The Hydrological Society of South Australia

and

The Department of Adult Education, The University of Adelaide

SECOND WATER RESOURCES SYMPOSIUM

WATER RESOURCES IN JEOPARDY?

YWCA Hall

16 Pennington Terrace

North Adelaide

6th August 1970

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F O R E W O R D

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The Hydrological Society of South Australia was established in March, 1969, to bring together the wide range of professional disciplines involved with water into a single learned society linked by interest rather than by professional grouping. Membership is completely open to lay people also so that, ideally, a proper and wide appreciation might be fostered of this vital natural resource.

This Seminar, considering the posed question of its title, is the second the Society has sponsored in the hope of seeing balanced answers to such questions of current import. It has been arranged jointly by the Society and the Department of Adult Education at The University of Adelaide.

We are grateful to the contributors who, of course, express their own opinions and ideas which are not necessarily those of their employing authorities nor of the Hydrological Society. We acknowledge with pleasure the ready permission granted by these authorities for their officers to speak and the support given to this Seminar by both State and Commonwealth parliamentarians.

We welcome your participation in this Seminar and in other activities of the Society.

R. Culver.
Chairman,
Hydrological Society of South Australia.

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C O N T E N T S

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(These papers are not necessarily in their order of presentation at the Seminar).

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THE EFFECTS OF LAND MANAGEMENT ON QUANTITY AND QUALITY OF AVAILABLE WATER.

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SUMMARY

Changes in the use and management of rural land in Australia have produced many serious effects on the quantity and quality of surface runoff and groundwater resources. Large scale irrigation development has substantially increased salinity levels in the Murray River, and the leaching of both fertilizer and pesticide residues from agricultural lands can create problems of water quality. Forestry practices have raised turbidity levels in surface runoff, and the conversion of the plant cover of a catchment from trees to grass can change the amount of runoff or groundwater recharge. Bushfires can substantially increase both peak rates of flood flow and rates of erosion from an affected area. Some examples of these problems in Australia are given.

1. INTRODUCTION

There are many problems caused by the effects of rural land use on the quality and quantity of water resources in Australia; the relative importance ascribed to each problem depends on the viewpoint of the individual affected.

Town water supply authorities are usually most concerned with agricultural and silvicultural practices which adversely affect the quality of the supply. Nutrients leached from fertilizers on agricultural lands can cause blooms of algae which deplete dissolved oxygen and cause a fishy taste in the water when they die. Forestry operations have caused high turbidity levels in the water supply to Canberra and other centres of population. Pesticide residues leached from agricultural lands accumulate in aquatic fish chains and can pass in increasing concentrations through fish to man. Persistent pesticides such as DDT are now recognised as a dangerous pollutant of water supplies.

By comparison, water resources authorities are concerned with assessing the influence of land use on the amount of surface runoff or groundwater recharge available for use. A change in the plant cover on a catchment such as conversion from trees to grass, can result in change in the available water. The Melbourne and Metropolitan Board of Works have long opposed logging of the fine stands of timber on the catchments providing Melbourne's water supply, on the grounds that young growing trees will consume more water than mature trees. More recently, there has been concern in other areas over the effects on water resources of such changes in land use as the conversion of native eucalypt forest to exotic softwood plantations, and the treatment of whole catchments with soil conservation works.

Another type of change in land use that can produce substantial effects on water resources is that of large scale irrigation development. In addition to depletion of the available water by abstractions for irrigation use, irrigation development in most semi-arid and arid regions results in problems of salinity, both in the area watered and in the downstream watercourse which carries drainage waters from the irrigated area. The problem of salinity in the Murray River resulting from irrigation development in New South Wales and Victoria is well-known in South Australia.

For the sake of brevity, the problems of catchment management which have occurred or have raised interest in Australia are briefly described in the following sections under the headings

- effects of land management on quantity of runoff
- effects of land management on peak rates of flood discharge
- effects of land management on water quality.

This information is mostly taken from a much larger report on catchment management in Australia, recently prepared by the writer. This report, of several hundred pages in length and containing in excess of 1000 references in the bibliography, is being published by the School of Civil Engineering of the University of New South Wales. The reader who is interested in the source of the following information is referred to the larger report.

2. EFFECTS OF LAND MANAGEMENT ON THE QUANTITY OF RUNOFF.

One of the major changes that has occurred in Australia in the period of European settlement is that large areas of native bush have been cleared for conversion to pasture or crop. Several changes appear to have resulted. Where deep rooting trees have been replaced by shallow rooting grasses, an increase in the total amount of runoff from the catchment usually results. In areas of Western Australia, South Australia, and

Victoria, the change from trees to grass has resulted in the raising of saline groundwaters at the foot of slopes and in the bottoms of valleys with subsequent salting of large areas of ground as water evaporates and the salt is accumulated on the surface. Raising of groundwater levels without any problems of salting has been recorded in the Callide Valley of Queensland.

Changes in runoff and/or groundwater recharge appear to be mainly due to effects on the evapotranspiration loss of the vegetation on the catchment. From the evidence available, three major influences on runoff and groundwater recharge seem to be significant:

(i) differences in incoming energy due to variations in slope and aspect over a catchment or between catchments.

(ii) differences in the rooting depths of vegetation which create different moisture deficiencies as the catchment dries out.

(iii) cultivation and cropping practices such as fallow which greatly reduce evapotranspiration loss for significant amounts of the tear.

Changes in land use which affect interception capacity, infiltration, of surface depression storage, do not show any consistent effect on water yield.

There is considerable evidence to show that conversion from trees to grass has resulted in increased surface runoff or groundwater recharge in a wide range of locations throughout the world. From the information available, it is possible to conclude that the cause is primarily the different rooting depths of the two forms of cover. The deeper rooting trees are able to extract more moisture from the soil than grass when climatic conditions permit, and so abstract more rain from following storms for soil moisture replenishment.

Because the effect is dependant upon climatic pattern, the amount of the increase in runoff or groundwater recharge due to clearing is not the same in all cases, but annual differences of 3 to 4 inches could be about the order of magnitude. No general prediction models have been developed for simulating the differences in water balance between trees and grass but there seems no reason why current mathematical catchment models could not be used for this purpose.

In Australia, the difference in water yield between trees and grass as catchment covers is most evident and of most concern as a difference in groundwater recharge rather than a difference in surface runoff. While the change from trees to grass can be treated as a single hydrological problem without separation into groundwater and runoff aspects it is the influences on groundwater that have been of most practical concern. and this extends to the problem of salinity associated with clearing.

There are two reasons for this. First, increases in groundwater recharge accumulate and even small changes show up over a period of time. Second, changes in groundwater recharge can raise shallow groundwaters, and have caused serious salting problems which are much more evident and significant than the small changes in recharge which produced them.

In a wide area extending from Western Australia to Victoria, the increased recharge of groundwater following clearing has resulted in raising of shallow saline groundwaters to the surface of the ground at the foot of slopes and in the bottoms of valleys. The salt, which accumulates at the surface as the water evaporates, has resulted in the gross deterioration of large areas of land, amounting to about 400,000 acres in Western Australia, 30,000 acres in South Australia, and over 10,000 acres in Victoria.

There is no evidence that soil conservation works and practices on a large scale are likely to reduce runoff to any significant extent. Farm dams have an obvious effect in abstracting runoff for use, but terraces and contour banks do not appear to reduce water yield in any systematic way. Some practices which affect evapotranspiration loss may affect water yield. The grassing or afforestation of bare areas seem likely to produce the most reduction in yield. Practices such as fallow which reduce evapotranspiration loss are likely to increase water yield. Extensive investigations in both the U.S.A. and U.S.S.R. have shown that soil conservation works have little effect on the water yield of large catchments.

Analysis of the differences in yield due to changes in land use are more complicated on large catchments than on small areas due to variation in hydrological behaviour over the catchment, to interflow and transmission losses, and to greater complexity in the groundwater patterns. Most research results are from experiments on small areas. It would be rash to extrapolate such data directly to large areas.

Since the Australian Forestry Council agreed to an accelerated programme of planting exotic pine species to make Australia self-sufficient in softwoods, some attention has been given to the hydrologic effects of replacing native eucalypt forest with radiata pine. An experiment has been in progress at Lidsdale in New South Wales since 1963, and early results show no substantial difference in water yield from catchments covered with eucalypt and Pinus radiata. Overseas studies in the U.S.A. and South Africa support the conclusion that there is no significant difference in yield between hardwood and softwood species other than can be attributed to differences in root depth.

Argument has been raised concerning the Melbourne water supply catchments that replacement of mature forest with young growing trees will decrease water yield. However, this proposition has no support whatsoever from the evidence available from overseas studies.

3. EFFECTS OF LAND MANAGEMENT ON PEAK RATES OF RUNOFF

Overseas results show that land treatment measures have little potential for significantly reducing floods on large catchments.

In the small watershed programme of the U.S. Soil Conservation Service, flood detention dams, with a storage capacity equivalent to about $3\frac{1}{2}$ inches of runoff from the catchment area controlled, are used as the primary flood mitigating measure. The reductions in flood peaks are greatest immediately downstream of the detention dams, and the effect diminishes with the distance downstream. A number of studies have shown that dams on tributaries mitigate flooding in those tributaries but have little influence on floods in the main river channel. The next most important flood mitigation measure in U.S. programmes is channel improvement to reduce overbank flow.

Land treatment measures, particularly contour banks and terraces, can reduce the peaks of small floods on small catchments. However, there is insufficient information available to generalize results or produce a general prediction model. Generally, the reductions seems to be significant only where the flood results from short duration high-intensity rain with runoff volumes of 2 inches or less. For a storm runoff of 2 inches, reductions in flood peaks due to land treatment would be in the order of 5% to 15%. In Australia, most floods (even on small to medium catchments) are the result of cyclonic storms which produce large amounts of runoff, of the order of 5 to 10 inches. Land treatment measures may have a small effect on flood peaks from small catchments under these conditions, but virtually no influence on flood peaks in large catchments.

However, bushfires can have a significant effect in increasing runoff volumes, flood flows and sediment yields. American data suggest that flood peaks may be doubled during the first year after a severe burn and that a period of 7 to 8 years is probably required to restore pre-burn conditions. The majority of results available for study are from California which has a bushfire problem similar to that in Australia.

There is opportunity for land management to influence the effects of bushfires by periodic control burning to prevent fuel accumulation and so reduce the severity of wild fires. Because the intensity of a control burn is very much less than that of a wild fire, the effect on plant cover is small, and any influences on runoff should take a much shorter time to disappear.

An experiment to determine the effects of soil conservation work on flood peaks was established by the Department of Conservation of New South Wales at Pokolbin in the Hunter Valley several years ago. From the little evidence which is available, it appears that this is probably the best instrumented and maintained experiment of its type in Australia but very little has been published about the experiment and no results have been made public. It seems that the experiment has not shown any significant effect of soil conservation works on flood peaks to date but this comment should not be taken as conclusive. To the best of the writer's knowledge, this experiment is still continuing.

In Victoria, the Soil Conservation Authority has established Limpet level recorders at a number of locations throughout Victoria to determine possible variations in peak flow from catchments under agricultural production. Experiments conducted at Parwan by the Authority have been used to study the effects of land management on rates of runoff. In Western Australia, the Soil Conservation Service of the Department of Agriculture is studying the effect of soil conservation earthworks on the runoff hydrograph at the Berkshire Valley experimental catchment, Moora.

The effect of bushfires on runoff flood flows and sediment yield is being studied in the Snowy Mountains area, in Queensland, and in Victoria. Following a severe bushfire in the Upper Tumut Valley in March, 1965, a study of its effect on sediment yields, catchment runoff and floods was commenced by the Snowy Mountains Hydro-Electric Authority. The Queensland Department of Forestry and the Forests Commission of Victoria are both using small plots (about 60-75 square feet) to study the effects of control burning practices, but these are more related to sediment and water yield than to floods.

4. EFFECTS OF LAND MANAGEMENT ON QUALITY OF WATER.

Rural land use affects the quality of available water in Australia by increasing the level of turbidity and sediment, by bacteriological contamination from animal wastes, by the leaching of nutrients and pesticide residues, and by increases in salinity resulting from large scale irrigation development.

Turbidity in water supplies can be substantially increased by clearing of land in the catchment, by construction activities on or near watercourses, by forestry operations such as logging, and by cultivation. The problem is more widespread in catchments providing town and city water supplies than is generally realized. The example of Canberra's water supply is probably the best documented; however, many other similar cases have occurred.

Bacteriological contamination from animal wastes has not produced widespread problems in Australia but this is undoubtedly because of the many controls which exist in public health and catchment management legislation. Pig farming is given particular attention in most regulations governing use of catchment lands, and the disposal of carcasses of dead animals is also controlled. In the U.S.A., problems are occurring because of high concentrations of animals on small areas in large-scale "factory farming". In cool climates where much runoff occurs from saturated ground each winter animal wastes are not absorbed into the soil and tend to contaminate surface water supplies. Neither of these two problems is widespread in Australia, although isolated problems occur.

The use of artificial fertilizers on agricultural lands is increasing rapidly and, because applications are never even or exact, the leaching of nutrients, particularly nitrate and phosphate, into water supplies is increasing. Infants and young animals are poisoned by excessive amounts of nitrate, but this does not appear to have happened in Australia. The more practical problem occurs where the nutrients accelerate the growth of algae and water weeds. Blooms of algae can deplete the oxygen in water and subsequently die, leaving an unpleasant taste and discolouration in the water. Clogging of filters, pumps and pipelines can occur. Problems with algal blooms have already occurred in most states.

The greatest single problem of water quality is that of salinity in the Murray River resulting from irrigation development in Victoria and New South Wales. Almost all natural waters contain some soluble salts. These derive from the weathering and breakdown of rock materials, or they may derive from the leaching of sedimentary rocks which were formed under a saline sea, or salts of oceanic origin may be deposited on a catchment by rain.

In irrigated areas where subsurface drains collect any excess from overwatering, the amount of salt passing through the system is not altered but the amount of water is substantially reduced by evapotranspiration loss. Consequently, the salinity of the drainage waters is usually substantially higher than the salinity of the irrigation supply. In areas where there is inadequate drainage, either natural or artificial, overwatering usually results in a rapid rise in groundwater levels and waterlogging when the watertable reaches the surface. If the groundwater is saline, as often occurs in Australia, salt accumulates at the surface as water evaporates, and salinization of the land results.

When very large areas are irrigated, the total amount of drainage effluent and the total quantity of salt for disposal can be very large. If this waste must be returned into the river channel and carried downstream in the river to the sea, the quality of water downstream of the irrigated area can be seriously degraded.

In Australia, the major areas of large scale irrigation development have been around the Murray River and its tributaries. Problems of waterlogging, salinization, and degradation of water quality in the lower reaches of the river, have occurred. Management of salt is now a major problem in the operation of the river.

The Murray Basin can be conveniently considered in three zones - Upland, Riverine Plain, and Mallee. There are two primary salinity problems associated with irrigation development. These are (1) shallow and highly saline watertables in the Riverine Plains; and (2) high salinity in the river water in the Mallee region. The main supply of runoff water comes from the well-watered Upland. The quality of this supply water is very good for irrigation, and the much higher salinities which occur in the river water further downstream derive from the Riverine Plain.

The Riverine Plain is characterised by shallow groundwaters, most of which are highly saline. Natural drainage is poor, and channel seepage and overwatering from irrigation has raised the watertables with subsequent waterlogging, and salinization where the groundwater is saline. With the rise in watertables, the discharge of saline groundwater into the base flow of the rivers has also risen, particularly after rain.

Because of the salt loads from tributaries entering the Murray River in the Riverine Plain, the salinity of the river water increases steadily from Hume Reservoir downstream to the mouth. The Mallee Zone commences near Swan Hill and includes the Sunraysia region, stretching to the South Australian border, and the South Australian region. In South Australia, the river flows in an incised channel and salt accessions to the river are from the generally saline groundwaters. This salt added to that brought down from the Riverine Plain produces salinities which reach critical levels in periods of low flow. The majority of irrigated land above Mannum in South Australia is devoted to horticultural crops, including stone fruits and citrus which are particularly salt-sensitive. It is the salinity of the river supply water that is important in this region.

Sacramento's channel 80-100 miles to carry poor quality drainage water to the Sea.

Salinity control in the Murray River is a complex problem involving the disposal of some very high saline waters into evaporation basins, and the regulation of flow by many dams to control quality by dilution. The River Murray Commission has commenced an extensive review of the problem by consultants. Their report is expected to be available some time in 1970.

CONCLUSION

Rural land use produces many problems of catchment management in Australia, and these include problems of quantity as well as quality of water. The problems are becoming more evident and better known as the concept of multi-purpose use of catchment lands , achieves wider acceptance. The old idea of single-purpose catchments used solely for providing water supplies to metropolitan areas is slowly fading.

A large amount of legislative control over land use in water supply catchment areas has been established in Australia. Indeed, the control already established is far in front of the scientific knowledge currently available to direct the use of this power. It should be stated that Australian knowledge and experience is high by world standards. The lag in scientific knowledge of catchment management is a world-wide lag and not a local deficiency.

One particular aspect in which a deficiency exists in Australia is in the teaching of catchment management. Most knowledge and information obtained in this country is the result of the personal interest of individual research workers. The practical art of managing catchment areas is usually learnt on the job when the responsibility is encountered. There is no systematic teaching or training in Australia of how rural land use affects water resources or how multi-purpose water supply catchments should be managed. This particular deficiency will take time to overcome, and warrants some immediate attention.

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RIVER HYDROLOGY AND RIVER REGULATION

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A. INTRODUCTION

Any natural fresh water stream, larger than a brook or creek, flowing in a well defined channel and discharging into a larger body of water, can be called a river. The larger body can be an ocean, another river or a lake.

Variations to the above definition exist. There are rivers that soak into porous ground, that evaporate in excessively arid areas (lost rivers), that, under favourable conditions, run underground for varying distances reappearing or disappearing one or more times.

Rivers pass through growth stages:- young (swift-flowing and deeply ravined), adolescent (well cut channel with graded bed and base level at the mouth) and old (widened valleys, meandering, slow flowing). They can even be beheaded! finding a new outlet and reducing the parent volume, force and length.

These "alive" and variably active water resources must be utilised and tamed by man who at times perhaps approaches the task with Gilbertian optimism.

In the broad concept, rivers can be classified as to:-

1. Size and Discharge - Size can be determined by the extent of the basin, defined by tidal limits and rainfall run-off areas. Discharge can be calculated in terms of the average fresh water volume.

   Size varies according to basin topography and can range from the small drained volumes of streams falling from high ground near the coast and flowing direct to the sea, to the immense flows of a river flowing down mountain slopes, traversing vast stretches of valleys and plains and finally reaching the ocean. The basin in the latter case can occupy a large part of a continent.

2. Slope - The rate of flow depends mainly on the slope and roughness of of the channel. The fall follows approximately that of the country it traverses, but the slope is generally more gentle because of its meandering alignment.

   In large basins, the river usually begins as a torrent of variable flow, ending as a gentle stream of comparatively regular discharge.

Other characteristics include the ability to transport detritus from erosive origins in the basin, the size range of such detritus; channel erosion patterns, flood and drought flows and water quality.

B. WATER RESOURCES

The ability to harness and control a river can only be as successful, in the long term, as the knowledge of all the facts associated with its geologic history and the hydrologic data related to its characteristics.

The quantitative water resource can be compounded from a knowledge of:-

1. Inflows - these are determined from observations, records and investigation of the natural factors of precipitation (rainfall, snowfall, snowmelt) evaporation, run-off factor, stream flows including flood flows, groundwater entry and the physical characteristics of stream channels.

   Inflows are determined for the basin catchment area which includes those portions associated with the main stream and with tributaries.

(a) Precipitation

Water vapour is always present in the atmosphere and under favourable conditions condenses into water droplets or ice crystals to form cloud and ultimately precipitates as rain or snow. The precipitation intensity, the annual amount, and the seasonal distribution for any given river basin must be determined and their effects on the regimen of surface and underground water established.

Rainfall is expressed in terms of the depth which would accumulate on a flat surface if none of the water were allowed to run-off and is measured in inches or millimetres by means of a rain gauge.

The snow pack accumulated in mountains melts during the Spring and early Summer. Snow surveys are conducted for intervals of altitude to determine the water content as the basis of forecasts of water yields to adjacent valleys. Where the snow fall is too heavy and the climate too cold for all of the snow to melt in Summer there is a progressive accumulation until glaciers are formed. These creep down the valleys and move into warmer zones where their fronts are melted off or are pushed into the sea forming icebergs.

(b) Run-off

As rain falls to the earth a portion is intercepted by the leaves and stems of vegetation and is eventually returned to the atmosphere by evaporation. Another portion is retained as puddles on the ground surface and part of this infiltrates into the soil, the greater part being evaporated. Much of the remaining water which reaches the ground infiltrates into the soil under the action of gravity and capillarity. The infiltration capacity of soils varies greatly. Water will infiltrate more rapidly into drier soils than into moist soils; sandy soils are more pervious than clay soils while broken lava and cavernous limestone are highly permeable. The infiltration capacity of rock outcrops, paved surfaces, buildings etc. is practically zero.

Forests and grasslands usually have a relatively higher infiltration capacity than cultivated soils because of the channels created by decayed roots and worms and because the vegetal cover protects the soil by compaction from raindrops.

When soil moisture is replenished, water slowly moves laterally through the soil toward streams and downward toward the groundwater. When rainfall exceeds the infiltration capacity surface run-off or "overland flow" occurs.

The quantities of precipitation distributed to interception, puddles, soil moisture, lateral flow, ground water and run-off vary greatly from storm to storm and the hydrological problem is to determine the relations governing the distribution so that the inflow to streams for a given storm can be reasonably predicted. This in turn assists designs for storage spillways, culverts and storm drains and provide a means of flood forecasting.

(c) Streamflow can be defined as the water in surface channels, and records are obtained at stations in several ways including the taking of periodic measurements of the flow velocity with a current meter. The cross sectional area of the stream multiplied by the measured velocity gives the flow rate. The discharge at each such measurement is correlated with the stage (water level) at the time of measurement to give a stage-discharge relationship. Continuous records of stage are then obtained by automatic recorders or frequent readings of water level can be obtained by reading from a scaled gauge set in the stream. Weir structures and storages can also be arranged to measure flow.

Predictions of stream flow can be made by the use of probability statistics correlated to antecedent flows.

(d) Floods and Droughts

Much study has been given to the many factors which determine the magnitude and expectancy of floods and droughts. The flood history of streams gauged over a long period of years may be analysed by statistical methods to estimate expectancy.

A drought is more difficult to define as a relative term and statistical analysis is less successful than for floods. Why?

Despite geologic evidence of long term climatic changes, indications are that within the time periods of interest in most engineering designs, extremes of flow may be considered as random processes subject to change rather than cyclic variation.

(e) Groundwater

Where the water table intersects streams, lakes or swamps under a positive hydraulic head, groundwater is discharged and becomes "surface" water. Movement of groundwater is extremely slow and does not ordinarily constitute a major stream resource. Nevertheless groundwater may be the source whereby pollutants enter a stream.

2. Losses - These include outflows from percolation, losses by evaporation and evapotranspiration, "operation" losses and "apparent" losses caused by gauging errors.

(a) Evapotranspiration and Evaporation

Water in lakes and streams, soil moisture and snow on the ground are subject to evaporation. Soil moisture is also subject to transpiration, the process by which plants take up moisture through their roots and discharge it to the atmosphere through their leaves. The total of these losses for a given area is called evapotranspiration.

Estimates of probable evapotranspiration from cropland serve as a basis for determining irrigation water demands.

Potential evapotranspiration can be measured by determining the water loss from tanks filled with soil planted with vegetation typical of the area and supplied with sufficient water to satisfy the needs of the plants. Actual evapotranspiration from the adjacent area will be less than the measured loss to the extent that the natural water supply for the plant growth is deficient during some parts of the year.

The associated hydrologic problem is to minimise non-beneficial evapotranspiration to provide a maximum water yield for land management and other uses.

The evaporation loss from a storage and/or river system can be an important factor in determining the amount of water which that storage can supply for beneficial use.

In general there is no simple method for direct measurement of evaporation or of evapotranspiration from land areas. Evaporation from small tanks can be measured, but these measurements must be adjusted to provide estimates of loss from natural water bodies.

(b) Percolation

When the level of the adjacent water table is lower than that of a stream surface, discharge from the stream will occur, dependent on the differential gradient and soil permeability. In some streams this can have a significant bearing on the magnitude of the useful water yield and the method of artificial regulation to meet water demands along its various sections.

(c) "Operation" Losses

"Operation" loss is a term that can be used to describe water, released from storage to meet a diversion demand, and not subsequently being used, due to rain falling in the areas of demand, after storage release has been effected. If there is a storage downstream, not at full capacity, the inadvertent surplus can be stored.

3. Water Quality

(a) Suspended Sediment

Much of the energy of falling raindrops and flowing water is expended in erosion of soil and rock. The impact of raindrops has been shown to be important in initiating soil erosion. Vegetal cover shelters the soil from this impact and reduces erosion.

Water in streams erodes the bed and banks carving canyons and forming flood plains. Erosion is a natural process which has created arable valleys and fertile deltas. Cultivation and other activities of man can accelerate erosion of valuable topsoil which may ultimately fill useful storage space in reservoirs or clog stream channels.

The quantity of suspended sediment in a stream is measured by sampling. The sample is filtered to remove the sediment, which is dried and weighed. The total volume of streamflow multiplied by a concentration ratio gives the total of sediment transported. In controlling this aspect of a stream system, means must be found of minimising erosion of land and the channel and of determining the quantity of transported sediments.

(b) Minerals

Most natural waters contain dissolved minerals derived from the mineral constituents of the rocks and soil of the drainage basin. Some of these minerals are undesirable for irrigation, domestic or industrial uses. Hence chemical analysis of natural waters is essential.

(c) Pollution

Any change in the physical, chemical and/or biological properties of water such that it is rendered unsuitable for its intended use can be classified within the term pollution. Changes can be incurred from bacteria, viruses and other organisms; by plant nutrients, inorganic salts (salinity), oily materials and toxic salts (pesticides etc.)

Uncontrolled pollution, can lead to the total loss of a water resource. Once the safe limit is passed it may be difficult or even impossible to restore a desirable status quo.

C. DEMANDS

Dependent on the present seasonal conditions and the correlated conditions of antecedent seasons, there is a demand, variable throughout that season, for water of a satisfactory quality and sufficient in quantity to satisfy requirements for domestic, industrial and irrigation usage. The vast majority of man regulated streams must meet these needs simultaneously at any point of time. In addition, for some streams an hydro-electric demand is incurred. A further demand can be brought about by navigation requirements.

Ingenuity, clear planning, and efficiency of design and operation of a stream are required to satisfactorily meet the demands, existent and projected.

To provide reliability of those obligations for all extremes of inflows and outflows, is a task demanding the co-ordination of the skill and knowledge of the engineer, hydrologist, geologist, geographer, lawyer, chemist, doctor, scientist, farmer, and many others.

D. UTILISATION OF RESOURCES - REGULATION

The ideal engineering history of development of a river system is a step by step process, planned to cover anticipated and actual demands on its resources. It is necessary to create structures to achieve this.

In planning any development, economic factors should always be taken into account. In practice, it is not always a simple matter to anticipate the true values of urban, rural and industrial expansion, and, as a consequence, the development can fall behind demand, creating an increasing severity and frequency of seasonal restriction.

In matching resources to demands consideration has to be given to obtaining the maximum yield of water from the river system and to achieve this, an examination and evaluation is made of many factors including-

1. Storages

Apart from the engineering problems associated with the site and structure of a proposed storage, the following are some of the considerations which must be evaluated.

(a) Spillway capacity - based on a knowledge of inflows, releases and estimated storage behaviour.

(b) Maximum release rate - calculated against downstream demands, storage behaviour, flood pondage etc.

(c) Natural Spill - beyond full capacity

(d) Evaporation - Storage Curve

(e) Storage - Level Curve

(f) Storage Behaviour Curve - predicted storage over years of assumed conditions.

(g) Flood Pondage Volume - to mitigate peak inflows. This can be a fixed or a variable storage versus time line.

(h) Reserve Storage - to provide a safeguard against years of low inflow.

(i) Dead Storage - the unusable volume.

(j) Siltation Rate - a factor determining the useful life span of the structure.

(k) Economic Storage - the storage size which provides the minimum cost per acre foot of yield.

(l) Hydro-Electric Reserve Storage and release rate.

(m) Capacity available in the channel downstream.

(n) The use of the storage as a recreational facility.

Some storages are built purely for flood control purposes, the actual water being held temporarily.

Ideally, all potential storage sites available to a river system are examined to estimate the potential gains in water and power and to consider these in relation to their likely cost. The state development of construction can then be established. It is of course necessary that updated reviews be carried out to allow for changes in demands and the general economy.

The capitalised cost of construction of each storage, allowing for interest and depreciation charges, increases the unit cost of water and this should be taken into account when reviewing the next stage of development.

2. Regulating Structures.

To control releases from storage, together with natural spills from tributary streams, the reduction in diversions caused by sudden rainfall and to maintain required levels and flows for irrigation and other diversions and for navigation it is necessary to augment storages with regulating structures. These are usually in the form of adjustable weirs both with and without navigation locks and are sited across the stream bed.

The sequential development of storages also provides a measure of regulation.

3. Measuring Structures

Apart from automatic or read gauge recording installations, use can be made of the weirs and storage spillways or separately designed structures (e.g. Parshall Flume). Assessments can then be made of losses along the stream system and a check is provided to measure the efficiency of regulation.

4. Channel Improvements.

It is usual to find, that, as the river system is developed, the natural capacity of the stream channel is, in places inadequate to meet the new demands imposed upon it, particularly when natural flooding beyond the channel banks is to be reduced or avoided because of rural development in the river valley. In such cases works can be carried out to improve the capacity.

In the case of a heavily meandered stream straightening and enlarging of the channel is carried out.

In regulating a stream, the times of travel for various levels of flow, the transit times of salt waves, and the ponded volume of water in transit must be known to assist in achieving more precise control. Comment has already been made on water losses which can occur. When salt flushes rise in the stream a regulation demand for dilution can occur.

Regulation must endeavour to satisfy the demands of riparian and other users, at the same time safeguarding against the year or years of low inflow. This demands co-operation with district, rural, State or County authorities to ensure that proper assessments of demand are made and that the ultimate limits of development and utilisation for the stream system are known.

As a very necessary adjunct, legislation must be provided in a workable form to permit a constituted authority to develop the system and to manage it.

E. INFLUENCES ON REGIONAL ECOLOGY

The development of a river system for the purposes of its regulation and operation, must, of necessity, change natural conditions over the whole basin, and an important aspect of that development must be the retention, as far as is practicable, of environmental conditions aimed to preserve a natural balance of flora and fauna.

Factors to be considered are:-

(a) The influence of ponding, effluent discharges, water temperatures and level fluctuations on breeding ground for marine life, aquatic birds and vegetation.

(b) The effect of disruption of the natural flow regime on leaching of soils of the flood plain. Salts which rise by capillary action in the soil over a period of normal flow years are leached by flood flows and this allows vegetative growth to survive. Regulation tends to modify the effect of smaller floods to the extent that flood plain coverage is reduced in frequency.

(c) Structures set across the stream, by the act of ponding, create an hydraulic head which influences groundwater profiles and can provide a groundwater front which affects areas downstream and adjacent to the structure. Erosion problems can also be created.

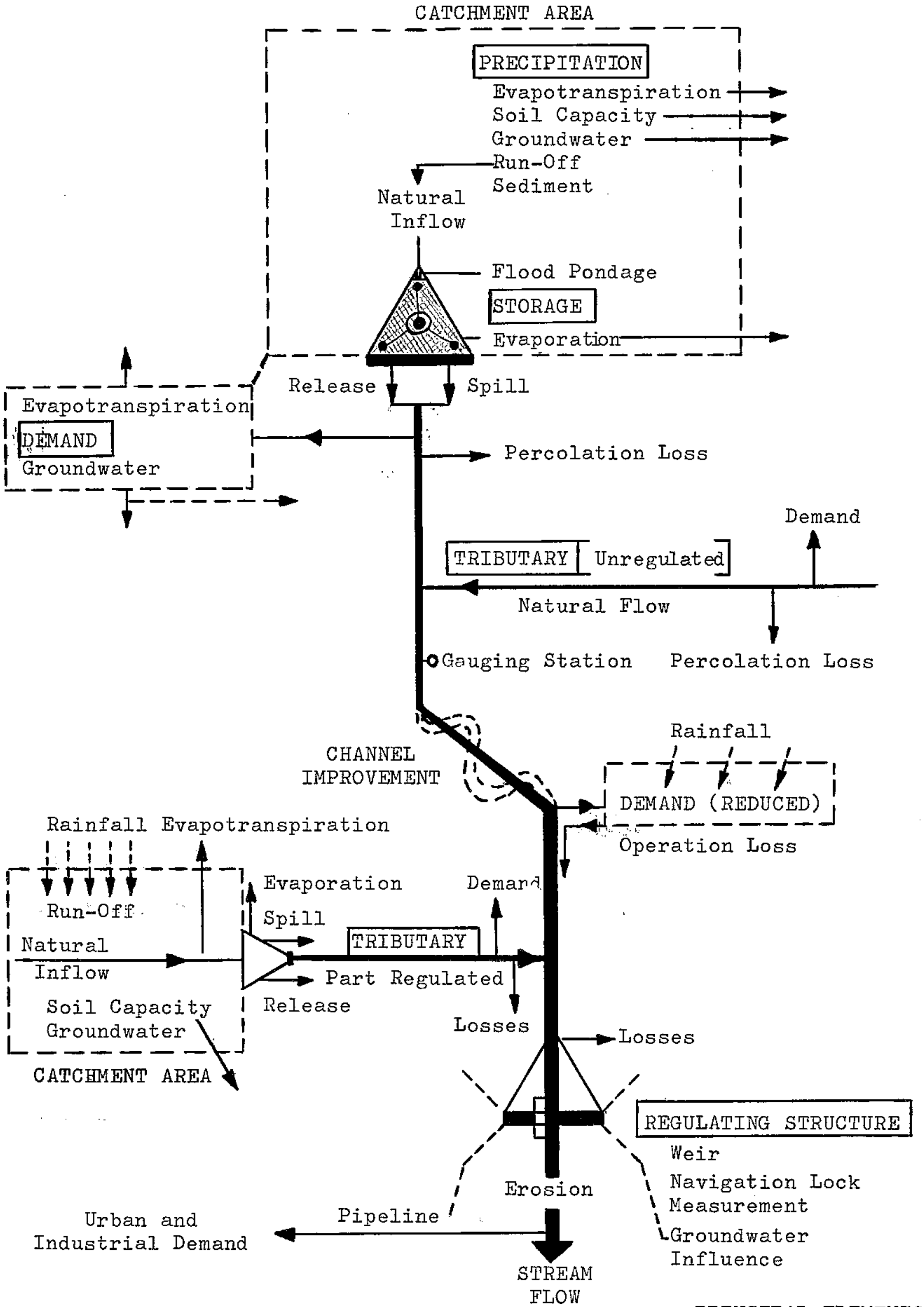
(d) Over-development and mismanagement of a catchment area can lead to erosion and silt problems as well as provide a strong influence on groundwater levels adjacent to the stream.

F. CONCLUSION

A carefully controlled and properly developed river system taking into account the various user demands placed on it, can provide a satisfactory result for water authorities and the community at large.

Economic production of goods, acceptable tourist and recreation facilities, regional and town growth and community health can result.

Additional co-operative efforts by the community can materially assist in the establishment and maintenance of a balance of flora and fauna.



PRINCIPAL ELEMENTS
RIVER SYSTEM

CONTAMINATION OF UNDERGROUND WATER SUPPLIES

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CONTENTS

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CONTAMINATION OF UNDERGROUND WATER SUPPLIES

It is perhaps significant that far more attention has been devoted over the years to the study of the orderly and economical development of groundwater than to the equally important evaluation of processes by which degradation of these resources is taking place. Now, there are clear signs that this situation is altering. It is realised that failure to understand how human activities can foul the natural environment may lead to the loss of valuable resources, sometimes permanently. The intention of this paper is to examine some of the more important threats posed to underground water resources as development gathers momentum.

DEFINITION

A number of different terms are in common use to describe processes by which the quality of groundwater is degraded. Pollution has lately become a fashionable word in discussions of man's interaction with his environment. In a groundwater context it has been used synonymously with contamination to describe the resource when it 'is altered, directly, or indirectly, as a result of the activities of man, so that it is less suitable for any or all purposes for which it would be used in its natural state'. (Buchan and Key, 1956). Normally groundwater is changed in its composition by the addition of biological or chemical pollutants. Other processes involve the progressive increase of mineral content particularly by the encroachment of sea water or from adjacent saline sources within the groundwater body. Finally, water quality may be impaired by rises in temperature when groundwater is used in heat exchange systems and subsequently returned to the aquifer.

MECHANISMS OF CONTAMINATION

The processes leading to groundwater contamination are best considered within the general framework of the hydrological cycle, despite the disadvantages of the form in which this cycle is commonly presented. In reality the movement of water on and in the earth's crust is exceedingly complex and if problems of contamination are to be solved, a wide variety of disciplines including geology, chemistry, biology and hydraulics must be utilised. Conversely a detailed study of the environment of groundwater will assist in an appreciation of those parts of the natural order which have operated to create and preserve the water reserves on which we now depend. Today we are becoming aware that many of the built-in safeguards of nature are being broken down as a by-product of man's technological advance.

Contamination of groundwater may take place as a result of two main processes:

1. Gradual degradation resulting from development techniques which draw on the resources beyond its natural recharge capacity, or are poorly designed, and result in wastage of the available reserves through unnecessary admixture with higher salinity water.

2. By the introduction of chemical or biological pollutants. This may be a deliberate policy arising from a decision to dispose of noxious substances underground or it may be a gradual but insidious process resulting from otherwise harmless activities such as farming, various industrial activities or the mundane task of disposal of household waste from our towns and cities.

Both processes outlined have parallels in surface water resources but several components operate to make underground contamination a more serious and intractable problem. Probably the most important factor is the slow movement of water underground. In contrast to a stream or river where velocities are measured in feet per second, movement in an aquifer is more likely to be expressed in feet per day or even feet per year. This means that underground contamination may go undetected for long periods; remedial measures are slow and in some cases reclamation becomes impossible or uneconomic once the affected area has become widespread. In contrast to surface water bodies, sampling of underground water is restricted to the few points of access provided by boreholes or wells. Provision of more sampling points is expensive, and in many cases it has proved impossible to define the limits of a contaminated zone in either a horizontal or vertical direction within an aquifer.

GEOLOGICAL CONTROLS

Figure 1 illustrates in simplified form the processes by which contamination may take place during the natural movement of water to a free water table type aquifer. Once the water has reached the ground surface geological factors become of paramount importance in the natural control of contaminants both in the aerated zone and in the aquifer itself.

Three main geological environments are recognised as important for study:

1. Unconsolidated materials including sands, clays and silts. They may result from transport and deposition by water or wind; alternatively they may have been formed in situ as products of rock weathering.

2. Consolidated rocks of either sedimentary or igneous origin.

3. Rocks formed by chemical or organic agencies.

Unconsolidated strata

These occur both in the aerated zone above the water table and also as the aquifer. Commonly sands, clays and silts form a mantle over consolidated rocks at depth, and this situation is ideal in providing a natural 'sieve' to help remove contamination from downward percolating water. The efficiency of this zone of purification is related to the nature of the contaminant and to the grain size and thickness of the strata. Several processes are involved including mechanical filtration, adsorption, chemical oxidation and microbial metabolism. Dissolved chemicals are not reduced by filtration but changes may occur in the proportion of each present as a result of reactions with chemicals originally held in the solid state in the strata.

The main benefit of percolation through the aerated zone is the destruction of harmful bacteria and the breakdown of organic pollutants. Barr (1957) has provided a well documented case on a large scale from Leyden in the Netherlands. Water for the township supply is filtered through dunes formed of fine sands, using a cyclic system dependent on the seasons. By alternating wet and dry cycles in the dune a high oxygen content is maintained and efficient purification achieved. Fig. 2 illustrates the sharp fall in bacteria counts under the infiltration basins in the dunes.

Considerable work has been carried out on the distance of travel of pollutants in sands and silts, with the object of trying to establish the safe distance required for the purification of water to the point where no health threat is posed. McGauhey (1968) has come to the conclusion that purification from bacterial hazards is achieved both in the biologically active earth mantle and in the aquifers composed of sands. He quotes work to show that bacteria in sewage is removed 'in from 3 to 7 feet of quite coarse soil' and that even in a course gravel aquifer coliform bacteria disappear within 200 feet of the entry zone.

An up-to-date survey of current knowledge is provided by Romero (1970). He notes that 'each individual stratum of porous media possesses its own filterability' and in consequence he is reluctant to establish a single line graph to show the relationship of grain size in the media and the distance of travel necessary to remove bacteria and viruses. Fig. 3 illustrates graphs prepared by Romero to indicate the degree of danger from biological pollutants in non-saturated materials and within the groundwater body. The potential for increased distance of travel within the groundwater should be noted, and Romero sounds a warning that distances may be increased if suitable nutrients for the bacteria or viruses are encountered en route.

Mallman and Mack (1961) have issued a warning on the effects of 'hard' synthetic detergents. These lower the surface tension and act as a suspending agent, thus increasing the danger of pollution travel over wider distances. Current changes to biodegradable detergents will undoubtedly reduce risks from this cause.

It is clear that several aspects are important in a consideration of the role of unconsolidated strata in preventing the transmission of contaminants both above and within the ground water. Entrapment and sedimentation are physical processes which are relatively well understood but much more remains to be done in the field of adsorption. Hem (1961) has pointed out the importance of ion exchange mechanisms on clay particles. Little work has been carried out to study changes which may occur as a wide range of chemicals is percolating through the aerated zone or within the groundwater body. In some cases purification may result and in others, chemical reactions produce more noxious substances even if these only cause aesthetic problems for users. An important field of research lies in the study of the migration of various nuclear fission products. Russian work has shown that although caesium 137 is readily absorbed by soil, ruthenium 106 is poorly retained and strontium 90 is capable of migrating a considerable distance from the source (Belitskiî and Orlova, 1960).

Consolidated Rocks

In contrast to the wide range of permeabilities exhibited by sands, silts and clays, most consolidated rocks have a moderate to low primary permeability as a result of compaction and lithification. This is frequently offset by high secondary permeability caused by faults and joints which break up the rock mass. Fractures vary in frequency, extent and size and further modifications may take place as weathering products fill the openings or chemical actions widen them.

Secondary permeability offers preferred travel paths for the passage of water and therefore of contaminants. Movement can take place rapidly over large distances without the opportunity for the purification associated with the slow passage of water in unconsolidated materials.

Sandstones and quartzites retain an open fracture system and in consequence produce large quantities of high quality ground water. Figure 4 shows how this may lead to contamination; the rocks tend to form outcrops because of a resistance to weathering and few weathering products are produced to seal the fracture systems. Contamination is thus able to move rapidly through the zone above the water table and the aquifer.

Specific examples of this type of environment are not given but attention is drawn to the potential for contamination in the Adelaide Hills area where boreholes are drawing supplies almost exclusively from fractured, consolidated rocks.

Rocks of chemical or organic origin

Special problems are posed by rocks of this type. Limestones and to a lesser degree dolomites, commonly provide very good aquifer conditions and are widely exploited for human and irrigation uses.

Primary permeability of limestones varies widely; Cretaceous chalk beds in England have a low permeability while high values are recorded in some of the limestones of the Murray Basin in South Australia and Victoria.

Secondary permeability results from solution activity along fractures and bedding planes and may reach the stage of producing long and complex open passages which function as conduits for water flow. In these conditions contamination can move very rapidly from the entry zone. MacLean (1961) has quoted a spectacular example of pollution entering swallow holes in a chalk aquifer in S.E. England and affecting wells $9\frac{1}{2}$ miles away within 80 hours, a mean velocity of over 550 feet per hour.

HYDROLOGICAL CONTROL

Movement of water underground is dependent on a number of physical laws which are studied collectively under the heading of groundwater hydraulics, and an understanding of the principles involved is necessary if contamination is to be controlled.

Two aquifer types are normally recognised:

1. Water table type aquifers in which the upper surface of the water is free, that is, under atmospheric pressure.

2. Pressure aquifers, where the water is confined beneath an impermeable capping.

It is recognised that contamination is much more likely to occur in water table aquifers; access by pollutants is often possible over wide areas and the water table is not infrequently within a few feet of the surface. In contrast, contamination under normal circumstances can only reach a pressure aquifer through a relatively small intake zone or by artificially induced methods such as pumping wastes underground by means of boreholes.

A superficial appreciation of the behaviour of contaminants in a groundwater body would suggest that normal rules of ground water hydraulics apply. Le Grand (1965) however, has warned of important questions to be taken into account, including -

a. Is the contaminant entering the aquifer continuously or as a series of slugs ?

b. Is the contaminant of a simple or complex chemical nature ?

c. Is the volume of contaminant enough to change the normal groundwater pattern of flow ?

d. Will alteration of the hazard take place by dispersion-dilution, chemical alteration or sorption ?

Le Grand refers to zones of contamination as malenclaves and notes a wide range in size from a few square inches to several square miles. He discussed a wide range of malenclave patterns and Fig. 5 illustrates a basic classification of changes which may occur and the factors causing those changes.

Definition of the boundary of contaminated zones is a difficult and expensive process. Most aquifers are not isotropic and permeability in a verticle direction is often extremely variable leading to the concentration of contamination in one particular stratum. Geological formations show facies changes laterally, and in sands and gravels high permeability zones of extreme assymetry of shape are a normal occurrence. A thorough understanding of the geological history of the area is therefore essential if the development of a contamination zone is to be understood.

The best documented examples of contamination zone definition are in areas of high density borehole development. Walker (1961) quotes an example near Denver, U.S.A. where contamination took place from an army chemical factory disposal lagoon. The area downstream was developed for irrigation and over 80 boreholes were available for monitoring purposes. The zone eventually covered an area of $6\frac{1}{2}$ square miles and closely matched the anticipated area of influence forecast from a study of groundwater stream lines. A noteworthy feature was the changing chemical content of the contaminant. This could be defined with some precision underground.

In the Montebello incident (Svenson, 1962) chemicals used in the manufacture of 2, 4-D weedkiller (2, 4 dichloro-phenoxyacetic acid) were dumped via a sewage treatment works into the Rio Hondo river, California. At the point of discharge the groundwater is effluent to the river and no contamination of the aquifer resulted. Downstream the opposite situation occurs and Montebello city draws water from aquifers charged by the river. A dilution of 1 to 10 million was estimated to have taken place, but this was insufficient to remove the taste and odour of dichlorophenol which persisted in the aquifer for 4 to 5 years.

CONTAMINATION CAUSED BY GROUNDWATER DEVELOPMENT.

The understanding of groundwater movement within an aquifer has increased significantly since the formulation by Theis of his theory of groundwater flow under unsteady state conditions. Nevertheless groundwater development has proceeded so quickly that details of its effect are known and understood only in very limited areas. In consequence it is not surprising that development has led to unforeseen consequences such as the ingress of saline water either laterally or vertically from within the complex groundwater body.

This type of contamination may be very slow with minor increases of salinity which pass unnoticed. Attention is focussed on more dramatic changes such as the movement of sea water inland. It is true however that all high quality underground water is surrounded on all sides and below by saline water, and success in the development of a particular resource can be judged by the hydraulic balance struck in the extraction of the maximum quantity of acceptable quality water, be it for human consumption, irrigation or industrial purposes.

Shallow aquifers have been widely developed because of low development costs and ready accessibility. If the water is used for irrigation, potential exists for slow contamination of the resource by recirculation. Each time the water is pumped and applied to the ground a certain percentage is lost by evapotranspiration and in the crop harvested. The remainder seeps back to the aquifer carrying with it a higher salt content. This sequence has been noted in small closed groundwater systems receiving comparatively little recharge from outside sources.

Deep pressure aquifers are less likely to be degraded by processes affecting shallow aquifers but contamination can and does take place during development. Among the more important mechanisms are:

1. Faulty well construction techniques.
2. Alteration of natural hydraulic equilibrium.

Faulty well construction

Fig. 6 illustrates several of the more common defects in well/borehole construction which lead to unnecessary contamination of a high quality resource. A variety of causes may be cited including poor technique on the part of the driller, the use of wrong or inferior materials, and construction carried out to a price criteria rather than to the minimum requirements for a successful installation capable of functioning efficiently over a long period.

Probably the most dangerous situation is the development of a fresh water resource, usually under pressure, but overlain by saline water. This is not an uncommon situation in South Australia and a sad list of case histories could be given of boreholes abandoned because saline water has entered the system either down the side of loose casing or through holes corroded in the casing. Plugging operations were non-existent or completely ineffective and wholesale contamination is an ever present danger to the fresh water resource.

Alteration of the hydraulic equilibrium

Prior to the large scale interference of man in the hydrologic cycle each part of that cycle was in general equilibrium with its neighbour. Changes took place slowly and balance was maintained by a series of minor and delicate adjustments to the system.

In contrast, large scale groundwater development has affected the cycle by a series of rapidly imposed stresses some of which have been sufficiently strong to produce rapid degeneration of the resource. Reference has already been made to the movement of sea water inland, but fresh-salt water interfaces occur in a variety of other situations and pumping beyond the natural recharge capacity of the system will result in the movement of these interfaces towards the point of groundwater extraction.

Expensive and technically difficult programmes have been carried out to slow down or reverse the movement of sea water inland. In California a curtain of wells has been constructed which delivers fresh water underground under pressure to maintain a buffer zone between the saline water at the sea coast and users inland (Laverty and van der Goot, 1955).

The salt water interface may also move vertically. Fig. 7 illustrates two examples of this as well as showing a typical coastline problem.

ASSESSMENT OF CONTAMINATION POTENTIAL.

In view of the extreme complexity of the problems associated with groundwater degradation it is not surprising that little progress has been made to introduce evaluation systems which can be applied as tests for contamination potential. Despite this much can be done to define areas under broad classifications of contamination potential by applying some of the geological and hydrological criteria outlined in previous sections. This type of detailed analysis has not yet been attempted in South Australia but the geology of the settled area of the state is known in sufficient detail for contamination potential maps to be prepared. In the U.S.A. the Illinois State Geological Survey has prepared at least two maps for the state. Walker (1969) presents such maps and explains the basis of construction under three classes; high, moderate and low potential. Unconsolidated aquifers are graded according to permeability as expressed by depth and well capacities, while bedrock aquifers are subdivided accordingly to rock type and potential yield, with a low potentiability assigned to rocks covered by thick impermeable strata.

In the same state Bergstrom (1968) has examined the feasibility of subsurface disposal of liquid wastes and has classified the state into five areas. Each area carries a different set of disposal conditions based on hydrogeological criteria designed to reduce the pollution risk for usable groundwater (<5000 parts per million of totally dissolved minerals) to an absolute minimum.

Le Grand (1963) has outlined a method for making preliminary assessments of specific areas. In the simplest case he establishes the degree of interaction between five environmental factors; depth to water table, degree of sorption by the materials between the contamination point and point of water use both above and below the water table, the permeability of the materials, the gradient of the water table and the straight line distance between the two points. Each factor is assessed on an arbitrary point count system and the contamination potential is evaluated from a total point count under five categories; imminent, probable or possible, possible but unlikely, very improbable and impossible. A rating chart is illustrated in Fig. 8.

Le Grand's system in its basic form provides a useful semi-quantitative tool for investigations and, provided it is used with care, is capable of extensive application in areas underlain by unconsolidated sediments. Grave problems arise in more complicated geological environments with unconsolidated materials overlying 'hard' rocks, fractured 'hard' rocks at the surface, or in limestone with widespread solution features.

OCCURRENCE OF CONTAMINATION IN SOUTH AUSTRALIA.

The possibility that the underground water reserves may be degrading in quality must be of primary concern to everyone because of the wide reliance placed on this resource in South Australia. Enquiries have shown that as yet, the number of known cases of groundwater contamination and in particular of pollution by chemical and biological agents is small. Several explanations may be advanced for this apparent state none of which give rise to any complacency as to the true position:

1. Pollution may be occurring which cannot be proved or may not be at a sufficiently high level to be reported.
2. Pollution is occurring but as yet the polluted areas have not been developed for use.
3. Pollution is occurring in areas adjacent to supply points but because of the slow rate of groundwater movement this has not yet been recognised.

Despite the small amount of data available and, it is suspected, the unknown extent of the true contamination picture in South Australia, a selection of examples can be given which indicate the type of problem which may be expected to recur with increasing frequency in future.

Unconsolidated rocks

A fully documented example of contamination in unconsolidated strata is not available but petroleum in borehole water used for Jamestown swimming pool is believed to have originated in disused petrol storage tanks approximately 600 ft. from the supply borehole. The pollutant probably migrated through a shallow aquifer consisting of sands under the influence of the cone of drawdown created at the borehole. (Bowden, 1968).

Limestone Areas

In the S.E. of the state a borehole producing low salinity water for the Bordertown water supply was abandoned within 8 months of commissioning when unacceptably high counts of bacteria were made during the winter rainy season. Chemical tracers added at Poocher waterhole, a collapse structure in the limestone exposing the water table and located approximately 300 ft. from the production borehole, were recovered from the borehole in 3-4 days. (Johnson J. 1961. unpub. data. South Aust. Eng. & Water Supply Dept.). The clear implication is that the Poocher waterhole provides a ready entry point for biological pollutants to the aquifer.

At least three cases have been recorded of contamination connected with cheese factories in the lower south eastern part of the state in an area which is underlain by highly permeable limestone.

The potential for pollution is high and in a formation with widespread and persistent solution cavities, travel over long distances may be anticipated. This raises the difficult problem of tracing a contaminant back to the original discharge point especially if the material involved is not unique to a particular industry or district.

Faulty borehole construction

Numerous examples exist of boreholes passing through shallow saline aquifers to reach better quality water below. Near Keith in the lower south east the shallow water contains up to 15,000 parts per million of totally dissolved solids, while pressure water exists below with a salinity of about 1500 parts per million. Several boreholes have failed to produce good quality water because of faulty borehole construction which allowed the saline water to percolate down the outside of the casing. Further failures have occurred through casing deterioration at the upper aquifer allowing saline water to pass down the borehole inside the casing. The situation is potentially serious as inadequate plugging will give rise to continuing contamination. Increased development of the low level aquifer will cause a drop in pressure inducing an increasing inflow of saline water from the higher salinity aquifer above.

Alteration of hydraulic equilibrium

The secret of successful groundwater development may be said to lie in the achievement of maximum production with minimum degradation, since in all cases where output exceeds natural recharge the overall trend in quality must be one of deterioration. This fact has not been recognised and particularly in the arid areas of the state small zones of fresh water accumulated perhaps over thousands of years have been tapped as stock and station supply points and rapidly exhausted often by thoughtless and wasteful exploitation or mining.

On a larger scale, concern has been expressed in certain areas of heavy exploitation of underground water for irrigation purposes, notably north of Adelaide on the Adelaide Plains and in the Milang-Langhorne Creek area. Other areas are likely to be added to the list as irrigation becomes increasingly necessary as part of the current trend to maximise production from each farming unit. Popular fear is that areas near the sea coast will eventually become contaminated by the ingress of sea water to replace the fresh reserves as they are extracted. A greater danger however lies in the movement laterally of saline water from adjacent secti on of the aquifers and in some cases vertically upwards or downwards, as pressure gradients are changed under the influence of heavy pumping. Shepherd (pers.comm.) reports that salinity increases from this cause have already been established in at least 6 bore holes in the North Adelaide Plains area.

PREVENTIVE MEASURES

Although little has been done on a systematic basis in the study and prevention of groundwater contamination in Australia, work in more heavily populated and industrial areas in Europe and the U.S.A. provides a preview of the type of activity which is likely to grow in the next few years.

The primary fields of activity for the future are:

1. Legal safeguards and controls.
2. Experimentation.
3. Data collection and collation.

Legal safeguards and controls.

It is not the purpose of this paper to discuss legislation for the protection of water resources. This subject is discussed in detail in a later paper.

Attention has already been drawn to work on the movement of bacteria and viruses underground and the natural outcome has been the preparation of recommendations for the safe distance between domestic supply wells and pollution sources such as septic tanks and seepage pits in various states of the U.S.A. and by the agency of the U.S. Public Health Service. Similar recommendations may be made by the Public Health Department in South Australia but no legislation exists which can prevent an individual from drilling a private supply well in close proximity to a known source of contamination.

Permission is now usually sought for construction of drainage boreholes for septic effluent and each case is referred by the Public Health Department to the Enginéering and Water Supply Department and the Mines Department for comment and objection where appropriate. In the case of noxious wastes action may be deferred until a hazard is established.

The demand for disposal of liquid wastes underground is likely to grow in the future and increasingly stringent controls will be necessary to ensure that contamination does not result. Highly sophisticated borehole completion techniques are inevitable if liquids such as a 30% hydrochloric acid solution at a temperature of 115°F, are to be safely handled. Marsh (1968) describes such a disposal well with fibre glass casing separated from an outer steel casing by diesel fuel and in turn surrounded with an annulus of acid resistant cement set in place under pressure.

Again in the U.S.A., the Illinois Sanitary Water Board issues permits for the construction and operation of waste disposal wells. Bergstrom(1968) notes that 'the burden of proof is on the applicant...to show that the installation will not be detrimental to the public interest'. An applicant may be required to investigate the area of disposal by regional studies, test drilling, geophysical logging, coring, water sampling, determination of potentiometric water levels and pumping or injection tests.

Experimentation

There is an increasing body of literature related to the problems of contamination in an underground environment but as has already been noted the cost of monitoring changes can be prohibitive and this has tended to reduce the scope of nearly all investigations. Laboratory experiments have assisted in the work but simulation of natural conditions underground is practically impossible, and results of such experiments must be applied with great care.

The major effort to date has been in the important field of sewage disposal. Far less is known of the changes likely to occur in the wide range of chemicals now being produced for agriculture and industrial uses; the indestructibility of chromium waste is well known (Deutsch, 1961) but more needs to be known of the history of fertilizers and pesticides particularly when used on land over shallow aquifers. The particular potency of phenol is a cause for concern and indeed the whole range of petroleum products gives cause for alarm not only as oil field wastes, (Maehler and Greenburg, 1962) but also from accidental spillage or leakage of refined products.

Data collection and collation

An increase in our understanding of groundwater contamination can only come from the accumulation and review of more data. Equally important is the application of established geological principles in the fields of hydrogeology and engineering geology to prepare maps and reports to assist in future planning. At present, for example, a factory is built first and then attention is turned to the problem of waste disposal, whereas a review of contamination hazards in the planning phase would lead to a more satisfactory solution by re-siting the factory in an area where contamination of underground water is unlikely to occur.

Because of the complexity of problems associated with groundwater contamination data collection will be a time consuming and expensive process. Sampling for both chemical and biological pollutants must be carried out under strictly controlled conditions and extensive programmes with adequate laboratory facilities will be needed to process the wide range and number of samples.

On the time scale changes may be very slow and therefore only show up after a prolonged series of samples.

Because of the nature of the problems involved, a far more serious effort will be necessary in data collection if significant progress is to be made in preserving the large and invaluable groundwater reserves available for use by the community.

SUMMARY

A review has been given of the main factors involved in the problem of degradation of groundwater and the assessment of it.

Examples have been cited from a variety of sources to illustrate the work that has been carried out, particularly over the past twenty years, to try and define the major areas of concern and how problems may be tackled in the future.

Little evidence can be found of a serious contamination problem in South Australia at present. Reasons for this are not clear but may rest partly on a paucity of data. Geological conditions conducive to contamination hazards are noted and the need for adequate definition using some of the classical geological tools is stressed.

The procedures to safeguard underground water as a usable resource are well known and it is only necessary to implement them on an appropriate scale as developments demand.

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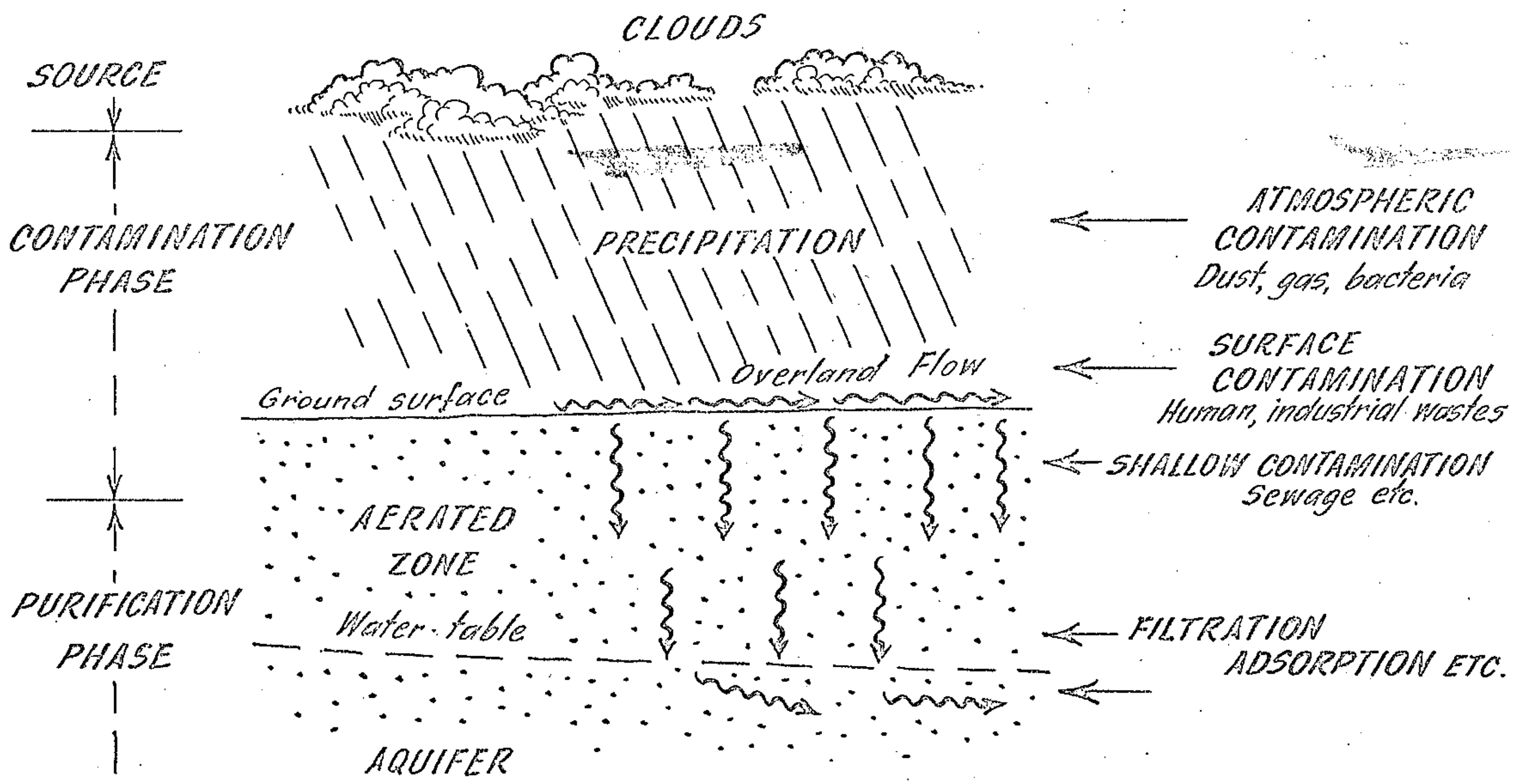
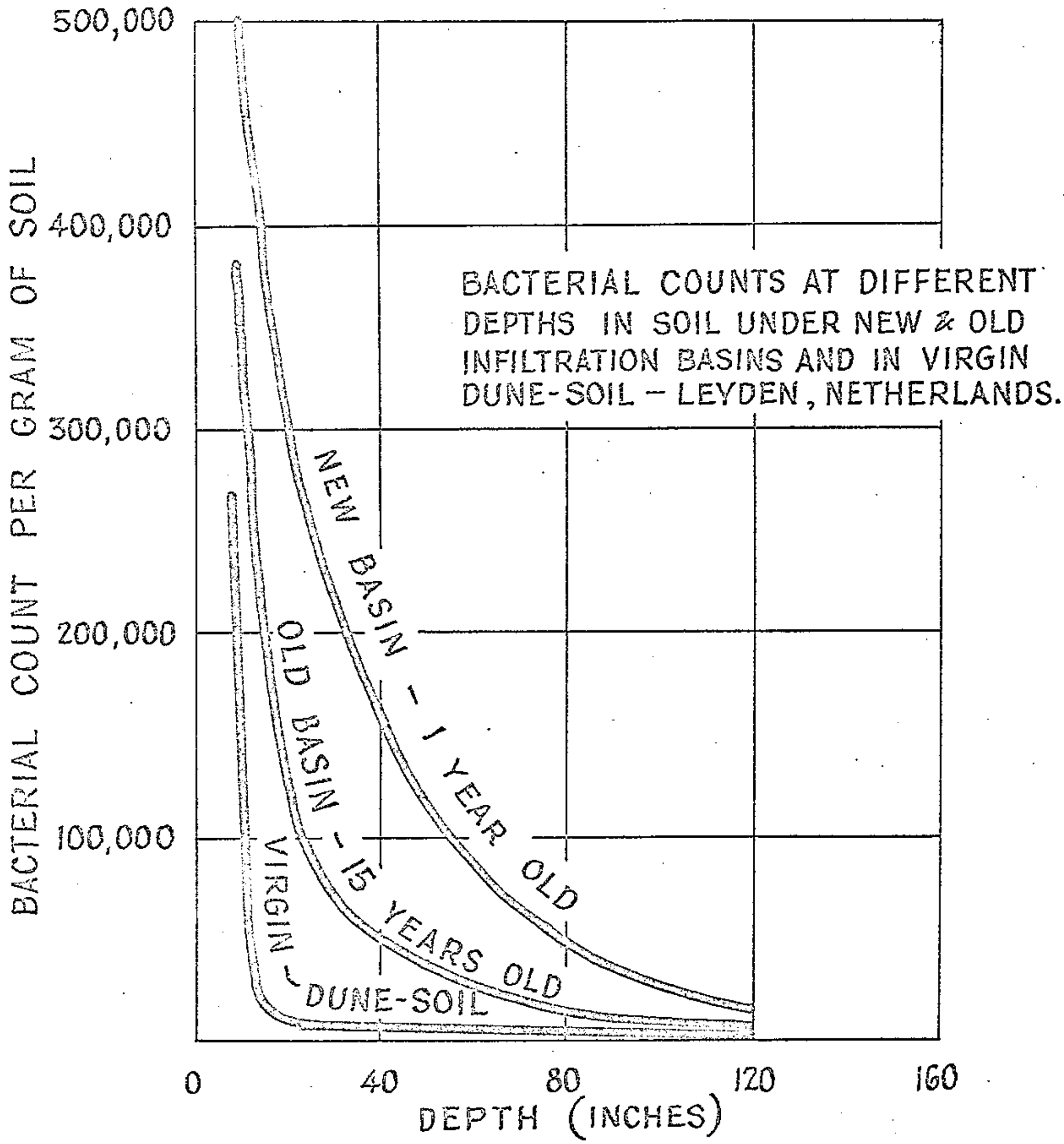


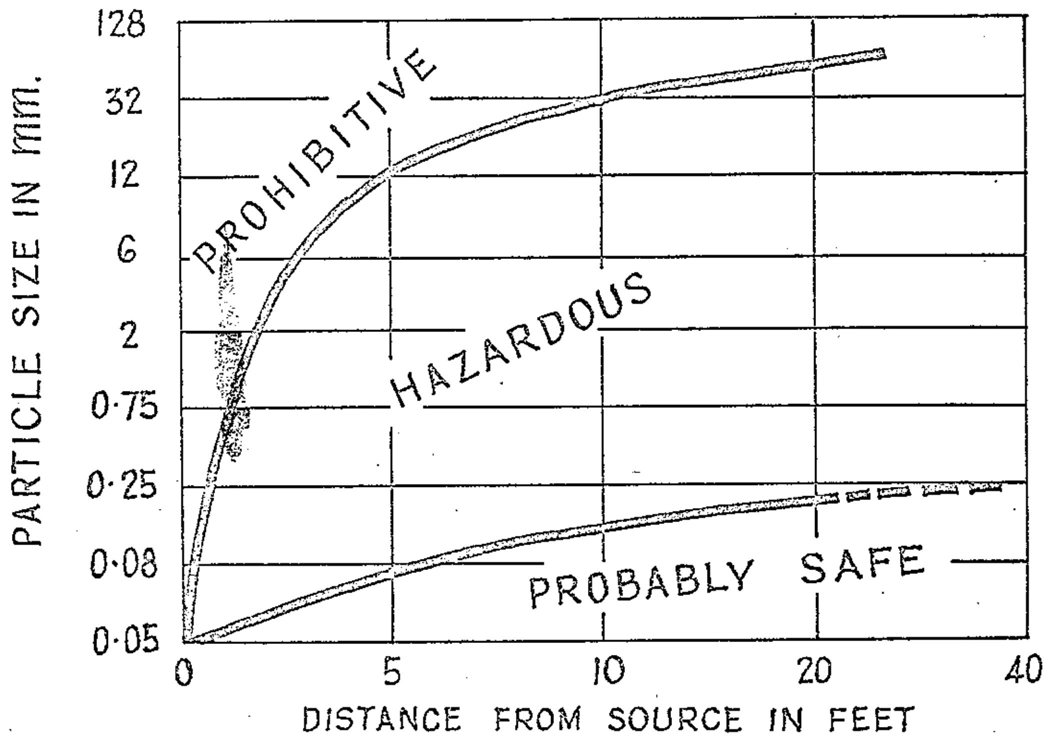
PROCESSES OF CONTAMINATION AND PURIFICATION

FIG. 1.

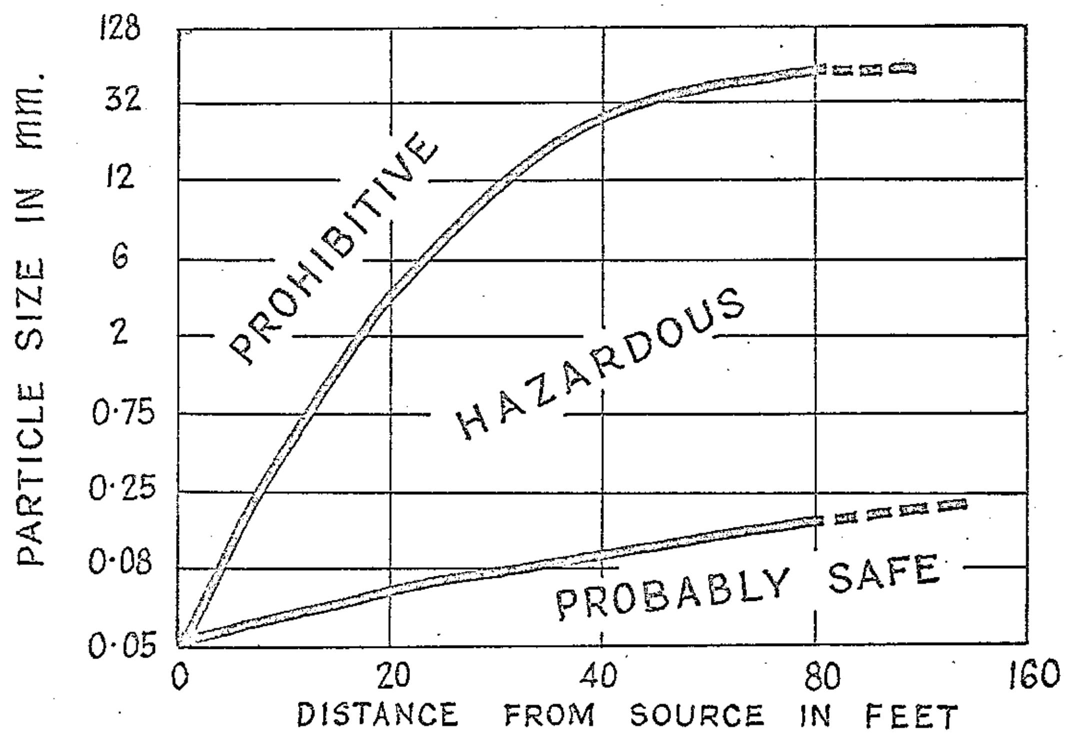


AFTER BAARS

FIG. 2

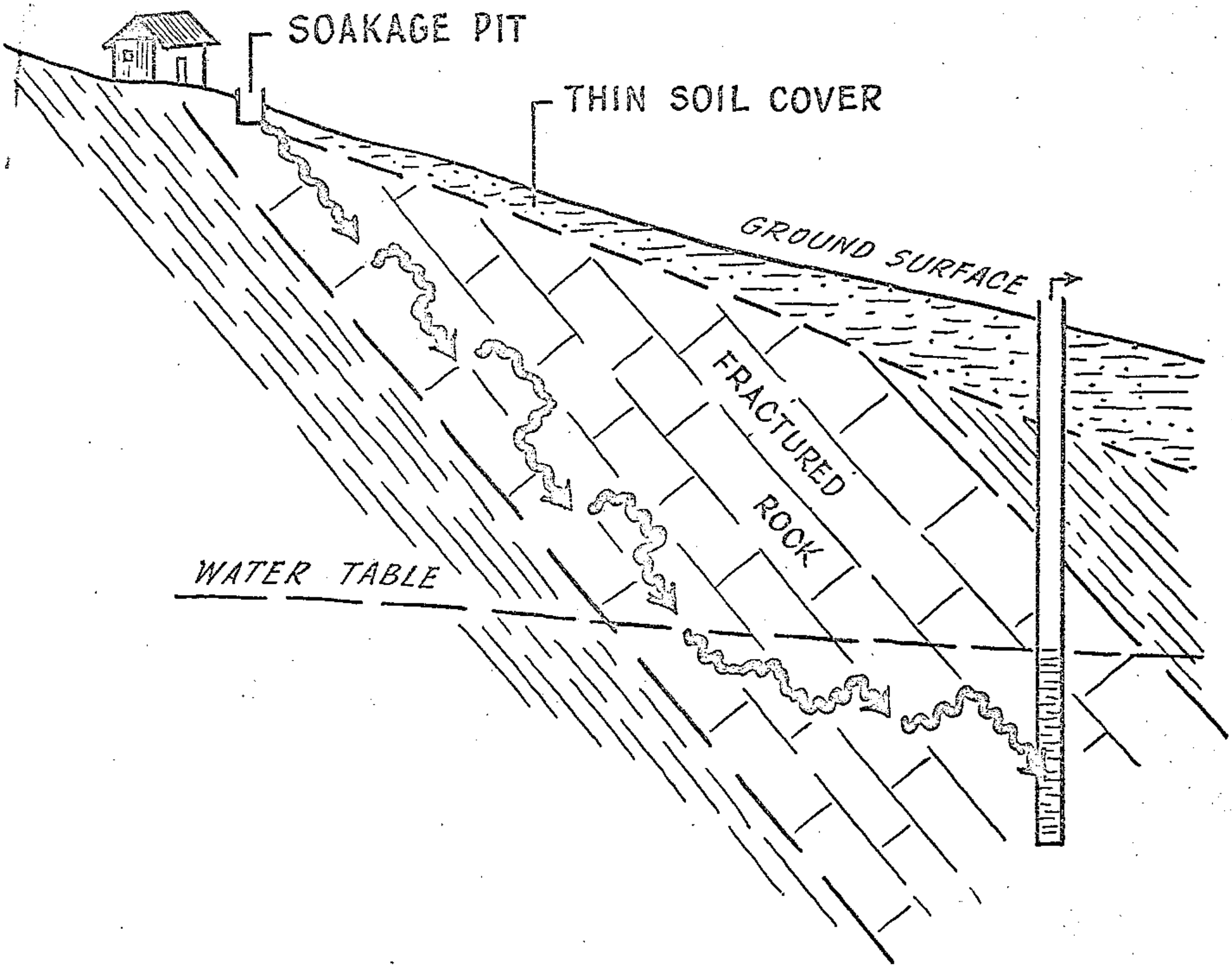


BIOLOGICAL POLLUTION TRAVEL IN NON-SATURATED MATERIALS



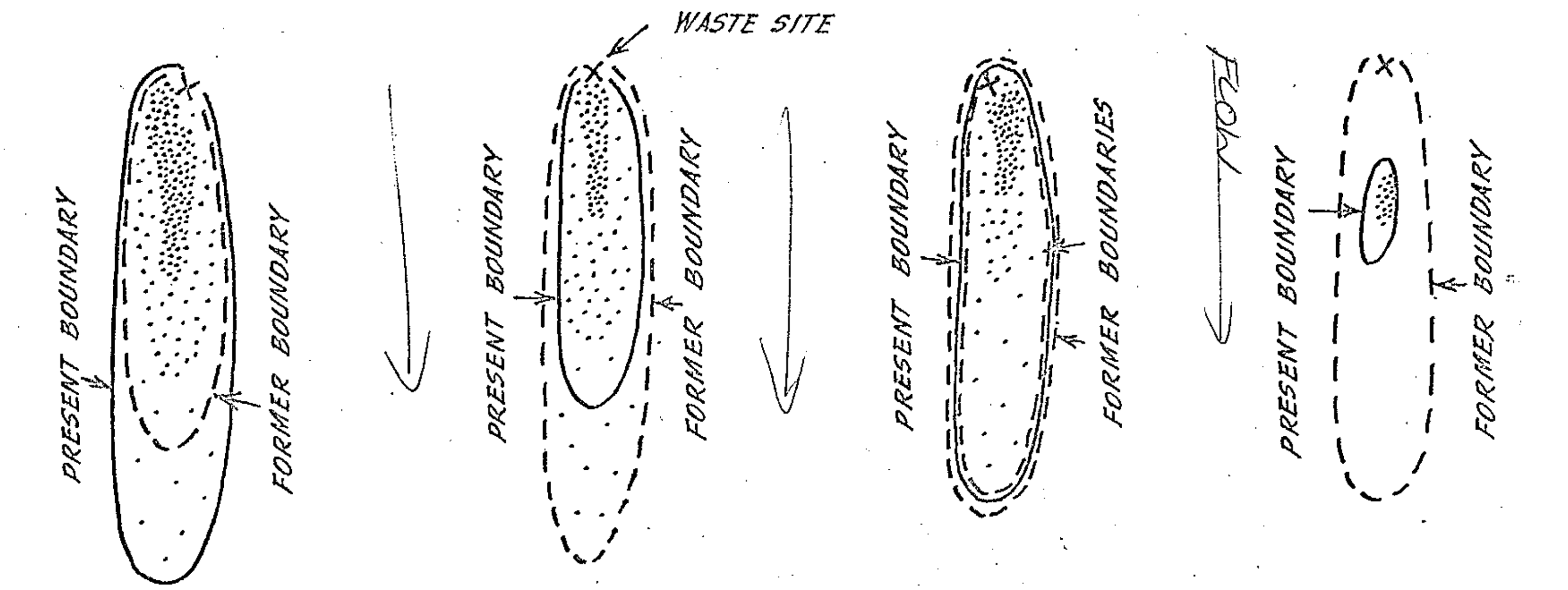
BIOLOGICAL POLLUTION TRAVEL IN GROUNDWATER

AFTER ROMERO FIG. 3



CONTAMINATION IN FRACTURED ROCKS

FIG. 4



ENLARGING MALENCLAVE

1. Increase in rate of discharged wastes.
2. Sorption activity used up.
3. Effects of changes in water-table.

REDUCING MALENCLAVE

1. Reduction in wastes.
2. Effects of changes in water-table.
   (a) More effective sorption
   (b) More effective dilution
   (c) Slower movement and more time for decay.

NEARLY STABLE MALENCLAVE

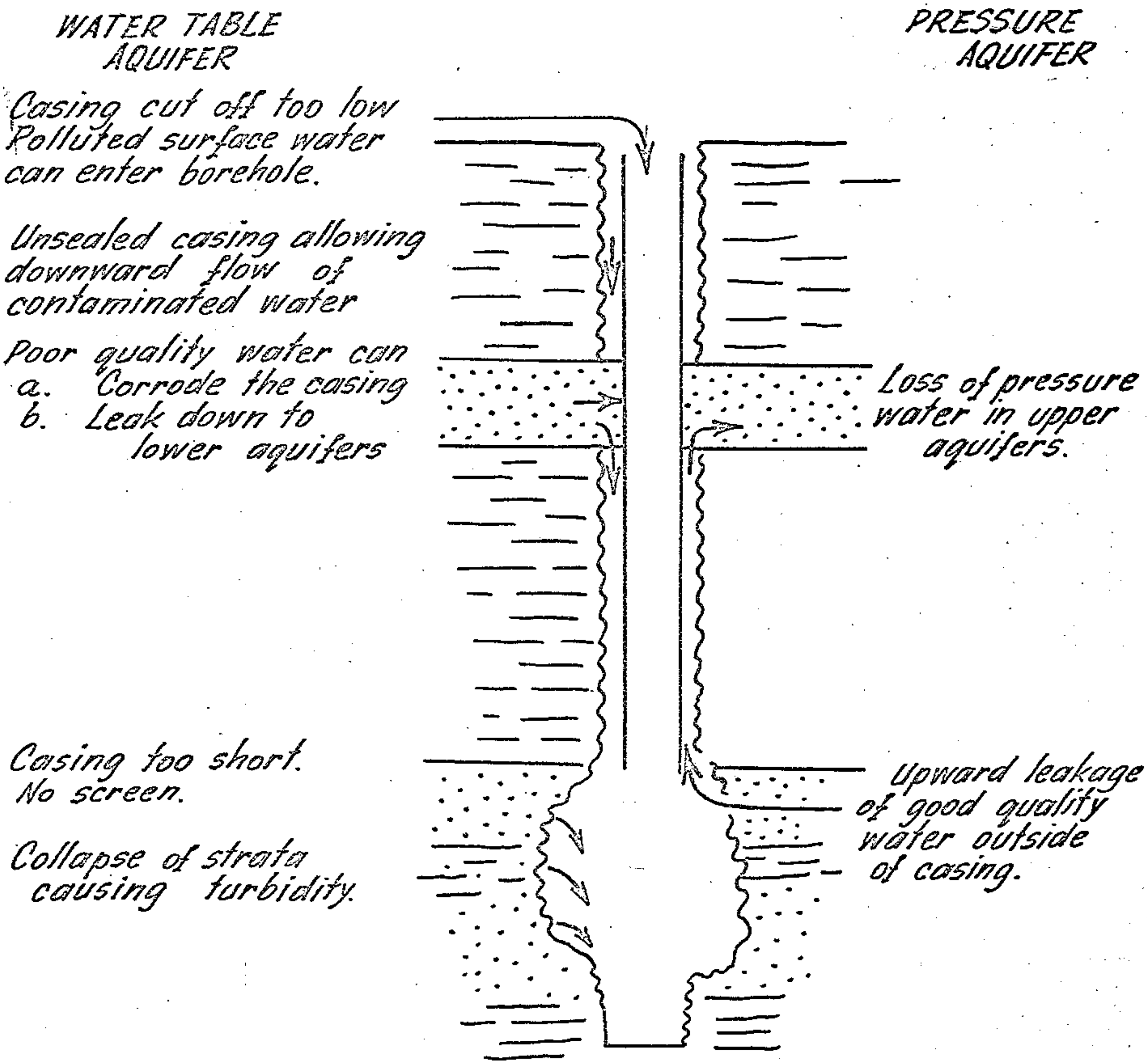
1. Essentially same waste input
2. Sorption capacity not fully utilized
3. Dilution effect fairly stable.
4. Slight water-table fluctuation or effects of water-table fluctuation not important.

SHRUNKEN MALENCLAVE

1. Waste no longer disposed and no longer leached at abandoned waste site.

FIG. 5

CHANGES IN MALENCLAVES & FACTORS CAUSING THE CHANGES.
AFTER LEGRAND



COMMON DEFECTS IN BOREHOLE CONSTRUCTION

FIG. 6

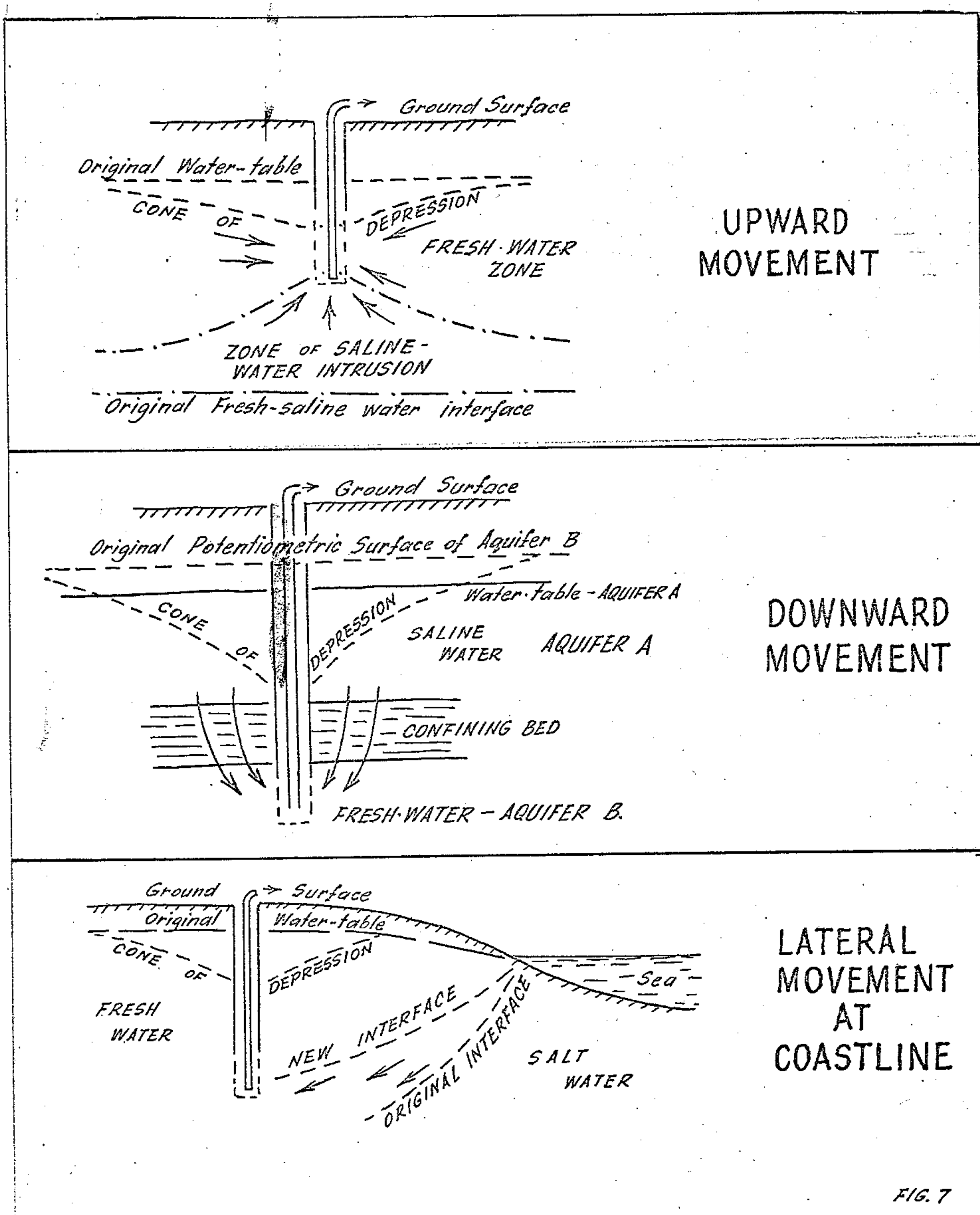
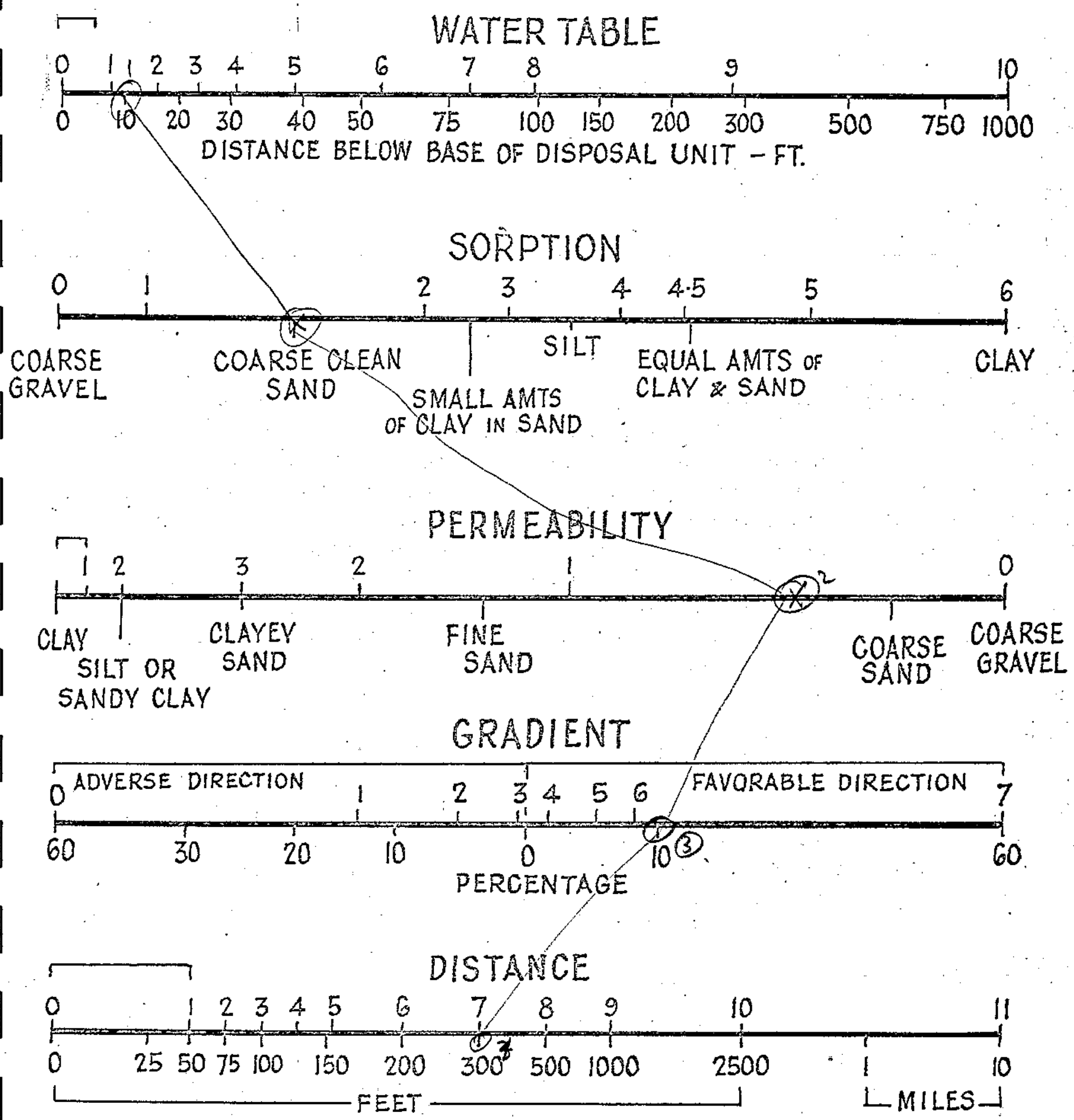

Ground Surface
Original Water-table
CONE OF DEPRESSION
FRESH-WATER ZONE
ZONE OF SALINE-WATER INTRUSION
Original Fresh-saline water interface
UPWARD MOVEMENT
Ground Surface
Original Potentiometric Surface of Aquifer B
Water-table - AQUIFER A
CONE OF DEPRESSION
SALINE WATER
AQUIFER A
CONFINING BED
FRESH-WATER - AQUIFER B.
DOWNWARD MOVEMENT
Ground Surface
Original Water-table
CONE OF DEPRESSION
FRESH WATER
NEW INTERFACE
ORIGINAL INTERFACE
Sea
SALT WATER
LATERAL MOVEMENT AT COASTLINE

FIG. 7



RATING CHART FOR SITES IN LOOSE GRANULAR MATERIAL

Situation Rate = 16.

AFTER LEGRAND

FIG. 8

SOME LEGAL ASPECTS OF WATER POLLUTION CONTROL

by M. L. W. Bowering, LL.B.,
Solicitor,
Crown Law Department, Adelaide.

Introduction.

The natural resource of water is but one natural resources essential for the continued life and health of every person, and therefore all responsible governments recognise and accept the obligation to protect its quality. However, in all civilized communities (especially those which are industrialised) water is more than merely an element essential for the preservation of life and health, for it is also used as a cheap and convenient disposal media, or, as some people put it, a huge natural garbage can. There appears little doubt that water must be used, to some extent, to dispose of the various wastes which seem to be one of the inevitable results of our mode of life, and, because of the tremendous increase in the output of these wastes, it appears equally apparent that the use of water, as a garbage bin, must be controlled.

Accordingly, our basic premise must, in relation to water, recognise two separate rights; namely the right to enjoy water which is sufficiently clean to sustain life and health (and, indeed, which is pleasant and attractive to use), and the right to pollute. Accordingly, pollution control may be regarded as the line which maintains and separates these two basic rights which, at first sight, may appear to be conflicting.

Why is legislative action necessary?

Common law (i.e. that law formulated, developed and administered by the old law courts: based on common custom, it was originally unwritten) clearly recognises the basic rights referred to above and did its best to evolve a solution. However, generally speaking, it can be said that common law was evolved during a non-mechanical and non-technical period, and therefore was not concerned with solving the problems which accompanied pollution on a large scale.

In dealing with matters of pollution, the common law proceeded upon the general principle that each person must regulate his actions or use his land or machinery in such a way as not to cause any injury (e.g., bodily, financial, etc.) to any other person or such other persons, land or possessions. Speaking generally, the common law provides four classes of action to a plaintiff seeking relief from pollution, namely:-

1. An action for damages for injury resulting from the defendant's negligence. This was an action which arose where pollution, although accidental, could have been avoided if the defendant had exercised due diligence. A typical example would occur where a factory owner negligently allowed liquid waste to flow on to the plaintiff's land, so that the plaintiff suffered some loss. To succeed, the plaintiff must be able to show that the defendant had been negligent and should have foreseen that he, the plaintiff, could be injured or suffer loss through such negligence. If successful, the plaintiff was entitled to damages.

2. Trespass was an appropriate action where the release of the pollutant was intentional. Damages were generally awarded, and, if appropriate, an injunction to stop a continuing trespass.

3. Where a person has, on his land, something which is not naturally there and dangerous should it escape, he must take the consequences if it does escape. A plaintiff whose property is injured by such an escape may recover damages without proving either negligence or intentional harm. This course of action is available to a plaintiff who can prove no more than the escape of some pollutant from the defendant's land on to his. For example, if a person builds a dam on top of a hill and stores, in the dam, vast quantities of water, he is liable for any damage to other person's property which may be occasioned by the collapse of the dam, even though all reasonable steps may have been taken by him to avoid such a mishap.

4. If a person uses his own land or premises in such a way that he disturbs or diminishes the use or enjoyment of land owned by another, he could be sued on the grounds of nuisance. If only one person or a few people are disturbed by the defendant's land use, the action is one of private nuisance resulting in damages, and, where the nuisance is of a continuing nature, in an injunction. If a large number of people are affected by the nuisance, the action, which is conducted by or on behalf of the Attorney-General, is for public nuisance, and generally results in an injunction to prevent further nuisance.

Although common law has a definite role to play in pollution control, it is far from adequate to control modern day pollution because:-

1. Its use cannot be invoked until after the pollution has occurred or commenced, for it is not until this stage that a cause of action exists. Modern pollution legislation must be aimed at keeping the pollution horse in its stable rather than closing the door after it has fled.

2. It is neither equitable nor wise to leave pollution control in the hands of John Citizen, because he may be ignorant of his rights or may be financially unable to enforce them. In any event, many people are unwilling to enter the litigation race, and prefer to simply tolerate the damage or nuisance sustained by them. Alternatively, there may be instances where the tracing and assessment of the pollution is a technical matter, and accordingly, the average citizen may not even be aware of its existence.

3. The citizen may, because of the onus of proof applied by the courts or because of inadequate evidence, lose his case and the pollution continued.

4. Whilst the courts, in administering common law, do not, as such, set pollution standards, legislation must be aimed at setting standards considerably higher than those which would result should pollution control be left to courts administering common law.

5. Except in cases where injunctions are issued, common law does not specifically stop the pollution (although it may have this result), but merely compensates those affected for damages sustained by them. The aim of legislation should be to either stop pollution or, at least, keep it within reasonable and acceptable limits.

In my opinion, the only reasonable and workable method of pollution control is legislative action. It is not the purpose of this paper to embark upon a documentary examination of existing legislation operating in various parts of the world, but rather to examine its criteria and the theory upon which it is based.

<u>The role of the lawyer in the formation of pollution controls.</u>

In any society (especially one which is heavily industrialised) the setting of pollution limits and methods of control are technical problems rather than legal matters. The lawyer is not qualified to determine what emission limits or other standards should be, or what is the best technical method to obtain a particular result. This is the role of the engineer, the scientist, the agriculturist, the doctor and other technical people who are specifically qualified to discover and resolve the pollution problems.

To me, the basic problem appears to be one of assessment: careful and precise assessment of the scope and nature of the problem, and, having made such an assessment, a further assessment of what is required to control pollution and to maintain acceptable standards of water purity. These are technical assessments.

Although it is appreciated that legislation is frequently required to establish commissions or committees (which should contain a high content of technical personnel) for the purposeof making these assessments, it is not until after these assessments have been made that the lawyer assumes any real responsibility in pollution control. It is the lawyer's task to carefully consider the technical assessments and then to draft legislation which, as far as possible, embodies the quality standards, control requirements, emission limits and other matters recommended by the technical personnel as a result of their assessments.

It logically follows from this that the best legislation cannot be better than the assessments upon which it is based. Similarly, it follows that the legislation must be enacted after the assessments, and any legislation passed before such assessments is, in my opinion, likely to be inadequate to cope with existing and later pollution problems, and transitory in nature in the sense that, if reasonable pollution standards are to be maintained, such legislation will need either substantial amendment or repeal and re-enactment.

At this point, a brief survey of what the term "legislation" (as used in its widest sense) encompasses. As well as statutes, legislation includes such things as regulations, by-laws, rules, proclamations etc. Although an Act of Parliament (dealing with pollution control) may precede the assessments to which I have referred, such a statute need be neither inadequate nor ill-advised. If it provides for the making of the necessary assessment (e.g. by setting up a committee) and includes wide regulation or by-law making powers to be exercised after the necessary assessments have been made. However, if such a legislative programme is decided upon, great care must be taken to ensure that the regulation or by-law making powers are adequate to efficiently establish such standards and control requirements as may appear, after the assessments have been made, desirable. It is the lawyer's responsibility to ensure that the regulation making power is adequate, and it is the technician's role to ensure that the lawyer knows what is required when he is drafting the necessary legislation.

Diversity of problems.

A brief perusal of pollution problems shows very clearly that one cannot hope to cover and solve, with one statute, the large variety of pollution problems. The standards and methods of control and quality requirements must vary when one considers the various categories of water which one seeks to protect.

Somewhat arbitrarily, I have divided water pollution problems into four categories, namely, rivers and streams, dams and reservoirs, underground water and the sea. Naturally, there are other important water resources, e.g. the time may well come when sewerage water is re-used to such an extent that the use of detergents and other water activities will have to be carefully controlled. Another very important water resource which will soon need careful protection is rain: we have all experienced muddy rain falling after a dust storm, and we can therefore appreciate that any rain falling through polluted air will naturally bring to earth with it some of the pollutants in the atmosphere through which it has passed. One problem which has recently caused some concern is the radio-activity of rain falling from clouds which may have been affected by a bomb test. However, before this problem can be overcome, further technical assessments appear to be necessary.

Rivers and streams present an unusual pollution problem because, in the vast majority of cases, they flow through land not owned or controlled by the Government responsible for pollution control. The answer (stated very simply) is to prevent pollutants from entering the rivers and streams, but this naturally involves controlling the use of land abutting the river. If the water in the river is to be used for human consumption, the controls and restrictions on the use of the abutting land may need to be severe. Common law is inadequate for the imposition of such restrictions.

A statute controlling such land use must ensure that any use resulting in pollution is either restricted or forbidden whilst uses not having such an effect are impeded as little as possible. Whilst penalties must be sufficient to stop pollutant resulting uses, the statute should empower the controlling authority to enter the subject land and to make such alterations thereto as are necessary to halt the pollution, should the land owner fail to do so.

Whilst reservoirs are generally owned or controlled by the authorities responsible for pollution control, legislation is necessary to prevent, in them, such activities as are likely to lead to pollution, e.g. swimming, fishing, etc. Similarly, the use of land abutting and situated within the watershed of the reservoir must be subject to sufficient legislative control to ensure that the water is not polluted before it enters the reservoir. Once again it is stressed that the determination of what land uses must be either restricted or forbidden in order to obtain a satisfactory water quality is a technical, and not a legal, assessment. The legislation can do no more than enforce remedies which have been arrived at as a result of technical assessments.

The preservation of underground water qualities is riddled with unusual problems in that pollution of good (or usable) quality water can result from pollutants entering from either outside or inside the aquifer wherein the usable water is contained. Pollution may result from the use of sub-artesian bores for the disposal of septic effluent or other waste matter. This source of pollution is controlled by forbidding or strictly regulating the use of such bores for this purpose.

However, many aquifers contain both highly saline water and usable water, the two being kept separate by the equality of pressure within the aquifer. The drawing out of the usable water results in pressure differences which cause the saline water to flow towards and intrude upon the usable water. To prevent or reduce this flow, legislation must be aimed at restricting the output of usable water so that it does not exceed the estimated natural intake into the aquifer, and so that the equalising pressures in the aquifer are maintained.

The legislation must therefore be such that it enables the controlling authority to backfill or restrict the output from existing bores, and to strictly control the sinking of further bores. As faulty drilling can result in both water wastage and saline water leakage (from higher or lower aquifers) into usable water, the legislation must also provide for the examination and licensing of drillers to ensure that the drilling standards are maintained at an acceptable level.

The control of sea pollution is a legally complex and difficult problem requiring, for its effective solution, state and commonwealth legislation plus, by means of treaties, recourse to international law. I do not think that, in this paper, I should attempt to discuss this particular problem.

Desirable characteristics of all pollution controlling legislation.

It will be appreciated that any statute seeking to preserve, from pollution, any of the water categories previously referred to will have to deal with a large variety and range of situations, e.g., any water pollution resulting from land use will have to be controlled by legislation affecting land in various situations, conditions and of various sizes, and supporting a wide variety of uses. It is obvious therefore, that one of the basic characteristics of good water pollution control legislation is flexibility, and any legislation which lacks flexibility is likely to be inept in many circumstances and become outdated in a relatively short time.

How is this flexibility to be obtained? To answer this question, it is necessary to explain how various types of legislation are made. A statute is an Act of Parliament and is, of course, made by Parliament and, as such, is supreme law. A statute may empower a Minister (or some other body) to make by-laws, or the Governor to make regulations, on the subjects referred to in and subject to the limits prescribed by the statute. A statute may also empower the Governor, inter alia, to make a proclamation, at any time, declaring that the statute shall or shall not apply to a certain specified area or areas or in certain specified circumstances.

Regulations (or by-laws) may provide for a system of licensing of pollutant outlets for various premises or land from which pollutants are likely to escape. These licences can be made subject to various terms or conditions, which may be "tailor made" so as to specifically suit the particular circumstances, use or situation of the land or premises being controlled.

As an example, I refer to the provisions of the Underground Waters Preservation Act, 1969, the aim of which is to preserve, as far as possible, the State's underground water reserves and, at the same time, make the best use of these reserves as an aid to primary production. In an endeavour to achieve this aim, the Act forbids the sinking of or the alteration to a bore, situated within any of the localities prescribed by the Act, without a permit so to do from the Minister of Mines. Any permit issued by the Minister is subject to conditions which have been "tailor made" to suit the circumstances of both the land owner concerned and the aquifer into which he wishes to tap. Furthermore, the Act provides that notices of restriction can be issued to the owners of existing bores, and, by using such notices, the Minister can impose such restrictions, varying from land owner to land owner, as are appropriate to the circumstances peculiar to each particular bore and owner thereof.

Naturally, the issue (or refusal) of any permit and the issue of any notice of restriction, together with the restrictions attached thereto, have been preceded by a careful and detailed survey and analysis of the situation pertaining to the land owner and the aquifer to which each permit or notice applies. Thus it will be seen that, by using a system such as this, the peculiar and personal circumstances of the person or property to be controlled can be easily fitted in to a comprehensive legislative programme.

Pollution control legislation must impose definite and rigid limits and standards, i.e., to be really effective, such legislation must be objective rather than subjective. Pollution control should not be based upon or justified by vague concepts such as "pollution is injurious to health" or "Pollution spoils our amenities". Concepts such as these can be argued until the cows come home.

As a practical example, I turn once again to the Underground Waters Preservation Act, Section 10 of which provides that the Minister of Mines may refuse a permit to sink or alter a bore if such work "would be likely to cause contamination or deterioration of any underground water, be likely to cause inequitable distribution of any underground water, be likely to cause undue loss or wastage of underground water, or would be likely to deplete unduly the supplies of underground water." The evidence, given before the Underground Waters Appeal Board (sitting as a Board to review the Minister's decision), in an attempt to decide, in each case, what constitutes "inequitable distribution", "undue loss or wastage" or "unlikely to deplete unduly" has to be heard to be believed. In other words, the assessment of what is required to control water pollution must be thorough and complete before the appropriate standards and requirements become law. Once these standards have the force of law, there should be no argument as to whether they can be justified on medical or aesthetic grounds, or whether they are reasonable or necessary. This may sound a little autocratic, but if the assessments upon which the laws are based are accurate and complete, the law, although perhaps a little dictatorial in nature, should be fair and reasonable, and, above all, should work.

Finally, pollution control legislation should be "tough". It will be appreciated that equipment necessary to materially reduce pollution may be very expensive, and the fines and penalties, should be sufficiently high to discourage would be polluters from breaking the law rather than installing the necessary equipment. For example, Section 12 of the Control of Waters Act, 1919-1925, makes it an offence to discharge into any watercourse to which the Act applies any filth, rubbish or other noisome thing. The penalty for a breach of this section is a fine of not less than $2.00, nor more than $40.00 for a first conviction, and a fine of not less than $20.00, nor more than $200.00 for a second conviction. In my opinion, this fine should be considerably higher.

In addition to providing for monetary penalties, pollution control legislation should empower the authorities concerned to enter premises or factories wherein offences are being committed, and, if necessary, take such action as is necessary to stop the continuing pollution. Whilst such action may only be warranted after the owner of the factory or premises has been requested to and has refused to stop the pollution, the necessary power should be provided in the Statute.

The Question of Compensation.

This seems to be a suitable place to consider the difficult question of compensation. It will, of course, be appreciated that when the Government acquires land surrounding a reservoir for the purpose of protecting the water therein, it must pay full and fair compensation for it. However, when pollution control legislation controls and often substantially restricts, the use to which a landholder can put his land, the law affords the landholder no remedy. Surely, the introduction of such controls must have a substantial influence on the value of all land to which they relate. For example, the recent introduction of subdivision and other controls in our Adelaide Hills watersheds must surely have influenced the values of large areas of land therein. The question therefor raised appears to be: should compensation be paid in such circumstances?

For many people the first reaction is to answer "Yes". Even leaving aside the question of the tremendous expense which would result from the payment of compensation, there is no easy answer to this question. All land, wherever situated, is subject to some use control which must influence its value. Such controls may be imposed under statutes such as the Local Government Act, 1934-1969, the Building Act, 1923-1965, the Planning and Development Act, 1966-1969, etc.

The fact is, that today, we all live in a controlled environment, and the question of compensation for pollution control restrictions is merely an extension of the question of whether we should receive compensation for environmental control. Whilst water pollution control is, in many circumstances, more restrictive than the normal environmental control, the fact that we are all the subjects of environmental control appears to be the basis for paying compensation to no one.

I do not pretend to know the answer to this question. However, although the above reasoning may appear a reasonable basis for refusing compensation, I think that any case in which extreme hardship results from pollution controls, payment of compensation should be considered.

Administration of pollution controls.

In South Australia, we have a number of bodies and departments each of which are responsible for or have power to control water pollution, e.g., various Government departments, the Central Board of Health, Local Government bodies, etc. It has been suggested by some that the responsibility for and control of water pollution should rest with one body which should, naturally, be either a Government department or agency.

In considering the question of water pollution control, it must be remembered that such control has two distinctive elements, namely, the setting of standards and their subsequent enforcement. In my opinion, uniformity of pollution standards is essential, and therefore it would appear essential that the aspect of control concerned with the setting of pollution standards should be the responsibility of one central body, which should, of course, contain personnel with the qualifications necessary to set the proper standards. Once this central body has set the standards, I see no reason why the enforcement thereof should not be left to the various departments or bodies concerned with the water the subject of the control. Again it will be appreciated that enforcement, like the setting of standards, can be a process requiring extensive technical skills, and it seems to me that the departments or bodies presently responsible for the control of the various types of water are those which are most likely to have the necessary technical personnel, and therefore perhaps, by using such a system, duplication or personnel may be reduced.

Conclusion.

There presently exists, in Australia, a large variety of legislative pollution controls. However, it would appear that pollution is on the increase in this country, and indeed, over the past year or so, various newspapers, journals and magazines have published articles which tend to paint an extremely gloomy picture. Although the pollution picture could certainly be brighter, I do not think that this means that our legislative controls are a failure. However, I do think it means that the provisions of our pollution control legislation need substantial revision, and, more particularly, considerable extension of application. It may be that existing legislation is sufficiently flexible to be materially extended without further parliamentary action. If this is the case, the effective provisions should be extended, whereas, if it is not the case, the future legislation should embody the characteristics to which I have referred.

RE-THINKING THE ROLE OF GOVERNMENT IN WATER RESOURCES MANAGEMENT

By Sandford D. Clark
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Law School,
Melbourne.

An old Moslem text sings the praise of water. According to a translation in my possession,

> "the Lord added that the water cleans up virility of men and fecundity of women and also makes it easy for women to bring forth children; purifies milk and increases cattle and herds; it brightens and makes green all over the country through the affluence, happiness and riches. So keep the water always clean, do not pour into it dirts and corpse of animals and also avoid to bath in it."

From the early publicity of the South Australian Colonization Commissioners to the effusions of Ernestine Hill, we in Australia have been treated to equally extravagant, if sometimes more grammatical, claims as to the potential of our water resources. Yet we are unlikely to forego the dubious distinction of being the world's driest continent and there is an urgent need for Australians to approach problems of water management with disinterested detachment, free from the cant and rhetoric which traditionally have infected public debate on this matter. We like to think of ourselves as a pragmatic, down-to-earth race with a healthy disrespect for the emotional intensity which often appears to govern debate amongst our American neighbours. Yet the history of water management in this country is redolent with narrow self-interest and political gamesmanship and our public reaction has largely been to swallow conclusions based on untested premises, not with phlegmatic resignation, but slovenly apathy.

In such a climate, the publication of the Senate Select Committee Report on Water Pollution, emerging as it does from that branch of government least known for disinterested debate, is a salutary sign. The problems it exposes are certainly not new to those who have been professionally associated with water resource development in this country. What is refreshing, however, is its willingness to move beyond the wringing of hands and knitting of brows, to challenge many of our received ideals as to the role of government in resource administration, to propose bold new forms of national co-operation; to reveal our abysmal lack of expertise and data and consequently to question the very basis of our traditional decision-making processes.

> "The faint flutter of debate that does proceed on water pollution often generates into a series of highly emotional altercations between isolated social and political units. They are usually settled by processes somewhat akin to crude tribal rites rather than by rational argument."[1.]

One may go one step further and say that, even in those areas where Australian hydrological expertise is acknowledged as being of world class, the noise of the didgeridoo and hysterical bone-pointing invariably drown out the voice of rational expertise. As a student of the history of Australian water-resources control and, tribally, a South Australian, I confess to a wry amusement at the recent pounding of ancient drums along the Murray. In the words of a now-famous American political commercial, "It would be funny if it weren't so frightening."

Yet the Senate Committee Report is a new star on our horoscope. It is vain to hope that the Age of Aquarius is upon us, but there is the possibility that informed expertise will not only be encouraged, but allowed to participate effectively in the making of decisions. In the hopefully prophetic words of an eminent American teacher, "while politics and self-interest temper both law and economics, it is similarly true that the rational arguments of lawyers, conservationists, and economists have prevented some outrageous boondoggles, or at least forced a search for more reasonable alternatives. Thus, our musings here are not without practical significance."[2.]

It is my purpose to examine some of the premises which lie behind our present attitudes towards the role of government in water-resources planning and to look at the wider implications of some of the proposals put forward by the Senate Select Committee. South Australia was, I think, one of the earliest modern political units to recognise the need for strong governmental intervention in the apportionment of water resources. In their instructions to Colonel Light in 1836, the Colonial Commissioners required that a strip of land be reserved to the Crown along the whole length of the Murray from the border to its mouth. This step potentially permitted a degree of government intervention in resource planning which was then unknown in England. Although the instruction was not meticulously observed and did not apply to other rivers in the Colony, it avoided in part problems of controlled development which beset the Eastern Colonies.

Today we do not question the notion that the State should assume an entrepreneurial role in water resources development. Whilst there are solid reasons for this attitude some of the conclusions drawn from them are not as automatic as we might think. It is useful, I think, for us to realise just where disguised or overt political considerations take over the argument and shape the final conclusions. My purpose is not necessarily to argue against these conclusions, but merely to point out that other rational and possibly viable alternatives could equally be reached from our accepted premises.

Economic considerations.

Our experience has been that major works to develop water resources, unlike the exploitation of other natural resources, are not attractive to private investment. The capital expenditure necessary to harness water resources is enormous and the investment is manifestly not convertible. Further, the service of controlling or distributing water, unlike the extraction and purification of minerals or the distribution of natural gas, rarely yields high direct financial returns. We therefore conclude that the conservation and development of water resources necessarily falls into the public sector. Government must provide.

Yet it was not always thus. The Chaffey scheme at Mildura and the early system of communal autonomous Trust irrigation in Victoria were viewed as "an encouragement to self-reliance, to self-support, to self-independence" and as "discouraging crawling by a locality to the Government for everything it wants."[3] It was, however, a catastrophic experiment and within four years of the inception of the Trust system in 1886, £918,000 of capital and interest was written off by the Victorian Government. In America, the experience of private development was otherwise, although there were such undesirable side-effects as abundant litigation. Whether the widespread failure of the Australian experiment was due to the lack of pioneer drive and initiative in our agricultural antecedents, as one American observer suggests,[4] is a moot point, yet it cannot be disputed that, from that day to this, an inordinate proportion of public spending has, either directly or indirectly, been necessary to produce the impression that irrigation in Australia does, in fact, turn water into gold.

Our experience and our conclusions on this matter are firmly based in our past agricultural patterns. The possibility of recouping from consumers not only interest, maintenance and distribution expenses, but also capital outlay, is much higher when water and, perhaps, hydro-electricity, is supplied to highly industrialised urban areas. It is also possible that, in terms of total productivity, it might eventually be in the national interest to allow a shifting of the allocation of a scarce resource to a higher-valued water use, consistent with emerging social changes. A New Mexico research team, for example, calculated that in the Rio Grande basin, an acre-foot of water used in agriculture supported only $50 of total product compared with over $200 for recreation and over $3,000 for industry. I think it is not unduly misanthropic to suggest that public demand will require a long, hard look to be taken at existing irrigation policies. The results of such an examination may not be readily palatable when the crunch comes, for "it is difficult in a nation accustomed to preserving the family farm as a social goal to interpret the demand-supply pinch as an excessive depletion of water in irrigation rather than simply a deficiency of water."[5]

The Senate Committee Report speaking, of course, of pollution rather than supply problems, unequivocally supports the need for comprehensive economic evaluation of both tangible and intangible costs and benefits in assessing future programs. "Costs", they say "must be weighed realistically against benefits and paid for realistically by polluters."[6] The same hard-headed resolve is apparent in the new Canada Water Act, passed by the Canadian House of Commons just six days before our Senate Committee reported. The Minister of Department of Energy, Mines and Resources, Mr. Greene, in addressing a House of Commons Committee remarked:

> "Let me clarify our position again by re-asserting that the polluter must pay. Now, we have all said this so often to each other that I think we have stopped realizing what it means. It means that either those who do the polluting or those who consume the products whose prices have, in the past, been kept artificially low through the free use of a public resource such as our waterways for waste disposal should now pay the full cost of disposal of their wastes... If one accepts that basic principle then it is a contradiction to propose that the federal government - that is all the taxpayers in Canada - should pay subsidies to polluters, provide grants for treatment of wastes or, generally, provide vast financial backing for pollution control. In that case everyone in Canada - whether he uses the offending products or produces an excess of waste - is paying for the polluter. I am sure that none of you want to see that sort of injustice perpetrated and I know that I don't. The time has clearly come to get tough..."

The Minister is as good as his word. He has met with detergent manufacturers and ordered the limitation of phosphorous pentoxide in detergents to 20% by weight by this autumn. They must be totally eliminated by 1972. Anyone manufacturing or importing detergents which do not comply with standards is liable to a fine of $5,000 and confiscation of the goods.

Such pragmatism denotes a remarkable change in the idea of government as a benevolent patriarch who will pull out his purse when the going gets tough. It may be that a similar change in emphasis is needed in Australia if we are to be dragged, kicking, into the twentieth century.

Social considerations.

Another reason for entrusting the development of water resources to the state stems from a fundamental idea of the nature of water. Water is a transient, elusive commodity, whether flowing in a river, diffused over land or percolating through it. Even when it comes to rest in an apparently stagnant pond, it is, in fact, subject to change by precipitation, natural surface drainage, seepage, evaporation and transpiration. Like air, it defies our ordinary concepts of possession and ownership. Coupled with this is the universal dependence of all life on water. Together, these notions have dictated the response of removing the vast bulk of visible water from the sphere of private ownership. It is not a large step in modern political theory to the view that the state must therefore exercise guardianship over water.

It must be remembered, however, that this is not an argument <u>for</u> state control but rather an argument <u>against</u> the possible evils of private domination of sources of supply. On this view, a government which allowed special interest groups excessive liberties in using or contaminating water might be failing in its public trust, unless it can point to reasons of national significance why these particular minority groups should enjoy more than their fair share of the cake. That illegitimate criteria are often allowed to interfere in balancing priorities cannot be doubted. The Senate Committee, for example, points to the reticence of certain local councils to enforce pollution by-laws against significant rate-payers in their municipalities. Is it fair to speculate that analogous considerations might affect decisions at a State or even a national level? If so, should there be some public, acknowledged criteria for measuring whether a particular proposal will produce national benefits which justify special privileges? Ought there to be a concept of geographic fairness so that those in one region do not get more than their "fair share" of privileged use or financial support? Alternatively, should there be a requirement that the benefits of a particular proposal will be widespread among citizens in an area, rather than producing a windfall for a small, special interest group which, for some reason or other, has a political voice disproportionate to its size?

It is possible that no precise, measureable criteria can be found to solve all situations. This definitely does not mean that the search should go by default. It is our public duty to provoke government into purging its motives through the knowledge that objective justification will be demanded and to be on our guard against the assumption that all Cabinet or Ministerial decisions reflect the expert opinion of the responsible Department. It is ironic that the essential data, expertise and experience for disinterested decision-making is primarily available to public servants who, by regulation, are hampered in their ability to speak frankly to the very public they serve.

A further and significant social reason for our reliance on public enterprise is the social complexity of modern water development projects. Few dams serve but one purpose. Usually they serve many distinct ends. Water will be directly used for domestic and stock purposes, for urban, irrigation and industrial supply. Projects may assist soil conservation, flood protection, land reclamation and transportation. They may provide hydro-electric energy and recreation or tourist facilities. Patently, such projects are not merely of regional significance. Single river basins may occupy large areas of land, all of which will be directly affected by a single dam. Indirect consequences may be nation-wide. The channelling of resources into a major dam automatically withdraws those resources from other employment. Patterns of agriculture, population density and national productivity may all be affected. In short, government is the only body with the mandate, the resources and the power to undertake such work and to plan and co-ordinate the consequent economic and social upheaval.

This argument is irrefutable, but it does not necessarily mean that our existing system is the optimum available. If we hand planning and co-ordination over to government on the grounds of complexity, we are entitled to expect that it will use its superior resources to train and to employ the most effective planners and co-ordinators. The Senate Committee condemns the lack of specialist education and research into pollution problems . The same is true of all fields of water management. Until government accepts the premises that education and research are a costly necessity, not a luxury, and that academicians and researchers are not a viperous band of unproductive malingerers but are a largely untapped source of potential planning skills, we will continue to lose our better men to private industry, or to other countries where their skills are actively solicited and their participation in productive planning is assured.

Another aspect of this problem is the traditional lack of breadth in Australian professional education and the absence of mobility between professional specialties. The Senate Committee wisely points to the need for "a multi-discipline administration involving specialists in the fields of health, engineering, ecology, finance, law, conservation, planning, research and education"[7] Yet merely bringing diverse specialists together is not necessarily fruitful. In my own work I have often encountered justifiable scepticism from engineers and administrators in government. Too often they have called on lawyers to assist in solving one problem only to find that lawyers, through lack of adequate understanding, offer solutions to another, non-existent problem. One reason for the haphazard approach to water legislation and the multiple inconsistencies observed by the Senate Committee[8] is the failure of lawyers to equip themselves adequately to participate in water planning. The primary responsibility for devising an administrative structure to control water has typically rested with scientists and engineers. Too often the lawyer's role has been purely surgical; he has only been called upon to ameliorate an existing situation when it becomes intolerable. Rarely is he called upon to exercise and develop his prophylactic skills. One may be pardoned for assuming that his only part in the planning process has been to translate the whim of engineers and administrators into that formidable and elusive jargon called "statutory language".

There is no reason why lawyers should not be able to equip themselves to participate in planning. The special skill required is, if anything, a basic understanding of the practical problems facing the other professions involved in water management. Unfortunately, except in the United States where litigation is rife, there is no attempt to develop these broader skills during the education of lawyers and little incentive for a busy practitioner to make himself familiar with the field. Even in Australia, where water is so essential to the economy, a water law specialist is generally regarded as a rarity.

Doubtless the same problems exist in other professions and with other fields of natural resources planning. Something must be done to bridge the widening gap between narrow professional disciplines and some re-thinking of our tertiary education programs seems inevitable.

I revert to our premise that social complexity and the national repercussions of modern water development require government to plan, control and co-ordinate our water use. It would seem obvious that water management problems do not respect political boundaries and that the management of the River Murray, for example, is manifestly a matter for dispassionate national co-operation. On such a hypothesis the major recommendations of the Senate Select Committee would appear uncontentious. They conclude, inter alia,

(a) that a national policy of water management must be formulated which establishes standards, co-ordinates the activities of State and local government bodies and provides the machinery to balance water development against other national goals;

(b) that a National Water Commission should be established, supported by a multi-disciplinary staff and expert advisory bodies, to formulate the national policy and to programme the orderly development of our water resources;

(c) that thought should be given to reviving the Inter-State Commission as an arbitrative body within the Federal framework to resolve those disputes between Commonwealth, State and individual interests which cannot be resolved by the National Water Commission itself.

These proposals, it would seem, admirably reflect the co-operative spirit of Federalism. But before we get carried away by the immutable logic of the proposals which, fittingly, emanate from a body which was originally conceived as a disinterested brake on the pressures and lobbying which might influence the lower House, it is well to recall those tribal rituals which have coloured our development so far. As good anthropologists, we must look to history if we are to predict the possible effects of these new suggestions.

Drums along the Murray.

Victoria was separated from New South Wales in 1850, but the Imperial Act of Parliament left some doubt as to which Colony owned the Riverina. An Act of 1855 thus declared that "the whole watercourse of the said River Murray, from its Source...to the Eastern Boundary of the Colony of South Australia, is and shall be within the Territory of New South Wales." Potentially, this raised problems both for Victoria and South Australia.

For Victoria, the question was whether riparian landowners on the Southern banks of the Murray enjoyed the normal rights of a riparian to use water and whether laws could be made granting Victorian residents the right to take and use waters of the Murray. For South Australia, the question was whether New South Wales could be restrained from diverting waters from the Murray to the detriment of the downstream Colony. By 1855 South

Australia had already established her interest in the River Murray with a blossoming river trade which extended up the Darling as far as Walgett, on the Murrumbridgee to Wagga and along the Murray to Echuca. Her interest thus extended not only to prevent diversions from the Murray itself but to prevent obstructions and major diversions in navigable tributaries. In an effort to secure year-round navigation on the Murray, she even went so far as to assert her claims to the uninterrupted flow of the non-navigable Victorian tributaries, such as the Goulbourn and Loddon.

The original feud thus reflects three contentions:

(a) South Australia's claim to maintain navigability in the Murray itself and major tributaries in New South Wales;

(b) Victoria's claim, as the first colony to realise and exploit the advantages of irrigation, to a right to divert water from the upper Murray and all tributaries within its territory;

(c) New South Wales' claim, based on territorial rights declared by the Imperial Parliament, to the exclusive use of waters in the upper Murray and territorial tributaries with no regard to the claims of Victoria and South Australia.

The first round was as impassioned as it was hilarious. In 1845, two squatters were granted pastoral licences in the Swan Hill district and part of their run included a marshy island sitting in the Murray. The property was described as being in the Port Phillip District and, when the Colonies were separated, the occupiers continued to pay their licence fees to Melbourne. In 1859, however, New South Wales demanded that Victoria pay over all revenues received from the island[9] and pompously informed the licensees where their fiscal allegiance lay.[10] The occupiers were content to render unto Caesar, and sought to ride out the wrangle by proceeding to pay rents levied by both Colonies. This thwarted the ardent Commissioner Lockhart, who was spoiling for a fight. Thus when the licensees isolated some diseased sheep on the island, he nabbed them under the Scab Act for importing diseased sheep into New South Wales.

The resulting clash of Colonies is of considerable legal interest. There was no local forum to resolve the difference. Yet, as the Duke of Buckingham pointed out, the Judicial Committee of the Privy Council strictly had no jurisdiction. It would only agree to hear the dispute if each Colony agreed to abide by its decision.[11] In the event, the Colonies agreed to accept the decision, which was then given in favour of Victoria. This arbitration was significant in two respects. First, it demonstrated that the Imperial Government was hesitant to intervene in inter-colonial disputes without the consent of both parties and thus lent a certain hollowness to South Australia's consistent threats, which continued down to 1909, to appeal to England for redress of its grievances. Secondly, because the Privy Council apparently exercised the Queen's Prerogative, rather than its judicial power in making the award, it casts doubt on the power of our

Federal High Court, which succeeded to the Council's judicial power only, to resolve similar disputes today.

The second bout, though more prolonged and acrimonious, is not without irony. It started with a resolution by the three Colonies in 1863 to co-operate in rendering the Murray system navigable and available for other uses. Victoria had already indicated that it felt river navigation was injurious to its revenue and the commercial interests of Melbourne, as well as being an avenue for smuggling.[12] A suggestion that the Murray be dammed and opened for irrigation penned, appropriately enough, from the Reform Club in Pall Mall, led the Governor of Victoria to remark that the conflicting interests of the Colonies made such a scheme unlikely.[13]

In the early 1880's, South Australia corresponded with the other Colonies in an attempt to improve navigation. Her letters were but formally acknowledged, as the other States were moving on to newer horizons. By 1885, both New South Wales and Victoria had appointed Royal Commissions which were enthusiastically formulating plans for irrigation. Victoria suggested that the three Colonies should form a joint Commission to consider the future of the Murray. South Australia was adamant that any irrigation in either Colony which detracted from navigation would be illegal, but sniffily agreed to join the Commission for the sole purpose of self-protection. It was perhaps her intransigence and indifference which led the other Colonies to meet without her and to agree to share the waters of the Murray, subject to compensation water being allowed to flow. South Australia's bitter protest reached screaming point when Victoria announced its Irrigation Bill in 1886. The Victorian Premier blandly replied that the proposed legislation was for water supply only and not for irrigation.[14.] The most charitable interpretation to be placed on this response is that the Premier was ignorant of both the title and purpose of the most important Bill of the Session.

Yet there was duplicity on both sides which, with hindsight, is amusing, to say the least. South Australia violently protested Victoria's agreement with the Chaffey brothers[15] but within three months had signed a similar agreement with the same brothers to develop irrigation at Renmark. Victoria again suggested that South Australia appoint a Royal Commission to consult with the other Colonies. This was done early in 1887. Although Victoria remained willing to meet, New South Wales refused even to acknowledge the persistent overtures from South Australia. In March 1890, Sir Henry Parkes stirred and raised his leonine paw. He referred to the fact that all the upper reaches of the Murray was New South Wales territory, but

> "(t)his being the law of the constitution, I have only to express the desire of the Government to act in all things most calculated to promote and strengthen friendly relations and to serve the common interests of all concerned in the navigation and legitimate use of the river."

Having thus disarmingly propped South Australia against the ropes, the coup de grace was delivered in the best traditions of forward defence.

> "We are, of course, fully aware that the River Murray, from the point where it enters your territory belongs to South Australia. I desire, however, to intimate that it is held by this Government that South Australia cannot use the waters to such unreasonable extent as would interfere with the normal level of the river without committing a breach of inter-colonial obligations."[16]

This exchange is all the more amusing when one recalls that poor South Australia had not yet fully realised the possibilities of irrigation and was basing her claims on navigation, which had already begun to diminish substantially as railways from both Sydney and Melbourne had reached the river and were siphoning off the river trade with heavily subsidized preferential tarrifs. Small wonder that P. M. Glynn mused whether "one unacquainted with the ways of politicians, which, like those of the Heathen Chinee, are peculiar" would understand the attitude of New South Wales.[17] Defeated, the South Australian Commission asked to be relieved of its functions.

The advent of federation presented South Australia with a new line; agreement on the Murray was a matter of "Australian concern" and should be approached in a federal spirit. In the Convention Debates, the river question looked large. Based on the American model, the founding fathers decided that the new Federal Government should have power over trade and commerce. They were also aware that contemporary interpretation of the American power gave the Federal Government almost absolute control over any river which was navigable for part of its length. It is ironic that, in view of current Federal-State tensions, South Australia saw its salvation in these American decisions. Her navigation interests might be revived if the Commonwealth, as benevolent protector, were given power over the River Murray and the plundering railways. To make assurance double sure, she successfully pressed for the inclusion of section 98 of the Constitution.

> "The power of the Parliament to make laws with respect to trade and commerce extends to navigation and shipping and to railways the property of any State."

This was agreeable to the other States, provided that the Commonwealth Government exercised its plenary powers in a way which also protected and enhanced irrigation. Thus we obtained section 100.

> "The Commonwealth shall not, by any law or regulation of trade or commerce, abridge the right of a State or of the residents therein to the reasonable use of the waters of rivers for conservation or irrigation."

This section was inserted not with the intention of limiting Commonwealth power, but of directing the Commonwealth, when exercising the broad powers which the framers thought they had conferred, to enhance rather than abridge irrigation and conservation. It is one of the mysteries of our constitutional development why these sections have subsequently been viewed as limiting Commonwealth power, which is precisely what the framers sought to avoid.

Federation did not, of itself, solve the wrangling of politicians over the Murray. It is a salutary lesson in participatory democracy that private citizens, acting through the various River Murray Leagues, finally coerced their unwilling statesmen to adopt a truly federal spirit and to meet with them at Corowa in 1902. An Interstate Royal Commission on the River Murray was convened as a direct result of this conference, but its recommendations again reflected the political intransigence of its members. The debate continued to rage, and as late as 1906, South Australia was obtaining opinions from such eminent barristers as Isaac Isaacs to support its proposed action against the upper States.

In 1912 the Commonwealth took the first step towards resolving the dispute. It set up the Inter-State Commission, which had been provided for in the Constitution, and specifically gave it powers to resolve inter-State water disputes.[18] The Commission was short-lived, however, and before the river question was raised before it, the High Court declared the Commission unconstitutional.[19] Its members were required to exercise a judicial function, and must therefore hold permanent office, not just for seven years. In the same year, however, the States finally got together with the Commonwealth and signed the first River Murray Waters Agreement. South Australia finally got its locks to support a navigation trade which was long since dead and the issue subsided under the delicate administration of the River Murray Commission.

One cannot but be impressed by the record of co-operation of the River Murray Commission, and of its Technical Committees. Together, representatives of the water authorities from each of the States have worked together on the collection and interpretation of data with single-minded professionalism, unblemished by regional prejudice and self-interest. It should be a matter of deep concern to all professional people that recent events have been shaped by casting reflections on the integrity of their deliberations. I do not for a moment suggest that the validity of their conclusions should not be the subject of public scrutiny; it is essential that they should be. But to impeach the professional integrity and honesty of their conclusions is little short of the most barbaric political opportunism.

Projections for the Future.

The fundamental premise of the Senate Select Committee's Report is that we have reached a stage of national development where some effective national co-ordination and planning of our water resources is imperative. Whilst this premise is, I think incontestible, the danger is that the concrete suggestions contained in the report may prove so politically unacceptable in the existing climate of Commonwealth-State relations, that the report may be shelved completely.

It may, for example, be argued that the Committee overstepped both its terms of reference, and the framework of the evidence put to it, in recommending a National Water Authority to have a planning role across the whole field of water management. On more narrow grounds, it seems inconsistent to decry the lack of expert knowledge about the causes and control of pollution and, in the same breath, to propose ex cathedra a quite detailed administrative structure to meet largely undefined needs. Whether it is necessary to establish a national body which, to meet its goals, would need to duplicate much of the expertise presently concentrated in the various State Authorities is questionable. It may not only prove to be an uneconomic form of duplication, but be actively detrimental to encouraging State Authorities to be more assiduous in eradicating local pollution. Furthermore, the suggestion may easily be misinterpreted by ardent State-rights advocates as yet another attempt at arrogant, high-handed Federal interposition. Again, the fact that Labour Party policy includes the revival and re-activation of the Inter-State Commission may introduce elements of party politics into the debate.

To a disinterested observer, then, the basic need for national co-ordination might have been more readily achieved by suggesting an interim co-operative body whose task would be to investigate a mutually acceptable means of establishing and implementing a national water policy. The obvious danger is that such a suggestion appears to lack teeth and may founder through lack of co-operation. One may look enviously at the new Canada Water Act where machinery for co-operative management of "inter-jurisdictional waters" is provided but, in the event that co-operation is hampered by the intransigence or self-interest of one Province, Federal power may be invoked to set up a public corporation to manage the waters.[20] Such power may only be invoked where "the water quality management of those waters has become a matter of urgent national concern" and either

(a) "all reasonable efforts" have been made to reach an agreement with the intransigent province, or

(b) although an agreement was reached, there is subsequent disagreement as to the water quality standards to be enforced.

Our constitutional structure might not permit such coercive national legislation. This need not be a failing, provided there is sufficient public pressure brought to bear on local, State and Federal Governments to pay more than verbal allegiance to the concept of national planning and co-operative federalism.

Provided the basic principle of the Senate Committee's Report can survive the inevitable bombardment of its detailed administrative recommendations, there is still hope. There are signs that, once a problem becomes significant enough, solutions may be found. Thus the recent conference on financial relations produced a suggestion by the Prime Minister that, with co-operation of the States, a body like the Grants Commission could be adapted to provide an independent source of research and advice in establishing national priorities. Alternatively, Mr. Dunstan suggested a system of joint secretariats, responsible to an inter-state commission. One can only hope that some similar mutually acceptable solution will be found to the problem of rational national planning for our water resources.

To adapt the words of a recent "Age" editorial:

> To work out who gets how much, the three tiers of government would have to work out a system of priorities balancing national, State and regional considerations. This would not be an easy task after decades of jealousy, in-fighting and me-firstism. However, after a 69-year adolescence in Federalism, Commonwealth, State and local government should be adult enough to work together for the good of the whole country."[21]

FOOTNOTES

1. Senate Select Committee, "Water Pollution in Australia", 1970, 93.
2. Sax, J. L., "Water Law, Planning and Policy", 1968, 29.
3. (1883) 44 Victoria Parliamentary Debates 1629.
4. Davis, "Australian and American Water Allocation Systems Compared" (1968) 9 Boston College Industrial and Commercial Law Review 647.
5. Clark, C.D. "Northwest-Southwest Water Diversion - Plans and Issues", (1965) 3 Willamette Law Journal 215, 261.
6. Senate Select Committee Report 184.
7. Senate Select Committee Report 189.
8. Ibid., 121.
9. Letter from N.S.W. Colonial Secretary to Vic. Chief Secretary, 21 October 1859; 20 February 1861.
10. Letter from Commissioner Lockhart, 20 June 1863.
11. Despatch from the Secretary of State for the Colonies to the Governor of N.S.W., 28 March, 1867.
12. Despatch from the Governor of Victoria to the Secretary of State for the Colonies, 26 August 1862, refusing a request that a reward be paid to Captain Cadell for opening up River Murray navigation.

13. Despatch from the Governor of Victoria to the Secretary of State for the Colonies 31 August 1857 replying to a letter from one J. Crawford, 28 April 1857.

14. Telegram from Premier of Victoria 21 August 1886. In all probability the date is incorrect as the South Australian protest is dated 30 August.

15. Telegram from Premier of South Australia to Premier of Victoria, 11 November 1886. The South Australian agreement with the Chaffeys was signed on 14 February 1887.

16. Letter from Parkes to the Premier of South Australia 6 March 1890.

17. Glynn, "A Review of the River Murray Question" reprinted from the "Register", 1891.

18. Inter-State Commission Act 1912, s. 17.

19. New South Wales v. Commonwealth (1915) 20 C. L. R. 54.

20. Canada Water Act 1970, s. 11.

21. "The Age", 29 June 1970.

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MEDICO-SOCIAL ASPECTS OF WATER POLLUTION.

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Much is being written about environmental pollution and water pollution in particular but the medico-social aspects have had little direct attention although the economic results are getting much attention. This latter interest is bound to the medical side in many diverse ways indirectly and I am approaching the discussion from this point of view. Populations which suffer physical deterioration resulting from the sequels of water pollution become inefficient in varying degrees and are thus less productive with reduction in standards of living. Impoverishment, malnutrition and perhaps outright starvation become aggravated by disease. From these developments political complications arise. The extent of these may affect only local areas or even whole nations. Finance may not be available to cope with the situation and civilian unrest with its consequences aggravate a difficult situation.

These problems can be acute in a backward country struggling to develop, though of course regional problems may arise in otherwise more advanced areas. The quantity of water available often determines the degree of pollution in that the degree of pollution tends, with a given population, to be in inverse proportion to the volume. The conservation and protection of supplies are related to the degree of man's ignorance and folly.

Chadwick in 1842 laid down that there were three fundamentals for a healthy community: drainage, and removal of refuse from habitations, streets, and roads and improvement of the supplies of water. Since then there have been many improvements in the means of carrying out these requirements. These matters are largely administrative but the need to implement control arises from the sources of pollution. These sources can be considered broadly to be natural and mechanical, animal, including birds, and humans. The human aspect would include the important industrial aspects. It is not proposed to discuss these origins nor their control but to show where they impinge on socio-medical conditions.

I mentioned the importance of available water a moment ago. Australia is not so well off in its quantity of available water as many other countries. Last year when I was in Europe I had cause to marvel at the flow of many rivers. The Danube flowing through Vienna would carry many times the water of our Murray system and provides a cheap means of transport over long distances which even in these troubled times seems relatively unhindered by national boundaries. On my last night in Vienna I dined with a barge captain who regularly took his vessel to Budapest and at times much further. The Rhine also carries much more water than our Murray and a very considerable amount of river transport. The Po, Rhone and Seine also discharge very considerable quantities and any one of them would make a considerable difference to our total if we had it. Of course in so far as they transport goods and carry wastes they are subject to pollution. Such an accidental and serious event occured near Bingen on the Rhine, about the time I was staying opposite, when a considerable amount of insecticide came off a barge and killed forty millions of fish. It is interesting to note that little was said of harm to humans. The dilution factor in these large fast flowing streams is very great. Besides with the considerable rainfall there is not the degree of use for irrigation.

The Rhine is referred to these days as the sewer of Europe, and no wonder with its origin in Switzerland and long course to the North Sea. The addition of manufacturing wastes is very considerable including the colossal amount of salt from the potassium production in Alsace. It was said recently that the waters before reaching the sea are used as much as eight times. This would seem an exaggeration for experience with re-use in California has been that the increase in salinity with two reconstitutions renders water too polluted for further use. The fact that it is claimed that the Bingen incident killed forty million fish would indicate that at this stage in its flow even below Mannheim, Frankfurt and Weisbaden, the residual oxygen is still sufficient to sustain fish under average conditions.

It is interesting to record that after greater pollution in the Thames and sustained efforts to reduce it, fish have been caught last year near Greenwich where previously they have not been present for many years. It is interesting to reflect that the cloaca maxima of Rome with its tributaries was started six centuries B.C. and was buried as much as forty feet below ground and apart from draining the marshy areas, also coped with the residue of the 300,000,000 gallons of water a day brought by the fourteen great aqueducts. There was little industry to cause pollution of the Tiber and little is heard of such occurring. Rome was mainly a healthy city despite its slums and recurring poverty in sections of the population.

That there was mechanical pollution is borne out by the extensive flood plains and the necessity to dig the Fiumicino channel in the times of Claudius and Trajan to provide an accessory outlet. The well-known occurrence of malaria in the Pontine Marshes arose through ineffectual drainage.

Relatively our largest flowing river is much affected by the increase of salinity from evapouration and carriage of irrigation drainage and contamination as a result of settlement along its banks and tributaries as well as those who ply on its surface. Bacteriologically this has become of much importance though the actual occurrence of disease from this source is apparently negligible.

Some Effects of Mechanical Pollution.

Rivers because of their energy of flow carry suspended solids of geological origin. These may be in the form of coarse gravels to fine mud particles and their carriage depends on their size, weight and force of the flow. Deposition occurs when the rate of flow is reduced. Deposition therefore tends to be downstream when flatter country is reached or when flood waters are widely dispersed in flat country. The history of the Mesapotamian civilizations illustrates how the course of rivers may be altered by these means to the detriment of established towns which have been left distances from the original course or from the seashore where once they were. It has been seen that extensive irrigation and draw off may have similar effects. On the other hand siltation, raising the level of flow and overflow to produce marshes, would favour the establishment of endemic insect-borne disease. These factors altering the environment bring about hardship and development of factors conducive to disease conditions. Economically over-drainage may alter the vegetative ecology by change in the salt content of the upper layers of the soil and thereby alter grazing conditions with change of pasture and grazing animals. In arid areas overhead irrigation can be detrimental to plant growth depending on the salinity of the water used and the sun temperature. Experience in the Murray lands has shown that the increase of salinity of residual water on the foliage and also on the ground may kill off fruit trees and vegetable growth. Methods of trickle irrigation have superseded the overhead method in many instances. The economic results and hardship caused by the over head method have been serious in areas of low rainfall.

Careless farming methods allowing strong run off of rain waters has caused erosion and carriage of detritus into creek, river channels and dams with siltation, alterations in flow and reduction of storage. In a similar manner shallow lakes receiving industrial and other deposits have been made shallow, subject to increased evaporation, and the development of obnoxious conditions besides elimination of the natural flora and fauna. Lake Bonney

The mechanical effects of marine pollution is illustrated by the "Torrey Canyon" disaster on the 18 March, 1967, when the ship carrying 117,000 tons of Kuwait crude oil ran aground 15 miles west of Land's End. The oil was carried by tide and driven by wind on to the coast of Cornwall and the west coast of Brittany. The latter portion had found its way down to the Bay of Biscay and returned towards Brest. A portion from the English Channel reached the north coast after passing Guernsey. It is possible that the oil recently reported by Hayerdahl on "Ra II" in mid-Atlantic well south, may be the residue of the Biscayan portion. The effect on the marine plant and fauna was considerable but regeneration has been found also to be considerable. Beaches were unusable in some instances for periods well into the summer. Efforts to bury the oil within the tidal range and below low water were not successful in the beginning for the seepage brought it to the surface. The use of detergents was costly and partly successful. They were found to be more toxic than the oil to both flora and fauna. It appears that natural processes of oxidation and dispersion, though slow, are effective.

Mechanical removal in favourable conditions is helpful in emergency. Oil disposed at sea may well be washed ashore again no matter how mixed with sand, chalk, or other materials. The total cost of treatment at sea was about $400, 000. The effect on humans was largely a matter of inconvenience to holiday makers and some interference with fisheries for a period. Perhaps the worst sufferers were sea and shore birds. Understandably there was much anxiety as to the possible seriousness and duration of the crisis. The effects could have been much worse than they were. They seem to have been much more serious in the Santa Barbara Channel off California. It was amusing when in Trieste last year to see on a British Admiralty chart, hung in a seaside hotel, a warning to mariners in the Gulf of Venice that many oil rigs therein were unlighted at night and though some were charted, many were not. I have not come across any reports of collisions, but in this shallow gulf, escape from an oil rig could have serious effects on Venice, Trieste and other seaside towns.

The mechanical effects of draw off in subartesian basins close to the sea can result in salt water from the sea entering the freshwater basin. This has been a real danger in Palestine and a possibility in the plains north of Adelaide. In the former instance the discharge of treated sewage effluent has been used as a barrier. In our instance legislation has been brought down to control the draw off.

Disease Originating from Water Pollution.

The sources of disease are human and animal and in each case are attributable mainly to direct contamination where non-vector transmission is involved. The diseases involved are mainly those with intestinal manifestation and include bacteria and viruses as well as various protozoa and metazoa. Some illustrative types will be discussed to show how medico-social factors are involved.

The enteric fevers caused by members of the Salmonella family, typhi and paratyphi A, B and C are systemic infections as distinct from the food poisoning members of the same group and are responsible for typhoid fever which is one of the classical water-borne infections. It flourishes where environmental sanitation is poor and is brought under control when piped or otherwise purified water supplies and safe sewage disposal are made available. The death rate in England in 1870 was 388 per million. By 1950 this had fallen to 0.5 per million with the introduction of effective sanitary measures.

Concurrently the occurrence in towns and cities gave way to the more relative frequency in country areas where these measures were lacking. Water supplies in recent years as in the 1937 Croydon epidemic in London have at times become involved in cross connection between sewer and water pipes. In non-city areas infection of wells from faecal contamination due to surface run off and underground seepage is the usual means of spread. Occasionally a carrier may spread the disease through non-water sources by direct infection of milk or other food. Generally the common source is from untreated water in backward communities. This was illustrated in the Middle East in the early campaigns with troops using untreated water. Although vaccinated, some troops contracted the disease. Oysters may carry the disease and one of the last cases to occur in Adelaide was spread in this way. The outbreaks usually are where environmental sanitation and living conditions are poor and reflect the low economic conditions. These are seen where production from the country is marginal and funds are not available for protection of water supplies nor provision of sewage. The paratyphoid group is less often associated with water pollution being more often spread by food and usually requires a more massive infection.

Bolivar

In recent years entero-viruses have been shown to be carried in water after excretion from carriers or sufferers of the infection. They can be demonstrated in sewage together with the poliomyelitis viruses. There are many varieties of this group which cause nausea, vomiting, abdominal pain and diarrhoea. They often begin with a sore throat. They cause distress for a few days usually and are, apart from the infantile paralysis type, not generally dangerous.

Cholera is perhaps the most dangerous of water-borne infections with a similar origin to typhoid fever. The disease is prone to occur in densely populated areas in undeveloped countries where infected water is consumed by large numbers of people. While break-down of protected water does occur the infection is more widespread where the water is untreated and subject to faecal pollution up stream. Major epidemics have broken out in India during the last 25 years. An epidemic in Egypt in 1947 produced nearly 33,000 cases with over 20,000 deaths. Another variety of cholera had become prevalent since the war spreading from the Indonesian area to the Asiatic continent. Carriers are more common than with classical cholera and it may be spread by sea-food but proper water conservation and treatment is still necessary to cope with pollution. Amoebic dysentery and infective hepatitis can spread through water pollution. In the former the existence of a resistant cystic stage favours spread particularly as superchlorination is necessary to kill the cysts. The evidence concerning virus hepatitis is not so clear but the possibility of water spread has been demonstrated. The ~~morbidity~~ mortality from these diseases is not as great as with typhoid and cholera, which have such a devastating epidemic potential with loss of life, production, and economic disturbance. Typhoid also is likely to interrupt recreational facilities as camping parties and out door recreation may be involved in outbreaks. In a similar manner virus diseases may be spread in swimming pools.

It can be understood that housing problems arise where domestic waste disposal and sewage is not treated effectively and local conditions of soakage are inadequate. At Tea Tree Gully where the soil mantle is shallow and the subsurface impermeable, the conditions could have caused restrictions on building and health problems. Provision of water carriage of sewage instead of local septic tanks has allowed development to continue. One can imagine the situation at Woomera if water were not available for sewage and sullage disposal. When Broken Hill was short of water in its early days, intestinal diseases were a recurring problem.

It is puzzling that Schistosomiasis has never flourished in Australia. Troops returning from service overseas in Egypt and the Middle East as well as in south east Asia must have brought back some infection. The saving link is perhaps the portion of the life cycle which requires the shed eggs to reach water of the correct temperature within four to six weeks from the time of excretion. The host for the African and Middle East variety, the water snail bullinus, is common in our swamps. A few months ago a case was reported in West Australia. The heavy rainfall and teatree swamps in the southwest corner would be suitable if temperature conditions were favourable. This disease is rife in the top half of Africa and through Palestine, South East Asia, the Philippines and Japan and the China mainland, India, and even Portugal and South America. It is estimated that there are 150 million sufferers from the disease throughout the world. Perhaps it is better known in Egypt where its characteristic manifestation is Egyptian splenomegaly but other forms cause cystitis, haematuria and dysentery and enlargement of the liver. The hatching of eggs in water and the infestation of appropriate snails which shed the next stage which enters man through the skin by drinking infected water. Since treatment is only partly effective, prevention is the main means of control and this depends on the interruption of the life cycle.

Another disease which occurs occasionally in Australia is associated with water indirectly but depends largely on rat and other animal infestation. This is Leptospirosis which is caused by several species of leptospira. Throughout the world rats tend to be infected and pollute all forms of water. It is common in European harbours and canals but may infect rivers and streams. In Australia the spread is mainly through abattoirs. Cattle become infected in ways not quite clear but rats, which are present everywhere about large cities and their abattoirs, maintain a reservoir and foul their environment with infected urine. The group of diseases is not common in Australia but is always with us nevertheless. In other countries it is more serious. Workers in rice fields in the East and northern Italy are sufferers and wet coal mines in Japan are involved. Only 113 cases were notified in Australia in 1968. One hundred of these were in Queensland but many more must have remained un-diagnosed. There is still an unawareness that the disease exists, although it is generally known as an occupational hazard in cane cutters.

A hazard associated with skiing was illustrated last year in a resort high in the Rocky Mountains at Aspen in Colorado. Of 1,350 skiers who had been at the resort in the season 294 reported a diarrhoeal illness. Investigation revealed that 59 of these were infested with the protozoon, Giadia intestinalis, and the average duration of the illness was 44 days. Virus and other infections were excluded in that the findings for these types were negative.

Investigations revealed there were two episodes of infection about three weeks apart when the water supply was at greatest strain. The water from two wells was found to be contaminated by old and decrepit sewer lines. It is known that giardiasis is common in poor communities in various parts of the world but this epidemic was in healthy adults who were free of other infections including amoebiasis.

An unusual explanation of an outbreak of hepatitis in children attending a primary school in a Melbourne suburb was traced to infected taps from which the children drank. It illustrated the faeces to mouth type of transmission. The disease was concentrated in two classes suggesting a common source of infection. Examination showed that the toilets used by the younger pupils were not cleaned at the time of inspection and faeces were adherent to them, nor was toilet paper present. There were taps at which children were expected to wash their hands and those for drinking purposes. The former were the rose type and the latter the bubble type. The two types were adjacent. It was observed that after washing, the children commonly wiped the bubble type with their hands prior to drinking and the shorter children had to reach over to the tap and make contact instead of drinking in the flow above the tap. This would seem to be the explanation for the illness predominating in the two classes.

Hookworm has been a pollutant in mines over a long period. Owing to the temperature and moisture in deep mines the environment for propagation is suitable for the spread of the disease. This is facilitated by miners skin being bared because of the heat and sweating. It has been shown nevertheless that the bookworm in its infective stage may penetrate thin clothing. This was established with troops in tropical swamps. Rigid sanitation will produce satisfactory results. The deep anaemia due to infestation produces severe debility both in children and adults in infested areas and is a problem in aboriginal populations in northern Australia.

An uncommon pollution in excavations over old sea shores occurs when there are considerable deposits of seaweed below the surface. The decomposition produces an abundance of sulphuretted hydrogen in the presence of sufficient moisture. Such an instance occurred some years ago when a man excavating for building purposes in an enclosed area was overcome by the gas and two others who went to his assistance also died with him. I investigated these fatalities personally and found the odour even about the surface quite strong. Despite the volatility, of the gas the concentration was considerable.

A rare occurrence reported in 1953 was the discovery of mercury poisoning in Minamata Bay in Japan, although the cause was only sheeted home to mercury as recently as 1966. The inhabitants, cats and waterfowl were the sufferers. It was shown that very small amounts of methyl mercury are produced when inorganic mercury compounds are used as catalysts in the production of acetaldehyde by the hydration of acetylene. The methyl mercury is carried forward to the acetaldehyde distillation column and discharged with drain waste from the bottom. A few parts per million only are present in the waste water from the distillation drains which is further diluted by waste from other sections. Concentrations in the receiving water and sea are even lower but the flora and fauna have the capacity to concentrate the organic mercury as much as a 100 times. The methyl mercury accumulates primarily in aquatic flora and secondarily in fish and shellfish. It can be detected in fish, flesh and scales, in the feathers of aquatic birds and in the hair of the inhabitants who have eaten large quantities of contaminated fish and shellfish. The effect of the poisoning was the occurrence of peripheral neuritis.

Research.

107 Scientists

In July 1969, I visited the Water Pollution Research Laboratory at Stevenage, Hertfordshire, which investigates the treatment and disposal of sewage and industrial waste waters and the effects of prevention of pollution of surface waters and underground water. Its programme is supervised by a Steering Committee and its activities are governed by the Water Pollution Research Board, both of which are appointed by the Minister of Technology. With the exception of its counterpart in the United States it is the largest organization of its type in the world. While I was there I was shown projects under way from all parts of the country and also from Canada. The laboratory's research work has been divided recently about equally between its two main objectives: development and improvement of processes for purifying sewage and industrial effluents, and the study of the polluting effects of discharge on surface waters. The first includes attempts to improve or cheapen existing methods of treatment; examination of methods likely to be required in the future and investigations made necessary by problems resulting from events affecting public health services. A recent example of the first is the study of the micro-biology of the activated sludge process of sewage treatment, which is leading increasingly to the possibility of designing and operating plants to yield an effluent of a required quality.

An example of the second is the reclamation of water by direct treatment of sewage effluent. It seems likely that such water may be used for certain industrial purposes, particularly in coastal towns. The third category includes many, often short, investigations concerning the effects of the discharge of industrial wastes to town sewers, as well as problems of much longer standing caused by the use of synthetic detergents in the home. Research on the effects of the pollution of surface waters is less easily divided but it too, includes continuation of work which has been in progress for some time such as the study of self-purification of rivers and estuaries and studies of more topical interest such as the relation between contamination of beaches and the design of outfalls discharging sewage to the sea. This latter project has a local interest for Adelaide beaches.

WATER AND SOCIETY

GEOGRAPHICAL PERSPECTIVES ON WATER USE.

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Water is a basic element and a fundamental factor in a great many of the patterns which can be observed over the surface of the earth.

In liquid form, it is a basic necessity of all forms of life, and the distribution of terrestial biotic communities is in large measure a reflection of areal variations or moisture availability and of the adaptations of various life forms to these varying moisture regimes. Water is a major agent in rock weathering, in erosion and in the redistribution of materials over the physical landscape, and an understanding of the areal variations of land forms depends largely on an appreciation of the contrasts in surface water supply from area to area and of the seasonal regime of water supply in any one region. Water is one of the major factors influencing the patterns of agricultural activity, both directly in terms of the moisture requirements of crop plants, and indirectly through its action as a factor of soil formation. Water also is a major factor in influencing the location of human settlements and the siting of manufacturing activities of all kinds; as modern urbanised societies continue to increase their total and per capita demands for water for domestic, industrial, and recreational purposes, this role of water as a constraint on the location of human activity will tend to become of greater importance.

Geographers have as the major focus of their discipline the study of patterns of distribution of both physical and human phenomena over the surface of the earth. Modern geography increasingly stresses the areal associations of these distribution patterns and attempts to discover the degree to which these areal associations can be explained in terms of complex causal relationships.

These relationships must not be thought of as simple relationships between Man and Environment. Man perceives his environment, and environmental conditions influence man's activities, in terms of the technology, the social and economic objectives, and the political organisation of his society. The reciprocal relationships between Man and Environment are therefore filtered through the mesh of a society's culture, and since culture is not static, these relationships are continuously being modified.

Considerations of this kind are relevant to this Symposium since the title of the Symposium refers to water resources. Water itself is, strictly speaking, not a resource. It only becomes a resource when society perceives a use or a range of uses for it, and develops the technology by means of which that use may be achieved. Thus water as a resource cannot be considered apart from the culture of the society which is harnessing it to satisfy a range of perceived needs or wants.

It is in this context that the papers in the Symposium should be read, and it is from this point of view that this introductory review has been written. In any other context, the invitation to a geographer to introduce the Symposium would have been much less appropriate.

To emphasise the importance of cultural change in the evaluation of water as a resource, the importance of water to early societies will be sketched before discussion focusses on the contemporary scene.

Historical Perspectives.

> 'Water has been a fundamental resource in the growth and spread of human societies, and the history of man could be written in terms of his attempts to exploit this basic resource". (Tweedie.)

In primitive societies the scale of water need is that of the family or of the small tribal group, and the constraints placed by water supply on the location of settlement or on the range of movement of a group are therefore minimal. Only in special cases would Palaeolithic societies have been closely constrained by water supplies. Such cases were the lake-dwelling societies of Europe who perceived water as a defensive moat, as well as a source of food, or the nomadic hunting groups of the desert fringe whose movements were tied to the relatively small number of water holes in an otherwise hostile environment.

With the advent of agriculture in Neolithic times, the perception of water as a resource was greatly modified, especially since many of the important Neolithic communities became established in areas which experience a markedly seasonal precipitation regime. By 4,000 B.C. flourishing agricultural communities had developed on the flat riveraine lands along the Nile, the Tigris and Euphrates, and the Indus, and these societies evolved a technology and a social and political structure closely tied to the fundamental importance of seasonal water supplies in their agricultural activities.

Along the Nile flood plain, annual flooding occurred between July and September, and the waters were fed into great basins formed by embankments of mud and stone. After a period of approximately a month, during which the soil had become fully recharged with moisture, and the sediment load of the flood waters had been deposited, the waters were drained off into basins at a lower level and finally back to the river. The drained basins were then cultivated, the crops depending on soil water storage. In contrast, the floods of the Tigris-Euphrates system are less predictable, and subside before the warmest season. As a result a complex system of irrigation and flood control canals was necessary which served a very large area between the rivers and demanded constant maintenance to avoid silting-up.

The development of these early hydraulic civilisations gave a great impetus to early science and technology and greatly influenced the social and political organisation of the communities concerned. Techniques of land measurement were developed to allow boundaries to be resurveyed after the annual flooding. An accurate calendar was necessary in order that the onset of the flood season might be predicted. Techniques of canal construction were developed and various devices for lifting water were invented. Above all, however, a strong centralised political system developed, with authority to mobilise massive labour forces for tasks of construction and of flood control: without such a centralised authority the complex integrated system would not have been possible, and when it was ultimately destroyed, the irrigation system also fell into disrepair.

Some of the early cities associated with these agricultural civilisations had elaborate water supply systems. The Indus cities of Harappa and Mohenjo-daro, dating from 2,200 B.C. had houses served by reticulated water supplies and by sewerage systems. Rome, with an estimated population of about one million at the beginning of the Christian era, had an impressive system of major channels and tunnels some 250 miles in length bringing approximately 100 million gallons per day into the city. Clearly, the civil engineering response to the demand for water by large concentrations of population 2000 or more years ago is quite as impressive, in the context of the technology of the time, as anything to be found today.

Water has continued to exert a powerful influence on the siting of settlement right up to the present day. In the scarplands of England and Northern France, one of the dominant characteristics of the pattern of rural settlement is the frequent alignment of villages along the scarp slopes and the dip slopes at the elevation at which springs occur. In the early days of the Industrial Revolution in England, when water power was the main source of energy, mills and their associated settlements were to be found along swiftly-flowing streams such as in the Yorkshire Dales. It was only later, with the development of the steam engine, that the burgeoning industrial centres relocated on the coalfields. The presence of navigable rivers has, of course, been vital to the rise to dominance of settlements such as London and Paris, which have depended so significantly on their port function.

Clearly, then, Tweedie's claim that the history of man - at least his economic and technological history - could be written in terms of his attempts to exploit water as a resource is one which can be defended.

Contemporary perspectives.

Discussion of water as a resource in contemporary societies must focus on three facets of the question viz. a) the total quantity and the areal variation and seasonal incidence of water supplies; b) the distribution and dynamics of population; and c) the changes in the uses to which water is put and the technology which makes these uses possible.

(a) Water Supplies.

Table I shows figures for the world's annual water balance. The table emphasises the enormous volumes of water which are involved annually in the hydrologic cycle, and, by implication, also underlines the great quantities of solar energy available to power that cycle. The table also draws attention to the areal variations in precipitation between the peripheral and the landlocked areas of the continents. Of the precipitation falling on the peripheral areas of the continents, approximately one third - 37,300 cu. km. - runs off as river discharge, and this represents the total of easily available water for human use.

Such gross calculations for the world as a whole, or for large segments of the earth's surface, must be supplemented by figures for much smaller areas. At this larger scale, the concept of a water balance, or water budget is again useful. If the monthly precipitation is plotted against the total loss of moisture which would occur from evaporation and transpiration if water supplies were at no season limiting, that is the potential evapotranspiration, then a clear picture of the seasonal availability of water supplies at any given place can be obtained. When precipitation exceeds potential evapotranspiration, then a water surplus will run off as surface or sub-surface discharge. When potential evapotranspiration exceeds precipitation, then water will be limiting for plant growth, once stored soil water reserves have been exhausted.

A series of such diagrams illustrates the variability from place to place over the earth's surface of total water supplies and of their seasonal regime.

(Table I - at end of paper)

Australia can be used to illustrate this variability and some of the direct consequences. Over its 3,000,000 square miles of land surface, Australia has an average rainfall of 16.5" and an average run-off of only 1.8", compared with world averages for land areas of 26" and 9.75". Table 2 (see end of paper) illustrates the fact that "northern" Australia is much more richly endowed than "southern" Australia with water and that 80% of the uncommitted streamflow is in the north, though only something of the order of 4% of the country's population is to be found there. The most striking feature of Australia's surface water discharge, however, is its extreme seasonal variability. The River Darling has a maximum recorded annual flow of 11,000,000 acre feet, and a minimum of only 1,000 acre feet. The Fitzroy has a maximum recorded annual flow of 28,000,000 acre feet and a minimum of 219,000 acre feet. This extreme variability raises great problems when Australian streams are used for irrigation, as waste disposal systems, or to feed water storage reservoirs. For example, Sydney stores 205,000 gallons per head of population, New York 55,000 and Birmingham 19,000, and in Australia, on the average, 6.9 acre feet are stored to irrigate 1 acre, compared with 3.1 acre feet in the U.S.A.

Bruce Davidson – Australia Wet or Dry.

(b) Population.

It is not appropriate in this paper to deal in great detail with population statistics, but a number of simple facts must be stressed. The first is that within the next 30 years the total world population will be some 7,000 million, or double its present number. No discussion of the problem of conservation of water resources - or any other type of resources - can validly take place except in terms of this one central consideration. No matter what the problems associated with our present level of resource utilisation may be, they are inevitably going to be rapidly exacerbated as world population doubles in these three decades. Again, however, crude figures do not reveal the full implications of the situation. Table 3 (see end of paper) illustrates areal variations in population increase and indicates that the areas of most rapid increase are Latin America, Africa and Asia. Tables 4-7 (see end of paper) draw attention to certain social and economic characteristics of the population of selected countries and areas. Tables 4, 5 and 6 show that those areas with rapidly increasing population have low percentages of dwellings serviced by water, low percentages of urban population, and low energy consumption per head. Yet Table 7 indicates that industrial expansion is taking place quite rapidly in these areas, and it is reasonable, therefore, to predict that there will be a swiftly accelerating demand for water as the rapidly increasing population seeks to improve its social and economic status vis a vis the developed nations of the world.

(c) Water Uses.

Modern urbanised society uses water for an increasing range of purposes at a constantly increasing rate. The per capita consumption of water in the U.S.A. is at present 1,350 gallons per day, much greater than the 101 gallons per capita used in Sydney in 1968. But it is reasonable to predict that, with increasing industrialisation, and with a rising standard of living bringing into use more automatic washing machines, dishwashers, and private filtered swimming pools, the Australian consumption will approach the present U.S. figure within the next two decades.

Some indication of the relative importance of different water uses can be obtained from Table 8 which refers to Adelaide in 1957-8. That 69% of the total water use went for domestic consumption may seem surprising, but it is even more striking to find from Table 9 that of the total water used for domestic purposes, no less than 70% was used on household gardens.

The principle ways in which water is used are -

i) in agriculture

ii) as an industrial coolant

iii) as a waste disposal medium

iv) as a source of power

v) for recreation.

i) In an increasing number of areas of the world irrigated agriculture is being developed. This is true even in areas such as Britain or the Netherlands where irrigation is used to increase production by combatting the mid-summer depression of growth rates of crops and pastures. In areas with warm dry summers such as California, massive irrigation provides the basis for a highly productive agriculture and horticulture industry. Where irrigation water is obtained from uncontrolled pumping from wells, the depth to the water table may be considerably increased, raising the costs of production and endangering the economic viability of the operation. In one county in California the water table is dropping 10-15 ft per year and in extreme cases irrigation wells have been sunk to a depth of 3000 ft. at a capital cost of U.S. $75,000. Legislation to control the rate of pumping may be necessary to preserve the water table and to avoid inflow of salt water as is the case in the horticultural district to the north of Adelaide.

In all irrigation schemes, salinisation of the soil is a major hazard. Even in modern irrigation schemes in Pakistan as much land is lost annually through salinisation as is reclaimed. The Imperial Valley area of California, with 500,000 acres under irrigation suffered progressive salt accumulation until after 1940 when adequate drainage systems were evolved to flush out the excess salt and to lower the water table.

The success which can be achieved by carefully controlled irrigation schemes is illustrated by modern Israel. To maximise agricultural production per unit of irrigation water soils are classified on the basis of their response to irrigation and irrigation supplies are carefully controlled to individual land holdings to avoid excessive irrigating. All the water resources of the country are integrated and the agricultural development of the loess soils of the Northern Negev has been made possible only by the major pipeline which taps Lake Tiberias in the north of the country. Israeli scientists have pioneered a drip irrigation technique which minimises evaporating losses and allows more saline water to be used without the danger of leaf damage to crops.

ii) As an industrial coolant, water is again playing an important part in the location of settlement and industry. Most manufacturing processes require very large quantities of water to produce a unit quantity of product and there is a strong tendency for heavy industries such as the iron and steel and chemical industries to locate along a major river or at the coast. Large thermal power stations show the same locational orientation: the River Trent in England, for example, has a series of major modern thermal power stations along its banks. The use of water in this way may result in "temperature pollution" of the water: stream temperatures in the vicinity of Cleveland, Ohio, are of the order of 85°F. Under these conditions, oxygenation of the water is much reduced and biological activity is inhibited.

iii) The use of water as a waste disposal medium represents one of the major demands on water resources since the dilution of industrial and domestic effluents requires very large quantities of water per unit mass of solid material if the natural biological processes of purification are to be able to operate. Strict control over the quantity and quality of discharged effluent is essential to ensure that materials which are not bio-degradable are kept out of our water systems. The ecological balance of water systems is easily disturbed and may be difficult to restore. Lake Erie is already biologically almost 'dead' and Lake Michigan is also seriously polluted. Striking disturbance of the ecological balance of lakes may be caused by the washing in of fertiliser from surrounding farm land. The consequent entrophication can encourage algal blooms and deoxygenation of the water, and can result in severe impoverishment of the lake ecosystem.

iv) The non-consumptive use of water in hydro-electric power schemes does not normally bring any pollution in its wake. Indeed in most cases such schemes, by providing large water storages may provide recreational opportunities and raise the scenic value of the area.

v) With increasing population, and greatly increased affluence and mobility of the population, water bodies are acquiring increased value as recreation areas. It is becoming increasingly necessary to take action to prevent the discharge of untreated industrial or domestic effluent into rivers or along shores which are used as recreational areas by urban populations. Oil discharged either purposely or accidentally from tankers represents a major hazard to our coastal water resources. A recent survey over a week-end in Britain reported 468 miles of oil polluted coastline and estimated that 3,000 birds of various species had died as a result of pollution by oil. The importance of water bodies can be illustrated by the fact that the last of the major polders in the Ijssel Meer project in the Netherlands is unlikely ever to be drained, since it is considered more valuable to the nation as a water body for recreation than as an area of first-class farmland.

In the development of water resources in recent decades one striking innovation has evolved - the multi-purpose scheme. The best known of these is the Tennessee Valley Authority scheme, but it has provided the model for other similar schemes such as the Damodas Valley project and the Mekong River project. Such schemes look on the entire river basin as a single unit and seek to develop the water resources simultaneously for irrigation, for industry, for power production, for transportation, and for recreation. As with the irrigation schemes of the early hydraulic civilisations, they demand centralised control and the T.V.A. was a major break through in co-operation between local, State and Federal authorities.

Faced with the certainty of a population of 7,000 million by the end of the century, the problem of optimal use of our water resources is not a local, not even a regional, but a global problem. Table 9 gives one estimate of world water need by the year 2,000. The immensity of the problems of distribution involved in meeting this demand is emphasised when it is recalled that the total available river discharge is only of the order of twice the value of the water need of 18,700 cu.km.

We must learn to think of our water resources in terms of a global ecosystem. There will be enormous tasks for the hydrologic engineer in the decades ahead, but the fundamental issues will be the setting of social and economic goals and objectives in the context of possibly very restricted resources. These issues are essentially political, and will demand a high level of skill and sophistication in social engineering for their solution.

(For Tables - see over).

TABLE I. WORLD'S ANNUAL WATER BALANCE

	Gain Volume (cu. km.)	Loss Volume (cu. km.)
Peripheral areas of continents. (117, 000, 000 sq. km.)		
Precipitation	101, 000	
River discharge		37, 300
Evaporation		63, 700
Landlocked areas of continents. (31, 000, 000 sq. km.)		
Precipitation	7, 400	
Evaporation		7, 400
The oceans (361, 000, 000 sq. km.)		
Precipitation	411, 600	
Discharge from rivers	37, 300	
Evaporation		448, 900

Source Kalinin and Bykov.

TABLE 2. AUSTRALIA'S WATER RESOURCES

	Area (sq. miles)	Annual Flow (Acre Feet).		
		Total	Already Used	Remaining available
"Northern" Basins	795, 900	178, 197, 000	3, 150, 000	175, 047, 000
"Southern" Basins	616, 800	60, 312, 000	16, 008, 000	44, 304, 000

Source Munro, 1969.

TABLE 3.

	Estimates of mid-year popln.			Annual pop. increase %
	1950	1960	1968	1960-68
World.	2517	3005	3483	1.9
Africa	222	278	336	2.4
Nth. America	166	199	222	1.4
Latin "	163	213	267	2.9
Asia	1381	1660	1946	2.0
Europe	392	425	455	0.9
Oceania	12.7	15.8	18.5	2.1
USSR	180	214	238	1.3

Source Demographic Yearbook 1968.

TABLE 4

PERCENT OF OCCUPIED DWELLINGS WITHOUT PIPED WATER EITHER INSIDE OR OUTSIDE THE DWELLING.

Cuba	41.6
Canada	6.7
Mexico	67.7
Brazil	78.9
Chile	44.0
Japan	32.1
Italy	33.4
Netherlands	10.4

Source: U.N. Compendium of Social Statistics, 1967

TABLE 5

PERCENTAGE OF POPULATION CLASSED AS URBAN FOR SELECTED COUNTRIES.

Ghana	23.1	1960
Nigeria	16.0	1963
Canada	69.6	1961
U.S.A.	69.9	1960
Brazil	45.1	1960
Chile	68.2	1960
India	18.0	1961
Indonesia	14.9	1961
Italy	47.7	1961
Netherlands	80.0	1960
Australia	82.1	1961

Source: U. N. Compendium of Social Statistics, 1967

TABLE 6.

ENERGY CONSUMPTION PER CAPITA - KILOGRAMMES

	1964	1967
World	1, 547	1, 648
Africa	271	285
N. America	8, 743	9, 660
C. America	922	998
S. America	566	618
Middle East	556	539
Asia (Excl. M. East)	306	383
Europe (Excl. E. Europe)	2, 986	3, 147
Oceania	3, 416	3, 627
Centrally planned economies	1, 403	1, 448

Source - Statistical Yearbook 1968.

TABLE 7.

1967 INDEX NUMBERS OF INDUSTRIAL PRODUCTION. 1963=100.

	Total Manufacturing	Light Manufacturing	Heavy Manufacturing.
N. America	128	120	132
L. America	126	121	131
Asia	150	131	166
Europe, excluding E. Europe	118	113	122

Source: Statistical Yearbook 1968

TABLE 8

URBAN WATER USE - ADELAIDE 1957-8

Type of Use	Percentage
Industrial and Commercial	20
Hospitals and Institutions	4
Primary Production	4
Parks etc.	3
Domestic	69

TABLE 9

DOMESTIC WATER USE - ADELAIDE 1957-8

Type of Use	Percentage
Sanitary and ablutionary	22
Culinary, laundry and miscellaneous	8
Household gardens	70

Source: Munro 1969.

TABLE 10

ESTIMATED TOTAL ANNUAL WORLD WATER REQUIREMENT BY YEAR 2000

Usage	Water required (cu. km.)
Irrigation	7,000
Domestic	600
Industrial	1,700
Dilution of effluents and waste	9,000
Other	400
Total:	18,700

Source: Kalinin and Bykov.

Only 30,odd ooo available from