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Man and His Water Resource

Dean F. Peterson
Utah State University

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THIRTY-SECOND FACULTY HONOR LECTURE

MAN AND HIS WATER RESOURCE

by

DEAN F. PETERSON

Dean, College of Engineering

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. . . That portion of the universe which at a given place and time is available for human use is not a fixed entity but in constant flux. Every change in human want patterns and in social objectives, every invention and increase in man's control over nature, constantly revises the criteria of availability and ordinarily tends to enlarge the aggregate of natural resources. *Man and his resources are functional reciprocals.* (Italics added)

Erich W. Zimmerman
Encyclopedia of Social Sciences
Natural Resources, 1935

MAN
AND HIS WATER RESOURCE

SEVERAL PRECEDING honor lectures have dealt with water. The title of a recent one, "Water and Man," by Dr. Sterling Taylor closely resembles the one for this paper. Dr. Taylor's paper dealt primarily with the physical science of water. This one will consider the nature of the use of water by man and the technological and institutional structure related to that use. Thus there should be no serious overlap. My friends in the social sciences may be surprised, too, to find that somehow this lecture has spilled over into their territory. But engineering is the implementation of science and technology. Evermore frequently such implementation requires both broad social decision and social action. This is certainly true of water resource development; water resource planning is a systems* problem. Coupled to physical water resource systems are people, and social institutions appear as much involved as technological concepts and hardware, thus the word "man" appears first in the title of this paper.

A rather single-minded interest in physical science and in technology during the first quarter century of my career left me little time to think about people. Society, as I saw it, seemed to muddle along pretty well. I certainly can't say I was unaware of the great social problems of the day, but the great depression

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* "In its broadest sense, system engineering is concerned with the synthesis and anlysis of the performance of *physical* systems, with or without automatic feedback control, which are optimized with respect to accepted criteria." *Concepts of Engineering System Design*, Warren E. Wilson, McGraw-Hill, New York City, 1965. p. 6

Ordinarily, one would think of institutions as placing constraints on the physical system. The writer suggests that it is possible to think of a system in an even broader sense, so that it includes social institutions as well. While they may be slow in responding, institutional reaction does occur as a result of technological feedback. Note the preface.

finally spun itself out and World War II was eventually won without stimulating more-than-ordinary social curiosity on my part. I was aware that technological advances seemed often to be accompanied by difficult social and economic consequences; but, at least in the United States, the power and exuberance of young American economic affluence seemed to heal the wounds rather quickly. It looked to me like the great productive capability of science and technology would provide such a stream of material "goodies" that no man would long have reason to complain.

A new page turned for me in 1959 when I was asked to develop an International Seminar on Irrigation Practice in the Middle East and South Asia. While dams and engineering works to convey water to the proper place at the right time had been developed with great success, no spectacular reformation of irrigation-agriculture was apparent. By and large, in the mid-20th Century, the same old medieval practices with low production results continued. The question was asked: "Should more attention be given to the propagation of modern irrigation technology at the farm level?" I spent ten weeks conferring with officials in nine different countries and in 1960, the seminar was held in Lahore, Pakistan. President Ayub himself opened the proceedings, showing great concern and good understanding for the problems under discussion. Since 1960, two more seminars have been organized and held and another is scheduled for Spring, 1966.

In 1960, I returned with the strong conviction that modern irrigation technology was impossible in the context of the low educational level prevailing and that massive programs to close the educational gap would be necessary. By 1961, I felt the growing conviction that the difficulties were really more basic and stemmed from the culture itself of which the lack of education was but another symptom. Moreover, in these countries, the timing of social evolution may have missed the fortuitous combination of circumstances associated with the industrial revolution in the West that caused the economic explosion which we in this country enjoy.

These considerations led me to make some study, albeit limited, of institutional development, especially related to water resources. There is a strong linkage, of course, and *the strength of the linkage depends on the degree to which water resource development places restraints on economic growth at a particular time and place.*

In the past few years in our own country, there has been a growing concern over the closing gap between water demand and available supply on a national scale. As a result, a number of important steps have been taken in recent years by the Federal Government. As they were in the West, and still are on a regional basis, water resource limitations have now become a national matter of great importance, and new institutions, now being formed, are truly national in scope.

Water, of course, is not the only resource which man uses and develops for his benefits. Others include the land itself, the earth's minerals and forests, and in some degree, the earth's atmosphere. Why then should extraordinary attention be given to this particular one? Land, water, and air are all pervading and all three are essential to human life in a particularly fundamental way. The use of land to grow crops is one of the most important achievements of the human race; and the use of fossil fuels has, in the last 300 years, resulted in environmental and social changes that are staggering. Nevertheless, water is unique. It is used by everyone, but it is not everywhere and always existent as are land and air.* But water can be transported to a different place or stored for later use. *Thus water is the one resource which is most susceptible to social action.* Indeed, except for the most primitive cases, social action is required in order to construct the works to make water usable. One man working alone can divert only

* That is, where man normally lives. The oceans are an exception, of course.

the very smallest stream; nor can any man use water without depriving his neighbor or without changing its quality. Thus there are two reasons for the emphatic impact of water on man's social progress. First, it satisfies a fundamental need required by everyone; and second, the nature of its availability and quality can be dramatically changed by social action.

No social action can be taken unless there is formed or exists a complementary social institution; neither can the consequences of the social action be conserved. Without an institution, a social decision will never be implemented and remains meaningless; and, once implemented, the action will wither and die unless there is an institution to keep it alive. Thus, there seems to be something fundamental about the relationship between society and the use of water. I suppose that the institutions man forms at any point in his social evolution tend to reflect the maturity of his intellectual progress and the state of his technology. Like architecture, they must be a reflection of his contemporary cultural value system. A culture committed intellectually to democracy would presumably tend to form institutions that operate in a relatively democratic way; or conversely, one which developed a "brave new world" of water resource management, might well be tacitly headed toward a similar fate on the common social front.

Institutions serve man well. On the other hand, he risks danger of becoming their captive. Undue homage may be paid to an institution long after its original useful purpose has been served or the strength of the institution may force man into patterns which are illogical or even undesirable. These ideas apply well to institutions related to water resource development.

There seems to be some good evidence that western man, at least, began to invent new institutions in connection with his evolution from the individualistic food gathering stage to the irrigated village agriculture stage in the hilly land bordering the fertile crescent in Mesopotamia, some 9,000 years ago. This cultural experience and the surplus wealth created by using the new technology of irrigation were parlayed into complex and effective institutions relating to urbanization, government, law, war, religion, resource development, etc. These institutions characterized the great city states of Mesopotamia and Egypt and provided the cultural foundation for western civilization.

As civilization grew and spread water resource development, while important, soon lost its primary place in the mainstream. But today the social exergy provided by the industrial revolution of the past 300 years has resulted in population increases to the point where the water resource appears again to be a limiting factor. This resource apparently is limited not only in regard to fundamental requirements for water and food, but in terms of the quality of the environment in which civilized man would like to live.

With this new constraint on the general horizon, our culture quite naturally feels impelled to use the full impact of technology to provide efficient physical solutions. Some have said, however, that for some water resource problems now facing us there may be non-technological alternatives which are better social solutions. In our culture, institutional development places high emphasis on technological efficiency. Are other alternatives or values obscured as a result?

Water and the Development of Civilization

Literature in anthropology related to the beginning of civilization invariably leads back to Mesopotamia, where the oldest village remains are found. There and in Egypt on the rainless river plains arose the first great cities which were the beginnings of western civilization. From these cities sprang much of the institutional structure of later western culture even down to the present. As summarized by Braidwood (1960), the agricultural revolution began less than 10,000 years ago first in southwestern

Asia on the hilly flank of the fertile crescent of Mesopotamia, and later in China and the New World.

"By about 5,000 B.C., the village-farming way of life seems to have been fingering down the valleys toward the alluvial bottom lands of the Tigris and Euphrates . . . In the bottom lands, a a very different climate, seasonal flooding of the land and small-scale irrigation led agriculture through a significant technological transformation. By about 4,000 B.C. the people of southern Mesopotamia had achieved such increases in productivity that their farms were beginning to support an ancient civilization. . . ."

"As man learned to produce food, instead of gathering, hunting or collecting it, and to store it in the grain bin or on the hoof, he was compelled as well as enabled to settle in larger communities. With human energy released for a whole spectrum of new activities, there came the development of specialized, nonagricultural crafts. It was no accident that such innovations as the discovery of basic mechanical principles, weaving, the plow, the wheel and metallurgy soon appeared."

Adams (1960) asks, "where in this pattern were the inducements, perhaps even preconditions for urbanization that explain the precocity of the Mesopotamian achievement?" He continues:

"*First* there was the productivity of irrigation agriculture. In spite of chronic water shortage during the growing season and periodic floods around the time of harvest, in spite of the debilitating summer climate and the ever-present danger of salinity in flooded or over-irrigated fields, farming yielded a clear and dependable source of food.

"*Second,* the very practice of irrigation must have helped induce the growth of cities . . . by engendering inequalities in the access to productive land, irrigation contributed to the formation of a stratified society. And by furnishing a reason for border disputes between neighboring communities, it surely promoted a warlike atmosphere that drew people together in offensive and defensive concentrations.

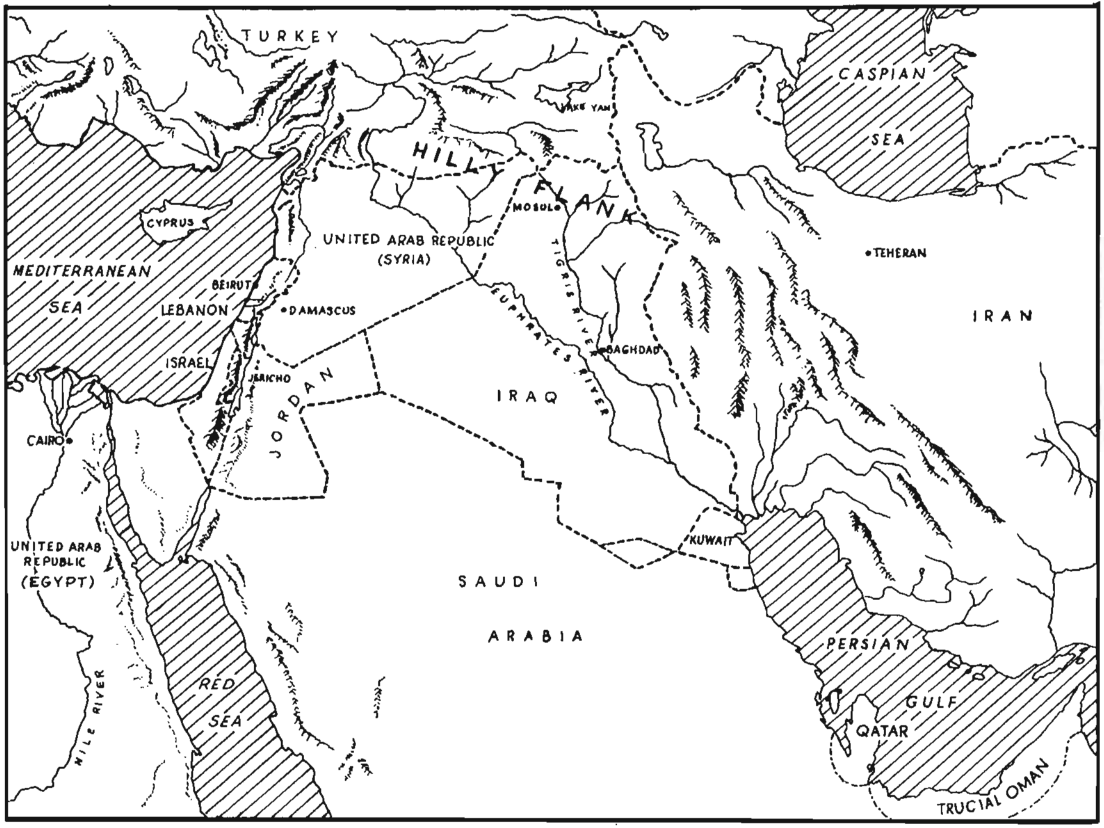

Figure 1. The Fertile Crescent and surrounding hilly flank where irrigation began.

"*Finally* the complexity of subsistence pursuits on the flood plains may have indirectly aided the movement toward the cities. Institutions were needed to mediate between herdsman and cultivator; between fisherman and sailor; and between plowmaker and plowman."

Turning again to Braidwood,

"Here in part is the reason why civilization grew in Egypt and Mesopotamia first, not in Palestine, Syria or Iran. In the latter areas, people could manage to produce their food as individuals. It wasn't too hard; there was rain and some streams, and good pasturage for animals even if a crop or two went awry. In Egypt or Mesopotamia, people had to put in a much greater amount of work, and this work couldn't be individual work. . . .

"There had to be hard and fast rules . . . It was not only the business of learning to control the rivers and making their waters do the farmer's work. It meant also controlling men. But once these men had managed both kinds of controls, what a wonderful yield they had.

"This learning to work together for the common good was the real germ of the Egyptian and Mesopotamian civilizations . . .

"I am particularly anxious that you do *not* understand me to mean that irrigation *caused* civilization. I am sure it is not as simple as that . . . Let's say rather that the simple beginnings of irrigation allowed, and in fact encouraged, a great number of things in the technological, social and moral realms of culture . . ."

There are many places in the world where irrigation generated food production such that village agriculture developed but progressed no farther. This phase still exists in much of the Middle East and was exemplified by American Indian culture in our own Southwest. In regard to the latter, Herold (1961), writes that, "Irrigation did not achieve the social development and stratification developed by the classical irrigation societies in Mesopotamia, China, Coastal Andes and Mesoamerica." Haury

(1962) notes that the idea of kings appears to be foreign to the great southwest, that civil leadership was important to canal building and maintenance and that religion was not strongly developed. The Southwest has a complete record of development up to the point of city achievement. Decline was well advanced before the Spanish conquest. The water supplies of this area were small and scattered and Herold (1961) notes, ". . . the inter-village co-operation needed . . . in Pueblo irrigation could readily be arranged on an informal basis."

Almost in our own time, the scattered water supplies of Utah probably provided a rather ideal condition to crystallize some of the basic institutional concepts of the L.D.S. church. The coherence, independence and social initiative of the individual wards doubtless found good proving grounds in the isolated communities of Utah. One might speculate about the secondary effects this environmental adaptation to hydrologic circumstances may have had on other mores and incentives of this group.

There is a great deal more that could be said about the development of the water resource throughout the ages, and its consequences to man, but my purpose is served. I cannot help but contrast classical Rome which constructed 359 miles of aqueducts to provide 50 gallons per day to each of its citizens with 17th Century Paris which provided only 2½ quarts. (In a modern American city per capita daily use is about 150 gallons). The development of pumps in the last 200 years finally paved the way to provide adequate supplies to many large cities, especially in Europe and by the turn of the last century, the basic technology for treatment of sewage had been developed.

All of these examples serve to illustrate the reciprocity of man and his water resource and the effects which the use of the water resource can have on man's culture. Water resource development was the catalyst whereby the preceding cultures of food-gathering man flowered into civilization on the river plains of Mesopotamia and Egypt. There can be no more forceful illustration than this.

International Assistance and the Water Resource

Many of the "underdeveloped countries" are located in the great deserts or semi-deserts of the World. Some of these are the same countries where the practice of irrigation made possible the flowering of the first civilizations. What is the reason for this return to the desert? Is this an inevitable consequence of social-economic evolution in an irrigated area?

In any case, investment in water resources development has been a major activity of foreign assistance programs. While some of this has been for municipal and industrial water supply, the large share has been for irrigation development and hydro-electricity. The hope is obvious. This is a means whereby dramatic increases in food production should be possible. This could provide relief from near starvation conditions existing in many of these countries, and electricity to stimulate commerce, industry, and capital accumulation for investment. Unfortunately, most efforts to date have met with considerable frustration. The new production just doesn't happen. The farmer, that highly essential person in the production chain, is confronted with a whole series of obstacles which impede change; these may be social as well as economic and technological. Without cataloging them, they include lack of technical farming information; inadequate drainage; inequitable or inadequate operation of the irrigation distribution system; lack of capital or credit; unreliable or unfair marketing practices, taxation and revenue systems; and lack of incentive to earn additional local exchange. Most of these the farmer cannot change by himself and many require deep-seated social changes.

Irrigation project developers in these countries face this dilemma: Shall the farms be large scale, profit-motivated, technologically efficient units or shall they be designed to merely take up the slack of population increases at, hopefully, a little better subsistence level? The first will yield a maximum return to the national economy, but quite obvious social difficulties rule against it. For one thing, there is no other place for the large numbers of people now on the land to go. The wishful hope is that at some not-too-distant future, and in the exuberance of new-found nationalism, industry or tourism will blossom forth and relieve the population burden on the land — a hope that I fear may never be realized.

A colleague and I recently served as consultants on an irrigation project in one of these countries. This project, requiring a large share of the national capital plus foreign assistance for a number of years, will take a minimum of 10 years to place under operation, but it will absorb only 1 year's increase of population.

The effect of recent (last 125 years) irrigation development on the Indian Punjab and Gangetic plain is to trap millions of people technologically and, essentially, socially also; in the village-agriculture stage of human development. Water allocations (3 c.f.s. per 1,000 acres as contrasted to from 12 to 16 in United States practice) are too low to permit more than subsistence agriculture.* With their village-agriculture institutional orientation, the cultural step for this society to enter a modern industrial-urban world is overwhelming. The tremendous investment in works designed to provide only these low values of irrigation water and the resulting geographical distribution of tens of thousands of villages would be extremely hard to change physically. The step from village agriculture to urbanization in Mesopotamia took 1,500 years; and it was based, because of low population density, on capital accumulations provided by an unsaturated village agriculture. This is not likely to soon be the case in present day India, where ever-increasing population permits no agricultural surplus.†

* There are probably several reasons for this low duty of water. One is the problem of underdrainage in the extremely flat plain - i.e. larger quantities may have caused waterlogging. Further, with his limited implements and energy sources, the farmer could rotate his operations to new ground so that planting need not await harvesting, thus much of the land was actually left fallow at any time. Probably also this subsistence agriculture was consistent with colonial and revenue policy.

† Hindu India does not permit the use of one of the important elements of the agricultural revolution — storage of food on-the-hoof. More than 200 million livestock thus compete with man for vegetable food supplies.

In much of the Middle East and the subcontinent, the glories of ancient civilizations have disappeared leaving only their institutional remnants, or else they never developed. The economic surpluses resulting from irrigation agriculture have been exhausted by over-population, salinity accumulation, siltation, wars, or colonial exploitation.

Thermodynamic analogy – Thermodynamics might provide at least a qualitative model of economic evolution. Corresponding qualities are:

Thermodynamic	**Economic**
Energy	Wealth
Mass	Population
Temperature	Density of liquid assets

Economic stratification corresponds to decreasing entropy, which permits an increasing power to do work (viz., achieve economic progress). Institutional structure provides the engine. In the capitalistic system corporate activity is a means of achieving additional effective stratification (reduced entropy) by combining the private capital of several individuals.*

The agricultural revolution accompanied by irrigation produced an increased wealth which led to the entropy reduction that eventually brought civilization to ancient Iraq from the antecedent, "low-temperature, = high entropy" food-gathering culture. Additional entropy reductions resulted from the increased wealth-producing capability of urban society, and more recently, in some parts of the world, by the dramatic inputs of the industrial revolution.

In America, the industrial revolution occurred concurrently

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* Under state capitalism, ideally, the capital is in the hands of the state and the general population is at a uniform low "temperature." While this system may possess low entropy, it is analogous to a single-stage heat engine; whereas societies with more elements of economic stratification may resemble the more efficient multiple-stage turbine.

with the transition from village agriculture to urbanization and this fortuitous double-headed entropy reduction was a major factor contributing to our spectacular economic achievements.

In mid-East and the subcontinent, the village agriculture and urban potentials were well exhausted under the inertia of increased population and the friction of institutional fixation along with colonial exploitation, and perhaps some lack of basic natural resources, long before the technology leading to the industrial revolution became available.

Since World War II, the United States and some other more wealthy nations have attempted to overcome this high entropy by fairly large injections of capital. For the subcontinent, India-Pakistan, these have amounted to perhaps 12 billion dollars and considering the tremendous size of the problem on the subcontinent, 12 billion dollars must be inadequate by at least one order of magnitude. The increase in population and the Indian-Pakistan conflict has probably more than offset any gain. Perhaps, this level of investment for 50 or 100 years without population increase might eventually build a new engine.

Some thermodynamic systems may be triggered to release large quantities of potential energy with little new input. This is true when dry ice or silver iodide is introduced into a supercooled cloud causing release of the heat of fusion as the water droplets turn to ice. This could be the effect of introducing new capital into a favorable social environment, as happened with Western Europe through the Marshall Plan following World War II. Perhaps, in the interest of humanity, we shall some day soon find such a key in the middle East and subcontinent. Latin America however, where the resource base is much less saturated, may be a more likely place.

Water in the United States

The history of water controversy in the United States predates the constitution. A mid-eighteenth century topic of discussion between Virginia and Maryland was the Potomac River. Navigation, until the settlement of the West, however, constituted the principal interest of the Federal Government in water resources.

While there is ancient historical precedent for many of the features of western water law in the Middle East and Spain and Italy, the basic law of the United States stemmed from England under the concept that the *riparian* landowner was entitled to have the stream flow by undisturbed. Any real use precludes this, of course, and there was developed the doctrine of co-relative rights whereby the riparian owners shared the encumbrances placed on the water. In the West, development of both mining and irrigation required an increased physical displacement of the stream and the doctrine of appropriation was developed by Anglo-Saxons. This independent blossoming of essentially the same concepts which arose in the Middle East centuries ago under a different culture in similar circumstances is a forceful commentary on the effect of environment on man's institutions.

Beginning with this century, the concern of the federal government has spread through a large list of interests including, successively, navigation, reclamation, flood control, soil conservation, parks, forests and wilderness areas, pollution, and now natural beauty. These activities are not organized into a single co-ordinated comprehensive effort. Each has its own separate administration essentially clear to the top. In the field of law, it seems likely that the Federal government will assert its dominance over the ownership of water as much as may be necessary in order to achieve national objectives.

Present Outlook

Ninety-seven percent of the earth's water is in the ocean. More than 99 percent of the 3 percent fresh water is retained in the ice cap, glaciers or underground, leaving less than 1 percent at any moment in the atmosphere, lakes, rivers and soil. Nevertheless, the total precipitation in the United States in a year is tremendous, amounting to about 4,200 billion gallons per day (4,750 million acre-feet/year), (Wolman, 1962). Only about 30 percent or 1,260 billion gallons per day reaches a stream, the remainder is transpired or evaporated essentially where it falls. About 315 billion gallons per day are withdrawn for use, and only about 90 billion gallons per day are actually consumed, principally by irrigation. In summary, the overall water budget appears as follows:

Streamflow			1,260 b.g.d.
Mined from groundwater	6 b.g.d.*		
Concentrated supply			*1,270 b.g.d.
Withdrawn from streams			315 b.g.d.
Not withdrawn			955 b.g.d.
Withdrawals		315 b.g.d.	
Consumed, irrigation	84 b.g.d.		
Consumed, industry	3 b.g.d.		
Consumed, municipal	3 b.g.d.		
		90 b.g.d.	
Returned to streams			225 b.g.d.
Total streamflow			1,180 b.g.d.

As a measure of demand on the resource, withdrawal figures other than for irrigation are rather meaningless because the same stream may be reused and returned more than once. Reuse is governed by what happens to water quality or the time of occurrence. Except for irrigation, therefore, the central question of water resource management is *quality* rather than quantity.

Quantatively, there is not a critical nation-wide water problem. But water supply is highly variable both in time and space,

* The 1260 b.g.d. is only accurate to the closest 10 b.g.d. so 1270 b.g.d. is rounded off.

and there are regional and local problems of varying urgency occurring across the nation.

Pollution

All of man's physical activities, including just being alive, produce wastes. Our knowledge of man's pre-history depends almost exclusively on his ancient wastes sifted from mounds or caves. Even tillage results in increased sediment to the streams, and there are many forms of waste produced in unending and staggering quantities. These range from human sewage, animal wastes, wood pulp and hundreds of kinds of industrial wastes in many forms: — soluble chemicals, suspended solids or immiscible liquids. Waste heat carried by water from power condensers and air conditioners poses an increasingly serious problem.

Maxwell (1965) holds, "*The supply of usable water is always a function of total pure water versus waste.*" Obviously we cannot use all of the remaining three-quarters of our available water to expand our economy. Many of our streams are so laden with waste that a much increased concentration would be intolerable.

A recent statement by a Chicago official illustrates the variety of forms and quantities of material which industries may dump into our streams and lakes:

"In December, 1964, we found millions of mysterious polyethelene pellets washed up on our 2 miles of breakwater. We learned that they represented just one flushing from a chemical plant, and that on the Michigan shore, part of the same flushing made up 30 or 40 miles of windrows." (Chicago Alderman Leon Depres, *Saturday Review*, Oct. 23, 1965). The fact that Detroit dumps 20 million pounds of contaminant material along with 1.5 billion gallons of water daily into the Great Lakes is only typical of what is happening to natural streams and lakes all over the United States. In the last few months, this problem has been thoroughly aired in our popular magazines. For example:

"We are living in our own filth," says John W. Gardner, the new Secretary of Health, Education and Welfare. United States rivers and streams, like the muddy Missouri, used to be contaminated with nothing worse than silt, some salt, and the acid from mines. Now they are garbage dumps. Raw sewage, scrap paper, ammonia compounds, toxic chemicals, pesticides, oil and grease balls as big as a human fist — these are the unsavory contents of United States waterways." (*Time*, Oct. 1, 1965)

Water is particularly vulnerable to waste pollution. It is a good solvent and, flowing, provides an easy and cheap means of transportation. It flows by gravity without extra expense for energy, carrying most of man's waste along on a relatively free ride. Not only does it carry away those with which it is directly loaded; but, running over the ground surface and penetrating through the soil, it seeks out and voluntarily flushes away other wastes as well.

Techniques for removing or stabilizing organic water-borne wastes have long been practiced. Unfortunately, however, reaeration and complete stability are difficult to achieve. Thus an important element in conventional sewage treatment is dilution by returning the effluent to a body of water of sufficient purity and oxygen content such that the residue can be absorbed without unacceptable effects. Under present levels of treatment, Wollman (Resources for the Future, 1960) says that by 1980, the nationwide requirement for dilution water might even be as large as the total flow available for all purposes. With the most efficient degrees of treatment, these might be reduced to 210 billion gallons per day in 1980 and 360 billion gallons per day in the year 2,000. Cooling water requirements for thermal energy plants are expected to total 265 billion gallons per day by 1980, but this need may be met in part by the same water used for dilution. Temperature changes, however, cause important biological changes downstream and these must be dealt with.

Water does not bear the entire pollution load alone. The atmosphere and the earth's crust assist. Once formed, pollution tends to be conserved. Most efforts to cope with it simply involve

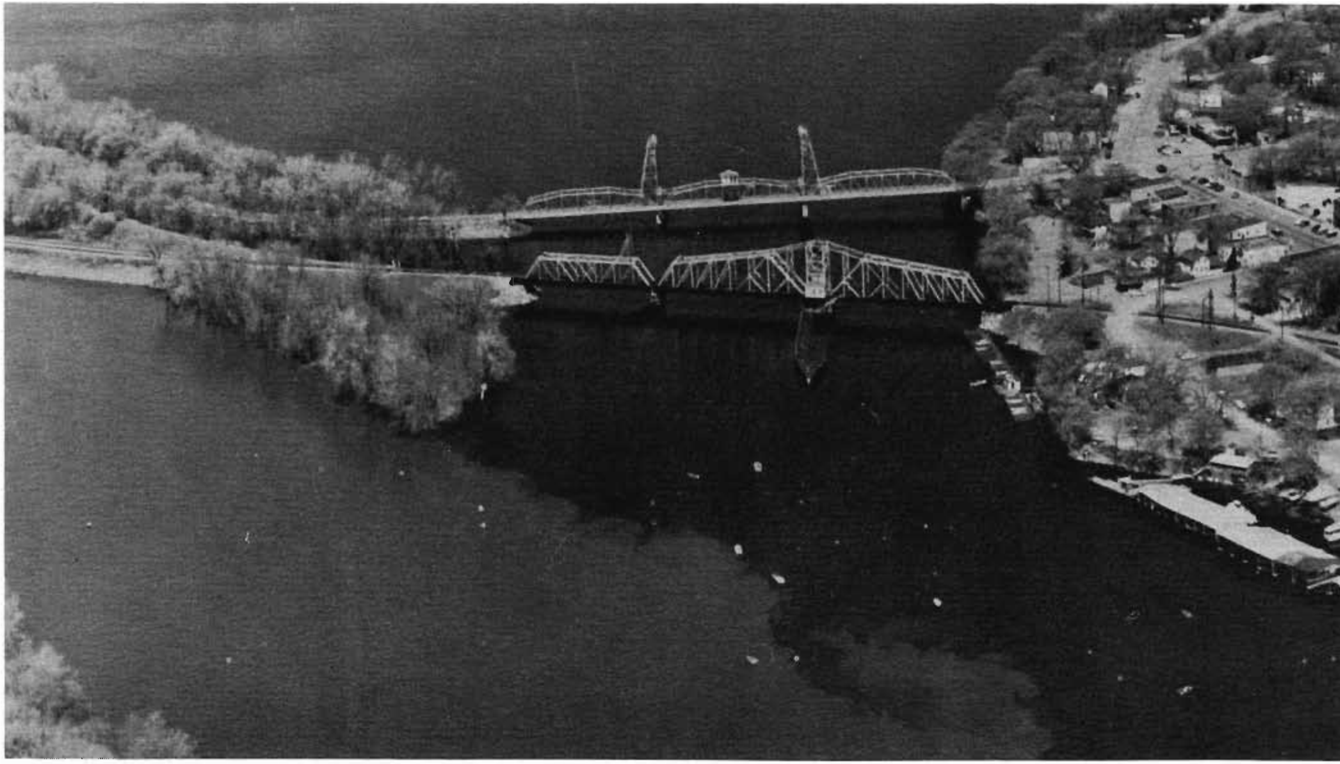

Figure 2. Water of St. Croix River joined by polluted waters of the Mississippi.
(Photo courtesy of United States Water Pollution Control Administration and Minnesota Conservation Commission.)

transfering it to a different form, place or time, hopefully less objectionable. For example, instead of grinding garbage and flushing it down a stream, it might be incinerated and the waste products introduced into the atmosphere or it might be buried in land-fill. Either may be objectionable. The land and the atmosphere are cleansed by water; and even groundwater is susceptible to pollution.

We now have the technology whereby sewage may be cleaned up and safely reused in the same city that produced it. However the stable dissolved solids would be conserved and concentrated by each recycling so that, eventually, the water would have to be wasted, diluted, or desalted. Although social objection to recycling remains strong, this technique will undoubtedly be used extensively in the future. The past summer, children in San Diego's Santee suburb swam in lakes filled with reclaimed sewage and reclaimed sewage is being returned to the groundwater on Long Island. However I know of no United States city now recycling its own reclaimed sewage directly into its water supply.

Basic responsibility for water pollution control is in the states (Stein, 1964). Federal legislation was limited until 1948 when the first Water Pollution Control Act was passed. This experimental action was made permanent in 1956 and strengthened in 1961. It gave the Public Health Service a mandate to clean up pollution on interstate streams through enforcement of pollution abatement measures. The procedure involves action by the states to call a conference on a polluted interstate stream. Under strong federal pressure, which includes legal enforcement powers, a reasonably acceptable solution is usually worked out. Legislation also provided for financial assistance to municipalities for construction of treatment plants, grants for research and development of comprehensive river basin programs. Construction of regional laboratories was also authorized.

Under the Water Pollution Act of 1965, a separate Water

Pollution Control Administration was established with the added authority to promulgate quality standards. It is clear that an all-out war on pollution is intended.

The problem is not simply one of enforcement. While much can be done to reduce the production of waste substances, these are inherent by-products of civilization. They will tend to increase with increasing population and expanding economy. Science and technology must give greater attention to this overwhelming problem — to reduce wastes and control them. Society must be prepared to invest large sums of money and to accept strong control. With demands for energy, metals and other raw materials estimated to double in the next 10 to 20 years, waste disposal technology will have to run very hard just to stay even.

Regions of Short Supply and Drought

While total United States water demand forecasts balanced against total supply indicate a wide margin of reserve for some time in the future, water problems are local and regional, and the national problem is really the sum of these separate ones. Both population and precipitation are unevenly distributed. Figure 3, (after Wollman in the 1960 Annual Report of Resources for the Future), shows predicted regions of shortage.

Our own state has a short supply and our agricultural base would be greatly expanded if there were more water. Utah has been one of the slowest of the western states to develop its groundwater. This is a potential new source and importations to the Bonneville Basin from the Colorado River appear likely within the next decade or two. Water use is far from being stingy along the Wasatch Front and there is a good water supply potential here for a commercial and industrial future by conversion from irrigation use. Our legal base and consequent public management policy with regard to water are among the most conservative and may well inhibit development of groundwater and transfer to new uses which could greatly stimulate our economy. Perhaps more critical for the future than the Wasatch Front is the

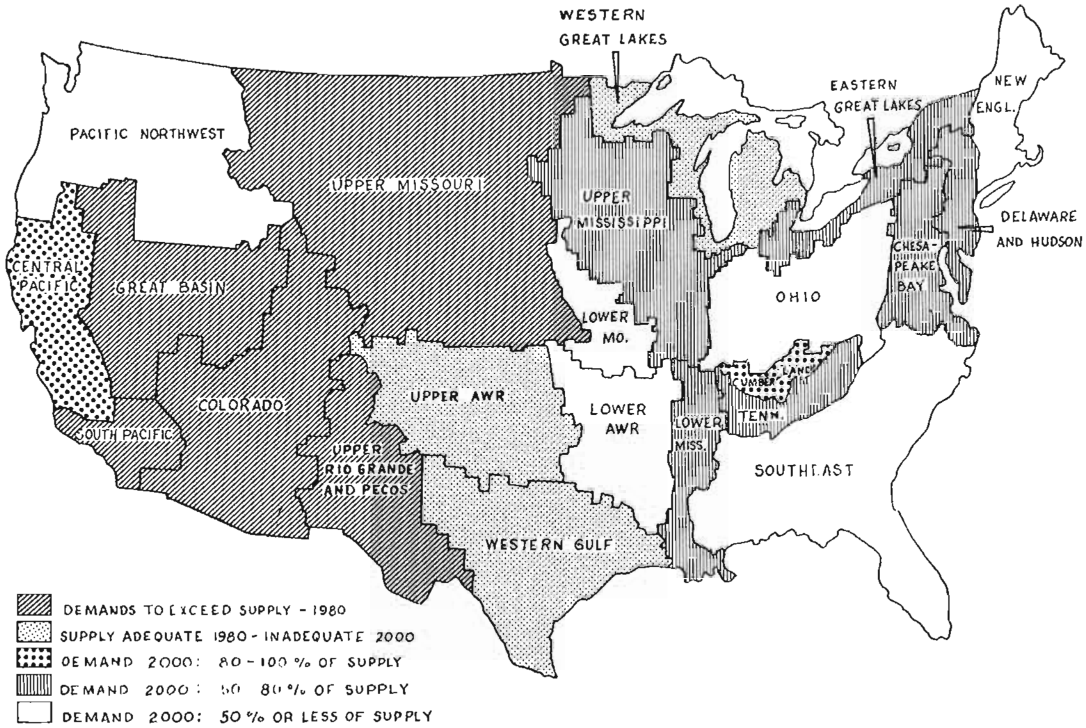

Figure 3. Regional variation of water demand and supply. (after Wollman. Annual Report. Resources for the Future. 1960.)

Colorado Basin, which is a storehouse of mineral and fuel reserves needing water for development. Utah's water law and its obligations under the Upper Colorado River Compact have left us with our appropriation account books already closed, and even though something like 500,000 acre-feet of Utah's Colorado allotment probably cannot be used physically for 40 or 50 years in the future, there is today no lawfully available water to develop these vital resources.

Although the entire southwest faces water shortages, Arizona, with less inhibition than Utah, provides an interesting illustration which is in some ways typical, but in other ways unique. In Southern Arizona, a 500-million-dollar annual agricultural industry has been built largely by mining groundwater, now at the rate of about 2.5 million acre-feet annually. Every day 5 billion gallons are pumped of which all but 110 million gallons (2 per cent) are used for irrigation. This cannot long continue and the area faces serious economic consequences as the result of a diminishing water supply. About two years ago, the Interior Department proposed its Southwest Water Plan to bring water into the Colorado River from Northern California. General opposition to this particular scheme placed it on the shelf and the present Central Arizona project, which contemplates bringing 1.2 million acre feet of Colorado River into Southern Arizona is now before the Congress. Even if this scheme survives its political difficulties and is translated into reality, a construction job of considerable difficulty, it will go only halfway in meeting the overdraft on groundwater and must be followed by other steps either to provide more water or to conserve the present supply. Involved in the ramifications of this complex plan are the dubious hydrology of the Colorado River and the consequences of the "basin account" concept whereby surplus power revenues may be used to finance new non-reimbursable construction. In Southern California problems are similar, but, thanks to the California Water Plan, the immediate future is more secure.

The Arizona example is only one illustration of short supply existing or developing in the arid and semi-arid West. Similar problems face the entire area from the Dakotas to Texas and from Kansas to California.

A related problem is the problem of drought. Customarily, municipal waterworks, as well as other water supply systems are designed to provide for droughts of a length and frequency indicated by statistics based on stream measurements over a period of time. Occasionally, however, great droughts occur which are far more severe than expected. For example, in the Northeast United States for the past 4 years, and especially in 1965, runoff remained far below the levels of expectancy with threatening consequences to the large cities of the region. Since climate is highly variable, even in humid regions, cities in such areas are not immune to occasional serious drought problems. With new reservoir sites and watersheds increasingly pre-empted by other uses, drought-proofing humid region cities in the future may well involve problems of supply approaching those in the arid West.

Solutions for short supply — One way to solve Arizona's problems would be to reduce irrigation since nearly all of the groundwater draft goes for this purpose. Because of agricultural surpluses, some argue that this production is not really needed. Massive urbanization would utilize presently irrigated lands for cities. Thus a water shortage might by solved by overpopulation.

Another solution, which probably has about the same level of expectancy, is for the people to move to an area with a better water supply. Probably only economic disaster or demographic regimentation could force this. It is higly unlikely that the former would be permitted on the American political scene; the second, of course, is unthinkable at this time.

Long-distance conveyance — Long-distance importations conveying water from the Northwest have been proposed. The latest and largest of these, *North American Water and Power Alliance*, a large-scale plan to import Canadian and Alaskan waters, would cost 100 billion dollars and would enhance the water supplies of all of the Western States and the Great Lakes as well. Long distance transfer schemes are naturally opposed at this stage by the water-donor areas, who see many adverse consequences involving future economic opportunities and effects on biological environment. Many conservationists also oppose further widespread inundation of natural lands and construction of canals as a matter of principle. Long-range importations will doubtless be one important means of solving regional water problems but they involve complex engineering problems and even more complex economic and political ones. Figure 4 shows several recent plans for long distance importations.

Many have attacked the NAWAPA scheme as ridiculously grandiose, i.e.—"A boondoggle visible from Mars," (Wallace Stegner in the *Saturday Review*, Oct. 23, 1965) or because of its effect on the landscape. The expenditure of 100 billion dollars over a 30-year period (3 to 4 billion dollars per year) in a country by then approaching an annual gross national product of 1,000 billion dollars hardly seems ridiculous. Annual expenditures for the space program are about this magnitude and defense costs 10 times this much. NAWAPA or something like it could well be an important element in our future water economy. It has the advantage that it increases the ratio of fresh water to wastes. Ecological and aesthetic effects of such a large scale displacement of water must be understood and evaluated in terms of alternatives, however.

Desalting — Separation of salt from ocean or brackish waters has been hailed by some as an answer to most of the water problems of mankind. Others are simply optimistic that this may become an important item in the kit of tools for developing comprehensive water plans in the future. Still others are more skeptical. In any case, important engineering advances have been made over the past few years.

This year a 200-million-dollar, 5-year program of research and development involving pilot-scale test plants has been approved by the Congress. Four different basic processes are under development: distillation, electrodialysis, reverse osmosis and crystallization.

Figure 4. Plans for transferring Northwest water to the Southwest. (after Colorado River Association Newsletter, August, 1965.)

Freezing is included in crystallization; other crystallization techniques depend on the ability of certain gases to form hydrate crystals with water which may be separated from the brine and decomposed by heating.

Distillation is an old process. It requires heat inputs of about 540 calories per gram to produce vapor; however, most of this heat is recovered by transfer to the incoming feed water so that the net thermal costs are in the range of 20 to 120 cal./gram for plants now built and as low as around 50 cal./gram for plants now under design. This is in contrast to the basic heat of solution of about 0.67 cal./gram for the salts in seawater. The most difficult problem in distillation is scale-formation by deposition of carbonates on the heat transfer surfaces. This requires that the process be conducted at low temperatures in the range of 200°F - 300°F.

Freezing requires only about one-fifth as much energy to overcome the heat of fusion; but difficulties have been encountered in separating the ice from the brine, and when the heat recovery is considered, this method may not have significant thermal advantages over distillation.

In the electrodialysis process, alternate membranes having positive and negative ion permeability are separated by spacers and placed under an electromotive potential. The ions accumulate in every other compartment, leaving fresh water in the alternate spaces. In reverse osmosis, the salty water is placed under pressure which squeezes the fresh water molecules out through a membrane having low permeability for salt. This process operates at high pressures, 150 p.s.i. and over, so there are difficult structural problems involved in supporting the membranes.

The energy cost for the electrodialysis processes is proportional to the salinity of the solution, but in the distillation or freezing processes, is related to the heat of vaporization or of fusion regardless of salt concentration. For this reason and others, the membrane processes are best used for brackish water at lower salt concentrations while distillation or freezing is adapted to sea water. There are many plants already in operation, mostly using distillation or electrodialysis. These range in size up to 1.7 million gallons per day. Costs as low as $1.00 per 1,000 gallons are being approached in the best of these. Combining a distillation plant with a thermal electric plant has economic advantages because of economies of scale. For large reactors energy costs should be well below those for fossil fuels. Bechtol Corporation recently released a study of a large nuclear dual-purpose plant producing 150 million gallons per day (230 c.f.s.) distilled water and 1,500 megawatts of electrical power that predicts costs of about 25 cents per 1,000 gallons for water delivered into the Los Angeles distribution mains and 3 mills/kwh for electrical energy. This is more expensive than Colorado River water, but less so than water under the California Water Plan. Blending of the salt-free water with the increasingly salty Colorado River water also has attractive possibilities.

Precipitation modification – Langmuir and his associates, Schaeffer and Vonnegut, demonstrated that introduction of condensation nucleii in the form of dry ice or silver iodide crystals causes supercooled fog or mist to freeze into ice thus permitting precipitation. There is no doubt that this process works – it works every time. Practical rainmaking by seeding the atmosphere using ground-based silver-iodide generators is a different matter and is not so easily demonstrated. Many difficulties are encountered in correlating precipitation at a seeded downstream target against unseeded targets either in space or in time sequence. Because of the natural variability of precipitation, random observational noise requires long-time obervations in order to obtain meaningful results. Seeding operations have usually not been subjected to acceptable statistical control. Until about 8 months ago, meteoroligists generally felt that there was no scientific basis for expecting cloud seeding operations to produce precipitation, and a National Academy of Science Panel said as much in a report, "Scientific Problems of Weather Modification," issued in late 1964. Recent critical review of commercial cloud seeding statistics by the Panel, however, is convincing that cloud seeding operations have definitely resulted in precipitation increases of 10 percent to 20 percent. There is no evidence that precipitation is reduced at points downward from the target. This development lends some encouragement to carefully designed engineering research and development efforts now under way.

The amount of water gained by desalting or by importation can be very accurately measured; in contrast, the amount gained by weather modification can never be known, only expressed in terms of probabilities. While evaluation methods doubtless will be greatly improved, a quantitative assessment of weather modification benefits is apt to remain forever quite vague.

The social and economic implications of cloud seeding are rather obvious. Any change in the weather is apt to be detrimental to someone, and drought or floods alike could be blamed on cloud seeding. Commercial cloud seeding also may foul scientific investigations in the atmosphere. At least one state has prohibited cloud seeding and most have some control legislation on the books. National Science Foundation now has power to require reports from weather modifiers.

The federal government will doubtless become more strongly involved in weather modification control as well as operations.

Water conservation practices — There are many ways in which the use of water can be reduced. In agriculture this includes improving irrigation efficiency, developing plant varieties which use less water, or by inhibiting transpiration, possibly with chemicals. Developing plants and techniques to produce the greatest yield per unit of transpiration may be more practical than transpiration suppression and would probably occur at high rates of transpiration per acre. Use of water for domestic and industrial purposes also could be cut by presently known or new conservation practices. For example, water requirements for refining crude petroleum now range from as low as 1.73 to as high at 44.5 gallons of water per gallon of petroleum.

General Conservation Values

No thoughtful person would willfully want to bring about the extinction of a natural species of life. Water resource development often has impacts on the use of land by man and by wildlife which extend far beyond the confines of the reservoir. The hazard of dams on the Columbia River to the salmon is well known, but changes of stream size, temperature, or chemistry can greatly affect life in the stream.

There is a value in having nature, at least in some places, remain unmolested and this is the argument of the conservationists to whom construction of reservoirs is particularly distasteful. They argue that, while the reservoir may be beautiful when full, this is not the case when it is drawn down and that the purposes of many reservoirs could be fulfilled by other means. They argue that the formula by which irrigation and flood control costs may be paid from sale of hydropower places planners under a strong incentive to unwisely expand reservoirs for power production.

Preservation of archeological or historic sites also restrains the planner. Particularly in the East, reservoir sites are apt to contain old battlefields, or parks which are worth preserving. As population increases, the public interest in conservation values is bound to increase at a rapid rate, and the problem of considering these in relation to other values will become increasingly difficult. Presently, the conservationist voice enters the decision-making process primarily at the legislative level which is late in the planning exercise. A further complication is the fact that the argument, which cannot be delineated in dollar values, is apt to become emotional. Without doubt much more serious consideration needs to be given to conservation policy. We may find it wiser, in an increasing number of cases, to attempt to adapt to our environment rather than to "tame nature."

Impact of population on nature – The battle over reservoirs is really superficial. It is a symptom of a much more fundamental issue, which is the *increasing visible impact of unrestrained population growth on nature including man himself.* That this issue is joined most forcefully in the context of water resource development illustrates the basic relationship between man and the water resource. Man's spectacular success as a biological species stems from his intellectual and manual capacity to plan and act individually and socially in order to improve his lot, or to avoid disaster. But he cannot have both unrestrained population growth, and an increasingly affluent standard of living without eventually dramatically affecting his natural environment. At a recent interstate water conference, Sierra Club members introduced a resolution advocating population growth restraints. It was declared, "out-of-order" as being irrelevant. Perhaps *nothing* is more relevant. In the long haul, more than the quality of life may be involved; survival of the species may be an issue.

A fairly optimistic view of the immediate future is taken by Fisher (1963) who believes that population growth in America can be accommodated for the rest of this century as far as food, energy, water, and most construction materials are concerned, but not without problems including a number of "ifs." Some "ifs" are technological advances, economic adaptation to technological change, foreign sources of raw material and farsighted government and private management of resources. A fivefold increase in energy output and in iron ore and production of ferro-alloys; somewhat less in copper; much more in aluminum, and tripling or more of lumber output will be needed by this doubled population. Obviously, these needs cannot be met without further consequences to the natural environment.

If we make it for the next 35 years, we might well ask, "What then?" Thirty-five years is not a long time. Despite my advancing years this could still happen in my lifetime. In the year 2000 our young children and grandchildren will be only young adults. It is, of course, possible that automatic, voluntary restraints will operate to curb population growth, but this has not happened in India or China. There is a basic moral question involved: Should

America continue to expand its resources primarily for its own material affluence in the face of increasingly imminent disaster in the form of widespread starvation in many other areas of the world?

Flood Control

Construction of dams and levees for the control of floods in the great river plains encourages increased investment in cities and industry on the dangerous flood plain. Some argue that sooner or later floods in excess of the capacity of the protective works are bound to occur. Because the vulnerable investment is greater than it would have been without "protection," the eventual loss exceeds that which would have occurred had there been no flood control to start with. National investment in flood control structures now exceeds 4 billion dollars. Since most of the more than one-half billion annual flood control program is borne by the federal treasury, there is an added public popularity about structural flood control, often described as "pork barrel."

Suggested alternatives to structural investment include flood plain zoning which would discourage heavy settlement in the most vulnerable area and the possibility of constructing buildings and cities on stilts to avoid flood damage.

Flood control planning obviously involves some particularly difficult economics. For one thing, the future investment in areas of high risk is difficult to predict.

Planning and Policy

Bradley (1962) points out that the water budget rather than available land may really place the limiting restraints on food production in the United States. Of the 4,200 billion gallons per day precipitation, about 70 percent or 3,000 b.g.d. is transpired and evaporated before reaching a stream. Most water budget analyses are concerned with the other 1,200 b.g.d. which appear as streamflow. But it is the 3,000 b.g.d. which provides our food, fiber and timber. A daily pound of bread and a pound of meat requires around 3,000 gallons per capita per day or, for the United States, 600 b.g.d. for "bare" subsistence for 200 million people. Allowing for additional needs of fiber and lumber and the fact that much rain falls and evaporates without producing crops, Bradley concludes there remains a margin for only about 50 million more people without significant change in our way of life.

This is a subtle restraint and the more visible ones relating to the use of water in streams may have a larger direct effect on our public policies. As the margin of supply decreases, there is a growing need for increased optimization through better planning. Better planning should improve the efficiency of use, make the best use of technological capabilities and decide on the most attractive alternatives. There is a vast reservoir of technology already available and more may be developed. What is needed is a more effective institutional mechanism to adequately direct that technology in such a way that it functions efficiently to achieve the best possible social objectives. Such a structure should be able to reflect the most desirable balance of social values.

The needs of man, aesthetic as well as material, rather than the availability of technology or of hydrologic opportunity should be central to the effort. It has been said that planning should be *anthropocentric* rather than *hydrocentric*, and I might add also, rather than *technocentric*.

To be homocentric, water resource planning must provide good resolution at the level of individuals. Nevertheless, individuals cannot escape the restraints which are placed on them by the Federal Government, states, districts and communities in the common interest. These already limit individual use of the wildlands and the diversion or pollution of streams.

Thus, water resource planning must involve every stratum of political organization, and since the implications of water use at one point on the watershed may have repercussions at other points geographically remote, the size of the planning unit may be quite large. Water resource planning must be prepared to resolve conflicts of interest at every level.

Idealized process – Ideally, planning would follow these steps: (1) statement of objectives by those in authority; (2) collection of the facts; (3) systems analysis involving full multiple use and social as well as natural and technological factors to predict the alternatives and consequences; (4) public discussion of the alternatives; (5) a choice by consensus. But planning is a circular process. Objectives can hardly be realistically stated until the opportunities are understood. Technological capability is particularly creative as new opportunities arise and these reflect changes in the economics; intangible clues may be involved and the objectives to be obtained may be fuzzy or even undefendable. Thus, continuing feedback and refinement are necessary. The public may be badly misinformed or even emotional. While today all water supply projects should be planned giving due consideration to all possible purposes, usually one agency with a particular mission orientation dominates the planning.

In spite of the difficulties, the five steps mentioned constitute the essential products that ought to come from a planning effort. It is particularly important that the planning be reviewed in the open public forum.

Problems of Planning

Besides developing adequate planning institutions, there are many steps to be taken before adequate planning can occur.

Technology – While there already exists a large reservoir of effective technology, new technological capability is needed in many areas. For example, if desalting costs could be reduced to 10 cents per 1,000 gallons or effective and inexpensive new methods of waste disposal were invented, some currently difficult planning problems would be greatly eased. Technological advances also depend on basic scientific research, which should be a continuing effort.

Quantitative and qualitative data, not only physical but economic, are often sadly lacking. Sometimes the need for particular information becomes apparent only as the planning process proceeds.

Economic evaluation – Understanding of economic implications of various alternatives of development is today far from adequate. The same is true regarding the assessment and allocation of costs and benefits. Economic descriptions of alternatives can only be as accurate as the assumptions which went into their postulation and a great deal of improvement is to be desired at the present time. There is no quantitative basis on which intangible benefits or costs may be compared, so that decisions on these points have to be made by public concensus separately on judgment (or emotional) grounds.

Systems analysis – Operations analysis of water works systems have been carried out manually for many years. These are, of course, greatly limited in scope especially if multiple-purpose efforts or economic optimization are involved. Much progress has been made (Thomas and Burden, 1965) in optimizing hydrological systems using computers, both digital or analogue, or in combination. Even hydrological optimization, however, requires computers larger than any now in existence. Computer techniques that provide economic optimization of large systems which take into account social restraints also are needed.

Planning unit – For rather obvious reasons, the river basin continues to emerge as the most desirable unit for planning. However, society is not necessarily organized on a river-basin basis.

River-basin planning should not disrupt economic or social needs which are organized differently. For example, the optimum future development of the entire existing Utah community should be served by Utah's interests in the Colorado River, even though this community extends beyond the Colorado Basin.

National organization – Presently some 25 units in five departments and at least three independent agencies of the Federal

Government have significant responsibility for various aspects of water resource management. There are, therefore, at least eight principal departments or agencies whose activities can be coordinated, other than voluntarily, only at the level of the Executive Office. There have been proposals that all water resources development be consolidated under a single agency whose head would be directly responsible to the President. It is quite possible that this should be done.

One might wonder about the wisdom of developing a powerful agency monolith which could be more resistent to criticism and review than the present agencies and which might well take on particular lines of emphasis to the disadvantage of others. The present structure may have grown around four principal value concepts endorsed by the Congress and which are separately important to society. These are reclamation, flood control and navigation, soil conservation, and pollution control. Each is organized directly under a different secretary and thus has rather easy access to political review by the public and the Congress. These agencies have greater responsibility to the public than simply to execute the construction and management wishes of some super all-wise authority. They rightfully should study the nature and validity of their respective missions and advise the Congress of their findings; but a corollary is that these should be subjected to critical external review and coordination. While this arrangement may have served as a means of achieving a value concensus in the past; modern society ought to be able to invent a more efficient and objective way.

While there are arguments for the status-quo, there are powerful arguments for consolidation of management. Without it, coordination is apt to be compromise.

Of great importance is the involvement of the states and communities in the planning process. The individual missions of the agencies are not inherently homocentric, and it is through state and community involvement that the broad integrated interests of people at the local (consumer's) level may be included.

States and communities have not ordinarily allocated adequate resources to water planning so that they can function effectively as integrative forces in the larger planning efforts. The new Water Resources Planning Act of 1965 which provides for joint state and agency planning on a river basin or regional scale, and for federal matching funds for state planning might prove to be an effective step toward improving the planning process. Whether this will produce truly unified plans or disjointed compromises remains to be tested.

Research — While the need for continuing basic and applied research in the physical and behavioral sciences and technology is urgent, the intellectual community has an even broader obligation — that of overall evaluation and criticism. The intellectual basis for our water resource objective is pretty materialistic and thin. Outside of trying to provide sufficient water by the application of technology to satisfy everybody's physical needs, consideration of national objectives where other values are involved, and there are many, has not been given adequate attention. It is imperative that critical and intelligent voices be raised in the public forum because in the task of molding our water resources policy, we may well mold our racial destiny.

Summary

A major element in the social development of pre-civilized man as he colonized the rainless Mesopotamian plain and rose to the first civilization, was wealth accumulation and institutional experience gained from water resource development in that water-restricted environment. Today, the entire world finds new and important restrictions imposed or threatened by water resource limitations. Again water institution and policy problems occupy positions of utmost importance and our economic, perhaps our racial, future may be tied up in the efficacy of solutions to those problems.

Irrigation development has been utilized as a means of assistance to improve wealth and food production in underdeveloped countries. Production levels comparable to modern agriculture in the West have not generally been achieved, apparently due to problems of social constraint. The social ordering characteristic of ancient civilizations dependent on irrigation has disappeared under population pressure or has not developed. "Thermodynamically" this "high entropy" condition may require large capital investment in entire economic systems and social changes involving demographic and institutional adjustments and population growth restraints if these efforts are to result in economic viability.

While the United States has an ample total water resource, there is an ever increasing number of difficult water resource problems and it is in terms of the sum of these, rather than in terms of national water supply, that the water resource problems must be measured.

Except for irrigation, actual consumptive use of water is only about 3 percent of withdrawals. The central problem of water resource management is therefore water *quality* not *quantity* because the water may be used as many times as quality and location permit. Major emphasis must therefore be given to the problem of waste reduction and disposal. Pollution has a conservative property. It may be transferred to a new medium or its state or nature changed, but it is hard to eliminate it. Further, production of wastes is an inherent characteristic of human life and activity which will never be eliminated. Faced with doubling our national population and increasing our use of raw materials from three to five times in the next 35 years, we will be hard put to stay ahead of pollution and, while necessary, the cost will be very large. Probably our streams and lakes will grow even more polluted, before they become less so.

Regional water shortages may be reduced in the future by long-distance transfers, by desalting, or even by rainmaking. On a national scale it is likely that the greatest benefits will come through improved planning and by control of pollution.

It is in the area of water resource development that the basic question of the impact on nature, including man, of unrestricted population increase may find its first clear focus. While technological advances will go a long way toward increasing man's usable water supply, the time may come when he may find it wiser, in some instances, to adapt to his environment rather than to modify it.

Water resource limitations have recently become important on the national scene whereas they were formerly mostly regional. There is, accordingly, a growing national importance to policy and institutional problems related to water resource development which deserve increased attention. Ideally, water resource planning should place more emphasis on system optimization but the decision-making process should remain within the public forum. Federal Government water development responsibility is fragmented among some 25 agencies. Four major value concepts, reclamation, navigation and flood control, soil conservation, and pollution control are represented by four powerful agencies each in a different department of the federal establishment. From the points-of-view of effective decision making, checks and balances, individual and community interests, and efficient implementation the adequacy of this arrangement may leave something to be desired. The Water Resources Planning Act of 1965 provides for basin-wide planning efforts in which the states participate. The central focus of water resource planning should be the needs of the people.

Water resources development is particularly susceptible to social action. Besides satisfying man's basic needs it provides a convenient vehicle for other social objectives, either formally or informally. In a broad sense an intellectual basis for modern United States water policy is quite incomplete and the intellectual community has a major obligation, which it has almost defaulted, to critically and rationally review water resource policy and the values which our society may gain from its intelligent application. Because of its deep entrenchment in our political processes, the best hope for reform and improvement is through an open dialogue on intellectual grounds.

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Thirty-second Honor Lecture Delivered at the University

February 18, 1966

A basic objective of the Faculty Association of the Utah State University, in the words of its constitution, is:

> To encourage intellectual growth and development of its members by sponsoring and arranging for the publication of two annual faculty lectures in the fields of (a) the biological and exact sciences, including engineering, called the Annual Faculty Honor Lecture in the Natural Sciences, and (b) the humanities and social sciences, including education and business administration, called the Annual Faculty Honor Lecture in the Humanities.

The adminisration of the University is sympathetic with these aims and shares the cost of publishing and distributing these lectures.

Lecturers are chosen by a standing committee of the Faculty Association. Among the factors considered by the committee in choosing lecturers are, in the words of the constitution:

> (1) creative activity in the field of the proposed lecture; (2) publication of research through recognized channels in the field of the proposed lecture; (3) outstanding teaching over an extended period of years; (4) personal influence in developing the character of students.

Dr. Peterson was selected by the committee to deliver the Faculty Honor Lecture in the Natural Sciences. On behalf of the members of the Association we are happy to present this paper: MAN AND HIS WATER RESOURCE.

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by Willard Gardner

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by Orson W. Israelsen

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