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COLD WATER ON SALT WATER
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P-546-RC
16 July 1954

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COLD WATER ON SALT WATER

I.

The search for fresh water has employed a large part of man's energies for a very long time because his very existence has depended on finding it. Civilizations themselves have risen and fallen with the water level, and history has often recorded the migrations of people trying, among other things, to quench their thirst.

They are still trying. In our country we have been hearing much in recent years about water shortages. Cattlemen and ranchers in the far West, plagued by a succession of severe drouths over a period of years, have been hard hit and in desperation have turned to professional rain-makers, have petitioned Congress, or have just prayed. City dwellers in the East and South have occasionally been sharply restricted in their use of water, have at times gone bathless, and, in restaurants and hotels, even drinkless.

Faced with the prospects of a nation getting thirstier and dirtier by the day, a joint committee of the United States Senate held a series of formal hearings in 1951 in an effort to remedy a situation reputedly bad and threatening to become worse. After a few preliminary remarks about Mark Twain's old saw to the effect that everybody talks about the weather but nobody ever does anything about it, the committee settled to the serious business of exploring two lines of thought: artificial rain-making by cloud nucleation and converting salt water into fresh. There were considerations and debates, reports, letters, claims and counterclaims. All kinds of people in public and private life, many of them eminent and reasonable men, were called to give their testimony. All kinds of schemes for increasing the available supply of water were proposed, some of them rational and

cautious, a few of them clearly lunatic. Eventually the committee emerged with a three hundred page report, calling for federally sponsored research into rain-making and salt water conversion. As subsequently reviewed by Congress, these goals were somewhat modified. Because of its equivocal nature, the problem of artificial rain-making was set aside altogether, and the bill that passed restricted itself to setting up a program for salt-water conversion, to be initiated by the Bureau of Reclamation and financed by two million dollars from the public funds. In recognition of the high costs of turning salt water into fresh, the specific purpose of this program was to develop a means of reducing the costs of this operation to a point within reach of ordinary people: farmers, townspeople, and industrialists in all water restricted areas of the United States.

The interesting thing about all this is that in neither committee hearings nor Congressional debate did anyone seriously challenge the assumptions underlying the bill, namely, that there really is a general shortage of fresh water in the United States and that the conversion of sea water into fresh promises to be the most sensible way of increasing our supply of it. Just how wide of the mark these assumptions really are has been shown by scientists at The RAND Corporation in Santa Monica, California, in a foundation-supported study. Two engineers, Mr. James C. DeHaven and Mr. Linn C. Gore, and an economist, Mr. Jack Hirshleifer, have taken a good, hard look at our water problem and have recently issued their report, A Brief Survey of the Technology and Economics of Water Supply. Because it goes far to dispel the errors of popular thinking that surround this issue at every turn and therefore deserves a wider audience than it can ever have as a scientific report, the present writer has undertaken to summarize its essential points.

The truth of the matter, as the RAND scientists point out, is that the term "water shortage" often conceals a confusion of thought. Thanks to the immensities of the hydrologic cycle (the natural course of water in its various forms from ocean to atmosphere to land), there can be no such thing as an absolute shortage of water. Rainfall for the United States as a whole averages approximately 1,568,400 billion gallons a year. The total national consumption of water amounts to about 4.7 per cent of this figure or 17 per cent if we deduct what is lost of this by evapotranspiration, the process whereby water from the ground passes through a plant and from the leaves into the atmosphere. This is not to say that everybody has all the water he needs or that water in certain isolated communities is not held at a premium. It is to say that water cannot be "short" in the sense that its total supply can be exhausted, for there is always more water available--for a price. The problem, therefore, for any community in need of water is one of determining the most economical and expeditious way of getting its next increment. And when it comes to examining its water problem in this way, no community of any size in the United States today is likely to find salt-water conversion now or in the immediate future the most sensible way of going about it.

II.

Superficially as the issue was appraised in Washington, probably nowhere is it today more generally misunderstood at the popular level than in Southern California. Los Angeles newspapers repeatedly talk about water shortages and just as frequently chronicle new schemes for turning sea water into fresh. Actually, there is no water crisis in Southern California at present. But if water problems exist anywhere in the United States,

Southern California is a good place to look for them. In fact, it is a good place to consider the whole question of water supply in general, for the situation there in respect to supply and demand is more or less typical of what exists or may exist in the future in other parts of the country. With regard to the potentialities of salt-water conversion, this section of California is representative of all coastal regions where people look expectantly to the ocean for additional supplies. As for the conventional sources of fresh water, whether pumped from the ground or piped in from distant sources, it is certainly no better off than other localities of equal size and importance where water has become, rightly or wrongly, a public issue; and it is a great deal worse off than most. Some of the things, therefore, that can be usefully said or done about the situation there may well be of significance elsewhere.

It is not entirely unnatural that the public outcry about water shortages should be especially loud in Southern California. With a yearly rainfall of about fifteen inches, and these almost entirely during the winter months, the land outside the cities is distressingly dry for long periods of the year. During such times water plays a critical, indeed a spectacular, role, particularly when the only water to be had must come out of a pipe. At least one of the alarming things you can say about Los Angeles is that though water makes it bloom—even as the rose—the desert threatens to reclaim it whenever you turn off the tap.

There are other places in the United States that are more arid the year round, but none of them even approaches Southern California industrially or in population. Half of all the people in California live in this one corner of the state, in what might roughly be called the Los Angeles area. The

region comprises the four counties of Los Angeles, San Bernardino, Riverside, and Orange, and adjoins San Diego and its environs to the south. For a large and growing population the area provides less than 1.5 per cent of the state's total water supply. This 1.5 per cent represents the water contained in a chain of aquifers, naturally formed reservoirs that underlie the area and are charged by runoff from the mountains to the north and east. It is relatively cheap water, about \$5 an acre-foot (325,851 gallons), free to anyone except for the expense of digging a hole in the ground and pumping it out.

This is precisely what people in ever increasing numbers have been doing. In 1949 approximately 980,000 acre-feet were drawn from these underground sources, principally for irrigational purposes. This rate of draft is about 250,000 acre-feet per year beyond the capacity of the aquifers to recharge themselves, for the water level has been consistently falling for a number of years. Today it is largely below sea level, in some places as much as seventy feet. This is a dangerous level in areas near the ocean because of the possibility of contamination by salt water. In fact this has actually occurred, to the great dismay of people whose wells have been made useless as far inland as two and three miles. In brief, if we consider the lack of rainfall, the sandy river beds, the contaminated wells, the falling water table, and a persistently growing demand for water, the picture looks pretty grim. If there really is a water problem anywhere in the United States, it certainly ought to be in Southern California.

But the picture is alarming only if one does not look closer. During the early development of this area, it was realized that the capacity of the local underground supply was going to be insufficient to meet the demands of

expected growth and development. In 1913 an aqueduct to the Owens River was installed and later extended to the Mono basin. It has a present capacity of about 320,000 acre-feet a year. For many years excess winter flow from this system was used to recharge the aquifer under the San Fernando Valley for use during peak demands in the summer. In recent years, however, increased year-round demand made storage out of the question. To meet this threat, the Metropolitan Water District of Southern California ran an aqueduct of immense proportions all the way to the Colorado River. Since 1941 this river has been supplying the area with a gradually increasing amount of fresh water. During fiscal year 1951-52 this came to 150,000 acre-feet. This amount plus approximately 320,000 from the Owens River, plus 980,000 from the local ground supply gives a total of 1,450,000 acre-feet as the annual water consumption of the four metropolitan counties. The District can supply them with an annual draft of about 1,050,000 acre-feet from the Colorado. The aqueduct was constructed to handle this capacity plus an additional 150,000 acre-feet for the San Diego region. In other words, current use from the aqueduct is only a fraction of the capacity assigned to the area. The untapped 900,000 acre-feet a year is more than sufficient to allow a 60 per cent increase in the present consumption of water.

This additional amount of water, it must be admitted, is in dispute. Litigation between California and Arizona over interpretation of earlier contracts is now before the Supreme Court. Should the Court find in favor of Arizona, it is perfectly reasonable to suppose that reallocations would be made anew.

There remains a further possibility of bringing water from the Feather River watershed north of Sacramento where there is an excess supply. A plan

to pipe it all the way down to the Mexican border has already been outlined by the Division of Water Resources of the California State Department of Public Works. It would have an estimated capacity of 3,600,000 acre-feet a year, of which 850,000 is scheduled for Los Angeles and surrounding areas.

In plain terms, if we ignore all other additional sources--redistribution and reclamation of water already used or the possibilities of turning the Pacific into drinking water--this part of Southern California has a potential supply of about three million acre-feet of fresh water a year or twice the amount now consumed. Even if population and industrial expansion continue at the same phenomenal rate of the past ten years, this amount of water can be considered adequate for a long time to come. The term "water shortage" in Southern California really means only that the next increment of water is going to cost more than the last.

People are already paying more, for there is no additional supply of \$5 water from underground. Owens River water is about \$20 an acre-foot. Colorado water, softened, is about the same price; unsoftened, about \$10. Water piped down from the Feather River will be most expensive of all, perhaps \$50 to \$100 an acre-foot or even more. It is obvious, therefore, that if we acknowledge the realities of the problem, we should be talking about what water can be had and what we are going to pay for it. And it is in just such terms that we ought to consider the popular proposal to convert sea water into drinking water.

III.

Any popular discussion of water shortage is frequently if not invariably followed by a proposal to convert salt water into fresh. And somebody, it

will usually be added, had better hurry up and do something about it.

There is a certain justification for people's thinking along these lines. It is generally known that distillation is used by ships at sea, has been, in fact, ever since Sir John Hawkyns sailed against the Spanish some four hundred years ago. It is also a relatively simple process, requiring only a tea-kettle and a fire. What most people do not know are the engineering and, in particular, the economic difficulties of changing salt water into fresh on any large scale. With respect to these difficulties, salt-water conversion has a popular appeal that is not warranted by the facts.

There are a number of methods currently in operation in and out of the laboratory that range from simple distilling to more or less complicated chemical processes. In effect they all remove either the salt from the water or the water from the salt. Among those that take the water away from the salt, the oldest and simplest is the distillation process. It consists basically of vaporizing water from salt water by heat and then condensing the steam. The machinery involved in this process varies from the pocket-size contrivance used by distressed seamen to the large commercial evaporator. The multiple-effect evaporator is nothing more than a series of distilling units, called effects, connected with each other so that the steam or vapor from one is used to heat the salt water in the next, and so on down the line to as many as five or six effects. Such is the one built recently in Persia, the largest multiple-effect evaporator in existence and capable of supplying 720,000 gallons of fresh water a day. In spite of its simplicity and the partial advantage of lifting itself, in effect, by its own hot straps, this particular method of getting fresh water is one of the more expensive. To produce an acre-foot of water costs about \$1200, a cost that can be reduced to—say \$900 if waste heat is employed.

The problem of heat is naturally of great importance and has been solved in a few instances by the direct application of solar energy. This is the method utilized in the salt water conversion kits used aboard life rafts in World War II. It was also used as far back as the 1880's in Chile, where a distillation system was set up in the nitrate mines to provide 6,000 gallons of fresh water a day. The equipment, covering an acre of ground and resembling a very large greenhouse, consisted of wooden trays filled with salt water under sloping glass covers. Heat from the sun turned the water into vapor which collected on and then ran down the glass covers into a system of pipes and receptacles. The fact that the energy to operate this method is had for nothing is much in its favor, though the vast acreage necessary to produce water in large quantities has made economists stop and consider. Even so, this method can produce fresh water at the rate of \$350 an acre-foot, and supposing a more ideal process with greater efficiencies, engineers have estimated that costs in the future may be reduced to \$100.

A more recent development is the vapor-compression evaporator. In this device, vapor from salt water is withdrawn by pump from an evaporator shell, is compressed to increase its condensation temperature a few degrees, and is then returned to a heat exchanger within the evaporator shell. Here it condenses, the latent heat given off being used to heat more saline water in the shell. This kind of evaporator is more economical than the multiple-effect type and can be built more compactly. According to Dean Sherwood of the Massachusetts Institute of Technology, it can produce fresh water for around \$700 an acre-foot. Thus far only relatively small units have been constructed, but larger ones are perfectly feasible. With improvements they may produce this same amount of water in the future for \$200.

Perhaps the most ingenious method of all is that of the French scientist Georges Claude. Working on the principle that temperature differences in nature constitute a potential source of energy, Claude suggested an apparatus that utilized cold deep sea water and relatively warm surface water. In this system, warm sea water is piped into an evaporator under reduced pressure, where a small fraction evaporates, gaining its latent heat through a 5° F cooling of the remainder of the water. The vapor formed passes to a condenser at still lower pressure, where it is condensed by cooler sea water. An unusual feature of this method is that in addition to fresh water it produces energy in the form of electricity. The vapor as it passes from the evaporator to the condenser is made to operate a turbine, connected in turn to a generator. A small model now in operation at the University of California requires 10 horsepower to generate 4.6 horsepower of electricity. A much larger and therefore more efficient unit, capable of producing 100,000 gallons of water, would generate a little more electricity than is needed to operate the pumps. When completely assembled and in operation, this machine -- one has to resist the impulse to call it a contraption -- ought to produce large quantities of fresh water and the illusion of perpetual motion. Engineers have proposed the construction of a plant in Abidjan, French West Africa, and it has been estimated that it could supply water for as little as \$150 an acre-foot. If waste heat is used in lieu of an undersea pipe line, the cost might be reduced to \$100.

There are other ways of removing water from salt, but most of them have not progressed beyond the exploratory stage and are therefore difficult to evaluate.

One such method involves freezing fresh-water crystals out of a saline

solution. Aside from the fact that it could not produce an acre-foot of fresh water for much under \$400. there is the technical difficulty, not yet satisfactorily overcome, of eliminating the salt water that occasionally becomes entrapped within the crystals. Another method, for which there are no cost estimates but which is technically feasible, operates by means of semi-permeable membranes. Salt water, separated from fresh by a membrane, is subjected to pressure that is sufficient to upset the osmotic balance, and fresh water is extruded from the salt through the membrane. The method does not work well even in the laboratory, and any attempt on a large and practical scale would inevitably meet with troubles. One of the more serious would be to keep the membranes from plugging up or collapsing under pressure.

Taking water out of salt is only one way of separating the two. Conversely, one may remove the salt from the water. Such processes have an advantage over those already mentioned in that their costs vary significantly with the amount of solids to be removed, unlike evaporative processes, whose energy requirements change little if brackish (semi-salt) water instead of sea water is used.

Methods for removing salts are largely chemical in nature. The classic one is the silver-salt precipitation unit developed for life raft use during the war. Unfortunately, the very high costs of the chemicals naturally eliminate precipitation methods from consideration. In recent years a new chemical process, the ion exchange method, has been developed. This makes use of resins that alter the chemical nature of salt water to produce fresh water. The resins, however, have to be periodically renewed, and the chemicals, together with some of the desalted water itself, needed for this regeneration seriously affect the economy of the process. In fact, the cost is prohibitive--

\$8000 an acre-foot—except for the treatment of brackish water, which contains fewer solid particles than sea water. Israel has recently built a pilot plant of this kind for just such a purpose.

One other method, the electrolytic ion exchange process, should be mentioned if only because of the recent interest in it. Although the details of commercial units have not been released by the manufacturer, they obviously employ a modified form of electrolysis. Under ordinary circumstances the ultimate effect of electrolysis on salt water would be to decompose water into its constituents, hydrogen and oxygen, leaving a muddy, concentrated residue of solids. In effect, one would end with salt but no water. In the method under discussion, however, this situation is forestalled by different membranes, permeable to ions of one kind of electrical charge, impermeable to those of another. A series of cells separated by such membranes produces concentrated solutions of salt water in some of them, fresh water in others. It was originally asserted by the manufacturer that fresh water could be made in this way for \$30 to \$65 an acre-foot. One can only suppose, however, that these costs were unduly optimistic, for according to recent news reports they have been revised upward to \$500 an acre-foot. Greater efficiencies in the future may bring this down to around \$130.

The whole question of determining the costs of turning salt water into fresh is admittedly a difficult one. With few exceptions, no plants with a capacity sufficient to meet the needs of a community have ever been built. Some of the processes described have not even been operated in the laboratory. In addition, costs supplied by the manufacturer or designer are often suspect because one seldom knows how they have been computed, or whether amortization, obsolescence, operating expenses and energy costs have all been included

or adequately considered. Furthermore, any consideration of a future reduction in costs is, by its very nature, hypothetical and depends, among other things, upon a careful appraisal of future technological possibilities. Some conversion processes, for instance, appear to have reached the limits that present and expected future technology will permit. Others can and may improve with time. In any such survey as this, complete and rigidly exact costs are out of the question, but the estimates that have been made are approximate. Approximations are all that we can ask for. After all, one cannot reasonably object that cost estimates come out of something that resembles a crystal ball. Unfortunately, there is no other place to look for them. One may only ask that the ball be free of obvious cracks.

From the view of conserving natural resources and of estimated lowest ultimate cost per unit of fresh water, those processes which use temperature differences, the Claude method, for instance, and direct solar energy are the most economical and most promising for development. The use of atomic energy is not at present a solution to the problem. Until its costs are considerably lower than they are now, we are going to have to continue using the more conventional sources of power. It should be remarked, however, that the economy of processes which take the salt out of the water, as distinct from those that remove the water from the salt, is directly related to the amount of solids present. It is reasonable to suppose that the former processes may be used in the near future for the treatment of brackish waters where removal of one or two thousand parts per million can produce good irrigation water. The counter-flow ion exchange system may be able to remove one thousand parts of solids for about \$190 per acre-foot. It has been said that the electrolytic ion exchange system can do the same job for \$10 an

acre-foot. Other more conservative estimates place this cost at about \$120 an acre-foot.

An analysis of costs should consider the possibility of marketable by-products. The ocean contains at least traces of half the elements, and it is technically possible to extract them. Unfortunately, only sodium and magnesium salts and bromine can now be extracted economically, and these are so abundant and cheap that there is very little profit in them. In addition, if really large volumes are produced (and it is possible that efficient extraction may depend upon large volumes), potential gains may be offset by a fall in prices. One must conclude that the reduction in the cost of water conversion by the sale of by-products is not significant.

The question of cost is a critical one in this argument. There is no present lack of water; there is more than enough readily available. In Southern California, as elsewhere, the so-called water shortage always turns out in the end to be a question of what the next increment of water will cost. If we compare the estimated costs of converting sea water into fresh with present costs of natural water in California -- and California prices of \$5 - \$20 an acre-foot are representative of water costs in many other parts of the United States -- the answer is clear. Sea water can cost from seven to several hundred times as much as natural water. Here are some sea changes with a vengeance. Probably the best that can be said is that the cheapest salt-water conversion process operating at some indefinite time in the future and at greatest efficiencies may be competitive in price with natural water brought in from very distant sources. There already are such places along the Persian Gulf. There is good reason, therefore, to encourage the development of improved sea-water conversion methods. But there are no coastal

areas of any size in the United States where this situation exists today or is likely to develop in the foreseeable future.

IV.

If we are really going to do something useful about our water supply, the economic facts of life should impel us in a slightly different direction, not toward salt water conversion -- certainly not immediately -- but in the direction of conservation, redistribution, and reclamation of the water we already have and use.

Increasing the natural supply of water by artificial nucleation over wide areas does not seem immediately feasible in spite of enthusiastic reports in the newspapers and the claims of professional and amateur rain-makers. Under certain conditions there is pretty good evidence that cloud seeding serves to decrease rather than increase precipitation. It appears, however, to have some value in specialized local areas. In combination with additional measures, artificial aerodynamic barriers and artificially altered reflectivity of the earth's surface, it may in the future assist nature in depositing rain where we want it. It is not likely to become a source for large supplies of fresh water. There are many other more practicable and profitable things to be done.

One of the first things we might do is to reduce the evaporative losses of water from storage lakes and reservoirs. In some extreme instances it is probable that the waste by evaporation equals the amount drawn for use. For example, a recent study by the Federal government showed that losses by evaporation at Lake Hefner in Oklahoma amounted on the average to about 90 per cent of the outflow. Since then the investigators have moved to Lake

Mead, and although results have not been released, the losses there, if comparable to those at Lake Hefner, may approximate 800,000 acre-feet a year, a quantity of water nearly equal to all that is consumed by the greater Los Angeles area in the same length of time.

How to put an end to this waste is not presently known. Not until recently was it even possible to measure it with any degree of precision. Whatever can be done, however, by oil layers or other forms of insulation will be a positive gain, and may prove to be far less expensive than bringing in an equal amount of water from more distant sources.

Similar to loss by evaporation is loss by evapotranspiration, wherein water passes from the ground through vegetation and thence into the atmosphere. For the United States as a whole it is estimated that by this natural process 72 per cent of the average rainfall literally vanishes into thin air. Some of this loss occurs in the growth of beneficial plants, such as crops and forests, and is therefore unavoidable; but some of it, perhaps a great amount, takes place in the growth of undesirable vegetation. The salt pines, for example, that grow along watercourses, send their roots deep into the aquifer and are greedy consumers of water. Inasmuch as these pines are good for neither man nor beast, the water that nurtures them is wasted. In some areas an effort is already being made to eradicate them and similar growths in large numbers. Exactly how much can be saved in this manner cannot yet be determined, but it may be very considerable.

Then there are direct economic measures that may be applied. Though Southern California serves as an example, these measures have universal application.

The only really alarming thing about the so-called water shortage in California is the situation with respect to ground water. The water level of the aquifer has dropped steadily because of excess pumping. The results are

twofold: an increase in the cost of pumping water from this underground source and a costly intrusion of sea water into the aquifer as far inland as two or three miles. The important thing about these costs is their inequitable distribution. The increased cost of pumping falls upon all well owners, regardless of where they live; but the intrusion of sea water involves a major, even catastrophic, loss only to those directly affected, and no loss at all to those further inland who may be equally responsible for the condition. It is the intrusion of salt water that constitutes the really serious problem because it may in time do irreparable damage to the aquifer as a whole, and because the cost of the damage lies disproportionately heavy, and therefore inequitably, upon property owners near the coast. In other words the private cost of pumping does not accurately reflect the social costs.

What is needed here is a water use tax on pumpers that will reflect the social cost of the intrusion to the community as a whole. Prorating or rationing the use of water is a comparatively inefficient remedy. It does little or nothing to prevent waste by the individual pumper and then, once the quota is reached, cuts off the supply completely however intense the demand. A simple tax per unit of water drawn is as easily enforceable and provides revenue with which to repair the social losses. Still another conservative measure is the possibility of consumptive pricing of water, which would charge more for water that was "used up" (water which is contaminated or is lost by evaporation or run off) than for water which is returned to the aquifer by spreading beds and recharging wells. Such a policy ought to encourage industry to adopt nonconsumptive techniques. It is well known that plants differ widely in their use of water even when manufacturing the same product. Intelligent conservation practices can

actually turn an industrial plant into a net contributor, even though a small one, to the general supply of water in the aquifer. This is precisely the situation at the Geneva Steel Plant near Provo, Utah. Drawing 240 million gallons a day, this plant actually consumes only 3 per cent, the rest being restored to the aquifer. This small use is more than made up by decreased evapotranspiration loss in the plant area.

Conservation of fresh water might even entail the direct use of sea water for a number of useful purposes in areas where it is readily accessible. There are coastal cities, for example, that use sea water for fire protection. Many industrial or sanitary purposes might easily be served by salt water.

The direct use of sea water raises the very interesting but little explored subject of "ocean farming". Water has ever been recognized as an important source of food. Enlightened farmers, for instance, know that by proper fertilization they can grow more meat (in the form of fish) on an acre pond than pork or beef on an acre of dry land. More specifically, the artificial culture of oysters for pearls and food and the cultivation of vegetable crops like kelp are instances of how the ocean itself can be "farmed". The varieties of plant life in the sea are fewer and simpler than those on land, but they produce the basic food for all marine life and might conceivably be cultivated for human or animal consumption. Even better, it is not impossible that useful land plants such as rice, for instance, might by selective breeding be adapted to marine growth. This process is not without precedent. Some of the highest forms of marine flora, such as the flowering plants, were originally land forms in the evolutionary past. This is a subject that cries out for investigation, for the direct use of the sea to produce food may hold greater promise for the large scale production of cheap food than any process for converting

sea water to fresh water for production of food in the conventional manner.

Hand in hand with conservation goes redistribution wherever this will result in a more economic use of water. While the four metropolitan counties have a Colorado River allocation of about 1,050,000 acre-feet, the Imperial Valley and adjacent areas have allocations of about 4,150,000. Other areas have residual claims. Essentially all the water for areas outside the coastal region goes into relatively low-value agricultural uses. It is therefore quite possible that by the time the heavily populated coastal area is paying \$50 for its water it may be able to make a satisfactory agreement to buy some of the water allocated to other sections.

There is still one other huge source of fresh water that must be mentioned. Startling though it is at first glance, this is the reclamation of fresh water from sewage. This is the sort of thing that delights engineers and economists but makes ordinary people grow pale. Whether we like it or not, reclamation of exactly this kind is going on inadvertently in river towns that use the same stream at once as a common sewer and a source of fresh water. It is also going on in Southern California where the overflow from thousands of septic tanks enters the aquifers, to be subsequently pumped out for municipal and irrigational purposes. And no one is the worse for it. Where properly controlled there is no danger to public health. The movement of water from sewage through six or more feet of earth reduces the presence of harmful organisms below the tolerable level. Of course, if such a scheme were intentionally put into effect, there would be engineering and legal problems to solve. Considering the resistance people can put up against having themselves and their dogs immunized for disease, one might guess that the legal problems would far outweigh the technical. As a problem in engineering it is perfectly feasible.

All things considered, this source of fresh water is much closer to being available at a much lower cost than water provided by any known means of sea-water conversion. It may, in fact, be more economical than piping in water from very distant sources. In the Los Angeles area more water is available from sewage than is now brought from the Owens-Mono watershed. This means that about 400,000 acre-feet a year, or about half the total amount of water now being used, could be made available for the Los Angeles area from this source alone at a cost between \$30 to \$35 an acre-foot. As more water is drawn from the Colorado by an increased population, proportionately more water will be available through reclamation, conceivably an additional million acre-feet a year. It is a simple instance of to him that hath shall be given.

If 1,400,000 acre-feet of water from reclaimed sewage are added to the quantities obtainable from all other natural sources--730,000 from the ground, 320,000 from the Owens River, 1,050,000 from the Colorado, and 850,000 from the Feather River--Southern California has a potential supply of well over four million acre-feet of fresh water a year. And these are sources and quantities that are in some degree determinable. Additional amounts of water that may eventually come through prevention of evaporation, purchase from the allocation of other regions, or further impounding of runoff, are not here included only because they are less calculable. They are not less real.

There is no generally accepted way of estimating the future demand for water. In general terms the demand is governed by the residential and industrial patterns of a community, by the level of business activity and by the price of water itself, which, as it increases, tends to check the per capita use. In Southern California the demand for water in the past has been closely related to growth in population. It will presumably continue to be. Between 1930 and 1950, for instance, total water consumption kept

pace with total population, each just about doubling. The per capita use during this time remained almost constant, increasing slightly in homes and industries, decreasing on farms. Assuming then that the population will continue to grow, but barring a radical increase in the rate of growth, one may conclude that the potential supply of fresh water (through the \$50 - \$100 cost range) of approximately three times the present consumption will be adequate for a long time to come, at least twenty years, perhaps even longer.

Reclamation, conservation, redistribution--these are measures that can usefully be employed, and not only in California but in other places as well. Most of them are already feasible, and in contrast to methods for converting sea water into fresh water they are inexpensive. Singly and together they can furnish large increments of fresh water when they are needed. When they are needed is an important consideration. The aqueduct to the Colorado, indispensable as it is today and a monument to civil engineering, may have been built at least five years too soon in that only comparatively minor use was made of its facilities for about that length of time. What it cost meanwhile in heavy interest and amortization charges made it an expensive venture in public finance. We can make the same mistake all over again by rushing to construct salt-water conversion plants before we need them. There may come a time in certain areas of the country when we shall have to turn to the ocean for fresh water, when salt-water conversion will be less expensive than any other source. But that time is not now. Certainly not when large quantities of fresh water are already at hand and even larger quantities will be available for years to come. If we stop talking about water shortages and consider the problem in terms of supply and costs, we will be prepared to do something sensible about it when we need to do it and not before.