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WATER AND THE CONSERVATION MOVEMENT

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WATER AND THE CONSERVATION MOVEMENT[1]

By Luna B. Leopold

Every age has its unique touchstone, its hallmark. The Nineties were thought gay. The Twenties had jazz and John Held, Jr. The Thirties had breadlines, dust bowls, the forgotten man. And each recent period has been studded with so many flashy gems, both paste and genuine, that no hallmark would alone be enough to label it.

Of the present age, one of the nameplates will carry the word "Conservation." The first time a museum visitor walks by that label he will probably stop, push back the plexiglas globe of his space helmet and say to himself, "I never thought that conservation was a keynote of the Fifties." But I imagine he might agree as the pathetic truth of that label dawned on his tired body, accustomed to canned entertainment, synthetic flavors, and fighting the afternoon traffic of the jet lanes. I can imagine him musing: "Conservation, the hallmark of the Fifties. Somebody about that time said about something or other, 'too little and too late.' "

If our generation is destined to leave that impression of our efforts, it will not be for lack of trying. Our trouble is, in fact, that Conservation has been so well advertised, so well sold, that it has become a popular item. Everybody is wearing one. We Americans are going to conserve forests, soil, birds, fish, metals, oil, water, coal, wilderness, and several other things. In the name of conservation our generation is going to build dams and prevent the building of dams; we are going to protect the wilderness and develop the wild places for mass recreation; we are going to protect wildlife, and poison wolves, coyotes and prairie dogs. For everything we Americans favor in the name of conservation we also favor the antithesis; it all depends on whom you ask.

When discussing conservation we tend to confuse two rather different aspects of the use of natural resources. The concept of conservation when applied to renewable resources, soil, water, and forests for example, might mean the use of the resource on a sustained yield basis. In other words, use at a rate and under such conditions that, on the average, the resource is replaced as fast as it is utilized.

When applied to nonrenewable resources, for example, the metals, and oil and coal, conservation might be described as orderly development without undue waste.

These simple definitions do not cover all cases but for the present discussion I wish to emphasize basic issues and ideas, relatively unconfused by distracting complications.

A second idea which I believe must be understood is that conservation means different things to different people. Conservation has been defined as the greatest good for the greatest number. I strongly protest this definition. So diverse are the interests of different groups it is nearly impossible to decide what is the greatest good, or to identify that intangible greatest good with any specific group of people who would constitute the majority.

Let me devise an example to clarify this point. Imagine a mountain area which is attractive enough to be potentially designated a national park, national monument or state park. Assume further that the area contains a diverse wildlife population and rivers that have potential for irrigation storage and hydroelectric power development.

To develop the area for one use precludes certain other uses. If the area is made a park, fishing but no hunting would be allowed. In some types of park no dam would be allowed for water storage or power development. On the other hand, if a resevoir is built, capacity used for storing water for irrigation is not available for flood control. Though a reservoir is useful for some kinds of recreation opportunities, other kinds may be curtailed.

How do you identify the greatest good among these possibilities? One may answer that the greatest good is measured by the largest financial return. That definition may be partly satisfactory for measuring power, irrigation, or perhaps some other uses, but long experience has demonstrated that esthetic and ethical values cannot be measured in dollars. Every time we try it the value so assessed is unrealistically low, or else the dollar value is measuring the wrong aspect.

Take recreation. Is the value of a park measured by the gate receipts plus the dollars spent at the hot dog concession, plus the gasoline sold at the filling station? Obviously this is too small a measure of real value of a park, and is a measure only of the least meaningful aspects of it. Is the value of the fishing measured by the dollars spent on tackle, plus boat, plus outing clothes, plus gasoline? Everyone knows that the dollar cost of a fish taken on a fishing trip is exorbitant. A true fisherman does not assess the cost in that way. I suggest you try placing a dollar value on that subtle thing you feel when you dangle your feet in the lovely lake and look across the blue water to the haze on the other shore.

All engineering projects are studied to assure an economical design. The benefits over a certain period of time must equal the costs. But in many instances engineering projects compete with other possible uses

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[1] Address at Chautauqua N. Y., July 9, 1957.

of the resources, the benefits from which are not so simple to estimate. Present practice is to place a value on wildlife, on recreation and on other associated uses; present practice has also demonstrated that it is an unsatisfactory system indeed. Esthetic values cannot be expressed in dollars and I assert that we should desist from trying to so assess them.

This analysis shows that to determine the greatest good is difficult indeed. If we could do so, could we identify the beneficiaries in order to assure ourselves that we are benefiting the greatest number of people? Are the benefits accruing to 50 fishermen to receive the same, less, or more weight than the benefits to 50 businessmen, or to 50 irrigators, or to 50 people in need of power or flood control? I cannot answer that. We might remind ourselves that the man who sells gasoline to a tourist may also be a fisherman, and he may also need both power and flood control. Such an analysis indicates to me that each person or each group is for conservation, because he is applying the word to the things that interest or benefit him.

With this general statement in mind let us examine the field of water-resource development. All of us recognize that we are part of a growing nation, burgeoning with new industries and new babies, and we are using water at an unprecedented rate. Therefore all of us think that the conservation of water is necessary and desirable. Just what would we mean by water conservation? As a prelude to an attempt to answer that question, let me review some hydrologic facts.

Water is a resource which we call renewable. Though water is constantly flowing to the oceans it is being replaced by rainfall. The amount of water which falls each year as precipitation averages about 30 inches for continental United States. That is, the water falling annually as precipitation would cover the whole area of the country to a depth of about 2½ feet.

Part of this water sinks into the ground and part runs off the surface, collects in stream channels and flows to the sea. Much of that which sinks into the ground is taken up by plants and returned to the atmosphere by transpiration through the leaves. Part of the water sinks deep enough into the ground to add to the free water of the saturated zone. The top of the saturated zone is what is called the water table.

This ground water is seldom stationary, but flows slowly under the influence of gravity. Ground water tends to reappear sooner or later at the surface, either in stream channels or along the margins of the continent in the ocean. To clarify this, did you ever wonder how rivers and streams may continue to flow during long periods of no rainfall? The flow in rivers during fair weather is water draining slowly out of the ground into surface streams. It is very important to keep in mind that ground water and surface water are not separate and distinct, but closely interrelated, as if they were two reservoirs piped together.

Most of the water which flows in surface streams has, in fact, already been infiltrated into the ground, and is reappearing in the form of surface flow in the river channel. Only during intense storms does over-the-ground flow occur which contributes runoff directly to streams without passing through the ground.

The amount of water that is returned to the atmosphere by direct evaporation and by the transpiration of plants is a large percentage of the total which falls. Only about one-fourth of the precipitation that falls over the country reaches the sea in the form of runoff. If three-quarters of the rain which falls does not reach the rivers and then the sea, is it wasted? Certainly not entirely, for from that three-quarters comes the water used to grow forests and agricultural crops—all the living green plants which are necessary to maintain life and to provide the organic materials we wear, the food we eat, the lumber we build with, and other organic things which we need and which moderate our climate. One can ask how efficiently that three-quarters of the total is applied to the production of useful biologic products, but I shall not discuss that large subject in this brief presentation.

Let us look at the other one-quarter of the water which flows in rivers to the sea. A quarter of the precipitated water is not transpired or evaporated to the atmosphere and is the portion we draw on for our use. It is necessary at the outset to define what we mean in the present discussion by "water use." When passing through the turbines of a hydroelectric powerplant water is not altered, diminished, or in any way consumed. Therefore we define one type of water use as nonconsumptive—a use which does not diminish the supply.

In contrast, consider water used for irrigation. The whole purpose is to put water in the soil where plant roots can absorb it. Most of the water taken up by a plant passes out of the stomata of the leaves into the atmosphere as vapor. A small part of the water taken up by the plant is used in the photosynthetic process, that is, in the manufacture of sugars or, let us say, plant tissue. Thus if irrigation is completely efficient, all of the water is lost to further use because it is returned to the atmosphere. We may say that such water is consumed.

The principal uses of water withdrawn from surface streams or from the ground include irrigation and municipal and industrial supplies. Irrigation is the primary consumptive use of water. By no means all of the water diverted—taken out of a stream or pumped from the ground—is lost to the atmosphere. There is considerable inefficiency in the irrigation process. Water seeps into the bed and banks of unlined canals, a considerable part sinks down into the ground out of the reach of the roots of the irrigated crop, and some is evaporated directly to the atmosphere. We will return to this matter and consider the quantities involved in a moment.

A principal use of water is for public supplies. By no means all of the water withdrawn for public supplies is used in the household. Just as you sprinkle your lawn with water from the tap, that is, you sprinkle with clean or potable water, so also industrial plants use a large amount of water from public supplies in their manufacturing processes. These industrial uses include washing, dilution, cooling, steam generation, waste disposal, and some water is used up in the product manufactured. Thus industrial plants use up or consume some water, but a relatively small percentage compared to irrigation.

Though a large number of industries buy water from public supply systems, and even larger number develop individual supplies either by drilling their own wells or by developing surface supplies from lakes or rivers. We can, therefore, speak of self-supplied industrial use as different from use of public supplies.

Household uses include cooking, washing, sanitary uses, waste disposal in the kitchen sink. The home owner also uses some water for irrigation or sprinkling. Household uses are like industrial uses—mostly non-consumptive. The largest part of water used from public supplies is returned to sewers and thence to surface streams.

Rural uses of water are mostly for domestic purposes and stock watering, and thus are partly consumptive.

Water power is an important use in terms of the amount of water passing through turbines but is non-consumptive in character. Because water power use does not involve withdrawal from the river or the ground, I am not going to discuss it further here.

In the United States as a whole, the present water use, excluding that for water power, is about 240,000 million gallons per day. Remembering that three-quarters of the total precipitated water normally returns to the atmosphere, the total available one-quarter consists on the average of about 1,200,000 mgd. Thus we now use about one gallon out of every 5 available, but consume only a portion of each gallon we use.

Let us now consider which of the various uses are the largest.[2] Use of water for development of electric power is excluded from the data below.

	Million gallons per day	Total Withdrawn (million gallons per day)	(percentage)
Public Supplies		17,000 mgd	7
Rural Use		3,000	1
Irrigation			
Delivered to farms	81,000		
Conveyance losses	29,000		
Total withdrawn	110,000	110,000	46
Self Supplied			
Industrial		110,000	46
Approximate total		240,000	100

This means that 92 percent of all the water withdrawn for use is made up of irrigation and self-supplied industrial uses. These two are about equal in amount. One of these two uses, irrigation, is by far the largest of all consumptive uses. It is not an efficient use in that only about three gallons out of every four diverted are actually delivered to the farm; the other gallon is lost in conveyance. That which is delivered to the farm is, to a great extent, returned to the atmosphere. Part of the water delivered to the farm, as well as some lost in conveyance, sinks into the ground. Portions may recharge ground-water supplies and some reach surface drains and thence stream channels again. It must be recognized that water which wets the soil particles will eventually be evaporated or transpired, and only after the soil is moistened can water percolate downward through the pores or interstices to the ground water table. Now transpiration, like any evaporative process, leaves the salts or dissolved minerals behind. Thus return flow from irrigation, that is, the part not transpired to the atmosphere, is higher in salts than originally and sometimes cannot be used again for irrigation because of the concentration of dissolved material.

Returning to water withdrawn for other uses, let us review what happens to it. Public water supplies are to a large extent treated to purify the water. Usually this consists of settling or filtration to get rid of the particles of foreign material and to oxidize organic matter; subsequently nearly all public water is chlorinated to kill the remaining germs. Water delivered to your house has been treated for your protection and this costs money. Yet the amount supplied is so large in comparison with the cost, that we are used to paying but a preposterously small charge for what we are getting. We pay on the average about 5 cents per ton of water delivered at our kitchen sink. Imagine what we pay for a ton of anything else, coal, gasoline, food, or structural steel. The low cost of water is undoubtedly one of the things which made our present standard of living possible, for it means that water for cleanliness, health, and convenience is available to nearly everybody.

After we have used the water, it goes down the drain into the sewer. Here is where one trouble lies. Public water-treatment plants serve 115,000,000 people in the United States, but only part of the communities treat the water before discharging it back into the rivers. Of 12,000 municipalities having sewers, that is, disposing of waste into streams, only 6,600 have sewage treatment plants. Municipalities with sewers serve a population of 92,000,000 persons, but sewage treatment plants serve only 56,000,000[3]. Thus less than 2/3 of the cities have sewage treatment and many of the existing plants are inadequate to treat all the sewage coming to them.

Of a sample consisting of 2,600 industrial plants, only 1,100 or about half are known to have adequate plants for treating their waste water. If the untreated waste of industry and of municipalities is considered together, the amount equals the sewage waste of a population of 150,000,000 persons[3].

Considering the averages just discussed one could summarize by saying that this country is fortunately endowed with large amounts of water of which about a quarter of the total is available to draw on for our use. On the average we are using only one gallon out of every five available and one might suppose, therefore, that there is water a-plenty. Shortages occur because of nonuniformity of distribution in time and geographically. These characteristics of maldistribution are to be expected from the fact that we live on a large continent at middle latitudes and the continent is varied in topography.

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[2] Data adapted from MacKichan, K. A., 1957, Estimated Use of Water in the United States, 1955; U. S. Geol. Surv. Circular 398.

[3] Data from "Water Pollution in the United States," 1951, U. S. Public Health Service.

The climates in the United States are determined principally by the size of the continent and its position relative to other continents and the oceans on our earth. Large continental masses tend to be hot in the summer and cold in the winter, owing to the fact that the ground surface can store but small amounts of heat energy. By its effect on air masses and general circulation, a large land mass influences the path of moisture carried inland from the adjoining oceans. Over the United States the principal sources of moisture are two. Air masses which originate over the Pacific tend to move inland from the West Coast. The second moisture source is the Gulf of Mexico, from which air masses sweep in a great quarter-circle northward and eastward from the Gulf to the Atlantic Seaboard.

On the West Coast the climate is comparable to that of the Mediterranean, with dry summers and maximum rainfall in winter. This gradually changes from West to East; the central United States is characterized by a continental climate of cold winters and hot summers and the maximum precipitation in summer. It can be seen, therefore, that the size and position of the continent on which we live, as well as the distribution of mountains and plains, create nonuniform distribution of precipitation in both time and space. This implies that at certain seasons of the year water from precipitation is relatively plentiful and at other seasons deficient.

Superimposed on this geographic and seasonal variation in precipitation is a year-to-year variation. Each successive year is somewhat different from the last— some high in rainfall and some low. The areas blessed with the largest total tend also to be subject to less year-to-year variation. On the other hand, as if semi-aridity were not already a sufficient lack of fortune, such areas bear the additional burden of the greatest variability. Portions of west-central Texas, for example, are semi-arid, to say the least, and yet hold some world's records for excessive storm precipitation, and for flood discharges from drainage areas of particular size. It can be said, therefore, that a basic element of our water problems is that some areas and some periods are water-deficient.

Geographic characteristics combined with the historical sequence of events in our country's development were factors controlling the present pattern of water occurrence and water use. In the western half of the United States three-quarters or more of the total water use is for irrigation. In the eastern United States three-quarters or more of water is for industry. From these same geographic and historical facts emerge the water problems of the present day. As matters stand now, water immediately available and inexpensive to utilize at each individual point is already put to use. Further expansion of any individual use must be balanced by a decrease in some other use or some attendant cost. For example, the growth of the large metropolitan centers in the West depends on increasing supplies of water. In order to get these increased quantities either some other use must be curtailed, or water must be transported from areas of excess to the place where supplies are needed, and at costs far in excess of the cost of similar amounts of water developed in the past.

If expanding industry in the East is to have the additional water supplies needed, it will usually be necessary to treat that water to improve its quality and thus the expense will be much greater than in the past when the readily available water was of requisite quality.

So it can be seen that water problems are of three basic types. Water may be immediately available but may be of improper quality and, therefore, treatment is necessary that may or may not make the cost prohibitive. The first problem is the problem of cost. The second type of problem is that associated with a physical shortage of water sufficient for the desired uses. This also reduces to a matter of cost because to increase the supply in an area which is deficient in total amount requires either that the money be spent to bring water in from elsewhere, or the use itself must be moved to the place where water is available.

The third problem is the legal problem of water rights. If a particular use can actually bear the cost of developing a new source, or transporting water from a great distance, it may be prevented from doing so because of the fact that others have the legal right to that water. In such an instance the legal owners must be paid to relinquish their right. This also, then, reduces to a question of economics, presuming that if one can pay a high enough price he can purchase even something dear to the present owner.

I have dealt with these general water problems in a most cursory way, and it should be recognized that in actual practice there are many ramifications. It is nevertheless true, I believe, that poor quality of water, physical shortage of water for all uses, and legal rights to water all have a common economic base. To the man who can pay enough these problems are soluble. Whether the price necessary can be justified by the benefit received is the issue. The economic justification, however, is partly influenced by what we have been accustomed to consider to be the value of water. Only now are people beginning to realize that we have always obtained water for bargain prices. We must steel ourselves to a new concept of what water really is worth. The economy will gradually reflect this realization.

None of the problems cited so far seem to have any specific bearing on the idea of conservation of water. Let us, therefore, refer back to the definitions of conservation mentioned earlier in an attempt to identify water problems which could be called problems of water conservation. By one set of definitions, conservation, we said, has two aspects; use on a sustained yield basis in the case of renewable resources, and orderly development without undue waste in the case of nonrenewable resources.

Are we using water on a sustained yield basis? In the broadest sense the total water budget can be affected but little by man. Water is continuously regenerated and purified in the natural process called the hydrologic cycle. From ocean to atmosphere, to the land and back to the air by evaporation or to the ocean in rivers, water moves in a never-ending cycle. As it passes within our reach, we use water as we need it. After its temporary service it continues its natural course in unending circuit.

But at any given place or in any short period of time we can indeed use it faster than it is supplied. In water we can draw on storage, gradually depleting it, just as in handling money we can draw out of our capital rather than live on the interest of our money. What is the nature of this storage? The principal example is in ground water. An immense amount of water is stored in the principal aquifers, or water-bearing formations, in the United States. As water is drawn from these aquifers it tends to be replaced by infiltration of precipitation, but it is quite possible to pump water out faster than recharge is replenishing the storage. Water moves slowly underground and the stored supply in some places accumulated over a very long time. The falling water tables we read about occur as a result of pumping faster than the rate of natural replenishment. We call this "mining" of ground water. There are many places where pumping has caused a serious lowering of the water table, but this is by no means universal over the country. The trouble spots are mostly concentrated in California, southern Nevada, southwestern Utah, southern Arizona and New Mexico, west Texas, and southwestern Louisiana.

Ground water is being mined in these areas because currently it is financially profitable to do so. Continued overdraft will sooner or later—and I might add quite soon in some places—mean either exhaustion of the stored supply, or such an increase in pumping cost as the depth to ground water increases that pumping becomes financially unprofitable. In certain areas the exhausted aquifer will not become replenished in the lifetime of our grandchildren or their grandchildren.

Mining of ground water is a problem in conservation in the truest sense of the word, because it involves the principle of exhaustion rather than sustained yield of a renewable resource.

Another aspect of conservation in the water field is related to the concept of waste of a limited resource. We sometimes hear about the need for conservation of that water which is wasted in flowing to the ocean. One of the principal uses of surface streams in a civilized economy is for the purpose of transporting and diluting waste products. We would be quite unrealistic if we supposed that water that reaches the ocean in a surface stream has been wasted. If there were no water in such streams it would be necessary to pump water from the ground in order to put water into stream channels, or into pipes, to carry industrial and municipal wastes to a disposal area.

In this light, therefore, it is logical that we should dump wastes into rivers, but the problem comes in how much waste and in what condition. A great many waste products, industrial as well as sanitary, are decomposed easily in the presence of oxygen and, after such oxidation, become inoffensive as far as odor, color, and other normal qualitites are concerned. Some bacteria are also destroyed in the oxidation process. Most normal surface waters contain a considerable amount of dissolved oxygen and when waste is dumped into such water the oxidation process begins naturally. If there is not an overload, the oxidation goes on to completion. When, however, more waste material is put into the stream than can be decomposed by the available oxygen, it is then that our olfactory and visual senses are outraged and hygiene endangered.

Granting that some water passing to the ocean constitutes a use rather than a waste of water, we may ask whether the loss of flood waters to the ocean is a waste. Flood waters can be stored and distributed over a period of time allowing more utilization of the water. To set the stage for an answer to this question we ought to know how much water actually passes during a flood as compared with normal periods of high water and low flow. A flood can be defined as a discharge in excess of channel capacity. Flood damage results from water flowing over the flood plain at times when the discharge is greater than can be contained in the normal stream channel. A computation shows that on the average the amount of water discharged by a river during those periods when the flow exceeds channel capacity, amounts to about 5 percent of the total annual flow of the river. Thus it can be seen that the proportion of the total water which can actually be conserved by storing it during periods of damaging flood is relatively small.

The effect of storage in reservoirs is to iron out the irregularities of flow and thus gain control over as large a portion of the available water as the reservoir capacity will allow. There is a definite limit, however, to the amount of control which can be exercised by reservoir storage owing to the fact that the second unit of storage provided in a drainage basin gives less control than the first unit, the third unit still less and so forth, following what is popularly called the law of diminishing returns. This can be exemplified by considering a sharp-crested hill on which we want to develop a flat piece of ground to build a house. Only a small amount of dirt removed from the sharp crest of the hill will develop a flat area wide enough for a one-room cabin. But to widen the area to accommodate a two-room house we must move away and dispose of a much larger amount of dirt; to build a three-room house even a much greater volume must be moved. To develop the absolute maximum possible space requires that we move the whole mountain.

Now the flood has a sharp crest and is triangular in form, as is the hill, for it has a rising side and a recession side. The peak flow is the top of the triangle. We want to store the peak in a reservoir, and the amount of storage is comparable to the amount of dirt removed from the mountain. To eliminate the flood entirely we must store all of it, just as we had to move the whole mountain. To gain each successive increment of control of flood water requires a larger volume of storage. The same principle applies to carrying over water from a year of ample streamflow to furnish water during a dry series of years. Every increment of control costs more than the preceding one.

How much of the maximum possible control of water have we gained by the reservoirs already built in the United States? In the Southwest the available reservoir storage is well along toward a large percentage of possible control, owing to the fact that reservoir storage has been justified by irrigation. In eastern United States the reservoir storage is, on the whole, so small that only a minor part of possible control is being exercised. However, the East is so blessed with relatively high and uniform precipitation that to date only a small amount of control has been necessary. The future will no doubt see development of a larger percent of control as water needs continue to expand.

Loss of flood waters to the ocean, then, is not the same kind of problem as mining of ground water because failure to develop a resource is not waste. Development will come naturally when the need arises and development costs can be justified by the benefits. This, then, is another problem of economics.

Stream pollution has been called a problem of conservation. Most individuals know that pollution exists, but the problem is somewhat abstract, or at least distant from his daily life. The ordinary citizen is usually not acquainted with the practices even of his own city. We abhor the idea of insufficient sewage-treatment plant capacity to treat the wastes from American cities, but passively condone the existence of inadequate treatment of sewage from the city in which we live. Water treatment costs money and, as in the case of most other water problems, the root of our difficulties is what we are willing to pay for, and how much. I think you will agree that the figures are deplorable and even astonishing. Let me repeat them. In the United States the untreated waste of industries and cities is equivalent to the untreated sewage of a population of 150, 000, 000 persons. It is probable, therefore, that among us here not one person in ten lives in a city which treats all of its municipal and industrial waste.

Pollution, then, involves both the economic and the esthetic or ethical aspects we have mentioned. The technology is readily available to eliminate the pollution problem. When we consider the intangible niceties of having clean streams, we are placing an esthetic or ethical value on the resource. However, to gain the esthetic advantage requires money, and as a whole, the American public has been willing only to foot the bill for some control of pollution but by no means for a complete job. Yet progress has been made and the outlook is heartening. Treatment of wastes, after all, is justified as both a public health measure and as an esthetic measure. Public health is a field in which we are willing to spend money though the benefits cannot be measured in dollars and cents.

I have attempted to analyze a few broad problems in the field of water resources as they bear on the conservation movement. Conservation as a concept is based essentially on the desire to provide for our grandchildren some values which we enjoy but which can be destroyed. Looking toward the preservation of these values, the conservation movement has resulted in the recognition of two lines of action—sustain the yield of renewable resources, and develop in an orderly manner without undue waste, the nonrenewable ones. Both of these courses of action are based in part on esthetic, ethical, or at least nonpecuniary considerations—social rather than economic values, if you will.

Our vicariousness prompts us to invest esthetic and ethical value with special merit or consideration, and we label these things with special names. In this instance we give special consideration to causes or to actions which can be labeled "conservation practices." We are, therefore, likely to have many quite different causes or actions presented to us as conservation when in fact they are quite antithetical to conservation. These tend to ride the coattail of a popular movement. I suggest that we examine more critically issues and practices which are called conservation and reserve our special consideration for those ethical and esthetic values which cannot compete in a strictly economic world where everything must have dollar value. We must be willing to stand up and assert that there are some things which we as a nation want, but which in purely economic terms would be described as valueless or sheer luxury. To preserve such values it may be necessary to decide a-priori that we want them and assign to them high priority without attempting to put a price tag on the benefit received. If we want a particular canyon, a rare species of bird, or a particular valley preserved because of its scenic beauty when threatened by some other use, strictly economic comparisons will seldom result in its preservation. The reason for this is that we have not found, and in my opinion we should stop looking for, ways of placing dollar values on scenery, on recreation, and on that intangible mental well-being which we associate with beauty. In this sense I think there is a real need for conservation in the field of water. Clear streams which are natural in their settings, nice to look at and pretty to fish in, have a certain esthetic value which defies the dollar. Some of these at least must be conserved if we are to leave to our sons and daughters what this country naturally provided to us and to our forefathers.

With this very important exception, I believe that the word conservation is being misused in the field of water today. All our other water problems are problems of shortage due to geographic and time variations, which, important as they are, can be reduced to problems of economics. Economic problems gradually become solved by the play of forces inherent in the market place. Water will be used in those places and for those purposes which can best afford to bear the cost under prevailing conditions.

Let us, therefore, cease to confuse the basic meaning of conservation with problems which are strictly economic. Those of us who are interested in conservation values as I have defined them see a real need for conservation in the field of water, but if we continue along our present course, trying to place dollar values on sunsets and canyons, there will soon enough be little of the best left to conserve.

THE NATURE OF OUR WATER PROBLEMS[4]

In south-central Wisconsin my family has a weekend retreat which we call The Shack. It consists of a couple of hundred acres of marsh, prairie, and swampwoods, no good for farming, but replete with a valuable commodity—solitude.

The Shack sits on a sandy terrace about 300 yards from the Wisconsin River. When we bought the place there was no water supply, so we drilled a hole about 10 feet deep, put down a pipe fitted with a well point, attached an old fashioned handle-type pump, and we were all fixed. To get a drink you just pump the handle a few times.

But we also hand-planted native wild flowers and some thousands of pine seedlings because we wanted our land to bear a sample of the original vetetation of the area. During dry summers hand-carried pails of water went from our little pump to water the nearest trees, but a water pail was hardly adequate for a complete job. As a result we lost a good many trees over a period of years.

The nearby river is quite unfit to drink but we swim in it nevertheless. The fun of swimming in your birthday suit quite outweighs the fears of getting a mouthful of germs.

Now it is immediately evident that we have no physical shortage of water at The Shack, but this does not prevent us from experiencing water problems. First consider the pump. There is an adequate supply of good quality water right at the door. To develop this supply for drinking purposes required a small expenditure which was obviously justified. But because of our agricultural pursuits we needed water over and above that for drinking. The technology was available in the form of a modern gasoline motor to pump water either from our shallow well, or from the river, to irrigate our crop. We chose not to avail ourselves of the gasoline-driven product of modern civilization. We preferred solitude to a put-put, and so would not put a motor near The Shack. To pump from the river at a distance from The Shack would be too expensive.

We had another problem. The river water is of inadequate quality for general purposes and marginal for the specialized need inherent in our operation—that is, for swimming. Therefore, we get along, but are somewhat less than fully satisfied with our situation.

This backwoods layout has most of the elements of modern water problems. Counterparts can be found in the operation of a farm, a home, a city, an industry, a State, and the United States as a whole. It is my purpose here to review first the general nature of these problems and then to analyze how the various elements comprise the problems of State and of Nation.

First is the question of total available supply; physical shortage of water in a particular area constitutes one general type of problem. As I will demonstrate, most areas are in the same position as The Shack—no general physical shortage. However, variations from year to year and season to season may cause difficulties.

A second principal problem is that of water quality. The available water may be of such quality that it would be satisfactory for some purposes but not for all desired purposes. We will swim in the river but would not drink of it.

A third principal kind of problem is economic. Even if water of satisfactory quality is available, the desired use may not justify the cost of developing the supply. We do not consider the cost of pumping from the river to our trees to be worth the tariff.

Different persons would make quite different categories to describe water problems, but for present purposes I believe one can say that the three types of problems just listed are general ones. There may be consequent or correlative problems. Water development, though economically justified, may compete with other uses of the area.

Attempts to resolve conflicts equitably has created other problems which are legal in nature. The physically available water may, in certain circumstances, be appropriated—that is, legally owned by another party. As riparian owners in a Midwestern State we had no legal problem at The Shack. The correlative problems may also involve balancing of economic against esthetic values. At our shack water development by gasoline pump competed with a major recreational use—solitude. The counterpart of this conflict is well known in cases where water development by a large dam would compete with maintenance of an area for its scenic and wilderness value.

This then is the structure of our water problems. The scheme of my further analysis will be to discuss how these general problems appear in actual practice, first in the Nation as a whole and then in a few localities as examples.

To begin, we must consider the magnitude of our total supply of water and its relation to present needs. The United States as a whole receives an average of about 30 inches of precipitation annually; that is, the annual fall would cover the whole country to a uniform depth of some 2½ feet. About 3/4 of the total precipitated water is returned to the atmosphere by evaporation and transpiration. The remaining 1/4 constitutes the water available for withdrawal use; if expressed as an average yield it would amount to 1,200,000 million gallons per day. To make this easier to visualize it can be expressed as 7,500 gallons per capita per day. This amount is about what would be contained in a cubical box 10 feet on a side. This figure is cited as a base for comparison with present water use in the United States

In the following discussion of water use I will deal with water which is withdrawn from surface streams or

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[4] Address before American Association of Newspaper Editors, San Francisco, Calif., July 12, 1957.

from the ground and not with water used to develop electric power.

The principal uses of water are irrigation, industrial supply, and municipal use. Industries developing their own supply rather than buying water from a city make up 46 percent of the total water use in the United States. Approximately an equal amount, or 46 percent, is used for irrigation. Water use for public supplies constitutes 7 percent of the total, and rural use 1 percent.

Irrigation is the principal consumptive use of water. Public water supply use and industrial use are only partly consumptive.

We can summarize the total picture of water availability and water use by saying that, at the present time, Americans are using only one gallon out of every five available. Of each gallon now being used, only 7 percent is used for public-water supplies. The remaining use is divided equally between irrigation and industry. We can say, therefore, that there is no over-all shortage of water in this country.

However, water aplenty does not prevent us from having serious local problems. These local problems result from the uneven geographic distribution of water over the country, as might be surmised from the regional distribution of precipitation. Similar types of problems arise from the season-to-season and year-to-year variation of precipitation in any given area and the more or less fortuitous occurrence of series of dry years.

Let us now view the second principal problem—water quality—as it applies to the United States as a whole. Water shortage can develop wherever the available supply is not of requisite quality when the use intended does not justify treatment to improve its quality. All waters contain dissolved salts, in variable amounts. All uses of water have a limiting amount of salt that is tolerable but there are particular limits on the kinds permissible. Irrigation demands water low in sodium and boron, municipal, low in hardness, and industry has many special requirements. Besides the natural load of salt, man uses water as a vehicle to transport wastes. Despite the heartening growth in the number of industries that are treating their waste water and the number of communities constructing adequate sewage treatment plants, in general we have been polluting the surface waters of this country at an increasing rate. Although carrying wastes is itself a necessary use of water, an excessive load of wastes impairs the further use of water. To this extent waste treatment can be considered water reclamation.

Before elaborating on the nature of local water shortages, let us consider the problem of economics which we listed as a third principal problem. At the present time the average cost for water is about 5 cents per ton delivered at the tap. Because of the over-all abundance of water in our country we have grown accustomed to the idea that water is a commodity as free as air. At 5 cents a ton one might say this is practically true. It is literally correct to say that water is "cheap as dirt," because you could not get dirt delivered at your doorstep for 10 times that price.

With rising demands for water it can be expected that the price of water must increase as the economic competition for available water becomes keener and as more expensive sources become developed.

Even with the price as low as it is, cost alone may make water a limiting factor for a particular use. Many irrigation farmers in the Southwest are growing cotton with water developed by pumping from an aquifer. As irrigation from ground water spreads in an individual area, at least in dry years, there is often a tendency to pump water from the aquifer at a rate greater than it is being replaced by infiltrated precipitation on the recharge area. During such periods the ground-water table will drop. The cost of electric energy becomes a principal item in the production of a crop, exceeding the amortization of the capital invested in the development and installation of the well and pump. The lowering of the ground-water table under the conditions outlined will increase the cost of pumping, and this increase may proceed to a point where the economic returns from the sale of the crop will no longer pay for the electric power necessary. Under such circumstances a water shortage can be said to have developed—an economic shortage rather than a physical one.

As another general type of example one might point to the fact that in an area of limited water supply a larger profit may be realized by using the available water for one use rather than for another. For example, a larger return may be realized from an industrial use rather than for applying the same amount of water to irrigation. A recent study published by a prominent consulting engineer, Shepard Powell, claims that for the United States as a whole, a unit quantity of water produces more than one hundred times the economic return when used by industry than when used for irrigation. [5] Considering that industry can pay more for water than can irrigation projects, as the West develops further one may expect to see a gradual shift of water use in the semiarid areas from irrigation toward industrial use. Such a shift could be expected as a natural result of the play of economic factors in an area where such a difference in return obtains.

Tightly woven in the fabric of the three kinds of water problems I have outlined is resolution of conflicts among contending demands and uses. Law is the social vehicle for adjusting uses equitably. Law is itself not a water problem but a consequence of those problems.

We find, almost without exception, that where water-resource development is seriously handicapped by legal restriction either technology or knowledge of actual conditions is inadequate. Inasmuch as our legal bases were laid many years ago, it is really to the credit of our courts and legislatures that we do as well as we do. For example, many laws and decisions have employed such terms as "diffuse surface waters," "underground rivers," and similar terms which either exist only rarely in nature, or which so poorly describe the conditions existing in nature that the terms are subject to equivocal or antithetical definitions. Nonetheless, these terms were the best available at one time to define equities in a complex situation. However, today we have the problem of writing codes for the administration of the use of ground water and I know of no more difficult task in the water-resource development field.

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[5] Powell, Shepard, 1956, Relative economic returns from industrial and agricultural water uses: Jour. Am. Water Works Assoc., v. 48, No. 8, p. 991–992.

Another complication to the legal problem is the different concept underlying the laws in the western as compared with the eastern States in this country. Eastern law is generally based on the idea of riparian right; that is, that the right to water belongs to the person whose property abuts the river channel or lake shore. In many States the riparian owner is free to use the water of a surface stream, provided he returns the water to the stream undiminished in quality or quantity.

Owing to the importance of irrigation in the development of the West, western water law is based on the concept of prior appropriation; that is, the right to water depends on the application of a given quantity to beneficial use and the priority of the right is determined by the priority in time of such beneficial use.

Over much of the West there is more good land to be irrigated than can be supplied with water. The result has been the total appropriation of the streamflow. Economic conditions have been such that land has been brought into production which cannot be adequately supplied with water even during years of normal rainfall. During droughts of long duration, no water can be supplied those lands because all of the water available is used by senior appropriations.

I believe the problems arising from legal issues are generally reducible to economic or political terms. Landowners with an inadequate supply will attempt to secure supplemental water through storage or transbasin diversion at their own or public expense. Where there is conflict between types of use, there will be a tendency for uses yielding the highest financial returns to acquire water rights from others of lesser value. Such actions are sometimes limited by State law, which has certain disadvantages. There is no way, for example, to insure that the best and most productive lands are favored to secure the greatest return from the use of the water resource.

Let me illustrate now each of the three general problems, quantity, quality, and costs, by particular local examples, pointing out as I do so that these few examples cannot adequately represent the variety of local problems which exist. As the examples show, the three kinds of problem are present in each, differing only in emphasis.

In the High Plains region of New Mexico and Texas supplies of surface water are generally inadequate for irrigation and the scanty supplies would be prohibitively expensive to develop. In this area ground water has been used for irrigation since the early 1900's and water levels have declined continuously in response to pumping from the major aquifer or ground-water storage reservoir, the geologic formation known as the Ogallala formation. Over a large area there is a specific limit to the amount of water stored in this bed and the replenishment of ground water from precipitation is much smaller than the depletion due to pumping. It has been estimated that at the present rate of decline of water levels in several counties in west Texas, the Ogallala formation will be pumped essentially dry in 30 to 60 years, the exact number of years depending upon climatic cycles, farm economy, and water-use practices. Though the physical shortage is not yet immediate, it is not far off, and owing to the meager surface supplies, the area will probably be forced at that time to change the pattern of water use to meet the dwindling supply.

As an example of economic stress as a result of continuing development, the situation in the Chicago area may be cited. Many industrial wells tap artesian sandstone aquifers from 800 to 2,200 feet below the surface. The water in these aquifers originally was under sufficient pressure to flow at the surface but, as a result of heavy pumping, the levels have declined hundreds of feet. However, the aquifer has not been dewatered, so that there is no danger of failure of the supply.

In order to utilize this water, however, wells have had to be deepened and pumps lowered. As a result, the cost of obtaining the water has increased to the point that many users have begun to buy water from the municipal supplies which are obtained from Lake Michigan.

Water quality is the limiting factor in many places where water is withdrawn from a surface stream, returned to the river, and withdrawn again at a downstream point for reuse. Along the Neosho River in Kansas, 12 cities use and reuse the water. Detergents, so prevalent in home sinks and laundries today, are not eliminated in usual municipal water-treatment plants and thus tend to accumulate during reuse. Detergents became so concentrated at times in Neosho River water that suds were formed when water was obtained at a faucet. Several times during 1953–54 the total flow in the river at each city waterworks did not exceed the sewage flow from the city upstream.[6]

A local example of water conflict concerns the use of ground water in Harvey and McPherson Counties, Kansas. An excellent sand and gravel aquifer there contains a large amount of water equal to about 5½ times as much as all the surface impoundments in the State. The natural decline of the water table during the recent drought, even without pumping, has been as much as 10 feet. The city of Wichita develops water from this aquifer and planned to drill some additional wells. Suits against the city were filed by local farmers who feared that the additional development would impair their supply. These actions have delayed the city's work and forced severe rationing during the summer months.[6]

A regional example of a water-right problem is the conflict among Texas, New Mexico, and Colorado over the waters of the Rio Grande. The Rio Grande Compact, ratified by Congress in May of 1939, was presumed to be a means by which Colorado and New Mexico could construct storage reservoirs needed for additional irrigation development and flood control, and operate them without injury to the prior developments under the Elephant Butte Dam in southern New Mexico and west Texas.

Under the compact, storage of water in any reservoir in Colorado and New Mexico built after 1929 was to be regulated in accordance with a system of debits and credits. This system was adopted to meet the variability of runoff of the Rio Grande by providing for the accumulation of debits by Colorado and New Mexico, limited to a fixed amount, in years of low

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[6] Data from Metzler, D. F., 1956, Recommended action against effects of severe droughts in Kansas: Jour. Am. Water Works Assoc., v. 48 No. 8, p. 999–1004.

runoff. A means was provided by which accumulated debits could be erased during periods of high runoff.

For several reasons the accumulated debits of Colorado and New Mexico have exceeded the allowable amount after a drought of almost 15 years' duration. Thus, any storage in Platoro Reservoir in Colorado and all in El Vado Reservoir in New Mexico, except that to provide for Indian rights, is subject to the demands of the lower States. The deficiency has become so great, however, that the compact commissioners have decided to restudy the whole question of water availability. The State of Texas, which being lowest on the river is subject to the greatest shortage of water, is attempting to bring the whole question before the Federal courts.

Any review of problems in a field of endeavor invites some discussion of solutions to the problems posed. My analysis of the nature of problems in the water field is designed to demonstrate what I believe to be a truth, that general solutions are not possible. There has been much written about the water shortage, the water crisis, and the tremendously expanding need for water. There is no denying that in many places there is such a shortage of water that the situation is, or approaches, a crisis. There is no denying that we have seen in the last decade an unprecedented demand for water.

Listed among the possible solutions to the water situation are two which have been given much publicity—increasing the total supply by cloud innoculation—that is, by inducing increased precipitation; second, the conversion of saline water. These I wish to place in proper perspective without deprecating at all the possibilities which they offer.

Cloud seeding has been demonstrated to produce slight increases in the precipitation from seeded storms under restricted conditions—specifically under conditions where air masses are naturally lifted by mountains. New technology resulting from research will, it is hoped, increase the effectiveness of the technique. Even modest increases in rainfall can be a big boon to a city or farmers beset by drought. However, it is agreed by all scientists in this field that under conditions of drought, weather situations giving rise to seedable clouds are abnormally infrequent, and cloud seeding cannot be viewed as capable of breaking a drought or bringing drought relief. Viewed against the fact that in the United States as a whole we are now using only one gallon of water out of every 5 available, increasing precipitation does not appear to me to be the kind of solution which fits the nature of the problem at hand.

Conversion of sea water is in somewhat a different position. Relatively well-developed technology is available to convert saline waters to fresh by any one of several different processes. The principal reason why conversion is not being widely practiced now is a matter of cost. As the demand for water increases, as it may be expected to do with our increasing population and industry, ventures of different kinds will be forced to spend more money for the required water than is necessary now. With increasing costs of water, processes which cannot now compete will become financially practical and under those conditions saline-water conversion will be a usable and practical answer to many a local situation.

Rather than look for overall solutions or panaceas for the water situation, I believe it is necessary to understand the nature of the forces operating in creating the problems which exist. If there were a better understanding on the part of a larger segment of our population as to the factors which lead to water crises, we should be able to avoid many problems before they become critical and would be able to act more surely when they do. I propose, then, to comment on some of these forces and trends in lieu of discussing specific kinds of solutions.

Let us consider what we mean by a water shortage. I have mentioned that a water shortage may result from a real physical lack of water, may be in reality an economic shortage resulting from lack of the financial return necessary to develop existing supplies, or may be the result of inadequate quality of the available water. Who knows there is a shortage when it exists? A shortage does not really count until the man in the street goes into his house, turns on the tap and no water flows out. At that moment there is a water shortage in all reality. The telephones begin to ring and the wheels of public opinion begin to close the vise called public pressure.

Therefore we may ask, why did not the water flow out of the tap. In many an instance it is because the peak load cannot be met by the water distribution system. The mains are too small or for some other technical reason the pressure cannot be maintained under the conditions of peak demand. During a long dry period in a summer when everyone comes home from the office hot and tired, each person turns on his garden hose to irrigate his flower garden, flips on the air conditioner, and steps into the shower. When enough persons do this simultaneously the pressure drops and no water flows to those who are on a slight hill or to those most distant from the reservoir or pumping station.

This situation arises in many a city. Rationing, curtailment of lawn sprinkling, and other measures to spread out the load are usually designed to maintain adequate pressure in the mains. All of these things may happen even when there is plenty of water in the reservoir.

A city council may have foreseen such a situation for several years and tried to promote a bond issue to expand the facilities, but as long as water flows from the tap the ordinary citizen has no personal reason for backing the measure. Thus water shortages and water crises are often the result of lag time between increasing demand and the required engineering work. Physical limitation in the distribution of available water is not necessarily the cause of water shortages.

This leads into the second comment I wish to make. Changing trends in water demand, and thus in water use, will tend to lead to development of water from existing or from new sources as economic forces make such development financially feasible. As in any other field of action, early developments tend to be cheaper than later ones because the most economical source is always the first to be tapped. Boston got along with local wells until after years of inconvenience, recurrent epidemics, and general dissatisfaction, the public became willing to pay the cost of a long aqueduct. This pattern has been experienced in city after city.

Similarly, when an industry finds that available sources of water are either insufficient or uneconomical, and the profits will, over a period, pay the cost of water development, an alternative scheme for water supply is found. This may take the form of developing an individual water supply, paying a higher price for water from an outside supplier, or a shift in plant operation to reuse the water available and thus reduce the total water requirement.

As pointed out earlier, the total supply of water in the United States is large and many of the problems stem from maldistribution in space or time. For the most part, water exists and can be obtained when the users are able to bear the cost. In the case of Los Angeles, a source was miles away and separated by a desert, but when the cost was considered justifiable, the water was obtained.

We must steel ourselves to the idea that further water development cannot be achieved at the price of five cents per ton to which we have grown accustomed in the past.

The next concept which I believe deserves discussion as a background for understanding our present situation is the following: Water control by storage follows a law of diminishing returns and, furthermore, has a specific physical limit. When people speak of conserving water, one aspect which is often alluded to is that of the waste of water flowing uncontrolled to the ocean. It is necessary to say first that water flowing to the ocean in surface streams must serve the important purpose of carrying off and diluting salts and wastes. If we were to control water so stringently that surface streams in an area were either to dry up or to be reduced to too low a flow, we would then be forced to supply water to some surface channels, either natural or artificial, to dilute and dispose of wastes.

As far as the flood-flows that pass to the ocean uncontrolled and therefore wasted are concerned, it is desirable to note the amount of water involved. I speak now of damage-producing flood waters, that is, water which passes through a segment of valley at discharge rates in excess of channel capacity. Such overbank flows are the ones that cause flood damage.

On the average, the water that is discharged at rates in excess of channel capacity constitute about five percent of the total annual discharge of the basin. In other words, the amount of such flood waters is not large.

A small reservoir may be able to store enough water to satisfy demands during a month of dry weather. A larger reservoir may store enough to supply even as much as a year of deficient flow. A still larger one, two successive years, and so forth.

Now, one of the characteristics of streamflow as well as of weather is the occurrence of relatively long periods of subnormal water supply alternating with periods of above-average supply. Our analysis shows that with a fluctuating resource, storage capable of delivering the water indefinitely at a rate equal to the average flow is impossible to obtain short of an omniscient view of the future.

Each successive increment of control desired takes a larger amount of reservoir storage space than the preceding increment. This may be illustrated by visualizing the building of a pyramid. To build a pyramid 20 feet high takes much more than twice as much stone as it would to build a similar structure only 10 feet high.

A flood wave is triangular in shape, like the profile of a pyramid. It has a rising side, a peak, and a falling side. To store enough water to reduce the peak by one half requires much less than half the reservoir capacity necessary to store the whole flood flow. Thus, water control by reservoir storage follows a law of diminishing returns; it takes larger and larger amounts of storage to obtain each successive increment of control.

Furthermore, there is another kind of limit inherent in water control by reservoir storage. As more and larger reservoirs are built the area of open water surface exposed to evaporation increases. Long before a hopeful complete control is exercised, water losses by evaporation may equal the additional water gained by the additional reservoir space.

Our analyses of our national inventory of major reservoirs enable us to report on the present degree of control effected by the existing storage development; including that part, generally less than 20 percent of the total flow is naturally regulated by ground-water storage. Expressing the degree of control by the percentage of the total flow that is available for use, we find that in the Cumberland-Tennessee basins, the existing reservoirs provide a control equal to 50 percent of the total flow. In the Ohio basin, excluding the Cumberland-Tennessee basins, control equals 25 percent. In the Colorado River basin, a large amount, 85 percent control, has already been attained, as would be expected from the large irrigation developments. For the United States as a whole, the percentage is about 35 percent.[7] The Colorado River basin already has reservoir storage built to a degree that approaches the optimum where evaporation losses will eat up any additional water conserved by providing added reservoir storage.

Thus, in the United States as a whole a considerable increase in water can be obtained for use by reservoir development, but places in the West are already approaching the limit.

A third concept I wish to discuss as background to understanding our water problems is the overdraft of aquifers, and the mining of ground water. As I mentioned previously, an aquifer is a porous bed or zone underground capable of absorbing and transmitting water. Ground water is generally in motion under the influence of gravity, moving toward areas of lower elevation or pressure. Recharge is the replenishment of water which is pumped out or moves out naturally from an aquifer. This replenishment comes from precipitation that falls on surface areas connected with the porous bed.

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[7] Data from W. B. Langbein, personal communication.

The amount of water stored in some underground reservoirs is tremendous. For example, in the Sacramento Valley alone just northeast of where we stand today, the storage capacity between depth of 20 and 200 feet is estimated at 34 million acre-feet, a volume equivalent to about one and one-fourth times the capacity of Lake Meade.[8]

Just as in a surface reservoir, it is perfectly feasible to draw on stored water during periods of drought, with a consequent lowering of the water table just as similar drawing on storage would lower the level of a lake or surface reservoir. The falling water tables we hear about are not unexpected during periods of low recharge, and during wet years the storage tends to be replenished.

However, the problem of lowering water tables is indeed serious where continued pumpage is known to exceed the average recharge. Under those circumstances, we are mining the stored ground water. Continuation of such overdraft in an area will have one of two effects: Either to lower the water table to the limit of economic lift, that is, to a point where the cost of pumping exceeds the revenue obtained from use of the water, or the stored water will become physically exhausted.

The example of the High Plains mentioned previously is only one place where the draft on ground water is in excess of the average recharge. Ground-water mining is particularly prevalent in the southern parts of the southwestern States, southern California, Arizona, New Mexico, and Texas.

Generally speaking, irrigation, and pumping at certain military installations, are the uses contributing particularly to ground-water mining. The recent blossoming of homesites and vacation places in the Mojave Desert will surely mean drawing on stored ground water in excess of recharge.

In many places, it is known by the water users that pumping exceeds the long-term average recharge, but as long as pumping is economically profitable, there is no reason to believe that anyone intends to curtail pumping, despite the fact that sooner or later the area will have to be abandoned for present purposes.

This leads to my final comment on the water situation. In many areas, it is not known by the water users or anyone else whether or not present pumping exceeds the rate of recharge. Ground-water studies require special skills combining both geological and hydraulic techniques, and these studies are time consuming.

Development has proceeded much faster than scientific studies and accumulation of data concerning the amount, occurrence, and characteristics of our water resources. Such studies are carried on principally by the Geological Survey in collaboration with States and with local governmental bodies.

Present water problems are sufficiently complex that new technical knowledge and additional data are essential. But such knowledge in the hands only of the specialists is not the full requirement. The public at large must become better acquainted with the general principles of water occurrence in order that decisions may be based on sound physical principles and fact, rather than on hearsay and various forms of witchcraft which always persist in the vacuum of insufficient knowledge.

The scientists in the water field as well as in other disciplines, have an obligation to the public and to the press which, in my opinion, they have not satisfactorily discharged. I am sure that the press is desirous of publishing fact rather than fancy, if the scientist provides it with usable and understandable information. I hope that the present expanding recognition of this responsibility which I think I perceive in scientific circles, will lead to the development of a closer working relationship between the press, the scientist, and the public.

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[8] Poland, J. F., and others, 1949, Ground-water storage capacity of the Sacramento Valley, Calif.: U. S. Geol. Survey. Open-file report.

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