in these fuels are getting more stringent each year. In Singapore, the combustion of petroleum fuels is the principal source of SO_2 emissions into the atmosphere. Petroleum fuel consumptions will increase as energy demands increase. SO_2 emissions will increase correspondingly. Trends of these increases for the period 1963 to 1970 are reported. Ground-level SO_2 measurements have been conducted and results obtained so far indicated that the SO_2 pollution is generally satisfactory as compared to that in some industrialised cities in other countries. The pollution, however, is on the increase. Desulphurisation of crude and fuel oils and stack gases is at present economically unfavourable. For the time being, tall chimneys will help to reduce ground-level SO_2 concentration while sulphur recovery in oil refineries will help to decrease total SO_2 emissions.

INTRODUCTION

The trend towards urbanisation, industrial growth, and a boom in the number of motor vehicles has aggravated the problems of air pollution. Undesirable gases, particulate matters and noxious chemicals are being discharged into the air man breathes and polluting the atmosphere in which man lives. These pollutants in the air corrode metals, soil and disfigure buildings, rot wool, cotton and leather materials and affects vegetation and animal life,including man. In these ways, air pollution is costing the world millions of dollars and also causing the loss of social amenities and many man-hours – a great social diseconomy.

One of the principal causes of air pollution arises from the need to provide energy to operate machinery and equipment in industries , to provide lightings, to provide heat for homes, and to operate motor vehicles, ships, trains and aeroplanes. In Singapore, the most important source of energy is the combustion of petroleum fuels. Coal and wood fuels are used in very small quantities.

The combustion of petroleum fuels in power stations, oil refineries, furnaces and boilers in factories causes emissions of sulphur oxides (mainly the dioxide), smoke and particulate matters. When gasoline is burnt in the internal combustion engine of motor vehicles carbon monoxide, hydrocarbons, sulphur and nitrogen oxides, lead and other organic pollutants are generated. Diesel oil gives rise to smoke, odour and a mixture of organic substances when it is burnt in diesel-operated engines like prime movers and diesel cars. Since energy demands are increasing, the emissions of these pollutants will increase correspondingly unless preventive measures are taken.

Sulphur oxides emissions result primarily from he processing and combustion of sulphur-bearing petroleum fuels, coal and wood, from the sulphuric acid manufacturing plants, from metal ore smeting and from refuse burning. In this paper sulphur oxides emissions arising from the combuston of petroleum fuels will be discussed only as his is the most important source of the emission n Singapore. The emphasis will be on the combustion of fuel oils as, by far, it contributes the nost to the sulphur oxides emissions.

SULPHUR CONTENT IN FUEL OILS

When crude oil is distilled, it is separated nto various components with different boiling ranges such as wet gas, gasoline, kerosene, fuel oils, heavy gas oil and heavy bottoms. The crudes that are brought into Singapore for refining come mainly from the Mid-East wells and contain sulphur from 1.4 to 2.5% by weight. The sulphur in the crudes generally occurs as sulphides, mercaptans, polysulphides and thiophenes. Most of the sulphur in the crude oil will be retained in the residual fuel oils. Diesel oil which is a blend of the other fractions contains less than 0.7% sulphur. Kerosene and gasoline contain sulphur of less than 0.2 and 0.1% respectively.

Fuel oils are burnt mainly in power stations, oil refineries, industries and ships. During the combustion process, the sulphur combines with oxygen from the air to produce sulphur oxides, mainly the dioxide. The emission of SO_2 from stacks into the atmosphere can be reduced by using low sulphur-bearing fuel oils or by removing the SO_2 from the stack gases. Low sulphur-bearing fuel oils can be obtained from low sulphur-bearing crudes or by desulphurisation of high sulphur crudes of fuel oils. At the present state of technology, the cost of desulphurisation of crude and fuel oils is high and uneconomical. Desulphurisation of stack gases has been the subject of much research and pilot plant studies. It may provide an alternative method for large fuel consumers where a switch to a low-sulphur fuels may present technical and economical problems. However, progress in developing suitable flue-gas desulphurisation processes has been slow because of the magnitude and complexity of the problem. One main difficulty is the low SO_2 concentration of between 0.2 and 0.3% by volume of the large volume of stack gases causing the removal economically unfavourable.

Whichever method is used and however the technology is improved, the investment required on sulphur removal equipment will add substantially to capital expenditure. Operating cost will also increase, and because of these extra expenditures, management can be very reluctant to undertake SO_2 pollution control measures. Added to this, there is no obvious return on the extra investment (from the management's point of view) except from the sales of the recovered sulphur which is now experiencing a world slump.

While sulphur is by no means the only pollutant under attack, it is of the most significant. In the United States of America, several local authorities have already specified standards of sulphur content in the fuel oils. Thus several West Coast municipalities have placed a 0.5% maximum limit on heavy fuel oils. In New York City, the maximum limit is now set at 1 per cent. The State of New Jersey has set even more stringent rules. The maximum for Nos. 4,5 and 6 fuel oils is 0.3% and for No. 2 fuel oil is 0.2%.

In Western Europe, legislation to combat SO_2 emission has also been considered. Matters are most advanced perhaps in Sweden, where the State National Resources Board has a preliminary target of 1 per cent sulphur by 1975 and 0.5% by 1995. The curb on high sulphur fuels is also on in Japan. The Japanese Government has recently introduced legislation specifying permissible sulphur content of 1.0 to 1.5% in fuel oils. This is to be phased out in a number of years.

The adoption of increasingly strict clean air standards by consumer nations will inevitably increase demand for low sulphur fuels at the expenses of high sulphur fuels. This is likely to be reflected in price differentials, not only between low and high sulphur fuel oils but eventually also between sweet and sour crudes. High sulphur crude and fuel oils will inevitably be driven out of several of their presently most significant markets, unless they are sweetened or are priced sufficiently low to compensate for the cost of desulphurisation (or for the removal of SO_2 from the stack gases).

The fuel oils supplied by oil refineries in Singapore to the power stations and industries come in different grades and contain between 2.5 and 3.5% sulphur by weight. For supply to the ship bunkers, the sulphur content could be higher. There is no restriction on the sulphur content in fuel oils in Singapore. However, individual users of fuel oils sometime do specify maximum sulphur content in the supply contract.

ENGERY CONSUMPTION AND USAGE TRENDS IN SINGAPORE

The pattern of fuel oil consumption for the period 1963 to 1970 is shown in Fig. 1. These figures do not include the consumption in oil refineries. It can be seen that there was a gradual increase in the fuel oil consumption of about 44,000 tons per year in the power stations since 1963. Fuel oil consumption in the industries appeared to reach a fairly stagnant figure from 1963 to 1967. This was followed by a considerable increase from 1968 to 1970, which could be explained by the large increase in the number of industries in this period. Expansion in power station capacities and the industrial sector will cause the fuel oil consumption to increase correspondingly in future.

Fuel oil consumption in oil refineries has also showed marked increase since 1963. Total crude oil refining capacity increased from about 6,500 tons per day in 1963 to about 54,000 tons per day in 1971. At the end of 1973, the total capacity will be about 125,000 tons per day making Singapore the biggest refining centre in this part of the world. Fuel oil consumption in the oil refineries will increase correspondingly and in 1971, the consumption is about 111,200 tons. It can be seen that the oil refineries as a group and the public utilities are the main consumers of fuel oil. Together, they account for about 75% of the total fuel oil consumption.

Patterns of diesel oil, gasoline and kerosene consumptions are also shown in Fig. 1 for a comparison. Diesel oil consumption increased threefold from 1963 to 1970. It will continue to increase as more industries and diesel vehicles using diesel oil are added to the country. Gasoline consumption will continue to increase because of the ever increasing number of motor vehicles on the road. Kerosene consumption remained fairly constant during the period 1963 to 1970. The introduction of liquified petroleum gases (L.P.G.) and rural electrification schemes has perhaps prevented increase in kerosene consumption.

Increasing fuel oil consumption in power stations is associated with the increasing demands for electrial power for industrial, commercial, domestic and public uses. Total electrical power generations and consumptions for the period 1964 to 1967 are shown in Fig. 2. The total generation increased by about 20 per cent annually from 914.2 million kwt-hours in 1964 to 2,205.3 million kwt-hours in 1970. Total generation is always higher than the total consumption by about 14 per cent. Consumption in domestic sectors remained fairly constant at about 275 million kwt-hours during the period while consumption in public and private lighting increased steadily from 183.2 million kwt-hours in 1964 to 328.0 million kwt-hours in 1970. Consumption in industrial and commerical sectors showed the greatest increase at about 35% annually from 373.0 million kwt-hours in 1964 to 1,272.9 million kwt-hours in 1970.

SULPHUR DIOXIDE EMISSIONS

Sulphur dioxide emissions from the combustion of petroleum fuels can be estimated if the sulphur content in the fuel is known. One pound of sulphur in the fuel will give two pounds of SO_2 on combustion. The average sulphur per cent by weight in the petroleum fuels obtainable in Singapore can be taken as 3 for fuel oil, 0.4 for diesel oil, 0.2 for kerosene and 0.1 for gasoline.

Using these average values for the sulphur contents in the fuels, the SO_2 emissions are calculated for the years 1963 to 1970 and plotted in Fig. 3. These figures do not include the substantial emissions from oil refineries. The emissions trends follow those of the yearly fuel consumptions. Fuel oil combustion contributes most of the emissions (about 93 per cent) since the sulphur content in the fuel oil is much higher than that in other fuels. Total emission had more than doubled from 21,200 tons in 1963 to 52,700 tons in 1970.

The public utilities accounted for about 71% of the total SO_2 emissions from the combustion of petroleum fuels (excluding those burnt in oil refineries). The emissions from the combustion of fuel oil in oil refineries if added to the total emissions would account for about 12%. This figures should be much higher when the SO_2 emissions from the combustion of unrecovered sulphur after hydrodesulphurisation processes are added. The rapid increase in refining capacities would also cause the oil refineries to contribute more significantly to the total SO_2 emissions.

It has been estimated elsewhere [1] that SO_2 emissions account for about 30% of the total emissions of pollutants resulting from the combustion of petroleum fuels. This figure is second highest after carbon monoxide from motor vehicles. SO_2 in the atmosphere if known to have many adverse effects upon health and welfare, and therefore the reduction of emissions is of prime importance to any effective air pollution abat-

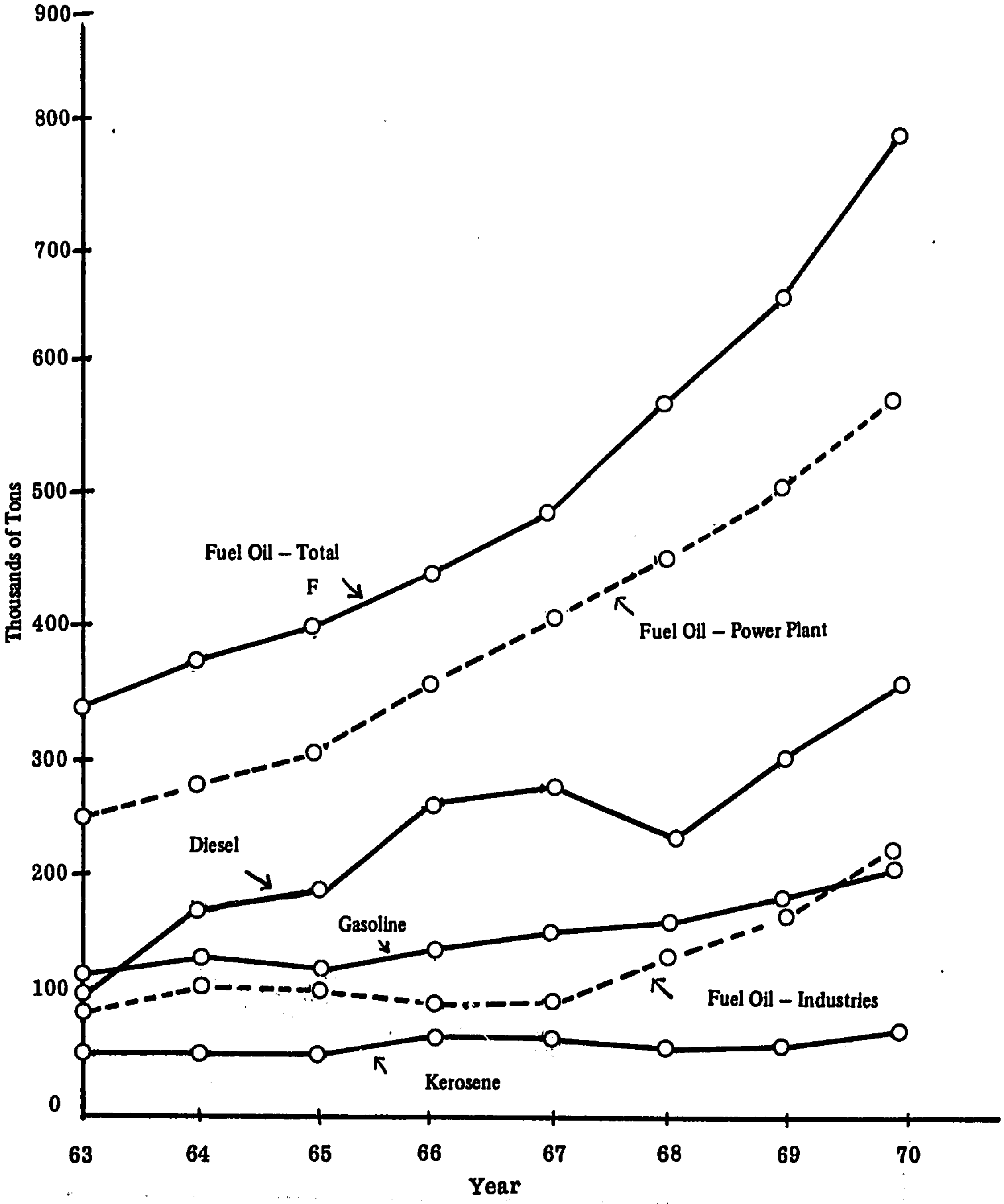

Fig. 1. Petroleum Fuel Consumptions in Singapore for the Period 1963 – 1970

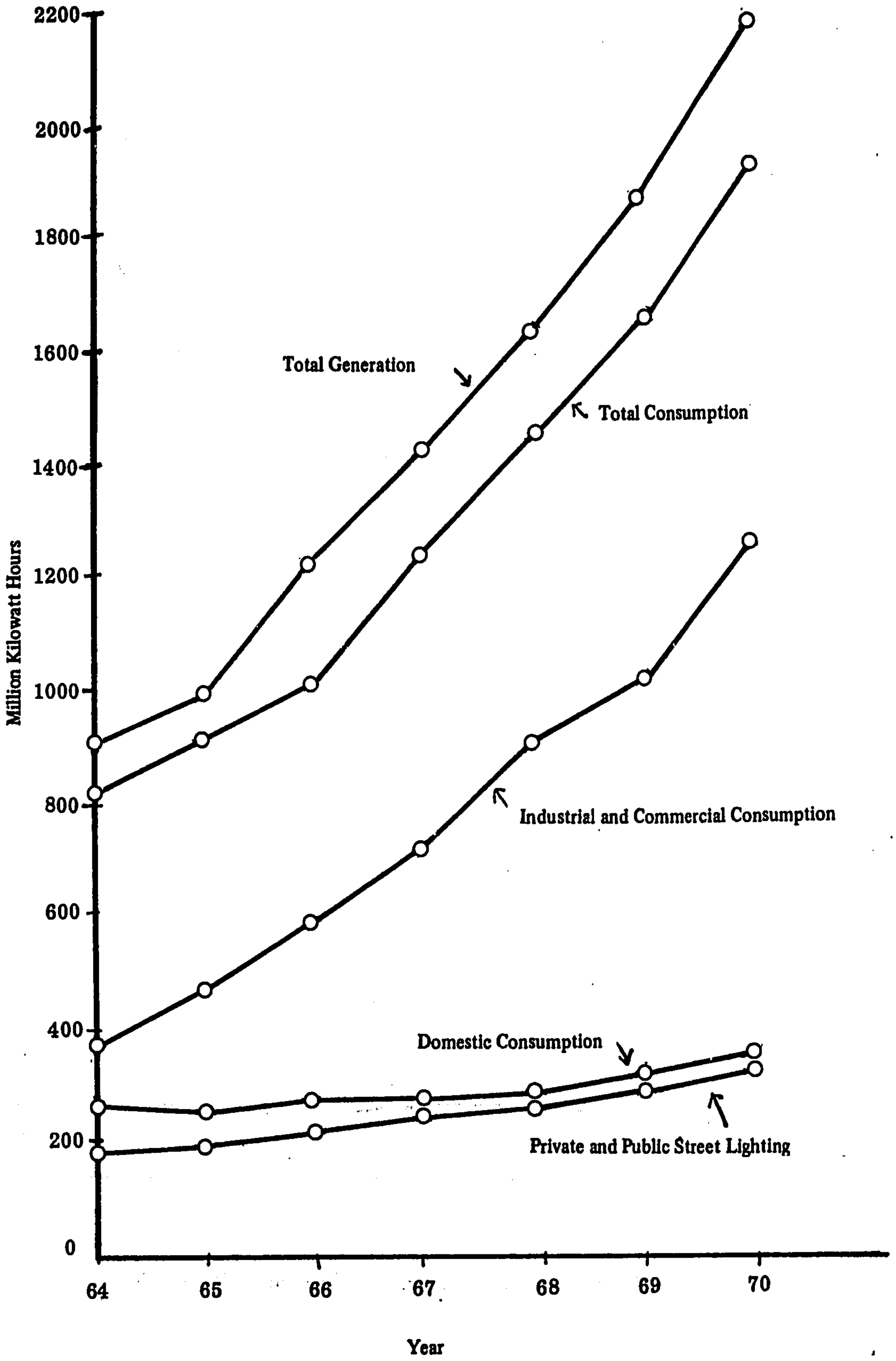

Fig. 2. Electricity Generation and Comsumption in Singapore for the Period 1964 – 1970

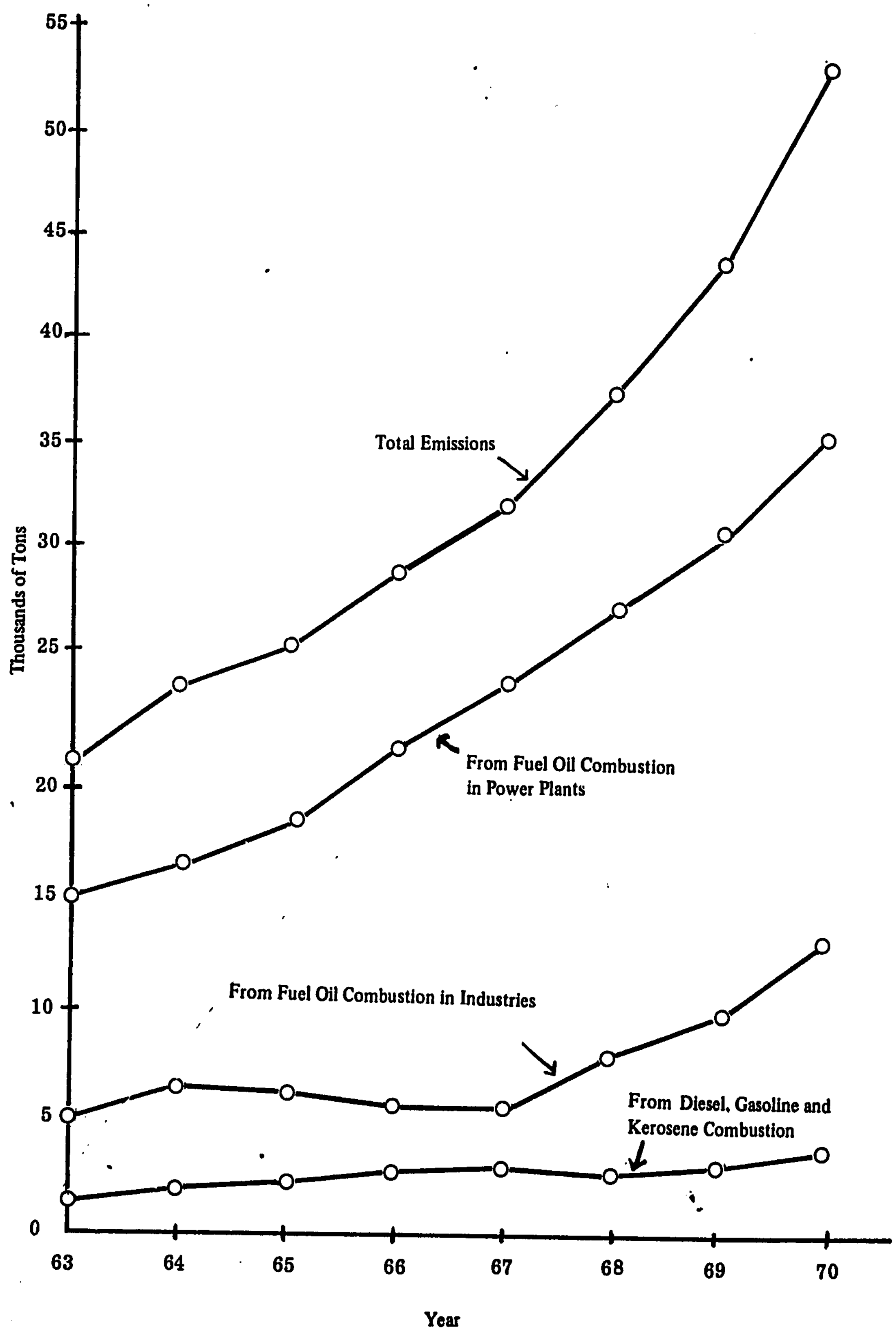

Fig. 3. SO_2 Emissions from Petroleum Fuel Combustion for the Period 1963 – 1970

ement programme.

AMBIENT SULPHUR DIOXIDE POLLUTION LEVEL

The absolute SO_2 emissions from the various sources do not reflect the relative significance to damage caused. Ambient air pollution levels depend on many factors such as rate of emissions, chimney height, and meteorological, climatic and topographical conditions surrounding the source of emissions. Measurements have been undertaken by the Government on the ground-level SO_2 concentration in the atmosphere since 1970. A total of 22 monitoring stations distributed in industrial, commercial and residential areas have been established. The hydrogen peroxide titrimetric method is used.

Results obtained so far show that the ambient SO_2 levels in Singapore are generally satisfactory compared to levels found in industrial cities in other countries. These are, however, sufficient indications that the general SO_2 level is on the increase and in the industrial areas like Jurong the local SO_2 level sometimes comes near to ambient air quality standards established in other countries. (U.S. Federal Government has established primary and secondary ambient air quality standards of 80 and 60 $\mu g/m^3$ – annual average respectively for SO_2. The State of California adopts a 24-hour mean value of 105 $\mu g/m^3$. In Tokyo, the yearly average of hourly value for SO_2 is set at 143 $\mu g/m^3$). Fig. 4 shows the trends of SO_2 levels taken over 3 areas. Generally, it can be seen that the SO_2 level in the industrial area is higher than in the commercial and residential areas.

Rainfalls and changes in the prevailing wind direction also affect the level of SO_2 recorded. High rainfalls in the late and early months of the year are found to be accompanied by an apparent decrease in SO_2 level. However, more data need to be collected over a longer period to derive at conclusions on the effects of climatic and meteorological conditions on the SO_2 level.

Chimney heights can influence significantly the ground-level SO_2 concentration too. The taller the chimney, the better is the dispersion of SO_2 into the atmosphere, thus reducing the ground-level concentration. In the commercial areas, the low level emissions from motor vehicles probably account for the considerably high SO_2 concentration recorded although the absolute load of emission is low. Nitrogen oxides from motor vehicles could also boost the SO_2 level recorded because the hydrogen peroxide method of measurement does not separate the two types of pollutants. In the industrial areas, SO_2 emissions through chimneys would give rise to lower ground-level SO_2 concentration despite the fact that most of the SO_2 is emitted in these areas.

CONCLUSIONS

Increasing public pressure for clean air will force more governments in the world to adopt stricter clean air standards. Limitations on sulphur contents in petroleum fuels will become more and more stringent and more countries will follow suit as the combustion of sulphur-bearing petroleum fuels is one of the principal sources of SO_2 pollution.

In Singapore, SO_2 emissions into the atmosphere will continue to increase as energy demand increases unless preventive measures are taken. The ground-level SO_2 concentration will also increase correspondingly. Emissions from power plants will continue to contribute a large percentage to the total emission. Expansion in the industrial sector especially the oil refineries will cause emissions from these sources to contribute more significantly to the SO_2 pollution.

At the present state of technology, desulphurisation of stack gases and of crude and fuel oils as emission control measures are very costly and economically unfavourable. This may not justify a switch to sweeter fuels or SO_2 removal from stack gases now. However, this has to be reviewed constantly taking into consideration that extensive research and pilot plant studies on desulphurisation processes are being conducted today. This may bring about some economic methods of sulphur removal.

Tall chimneys therefore appear to be an effective measure to abate the SO_2 pollution in Singapore for the time being. However, it must be noted that tall chimneys help only in the effective dispersion of pollutants so that the ground-level concentration is reduced. They do not reduce the absolute amount of SO_2 emitted. In oil refineries, besides tall chimneys, sulphur recovery must be expanded to reduce SO_2 emissions.

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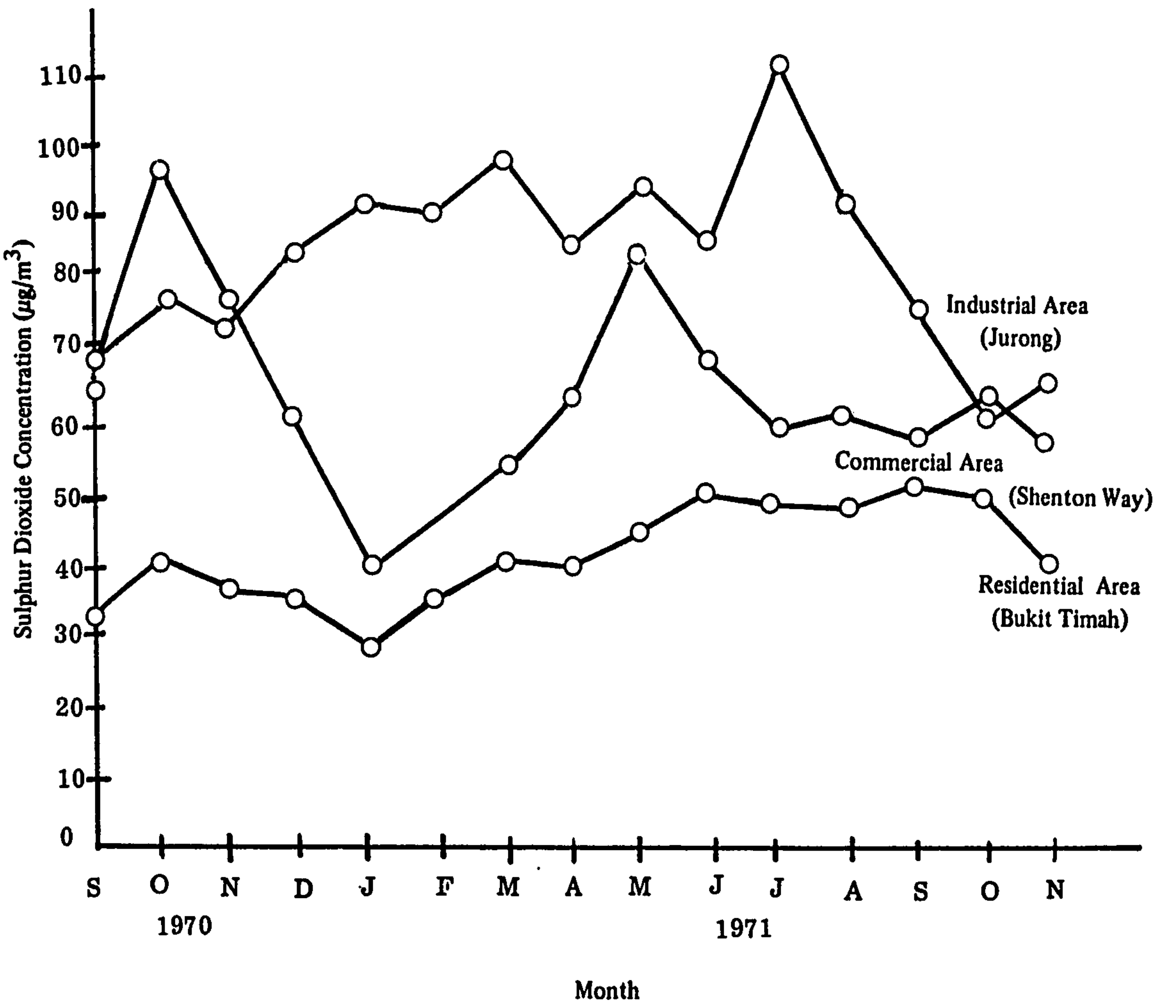

Fig. 4. Ground-Level Sulphur Dioxide Concentration in the Atmosphere

Public Utilities Board for providing some of the figures.

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Paper No. III/14

ENVIRONMENTAL CONTROL OF MARKETS AND HAWKERS

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ABSTRACT

The hawker population as it affects our environment and the need for their control and identification by the licensing in the short and long-term process.

Formulation of positive action to resite and license the hawkers at temporary open sites, as a form of 'holding action', and ultimately to house them permanently within buildings where proper sanitary facilities and anti-pollution measures are provided.

The deteriorating factor of the environment of major industrial cities has recently came into sharp focus and has aroused international interest and the concern of the governments. Singapore has not reached that point but nonetheless it must be our concern that our environment is kept clean as we enter into an accelerated phase of industrial development.

In order to set our goal for a pollution-free environment, we will require not only massive and unrelenting efforts by the Government but also from all quarters.

Hawkers by their vast numbers (24,845 hawkers) could, through their insanitary practices and neglect both in the markets and in the streets contribute and aggravate the pollution of our environment, if no positive preventive measures are formulated to control their very existence.

Their congregations not only present serious obstruction to the ever increasing volume of traffic but also make cleaning an expensive and near impossible task. The result is the accumulation of refuse and choked drains leading to a polluted environment. Their presence scattered in almost every street, footway and backlane present a 'blighty' sight to the scenic surroundings and defeats the very objective of making Singapore, a clean and pollution-free garden city.

In order that proper action can be formulated to prevent pollution, it is necessary to know the nature of pollutants that each type of hawker can produce. The Market Produce Hawkers for instance, by their very nature in trading, will result in vegetable wastes, poultry droppings, fish cuttings and other litter being left behind on the roads and invariably finds its way into our waterways and streams. The cooked food hawkers on the other hand, dump its food wastes and washings into the nearest roadside drain.

It is with this seemingly intractable problem in mind that an island-wide hawkers survey was carried out in December 1968. A paper setting out the difficulties and suggesting solutions was submitted to the Government which decided, inter alia, two courses of action to solve the hawkers problem. They are the "short-term" temporary and the "long-term" permanent solutions.

The short-term solution involves the conduct of "holding" operations by resiting and licensing hawkers at suitable temporary sites where they can be controlled and at the same time ensure that no new hawkers take the place of those resited. This exercise is being implemented where possible constituency by constituency. By virtue of resiting and licensing although on a temporary basis, the gap for the implementation of anti-pollution measure is bridged. The provision of washing areas connected to the sewers for use by the licensed hawkers is made possible at suitable convenient sites. The Environmental Public Health (Hawkers) Regulation and those sections of the Environmental Public Health Act relating to hawkers to ensure that the stall sites and surroundings are kept clean at all times are rigidly enforced. This exercise also serves the purpose of identification and to ensure that only bona-fide hawkers will be ultimately relocated into permanent premises.

The long-term solution involves Government decision to house all street hawkers in buildings within five years. The decision was implemented in the second quarter of 1971 with an initial provision of five million dollars provided for the construction of permanent hawkers centres and markets. Hawkers sites were selected in which projects for the construction of three new cooked food centres at Boat Quay, former Marine Police Station at Empress Place, Jurong Town and the conversion of Telok Ayer Market into a proper cooked food centre were approved. A new market/hawker centre was also approved for construction at North Bridge Road (Palembang Estate) where construction work had begun. All these projects and future planning will have, provided in the premises the necessary permanent anti-pollution measures which are enumerated as follows:

(1) The floorings of markets and cooked food centres are recessed to a minimum of 2 ins below the external ground level and graded towards the sullage drains and or washing areas.

(2) All sullage drains are made to discharge into the sewer. Open storm water drains are to be designed and constructed to the satisfaction of the Public Health Engineering Branch and or the Public Works Department.

(3) Individual or common washing area is provided within the stall unit for cooked food stalls. The wash area is to be recessed 3 ins below the floor level of the stall and covered eating area. It is tiled and connected to the sewer.

(4) Sanitary accommodation is provided in accordance with the Sanitary Accommodation Requirements.

(5) A covered bin centre is provided in accordance with the requirements of the Public Cleansing Department among which are the recessing of the floor level below external ground level and connected to sewer.

In connection with the Garden City Campaign and a step towards the Keep Singapore Clean & Pollution-Free, three congregations of street hawkers at Newton Circus, Dunearn Road, and Bedok Road have been removed into new hawkers centres where proper sanitary facilities including anti-pollution measures are provided. In addition these centres are landscaped to cater for a healthy and pollution free environment. Another such project which is nearing completion will be utilised to accomodate the street hawkers in Serangoon Garden Bus Bay.

Existing Government and private markets are also being spruced up incorporating among other improvements, anti-pollution measures which include the connection of all sullage drains carrying discharges of liquid wastes into the sewers.

Another long-term measure in the field of pollution control is the Stamford Canal Catchment area pilot project where wash areas connected to the sewers have been constructed for the use of street hawkers at Stamford Road backlane, Cuppage Road vacant land, St. Gregory's backlane, Hock Lam Street/Chin Nam Street, Exeter Road and Killiney Road backlanes. The three markets in the area, Orchard Road, Killiney and Grange Road have also been provided with adequate wash areas and connection of all sullage drains into the sewer.

The whole context of environmental control of markets and hawkers within our Republic must be one of a primary function which can be summarised as: firstly, the resettlement of unaccommodated street hawkers under the short-term solution and holding them until the required accommodation is available. Secondly, under the long-term solution, the physical construction of markets and hawkers centres in adequate numbers at strategic locations must be undertaken under the five-year plan.

In conclusion there is no doubt that Government's decision to implement the short-term and long-term solutions will be the answer to the hawkers problem and with proper planning, construction, control and management it will also be the ultimate solution to attaining a pollution-free Singapore and thus progress a step further towards a better environment.

Paper No. III/15

DISPOSAL OF REFUSE IN AN URBAN ENVIRONMENT

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ABSTRACT

The present refuse production rate in Singapore is about 1.48 pounds per capita per day and is increasing at a rate of 2% per annum as a result of rapid industrialization and urbanisation. With limited land area, traditional sanitary landfill method is clearly not the solution for refuse disposal in Singapore. Other refuse treatment techniques which will give maximum reduction in the refuse volume for final disposal will have to be adopted. There is an urgent need to appreciate the requirement for adequate land reservation and land allocation for refuse treatment plants and the final disposal ground, to receive, treat and finally dispose of the solid wastes from a community.

(Abstracted by Chin Kee Kean)

INTRODUCTION

The indiscriminate discharge of various wastes from the community has caused pollution of the environment. The more urbanised, industrialised and affluent the community, the more the quantities of such wastes.

The efforts of most Public Health Authorities, in environmental control and conservation, however, have tended to be concentrated on the control of liquid and gaseous wastes. Although it is realised that inadequate refuse collection service in urban areas has caused piles of rotting, stinking refuse to accumulate; and improper refuse disposal facilities have blighted the landscape with refuse dumps; affronting the aesthetic sense, polluting the atmosphere when they burn, fouling water resources, and causing a health hazard, yet in environmental control work, very little emphasis has been placed on solid wastes management generally, and solid wastes disposal in particular.

There appears to be less glamour in solid wastes management when compared with other forms of environmental control activities, with observable paucity in practical research and development in solid waste management. There is marked reluctance by financial authorities to allocate adequate funds for refuse collection equipment and to build proper refuse disposal plants. While planning authorities realise there is a need for adequate and proper refuse disposal facilities, there is hesitancy when considering land usage to reserve and apportion land for such refuse disposal purposes, especially when there are competing demands for land in similar locations for other development projects.

It has to be appreciated that pollution of the environment from liquid and gaseous wastes is mainly attributable to industrial establishments. But solid wastes are produced everyday by every member of the community; man, woman and child. Such solid wastes have to be collected and disposed everyday. While public opinion may grouse against a poor refuse collection service, there is little public information and much less public criticism of inadequate refuse disposal facilities and their polluting effects on the environment.

QUANTITIES OF REFUSE

The present refuse production rate in the United Kingdom is about 1.7 lbs/capita/day, while in the greater London Council, it is about 2.2 lbs/capita/day. This refuse is mainly domestic refuse, but does contain a small amount of trade wastes which have been collected during the usual refuse collection service; but it is expected that this trade waste does not exceed 20%. In England, the rate of increase of refuse production has been found to be about 1% per annum, and it is estimated that by 1980 the refuse in the UK will be about 2 lbs/capita/day.

In the USA, refuse is usually taken to include some garbage refuse and a small amount of industrial solid wastes as well; and the refuse production rate per capita per day is about 4.5 pounds. By 1980 it is likely that this refuse production will be about 5.5 lbs/day. In both the UK and the US, it is important to note that there is a definite upward trend in the rate of refuse production. In conjunction with natural population increase, the total amount of solid wastes produced by any community will be correspondingly larger in the future.

The conditions in Singapore are very similar. Present refuse production rate is about 1.48 lbs/capita/day. It is estimated that the refuse production rate will be increasing at about 2% per annum due to the rapid rate of industrialisation and urbanisation at the moment, and by 1980 the refuse production rate will be about 1.86 lbs/capita/day. Taking the context of Singapore with a rate of population increase of 1.5% per annum, the total refuse production in tons per day for 1972 will be about 1,470 tons/day and this will increase to 1,975 tons/day by 1980. (see Table 1)

It is also to be noted that refuse over the last ten years has changed very markedly in composition due to the use of more wrappers, cartons and other packaging materials for the wrapping up of various goods and merchandise for sale. There is a tremendous increase in the use of various types of paper, paper cartons, plastics and other containers made of paper or plastic materials. Such wrapping material being very bulky and light has affected the density and consequently the volume of refuse being produced.

REFUSE TREATMENT METHODS

Due to the light and bulky nature of refuse, its direct disposal on to the land will require immense areas. Some form of treatment is usually necessary to reduce such space requirement, so as to conserve available land area within reasonable haulage distance from the refuse producing centtres for refuse disposal. Such treatment processes to reduce the volume of refuse for final disposal are becoming increasingly important as urban areas become more and more developed, with rapidly diminishing waste land remaining for refuse disposal. Brief outlines of available refuse treatment processes with capacity for volume reduction are discussed below.

Incineration

Modern incinerators for the treatment of urban refuse are clean and highly mechanised. Refuse is mechanically fed into the furnace, fitted with moving grates. There is automatic stoking of the burning material, and ash is discharged into a water-sealed pit. As the furnaces need not be opened for refuse charging, stoking, or ash removal, there is complete control of the combustion process, air requirements, and furnace temperature, thus ensuring almost complete combustion of the burnable material without smoke emission.

In conjunction with various types of gas cleaning equipment like centrifugal separators, liquid scrubbers, and electrostatic precipitators, grit, dust and other particulate matters are effectively removed. The resultant effluent gases comply with clean air regulations and there is, therefore, no air pollution problem.

The weight of the remaining ash is usually about 25% of the weight of the incoming refuse, while the volume has been reduced to about 10% of the incoming refuse. Refuse incineration is thus the most effective method for volume reduction available at the moment.

Pulverisation

Pulverisation of the refuse in hammer-mills, or shredding machines will cut up the refuse into very small pieces, causing thorough mixing, and changing of the refuse into a more homogeneous and less offensive mass, which is no more attractive to insects, rodents and other vermin. The resultant pulverised material is reduced to about one third the volume of the incoming refuse.

Compaction into High-Density Bales

Refuse is compressed and compacted into high-density bales in huge hydraulic presses. The resultant bales measure about 1 metre cube in size and weighs about a ton or more per bale. The volume has been reduced to about 1 : 7 or 1 : 8 the volume of the incoming refuse, with a density of about 1.2 or more. There is no spring back in this high-density refuse bale. When wrapped in chicken wire-mesh and coated with a layer of bitumen, the bales are easily transportable and can be used as filling material in land or sea reclamation. This technique originated in Japan, and it is claimed that there is negligible decomposition of the refuse in such high-density bales wrapped in chicken wire-mesh and coated with asphalt.

Composting

The aerobic fermentation of refuse under optimum conditions in enclosed housing, with secondary seasoning in the open, can produce good quality compost. There is a volume reduction of about 1 : 2 to 1 : 3.

Re-cycling of Refuse

Although there is recovery of ferrous metals from the ash and clinker after incineration, and from the rejects of the composting process, the refuse treatment techniques mentioned above do not extract other items of reusable material for re-cycling. Any reusable item in refuse that is not salvaged for re-cycling will increase the space requirement in the final disposal of the refuse. Also, if raw materials have to be imported, then it is also economically justifiable to re-cycle various items for reuse.

But the traditional method of hand-sorting in such salvaging or recovery process for re-cycling is both insanitary and repugnant. Newer methods of separation by mechanical means, for example by air classification of mixed pulverised refuse, should be looked into. Depending on the amount of material recovered for re-cycling, there will be a corresponding reduction in the remaining amount of solid waste for final disposal.

LAND REQUIREMENT FOR THE FINAL DISPOSAL OF REFUSE

Whatever the process of refuse treatment used, there is still the resultant material to be disposed off; e.g. the ash and clinker after incineration; the rejects from the composting plant (assuming that all compost is sold for soil conditioning, otherwise finished compost may have to be dumped away as well); the pulverised refuse; and the compacted high-density bales.

Disregarding the possibility of dumping refuse into the sea, either in its crude state or after treatment, because of the obvious pollution load and the effects on the ecological conditions in the sea around where such refuse is dumped, it is necessary that final disposal of solid wastes will be on to the land.

In the case of crude refuse, the disposal on land will be by controlled tipping or sanitary landfill. It is necessary that this be properly planned to avoid leachate from polluting nearby water courses, and to ensure proper landscaping and development of the completed sanitary landfill area into parks, playground, golf courses and similar social amenities. The volume reduction factor for sanitary landfill is about 1 : 3.

As an illustration of the land requirement for final disposal of refuse, for a population of 100,000 people and a refuse production rate of 2.0 lbs/capita/day, the land requirement for final disposal by sanitary landfill will be about 6.83 acres per year. The corresponding land requirements for the other refuse treatment processes are shown in Table 3.

In Singapore, a variation of the traditional sanitary landfill method is used. The refuse is disposed of in three successive layers, each about 10 ft deep, giving a total depth of fill of about 30ft. Even so, the land requirement is at the rate of 1 acre per annum for every refuse load of 65 tons/day. For 1972 for example, the refuse load is about 1,471 tons/day, and the land area required for final refuse disposal is about 26.8 acres. With a rising per capita refuse production rate of about 2% per annum, and the population increasing at the rate of 1.5% per annum, the refuse load in 1980 for an estimated population of 2.376 millions will be about 1,975 tons/day. This will require a land area of 37 acres for final refuse disposal. Thus the estimated cumulative total of land area required up to 1980 will be about 291.8 acres. Table 4.

Clearly such an immense area of land required for refuse disposal by sanitary landfill for this short period of 9 years (1972-1980) is unacceptable in the context of Singapore, where maximum use of the limited land area is of primary economic importance. Other refuse treatment techniques which will give maximum reduction in the refuse volume for final disposal will have to be adopted. Refuse incineration and refuse compaction into high-density bales are the only acceptable alternatives.

CONCLUSION

The proper treatment and disposal of solid wastes from a community in preventing environmental pollution is no less important than the need for treatment and control measures in respect of gaseous and liquid wastes from industrial premises.

In the planning and consideration of land usage, competing demands of land for other economic development projects notwithstanding, there is therefore an urgent need to appreciate the requirement for adequate land reservation and land allocation for refuse treatment plants and the final refuse disposal ground to receive, treat and finally dispose of the solid wastes from a community.

Year	Population	Refuse Production Tons/Day	Per Capita Refuse Load	Increment	% Increase
1965	1,864,900	604	0.727	–	–
1966	1,913,500	614	0.719	–	–
1967	1,955,600	846	0.97	0.251	35%
1968	1,987,900	1100	1.24	0.27	27.9%
1969	2,016,800	1131	1.26	0.02	1.6%
1970	2,047,000	1259	1.38	0.12	9.5%
1971	2,078,000	1375	1.48	0.10	7.25%
1972	2,109,000	1471	1.56	0.08	5.4%
1973	2,141,000	1545	1.62	0.06	4.0%
1974	2,173,000	1620	1.67	0.05	3.0%
1975	2,205,000	1685	1.71	0.04	2.4%
1976	2,238,000	1740	1.74	0.03	2.0%
1977	2,272,000	1800	1.77	0.03	2.0%
1978	2,306,000	1853	1.80	0.03	2.0%
1979	2,341,000	1914	1.83	0.03	2.0%
1980	2,376,000	1975	1.86	0.04	2.0%

Table 1. Projection of Refuse Production in Singapore Based on Daily Average Refuse Production

Notes:

(1) Rate of Population Increase assumed as 1.5% per annum

(2) Rate of increase of per capita refuse load is assumed to taper off from the present 7.25% (1971) to 2.0% in 1976 and thereafter a constant increase of 2.0% per annum.

Type of Refuse Treatment Process	Volume Reduction Factor	Reduced Volume for Disposal (cu ft)	Land Area Required – Assuming 10 ft. Depth of Refuse (sq ft)
1. Crude refuse	1	270	27
2. Refuse dumping	1 : 2	135	13.5
3. Controlled tipping (sanitary landfill)	1 : 3	90	9
4. Controlled tipping with pulverised refuse	1 : 5	54	5.4
5. High-density compacted bales	1 : 7	39	3.9
6. Incinerator ash & residue	1 : 10	27	2.7

Table 2. Space Requirement of One Ton of Refuse after Various Refuse Treatment Processes

Note: Refuse is assumed to weigh about 225 lbs per cu yd or approximately 10 cu yds to a ton.

Type of Refuse Treatment Process	Land Area Required in Acres					
	Refuse Load lbs/capita/day					
	1.5	2.0	2.5	3.0	3.5	4.0
1. Crude refuse	15.4	20.5	25.6	30.7	35.8	41.0
2. Refuse dumping	7.7	10.25	12.8	15.3	17.9	20.5
3. Controlled tipping (sanitary landfill)	5.13	6.83	8.54	10.2	11.9	13.7
4. Controlled tipping with pulverised refuse	3.08	4.10	5.12	6.15	7.17	8.2
5. High-density compacted bales	2.2	2.93	3.66	4.39	5.12	5.86
6. Incinerator ash & residue		2.05	2.56	3.07	3.58	4.10

Table 3. Area of Land Required Per Annum for Refuse Disposal from a Population of 100,000 People

Note:

(1) Refuse is assumed to weigh about 225 lbs per cu yd or approximately 10 cu yds to one ton.
(2) Depth of refuse filling is assumed to be 10 ft.

Year	Population	Refuse Production tons/day	Land Area Required at Rate of 1 acre/ annum for 65 tons/ day of Refuse Load	Cumulative Total
1972	2.109 millions	1471 tons	26.8 acres	26.8
1973	2.141 millions	1545 tons	29.1 acres	55.9
1974	2.173 millions	1620 tons	30.3 acres	86.2
1975	2.205 millions	1685 tons	31.5 acres	117.7
1976	2.238 millions	1740 tons	32.8 acres	150.5
1977	2.272 millions	1800 tons	33.7 acres	184.2
1978	2.306 millions	1853 tons	34.7 acres	218.9
1979	2.341 millions	1914 tons	35.9 acres	254.8
1980	2.376 millions	1975 tons	37.0 acres	291.8
Total land area required for period 1972 to 1980			291.8 acres	

Table 4. Refuse Disposal – Singapore Estimated Swampland Requirement for the Disposal of Refuse by Dumping

Note: Refuse is disposed off in 3 successive layers, each about 10 ft thick, giving a total depth of fill of about 30 ft.

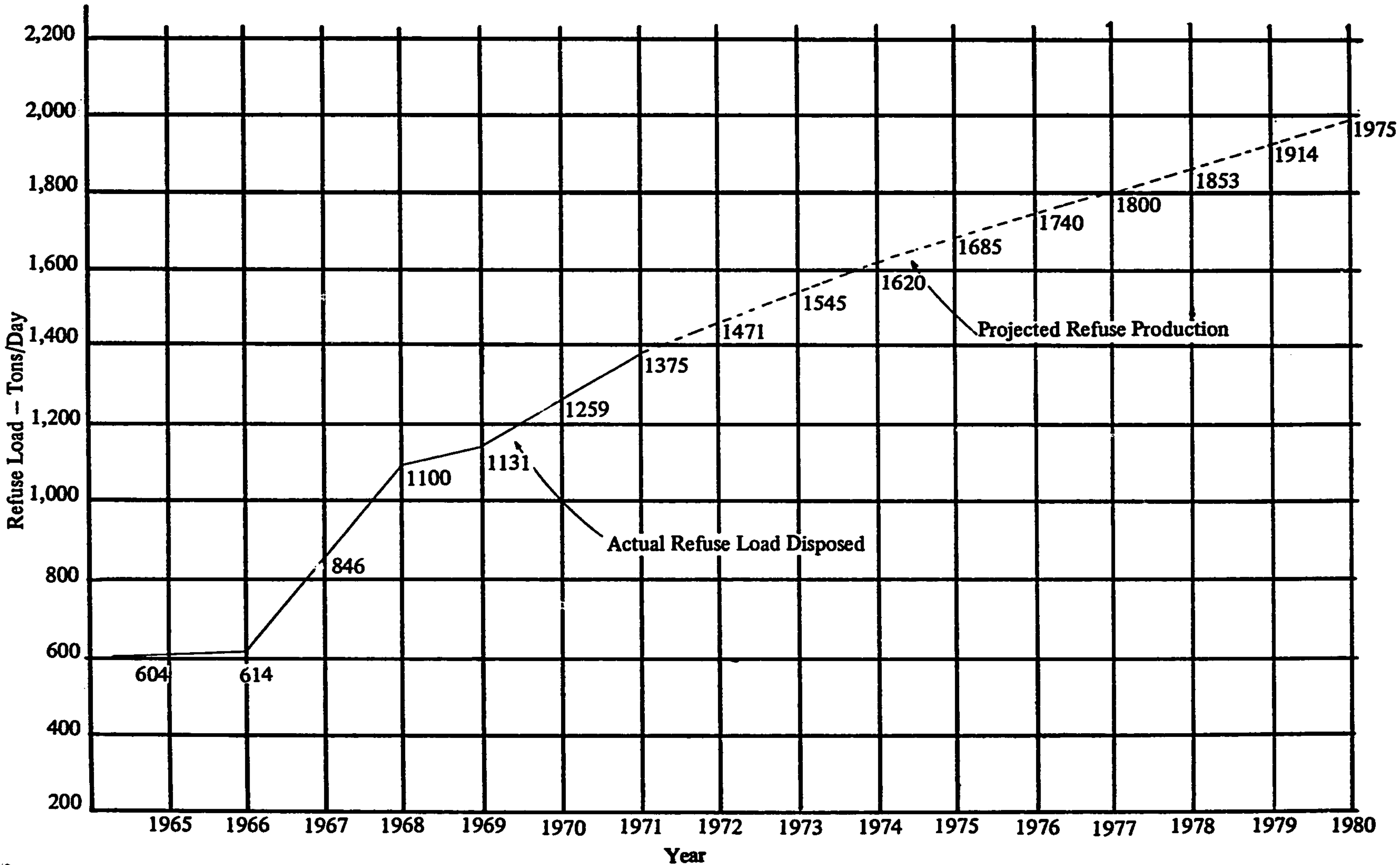

Fig. 1 Average Tonnage of Refuse Produced Per Day and Disposed at Refuse Disposal Grounds

Paper No. III/19

ENVIRONMENTAL HEALTH PROBLEMS AND CONTROL IN THE PHILIPPINES

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ABSTRACT

Adverse geographical conditions in the Philippines make provisions for the health of the people difficult. Furthermore, aggravations from rapid industrialisation, urbanisation and high growth rate of population increase environmental health problems. This calls for concerted action by a well coordinated Department of Health in planning on a long-term basis to eradicate these problems.

(Abstracted by Chan Joo Phek)

THE PHYSICAL AND GEOGRAPHICAL AREA

The Philippines located in the Western Pacific comprise of 7,100 islands with a total land area of 299,404 km^2 and only one third inhabited (lakes included). Eleven large islands make up more than 90% of this area and only 45 islands have areas greater than 100 km^2, the largest being Luzon in the north and the second largest, Mindanao in the south. They are bounded on the east by the Pacific Ocean, on the south by the Celebes Sea and the coastal waters of Borneo and on the west and north by the China Sea which separates them from the Asiatic mainland.

The islands have a total coastline of 17,460 km in length with many navigable bays and gulfs. The territorial waters are estimated to cover an area of 11 ⅔ million km^2. There are about 6,070 km^2 of fresh and brackish water swamps. A total of 85 lakes contribute 1,994 km^2 more of inland water, in addition to about 1,100 rivers and creeks.

CLIMATE AND WEATHER

The position of the islands gives rise to marked variations in weather conditions in different regions of the Philippines. Temperature and rainfall are considered as the climatic elements of greatest importance. Because of the high temperature and the heavy rainfall, the Philippine climate has been classified as fundamentally tropical and marine, of the monsoon variety. It is characterized by continuous heat and abundant rainfall, uniformly high relative humidity, moderate cloudiness, and normally gentle winds which are periodically disturbed by the frequency, position and intensity of passing tropical storms. The normal annual average rainfall of 50 weather stations varies from 1,087.4 mm a year with 12 to 18 rainy days a month from May to November. A rainy day is one with 0.01 inch or more of rain. Based on rainfall, the dry season is from December to April and the wet season from May to November.

The winds are normally light to moderate and speeds of 45 km/hr are very rare except during the tropical storms. Three general air streams govern the climatic pattern and divide the year into three seasons. The Southwest Monsoon causes a cloudy and rainy season from June to October. The Northeast Monsoon causes generally cool and dry weather from November to March, and the trade wind which dominates the air pattern during April and May is moderate in force and the least moist of the 3 air streams.

The population in 1971 is 38 million with a population increase of about 3.2% annually. It is estimated that 75% of the population lives in rural areas and are engaged in some form of agricultural activities. The very hard geographical conditions with formidable difficulties of land and water transportation has made it hard to provide adequately for the health, and environmental health control, and improvement needs. This situation called it necessary for regionalizing the activities of the Department of Health.

Today this Department provides their services to the people of the Philippines through 8 Regional Health Offices which are responsible for 66 Provincial Health Units and exercising control over 1,500 municipalities and 61 cities.

THE ENVIRONMENTAL HEALTH

The existing environmental sanitation condition is poor. The rapid growth of population estimated to be 3.1% yearly, the continuing favourable trend towards industrialization, trade and marketing are making the existing situation worse with the wide-ranging hazards to health of environmental degradation. Rapid and uncontrolled urbanization and the increased mobility of the population result in changes of social patterns which cause the re-appearance of cholera epidemics and the resurgence of filth associated diseases.

The exposure of man to a constantly growing number of environmental influences, requires increased attention to health consequences of the lack of environmental sanitation and of the changes in the environment that will require new programmes, attitudes and policies for environmental control.

CRITICAL PROBLEMS IN THE ADMINISTRATION OF ENVIRONMENTAL HEALTH SERVICES

It is better to discuss first the institutions and environmental health services provided in the overall organizational set-up of the Department of Health assigned to environmental control for the improvement of health through preventives and corrective measures.

First, with the policy of decentralization of the Department of Health, the Philippines was divided into 8 Regional Health Offices with their own Regional Health directors and staffs. (See Appendices 1, 2).

We have a division of Environmental Sanitation in the Bureau of Health Services, one of the 5 bureaus of the Department of Health with no line authority down to the 8 Regional, 66 Provincial and 61 City Health Offices. The functions of the Division of Environmental Sanitation are defined to be more advisory in nature like that of its mother bureau. There is no line authority from the Division of Environmental Sanitation down towards the environmental sanitation staff in the progressively decentralized regional, provincial, city and municipal levels. There is no close contact with the field staffs so much so that it does not facilitate consultation and acceleration on the implementation of sanitation and environmental health programmes prepared at the central office.

There is indeed official communication gaps between the Chief Sanitary Engineer and 5 Sanitary Engineering Advisers at the Central Office in Manila with the 52 Environmental Sanitation Engineers at the Regional and Provincial Offices. Worse still is the fact that the 2,624 Sanitary Inspectors assigned under the Municipal and Rural Medical Officers of Health Units work independently of the Sanitary Engineers.

Mention may be made of the proliferation of units dealing with other environmental health problems connected with malaria and schistosomiasis control programmes and the Stream and Air Pollution Control Units involving the split down of the services of some 35 well trained Sanitary Engineers.

Due to administrative gaps between the 82 Sanitary Engineers and the army of 2,624 Sanitary Inspectors, all are expected to work on environmental health problems, Sanitary Engineers have to perform other duties for which well-trained Sanitary Inspectors would be equally suitable to do the job.

Brought about by this system of independent activities of the units mentioned, is the difficulty to get the real state of affairs, in as much as there is no obligatory and standardized reporting system. The unavailability and inadequacy of basic data of the existing problems and performance from the field lead to failure to use data in programming, planning and evaluation of specific programmes already introduced.

The facts narrated above may just as well be termed critical problems in the administration of Environmental Health Services in the Department of Health.

THE NEED FOR LONG-TERM PROGRAMMES ON ENVIRONMENTAL HEALTH

The Department of Health, through the Division of Environmental Sanitation of the Bureau of Health Services provides basic sanitary measures with the aim of giving essential environmental sanitation for the prevention and control of communicable diseases and promote physical, mental and social well-being. The scope of activities on environmental health in the central office in Manila, at the regional, city and provincial levels has been devoted during the last few years on problems of environmental sanitation. Due to inadequacy of technical facilities, trained personnel and financial support from the regular budget, there is no marked improvement or significant indications of reductions on the cases and deaths on poor-environmental-health condition-associated diseases. (See Appendix 3). The major activities and services provided by the Department of Health as reflected in its regular budget are directed against communicable diseases from medical and curative aspects and less are directed on environmental control. Other agencies of the national government are however involved in coping with other problems of the human environment that of stream and air pollution, housing and planning projects, water and sewerage projects. The Division of Environmental Sanitation is getting involved on these environmental activities just mentioned above with other national government agencies through close coordination and cooperation, by establishing inter-agency committees for the purpose of attaining unified efforts on the implementation of common programmes.

The Department of Health through the Division of Environmental Sanitation has so far initiated the following environmental programmes to cope with the critical problems of the environment.

National Rural Community Water Supply Programmes - (See Appendices 4 & 5).

To provide safe and adequate water supplies to 80% of the population with emphasis on the rural areas where 70% of the 37,000,000 population live.

The programme calls for the organization of an Inter-Agency Executive Committee to carry on the unified efforts on planning and coordination of work of various agencies involved in rural water supply.

Water Quality Control Programme (See Appendix 6)

To minimize and prevent the occurrence and outbreak of water-borne diseases, by controlling water quality of existing water supplies and water resources to comply with National Drinking Water Standards.

80% of our 37,000,000 population still get their water supply from sources of questionable quality. This programme calls for sustained surveillance of water quality.

Action Programme for Community Development Project on Environmental Sanitation - (See Appendix 7)

To provide basic sanitary measures to communities for the promotion of environmental sanitation.

This programme covers the improvement of the community water supply, excreta disposal, liquid and solid waste disposal and promotes improvement of the sanitary quality of the environment. The significant feature of this programme is the involvement of the people of the community on the implementation.

Sewage Disposal by Means of Waste Stabilization Ponds in Sub-Urban and Urban Areas - (See Appendix 8).

To construct and develop pilot demonstration waste stabilization ponds and to make studies and researches for the determination of Philippines design criteria and performance.

This programme will play an important role in the prevention of gastro-intestinal infections such as cholera, typhoid and dysentery and will minimize the problems of stream and land pollution.

The implementation and planning of the programme will need the cooperation of other government agencies by way of organizing a National Inter-Agency Committee with members coming from various national institutions dealing on housing, sewerage and pollution controls.

Mosquito and Fly Control Programme (See Appendix 9)

A programme on the elimination of mosquitoes and flies was prepared with emphasis on the involvement of the people in communities. This is one phase of environmental control work so much neglected on city and municipal level. Most City and Municipal Health Offices have not provided personnel, equipment nor funds in their regular budget appropriations to cope with this critical problem of the environment. Among the salient points emphasized in the implementation of the programme are:

1) The programme must be a continuing project throughout the year.

2) That the operation must have full coverage of the area.

3) Identification of the respective role of activities of the community and that of the government.

4) The need for technical coordination and proper timing of activities by all participating entities.

5) Outline of the plan of action into separate phases and measures to be undertaken.

OTHER CRITICIAL PROBLEMS OF THE ENVIRONMENT

As pointed out earlier in this paper, there are various specialized governmental agencies, under their own respective mandates, engage in activities related to problems on human environment.

Among them are: - housing and resettlement, sewerage, community planning, and stream and air pollution. These agencies perform their duties, no doubt, for the benefit of the public and environmental health. The writer can however see possibilities for the good of the service by involving environmental health experts of the Department of Health in the determination of priorities and allocation of resources to the environmental health aspects. The Division of Environmental Sanitation, Regional, Provincial and City Sanitary Engineers are not involved in those activities and more often than not, they are called for assistance after the problems are already created.

POLLUTION OF WATER, AIR AND SOIL

It is not intended, in this paper, to discuss at length the wide range of factors that will protect man from natural or man-made hazards which surround him, like pollution of water, air and soil, excessive noise and extremes of temperature. Only those aspects which relate to the transmission of filth associated diseases have been discussed with appropriate environmental health programmes.

A National Water and Air Pollution Control Commission was constituted since 1964 given the responsibility to maintain reasonable standards of purity for the waters and air of the Philippines. The present state of pollution of the environment in our urban areas is brought about by industrialization, rapid population growth, urbanization and the increasing use of motor vehicles.

Water pollution comes from the general public and industry, most of which discharge their liquid waste into bodies of water without any treatment.

Air pollution comes mostly from internal combustion engines on land, sea and air transports and industrial plants.

The Department of Health has its own Stream and Air Pollution Control Units. Since the creation of the National Water and Air Pollution Control Commission, the agency of the Department of Health has been coordinating its activities with that of the Commission.

FOOD SANITATION

The critical problems on food sanitation, low sanitary standards in food establishment, and the lack of essential sanitary facilities has contributed to illnesses due to unhygienic food practices and food poisoning.

A Food Sanitation Project was organized in 1964 in the Bureau of Health Services by mutual agreement between the World Health Organization and the Department of Health.

The objectives are (1) to reduce incidence of food-borne diseases (2) develop policies and methods of control of food productions, transport, storage and service of food and drinks (3) training of personnel on food-sanitation and plan educational programmes in food handling.

With the assistance of a WHO consultant on Food Hygiene, the Division of Environmental Sanitation was able to formulate new laws and regulations and the printing of a manual on Food Hygiene Regulations.

SOLID WASTE MANAGEMENT

The current solid waste management and practices in the 61 cities and some 100 big capital towns or municipalities of the country are quite inadequate and well below by modern standards. Inadequate number of collection vehicles, and insufficient findings by city and municipal governments result in conditions hazardous to the public health and productive of nuisances. The rapid growth of urbanization complicates the problems beyond local capabilities. The particular case of the Manila Metropolitan Area comprised of 4 adjoining big populous cities and 9 contiguous municipalities needs participation of the National Government. In the Metropolitan Manila Area, there is divided responsibilities and authority in the administration of solid waste collection and disposal as well as the allied fields for street cleaning and market sanitation.

The deficiencies noted are as follows:

(1) General practice of final disposal by open dumping and burning, a method condemned by public health authorities.

(2) Insufficient, inadequate and use of open collection garbage trucks resulting to unreliable, irregular, inefficient and inadequate collection.

After many years of study and with the help of WHO consultants, the writer of this paper finally was able to put up a draft of a proposed Act of the Philippine Congress to create a Solid

Waste Management Authority.

THE NEED FOR A NATIONAL ENVIRONMENTAL HEALTH CODE

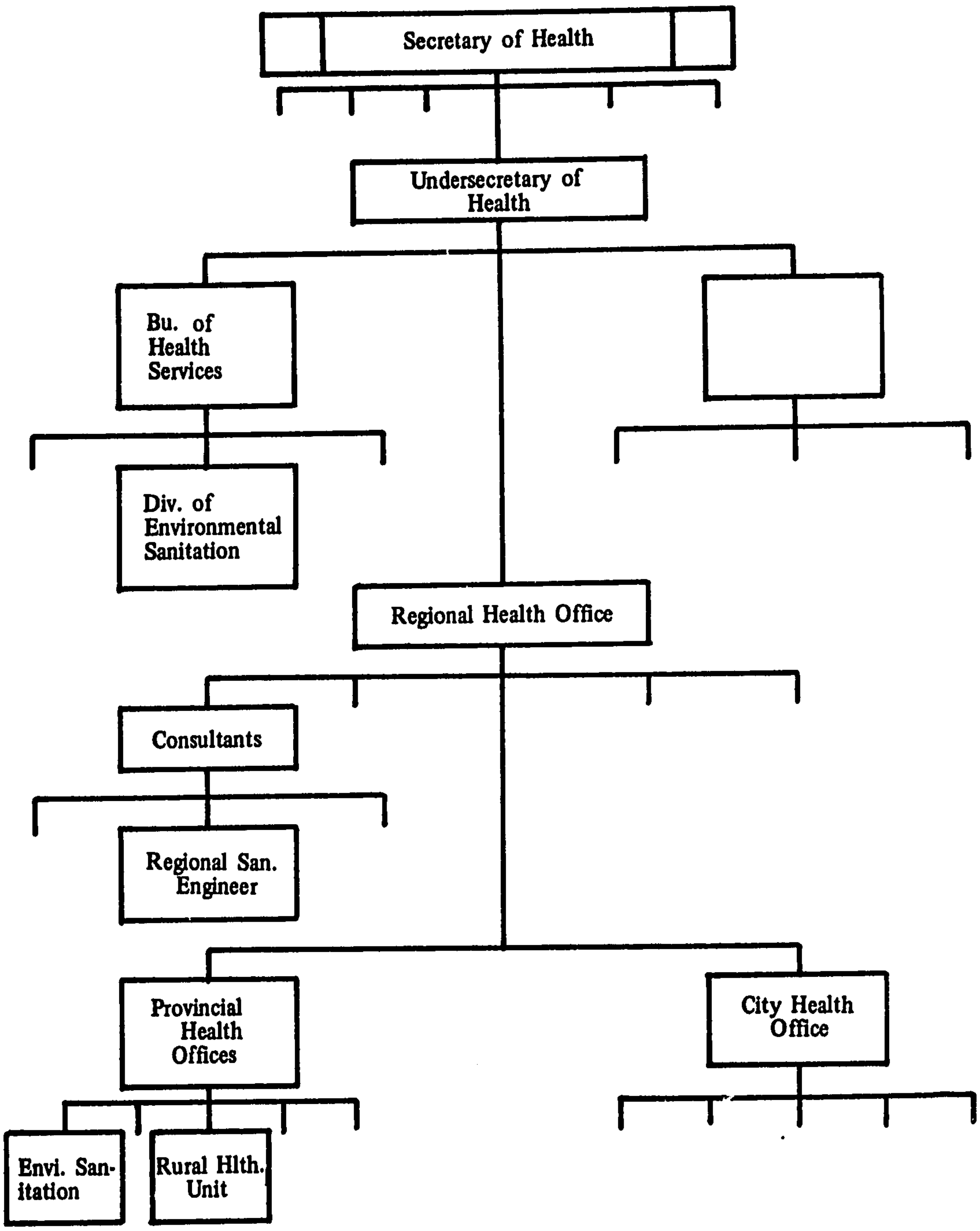
For the last decade, the Department of Health was beset with series of reorganizations brought about by the policy of decentralization. Pending again in the Congress of the Philippine Government are plans for another reorganization of the Executive Department to which the Department of Health is part and parcel.

While this paper is being written, there is convened a Constitutional Assembly in convention to change or improve the Constitution of the Philippines.

Through all these years, the Department of Health was conscious of the need to put up its own Public Health Code.

It is hoped, in the near future, such basic code may be realized whereby the Department of Health will be clothed with Administrative Authority and power to formulate from time to time rules, regulations and standards for carrying out the purpose of the law.

It is further hoped that the new code will consider the existence of various government agencies engaged in activities related to human environment and should provide the Department of Health with the authority to get involved in their activities.



Department of Health

Existing Organizational Chart Considering the Line Authority of Environmental Sanitation

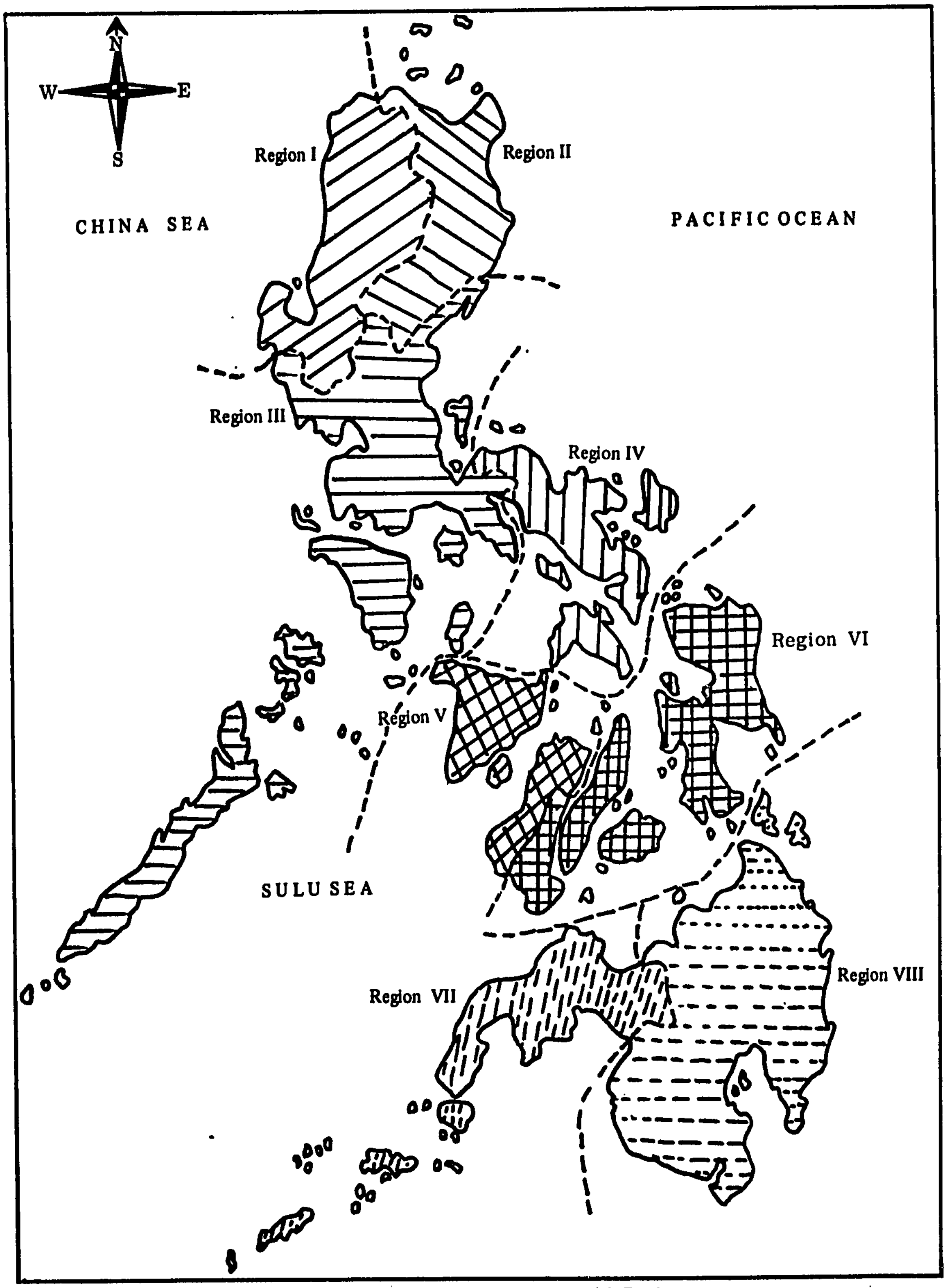
APPENDIX 2

Health Region	Population 1971	No. of Provinces	No. of Cities	No. of Munici-palities	No. of Barrios	No. of Sanitary Inspectors	No. of Sanitary Engineers		
							Field & Seniors*	Malaria@	Schisto@
I	3,910,000	10	4	210	4,384	317	7	2	–
II	1,502,000	3	0	90	1,569	117	4	3	–
III	11,891,000	16	17	230	2,678	789	13	8	1
IV	3,069,000	6	3	110	2,332	188	4	2	1
V	3,744,000	5	8	122	3,360	261	6	2	–
VI	5,602,000	8	12	252	5,874	441	7	–	3
VII	3,098,000	6	10	107	2,353	228	4	2	1
VIII	5,143,000	12	7	165	2,140	283	7	4	1
TOTAL	37,959,000	66	61	1,276	24,690	2,624	52	23	7

Central Office: 1– Chief Sanitary Engineer
5– Sanitary Engineering Advisers
7– Stream & Air Pollution Engineers

@ No connection with the existing Div. of Env. Sanitation
* Some utilized as transport and training officers.

Sanitary Engineers and Inspectors (employed by the Department of Health)
Personnel Distribution



Map of the Philippines Showing the Health Regions.

	1962		1963		1964		1965	
	CASES	DEATHS	CASES	DEATHS	CASES	DEATHS	CASES	DEATHS
CHOLERA EL TOR	13,015	1,682	3,979	433	16,464	1,518	4,507	493
GASTRO ENTERITIS	212,969	15,083	213,613	15,157	230,464	16,081	179,668	11,745
DYSENTERY	13,596	793	16,036	947	7,465	1,107	15,415	847
TYPHOID FEVER	153	115	210	134	250	123	165	65
POLIOMYELITIS	552	165	527	166	412	160	772	91
H-FEVER	143	62	151	39	1,327	141	652	50
MALARIA	40,342	1,273	33,517	1,113	40,854	976	25,373	705
FILARIASIS	386	5	32	6	60	4	62	4

	1966		1967		1968		1969	
	CASES	DEATHS	CASES	DEATHS	CASES	DEATHS	CASES	DEATHS
CHOLERA EL TOR	7,337	572	2,366	193	3,777	305	1,427	174
GASTRO ENTERITIS	209,710	18,692	177,860	15,091	179,129	14,795	245,918	15,200
DYSENTERY	22,099	1,325	17,792	1,042	19,072	1,356	13,815	1,247
TYPHOID EEVER	261	126	274	168	708	240	1,508	391
POLIOMYELITIS	499	164	466	186	568	258	665	252
H-FEVER	9,384	250	1,371	105	1,116	115	1,336	103
MALARIA	33,737	1,373	31,441	1,143	28,354	1,061	31,756	860
FILARIASIS	99	1	0	3	11	3	29	2

Cases and Deaths Caused by Poor Environmental Health Conditions – Associated Diseases

THE NEED FOR NATIONAL RURAL COMMUNITY WATER SUPPLY PROGRAMME

Background Information

About 70% of the 37 million population of the Philippines live in the rural areas. The cases and deaths on filth associated and water-borne diseases are still disturbingly high causing yearly average of 230,000 cases and 17,500 deaths for the last 7 years. Water-borne diseases pose major health problems that reduce the vigour and productiveness of the people and indirectly inhibit rural development.

The people in the rural areas obtain water from unprotected open dug wells and sometimes from streams and rivers which are heavily polluted by human excreta. In many barrios, people have to walk considerable distances to fetch water and in many places water are transported by water vendors and sold at high prices. Water, then as basic necessity for life, cost more in time and money to maintain minimum basic hygiene.

In the light of the recent abolition of NWSA which has as its prime objective of consolidating and centralizing all activities on water supply projects under its control, direction, and general supervision. It is high time that the Department of Health should step in and initiate a programme in which many agencies will be involved to provide potable water supply to the people, a service so important to the health and growth of the nation. This programme recognizes the need for water supplies in the rural areas and will lay emphasis on inviting all agencies interested to bring concentrated attack on the current severe inequities suffered by the rural people due to isolation and lack of opportunity which are particularly characteristic of the activities of previous.programmes.

It is expected that this programme which will definitely reduce the incidence of water-borne diseases would affect approximately 20 million inhabitants in the rural areas which up to this time are not provided with safe water supply.

This will be an inter-agency programme where all the agencies involved will come under an Executive Committee to be organized.

Objective of the Programme

To provide safe and adequate water supplies to 80% of the population with emphasis on the rural areas to step up the country's rural developmental programme.

Scope

Ground water resource programmes are carried out at present by several government agencies.To avoid the overlapping of interests and conflicts brought about by the enormity of the programme it is necessary to limit the goal compatible to a 5-year programme and indicate the respective responsibilities of each agency for carrying out various functions of the national water supply programme in the rural areas.

(1) A National Executive Committee for the National Rural Community Water Supply Programme is organized to carry out the planning and coordination of the work of the various government agencies involved in rural water supply.

The members of this Committee are representatives from the various agencies involved, namely:

(a) A Chairman (elected by the members of the Committee)
(b) Department of Health (Environmental Health Services)
(c) Bureau of Public Works (Wells & Springs Office) WAS
(d) Metropolitan Waterworks and Sewerage System (MWSS) (Provincial Waterworks Department)
(e) Presidential Assistance on Community Development (PACD)
(f) National Irrigation Administration
(g) National Planning Commission
(h) Water Resources Planning Office (Bureau of Public Works)
(i) Philippine Rural Reconstruction Movement

(2) Responsibilities for carrying out various functions of implementing agencies involved in supply are as follows:

(a). The Interagency Committee on Regional Level
(i) Chairman (elected by the members)
(ii) Regional Sanitary Engineer
(iii) Regional Public Works Offices (WAS)
(iv) PACD Staff on Regional Levels
(v) Regional Training Centres
(vi) Regional Health Laboratories

(b). Provincial and City Level
(i) Chairman (elected by the members)
(ii) Provincial and City Engineers
(iii) Provincial Waterworks Offices
(iv) City Waterworks Offices
(vi) PACD Provincial Staff Offices
(v) District Offices for Wells and Spring Development
(vii) Provincial and City Health Laboratories
(viii) Provincial and City Planning Boards.

Implementation

An inter-agency agreement on the organization of common regional office for the programm to be reached whereby equipment, supplies, commodities and manpower of each participating (a shall be geared together towards attaining the objective of the programme.

It is contemplated to recommend the adoption of the pattern of regionalization of the Depart of Health into 8 Regional Offices with headquarters indicated below:

Regions	Headquarters	Provinces	Cities
I	Degupan City	10	4
II	Tuguegarao, Cagayan	3	
III	Quezon City	16	17
IV	Naga City	6	3
V	Iloilo City	5	8
VI	Cebu City	8	12
VII	Zamboanga City	6	10
VIII	Davao City	12	7

The Department of Health at its present set-up has among others in each Regional Health O the following:

(1) Regional Laboratories
(2) Assigned Regional Sanitary Engineer
(3) Regional Training Centre
(4) Regional Motor Transport Office

Priority must be given to the staffing of the organized Regional Committee Office for this progra in terms of additional engineering support personnel, construction technicians, draftsman and other tical support to meet and cover programme activities and responsibilities. Among the responsibi and activities under the regional level are:

(1) Investigation of proposed project sites.
(2) Make recommendations to the Central Office on the suitability of the proposal coming fron provincial and city level and set-up priorities.

(3) Develop standard and specialized designs beyond the capability of those assigned at the provincial and city levels.

(4) Review field designs and commodity requirements which in turn are submitted to the Central Office for final approval and budgetary processing.

(5) Attend to construction, supervision and preventive maintenance.

(6) Operate a training centre for progress in community management, operation and plant operators and other seminars or in-service training of personnel.

(7) Regional, provincial and city laboratories shall be utilized.

Operating Procedures and Method of Approach Towards Providing a Water System to a Community on Self-Help Basis

(1) The initiative for obtaining a potable water system must come from the people themselves, often stimulated by public health workers or community development officers.

(2) The requests for the water system are submitted to the Provincial Governor or City Mayor through the Provincial or City Feld Units.

(3) For the determination of priority projects, the amount of local contribution and participation, must be taken into account which is an indication of the community's capability for self-support.

(4) The Field Unit which covers the area makes an initial feasibility study of the source of water available and gathers other pertinent information, submits the recommendations to the Regional Staff with a sanitary survey of the project site.

(5) Utilizing standard designs based on the needs and size of the community, the plans are sent to the Governor's or City Mayor's Office for approval.

(6) The plans estimates, specific system designs which have the approval of the Governor's Office are finally submitted to the Executive Committee at Manila for final approval and budgetary processing and programming.

(7) The plant is constructed under the supervision of the Field Units.

(8) When construction of the plant is completed, the system is turned over to the local government for operation and maintenance. after the training of the local plant operations at the Regional Training Centre.

Financing

There is need to discuss financing of various projects separately for each type of water supply depending upon many factors namely:

(1) Size of community and annual growth rate of population.
(2) Type of system.
(3) Source of water.
(4) Degree of treatment required.
(5) Budget subsidies from national government.
(6) Amount of community contribution.
(a). In soliciting village support at the initial phase.

(b) Community involvement in the management of systems
(i) Collection of water charges.
(ii) Operational and maintenance costs.

(7) Determination of the per capita cost of supplying potable water to the rural villages.

Problems Facing the Implementation of the National Programme and Proposed Resolution

(1) The need for more professional personnel in the service to cover the 69 provinces and 61 cities. Inexperienced engineers and technicians may be hired but it is necessary to give them considerable additional training.

(2) Because of the remoteness of the sites of the projects and the small scope of the individual projects, there is lack of enthusiasm on the part of local contractors to bid for the work and there will be a tendency to increase the price on construction. The Provincial Field Teams will have to undertake the job.

(3) Lag time in obtaining imported items. It takes a year or more from the time a commodity is ordered until it arrives on the construction site. As the central office becomes better in forcasting the needs of the regional or provincial projects, advanced ordering with reasonable accuracy can be made so that construction will not be held up.

(4) Transportation over great distances from central offices to regional and provincial construction sites and poor condition of roads especially during rainy season may hamper supervision and impede progress of construction. Besides providing each Field Team with vehicles, efforts must be made at the Regional Offices to keep vehicles in running order.

(5) Local authorities and the people in the community do not immediately see the importance of their operating, maintaining and managing the system but will rather prefer to expect the government to give them the system and then maintain it as a government entity.
Field units will have to supervise construction and must be instructed to only advise and assist completed projects and must promote comprehensive "self-help" projects. Promote preventive maintenance so that the people of the community themselves will ultimately take over the operation of the system. Acceptance by the people of the value of potable water supplies must be encouraged through education in public health and hygiene.
Water supplies should be part of the over-all rural health programme and RHU personnel should be utilized to educate the people.

Health Region	Population	No. of Munici-palities	No. of Barrios	Water Works System	ARTESIAN WELL		DUG WELLS		SPRINGS		Rain Water
					Operating	Not Operating	Improved	Open	Improved	Not Improved	
I	3,910,000	240	4,384	468	3,985	963	24,270	19,317	2,216	1,793	720
II	1,502,000	80	1,569	11	455	372	4,927	7,530	314	703	468
III	11,891,000	230	2,678	291	18,478	1,234	71,357	12,388	4,311	109	10,174
IV	3,069,000	110	2,399	655	1,636	682	3,826	7,747	939	1,883	714
V	3,744,000	122	3,360	174	1,436	537	17,237	22,272	1,446	2,039	15,400
VI	5,602,000	252	5,874	1,090	3,090	721	1,785	13,210	1,442	3,433	19,799
VII	3,098,000	107	2,353	108	1,033	206	2,628	4,992	639	1,394	6,530
VIII	5,143,000	165	2,140	384	1,420	524	8,797	21,273	794	2,351	131,042
TOTAL	37,959,000	1,306	24,757	3,091	31,533	5,239	134,827	108,729	12,101	13,705	184,847

Water Supply 1970

NATIONAL WATER QUALITY CONTROL PROGRAMME

Background Information

To effectively control the water quality of water resources in the Philippines that are developed and to be developed for public use, a National Water Quality Control Programme to be administered by the Department of Health will be implemented to minimize and prevent the occurrence and outbreak of water-borne diseases in the country. The staggering toll in money, manpower and other economic losses attributable to outbreak of Cholera El Tor, typhoid, dysentery and other diseases transmitted by infected water still continues to cause financial, manpower and other economic losses to the country. The Division of Environmental Sanitation through the Department of Health hopes to permanently control and eradicate these debilitating diseases through the implementation of this programme. There are at present about 1,142 waterworks in operation throughout the country, 20,240 deep wells, 42,258 improved wells and 2,062 improved springs providing supposed safe potable water supply to approximately 17,000,000 people with the rest of our population of approximately 20,000,000 relying on questionable water supply for domestic use. The provision of water supply in conformity to our National Drinking Water Standard is basically a responsibility of the Department of Health and this programme offers positive steps in complying to that responsibility.

Objectives

(1) *General Objective* –
To control the water quality of existing water supply and water resources of the country to comply with standards as set forth in the National Drinking Water Standards of the Philippines with the end in view of preventing and minimizing the occurrence and outbreak of water-borne diseases.

(2) *Specific Objectives* –

(a) To provide municipality, city, provincial, regional and national health authorities and other national agencies up-to-date information and data on water quality throughout the country and under their respective health responsibility.

(b) To set up a programme of priorities in improving existing water treatment facilities to attain desired water quality standards.

(c) To upgrade existing regional, provincial and city laboratories to adequately undertake all aspects of water analysis and train field and laboratory personnel in water quality control work and performing required laboratory examinations.

(d) To collect scientific data to be able to set up a programme of health information drive and health education of the public in the health importance and desirability of safe potable water supply and required research if needed.

Resources to Implement the Programme

(1) Manpower Resources
- (a) Sanitary Engineers
- (b) Sanitary Inspectors
- (c) Laboratory Personnel

(2) Facilities
- (a) Regional Laboratories (laboratories of water surveyors)
- (b) Provincial Hospital Laboratories
- (c) Provincial Health Laboratories
- (d) City Health Laboratories

The Programme

This is the programme initiated by the Division of Environmental Sanitation of the Department of Health for the implementation of the National Quality Control Programme by the Regional Health Offices. On the basis of data to be submitted by the Regional Health Offices of existing water supply and available water resources, the Regional Sanitary Engineers shall programme the yearly sampling and examination of water resources for each region. Records and report forms to be made by the Division are thereby distributed to all regions for use.

Regular monthly bacteriological examination of existing water supply shall be undertaken by Regional Health Offices with required physical and chemical examinations to be made of water resources proposed for development. Monthly and annual reports shall be submitted by the Regional Health Offices to the Division of Environmental Sanitation at the Department of Health for evaluation and assessment to pinpoint areas where questionable water quality may give rise to the outbreak of water-borne diseases in the country. Regular evaluation and assessment on provincial and regional basis will be done by the Provincial and Regional Sanitary Engineer. In conjunction with these regular examinations of water supplies, a programme to upgrade laboratory facilities in the country and a training programme for field and laboratory personnel shall be instituted. A public information and health education drive shall be initated to raise public interest on the benefits and health importance of safe potable water supply on the basis of the exact data collected.

Plan of Operation

(1) Based on data and information supplied to Regional Health Offices, the Regional Sanitary Engineer shall prepare yearly sampling and examination programme for the Environmental Sanitation Services in the Health Regions. A copy of this programme will be sent to the Bureau of Health Services and the Bureau of Research and Laboratories.

(2) Based on the predicted programme on sampling and examination, the Regional Engineers will prepare his water quality control programme for the region making use of Sanitary Engineers and Sanitary Inspectors in programme implementation.

(3) All laboratories in the region shall be upgraded in terms of facilities and presonnel capability to undertake all aspects of water examination.

(4) Monthly reports (Form III shall be forwarded to the Division of Environmental Sanitation for records, evaluation and assessment of water quality throughout the country.)

(5) Interpretation of monthly reports shall be fed back by the Regional Environmental Sanitation Services for the information of all health authorities concerned including recommendations that may be required in cases of adverse examination results to prevent the outbreak of water-borne diseases.

(6) Programme implementation shall give priority to city and progressive municipal water systems. Dependent on capabilities of regional laboratories, total programme implementation for the region shall be desired.

Method of Approach to Accomplish Desired Objective

(1) The Provincial Health Office shall designate a provincial coordinator for community development projects in the province.

(2) The Municipal Health Officer or Head of Rural Health Units, the Provincial Coordinator, and Barrio Captain will organise the survey team for the selected pilot community.

(3) The members of the survey team shall be convened by the Municipal Health Officer for orientation and instructions.

(4) Memberships to the survey teams will be left at the discretion of the Municipal Health Officer. It is suggested that representatives from other assisting agencies be made members of the Survey Teams.

(5) Selected barrio people may be invited to take part in all phases of the plan of operation of the programme.

(6) The project has to be identified as a civic or barrio project by involving the people who will take the leading role while government personnel assuming the supporting role.

(7) Health personnel will transmit technical information and materials for educational and demonstrational purposes.

(8) An Evaluation Team has to be organised for each community project to determine the progress of work and accomplishments achieved. It is suggested that the membership of the Evaluation Team be expanded to include government personnel, selected private citizens and representatives from assisting agencies.

Phase I – Survey of the Community

Nature of Activities

The general survey of the community is to determine the status of environmental sanitation by physical count of existing sanitary facilities, sizing up local resources available, the interest of the Barrio Council and response of the people in the community.

Purpose and Objective

To appraise the Survey Team of the health problems of the community, its magnitude and needs, and available local resources for the setting of priorities on the work programme.

Phase II – Health Education

Nature of Activities

The health education of the barrio people may be achieved by members of the RHU, Sanitary Engineers and Inspectors, Health Educators, School Officials and other Provincial and Municipal Officials through the following:-

(1) Individual contact at RHU clinic, home visits and interviews.

(2) Small group meetings and conferences, lectures at Mother's Classes, PTA meetings, Bo. Council meetings and community assemblies

(3) Demonstrational and instructional phase on the following:

(a) Improving open dug wells

(b) Improving springs
(c) Preparation of moulds for water-sealed toilet bowls and the likes
(d) Installation of toilet bowls
(e) Construction of a blind drainage for kitchen liquid waste
(f) Putting up of posters, pamphlets or films.

Purpose and Objective

To enlighten the people of the community on the importance of environmental sanitation in relation to health and well-being and to develop in them an appreciation of the sanitary way of living. The Barrio Council and the people of the barrio will be appraised of the existing problems on sanitation as revealed in the survey report to guide them in determining their priority projects.

At the close of Phases I and II, the following facts must have been fully covered:-

(1) The Barrio Council must be properly appraised of the magnitude of sanitation problems.

(2) The health problems of the community identified from the survey report.

(3) The people of the community should have been organised and ready to receive the programme as theirs.

(4) Agencies to be involved in the final implementation of the programme.

______	______	______	______
PTA	PACD	SCHOOLS	OTHERS

(5) Local resources available:

______	______	______
Labour	Materials of Construction	Funds

Phase III – Implementation

Preparatory Phase

(1) *Organising the barrio working crew:* The recruitment of the barrio working crew shall be left entirely to the Barrio Council.

(2) *Procurement of working tools and equipment:* Working tools and equipment needed in the prosecution of the work may come from assisting agencies like the PACD, Provincial or City Engineers Office, Public Service Offices, or borrowed from government, civic or private assisting agencies.

(3) *Funding :* The disposition of barrio funds should be left to the Barrio Council.

(4) *Setting of priorities :* The Barrio Council in session with members of the Survey Team and representatives from assisting agencies attending, will decide and made the choice of priority projects from the community. The decision of the Barrio Council is final and must be adopted for implementation.

Construction Phase

Utilising local resources on labour, materials, barrio appropriation and donated funds, the improvement of sanitary facilities and other new construction for the barrio projects must be pursued with unrelenting vigour giving no chance to cool off the motivated interest of the barrio people.

Phase IV – Evaluation

Purpose and Objectives

· To determine the progress of work and accomplishments achieved.

The composition of evaluation team

The members of the Evaluation Team may be chosen from among the following:-

Officials from the Provincial and Municipal Government, Schools, Health Offices, representatives from Assisting Agencies, religious institutions and selected private citizens of the community. The Chairman may be designated by the Municipal Mayor or Municipal Health Officer.

Results of final evaluation

The Water Seal Squat Type Toilet Seat

This device was conceived to provide means of dispensing human excreta in unsewered areas in order that the usual objections from ordinary latrines due to odour nuisance is eliminated. It also meets these requirements for the hygienic disposal of faeces and urine:

(1) That none of the faeces and urine shall be disposed so that they will pollute the soil surface.

(2) That none shall be accessible to flies, insects and animals.

(3) That none shall be disposed that it is possible to carry it back to the food.

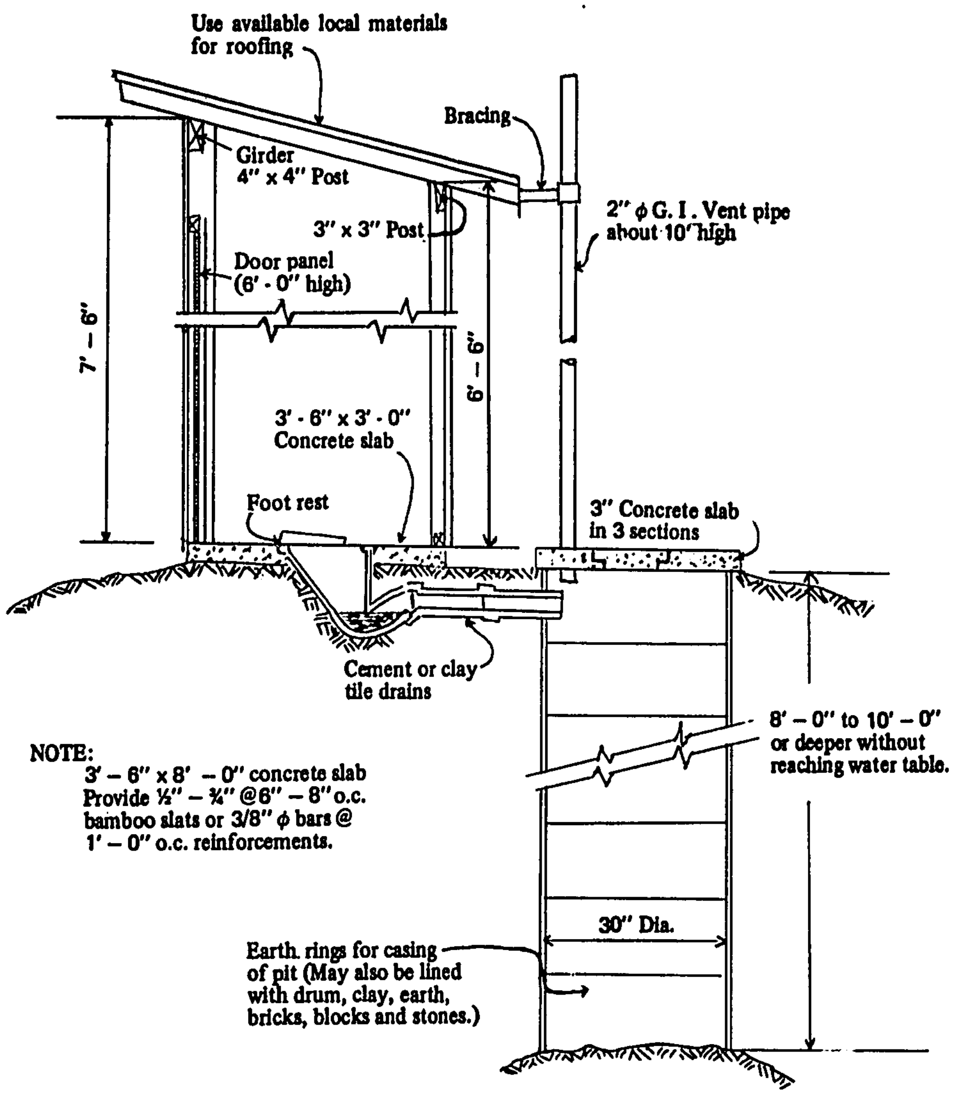
(4) That none shall be used to fertilise soil for growing vegetables that are eaten raw.

This device in addition to meeting the above requirements also provides an acceptable latrine from the standpoint of its:

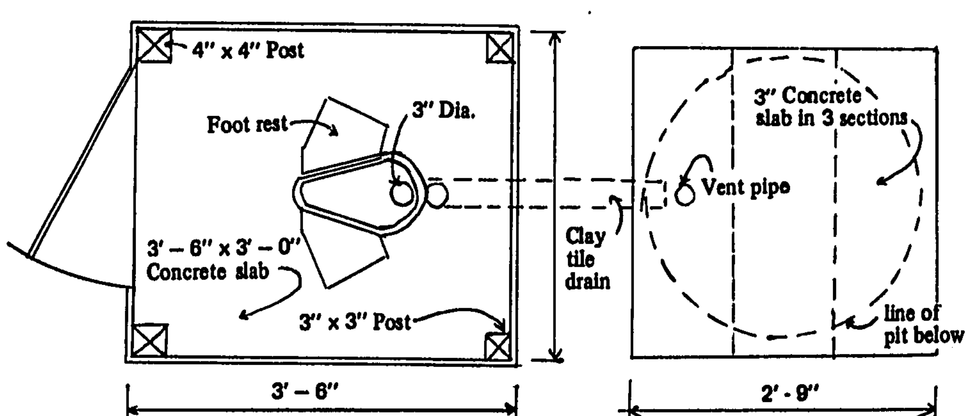
(a) Simplicity
(b) Inexpensiveness
(c) Minimum reliance upon individual for maintenance
(d) Convenience and comfort

The water seal type toilet seat works on the same principle as the common flush type water closet except that the removal of the waste matter is achieved by pouring a certain volume of water into the device. Enough water is retained in the lower portion of the device which forms a seal and prevents odour from the pit in getting into the toilet room and flies from getting into the pit. This type of seat may be constructed out of clay or cement and has the following advantages over other cheap types of excreta disposal:

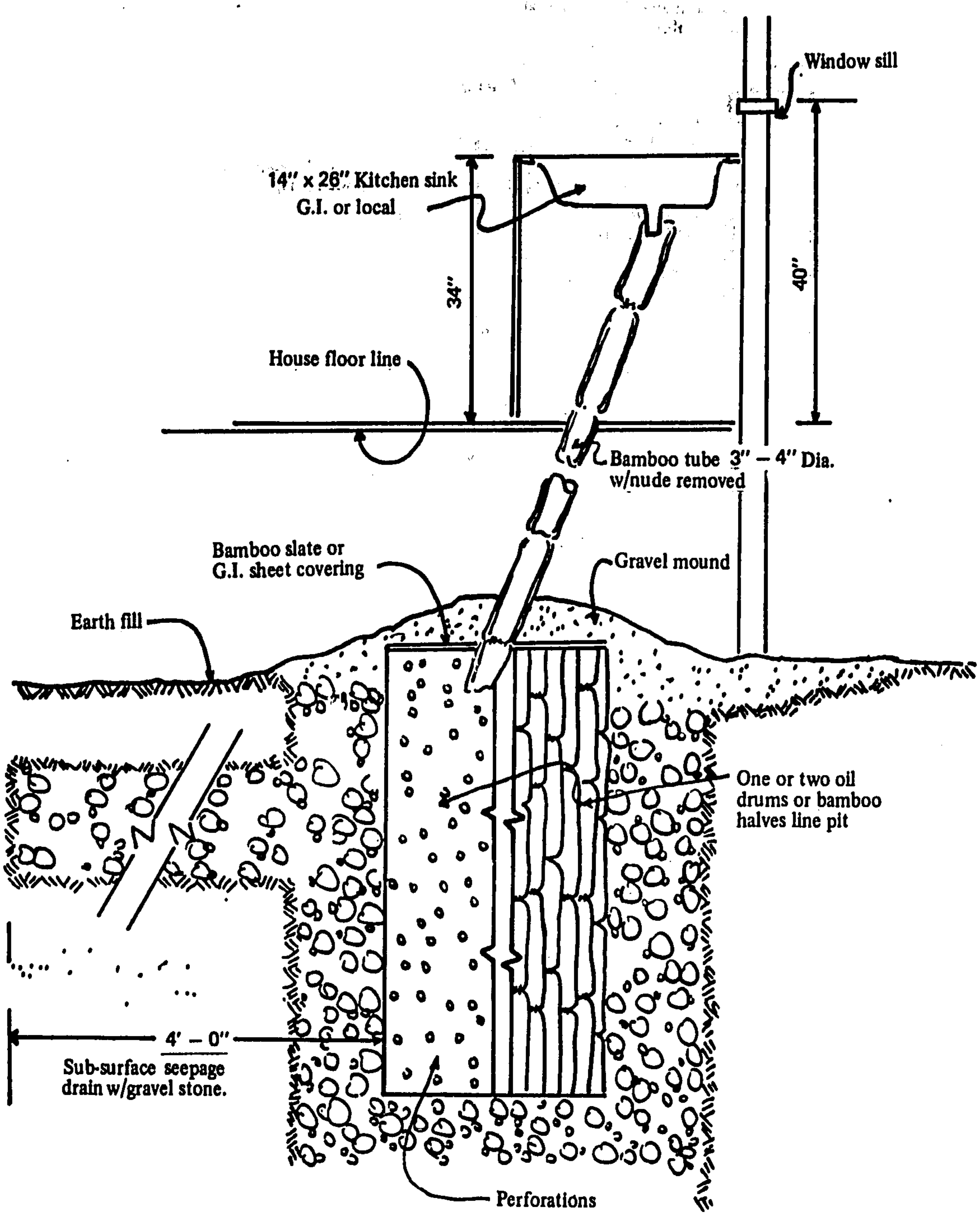
(i) Contact of faeces from flies eliminated
(ii) It encourages higher standard of maintenance
(iii) It cannot be easily clogged
(iv) It is safe for children
(v) It can be installed near or within the house
(vi) Digestion more rapid hence longer period of use
(vii) It can be used in wide range type of soil.



LONGITUDINAL SECTION
Scale ½" – 1' – 0"



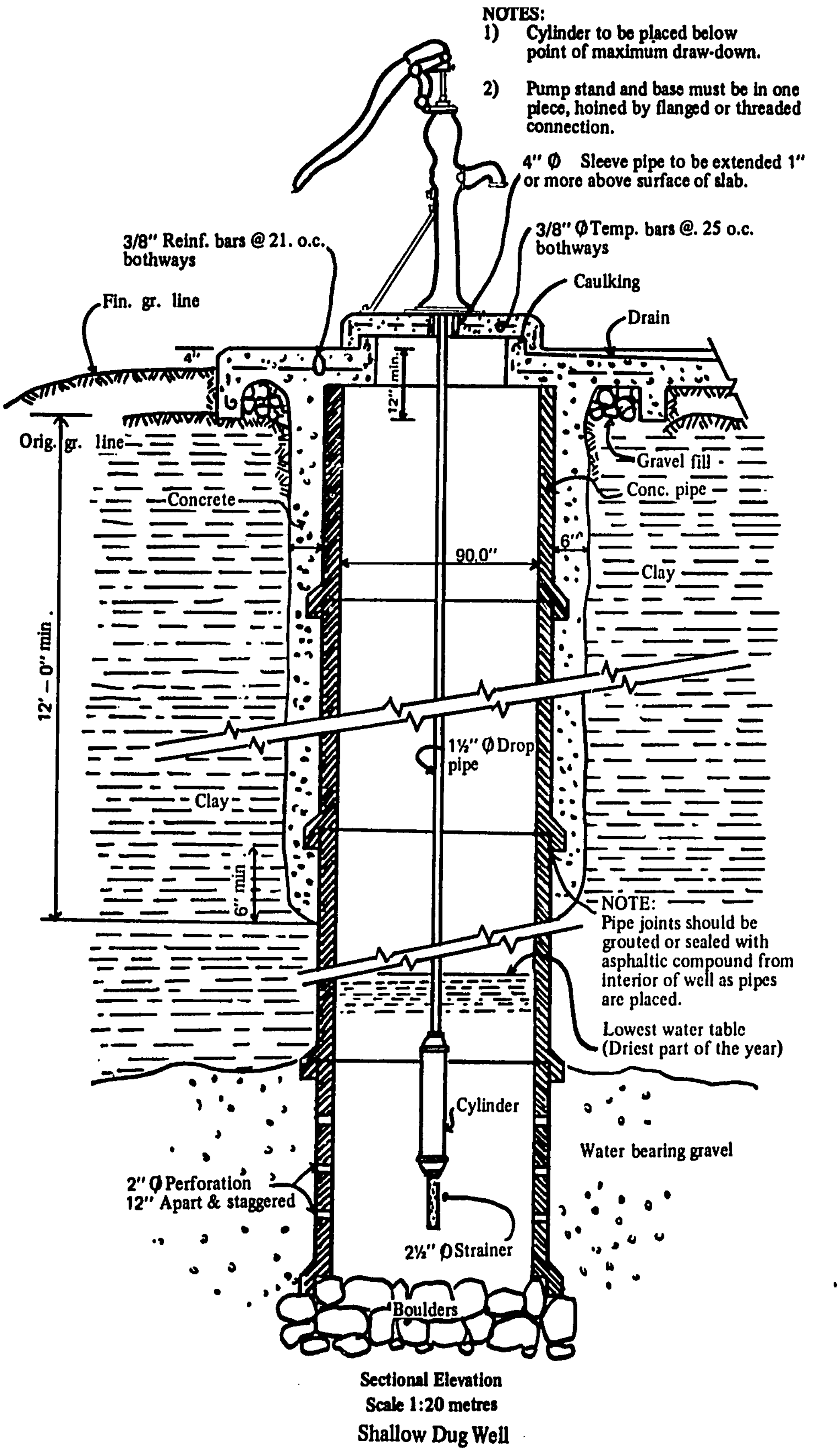
PLAN
Scale ¾" = 1' – 0"



Blind drainage system will provide means of disposing liquid kitchen waste into a seepage pit instead of allowing waste to form pools underneath houses that serve as breeding places for mosquitoes, flies and other insects.

The system can be constructed near the house and the sub-surface seepage around the yard will help in the irrigation of backyard gardening.

Construction of Blind Drainage for Liquid Kitchen Waste



Sectional Elevation
Scale 1:20 metres

Shallow Dug Well

Health Regions 1	2	3	4	Satisfactory 5	6	7	Unsatisfactory Non-Water Carriage 8	9	10	11	12	13
Provinces, Cities, Municipalities or Barrios	No. of Dwellings	With Toilets	Without Toilets	Septic Tank	Water Sealed Privy	Total for 5&6	Pit Privy	Antipolo	Other	Total for 8, 9 & 10	Percent Dwellings w/Toilets (3)/(2)	Percent Satisfactory Toilets (7)/(2)
I	582,600	358,300	224,300	7,500	85,800	93,300	224,400	39,100	1,500	265,000	61.5	16
II	263,200	156,600	106,600	3,000	42,000	45,200	100,400	5,100	5,900	111,400	59.5	17
III	1,634,000	653,600	980,400	134,500	111,200	245,700	216,700	99,700	91,500	407,900	40	15
IV	545,500	237,300	308,200	9,800	66,500	76,300	102,500	40,400	18,100	161,000	43.5	14
V	657,200	348,500	308,500	28,500	44,200	72,700	125,600	127,800	22,400	275,800	53	11
VI	997,200	485,700	513,500	31,400	208,000	239,400	138,800	102,300	3,200	244,300	48.5	24
VII	444,900	218,400	226,500	13,700	62,200	75,900	102,600	39,900	—	142,500	49	17
VIII	750,400	337,200	412,700	25,500	67,100	92,600	142,400	96,200	6,500	245,100	45	12
TOTAL	5,875,000	2,794,100	3,080,900	253,900	687,200	941,100	1,153,400	550,800	149,100	1,853,000	47	16

Health Region No. . . . .
Toilet Construction, Fy 1970 – 71.

THE NEED FOR SEWAGE DISPOSAL BY MEANS OF WASTE STABILIZATION PONDS IN SUB-URBAN AND URBAN AREAS

Background Information

Proper sewage treatment and disposal play an important role in the prevention of gastro-intestinal infections such as cholera, typhoid and dysentery. Epidemiological investigations linking domestic waste with the above-mentioned diseases have been well established so that there is need for proper treatment and disposal of sewage to protect our population from these scourges. Proper sewage treatment minimizes the problems of stream and land pollution.

Records in the Department of Health indicate that of the 6 million occupied dwellings only about 2.9 million are provided with toilets. Of this figure, only 16% are provided with "satisfactory" or water sealed means of excreta disposal. Modern sanitary science considers that a septic tank is not the most satisfactory way of sewage treatment. It removes only a certain percent of the organic content of the sewage to be treated. Even from epidemiological point of view because of its short period of detention time, it does not perform a satisfactory means of treatment. Moreover the effluent from a septic tank is anaerobic causing nuisances and odour problems and may have detrimental influence to the rivers which absorb this effluent. Not one city or municipality in the country is completely sewered or has a complete sewage treatment plant.

The programme is intended to:

(1) Demonstrate to the public a cheap and easily constructed and maintained sewage treatment plant which will be based on the favourable climatic conditions of the country.

(2) Demonstrate the efficiency in the removal of organic load in sewage (expressed in ppm BOD and ppm suspended solids.)

(3) Demonstrate the way of providing oxidised treatment effluents to the rivers instead of the present way of disposal of septic tanks effluents.

(4) Demonstrate the reduction of incidence of waste-borne diseases and improve health status of the population in areas served.

(5) To undertake field studies to determine the design criteria to suit local conditions.

This programme will definitely reduce the pollution of water sources and incidence of water-borne diseases. There will be an inter-agency programme where all agencies involved will get together under an Executive Committee to be organized.

Objective of the Programme

To construct and develop pilot demonstration waste stabilization ponds and to conduct studies and researches for the local design criteria and performance of this kind of sewage treatment.

It should be pointed out that the use of waste stabilization ponds as a method of sewage treatment has been increasingly used in many countries in the world like India, South Africa, Austria, Israel, Southern California, Australia, New Zealand, etc. This is considered the cheapest means of sewage treatment compared to other methods provided land cost will not be prohibitive. The cost of reducing the putrescible content of wastewater in a waste stabilization pond is up to 1/6 that of other methods of treatment. It does not need equipment which will have to be imported from other countries and does not need sophisticated maintenance.

Scope

As the matter treated herein concerns the health of the people, the Department of Health through its different health units in the country has continuously campaign for the construction of sanitary method of disposal of domestic wastes. This undertaking will need the cooperation of other government agencies and the people in general.

The construction of pilot demonstration waste stabilization ponds is planned to be made in the 8 health regions of the country. Respective responsibilities of the different agencies involved shall be indicated in carrying out the project.

(1) A National Interagency Committee for the construction and development of pilot waste stabilization pond is to be organized to carry out the planning and coordination of work.

The members of this Committee are representatives from the various agencies, namely:-

(a) Chairman (To be elected by the committee members)
(b) People Homesite & Housing Corporation (PHHC)
(c) National Housing Corporation (NHC)
(d) National Science Commission (NPC)
(e) National Science Development Board
(f) Social Security System (SSS)
(g) Metropolitan Water & Sewerage System (MWSS)
(h) Government Service Insurance System (GSIS)
(i) Institute of Public Health, UP

(2) Responsibilities for carrying out various functions of the implementing inter-agency committee in sewage disposal are as follws:

(a) Regional Level
(i) Chairman (To be chosen by the committee members)
(ii) Regional Sanitary Engineers
(iii) PHHC
(iv) NHC
(v) NPC
(vi) SSS
(vii) NWSS
(viii) Regional Health Laboratory
(ix) GSIS

(b) Provincial and City Level
A committee with representatives from involved Regional Agencies will be organized.

Implementation

An inter-agency agreement in the organization of a common regional office for the programme has to be reached whereby equipment, supplies commodities and manpower of each participating agency shall be geared towards attaining the objective of the programme.

It is recommended that the pattern of the 8 Regional Offices be adopted:

Region

I	Dagupan City	10 provinces	4 cities
II	Tuguegarao, Cagayan	3 provinces	
III	Quezon City	16 provinces	17 cities
IV	Naga City	6 provinces	3 cities
V	Iloilo City	5 provinces	8 cities
VI	Cebu City	8 provinces	12 cities
VII	Zamboanga City	6 provinces	10 cities
VIII	Davao City	12 provinces	7 cities

The Department of Health at its present set-up has among others in each Regional Health Office the following:

(1) Regonal Sanitary Engineers

(2) Regional Training Centre

(3) Regional Motor Transport Office

(4) Regional Laboratories

The first phase of the programme will be demonstration, study and research in nature until a design criteria for the Philippines have been established.

First priority must be given to the organization of the National and Regional Committees for this programme

Among the responsibilities and activities under the regional level are:

(1) Investigations of the proposed project sites.

(2) Make recommendations to the Central Office on the suitability of the proposals coming from the provincial and city level and to set up priorities.

(3) Review field designs and commodity requirements which in turn are submitted to the Central Office for final approval and budget processing.

(4) Attend to construction supervision and preventive maintenance.

(5) Undertake field studies to determine design criteria to suit local conditions. (Design criteria to be determined is in separate attached sheet).

(6) Submits studies findings for evaluation.

(7) Regional, provincial and city laboratories shall be utilized.

perating Procedures

(1) The Inter-agency Committee shall initiate the construction of waste stabilization ponds for sewage treatment be it on new or existing projects.

(2) The field units which cover the area will gather pertinent information and make initial feasibiltiy studies and submits the recommendation to the regional staff with a sanitary survey of the project sites.

(3) Design of waste stabilization ponds to be adopted at the start shall be in accordance with Appendix 8, (Israeli design criteria for oxidation pond) considering that the Philippines and Israel have almost the same climatical condition in some respect.

(4) Plans and estimates of specific pond design shall be submitted to the National Inter-agency Committee at Manila for approval.

(5) The pond will be constructed under the supervision of the field units.

(6) Upon completion of the construction, the system shall be turned over to the agency concerned for operation and maintenance.

(7) The field units shall conduct observations, studies and researches on the design parameters and shall submit their records and findings to the National Inter-agency Committee.

APPENDIX 8A

Basic Principles of Operation of a Waste Stabilization Pond

A waste stabilization pond is an earth structure without equipment designed to treat liquid organic wastes by biological, chemical and physical processes commonly referred to as natural self-purification. The process is as old as nature itself and is taking place constantly in our streams and lakes.The stabilization process is a mutually beneficial interaction between bacteria and algae. The organic matter in the sewage waste is broken down by bacteria to carbon dioxide, ammonia and other nutrients. These, with light energy, supply the principal requirements for algae photosynthesis which liberates excess oxygen to maintain an aerobic system.

Another important physical process is the functioning of stabilization ponds in sedimentation of organic matter which may undergo either aerobic or anaerobic decomposition, depending upon the intimacy of contact with overlying aerobic liquid. The efficiency of the biochemical breakdown of the organic matter in this system will depend on temperature (as every biochemical process increases its efficiency with the increase of temperature) and of the solar radiation which is required for the photosynthesis of the algae which in return will be the "suppliers" of oxygen needed for the biochemical reaction in an aerobic system.

As the Philippines is blessed with high temperature and sunlight all round the year that is the reason we feel that oxygen ponds may be économical and practical sewage treatment system for small communities in this country.

Design Criteria
(For the Pilot Demonstration Oxidation Ponds Based on Israeli Practice)

I. **BOD per capita** – 50 g per capita per day

II. **Aerobic Facultative Ponds**

Loading:	100–150 lb/ha
Depth of water level:	1.20 m (maximum)
Depth of pond:	1.50 m (minimum)
Detention time:	10 days (minimum)
Size (ratio of L to W):	2:1
Entrance:	multi-channel at least 0.5 m below the top-water level
Exit:	C. 20 m from the top-water level preferable to a filter or baffle
Slope of banks:	1:2 to 1:3
Location:	500 m from housing area in opposite direction to prevailing winds.

III. **Pre-Treatment for Aerobic Facultative Ponds**

A. If an Imhoff tank can exist 30–40% of BOD should be removed.

B. If a septic tank exist or anaerobic pond exists 50–60% of BOD should be removed.

IV. **Design of Anaerobic Pond as a Pre-Treatment Before Aerobic Facultative Pond.**

Loading :	1000–2000 kg/ha
Depth of water level:	1.50 m (minimum)
Depth of pond:	1.80 m (minimum)
Detention time:	1–5 days
Size (ratio of L to W):	1:1 to 1:2
Entrance:	0.50 m from the top-water level
Exit:	0.50 m from the top-water level
Slope of banks:	1:2 or 1:3
Location:	1.5 km from any housing area in opposite direction to prevailing winds

Remarks:

The aerobic and anaerobic ponds preferably should always be in two parallel units so that cleaning and maintenance will be easy.

Design Consideration

(1) Type of waste to be treated

(2) Characteristics of water

(a) Volume of flow daily
(b) BOD
(c) COD
(d) pH
(e) Solids – (i) total
(ii) suspended

(3) Materiological data

(a) Rainfall
(b) Temperature
(i) air
(ii) water
(c) Prevailing winds
(d) Evaporation

(4) Topography

(a) Soil characteristics
(b) Flood stages
(c) Location of houses
(d) Streams, rivers
(e) Gound water table

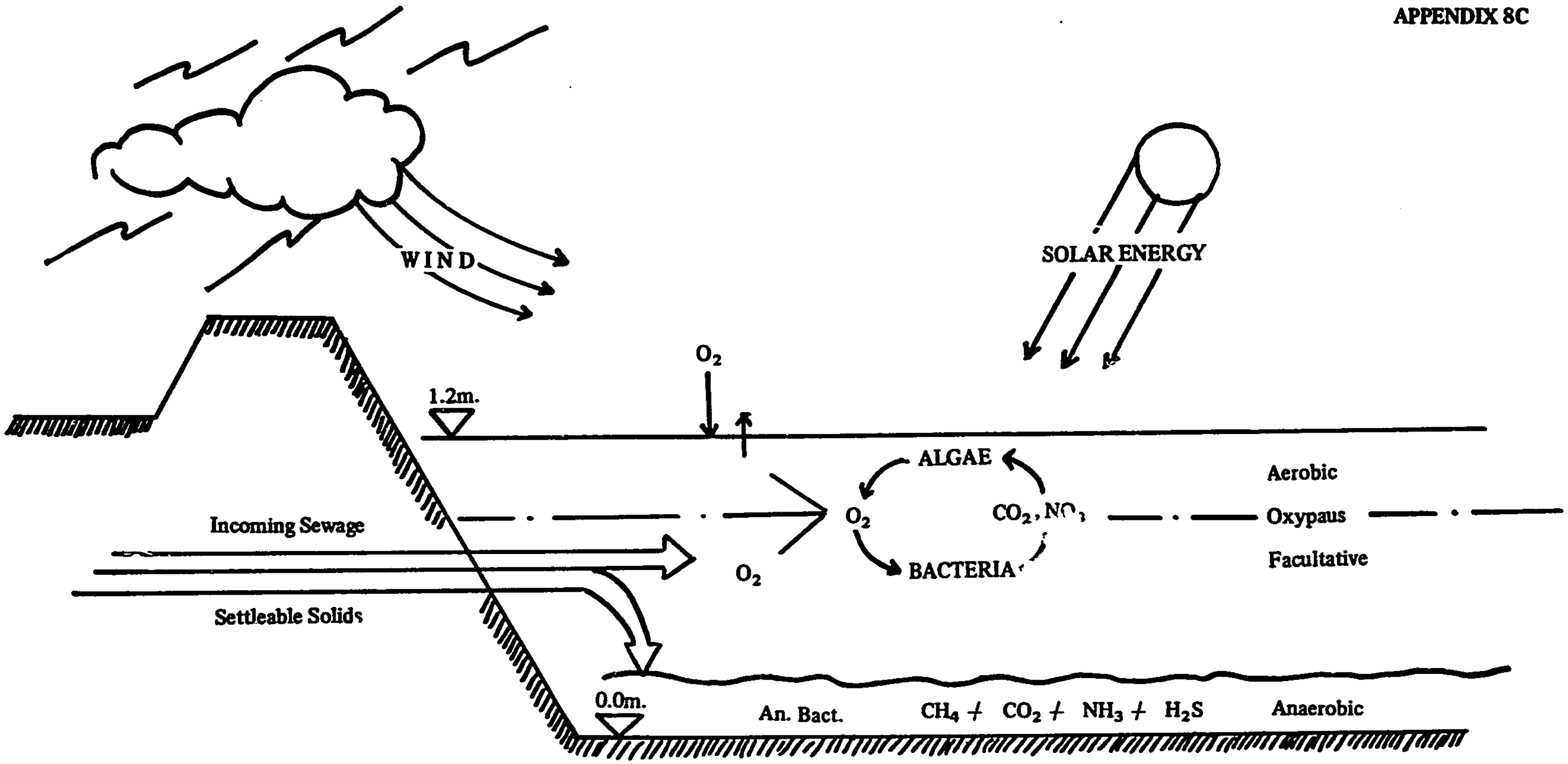
(5) Pond System

(a) Type
(b) Unit
(c) Shape
(d) Depth

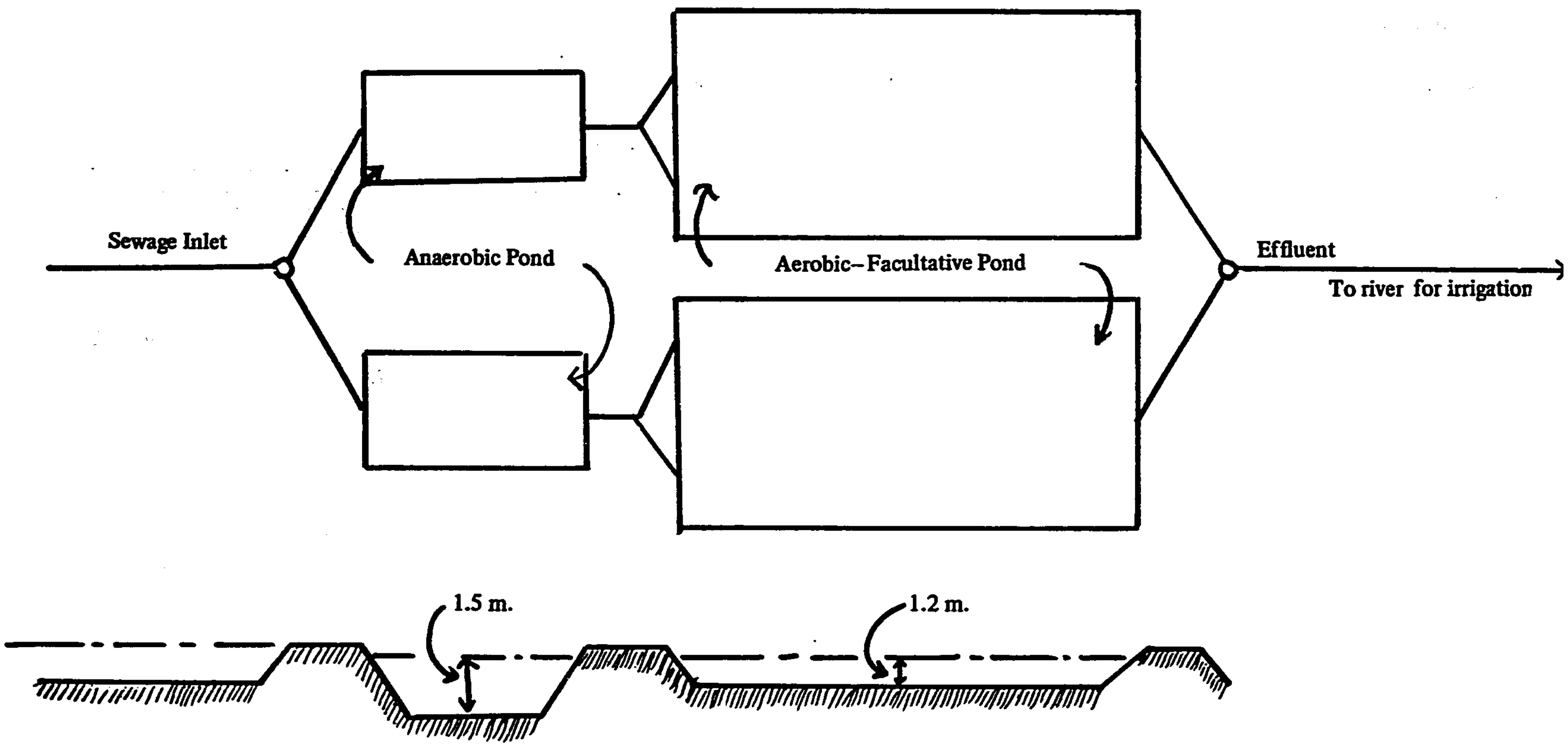
(6) Loading

(a) Organic
(b) Hydraulic

(7) Mode of disposal of effluent



Basic Biochemical Process in an Oxidation Pond



Anaerobic - Aerobic Oxidation Pond
(Typical Set-up Israel)

MOSQUITO AND FLY CONTROL PROGRAMME

General Description of the Programme

Every year thousands of people get sick and die because of deadly diseases transmitted by mosquitoes and flies. They cause great suffering and economic losses and their continuous annoyance affect physical efficiency, comfort, mental equanimity, and the enjoyment of life. Diseases transmitted by filth associated mosquito and fly rank second in the 10 leading causes of death and illness. We have a yearly average of 256,220 cases and 18,535 deaths.

This is a continuing and organized programme that requires the cooperation of the people in the community. The implementation of this programme begins with the identification of existing problems in the community that will confront the mosquito and fly control programme the orientation of officials from public and private sectors who will take part in the implementation and finally reaches its fruition in the education of the people. Once a certain degree of achievement has been attained, a continuing programme is necessary to maintain the gain.

It is proposed that a Mosquito and Fly Control Board composed of members selected from government, civic and professional groups be activated in the community with the task of directing, supervising and coordinating the different phases of operation of the programme. Personnel, equipment and funds made available and purposely alloted for insect control work will be put under the direct control of the Control Board. The Board will undertake massive campaigns in soliciting community participation and local counterparts in personnel and additional operational funds.

Objectives of the Board for the Implementation of the Programme

(1) Identification of the local environmental sanitation problems

(2) Determination of available resources from the government and community in terms of equipment, personnel and local funds.

(3) Wide dissemination of the environmental sanitation information through community meetings, assemblies, home visits, interviews, posters, pamphlets, films, radio and press releases.

(4) Formulation of practical control procedures.

Guiding Principles

Full Coverage

The area included in the operation has to be thoroughly covered. This can be achieved through the unified efforts and participation of the government and the people of the community. Government agencies will have to cover markets, canals, esteros, slum areas, garbage dumps, and vacant lots. The people of the communities will cover their private homes and environs to include laundry and garbage areas, gardens, backyards and other shelters where mosquitoes and flies dwell.

Identification of Role and Responsibilities

The whole operation must be identified more as a civic project with the people of the communities taking the leading role while the government assuming the supporting role.

The Government cannot afford or sustain the treatment of private properties, homes and building establishments because it has bigger areas and will prove more expensive than the treatment of public areas. The people of the community will not spend their time and money for this operation the moment that they are made to believe that the government with some aid from assisting agencies is shouldering the leading role of the operation. Through health education and campaign, they must be made to realize that the control of household pests in their respective premises is part of their daily activities in protecting themselves from diseases.

The interest of the people on this programme may be activated by the response of government agencies in doing its part and role and give encouragement by way of proper collection of garbage and refuse, maintenance of market sanitation, treatment of canals, esteros, garbage dumps and attending to the needs of the slum areas.

Continuing Project

By the very nature and life habits of flies and mosquitoes in that both are very prolific and can adapt themselves to many situations, these pests and problems all the time of the year in our tropical country. When this operation starts and a certain degree of achievement has been attained, a continuing programme is necessary to maintain the gain. Yet it is this area that pest control progresses most often fail. When flies and mosquitoes are no longer serious problems, public interest lags, other problems take away the attention of public officials and the pests begin a subtle but certain re-occupation.

Work on the improvement of environmental sanitation, covering or cleaning of drainage canals, filling of low areas, removal of vegetative growth, application of insecticides to supplement other control activities has to be used repeatedly throughout the year to maintain control.

Coordination

To attain the objective of this operation, that is control of mosquitoes and flies in a manner that is simple, inexpensive, safe, standardized, and uncomplicated, there must be technical coordination and proper timing of work by all entities.

The pest control measures can best be accomplished with an organized programme using all effective means and must have the cooperation of the entire community. The operation begins with the identification of the problems, orientation of the participating private and public officials and reaches its fruition in the education of the people in the communities.

Public Relation through Health Education

For maximum effectiveness, the pest control measures must be understood and supported by the people for whom protection is provided. They must therefore be informed about pest control work, they must be fed with the specific facts and instructions which should result in the development of sound habits, practices and attitudes. For these to reach the public, it is necessary to work through officials of established organization and agencies such as schools, Lions, Jaycees, Boy and Girl Scouts, 4-h Clubs, PTA's, religious institutions and other civic organizations. As a free public service, newspapers, radio and television stations and motion picture operators must be approached. Good public relations do not result merely because someone tells people that pest control is good for them. They need to understand the many facets of pest control and how they can benefit from this operation. To supplement the spoken and written words, charts, maps, posters, photographs, slides, film strips may be used.

Finally, pest control unit organization should have in readiness, a courteous, well informed staff who could answer telephone or person to person inquiries, should have ready personnel who can speak at various community meetings, and should have supervisors who are always ready to answer complaints promptly and give advice on a wide variety of problems.

Plan of Action

The following outlines are laid down as guides to the programme of work for the control of mosquitoes and flies.

I. Preparatory Phase

(1) Mapping of communities indicating breeding places and extent to ensure good coverage.

(2) Preparation of the community operating personnel, equipment and funds.

(3) Start of health education with the aim of inviting public support, and active community participation.

(a) Through public and private schools.
(b) Boy and Girl Scouts of the Philippines.
(c) Community health units.
(d) Civic organizations.
(e) By community meetings, assemblies, posters, pamphlets, films, radio and press releases.

(4) Dissemination of technical information and materials for instruction and demonstration on mosquito and fly control.

II. Attack Phase

Destructive measures against larvae and adult mosquitoes

(1) Get rid of breeding places of mosquitoes. Do not leave empty tins or bottles, coconut shells or other trash that can hold water. Remove and destroy unnecessary artificial water containers which can be hammered flat or perforated before burying them deep in the ground.

(2) Fill the holes of bamboo fence with concrete, sand or local material that will close the holes tightly.

(3) See that rain barrels, tube or any water containers used to hold water are covered tightly. Change water every 3 days in all drinking jars or flower vases. Scrub jars every 3 days to remove mosquito eggs.

(4) Drain or fill in all small puddles which have stagnant water. Earth or gravel may be used. Have a good drainage around the house and yard.

(5) Put oil or kerosene on small puddles of stagnant water to produce continuous film when you cannot drain them. Rain will wash away kerosene or oil so you will have to put oil and kerosene on the water often. Do not spray oil solution near open flames.

(6) For larger bodies of water that cannot be drained, spray the top with an insecticide recommended by government officials. The prevailing species of mosquitoes, the *Culex* and the *Aedes aegypti* have already attained a certain degree of resistance to insecticides, especially DDT. Use insecticides with care. They are poisonous to people and animals.

(7) Pans for watering chickens must be emptied and washed once a week.

(8) Remove and destroy mosquito shelters and daytime resting places around and inside dwellings by keeping weeds and shrubs away from houses and removing hanging clothes and putting them inside closed closets.

(9) Clean regularly drainage canals to maintain continuous flow to avoid standing water.

(10) Introduce sub-surface drainage or blind drainage method of disposal of liquid waste.

(11) Mosquito proffing of cisterns, wells and septic tanks.

(12) Use larvacidal fish (rainbow fish) at artificial ponds in and outside dwellings to attain biological control.

(13) Report leaks or defects in water system or help repair leaks.

(14) Cultivate dry kangkong varieties that grow in ground plots.

(15) Regular spraying with insecticides on open canals, wet basement, private drains, street drains, sterns and other breeding places.

(16) You may screen windows and doors to keep out mosquitoes and other insects. Use screens made

of rust resisting metals or woven materials such as mosquito netting. Everyone in the community

Everyone in the community should take all the above precautions as mosquitoes come from neighbouring places.

Destructive measures against flies

(1) Mass spraying of all uncollected garbage and other waste materials whether breeding flies or not.

(2) Mass spraying of fly granules in all places flies abound.

(3) Application of chlorides of lime on wet organic residue, pail depositories and garbage receptacles.

(4) All stables and smoke fish factories be treated with fly granules or insecticides sprays.

(5) All markets (public and private) be subject to regular spraying and fogging. Establish bait stations around market area.

(6) All hanging cords and electrical wiring in markets and food establishments where flies rest at night be treated with liquid insecticides.

(7) Cleaning of vacant lots and spraying some with insecticides.

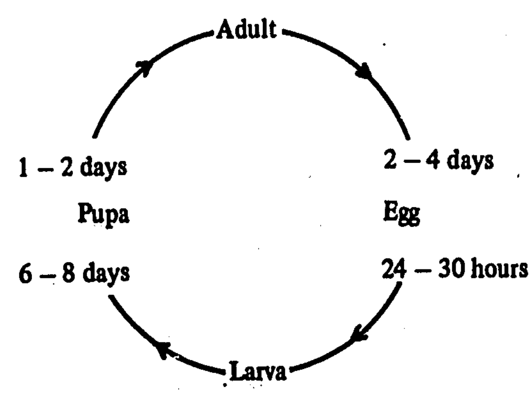
(8) Use covered metal container for garbage and refuse.

(9) Put up fly traps in places where flies abound.

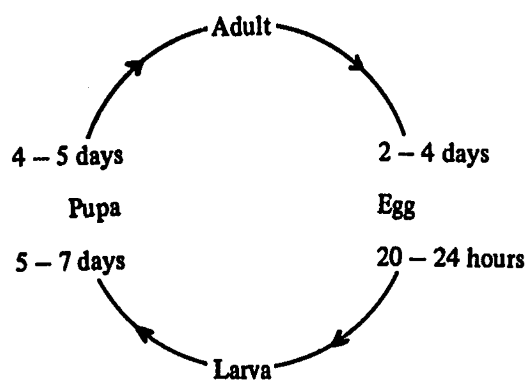
Suppressive measure

Strict enforcement of ordinances related to the control of flies and mosquitoes, Food Sanitation Regulations and disposal of garbage.

Life Cycle of the Mosquito



Life Cycle of the House Fly



Prevailing species of mosquitoes in the Metropolitan Area:

The Metropolitan Area is infested by two general species of mosquitoes – the *Culex* species which is a night nuisance and the *Aedes* species which is a day-biting mosquito.

The *Aedes aegypti*, vectors of H-Fever are present here. The most common sources of this particular species of mosquitoes and domestic breeding sources in the forms of flower bases, discarded auto tires, water storage in drums and drinking jars, baptismal fonts in churches, obstructed and sagging roof gutters, and urns in our cemeteries.

Vector	Disease
(1) Mosquitoes	
(a) *Culex* sp.	Filariasis, Encephalitis
(b) *Aedes* sp.	Yellow Fever, H-fever, Filariasis
(c) *Anopheles* sp.	Malaria
(2) House Flies	Summer diarrhoea, Typhoid fever, Dysentery, Cholera, Poliomyelitis, Tuberculosis, Anthrax, Intestinal Worms.
(3) Cookroaches	Cholera, Coliformbacilli, Food poisoning, Leprosy, Hepatitis, Plague, Tuberculosis, Dysentery, Intestinal Worms, Anthrax.
(a) *Periplaneta americana*	
(b) *Blatella germanica*	
(c) *Blatta orientalis*	
(4) Rats	Murine Typhus, Plague, Rat Bite Fever, Salmonollosis, Weil's Disease, Ricketsial pox.
(a) *Rattus rattus* (Roof rat)	
(b) *Rattus norvegicus* (Norway rat)	
(c) *Mus musculus* (House rat)	