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Preliminary Report on the Development of Water Resources in the ECWA Region

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TABLE OF CONTENTS

Page

Introduction

DEVELOPMENT OF WATER RESOURCES

CHAPTER I. Water demand models 1

Project objectives 2

Methods of data collection and analysis 2

CHAPTER II. Ways and means of using water more efficiently in the agricultural sector 11

1. Introduction 11
2. Surface water management 11
3. Management of groundwater resources 13
4. Irrigation methods and means 14
5. Rainfall 18
6. Mixing of saline water and sewage effluent 18
7. Desalination procedure 18
8. Economic evaluation 19
9. Future outlook 19

CHAPTER III. Multiple use of water - Has it arrived? 21

Water reuse for special purposes 23

Water reuse in agriculture 28

Water reuse for industrial supply 29

REFERENCES 30

CHAPTER IV. Potential and limitations of technology with regard to increase in water use 31

1. Introduction 31
2. Technologies for exploration of water resources 32
3. Technologies for increasing water supply 34
4. Technologies for water conservation 41

TABLE OF CONTENTS (CONT'D)

		Page
CHAPTER V.	Regional and subregional co-operation	45
	Exchange of technical information	45
	Education and training	46
	Financial aspects	47
	Research	48
	Experts and consultancy services	48
	Environmental aspects	48
CHAPTER VI.	Conclusions and recommendations	51

LIST OF TABLES

Page

CHAPTER I.

AGRICULTURAL WATER DEMAND PROJECTS

- Bahrain 5
- Iraq 5
- Jordan 6
- Kuwait 6
- Lebanon 7
- Oman 7
- People's Democratic Republic of Yemen 8
- Qatar 8
- Saudi Arabia 9
- Syria 9
- United Arab Emirates 10
- Yemen Arab Republic 10

CHAPTER III.

Table 1. Suggested Treatment Processes to meet the given health criteria for wastewater reuse 24

Table 2. Cost Estimates of Wastewater Treatment 25

Table 3. Costs of Artificial Recharge .... 26 - 27

Introduction

DEVELOPMENT OF WATER RESOURCES

The development and management of water resources all over the ECWA region has been marked in recent decades by an increase and at the same time a growing diversification of demands for various uses. Both aspects have created considerable problems. Competition for the use of scarce resources has become more intense while the interdependencies between the various uses and between them and other sectors of the social and economic systems have called for more comprehensive planning, development and allocation of resources.

The climatic conditions characterized by low rainfall, high evaporation rates partly explains the scarcity and limited availability of water which has become a major development constraint in the fast growing ECWA region.

Until recently, countries of the ECWA region did not fully appreciate the importance of water for development purposes. Their efforts to develop systems of water were considerable but piecemeal and the lack of a comprehensive approach to planning and development of water resources has made the water situation in the region more acute and the eventuality of a "water gap in the near future a forthcoming reality".

It is becoming more and more evident that the surface and groundwater potentialities of a country constitute national assets vital to almost every phase of the economy. Neglect or misuse of these assets can prejudice the health and prosperity of the inhabitants and can prevent or retard the economic and social development of a nation.

At the same time, an increasing technical knowledge is becoming available which, properly applied, will enable more accurate assessment to be made of water potentialities, more efficient development methods to be introduced, and a wider variety of benefit to be obtained.

This preliminary report covers the following five chapters in accordance with the programme of work in the field of water resources:

1. Water demand models.
2. Ways and means of using water more efficiently in the agricultural sector;
3. Multiple use of water - has it arrived?
4. Potential and limitations of technology with regard to increase in water use;
5. Regional and subregional co-operation.

CHAPTER I. Water demand models

Development of natural resources in ECWA countries plays a large part in general socio-economic development, and in turn, depends to a large extent upon the quality and quantity of information upon which plans and programmes can be based. Collecting natural resource information and developing short and long range demand and supply models is a matter of first importance, especially in these countries.

National governments cannot proceed in planning their socio-economic development by guesswork. Thus, before more natural resources can be brought into use or their present productivity raised, additional data on their physical characteristic and related economic and social information must be assembled. Sometimes, the pressure for action results in premature commitments to resource development projects without enough information at hand to evaluate them adequately. Those who are concerned with national socio-economic development must be reasonably certain that additional gain will accrue to socio-economic development if a certain proportion of their budget is used to produce more information and data concerning long range demand and supply of natural resources.

Water is, in these countries in particular, a most important resource, with development of natural and human resources dependent on the availability of water supply. With the abundance of petro-chemicals and other natural resources, effective water demand models are needed if these resources are to be developed adequately. That is, water is a necessary but not an independent condition for economic development. With ratios of water production low because of dominant arid conditions, demand orientation stages of development will not be far off in the future, necessitating careful planning now. When population was less and supply was in abundance and accessible to the consumers, projections were of less importance to national planning. Nevertheless, population and industrialization in some of the oil producing countries, especially in the last ten years, has greatly increased, calling for better national planning which includes water projections - projections looking to total societal effect on demand.

Project Objectives:

The primary objective of this project is to develop a systematic methodology for forecasting water demand in the twelve ECWA countries. To achieve this objective, it is necessary first of all to identify the level and development of the socio-economic and technological factors associated with water usage in these countries.

More specifically, the purpose of this projection is:

1. To develop a model for forecasting water demand in twelve Arab countries: Bahrain, Iraq, Jordan, Kuwait, Lebanon, Oman, People's Democratic Republic of Yemen, Qatar, Saudi Arabia, Syria, United Arab Emirates and Yemen Arab Republic.

2. To provide national planners in these countries with particular reliable future water projections.

3. To establish per capita water demand for municipal, industrial, and agricultural users using socio-economic, technological and environmental factors of the twelve countries.

4. To provide a means for projecting these socio-economic, technological and environmental factors to the year two thousand.

5. To use the model and the projected socio-economic and technological factors to project municipal, industrial, and agricultural water demands for each country to the year two thousand.

Methods of data collection and analysis:

In order to obtain reliable data for this study, two sources of data were used. First, a questionnaire was used in the field for collecting water demand data, socio-economic factors and other information which influence water use. An attempt was made to complete the questionnaire in all ECWA countries.

The response to these field questionnaires was not sufficient alone to develop the model. Published sources were used as much as necessary to develop a sufficient data base to permit development of the model. The model so developed was for the entire region and was not country specific.

There are many social, economic, environmental and other conditions which vary among users and which do affect water demand. At the beginning of forecasting, the exact number of the factors which influence water usage usually is not known, and thus, some hypotheses must be made regarding these factors. The questionnaire was developed for two kinds of data needs:

1. General data needed to develop model at country level

2. General data at regional level

Since the data was so limited, only the regional model was developed as in the equation (1-1) below.

$$UU_{i,t} = A_o + A_1X_1 + A_2X_2 + \dots + A_nX_n \qquad (1\text{-}1)$$

where

$UU_{i,t}$ = Unit demand of category i^{th} at time t

A_n = regression coefficients n = 1, 2, 3 ...

X_n = independent variables n = 1, 2, 3 ...

However, it has been abundantly clear from the start of this exercise that although a predictive equation has been developed, the projected values could not be truly representative because of:

(1) available data was limited and unreliable

(2) regional model cannot be satisfactorily applied to predict national resources due to the wide array in socio-economic, industrial, and agricultural variation from one country to another.

The preliminary output from this model confirmed these observations. Therefore, this output has been disregarded and a new, modified, attempt has been made.

In the new approach, instead of taking the whole region as one unit, it was divided into three subregional groups based on the similarity in topography and availability of water resources as follows:

(1) Iraq, Jordan, Lebanon, and Syria

(2) Bahrain, Kuwait, Qatar, Saudi Arabia and United Arab Emirates

(3) Democratic Republic of Yemen, Oman, and Yemen Arab Republic.

Fortunately, too, by this time we were able to collect few more data particularly as it pertains to the agricultural sector. Therefore, the projections reported in this chapter were limited to agricultural demands only.

Below are the projection equations (1-2), (1-3) and (1-4) with respect to subregions 1, 2, and 3 respectively.

$$A_{n,t} = 42.7360 + 0.0185NP_{n,t} + 0.0165GNP_{n,t} + 0.0516HLI_{n,t} \quad \text{(1-2)}$$

$$A_{n,t} = 116.0224 + 0.0046NP_{n,t} + 0.0069GNP_{n,t} + 0.0823HLI_{n,t} \quad \text{(1-3)}$$

$$A_{n,t} = 23.9730 + 0.0093NP_{n,t} + 0.0840GNP_{n,t} + 0.0556HLI_{n,t} \quad \text{(1-4)}$$

where

$A_{n,t}$ = Agricultural water demand for country n at year t in gallons per capita per day.

$NP_{n,t}$ = National population in thousands of country n at year t

$HLI_{n,t}$ = National irrigated land of country n at year t in thousands hectares.

Although the new projections are an improvement over the previous values, they, nonetheless, are not final. We are still collecting more data to update and expand the existing data base. When enough data have been accumulated, models will be refined accordingly and a new output of water demands for agricultural, domestic, and industrial use will be presented.

Projections of water demands for the countries of the region in millions of cubic metres per year and in acre-feet are presented in the following tables;

AGRICULTURAL WATER DEMAND PROJECTIONS

Bahrain

Year	Total National Annual Agricultural Demand In Millions Cubic Metres	Total National Annual Agricultural Demand In Acre - Feet
1970	26.	79.
1975	31.	95.
1980	37.	114.
1985	45.	137.
1990	54.	167.
1995	66.	203.
2000	81.	250.

Iraq

Year	Total National Annual Agricultural Demand In Millions Cubic Metres	Total National Annual Agricultural Demand In Acre - Feet
1970	1505.	4619.
1975	2031.	6231.
1980	2750.	8439.
1985	3739.	11474.
1990	5103.	15657.
1995	6985.	21433.
2000	9590.	29427.

AGRICULTURAL WATER DEMAND PROJECTIONS

Jordan

Year	Total National Annual Agricultural Demand In Millions Cubic Metres	Total National Annual Agricultural Demand In Acre - Feet
1970	215.	660.
1975	281.	865.
1980	370.	1136.
1985	491.	1506.
1990	655.	2009.
1995	679.	2698.
2000	1187.	3643.

Kuwait

Year	Total National Annual Agricultural Demand In Millions Cubic Metres	Total National Annual Agricultural Demand In Acre - Feet
1970	111.	339.
1975	124.	380.
1980	139.	425.
1985	155.	477.
1990	174.	535.
1995	196.	601.
2000	220.	676.

AGRICULTURAL WATER DEMAND PROJECTIONS

Lebanon

Year	Total National Annual Agricultural Demand In Millions Cubic Metres	Total National Annual Agricultural Demand In Acre - Feet
1970	292.	896.
1975	356.	1094.
1980	437.	1341.
1985	538.	1649.
1990	664.	2037.
1995	822.	2524.
2000	1023.	3138.

Oman

Year	Total National Annual Agricultural Demand In Millions Cubic Metres	Total National Annual Agricultural Demand In Acre - Feet
1970	37.	112.
1975	47.	146.
1980	62.	190.
1985	81.	249.
1990	107.	328.
1995	141.	433.
2000	187.	575.

AGRICULTURAL WATER DEMAND PROJECTIONS

People's Democratic Republic of Yemen

Year	Total National Annual Agricultural Demand In Millions Cubic Metres	Total National Annual Agricultural Demand In Acre - Feet
1970	124.	380.
1975	150.	462.
1980	183.	562.
1985	223.	685.
1990	273.	838.
1995	334.	1025.
2000	410.	1257.

Qatar

Year	Total National Annual Agricultural Demand In Millions Cubic Metres	Total National Annual Agricultural Demand In Acre - Feet
1970	15.	45.
1975	18.	56.
1980	23.	70.
1985	28.	87.
1990	35.	108.
1995	44.	136.
2000	56.	173.

AGRICULTURAL WATER DEMAND PROJECTIONS

Saudi Arabia

Year	Total National Annual Agricultural Demand In Millions Cubic Metres	Total National Annual Agricultural Demand In Acre - Feet
1970	1233.	3784.
1975	1410.	4326.
1980	1626.	4989.
1985	1894.	5813.
1990	2233.	6852.
1995	2668.	8187.
2000	3235.	9926.

Syria

Year	Total National Annual Agricultural Demand In Millions Cubic Metres	Total National Annual Agricultural Demand In Acre - Feet
1970	997.	3059.
1975	1191.	3654.
1980	1426.	4376.
1985	1712.	5252.
1990	2059.	6319.
1995	2483.	7618.
2000	3000.	9204.

AGRICULTURAL WATER DEMAND PROJECTIONS

United Arab Emirates

Year	Total National Annual Agricultural Demand In Millions Cubic Metres	Total National Annual Agricultural Demand In Acre - Feet
1970	29.	90.
1975	34.	105.
1980	40.	123.
1985	47.	144.
1990	55.	170.
1995	66.	202.
2000	79.	242.

Yemen Arab Republic

Year	Total National Annual Agricultural Demand In Millions Cubic Metres	Total National Annual Agricultural Demand In Acre - Feet
1970	767.	2354.
1975	902.	2787.
1980	1062.	3258.
1985	1251.	3839.
1990	1476.	4530.
1995	1744.	5351.
2000	2062.	6327.

CHAPTER II. Ways and means of using water more efficiently in the Agricultural Sector

1. Introcution

The scarcity or limited availability of water is a major development constraint which faces, in various degrees, all the countries of Western Asia.

With the continued growth of population, expansion of industry, increase in urbanization, problems of water shortage, food production and pollution are bound to emerge and unless additional sources of supply are explored for and efficiently managed, the region might face a serious water gap in the not too distant future.

In as much as agriculture is still the main consumer of water in the ECWA region, its problems are thus more important and more urgent. Agriculture is mainly based on dry land forming,nevertheless irrigation is practiced in many parts of the region. In some countries, surface water is the main source for irrigation, whereas in others such as Saudi Arabia, the Gulf States, YAR and PDRY, groundwater and/or desalinated water constitutes the main source. Thus ways and means are to be studied and evaluated for more efficient water use and management starting from the water source of supply down to the plant root zone in the soil.

2. Surface Water Management

A. Water Control at Source

Water management and control should start with the source of supply at the watershed area where preservation of water in this area means provision of proper storage and directing the stream and valley run-off towards the better controlled waterways. Moreover, groundwater reservoirs are to be classified and more attention is to be given to those reservoirs where salinity problems are less severe and where groundwater recovery is useful and practical.

B. Desert Water Sheds

In most of the world's arid and semi-arid regions deserts and deserted land constitute a big portion of the region. In many such areas a reasonable amount of rain usually falls during storms of short duration. A part of it finds its way to the underground reservoir while the rest will either be lost by evaporation or flows in as flash flood of short duration. Study and conservation of such amounts is very important to restore cultivation and livestock and help nomads settle in and around these areas. Utilization of these quantities is usually done by the construction of small reservoirs, water proofing some of the land surface in order to collect all surplus water and to make use of any available groundwater.

C. Flood Routing and Control

Flood routing and proper control of river banks forms the major process of water control especially to prevent flood water from spelling over its banks thus innundating the nearby areas, wasting valuable water and destroying the cultivated areas causing more shortage in water and in agricultural products.

Construction of small and/or big dams for water storage is an indispensable approach to better water management. Huge amounts of flood water usually flows to the sea unless proper measures are taken to store it somewhere.

D. Reduction of Evaporation Losses

Evaporation losses from open water resources, lakes, marshes and other water surface is a serious problem which needs special attention. Where alternatives exist, dam sites which will have deeper reservoirs and less evaporation potentialities should be chosen.

The application of a microscopically fine film of cetyl alcohol to the surface of large reservoirs is being used in some warm countries to reduce surface evaporation. Further research is needed for the development of chemical compounds to provide a mono-molecular film over the water surface which controls evaporation while permitting the passage of oxygen and sunlight - both essential to the natural self-purification process - and also of rain. Perhaps this or a similar process can be applied to slow-moving water in channels.

Existing evaporation losses nowadays may equal the discharge of a big river in countries with big reservoir surface areas and scattered marshes and water logged lands. The reduction of these losses will actually mean the recovery of huge amounts of wasted water. It goes without saying that reduction of marsh areas by drainage is a direct and straight forward procedure which may be adopted.

3. Management of Groundwater Resources

Groundwater resources may by far exceed the surface supplies. These are not subject to war or negligence destruction and they suffer no evaporation problems. Where salinity is not an issue in these reservoirs, they have to be well surveyed and maintained from pollution and replenished by the available water of inferior quality.

Continuous observations and records have to be maintained and efficient recovery of water for agricultural use may then be made in the proper quantity and at the time it is most needed.

Reducing Seepage Water

Seepage water from reservoirs, rivers, canals, distributors and field ditches are usually large amounts and represent the major factor of wastage through deep percolation to the groundwater.

While it is difficult to stop or to reduce those losses in rivers or big reservoirs, it is possible to do so in artificial canals and in irrigation systems through the use of proper conveyance canals or pipes with the help of one or more of the available lining methods and materials.

The required effects and costs involved will usually dictate the type of lining to be used. Concrete lining is very popular as it is very reliable if joints are sealed properly. Where concrete canal laying plant is not available, alternative materials may prove economical for lining water channels. These include asphalt, brick or tile, stabilized soil, cement mortar or mesh reinforcement and asbestos cement. The development of plastics has also made it possible to line the canals with impervious membranes.

The cost of lining is balanced against the reduced volume of earth moving since higher velocities can be used in lined canals and accordingly a smaller cross section can be used to carry a given flow than an equivalent earth channel. Furthermore, weed transpiration are eliminated and maintenance costs greatly reduced, as well as the reduced requirements for drainage as seepage will be made negligible.

Deep percolation of water from the plant root zone down to groundwater, or through the form ditches is usually of a very high percentage and is reflected by the low irrigation application efficiency attainable through the various irrigation methods, the highest figure of which may not be more than 75 to 80% while the lowest may go down to 30% with an average figure of 50-60% for free flow irrigation methods.

Reducing Field Evaporation Losses

Field evaporation is indispensable, since it is through evapotranspiration that the plant nutrient takes place from the soil to the different parts of the plant. This considered an essential use of water. But the losses that take place from the soil surface through uncultivated areas of land, water-logged areas, excess of irrigation water; if not wholly avoidable can be substantially reduced by new mulching methods (covering the soil traditionally with a layer of compost or sawdust).

4. Irrigation methods and means

More efficient use of water is reflected by more area of cultivation by the same amount of water. This may be done by elimination or reducing the factors of losses discussed above both within and outside the farm.

Recommendations of a general nature regarding watershed, river valleys, desert lands, open and groundwater reservoirs were briefly mentioned above. However, within an irrigation or agricultural project, the recommendations may be more detailed by following the methods and means discussed below:

A. Conveyance System

Main and smaller canal system needs some form of lining to reduce the conveyance losses which may amount to 40% of supplied water. This is an expensive procedure but as mentioned earlier may be balanced by the advantages gained and is indispensible where any water economy is to be affected. In severe shortage cases, conveyance by closed conduits should be used to completely eliminate percolation and evaporation losses. Evaporation losses from distribution systems are usually of small percentage but it will be needed where utmost economy is to be exercised. Those procedures should continue from the main canal down to the farm inlet.

B. Drainage System

Paradoxically, sound irrigation embodies sound drainage. Water is Usually applied to the land in excess of plant consumption. This is partly due to an intentional excess calculated to leach harmful salts present in water, below the root zone. Drainage is therefore needed to remove the unwanted water in order that soil structure and aeration are maintained.

Deep drainage should be applied with all details down to the field drains to lower the groundwater and eliminate capillary water rise and subsequent evaporation losses with the resulting increase in leaching water requirement which may be saved by lowering the groundwater to a sufficient limit depending on the soil texture. The heavier the soil, the deeper should be the groundwater.

C. Irrigation Procedure

Water should be applied as near to the root zone as possible. Application rate should always be less than the soil intake rate to ensure unsaturated soil surface and thus reduce evaporation losses during irrigation period and keeps the root zone from saturation with consequent harmful physiological effects on the plant itself. Even water application on soil surfaces is very important to ensure even water distribution throughout the irrigated area and thus increase application efficiency. This may be done if efficient sprinkling irrigation is used or in case of free flow, proper land levelling with proper shapes. Land levelling is usually the most neglected factor and probably the most important one.

D. Irrigation Timing and Quantities

Irrigation water is needed when a certain percentage of available soil water is used up say 50 to 75% and at that time irrigation should be applied only in an amount equal to the depleted available water, i.e. water is added until the whole profile of the plant root reaches field capacity as an average with some additional percentage for leaching requirement which depends on the plant tolerance to salt concentration and the amount of salts within the irrigation water.

The period between irrigations naturally depends on the amount of water needed and the evapotranspiration rate which in turn is a function of the plant and climate.

Thus, the problem is a complicated one and standard practice should be established for each climate and each plant with a proper schedule as to the timing of irrigation and amount of water needed throughout the irrigation season of each plant.

E. Irrigation Methods

There are many facets of irrigation efficiency, depending on as many factors. Not the least of these is the method used for distributing water over the area under cultivation. There are three basic methods: surface irrigation, by flooding or by furrow distribution; sub-surface irrigation, either by exploiting natural subsoil flow or by the use of porous or open jointed pipes under the land; and overhead irrigation, by sprinkler, trickle, etc.

(1) Surface Irrigation (Free Flow Irrigation)

Surface irrigation by flooding is the oldest known method and is still the dominant one in plain areas. It may be of the boarder, strip-boarder furrows or basin type. Almost all these types or methods depend on good land levelling and preparation. The application efficiency is generally low. Where the land is flat and flooding consequently covers wide areas, there is excessive loss both by evaporation and deep percolation, where it is not flat, there is excessive runoff. Raising the efficiency can only be done by observation and reducing these factors of losses.

(2) Sub-surface Irrigation

(2.1) Natural Sub-irrigation*

Natural sub-irrigation is so called because of the conditions which make it possible are geological and topographical. These are near-level terrain and a deep topsoil of very high lateral permeability underlaid at 2m to 7m depth by an impermeable stratum.

Since all water movement in the process of supply to the plant is upwards from the water table, there is also an upward movement of unwanted salts within the soil. In arid climates where there is no significant rainfall to counteract this effect, there is a risk of a build-up of harmful salts close to or on the soil surface.

(2.2) Artificial Sub-irrigation

Artificial sub-irrigation involves the use of a network of buried perforated pipes under the land surface. Systems of this type are usually costly and can rarely be justified economically except where high-priced

* Bruce Withers & Stanley Vipond; Irrigation design and practice, p.47.

crops are grown and soil conditions are ideal, inhibiting downward percolation much beyond root zone, yet permitting free lateral water movement and encouraging upward movement by capillary action.

(3) Overhead Irrigation

(3.1) Sprinkler Irrigation

Under certain conditions sprinkler irrigation is more efficient than surface or sub-surface methods of water distribution. Among the factors favouring it are excessive soil porosity (which makes distribution of water evenly by other methods difficult), the existence of gradients unsuitable for surface flow systems and the need for high application efficiency due to a general shortage of available water. Top efficiency in the system may be around 75%. Limitations of the method are the high wind losses and the presence of salts in the irrigation water. This latter factor may be the decisive factor specially that some plantations are very sensitive to salts deposited on their leaves.

In temperate and humid climates, evaporative loss from a spray could be much the same as the loss from open water surface irrigation, but in hot dry climates evaporative loss can be excessive during the summer months and night irrigation alone is advisable.

(3.2) Trickle Irrigation

Although trickle or drip irrigation has long been established as a method for glasshouse crops, it is only in recent years that it has been developed for use in the field.

The main advantage of trickle over other types of irrigation is the excellent control of water application which it provides. Water is applied daily at a rate as close as possible to the rate of consumption by the plant. Evaporation from the soil surface is minimal and deep percolation can be almost entirely avoided.

The prohibitive factor against it is its high cost and some flow problems which are not easily overcome and its limits as it can be used for orchards and plantation with individual plants. It is not suitable for grains and similar crops.

5. Rainfall

Although rainfall is a natural process, great progress is being done to provide adequate cultivation by dry farming in areas of low precipitation. Scientific investigations are needed to ensure an acceptable level of yield for years of low precipitation and provision of emergency irrigation from groundwater or nearby streams should be investigated to encourage this process and increase its yield.

Furthermore, most of the rainfed soils are non-saline and consequently a considerable amount of water that has seeped to the groundwater may be recovered for emergency irrigation or any other use.

6. Mixing of Saline Water and Sewage Effluent

Procedures have been developed in some countries to irrigate with high salinity water either directly or after dilution with better quality water. This procedure may give promising results if properly applied and it will definitely mean an additional cultivation with otherwise useless water. However, great care should be exercised to keep the soil structure from deterioration.

Drainage water may be reused by this process as well as brackish groundwater with reasonable amount of salinity. However, further research is needed to either modify the requirements of the crops themselves so that the ratio of yield to transpiration may be raised, or species tolerant to salty water developed.

7. Desalination Procedure

No matter what process is used to remove or reduce the salinity from brackish water, the cost per unit volume is so far so high as not to justify its use on any reasonably economical scale. However, national reasons and pride may dictate its use in some rather exeptional cases.

In arid and semi-arid regions, the use of solar energy may be promising for this purpose. If it is sufficiently developed to an acceptable scale, it may give a partial solution to such countries.

8. Economic Evaluation

Water resources in any country is one of the important factors in the national economy of the country and should be always treated as such. The cost of water as a material should always be evaluated and added to the cost of its delivery to the farm to make up a part of the agricultural production.

Comparative economical study of any agricultural product should always include the amount of product per unit of supplied water as a main factor. This will ultimately lead to more realistic conclusions as far as the real value of water in the national economy as well as in the world water conservation policy.

9. Future Outlook

In view of the fact that water losses are so many in all stages of storage and conveyance as well as the present low efficiency of most irrigation systems and methods, expectations of possible improvement in these respects may mean more than doubling the effective water use with consequent improvement and expansion of domestic and agricultural uses.

CHAPTER III. Multiple Use of Water - Has it Arrived?

"A unique festival is held each June in Santee, California. It features a long, colourful saturday morning parade that starts from the shopping centre and ends up at the town's recreational lakes. For the remainder of the weekend, as many as ten thousand people celebrate the construction of eight beautiful man-made lakes laid out in a line for the better part of a mile. At this [Festival of the Lakes] people fish, picnic, boat, and swim, with little concern that nearly every drop of the water is supplied Santee's municipal sewage system".[11]

Recycling of wastewater is unavoidable and logical. Population explosion and the rapid growth in the industrial and agricultural sectors are exerting heavy demand on the available water supplies. Recycling can both increase the water supply and alleviate the pollution problem.

The concept of water reuse is not new. It has had its precedents in USA, South Africa, and Europe. As a matter of fact, we all are drinking water that has been circulated thousands of times through the hydrological cycle: atmosphere, rain, streams, ocean, vapor to the atmosphere.

The main obstacles to a wider acceptance of reprocessed water are economical and psychological. The psychological "hang-up" could be overcome by pointing out some case histories. Therefore, whether a community will accept reclaimed water or not becomes a matter of economics. It depends on the availability and cost of fresh water, the cost of desalination, and the practicality of non-conventional sources such as weather modification to increase precipitation.

Only domestic and industrial wastewater could be treated. Type and extent of treatment depends on the ultimate use.

In general, there are three basic types of treatment: primary, secondary, and tertiary (advanced).

Primary treatment consists of removing of suspended solids from effluents by plain sedimentation (gravity settling). About 40% of the suspended solids is precipitated from the mother liquor. Usually settling is aided by the addition of certain types of chemicals (organic or inorganic) known as coagulants. The function of these chemicals is to build up large size flocs from colloidal particles and, thereby, facilitate their settling. By using this technique, removed suspended solids could reach 70%.

The aim of secondary treatment is to remove dissolved organic matter using a wide array of micro-organisms the most important of which is bacteria. This could be done in many ways. But the most common one is the activated sludge process which has been in use for over seventy years.

The activated sludge process consists of bringing together primary effluent and bacteria in an agitated tank in the presence of oxygen. Within 4 to 6 hours detention time, soluble organic matter is consumed by bacteria. Part of the consumed organic matter is utilized in the production of new cells. The remainder is oxidized to CO_2 and H_2O. The treated effluent overflows to a settling tank where solids agglomerate and settle. The settled flow is rich in active bacterial cells. Most of it is returned to the aeration tank to keep the process operating, the rest is pumped to waste or further treatment. Fig. 1. is a schematic diagram of an activated sludge plant.

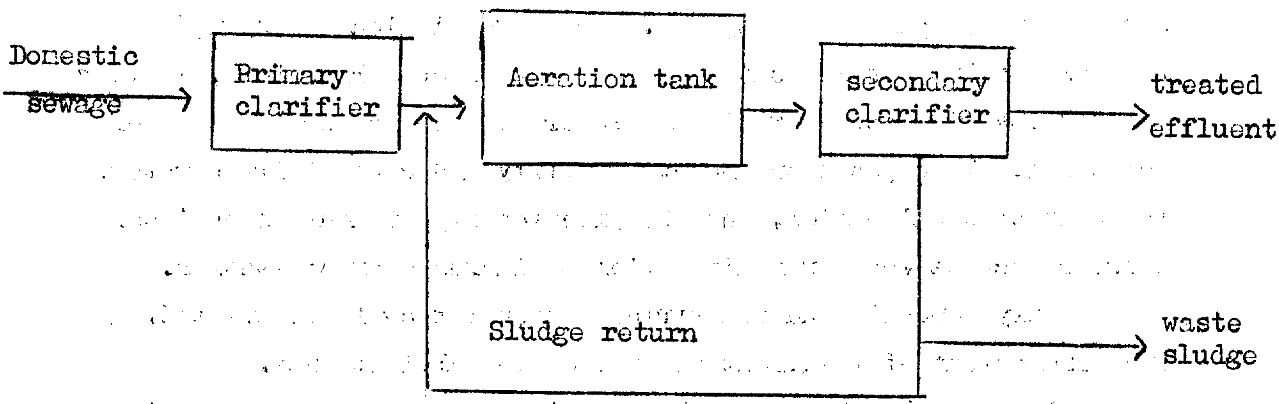

Fig.1. The Activated Sludge Process.

Advanced or tertiary treatment is a polishing process to secondary effluent. The goal is to raise the level of purification a few extra percentage points. However, removal of these few points can be very expensive because there is no one single process that can achieve this. Rather, it involves a series of successive processes each for one or more type of contaminants.

Contaminants in secondary effluent of treated sewage consist of: suspended solids, plant nutrients (mostly phosphates), non-biodegradable organic substances (refractory), inorganic salts, and micro-organism cells (mostly bacteria). All in all, their concentration in the effluent is less than 0.1% (1000 mg/1). Yet, their removal is not easy as has been mentioned.

Table 1. shows the required level of treatment to meet certain applications.

Table 2. shows the cost of treating wastewater for various purposes (1968 costs - USA).

Water reuse for special purposes

Except for domestic purposes, wastewater reuse does not often require excessive treatment. Among the special purposes for which wastewater may be used are groundwater recharge, recreational purposes, and the control of sea water intrusion.

Both treated and untreated wastewater has been used to replenish groundwater supplies. However, when not adequately treated, wastewater may pose a threat to the quality of aquifers. Buildup of dissolved mineral ions particularly the nitrate ions has been observed in certain locations. Nitrates in water in excess of 45 mg/1 may cause fatalities among children. Because of this, large scale groundwater recharge should not be carried out, even where geological formations are favourable, unless dissolved ions had been removed. This is specially so if groundwater is to be used for municipal purposes.

Groundwater recharge as means of increasing water supplies is only economic as long as they are less costly than any other alternate to supply water.

Table 3. is a tabulation of the cost of artificial recharge in selected countries.

Table 1. Suggested Treatment Processes to meet the given health criteria for wastewater reuse.[3]

	Irrigation			Recreation		Industrial Reuse	Municipal Reuse	
	Crops not for direct human consumption	Crops eaten cooked; fish culture	Crops eaten raw	No Contact	Contact		Non potable	Potable
Health criteria (see below for explanation of symbols)	A+F	B+F or D+F	D+F	B	D+G	C or D	C	E
Primary treatment	***	***	***	***	***	***	***	***
Secondary treatment		***	***	***	***	***	***	***
Sand filtration or equivalent polishing methods		*	*		***	*	***	**
Nitrification						*		***
Denitrification								**
Chemical clarification						*		**
Carbon absorption								**
Ion exchange or other means of removing ions						*		**
Disinfection		*	***	*	***	*	***	***

Health criteria:

A Freedom from gross solids: significant removal of parasite eggs.

B As A, plus significant removal of bacteria

C As A, plus more effective removal of bacteria, plus some removal of viruses.

D Not more than 100 coliform organisms per 100ml in 80% of samples.

E No fecal coliform organisms in 100ml, plus no virus particles in 1000ml, plus no toxic effects on man, and other drinking water criteria.

F No chemicals that lead to undesirable residues in crops or fish.

G No chemicals that lead to irritation of mucous membranes and skin.

In order to meet the given health criteria, processes marked *** will be essential. In addition, processes marked ** will also be essential, one or more processes marked ** will also be essential, and furtive processes marked * may sometimes be required.

Free chlorine after 1 hour.

Table 2. Cost Estimates of Wastewater Treatment

Treatment Sequence	Estimated Cumulative Capital Cost		Estimated Cumulative Operating Cost		Reuse Applications
	15 mgd ($ mil)	100 mgd ($ mil)	15 mgd (¢ /1000 gal)	100 mgd (¢ /1000 gal)	
Raw Wastewater	0	0	0	0	None - highly polluting
Primary Treatment	2.2	9.5	5.2	3.5	Partial pollution control - no direct reuse possible.
Secondary Treatment	4.5	20	11	8.3	Conventional pollution control; non-food crop irrigation.
Coagulation-Sedimentation	5.1	24	15	19	Improved pollution control; general irrigation supply; low quality industrial supply; recreational water supply; short-term recharge.
Carbon Adsorption	7.3	30	23	17	Complete organic pollution control; high quality irrigation supply; good quality industrial supply; body-contact recreational supply long-term ground-water recharge.
Electrodialysis	11	47	37	26	Complete organic-inorganic pollution control; high quality industrial supply indefinite groundwater recharge.
------ Brine Disposal	25	77	53	33	
Disinfection	25	77	54	34	Absolute polluction control; potable water supply.

Table 3. Costs of Artificial Recharge[7]
(1971 dollar per 1,000 m^3)

Area and description	Capital costs	Operation and maintenance costs	Total	Type	Remarks
France					
Croissy area; chalk reservoir; annual spreading, 11,000 m^3.			60.00	Spreading	
Federal Republic of Germany					
1. Dortmund area; alluvium reservoir; annual spreading, 5,000,000 m^3.			30.00-40.00	Spreading	
2. Dusseldorf area; alluvium reservoirs, annual spreading, 60-70,000,000 m^3.			120.00	Spreading	High cost attributed mainly to treatment.
3. Frankfurt, alluvium reservoir.			10.00	Injection	A lateral leaching line from the river.
Japan					
Unconsolidated formation; injection test, fixed-assets cost $97,353 represents first year's operation, injection of 1,947,175 m^3 from Nov. 1961 to Sept. 1962.		19.00		Injection	
Switzerland					
Basel area; alluvium formation.			25.00	Spreading	
United States of America					
Los Angeles area; spreading in unconsolidated formation; injection into confined but unconsolidated formation.					

/...

Table 3. (cont'd) Costs of Artificial Recharge[7]
(1971 dollar per 1,000 m^3)

Area and description	Capital costs	Operation and maintenance costs	Total	Type	Remarks
USA (Cont'd)					
1. Local storm run-off; costs based on seven spreading grounds, and 683,492,000 m^3 total spread.	4.16	6.25	10.41	Spreading	
2. and five spreading basins costs based on 98,796,508 m^3 total spread.	7.52	7.18	14.70	Spreading	
3. Imported, untreated Colorado River water, costs based on 1,472,101,000 m^3 total spread.		0.78	0.78	Spreading	Utilizing existing facilities which were justified for spreading local storm run-off there-fore, only operations and maintenance costs are attributed to spreading, not including cost of water, which at 1969 prices is $16.21 per 1,000 m^3
4. West Coast Basin Barrier Project, about 55,000,000 m^3 injected annually. Total fixed assets cost about 7,000,000.	5.87	7.49	13.36	Injection	Not including cost of water; which at 1969 prices is $ 20.26 per 1,000 m^3

Wastewater has been successfully used to reduce or stop sea or ocean waters from intruding into groundwater aquifers. Usually, the wastewater is pumped into injection wells located on the sea side of the aquifers. The injected water acts as a hydraulic barrier against the intrusion of salty water into the aquifer. Movement of water within the aquifer itself mixes the recharge stream with the main bulk of water, and, thereby, prevents minerals buildup. However, enough precautions should be made so as to maintain the withdrawal rate equal or less than the injection rate.

Treated secondary effluents have been used to provide recreational lakes and swimming pools. Such facilities can be economically and socially justified where conventional water resources are scarce. Santee's lakes mentioned above are good example.

Water reuse in agriculture[8]

The widest application of wastewater reuse is in the field of agriculture.

The main reasons for making irrigation with sewage attractive are:

(a) availability of cheap land, because wide space is required;

(b) sewage cannot be discharged to stream either because streams are too small to acconodate the sewage volume or they are dry for a long period of time each year;

(c) there is an acute need for irrigation of crops; and,

(d) there is the possibility of return from sales of crop.

Sandy soils are ideal for successful irrigation schemes. Low rainfall is an added advantage because it absorbs relatively large amount of water. In most cases sewage is given primary treatment before application to land. Sewage is applied intermittently. A dosage is applied until the soil is soaked, and the flow is then diverted to another plot while the wet soil is drying.

The common method of application is by furrows fed from a header ditch controlled by a small earth dam. Crops are grown on ridges between furrows.

Spray irrigation is gaining popularity, especially for milk and cannery wastes. There are several ways in which sewage can be sprayed. It can be done through distribution systems, or from a tank mounted on a truck with a pump and a nozzle attached to it.

Odour problems are not uncommon. This is specially true in overdosage which waterlogs the soil.

Water reuse for industrial supply

Reuse of cooling water in industrial processes has been, so far, the most common and accepted practice.

There has been some reuse of municipal wastewater by industry, but the amount is relatively small. Reuse of secondary effluent that has been through advanced treatment is too expensive compared to natural supplies of water.

Water reuse for general supply

The greatest potential for wastewater reuse is for general water supply including potable water. The main concern there, is the presence of toxic substances or bacteria and virus.

Public acceptance of the concept of wastewater reuse for domestic supplies is still not forthcoming as was indicated earlier. However, the potential is still there especially in certain areas of critical supplies or in emergencies. But, in general, the need for reclaimed water for domestic purposes is not acute yet.

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CHAPTER IV. Potential and limitations of technology with regard to increase in water use

1. Introduction

In arid or semi-arid regions, in particular, even more than elsewhere, water is a vital element of life for man, animals and plants. Human life in these regions has only been kept alive by continuous struggle against the inhospitality of nature - low rainfall and extreme heat and aridity. Rainfall is rare, localized, irregular and often violent, the land is sparsely covered by vegetation, and the soil is shallow with fluctuating moisture content. Living conditions in these regions are greatly affected by man's behaviour with regard to the physical environment, his use and misuse of natural resources. Negligence on his part when trying to improve or control the circumstantial conditions which could be to his benefit may easily lead to environmental deterioration, accelerated erosion, etc.

The arid parts of the globe do not lag behind in such recent world trends as the rapid growth of industrialization, expeditious concentration of urban populations and the expansion of populated areas, with the result that water shortages have become more severe and the demand for water has sharply increased.

Prerequisites for a satisfactory solution to these problems are the integrated assessment of present water potentials and the re-examination of its optimum use. Scientists while challenging the traditional perspectives of water use, have been calling for the scrutiny, in a new light, of the diversified aspects of water management. In this respect, they have been re-examining the proper allocation of water among different economic sectors, the function of various plant covers, and the importance of industrial as against agricultural needs. Obstacles to highly effective water use, which have previously been pointed out, include slowness in translating scientific findings into action at the level of operation; lack of comprehensive surveys; traditional property rights; political control and social attitudes.

It is evident that future success in increasing the quantitative and qualitative utility of water hinges to a great extent on ingenuity in finding new and improved methods and technologies, ranging from radical innovations in discovering new water resources to patient application of principles discovered centuries ago. The need for technology varies from region to region and should be assessed according to specific features of individual and local situations. Some cases may justify large capital-intensive projects while, more often than not, simple technological improvements in water exploitation or conservation may have immediate local results. It should be noted, however, that technology alone is not the panacea which will solve all the water problems faced by arid or semi-arid zones today. Local application of advanced technology calls for overwhelming support from the indigenous population and social institutions and will also depend on the economic conditions and political climate of the regions involved. For further development of applied technology, concrete public policies with specific objectives are needed.

This report sets out some of the practical techniques offering effective tools for improving the water situation in arid or semi-arid zones. They are described in the following order:

- Technologies for exploration of water resources;
- Technologies for increasing water supply;
- Technologies for the conservation of water.

The report gives only a general outline of possible methods, and their applicability should, therefore, be studied in the light of specific conditions in each region. The report does not describe the pros and cons of reservoir construction and advanced irrigation techniques which have already been discussed elsewhere in a satisfactory manner.

2. Technologies for exploration of water resources

1) Remote Sensing

The progress of aeronautic and space activities in the last decade has led to an outstanding development of remote operation investigations of both surface and underground water resources. The principles of the sensing methods are based on the transmission of language electromagnetic waves. Acoustic waves have also been effectively used for many purposes and are superior to electromagnetic methods, particularly where the transmission methods involved weaken the electromagnetic waves to a great extent. Active methods employed by most sensor types are based on analysing the reflection of an artificial signal transmitted to the remote senses (sensors). Passive methods, on the other hand, are based on the emission by the observed objects of a type of radiation characteristic of the methods or their environmental state.

Visible, in infra-red aerial microwave measurements carried out by these satellites have been providing routine, repetitive and quantitative observations of terrestrial features. Aerial photographic techniques have adopted invisible wavelengths with non-camera instruments. Communication satellites have also revolutionized the transmission of messages from continent to continent and the collection of data from the ground instrumentation networks. These developments have contributed greatly to better prediction, definition and management of the components of the hydrological cycle.

The remote probing techniques from space have brought important achievements for the preparation of various hydrological data including:

- Showing the extent of springs and shallow groundwater in alluvial channels;
- Effects of rainwater on deserts;
- Maps presenting fracture systems of watersheds which allow the location of areas of potential high water yield;
- Continuing and detailed data regarding physiographic parameters such as drainage area and patterns, streamflow network, vegetation cover and surface water features;
- Maps of snow covered areas which contribute to the estimation of the amount of snow melting run-off and flood flow;
- Identification of snow lines on glaciers which help in the calculation of the glacier accumulation area.

2) Isotope Techniques for Groundwater Investigation

The increased potentialities of isotope techniques and the accumulated experience in a variety of related civil applications over the last twenty years have achieved new ways for the solution of several types of hydrological problems. Groundwater investigation has benefited greatly from the use of isotope techniques. Further utilization of these techniques, however, is expected to bring about even more important achievements during the coming decades by quantitative and qualitative improvements leading to increased efficiency.

These techniques fall broadly into two categories. The first technique consists of observing and interpreting isotope variations established in water by natural processes. Regional hydrological problems can be studied with environmental isotopes if natural conditions establish measurable variations in isotope concentration in different waters.

The second is to make use of radioactive isotopes artificially injected into well-defined points of the hydrogeological system under investigation.

The measuring of the evolution of isotope concentration which follows gives a very detailed account of the system in question if the measurements are performed at a sufficient number of points and repeated at different times.

The problems which can be resolved include, but are not necessarily limited, to the identification of the origin of groundwater; determination of its age; flow velocity and direction; interrelations between surface water and groundwater; possible interconnexions between different investigations; local porosity, transmissivity and dispersion of an aquifer.

Investigation by isotope techniques is less costly than other prevailing techniques and furthermore it can provide information which may not be obtainable by other methods. However, the use of radio isotopes causes an increase in cost due to the extra care needed for their use and for the prevention of health hazards.

3. Technologies for increasing water supply

1) Desalination

Desalination of salt water has been a widely known and frequently used technique to produce fresh water for human life and agriculture in arid lands bordering on seas. Desalination process technology has been immensely developed during the last few decades; series of new processes have been invented and their technical performance and economic viability have been increasingly improved.

As a result, the recent progress of desalination techniques has made it possible to build a plant in Kuwait with a 40 mgd capactiy.

The techniques which are commonly used today may be grouped according to the phenomena involved, as follows:

- Processes using a phase change of water: distillation (simple multi-effect flash, vapour compression and solar distillation), freeze separation and hydrate separation;

- Processes utilizing properties of membranes: electrodialysis and reverse osmosis;

- Processes utilizing ion selective properties of solids and liquids: ion exchange.

For most local economies obtaining water through any type of modern desalination plant is still expensive for domestic, industrial and agricultural purposes. The cost of desalination decreases as the size of plants increases. However, for many countries, the large amount of energy required is a major limitation on the further development of large scale distillation plants. Methods using membranes or ion exchange have not yet succeeded in providing low-cost fresh water, except in special circumstances. It has to be admitted that the use of desalinated water is still limited to communities where cheap energy is obtainable. This subject is further elaborated in Chapter III.

Individual household size units in a situation where saline water is easily available to each residential unit, might be considered more economical than a large central desalinating facility in a municipal system. Some home desalinating units are already in use in the USA.

2) Rainfall Collection

Even slight rainfall can supply a considerable amount of water if it is successfully collected from large catchments. The rainfall harvesting technique is designed to collect and convey rainwater by digging ponds in small depressions and/or by building ditches or rock walls along the contours of slopes. To prevent loss from collected water, the clearing away of rocks, the eradication of vegetation and the treatment of the soil surface has proved to be very effective. Treatment by chemicals to fill pores and make soil water repellent is a promising method of overcoming infiltration. Sodium salts are used for soils containing clay because of their low cost, availability and reduction of weed growth. Silicons, latexes and waxes such as water repellent chemicals are being tested with success. When soils are too porous or unstable, a waterproof cover over them is less costly than making the soil itself the water shedding surface. Plastic sheets, butyl rubber and metal foil are usable but subject to wind damage. Plastic film covered with gravel has proved more successful as the gravel protects the underlying membrane from radiation and wind damage. Such film has a projected life of more than 20 years.

Rainwater harvesting is one of the least expensive systems for the provision of water without fuel or power. Chemical treatment and soil covers cost comparatively little. The asphalt treatment would be very economical in countries which produce and refine crude oil. Soil surface treatment calls for occasional maintenance because of the cracking of the catchment surface caused by unstable soils, oxidation and plant growth.

The rainfall collecting system is not economically suitable for areas with an annual average rainfall of less than 50 to 80mm. Adequate storage devices are quite indispensible. In designing the process, careful consideration should be given to the prevention of erosion, instability and local floods. The most desirable topography is gently sloping (preferably 1-5 per cent) catchments.

3) Saline Water Irrigation

Many arid lands are often rich in saline water aquifers, esuaries, coastal lagoons and closed lakes. Recent plant physiology and soil science studies have successfully discovered how to select crops with suitable saline water resistence and also devised practical ways of saline water irrigation. The studies have revealed high salt tolerance crops such as cotton, barley, wheat, sugar beet, ray grass, Bermuda grass and wheat grass. However, undiluted seawater, with a TDS of normally about 35,000 mg/l has not proved practical for irrigation purposes even for the most salt tolerant crops. The applicability of saline water irrigation is limited to areas where the main characteristics of soil particles and the overall drainage of farms are appropriate to prevent salt concentration in the soil.

4) Reuse of Water

Wastewater, if properly treated, can be a good resource for agricultural, industrial and municipal use. Agriculture is the first beneficiary of processed wastewater. Treated sewage has been widely used for irrigation. The technical requirements for this are relatively few, in particular for garden crops and trees, except for sedimentation and biological treatment in oxidation ponds. Where irrigation systems are already in use, little investment is necessary for connecting them to sewerage systems. However, the removal of pathogenes seems to be the most important problem in wastewater irrigation. Other disadvantages are inflexibility in supplying the seasonally fluctuating irrigation needs and the resulting high salt concentrations in soils which are detrimental for some plant growing.

The necessity for water reuse and recycling is increasingly felt in highly industrialized countries. Although the cost of the treatment to meet required effluent standards is a major constraint, many industries are obtaining great benefits from the reuse of wastewater. Many oil, steel and chemical industries are using processed water for cooling purposes. In this instance, desirable water qualities are non-sealing, non-corrosive and slime-resistent, and municipal wastewater, after a little advanced treatment, is found to be economically feasible for pulp and paper industries and ore separation. The advantage of water reuse for industrial purposes lies in the fact that the supply is stable and connecting pipelines are relatively short.

The present level of wastewater treatment technology can promise the production of an effluent of potable water. However, these processes involve large capital investment, trained manpower and a high operation cost. The reuse of wastewater is, at present, limited to societies which can provide chemical and microbiological treatment processes to prevent potential health risks, as well as those able to afford good management of the process and a good understanding of the user's requirement to minimize harm to the environment. This subject is further elaborated in Chapter III.

5) Artificial Recharge of Groundwater

Although the amount of artificially recharged groundwater is very minor in comparison to the discharge of an aquifer, its importance is increasingly realized, particularly in basins where extensive use of groundwater resources has been developed. Ordinarily natural recharge of an aquifer is not sufficient for maximum beneficial use, and at present artificial recharge is thought to be most effective to maximize the potential benefits.

Interest has been growing in artificial recharge for various purposes: storing water in aquifers, ready-made evaporation free reservoirs, prevention of saline water intrusion and land subsidence and wastewater reclamation.

Studies and experiments have developed various methods of recharge, the application of which is governed by local water availability and quality, the value of land and climatic conditions.

The most common principle of the method is to spread water over the ground surface to increase percolation to the water table. The water spreading is performed in the following ways: flooding the basin, ditch or furrow, natural channel and irrigation methods.

The flooding method is simple and less expensive than other methods. Streams flood the ground surface in such a way that vegetation and soil are left undisturbed.

In the basin method, water is released into basins by dikes or low dams. Usually basins are constructed in a series by parallel channels so that water may spill from the upper basin into the lower basin. It is desirable that water be relatively free from silt and the basin be of a small but continuous gradient in order to maintain the filtration rate of the basin.

The ditch or furrow method is suitable where the terrain is relatively irregular and steep. The ditches are usually shallow, flat bottomed and closely spaced. The ditch patterns vary according to local topography.

The natural channel method is to spread water over relatively flat areas in existing stream channels to retard the flow of stream water and enhance its infiltration. In many cases, this method involves the construction of small concrete of rock check dams in flat channels which may adversely result in a flood hazard.

In the irrigation method, extra water is supplied to irrigated fields for percolation into underground formations mainly during winter or dormant seasons. Careful studies on leaching effects of crops and soils in the area should precede local application.

Injection through pits or shafts is also commonly used to supplement the potential of aquifers under impermeable layers. This is more costly but economically feasible at times when the area has been overpumped due to large industrial and municipal demands. Recharge wells also work effectively in permeable formations such as lava and porous limestones. The recharge rate of these methods is often lowered when the walls are sealed by small non-organic or organic particles. Therefore, periodic cleaning is necessary to maintain the standard rate.

Artificial recharge is relatively inexpensive but calls for a minimum technical expertise in operation and maintenance except in the case of water being injected into the aquifers under pressure.

6) Weather Modification

To hasten rainfall by cloud seeding, the use of ice, frozen carbon dioxide and silver iodide has proved to be promising in areas where wet air masses are swept over mountain ranges. Experiments made in the USA have resulted in a precipitation increase as high as 200 per cent in some individual storms. However, the processes and potentials of cloud seeding are not completely understood.

Apart from advanced analysis of the mechanism of cloud seeding, there is still a wide range of problems to be solved in order to ensure that maximum benefit is derived from the rainfall augmentation:

These are:

(i) the economical and environmental assessment of the pros and cons of rainfall augmentation;

(ii) the effect of rainfall augmentation on the increase in usable water. The numerical relation between the increases in precipitation and usable water is not linear. It is largely affected by the amount of increased precipitation, local geology, vegetal cover and climatic conditions;

(iii) the analysis of costs of an economic, social and environmental nature in comparison to the direct and indirect benefits;

(iv) the examination of the legal and institutional implications with a view to regulating the performance of rainfall augmentation, which generates potentially strong impacts on human activities in widely affected areas.

7) Iceberg Transportation

Some engineers, glaciologists and physicists, admit that towing icebergs from the polar regions to water deficient regions appears technically feasible and economically attractive. Possible suitable regions to be supplied are

Australia, Chile and other arid regions of the southern and perhaps even the northern hemisphere. One report estimated that a hypothetical supertug, where water temperatures are not high, could tow icebergs up to 16 km long, 3.5 km wide and 200 m high. Major problems that should be carefully examined in advance are towing speeds, melting rates while being towed, how to melt on arrival at destination and pumping the melted water from the sea into the supply systems. The waste heat of coastal power plants could be utilized for the melting process. This device is still at the stage where critical technological assessment should precede any realistic proposal.

8) Other Techniques

- Collapsible bags for transporting large water-tight bags made from strong synthetic rubber or some type of plastic films could be used to transport fresh water to various destinations. The folded or rolled empty bag would be loaded with fresh water perhaps at river mouths and then towed by ship to coastal cities or industrial centres where fresh water supplies are scarce. In certain cases, this system may be more economical than the construction of desalination plants or long distance pipelines.

- Undersea Aqueducts

Freshwater might be economically conveyed by a large diameter flexible or semi rigid plastic pipe which could be laid undersea from a specially designed vessel. The lower density of fresh water limits the foundation problems to holding down the aqueduet and the required strength of the pipe for water flowing under pressure could be reduced by the density of seawater. The pipeline would run along the coast with several pumping stations as required.

- Offshore reservoirs

Large offshore reservoirs would be made of flexible materials for the temporary storage of combined sewers until treatment, or reclaimed effluent from waste treatment systems.

Such reservoirs could be floating or submerged depending upon the construction cost, wave and current movements and the availability of the ocean surface without interfering with other ocean surface users.

4. Technologies for water conservation

1) Evaporation Control

Surface water resources of hot arid zones suffer seriously from heavy evaporation losses. One important means of increasing water supply for human activities is reducing evaporation. The general and simple principle of reducing evaporation over the whole extent of the water surface is to cover it.

Aliphatic alcohols, eg. cetyl alcohol is effective for covering water surfaces as it forms a film of a thickness of one molecule. This monolayer has advantages such as low consumption (less than 60 g/ha of water surface) high oxygen transmissivity to the water, nontoxicity to fish or humans. Unfortunately, since the film does not prevent solar energy from being absorbed into the water, the higher water temperature rather increases evaporation at any part of the water surface the film does not cover. Furthermore, it is difficult to maintain continuously against wind and wave action. Experiments using plastic nets to restrict the drift and disruption of alcohol layers have been carried out. Due to these problems, this method is not frequently used.

Floating blocks could prevent evaporation from the water surface. The materials which have been used, on a trial basis, are light weight concrete rubber or plastic. In order to reduce the increase of water temperature by solar energy, floats could be made of insulating and light-coloured reflecting materials. The estimated evaporation control efficiency of this method is 80-90% under proper operation.

Evaporation can be retarded by filling reservoirs or basins with sand and gravel although this decreases the water storing space of reservoirs or basins. The water stored in the pores between the particles is effectively shielded from evaporation to the extent of about 90% of the total evaporation potential.

The control of evaporation from water surfaces has many advantages: Installation or construction does not require elaborate techniques; floating materials do not need time for spreading; the cost is normally lower than that of collecting, storing or producing the equivalent amount of water through other methods; salt concentration in impounded waters due to evaporation can be retarded and growth of undesirable algae and submerged aquatic weeds can be reduced as sunlight is cut off by the floating material. Because of the difficulty of maintaining this system against heavy winds, storms and floods, the application of evaporation control is as yet limited to small water surfaces such as ponds, tanks, troughs and oases. Sand-filled dams can be constructed only on absolutely watertight foundations to avoid seepage loss. If necessary, the foundation is treated by cement grouting.

Evaporation from soil surfaces used for agricultural purposes can be retarded by placing watertight moisture materials or water-retardent mulches. Materials spread over soil surfaces such as straw, sawdust, wood bark, cotton burs, gravel, sand or cinders. These evaporation barriers are also useful for stabilizing loose soils, stopping desert encroachment, allowing agricultural run-off and reducing salinity buildup. However, the relatively high cost of materials limits the widespread use of this method except for intensive cultivation of high income crops. The effect of the reduction of evaporation losses on agriculture is also dealt with in Chapter II.

2) Seepage and Percolation Control

Seepage from earth canals and reservoirs not only causes severe water losses but water logging, salination and erosion of neighbouring soils. Modern technology has invented many methods to reduce water seepage while being stored in a reservoir or conveyed: Soil compaction, chemical treatment of soil, and lining of reservoirs or channels. Among them, the least costly and the most practical are:

- Treatment of soil with a sodium salt which breaks up clay aggregation and causes clay particles to swell and plug the soil pores;
- Lining reservoirs or water channels with polyethylene, polypropylene film or butyl rubber;
- Lining with concrete-based materials, such as cement-stabilized soil, ferro-concrete and concrete filled fabric;
- Protecting steep banks with bags, stuffed by used rubber tyres, ferro-concrete and soil cement.

The means to reduce seepage from water storing or conveying facilities are generally practicable locally. However, these are disadvantages to most methods. Constant and careful maintenance is required.

Inability to keep adequate moisture in soils due to rapid percolation deprives vast areas of sandy lands of cropping opportunity. Recent techniques have succeeded in producing artificial underground moisture barriers in order to keep water and nutrients from percolating below the root zone. They are frequently made of asphalt barrier plastic sheets or layers of compost or manure rich in colloids. Machines are being manufactured and tested in Japan to install a waterproof asphalt barrier without excavating soil surfaces. The optimum depth and extent of the barrier is subject to the moisture capacity characteristics of the sand. Experiments demonstrated that 50-75 per cent of irrigation water was saved by this method. Sandy soils have many advantages: good durability against the abuses of tillage and farming, quick intake of irrigation water, good capacity for aeration favouring root development and efficiency against evaporation due to upper layers serving as mulch. Once adequate moisture storage capacity has been achieved sandy soils can produce crop yields equivalent to those of very fertile soils.

CHAPTER V. Regional and Subregional Co-operation

No developing country has the know-how and the financial means to develop, by itself, its own resources to the level of the developed and industrialized nations. In order for the developing countries to catch up with advanced ones, they need, among other things, to co-operate as much as possible, within themselves. This should in no way preclude help from developed nations.

Being a regional commission, ECWA is very keen on developing and fostering co-operation among its member states. This has been well reflected in all its water resources programmes, especially the action proposals submitted at the Baghdad meeting, 11 - 16 December 1976.

Our endeavour and programming to promote regional/subregional co-operation and co-ordination included, but was not limited to, the following areas:

- Exchange of technical information;
- Education and training;
- Financial aspects;
- Research;
- Experts and consulting services;
- Environmental aspects;

For the sake of emphasis, the above points will be briefly discussed, and the relevant recommendations presented.

Exchange of technical information

This activity is aimed at collecting and disseminating of technical information on the development of water resources within the region including reports and studies prepared by governmental and non-governmental groups and agencies. This is a vital regional activity because, in order to develop a meaningful regional/subregional water programmes of co-operation, available information should be circulated within the region. This way gaps are clearly identified, and duplication is avoided.

To implement this, missions had been mounted to all countries of ECWA during the past two years, and considerable amount of data has been collected and carefully analysed. However, the activity is continuous in nature and the existing information will be updated as new data become available.

Ultimately, the Division of Natural Resources of ECWA hopes to establish a data bank on water resources to be part of ECWA's documentation centre under study.

Dissemination of information among the countries of the region is only the first step of ECWA's efforts to bridge the water gap in the region. A programme for the projection of the future demands to the year 2000 has also been initiated. This is being done in light of the projected industrial, and agricultural developments. An approximate output has been already obtained. We will continue to refine the model as more data become available.

The projected values will make available preliminary estimates of the water needs in the region. This will contribute towards assisting the planners to determine the magnitude and distribution of the increase in water demands relative to all possible sources of supply.

In order to improve the quality of data in the region, ECWA is recommending the strengthening and/or establishing adequate hydrological and meteorological stations, and the adoption of modern and standardized procedures through which basic information is transferred into more usable form.

Education and training

The lack of trained personnel at professional and subprofessional levels in all fields including water resources developments is a major constraint to the progress of the region.

Assessment of the region's supply in each category is underway. The activity will also study the existing facilities for manpower training.

To bridge the gap, ECWA is recommending the establishment of a training centre for training of personnel in all areas of water resources development. Location and size of such a centre are to be determined by the member countries of the region. The types of training that the centre will give include:

- Training in proper techniques of installation of data networks and evaluation of such data;

- Fundamentals and principles of hydrology;
- Operation and maintenance of water systems;
- Training of well drilling crews.

At the professional level, facilities and curriculum of existing higher educational institutions in Western Asia will be surveyed with the view towards determining the extent of coverage given to water resources development. If needed, institutes and universities should upgrade their present standards for professional graduates.

Implementation of such component of the programme will be co-ordinated with specialized agencies such as ILO, UNESCO, FAO, and the United Nations Centre for Natural Resources, Energy and Transport.

Financial Aspects

Some nations lack financial resources to adequately develop and manage their water resources.

ECWA is recommending that nations with abundant financial resources have joint ventures in the field of water management and development with less affluent countries which have abundant water resources. This may be done on country by country basis but preferably should be handled on a combined regional basis.

We are also recommending the establishment of a new fund or access to existing funds to be used in the form of grants and loans to be made available to ECWA member countries at the national, subregional and regional levels for worthwhile water related programmes. Specialists may be employed to determine eligibilities of need for assistance from the fund.

This should, in no way, exclude financial aids from local and regional banks. By the same token, the countries themselves have to participate in funding of their own projects through budgetary allocations where possible.

Research

Properly planned research, particularly applied research, is an important ingredient of water resources development programmes.

Especially needed is research on how to reduce the water demand, as well as how to use water more efficiently in agriculture. There is also need for research on new non-conventional water resources (See chapters II, III, IV of this document).

As a result, ECWA is recommending that the countries of the region should strengthen existing and establish new institutions for the purpose of conducting water resources research, and exchange such information with other countries and specialized United Nations agencies.

Experts and consultancy services

To that end, ECWA has suggested that a team of qualified consultants or specialists be made available to any state requesting assistance in the field of water resources development. Such teams of experts could be paid either by the country asking assistance or from a special fund.

Substantial advantages could be gained if the consulting team or firm are from the region as a whole or certain countries of the region. Good consulting firms from one country could serve others in the same region under suitable encouragement from the home governments.

ECWA, by virtue of its international connexion is always prepared to assist the governments of the region to locate specific talents from outside the region.

Environmental aspects

Practically, no country within ECWA region is immune from floods or droughts which could lead to a great damage and/or loss of life. In order to guard against such disasters, programmes for flood and drought control should be combined with other conservation measures to minimize damages. Local participation should be encouraged.

Environmental impacts of all water resources activities should be carefully looked into. This is not intended to duplicate programmes of other agencies in the region. Rather, close co-operation should be maintained.

It is interesting to note that an ad hoc group of experts on technical co-operation in the water resources sector among developing countries was convened by CNRET and UNDP, 6-10 December, 1976 in New York. The purpose of the meeting was to discuss possible ways and means of technical co-operation in water resources among developing countries.

The following subjects were discussed:

1. Improved information base.
2. Research, education, and training.
3. Experts and consultancy services.
4. Standardization of services and equipment.
5. Planning and Management problems.
6. Financial aspects.
7. Actions at regional and international levels.

It can be seen that similarity with what we have been doing and/or proposing to do is striking.

CHAPTER VI. Conclusions and Recommendations

An attempt has been made to forecast the water needs of the member states by the year 2000. But because only a limited amount of data has been available, the projections are far from being complete or accurate. Once enough and better data becomes available, more attempts will be made.

As for the development of water resources in the region, it can be safely stated that, whereas some member states, due to the comfortable financial situation they enjoy, are increasing their water supplies (mainly through desalination) at relatively fast pace, the less fortunate ones are still lagging behind.

It should be pointed out, however, that imported technology and advanced engineering is not necessarily a prerequisite for the development of water resources. Sometimes much can be accomplished by adopting low-cost technologies that lean heavily on the use of local skills and materials. Attempt to rely only on the transfer of expensive and advanced technologies which is insensitive to local needs and capacities could very well complicate matters rather than solve them.

Reuse of domestic effluent does not fit very well with the traditions of the region. However, its use in irrigation is not a distant possibility. In fact, Kuwait is already using treated effluent at its experimental agricultural station. But regardless of the extent to which wastewater is being used, it, nontheless, has a great potential for increasing the water supply of the region and the world.

The member states should also address themselves more seriously to the adoption of better ways and means of managing the existing water resources. All countries of the region are moving very slowly to initiate policies geared to conserve available resources and use them more efficiently. This should no longer go unheeded.

Finally, we recommend the following:

- educating the public on the acceptance of wastewater reuse;
- establishing a pilot project in the region to treat domestic sewage for reuse in recreational, agricultural, industrial, and

municipal application, to determine cost estimates and, thus, evaluate the possibility of using wastewater as a source of supply in one sector or another;

- establishing a pilot project, including cost estimates, on the use of domestic sewage and industrial effluents to recharge groundwater aquifers or stop the intrusion of sea water;

- studying the long range impact of the discharge of brines from distillation plants on the ecological balance and on marine life.

- evaluating sediments from erosion, their volume and transport, and effect on cultivated soil and waterway;

- extending the use of modelling techniques and computers to catchment developments, snow accumulation, flood routing, prediction of sea water intrusion, and simulation of groundwater aquifers;

- evaluating the feasibility of weather modification and evaporation suppression from economic as well as technical viewpoint;

- improvement of existing irrigation methods with the idea of raising productivity with minimum use of water, preventing waste and conserving water quality;

- improving the ways and means of protection against flooding and water logging;

- developing low water consuming agricultural products, and improving and extending rainfed crops.
