WATER SUPPLY & MANAGEMENT CONCEPTS

By Luna B. Leopold

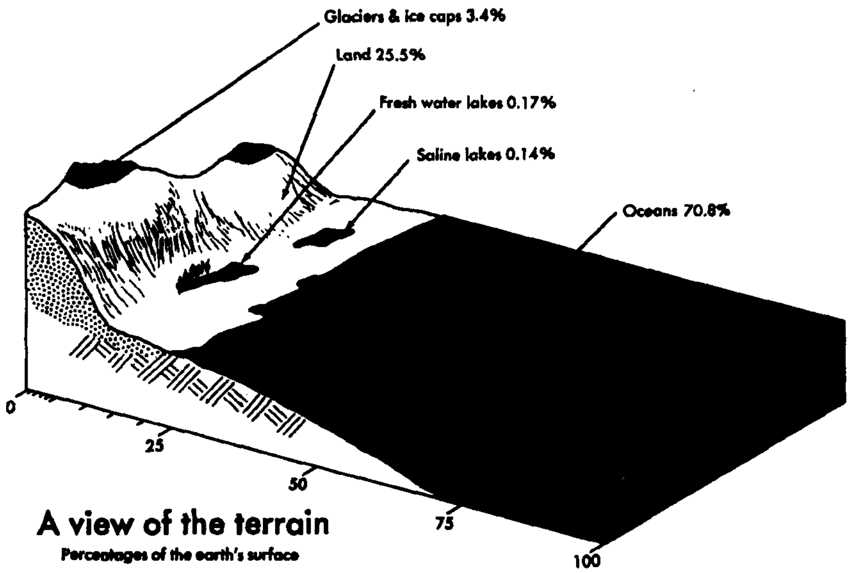

FIGURE 1—74.5% of the earth's surface is water or ice.

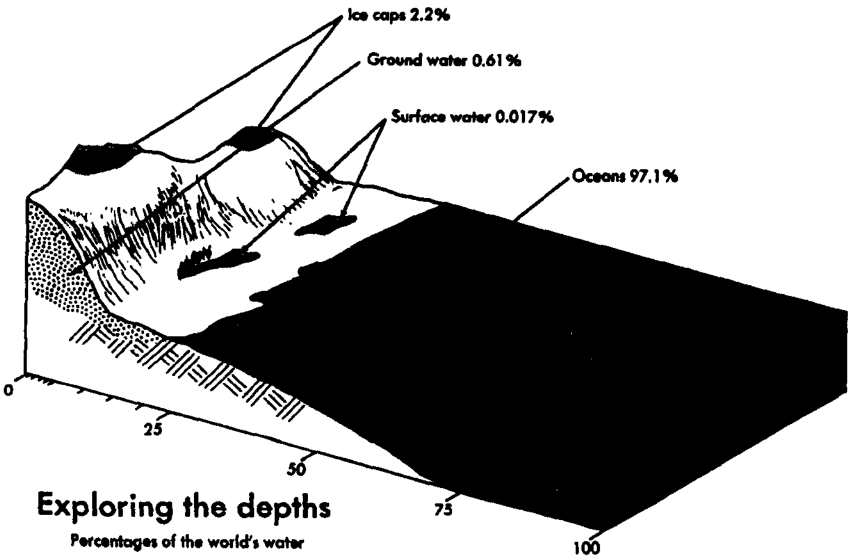

FIGURE 2—Oceans account for 97.1% of water volume.

If I had to cite one fact about water in the United States which would be not only the most important but also the most informative, the one I would choose would be this: Over 50 percent of all the water presently being used in the United States is used by industry, and nearly all of that is used for cooling.

The large amount of attention recently being given to water shortage and the expected rapid increase in demand for water is probably to some extent clouded because there are certain simple facts about water availability and water use which, though readily available, are not generally either known or understood.

Probably most people react to information in the public press about present and possible future water shortages with the thought that it is going to be more difficult in the future to supply the ordinary household with water for drinking, washing, and the culinary arts. As a matter of fact that may be true to some extent, but it is not the salient aspect.

Municipal use of water in the United States—that is the supplies used in the household and by municipalities for fire extinguishing, parks, street cleaning, and for sale to some industries — accounts for only about 8 percent of water presently being used. In other words, municipal use and certainly household use do not constitute by any means the bulk of water used, and therefore, by implication, these needs can most certainly be met for all time in the foreseeable future.

By far, the greatest water use in the country is for industry and irrigation. There exists wide latitude for alteration in use patterns without increasing the level of total water development. Alterations are now being made locally as patterns of water values adjust to economic forces. No doubt recirculation use of water for cooling in industry will be increasingly important.

These changes in use patterns will grow out of the economic reality that we in the United States have always obtained water at bargain prices. We must now steel ourselves to a new conception of what water really is worth.

Deterioration of water quality, physical shortage of water for all uses, and problems of the legal rights to water all have a common economic base. To those who can pay the price, these problems are soluble. Whether the price can be justified by the benefit received, however, is the real issue. The economic justification is partly influenced by what we have become accustomed to consider to be the "value" of water.

In considering the subject of water supply and management we might first take a panoramic view of how much water is available, how much is used and by whom, and how much is consumed. We can then explore the *concepts* of water management . . . the utilization of data to predict the possibilities and difficulties in future water use.

A Panoramic View

We truly live in a world surrounded by water. The big problems we face, however, are the poor geographical distribution and the fact that our largest source of water, sea water, contains about 35,000 ppm of dissolved minerals, making it unsuitable for many uses.

Some perspective on the subject of the world's water supply is provided by R. L. Nace of the U. S. Geological Survey in his statistical tabulation shown in Figures 1 and 2. While 74.5 percent of our earth's surface is water or ice, fresh water lakes account for only 0.17 percent of the total surface area. Polar icecaps and glaciers cover a relatively large surface area but their location, of course, makes their use as a source of fresh water impractical.

In exploring the depths, we can note in Figure 2 that the oceans make up 97.1 percent of the total water volume on earth. It is also significant that the world's ground water supplies are vastly greater than the fresh water surface supplies. Dr. Nace figures that of the ground water available, about half exists above the depth of 2,640 feet (one-half mile).

Our country has a generous supply of the world's water. Large lakes on the North American Continent contain about one-fourth of all the fresh liquid surface water on the globe. In the continental United States, annual precipitation averages 30 inches for a yearly volume of 1370 cubic miles. Natural annual recharge of ground water is estimated (liberally) at about a fourth of precipitation or 340 cubic miles yearly. The amount of water stored in the U. S.'s ground water "bank" is *roughly* the amount recharged during the last 160 years (54,400 cubic miles of water).

These panoramic statistics highlight one major point: we are not short of water. We are only using, at present, less than one gallon out of every five potentially available to us as run-off.

Water Use in the U. S.

The estimated average withdrawal use of water in the United States during 1960 was about 270 billion gallons per day (bgd). This withdrawal does not include 2000 billion gallons per day routed through turbines to develop water power. An approximate breakdown of the 270 bgd use is shown in Figure 3. One point which is not indicated by these statistics, however, is that about a third of the water withdrawn for public supplies was utilized by commercial or industrial firms.

It is important at this point to make the distinction between water withdrawn and water consumed. Of the 270 bgd withdrawn in 1960 all but 61 bgd was returned to the supply, somewhat changed, to be sure, in temperature or in chemical character. Figure 3 shows the breakdown on the water consumed. As might be ex-

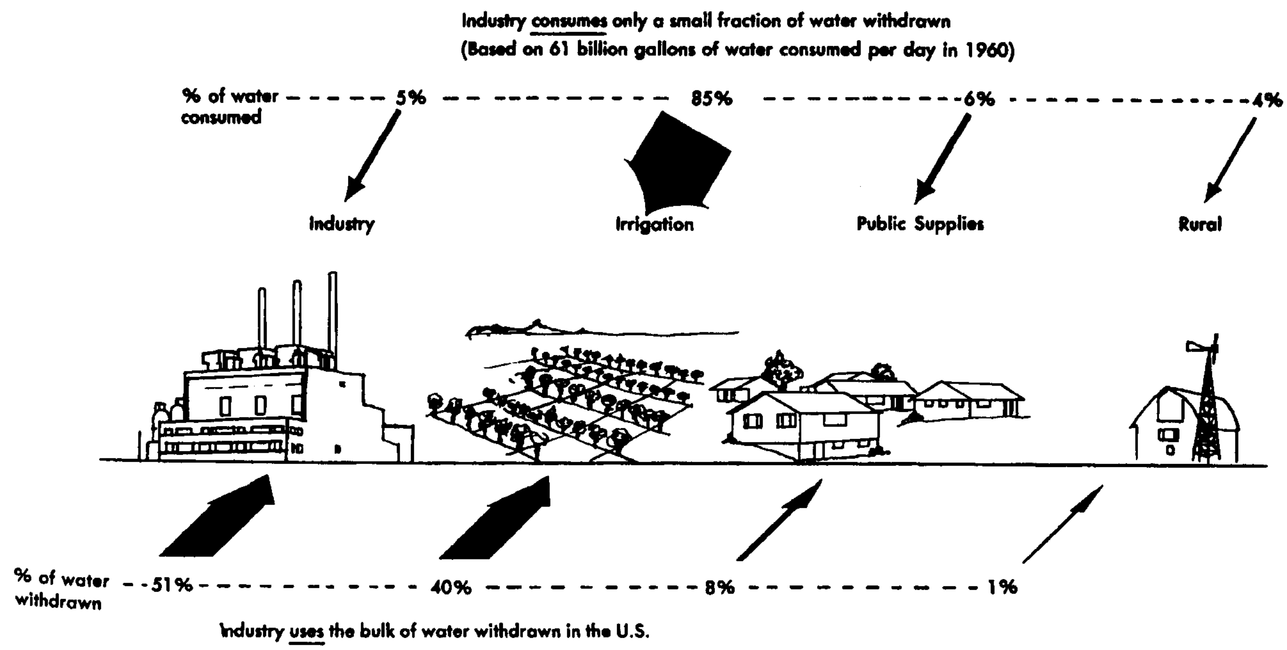

FIGURE 3—Industry withdraws the bulk of water but consumes only a fraction.

pected, the greatest losses of water were in irrigation where a very high percentage of water is consumed by evaporation and transpiration.

The trends in water use between 1945 and 1960 are illustrated in Figure 4. The graphs show a significant increase in the use of surface water by industry. This is attributed to the great demand for condenser cooling water for fuel-electric power plants. Fortunately, of the water used for this purpose, very little is actually lost.

Industrial Water Use

During 1960, industry used an average of 140 bgd of self supplied water, including 100 bgd used for fuel-electric power. An additional 6.6 bgd of water used by industry came from public supplies. About 95 percent of the self-supplied industrial water is obtained from surface supplies and only about two percent of the water withdrawn is consumed.

About 94 percent of the self-supplied industrial water is used for cooling purposes. About 24 percent of this water is saline water. Figure 5 shows how industrial water use varies by state.

Appraising the Data

While the foregoing discussion provides some broad parameters of water supply, there is at this time only an incomplete picture of the water resources of the country. We have certainly not made more than a beginning on a real appraisal of the resource, state by state, with a quantitative picture of the water budget, however rough present knowledge would require such a budget to be. We in the water-resource field talk a lot about water appraisal, but when our activities are studied in detail it becomes apparent that our effort has been overbalanced, with disproportionate emphasis on the collection of data.

We are not really translating enough measurement data in the manner that would be most helpful for true management. For example, quantitative estimates of ground water resources, including the requisite sub-surface geologic information, have been completed for only a few drainage basins in the United States. With regard to the surface water resource, the samples represented by stream-gaging data have been obtained at 10,000 sites in the United States. Although this is better coverage than in any other large country in the world, it still is not a large sample of the three million odd miles of surface streams which exist in this country.

More of this information on streamflow must be analyzed, together with ground-water information, to compile a water budget for each basin, aquifer, or other hydrologic unit, so that the possibilities of management might be evaluated.

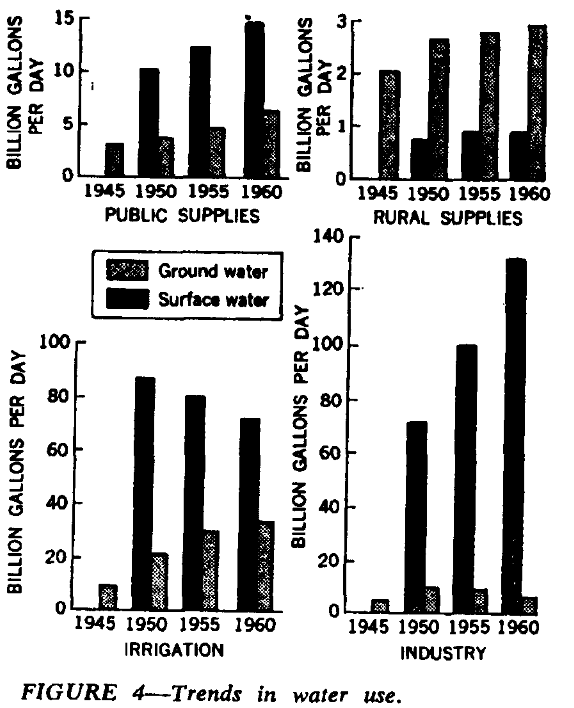

FIGURE 4—Trends in water use.

The Concept of Management

Let us clarify what we mean by management. By the management of money we think of making sound investments which give a satisfactory balance between risk of loss and financial return. Management of water might be considered to have analogous elements. To make a sound investment of water would be to apply water to uses which are fitting and reasonable; that is, uses which are in consonance with the supply, the variability that is characteristic of the supply, and with the quality.

Risk of loss in the field of water might be defined as undue depletion or unnecessary degradation of the quality. The analogy to financial return might be to the number of times a given supply is used and the social values accruing from these uses.

Probably the most obvious type of water management is by reservoir storage, impounding flow which occurs during periods of high runoff, and later releasing this stored water to supply needs during periods of low flow. A higher type of management is that concerned with releases from a reservoir when hydroelectric power is to be developed as well as, say, irrigation needs are to be met. Reservoir operation involving more than a single use of stored water is often specialized and complex.

In large river basins a system of reservoirs presents even more complicated problems. Consider the much more complicated system of water relations in a drainage basin. Let storage be considered to include reservoir storage, ground or aquifer storage, and storage as soil moisture. Let water use include municipal, industrial, agricultural (both dry-farmed and irrigated), and recreational and scenic, as well as water used by natural vegetation. Let water availability mean how much water is at a given place at a given time, but availability is inter-related to utility of water . . . that is, the applicability of a given quality to a particular use.

Management in this broader context, then, requires particular kinds of information and data, and the utilization of such information for advising the industry and for the decisions concerning the issuance of water-use permits.

A Case in Point

Assume that an appraisal has been made which is sufficiently complete to allow some reasonable generalization to be made about the amounts, variability, and quality of water in various districts or areal units within the basin. Industry is increasing. A particular industry wishes to know

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FIGURE 5— Self-supplied industrial water in 1960 (million gallons per day)
Source: U. S. Geological Survey

	Fuel-electric power (public utility) use					Other uses						All industrial uses				
	Water withdrawn				Water consumed	Water withdrawn					Water consumed	Water withdrawn				Water consumed
	Ground water		Surface water			Ground water		Surface water		Sewage		Fresh	Saline	Sewage	All water	
	Fresh	Saline	Fresh	Saline		Fresh	Saline	Fresh	Saline							
Alabama	1	0	3,000	140	0	79	0	810	0	0	87	3,900	140	0	4,000	87
Alaska	0	0	86	0	0	12	0	70	0	0	0	170	0	0	170	0
Arizona	18	0	33	0	12	62	0	16	0	0	24	130	0	0	130	36
Arkansas	7	0	270	0	7	140	0	43	0	0	40	470	0	0	470	47
California	290	0	140	8,600	17	310	140	42	510	.5	81	790	9,300	.5	10,000	98
Colorado	2	0	160	0	7	35	10	120	10	0	36	310	20	0	330	44
Connecticut	0	0	580	940	0	40	0	210	66	0	20	830	1,000	0	1,800	20
Delaware	2	0	0	440	0	27	0	28	380	0	54	57	820	0	880	54
Florida	8	0	1,700	3,100	2	680	0	79	260	0	300	2,500	3,300	0	5,800	300
Georgia	3	0	1,400	320	0	230	0	76	100	0	6.9	1,800	430	0	2,200	7
Hawaii	14	16	12	260	0	110	5.0	33	.1	0	13	170	280	0	450	13
Idaho	0	0	0	0	0	91	0	90	0	0	36	180	0	0	180	36
Illinois	8	0	9,700	0	2	280	40	1,800	0	0	44	12,000	40	0	12,000	46
Indiana	0	0	3,200	0	7	150	11	1,900	0	0	78	5,300	11	0	5,300	85
Iowa	0	0	1,500	0	2	74	0	37	0	0	11	1,600	0	0	1,600	13
Kansas	24	0	510	0	12	120	0	60	0	0	8.9	710	0	0	710	21
Kentucky	0	0	2,000	0	1	68	.6	180	.3	0	24	2,300	1	0	2,300	25
Louisiana	28	0	3,000	1,700	11	310	39	1,700	0	0	540	5,000	1,700	0	6,800	550
Maine	0	0	1	120	0	12	0	340	3.0	0	25	350	120	0	480	25
Maryland	0	0	500	590	0	49	0	140	690	70	74	700	1,300	70	2,000	74
Massachusetts	0	0	160	1,600	1	66	0	380	140	0	30	600	1,800	0	2,300	31
Michigan	0	0	3,900	0	1	99	14	1,700	0	0	51	5,800	14	0	5,800	52
Minnesota	0	0	1,200	0	0	120	0	720	0	0	59	2,100	0	0	2,100	59
Mississippi	6	0	110	160	10	160	0	58	0	0	29	330	160	0	480	39
Missouri	1	0	1,300	0	1	55	3.0	110	0	0	9.0	1,500	3	0	1,500	10
Montana	0	0	58	0	0	35	1.0	170	0	0	23	260	1	0	260	23
Nebraska	0	0	640	0	2	12	0	32	0	0	4.2	680	0	0	680	6
Nevada	0	3	0	0	1	34	0	10	0	.2	8.8	44	3	.2	48	10
New Hampshire	6	0	0	250	0	2.0	0	150	0	0	8.0	160	250	0	410	8
New Jersey	0	0	1,300	1,400	4	190	7.6	370	760	0	150	1,800	2,100	0	4,000	150
New Mexico	5	0	18	0	8	18	.1	4.1	0	0	4.5	45	.1	0	45	12
New York	1	0	3,900	4,400	8	150	15	1,600	1,300	0	120	5,600	5,800	0	11,000	130
North Carolina	0	0	2,000	32	0	33	0	230	0	0	22	2,300	32	0	2,300	22
North Dakota	3	0	7	0	2	1.6	6.0	1.4	0	0	.9	13	6	0	19	2.9
Ohio	18	0	8,100	0	22	270	0	2,300	0	0	87	12,000	0	0	12,000	110
Oklahoma	6	0	180	120	8	23	46	26	11	0	21	240	180	0	420	29
Oregon	0	0	7	0	0	140	0	1,000	0	0	33	1,200	0	0	1,200	33
Pennsylvania	0	0	6,600	0	4	300	0	4,100	460	0	190	11,000	460	0	11,000	200
Puerto Rico and Virgin Islands	0	0	4	490	0	29	1.6	130	160	0	6.9	160	650	0	810	6.9
Rhode Island	0	0	0	300	0	15	0	32	.3	0	2.2	47	300	0	340	2.2
South Carolina	0	0	560	95	2	54	0	84	28	0	13	700	120	0	820	15
South Dakota	0	0	1	0	1	6.7	3.9	5.8	0	0	4.4	14	3.9	0	17	5.4
Tennessee	0	0	3,900	0	1	420	0	940	0	0	310	5,200	0	0	5,200	310
Texas	470	0	2,000	1,300	52	330	11	430	3.6	0	100	3,300	1,400	0	4,600	160
Utah	0	0	77	0	3	58	3.0	150	5.5	0	4.6	290	8.5	0	300	7.6
Vermont	0	0	29	0	0	9.1	0	25	0	0	2.0	63	0	0	63	2.0
Virginia	0	0	2,500	810	2	51	0	1,100	85	0	0	3,700	900	0	4,600	2.0
Washington	0	0	0	0	0	170	0	520	48	0	14	690	48	0	740	14
West Virginia	3	0	3,700	0	10	73	.4	2,200	0	0	120	6,000	.4	0	6,000	130
Wisconsin	0	0	2,900	0	0	230	0	470	0	0	17	3,600	0	0	3,600	17
Wyoming	0	0	84	0	1	8.5	0	56	0	0	7.3	150	0	0	150	8.3
District of Columbia	0	0	270	0	0	1.0	0	.8	0	0	.7	280	0	0	280	.7
United States[1]	910	3	73,000	26,000	220	5,900	350	27,000	4,900	71	2,900	110,000	32,000	71	140,000	3,200
United States	920	19	73,000	27,000	220	6,000	360	27,000	5,000	71	3,000	110,000	33,000	71	140,000	3,200

[1] Excluding Alaska, Hawaii, Puerto and Virgin Islands.

WATER SUPPLY . . . *continued*

the possible places where certain amounts of water would be available. The proper governing body would inquire first concerning the minimum quality characteristics necessary for that industry, and then about the amount and types of waste products which would be discharged.

An inspection of the appraisal information would show areas where water exists which would satisfy the minimum quality requirements. An industry requiring water only for cooling might use a water higher in salts than would be needed for municipal use. The industry would be urged to use the lowest quality water which would meet the needs.

The areas which might supply such water would then be considered in terms of the effects of the pollutants to be discharged. One area might have sufficient flow during drought periods to dilute industrial pollutants enough to make treatment unnecessary. Another area under consideration may not be so blessed. For use of the latter, any permit to use water would include a provision that the industrial user undertake a specified type and degree of treatment of wastes before they are liberated into a stream.

Competition for Water

Water problems arise primarily at the time competition develops. As long as the supply is adequate, problems are minimal. But as development of water supply progresses, and particularly during periods of less than normal supply, competition intensifies.

Comprehensive river basin development implies drawing up plans for guiding resource utilization toward the ultimate goal of obtaining the maximum benefits from the resources. The goal of maximum benefits is sound, but our measure of benefits and our yardsticks of value are still so rudimentary that one wonders whether the results have any real meaning.

We speak blithely of a plan for optimum ultimate use of all the resources of a basin. But it is difficult enough to evaluate even a single-purpose project. Even to do this we are already attempting to weigh in monetary terms flood control benefits, power benefits, public health benefits, recreation benefits, sedimentation benefits, municipal water benefits, pollution-control benefits, navigation benefits, fishery benefits, wildlife benefits, and drainage benefits, to name but a few. And most of these are purported to have conservation aims.

Each of these benefits is computed on the basis of present monetary value. The procedures are usually complex. Then the future worth is computed by expanding these present values to a level they are supposed to attain 50 years hence.

Our problems arise principally because resource use involves people. Attempts to forecast 50 years in advance what is best for the people requires more Solomons than we have at hand. Solution of today's problems must begin with the recognition that esthetic values cannot be assessed in monetary terms. And protection of values implies identification of values.

A New Era

America is now entering a period when water management rather than water development is the major engineering task confronting us. There must be certain generalized decisions concerning what we want to be and want to have as a people. These decisions can stem only from a philosophy which extends into the field of esthetic values as well as economic ones.

As a people, we must decide what we want in the way of clean streams, of natural scenery and wilderness, and of other values for recreation and beauty which compete with the economic possibilities of resource development. The engineer has a peculiar responsibility in this field, which in my opinion is not now being adequately discharged. It is up to the engineering specialists in the field of water not only to analyze and appraise the magnitude and characteristics of the resource, but also to present this information in such a way that a philosophy about management and use can gradually emerge. ■

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