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INDUSTRIAL WATER SUPPLIES OF THE UNITED STATES

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INTRODUCTION

The availability of adequate supplies of water of suitable quality determines in large measure the potential for industrial development in any community. However, the pattern of availability of water for industrial use is not so generally recognized. It is the purpose of this paper to point out the more important factors affecting the distribution and quality of existing and potential sources of water with particular reference to industrial development.

From a nation-wide standpoint our country is blessed with plenty of water. If the available water could be distributed completely in accordance with needs, it is probable that no part of the country would suffer from lack of water either now or in the foreseeable future. As nature has not dealt so providently however, or perhaps as man has not been able to cope with the vagaries of nature, we find ourselves beset with droughts and floods. Added to the natural deficiencies of nature are man-made difficulties such as lowered ground-water tables and salt-water encroachment of fresh water supplies resulting from overpumping of ground waters, pollution in all its forms, and wasteful use of water for many purposes. It becomes necessary, therefore, to study and evaluate our most important natural resource in order that we may use it more intelligently. This is particularly true in regard to continued industrial growth of our country.

DISTRIBUTION OF WATER RESOURCES

Precipitation. --Essentially all the existing supplies of fresh water result from precipitation in the form of rain and snow. The distribution of precipitation, however, vitally affects all users of water.

The average annual precipitation in the United States is about 30 inches. The range is from 5 inches or less in some of the arid sections of the southwest to over 150 inches in parts of the Olympic peninsula in Washington. In general the eastern half of the United States is humid to subhumid, and the western half is subhumid to arid with many exceptions as to specific small areas. The generalized pattern of precipitation for the United States is shown in figure 1.

Surface water. --The average annual discharge of surface waters of the United States into the sea amounts to about 8.5 inches or about 28 percent of the average precipitation. This includes water which, after entering the ground and reaching the water table, flows into a surface-water body. The rest of the water falling as rain or snow is discharged by evaporation and transpiration. This too, includes more ground water - that which after reaching the water table, is discharged by evapotranspiration. The pattern of the average runoff is illustrated in figure 2.

Supposedly, the 8.5 inches that now run off to the sea should be utilizable by man, but in practice this is not possible. A substantial part cannot be used economically, because it is flood flow that occurs in such tremendous volume that storage is not feasible. On the other hand, a considerable part of the low flow of streams must be reserved because it dilutes and carries off municipal, industrial, and other wastes. Also, a part cannot be consumed because it produces hydroelectric power, maintains navigation, or serves other uses. Moreover, in some streams there is the problem of maintaining enough flow to carry off the products of natural erosion. Therefore, our use of the 8.5 inches of runoff is severely limited and restricted.

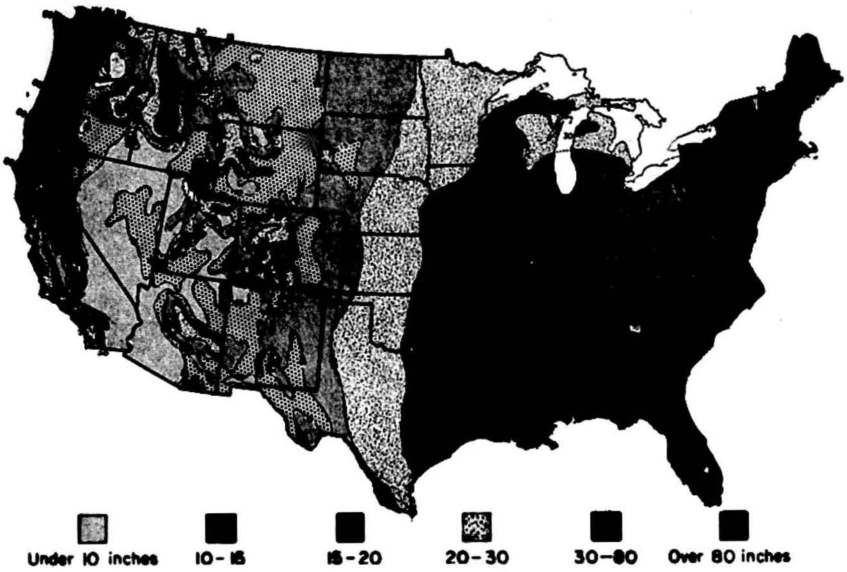

Figure 1.--Average annual precipitation in the United States

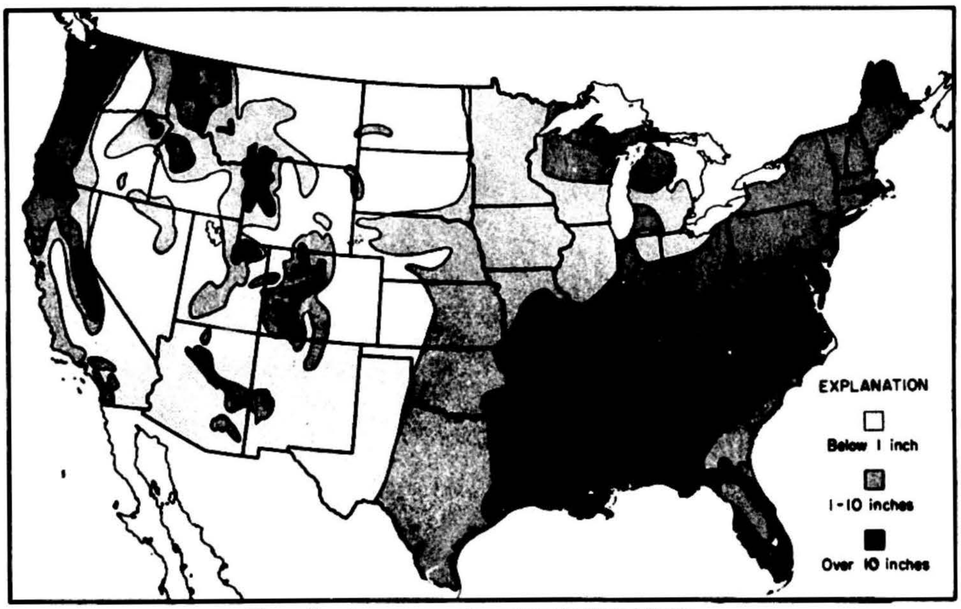

Figure 2.--Average annual runoff in the United States

The dependable yield of surface-water sources is of primary consideration for industrial as well as for other uses. A determination of the yield of a surface-water supply depends foremost on adequate records of stream flow, as well as on their competent analysis and interpretation. It involves the analysis of storage requirements, effects of upstream utilization and depletions, and the frequency of recurrence of droughts and subsequent drafts on storage. It is important to observe that because of the variable nature of stream flow, estimates of dependable yield of a stream must be qualified by available information of the average interval between years in which lesser yields might be expected to occur. Without such information, the term dependable yield is meaningless, if not misleading.

The Great Lakes form a huge reservoir system of fresh water that is suitable, with relatively little treatment, for a great variety of industrial uses. The volume of the Great Lakes has been estimated to be over 5,000 cubic miles or equivalent to 15 times the average annual discharge of all surface streams in the United States into the ocean.

Ground water. --Although the water stored at any one time in all of the rivers and lakes of the country is enormous, the volume of fresh water stored in the countless natural openings in the rocks beneath the water table is probably several times greater. In marked contrast to the close relationship that exists between surface water and precipitation, the volume of water stored beneath the land surface is determined primarily by the physical characteristics of the reservoir rocks. Thus, some of the largest reservoirs of ground water occur in sandstones and limestones of the arid Southwest, whereas the dense crystalline rocks of the Canadian Shield and similar formations in the humid eastern United States can be numbered among the poorest of ground-water aquifers. The range in ground-water conditions is almost as great as the geology of the continent is diversified.

Nevertheless, as these varied reservoirs are drawn upon by man, their continued usefulness depends not so much on their extent or the quantity of water originally contained, but upon the occurrence of precipitation of surface water for recharge, and the opportunity for such recharge to reach the aquifer after its storage has been drawn down. So in the final analysis, the same climatic conditions that control the quantity and distribution of surface water will control, to a considerable degree, the limits of ground-water withdrawal.

There is a widespread public impression that the over-all ground-water supply of the United States is being depleted at an alarming rate, and that soon the supply may be exhausted. The truth is that there is no such thing as an over-all nation-wide depletion of ground water, although there are many local areas and a few larger regions, the latter mainly in the Southwest, where ground-water levels are declining so much as a result of heavy pumping, that they might be regarded as overdeveloped. Nevertheless, large undeveloped supplies remain in many areas - in fact, the present total ground-water withdrawal in the United States represents only a fraction of the potential. Outside the relatively widely spaced areas of overdevelopment there is at present no progressive depletion of ground water. The ground-water levels rise in wet years and fall in dry years, and occasionally there is a more or less permanent local decline as a result of land drainage or some similar practice, but on the whole it is safe to say that ground-water reserves in the United States are sufficient for greatly increased use of this resource. Instead of being faced with the national problem of reducing our ground-water use, the problem is, rather, one of distributing the use so that overdevelopment of local areas can be eliminated or kept to a minimum, and so that better advantage can be taken of the ground water that is now wasted through passing unused on the way to streams and thence to the sea.

QUALITY OF WATER

Next to having enough water the quality of the available water is of primary importance for industrial use. Quite often water of good quality is of considerably more importance than unlimited quantity, particularly process water, and water used in high pressure boilers.

Surface water quality. --The major characteristic of surface waters, other than lakes, is that they vary in chemical and physical quality almost continuously. The variations in quality are caused by several factors including the nature of soils and rocks over which the water flows and the length of time the water is in contact with them, the changes in quality of tributary streams, proportion of flow due to ground-water discharge, flood and drought conditions, and of course, man-made conditions such as pollution in all its forms.

Figures 3 and 4 illustrate annual ranges in amount of dissolved matter in two streams, one with large variations and the other with relatively small changes.

In general, streams flowing into the Atlantic Ocean, eastern Gulf of Mexico, and the North Pacific Ocean are of good to excellent quality for industrial purposes. Dissolved matter and hardness are usually below 100 parts per million and often below 50. This applies to streams in their natural state and does not take into account the effects of pollution.

Midcontinent and southwestern streams are generally more concentrated with dissolved

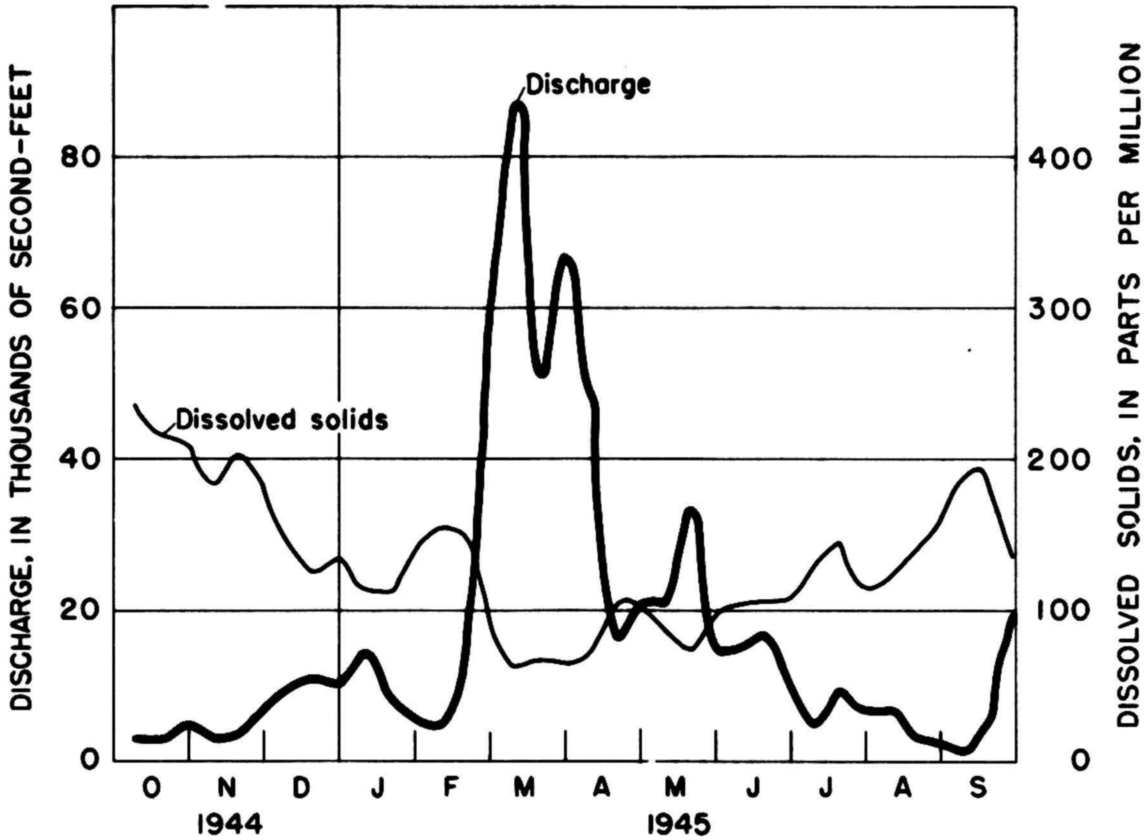

Figure 3.--Discharge and dissolved solids in Allegheny River at Kittanning, Pennsylvania

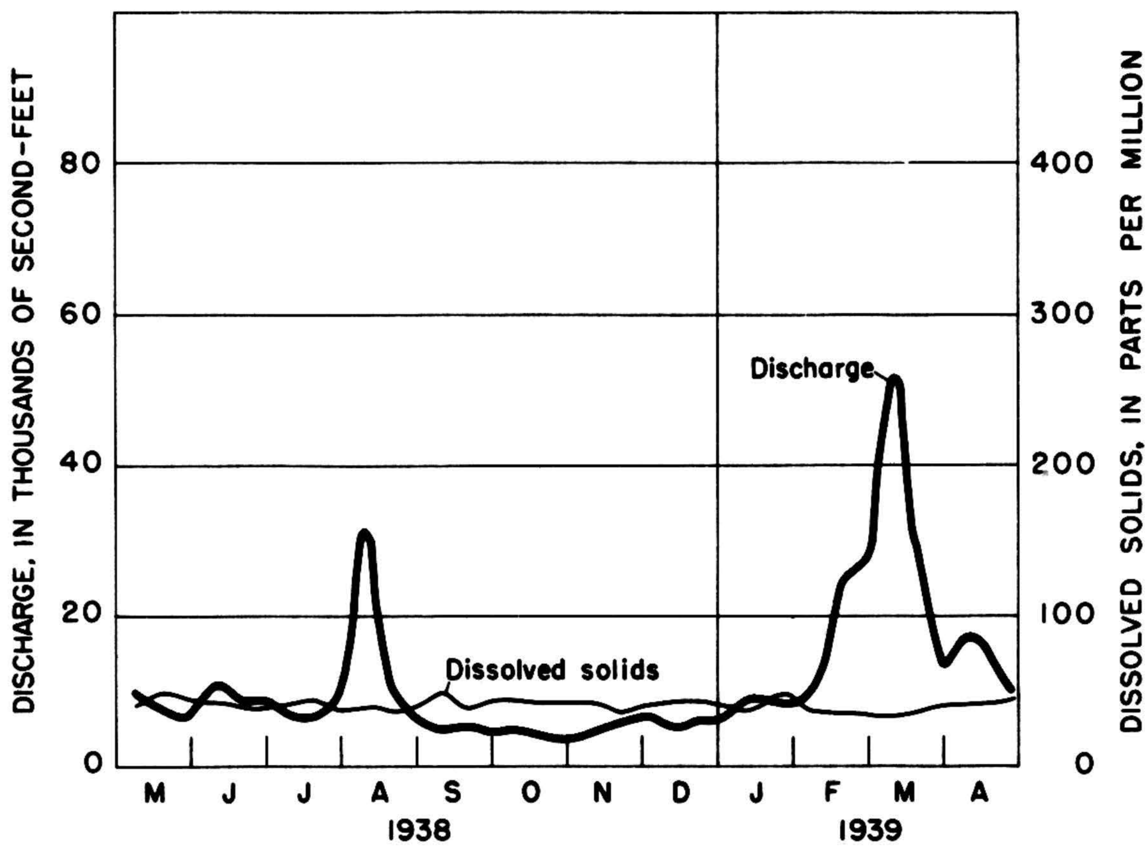

Figure 4.--Discharge and dissolved solids in Savannah River near Clyo, Georgia

matter, some excessively so, and must be treated extensively for a large variety of industrial uses. For example, the Missouri River at Kansas City contains from about 220 to 500 ppm of dissolved matter and has hardness of from about 190 to 300 ppm during a typical year. A generalized picture of the variations in surface-water quality throughout the country is given in figure 5.

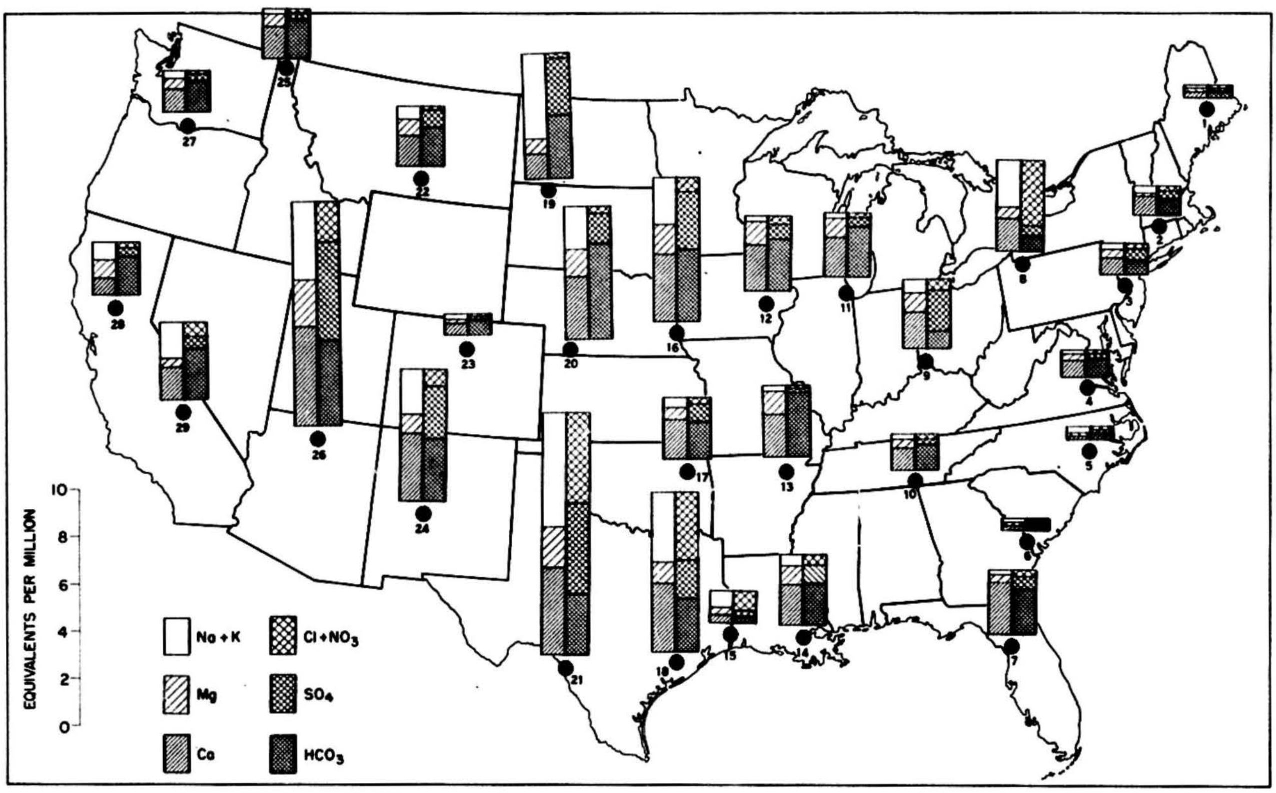

Figure 5. --Average analyses of surface waters in the United States

Surface Waters Represented by Diagrams in Figure 5.
(Numbers preceded by dagger indicate sources for which analyses are given in table 1.)

† 1. Penobscot River at Passadumkeag, Maine
2. Connecticut River at Thompsonville, Conn.
† 3. Delaware River at Trenton, N. J.
4. James River at Richmond, Va.
† 5. Neuse River near Goldsboro, N. C.
6. Savannah River near Clyo, Ga.
† 7. Withlacoochee River near Holder, Fla.
8. Allegheny River at Warren, Pa.
† 9. Ohio River at Cincinnati, Ohio
† 10. Tennessee River at Chattanooga, Tenn.
† 11. Lake Michigan at Chicago, Ill.
12. Iowa River at Iowa City, Iowa
13. White River at Batesville, Ark.
† 14. Mississippi River at New Orleans, La.
15. Sabine River near Ruliff, Tex.
† 16. Missouri River at Nebraska City, Nebr.
17. Neosho River near Wagoner, Okla.

† 18. Brazos River at Richmond, Tex.
19. Grand River at Shadehill, S. Dak.
20. Republican River at Trenton, Nebr.
21. Rio Grande at Eagle Pass, Tex.
† 22. Yellowstone River at Billings, Mont.
23. Colorado River at Hot Sulphur Springs, Colo.
† 24. Rio Grande at San Marcial, N. Mex.
25. Kootenai River at Porthill, Idaho
† 26. Colorado River near Grand Canyon, Ariz.
† 27. Columbia River at Maryhill Ferry near Rufus, Oreg.
† 28. Sacramento River at Knight's Landing, Calif.
29. Owens River at Crowley, Calif.

The chemical quality of lakes, especially large lakes, is usually relatively constant. Also man-made lakes formed by the construction of dams on streams tend to smooth out variable concentrations of inflowing water. However, stratification occurs in many large lakes and reservoirs which often affects the chemical as well as the physical quality of the water.

The temperature of streams varies continuously throughout the year. They range from a minimum of freezing (about 32°F) in winter in northern latitudes (higher in southern latitudes) to a maximum of about 80 to 85°F or slightly higher in summer. The average daily water temperature generally follows rather closely the average daily air temperature except at times and in areas where the flow is made up largely of melting snow or ice or from cold springs in which event the water temperature would be lower than the air temperature for some distances downstream.

Sediment also affects surface-water quality. Nearly all streams are turbid during flood periods, some carrying tremendous quantities of sediment which must be removed before the water is suitable for industrial and most other uses. In eastern United States the amount of suspended matter in many typical streams seldom exceeds 0.3 percent (3,000 ppm) and generally averages a few hundred parts per million. In many mid-continent and western streams sediment concentrations are much greater, a maximum of 10 percent not being uncommon in some small streams and frequently considerable higher.

The sediment-carrying characteristics of western streams range from relatively clear-flowing mountain streams to near mud flows in the intermittent streams of arid regions. The sediment concentration of the Colorado River at Grand Canyon, Ariz., averaged about 0.6 percent (6,000 ppm) over a period of nearly 30 years.

Ground-water quality.--The principal differences in quality between ground and surface waters are ground waters' somewhat higher but relatively uniform content of dissolved matter, general freedom from turbidity, and nearly constant temperature.

The higher concentration of dissolved matter in ground water is considered objectionable for many industrial applications. The higher concentration of soluble salts necessitates treatment for their reduction in order to make the water suitable for many uses. There is an offsetting advantage, however, in that constant treatment practices can usually be employed whereas with surface waters changes in composition necessitate frequent changes in the treatment process.

Most ground-water supplies obtained from properly developed wells will be free of turbidity and sediment. Exceptions are those waters containing significant amounts of hydrolyzable salts, particularly iron and manganese, for which special treatment must be employed. In certain parts of the country, notably the southeast, much of the ground water is colored with organic matter. Color in industrial water is usually objectionable and for many purposes must be removed.

Most ground waters are nearly devoid of oxygen which is an advantage for certain industrial uses. However, many ground waters, expecially those low in dissolved matter, tend to contain relatively large amounts of carbon dioxide which renders the water corrosive. For certain industrial applications the carbon dioxide must be reduced or completely removed.

The generally constant temperature of ground waters makes them attractive for special uses, notably for cooling and for air conditioning. Furthermore, ground-water temperatures are usually much lower than surface-water temperatures during the summer months when the demand for air conditioning is heaviest. The increasingly heavy demands on ground water for air conditioning have created grave water problems in some areas. The tendency is toward stricter regulations requiring the use of cooling towers and recirculation of the water rather than the normally much cheaper once-through practice. In a few areas where the once-through practice is still employed it is required that the used water be returned to the ground-water reservoir through recharge wells. This has had the effect of gradually increasing the temperature of the ground-water body in the immediate area such as on Long Island.

Ground waters normally have a constant temperature that is close to the mean annual air temperature for water from depths of 30 to 60 feet. Below 60 feet the temperature increases about 1°F for each increase in depth of from 50 to 100 feet depending on location.

Quality of public supplies. --Although the major part of water used by industry is obtained from private sources, it is probable that the greatest number of industrial establishments rely on public supply systems. This is because most of the large corporations generally develop their own water supplies whereas the smaller concerns, numerically much larger, more often obtain water from public supplies. For this reason it will be of interest to summarize briefly the information presently obtained by the Geological Survey about the chemical quality of water used by 1,315 of the larger cities throughout the country.

The data were obtained between 1950 and 1952. They represent 58 percent of the total population and 90 percent of the urban population of the United States as reported in 1950 by the Bureau of the Census. Hardness is the chemical characteristic of these public supplies that is of greatest interest. The hardness data have been analyzed and are represented by States in two hardness maps shown in figures 6 and 7. For purpose of illustration degrees of hardness are divided into 4 groups. The first group represents water with hardness from 1 to 60 ppm. The second group is for hardness from 61 to 120; the third, from 121 to 180; and the fourth above 180.

Water in the first group is definitely soft; that in the second may be termed moderately hard; in the third, hard; and in the fourth, very hard. Other groupings and descriptive terms could be selected. The percent of population served in 1952 by large public supplies with water having hardness of 100 ppm or less is shown in figure 8.

Analyses of typical surface and ground waters are given in tables 1 and 2.

USES OF WATER IN THE UNITED STATES

Uses of water may be classified in several different ways. Among them are withdrawal and non-withdrawal uses, and consumptive and non-consumptive uses. Examples of withdrawal uses are irrigation, water power, domestic, municipal, and industrial uses. Examples of non-withdrawal uses are navigation, recreation, waste disposal, and conservation of wildlife. Water is consumptively used when it is incorporated into a product, is evaporated or transpired such as in irrigation. It is non-consumptively used when returned to the stream or ground such as in the development of power, for cooling and for most of the non-withdrawal uses.

We are concerned here with withdrawal uses which include municipal, rural, irrigation, industrial, and water power. An estimate of withdrawal use in the United States during 1950 is given in figure 9. In figures, the total amounts to about 170 billion gallons per day exclusive of that used for power. An additional 1,100 billion gallons was used for power development or a grand total of about 1,270 billion gallons per day.

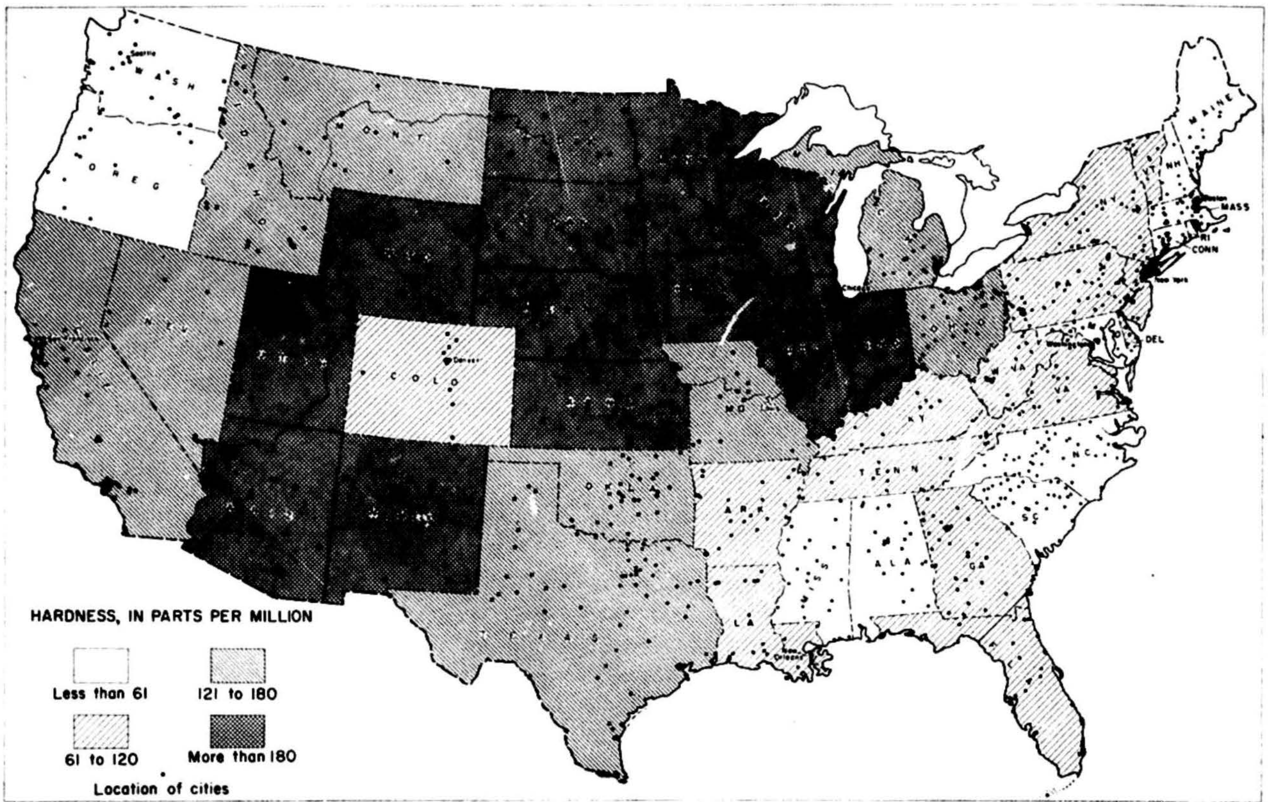

Figure 6. --Average hardness of finished water from large public supplies, 1952

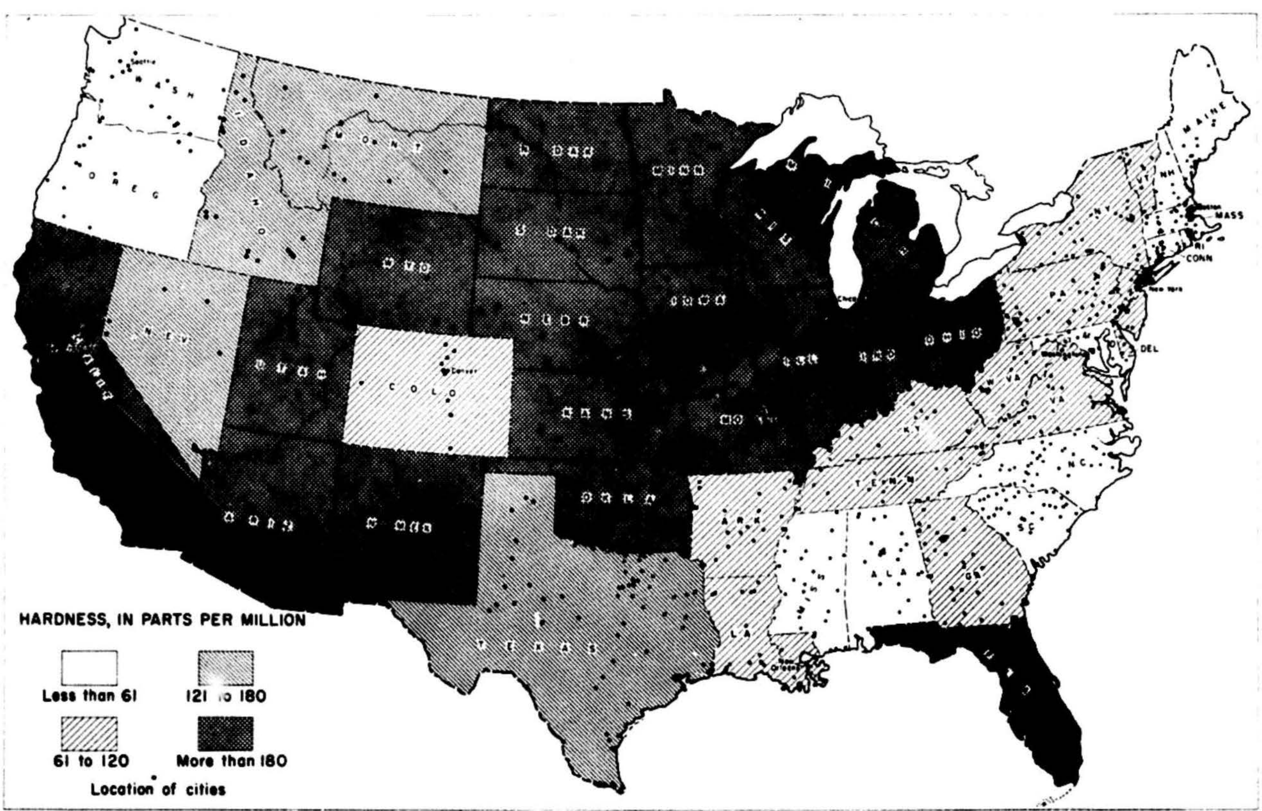

Figure 7. --Average hardness of raw water for large public supplies, 1952

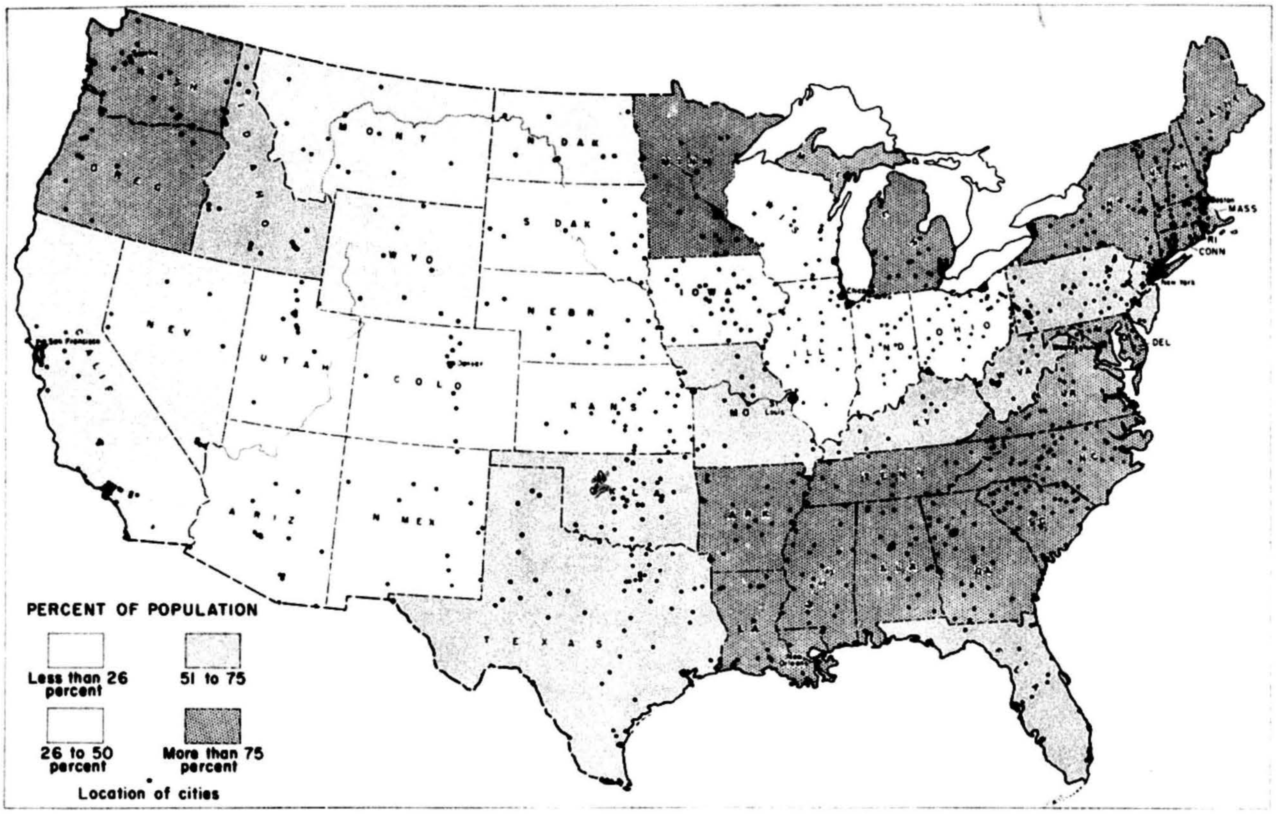

Figure 8. --Percent of population served in 1952 by large public supplies with water having hardness of 100 ppm or less

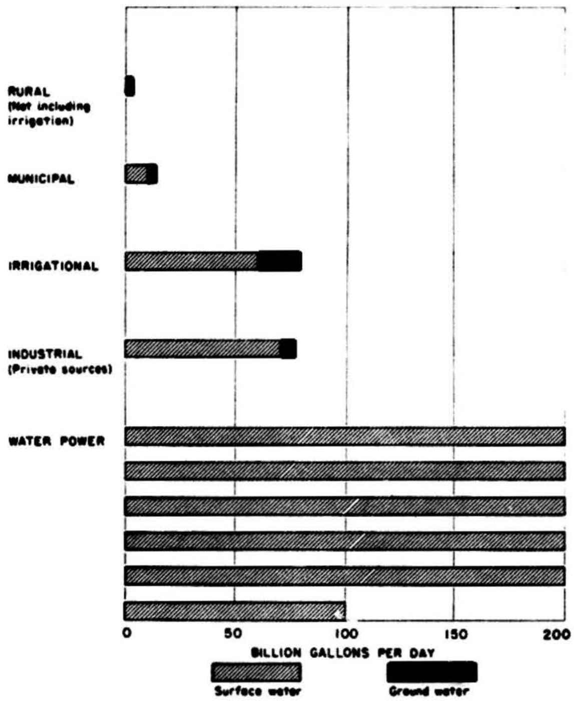

Figure 9. --Quantity of water used in the United States, 1950

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TABLE 1

AVERAGE ANALYSES OF SURFACE WATERS IN THE UNITED STATES

(Analyses, in parts per million, by U. S. Geological Survey unless otherwise indicated)

Number a/	1	3	5	7	9	10	11 b/	14	16	18	22	24	26	27	28
Silica (SiO_2)	3.2	3.8	11	7.6	7.0	7.3	2.3	16	17	12	14	26	15	13	--
Iron (Fe)	.08	.05	.07	.04	.04	.03	.09	.39	--	--	--	--	.20	--	--
Calcium (Ca)	5.0	14	3.7	44	31	19	32	34	57	59	26	57	84	19	15
Magnesium (Mg)	1.2	4.4	1.5	3.8	8.0	5.0	10	9.5	16	10	6.4	10	24	5.5	8.9
Sodium (Na)	1.7	3.9	5.8	5.0	12	5.2	3.5	12	42	70	15	44	75	6.0	16
Potassium (K)	.5			.3	3.5	.8	1.0	.0	5.9		2.0		4.1	3.1	2.7
Bicarbonate (HCO_3)	14	35	18	118	46	67	138	108	187	141	100	161	220	80	94
Sulfate (SO_4)	9.6	23	5.0	23	81	10	17	38	122	76	38	109	201	14	19
Chloride (Cl)	.9	4.4	5.4	10	14	7.0	6.5	11	13	103	4.3	24	57	3.2	11
Fluoride (F)	.1	--	.1	.2	.2	.1	.1	.2	.4	.4	.4	--	.3	.4	.2
Nitrate (NO_3)	.6	3.2	.7	.7	2.4	1.6	--	5.0	5.0	2.1	1.9	1.2	2.6	1.2	.6
Dissolved solids	44	80	52	174	185	92	171	191	384	423	167	350	572	105	148
Hardness as $CaCO_3$	18	53	15	124	110	68	121	124	--	188	--	183	308	70	--
Non-carbonate	7	24	1	27	73	13	8	35	--	72	--	51	128	4	--
Specific conductance (micromhos at 25°C)	41.9	127	60.5	259	304	173	263	293	575	703	255	543	880	164	--
pH	6.5	7.0	--	7.5	7.0	7.6	8.2	7.7	--	--	--	--	--	--	--
Color	25	5	28	75	2	7	3	40	--	--	--	--	--	--	--
Date of collection	10/12/53	Average 1946-47	Average 1948-49	Average 1951	5/19/51	6/2/52	4/9/52	4/16/52	Average 1951	Average 1948-49	Average 1950-51	Average 1948-49	Average 1948-49	Average 1950-51	Average 1951

a/ Numbers refer to diagrams in figure 5.
b/ Analysis by Chicago Department of Public Works.

1. Penobscot River at Passadumkeag, Maine.
3. Delaware River at Trenton, N. J.
5. Neuse River near Goldsboro, N. C.
7. Withlacoochee River near Holder, Fla.
9. Ohio River at Cincinnati, Ohio.
10. Tennessee River at Chattanooga, Tenn.
11. Lake Michigan at Chicago, Ill.
14. Mississippi River at New Orleans, La.
16. Missouri River at Nebraska City, Nebr.
18. Brazos River at Richmond, Tex.
22. Yellowstone River at Billings, Mont.
24. Rio Grande at San Marcial, N. Mex.
26. Colorado River near Grand Canyon, Ariz.
27. Columbia River at Maryhill Ferry near Rufus, Oreg.
28. Sacramento River at Knights Landing, Calif.

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TABLE 2

ANALYSES OF TYPICAL GROUND WATERS IN THE UNITED STATES

(Analyses, in parts per million, by U. S. Geological Survey)

	1	2	3	4	5	6	7	8	9	10
Silica (SiO_2)	7.0	13	11	20	23	13	28	21	19	80
Iron (Fe)	.00	1.2	1.4	1.4	.29	.44	.10	1.6	.15	.01
Manganese (Mn)	--	.28	--	.00	1.1	.0	--	--	--	--
Calcium (Ca)	43	24	96	80	156	10	3.6	62	8.0	28
Magnesium (Mg)	8.3	9.4	37	30	39	5.5	1.7	11	3.1	17
Sodium (Na)	4.7	18	61	25	13	8.2	73	56	} 310	{ 23
Potassium (K)	1.0	3.6	1.2	3.0	2.0	1.3	4.4	2.1		5.2
Bicarbonate (HCO_3)	147	63	291	390	420	72	165	255	366	170
Sulfate (SO_4)	24	37	91	32	213	3.2	13	54	2.0	9.3
Chloride (Cl)	4.9	36	112	22	12	3.0	8.0	36	285	18
Fluoride (F)	.0	.2	.1	.5	.4	.0	.2	.3	1.0	.0
Nitrate (NO_3)	1.4	1.0	20	2.5	.0	.4	2.8	1.8	.5	22
Dissolved solids	170	181	582	408	674	81	228	370	834	286
Hardness as $CaCO_3$	141	99	392	324	550	48	16	200	33	140
Non-carbonate	21	47	153	3	205	0	0	0	0	0
Specific conductance (micromhos at 25°C)	290	306	963	676	951	123	322	595	1,460	378
pH	7.8	6.0	7.3	7.4	6.9	7.0	8.7	7.3	7.8	7.6
Color	2	3	5	3	1	6	--	0	--	5
Date of collection	1/16/52	11/28/49	10/3/52	6/26/51	12/11/52	4/2/51	9/26/49	5/24/51	10/8/44	10/17/51

1. Well 66 feet deep used for part of public supply of Schenectady, N. Y.
2. Wells 120 to 195 feet deep used for part of public supply of Camden, N. J.
3. Well 310 feet deep used for industrial supply at Birmingham, Ala.
4. Well 195 feet deep used for part of public supply of Pontiac, Mich.
5. Well in limestone used for industrial supply at Louisville, Ky.
6. Well 567 feet deep used for part of public supply of Memphis, Tenn.
7. Well 1,732 feet deep used for part of public supply of Baton Rouge, La.
8. Wells 90 to 265 feet deep used for public supply of Wichita, Kans.
9. Well 778 feet deep used for part of public supply of Texas City, Tex.
10. Well 123 feet deep used for part of public supply of Fresno, Calif.

The amount of industrial water obtained from private sources in 1950 approximated 80 billion gallons per day of which about 90 percent was surface water (figure 10). This does not

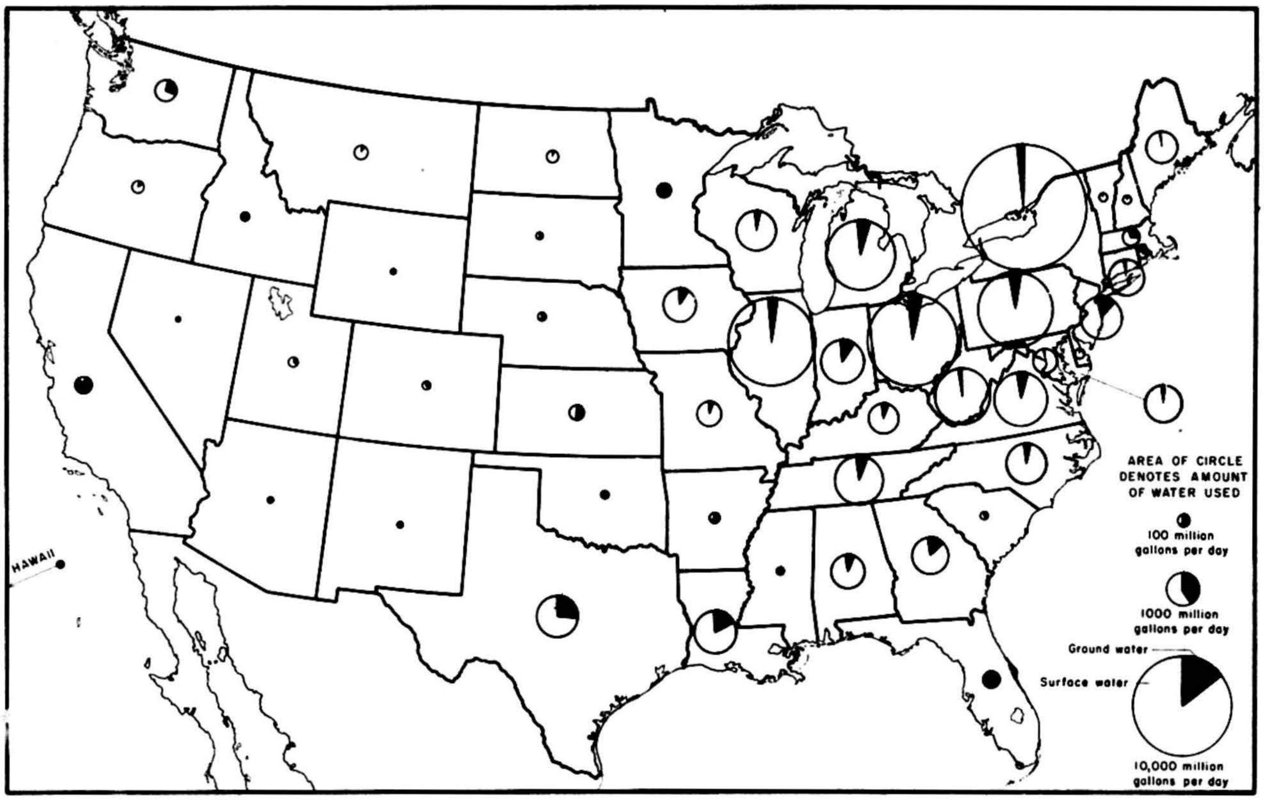

Figure 10. --Water used for industrial supply from private sources, 1950

include industrial water obtained from municipal systems but does include brackish waters. Since this estimate is already four years old, and also because it is believed the 1950 estimate is conservative, it is probable that present industrial water requirements including that obtained from municipal systems, is about equal to or slightly in excess of 100 billion gallons per day. As time goes on this industrial demand is certain to increase. It has been estimated that the direct industrial requirements, exclusive of that obtained from municipal sources, will amount to 215 billion gallons per day in 1975. This is an increase of 170 percent over the corresponding figure in 1950.

INDUSTRIAL WATER REQUIREMENTS

In an appraisal of the industrial water supplies of the Nation consideration must be given to water requirements both as to quantity and as to quality. Much has been written on this subject and it will only be touched upon lightly here.

Quantity requirements. --The quantity of water required per unit of product varies widely as to product and as to individual plant. The reasons for the wide variations are sometimes complex, but they are largely a matter of economics. If water is plentiful and cheap the tendency is to use large quantities per unit of product. If water is scarce or expensive, or both, efforts are made to cut down on the amount used. Included in the conservation practices are treatment to soften, to reduce dissolved solids, to reduce corrosion, and to prevent carryover in boiler; recirculation of water to cut down on make up; and installation of better equipment for more economical use of water.

An example of widely different quantity requirements per unit of product is in the production of steel. Under normal operating conditions in eastern United States from 65,000 to 80,000 gallons of water are required to produce a ton of steel. In a west coast plant where water is extremely scarce, it requires only about 1,400 gallons of make-up water per ton of product.

Another example is in the production of steam electric power. The commonly accepted water requirement for conventional steam plants is about 80 gallons per kilowatt-hour. A recently constructed steam plant in Texas, however, is reported to use just over one gallon of water per kilowatt-hour.

Recirculation in modern equipment makes possible the low requirements of these new industrial plants. There is little doubt that many industrial plants can reduce their unit product water requirements when economics or other factors provide the incentive.

Quality requirements.--There is no question but that water of better quality is being required throughout the industrial field. The term "better quality" may mean lower concentration of dissolved solids, even to the vanishing point for some purposes; reduction in hardness, often to zero; complete removal of heavy metals; removal of dissolved oxygen and carbon dioxide; adjustment in pH, or, in some instances where surface water is used, only simple filtration. Very few waters in their natural state are completely satisfactory for industrial use. In many plants several water-quality requirements are commonplace.

INDUSTRIAL EXPANSION AS AFFECTED BY AVAILABLE WATER SUPPLIES

Great industrial expansion has taken place during the past 20 years. Much of it was occasioned by the stimulus of World War II and to a lesser extent by the war in Korea. The sharp rise in population has also been an important factor.

Large industrial growth has been experienced in many parts of the country. Some of the outstanding areas are the Gulf Coast, the Southeast, and Southern California. Many of the new industries require large quantities of water. It was not uncommon during World War II for the Geological Survey to receive requests for information about areas capable of producing from 1 to 20 million gallons of water per day for new industrial plants. Many areas, otherwise desirable, were eliminated from consideration because of probable limitation on the quantity or quality of water needed for a particular plant.

In several instances concern about the availability of an adequate quantity of water of suitable quality was neglected until the plant site had been selected and sometimes actually constructed. Occasionally the plant owners were lucky in finding the amount and kind of water they wanted. More often, however, procrastination about water supply resulted in either too little water or poor quality, or both. Sometimes adequate water was available at a distance to supplement or to substitute for the local supply. On other occasions a locally developed water of inferior quality could be treated to make it acceptable. Either course of action obviously added to the cost of the product.

Lack of knowledge of the water resources potential for many parts of the country has prevented the Geological Survey and other agencies from furnishing the information desired for industrial expansion. Although progress has been made in this direction, it is still impossible to give more than very general information about many sections, especially in regard to the quantity and quality of ground water. Additional detailed investigations will be required to provide the kind of assistance that industry requires for intelligent evaluation of proposed plant sites or for expansion of existing plants.

What, then, is the over-all picture in regard to the availability of water of suitable quality for continued industrial expansion? Since municipal systems furnish only a small fraction of the total industrial requirements, they cannot be considered as a major source of industrial water. Furthermore, the increasingly greater demands on municipal supplies for normal purposes has caused critical water shortages in many cities. These shortages consist of both inadequate sources and inadequate distribution systems. The net results, however, point to less and less water available for industrial expansion.

Need for water data. --As mentioned above, there is an urgent need for more detailed water data in nearly all parts of the country. In some areas there may be surplus water available but the surpluses have not been proven by systematic investigations. Furthermore, the quality may or may not be satisfactory for certain industrial uses, even with treatment.

During the past 3 years the Geological Survey has issued a series of reports on 16 metropolitan areas that give information about the water potential of these areas. Although many of the studies were reconnaissance in nature and give summaries based mostly on quickly-gathered facts, the reports have been in large demand. Some 10 to 12 more metropolitan areas will be covered in the next 2 or 3 years.

Reuse of water. --A considerable amount of attention has been given in recent years to the reuse of water. A major potential source of water for reuse by industry is treated municipal sewage. A steel plant in Baltimore faced with the need for an additional supply of process water, found it economically advantageous to purchase reclaimed municipal sewage.

In the Los Angeles area consideration is being given to use of treated sewage to stop the present ocean-water encroachment into the depleted ground-water reservoir, thus providing more ground water for industrial and other uses.

Surface water is reused by industries in several areas. Most notable is the Youngstown area where the total use by industries (1.2 billion gallons per day) has on occasion exceeded the flow of the Mahoning River, the chief source of supply, by 14 times.

The reuse by industry of water used for other purposes such as irrigation, raises a serious problem. In normal practice water returned to streams from irrigation projects contains much more dissolved solids than the applied water. Consequently the water quality is considerably deteriorated, depending on the diluting effect of the receiving streams. The use of irrigation return water for industrial purposes will generally be less favorable than use of the water before it is taken for irrigation. Fortunately, most of the areas in which irrigation is most widely practiced have not in the past been centers of large industrial activity. However, with increasing demands for the expansion and decentralization of industry, together with increasing acreage under irrigation, the effect of the quality of irrigation return water on industrial use is bound to create additional problems.

DEMINERALIZATION OF SALINE WATERS

Much interest has developed in the last few years in the prospective use of demineralized saline waters for industrial and other purposes. Until recently, in a few quarters, it was thought that it might soon be possible to convert ocean water to fresh water and convey it to almost any place where additional water was needed, all at an economical cost. Unfortunately, it is not that simple and the impression has been largely corrected. Furthermore, concerted efforts on the part of the public and private agencies have produced results that are encouraging for the conversion of saline water, especially water not as concentrated as ocean water, to fresh water at a cost competitive with existing sources in areas where the going price for water is substantially above average.

In 1952, Congress passed Public Law 448 which provides for research that it is hoped will lead to development of practicable low-cost means of producing from sea water, or other saline waters, water of a quality suitable for agricultural, industrial, municipal, and other beneficial uses. The Saline Water Conversion Program is conducted by the Department of the Interior. More than 20 research contracts have been negotiated with universities, research institutions, and private companies for investigation of many avenues of research. Included in these contracts are studies involving vapor compression distillation, solar radiation, ion-membrane separation of salts from solution, osmotic pressure, supersonic phenomena, separation of salts by freezing, and several others.

Preliminary reports on some of these contracts indicate that much-needed basic data are being obtained and that some of the processes under study may have reasonably early application. One of the processes has advanced to the pilot field stage. It involves just one use of ion-permeable membranes. The nature of the process is such that the cost of conversion of saline water to fresh water is proportional to the amount of dissolved salts in the water. Thus, it appears that this process will be more attractive for moderately saline waters than for concentrated waters such as ocean water.

Improvements are constantly being made in the vapor compression distillation process which has been used for several years, principally by the military, in suppling fresh water on board ship and in islands and other areas where fresh water is extremely limited or nonexistent. This process is relatively independent of the concentration of dissolved salts as far as energy requirements are concerned. Corrosion and deposition of scale are, of course, serious problems, but definite progress in their solution is being made.

It appears that the conversion of ocean water to fresh water may be practicable in certain coastal areas where existing sources of fresh water are inadequate to satisfy the demands. For areas more than about one hundred miles or so inland, however, it is probable that existing saline surface and ground water will be a more promising source of additional water supply. Furthermore, it may become feasible to serve by exchanges of water those inland areas from which diversions to coastal areas now exist.

This raises the question, where are the major sources of these inland saline waters located? The Geological Survey is currently engaged in providing preliminary information of this kind. Within a few months two reports will be available: One will deal with a reconnaissance study of the saline waters of the United States in which the existing information about saline waters will be summarized; the second will deal in somewhat greater detail about saline waters in Texas. Additional reports dealing with the availability of saline waters in water-short areas are planned.

The State of South Dakota is currently completing a report on the existing information about saline waters in that State. The work has been conducted in cooperation with the Department of Interior Saline Water Conversion Program.

FUTURE OUTLOOK FOR INDUSTRIAL EXPANSION

So far as water supply is concerned, what is the future outlook for the expansion of industry? It may be concluded, on the basis of existing information, that the major problem is not one of total supply, but the distribution of water and the effective planning in the development and use of this resource.

Our present water use amounts to a low percentage of our potential available supply. Furthermore, some uses, including that of industry, are not highly consumptive so that repeated use of water is possible. On the other hand, we find ourselves profligate in the use of water, including that for industry. Withdrawals of water can be greatly reduced if recirculation is widely applied and improved.

In the eastern part of the country, the major water problem is related not so much to quantity of water as to maintaining a satisfactory quality. The chief problem is the pollution of streams. Rapid strides are being made in the curtailment and prevention of pollution but much remains to be done.

Extended periods of low flow permit upstream movement of salt water in coastal streams. Thus, in highly industrialized areas such as the Lower Delaware River, where fresh water is

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at a premium, raising the natural flow by regulation offers a means to restrain upstream movement of salt water and in effect increases the supply of fresh water. In many parts of the country, industrial wastes, natural brines, and the salt concentrated through irrigation practices are loading streams at a more or less constant rate so that during low flow, these streams may lose their usefulness for water supply. Where flow regulation is feasible, the mineral concentration of these streams may be maintained at levels permitting continued use for industrial and other purposes.

One of the biggest problems is timing. On the one hand, we are prone to build costly surface-water structures and develop ground-water supplies before we have adequate hydrologic data for the best design and operational procedures, and on the other hand, legal and financial impasses frequently delay needed improvements long after the hydrologic characteristics have been satisfactorily determined. These factors of timing may well be the most frequent cause of water problems.

Thus, it appears that there are ample supplies of water for continued industrial expansion. But information on the location, quantity, and quality of these supplies is not available just for the asking. Detailed hydrologic facts will be necessary and, when available, must be used intelligently with due regard to the needs of others so that maximum use of the available water supplies will be realized. Such facts must be related to dependable data on water needs. What is a reasonable water requirement for the production of a given commodity? What are the chemical, turbidity, and temperature limitations for its various uses? In local areas of shortage what is the most beneficial use of the available supply? Is the high consumptive use of irrigation to be given preference over industrial requirements in some areas? What are the standards by which our water resources can serve both as the medium of waste disposal and water supply? Not until we have satisfactorily answered these questions will we be able to plan the development and utilize our abundant waters with the assurance that all will have an adequate supply of water of good quality.