OUR CHEAPEST SOURCE OF ADDITIONAL WATER

by Jack E. McKee

Even before the turn of the century southern California planners recognized that local water supplies would be insufficient to support the expected population of the area. To supplement the limited local supply, which might be adequate for no more than a few hundred thousand people, they went first to the Owens Valley (in 1907), then to the Colorado River (in 1939), and are now going to northern California and to demineralization of sea water.

Because each new attempt to get additional water results in more expense, it is surprising that so little attention has been paid to another, very economical source: re-use of that imported water we have paid so much to get. We have become accustomed to discharging once-used water into the ocean, but there is good evidence that this is a needless waste of a precious commodity.

For use in an urban environment, water must be adequate in quantity and potable in quality. The water supply system should be so reliable that it will not be disrupted for more than a few days by earthquakes, floods, power outages, or even acts of war. Preferably there should be multiple sources of supply, and they should originate as close to the area as possible. The water system of Berlin, for example, could not be destroyed by Allied bombing in World War II because it comprised hundreds of wells within the city limits. Even during the Berlin blockade of 1949 the Russians could not shut off the water supply. How many large American cities could retain their sources of water when surrounded by hostile forces? In assessing alternative sources of supply, it behooves us to give strong weight to reliability in both peace and war.

Potability of water in the United States is judged largely by the United States Public Health Service Drinking Water Standards of 1962, which have been adopted by, and are generally enforced by, the various state and local health departments. Some of these standards are mandatory; others are non-mandatory but strongly recommended. Where alternative supplies of better quality are not economically available, water that exceeds one or more of the recommended limits may be utilized. In 1965, for example, raw Colorado River water contained an average of 712 milligrams per liter of total dissolved solids (vs a USPHS recommended limit of 500 mg/l) and a sulfate concentration of 306 mg/l (vs 250 mg/l recommended). Yet, as we all know, Colorado River water is accepted and used thankfully by millions of residents of southern California, with no apparent detrimental effects. Some local water supplies, such as Ventura's, which contains over 1,200 mg/l of total dissolved solids, appear to be more than adequate for municipal needs.

In addition to ample quantity, firm reliability, and healthful potability, a water supply should also be economic. Despite the fact that water is, by far, our cheapest domestic commodity (it is delivered to our taps for less than 10 cents per metric ton), the total cost of water for a large metropolitan area is enormous because we use and need so much of it. Given a choice of alternative supplies, we should naturally favor the least costly source, within the parameters of reliability and potability. But this choice brings up the question of how much economic value can be placed on better quality and improved reliability. In 1963, for example, a report to the San Diego County Water Authority by a group of consulting engineers indicated that the hardness and dissolved solids in Colorado River water (as compared with purer, northern California water) would cost the users an additional $23 per 1,000 cubic meters over the base cost. Hence, quality as well as quantity must be considered in comparing the total costs of alternative supplies.

The dynamics of a water system can be repre-

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sented by the simple "water equation," which says that over a long period of time, such as several decades, the output must equal the input, or for shorter time intervals, such as a year:

$$\text{Output} = \text{input} \pm \text{change in storage.}$$

This equation relates not only to quantity but also to quality, not only to volumes of water in cubic meters but also to weights of solids in kilograms or metric tons. Over an extended period of time, the simple form of the equation for any area, urban or rural, must be in balance.

If the output or usage exceeds the input for many years with respect to water volume, a drought or acute water shortage is inevitable. Conversely, if the input of dissolved salts in the water supply and the additions of solids from the use of such water exceed the weight in the output, salts and other solids will accumulate in the environmental system. This problem has been especially acute in many areas of irrigated agriculture. It may also become severe in urban environments if adequate measures are not taken to remove or minimize liquid wastes.

In the water equation for the coastal basin of southern California a large part of the total input comes from rainfall, and, similarly, a substantial portion of the output occurs as evaporation and transpiration. Some of the output is attributable to surface runoff, ground-water seepage, and possibly some deep percolation, but the major avenue of output in addition to evaporation and transpiration is discharge of waste water to the ocean.

Requirements for waste water disposal to the ocean or at inland locations are predicated on the subsequent beneficial uses of the receiving waters. Such discharges are subject to careful supervision by the California Regional Water Quality Control Boards. A primary factor in the various requirements promulgated by the Regional Boards is protection of human health and public water supplies. Consideration is also given to the preservation of aquatic and marine life; to the quality of water needed for irrigation and industrial purposes; and to esthetic factors related to bathing, boating, and other water sports. Within the constraints and boundary conditions that result from the requirements of the Regional Boards to protect beneficial uses of the receiving waters, recognition must be given also to economic factors, because waste disposal (like water supply) is a costly undertaking.

How much water is needed?

In the coastal basin of southern California it is estimated that an ultimate mixed agricultural, residential, business, commercial, and industrial economy will have a net annual water requirement (in addition to rainfall) of about 700 mm or 0.7 of a meter. For an ultimate habitable and useful area of about 1,100,000 hectares, the total ultimate water requirement will be 7.7 cubic kilometers per year.

The present sources of local and imported water supply provide a safe yearly yield of 3.3 cubic kilometers (assuming full use of the original Colorado

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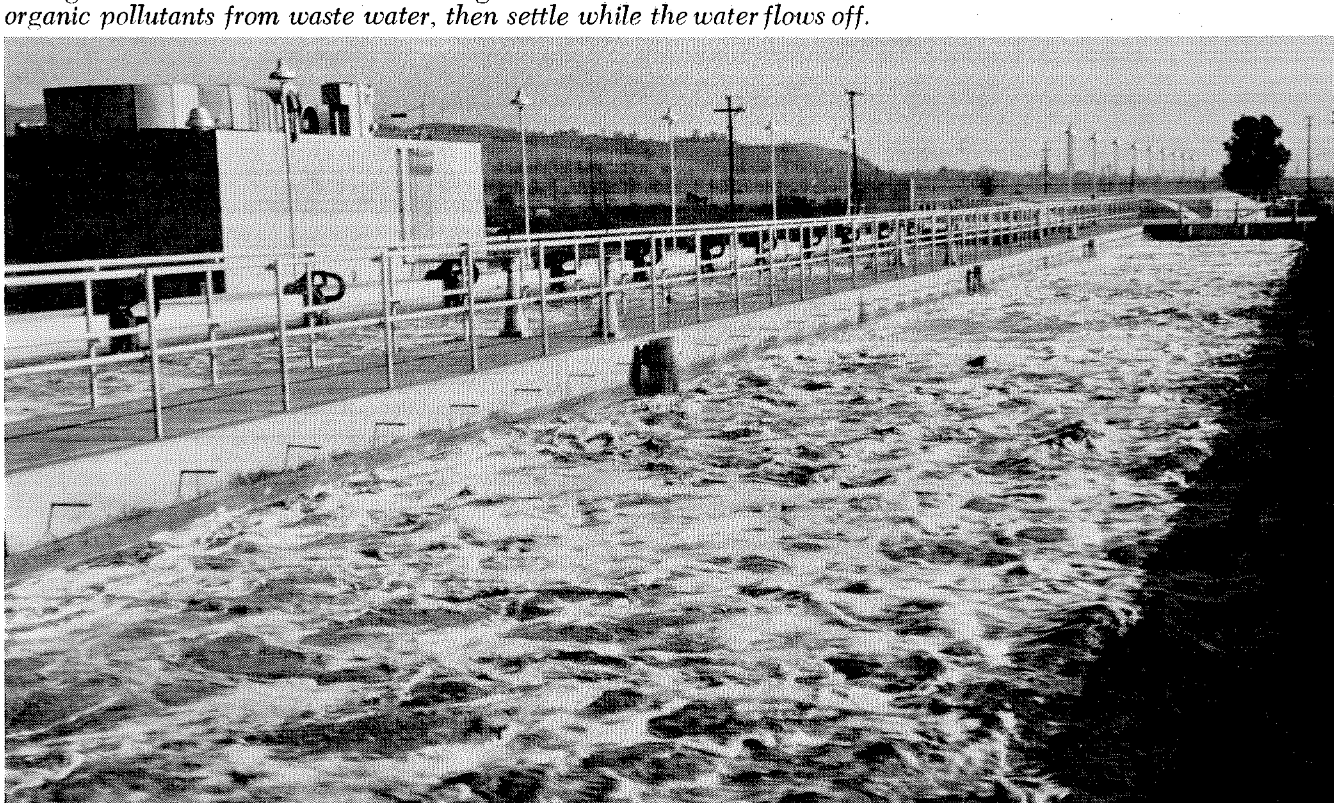
Biological cultures in this activated-sludge aeration tank at Whittier Narrows Water Reclamation Plant remove organic pollutants from waste water, then settle while the water flows off.



River entitlement) and the new aqueduct from northern California will provide about 2.7 cubic kilometers, giving a total water supply potential of 6.0 cubic kilometers, or 1.7 cubic kilometers short of the ultimate yearly requirement. It is not too early for us to look for ways to augment the present supplies and to provide insurance, through a diversity of sources, to protect against acts of nature or war.

The discharge of municipal waste water and fresh liquid industrial effluents to the ocean in southern California totalled approximately 1.2 cubic kilometers in 1965, or about 35 percent of the total fresh water used in the basin. Furthermore, ocean discharge amounted to more than 55 percent of the total importation through the Colorado and Owens aqueducts. It is logical, therefore, that we should inquire into the rationale of importing water 400 to 700 kilometers, or even further under the California Water Plan, using it once, and then discharging it, still fresh, to the ocean. Reclamation of some of this water would help to meet the ultimate water requirements of this region.

The chemical, physical, and biological quality of municipal waste water depends on the mineral content of the originating water supply and the substances added by municipal use, most of which can be removed by conventional activated-sludge treatment (where organic pollutants are adsorbed and utilized by biological cultures, which are then easily separated from the water). The water from the activated-sludge plants at Hyperion and Whittier Narrows, for example, meets all of the specific mineral standards of the USPHS (both mandatory and recommended); it exceeds some other drinking water standards, but they can be met by various secondary treatments.

Underground water storage

Los Angeles, Orange, San Bernardino, Riverside, and Ventura Counties are fortunate, indeed, to have voluminous ground-water basins. San Diego County, on the other hand, has only a few very small underground basins. It is estimated that the storage capacity of ground-water basins in the south coastal area, in a depth of about three meters above and below the present water tables, amounts to about 60 cubic kilometers, or about an eight-year supply of water at the ultimate demand. Hence, these ground-water basins represent a tremendous economic asset in being able to provide voluminous storage close to the area of use. Furthermore, they serve as insurance against disruptions of the imported supplies.

Ground-water basins can serve another important function in the water equation for southern California. The passage of water through soil is one of the most effective and economical purifying mechanisms known to man. Research by the City of Los Angeles, the Los Angeles County Flood Control District, and Caltech has demonstrated conclusively that Hyperion effluent can be purified by filtration and chlorination for injection into confined aquifers with no hazard to health and with replenishment of potable ground-water reserves. Additional research at Whittier Narrows by Los Angeles County Sanitation Districts, the Los Angeles County Flood Control District, and Caltech has shown that normal activated-sludge effluent water can be percolated intermittently into unconfined aquifers for the effective and safe recharge of ground-water basins.

Europeans, and especially Germans, are far ahead of us in utilizing soil for the purification of water. Indeed, there are very few municipal water supplies in Germany that do not involve some type of ground-water travel. Germans don't believe that any water is fit to drink if it hasn't passed through soil. Near Dortmund, for example, water from the Ruhr River, heavily polluted with municipal and industrial wastes, is diverted into a series of spreading basins, percolated through soil, and collected by infiltration galleries for pumping to the city. In West Berlin, polluted water from the River Spree is passed through a microstrainer, diverted through a tortuous channel filled with bullrushes, then percolated through spreading basins into the sandy soil. The spreading basins are ringed by scores of shallow wells from which the water is pumped into a treatment plant for the removal of iron and manganese and thence to the municipal distribution system.

There is no question that intermittent percolation and even saturated flow of water through soil are generally efficacious in the improvement and stabilization of water quality through the mechanisms of filtration, adsorption, biodegradation, and ion exchange. In some soils and underground formations, however, flowing water may pick up undesirable constituents such as iron, manganese, and sulfides; but these impurities can readily be removed by topside treatment processes. It must be recognized, parenthetically, that travel through soil does not decrease the total dissolved solids and in some cases may increase them slightly. A major advantage of

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water reclamation through ground-water recharge is the fact that such water loses its identity and blends with natural ground water.

Not all of the municipal and industrial waste waters of the south coastal basin are amenable to reclamation by ground-water recharge. In some areas total dissolved solids are excessive because of brines from oil production or seawater infiltration or the regeneration of ion-exchange resins. In other regions, industrial processes discharge chromates, borates, fluorides, and other minerals that are difficult to remove by treatment processes and that travel through the soil with little or no change.

It has been estimated by the California Department of Water Resources, and others, that about half of the present municipal waste water in the south coastal basin is suitable in quality for reclamation by ground-water recharge. Hence, the safe yearly yield of ground-water basins could be increased by about 0.6 of a cubic kilometer, based on the present water equation. In the future, when the full quota of northern California water is being used, the total quantity of waste water may be expected to increase to about 2.8 cubic kilometers, of which about 60 percent, or 1.7 cubic kilometers could be reclaimed. This increment should be sufficient to meet southern California's ultimate water requirement.

What will it cost?

How much will renovated water cost in comparison with alternative sources of suppy? True cost figures are difficult to ascertain, not so much for waste-water reclamation as for the present and planned future sources. True total cost figures include bond redemption over a reasonable period, interest on outstanding indebtedness at prevailing rates, operation and maintenance, power, and insurance. For any year, the actual cost of water is the total outlay for all expenses divided by the total volume of water produced. Digging out such figures is difficult indeed.

Estimated Total Costs for Water

Source	Approximate Cost ($ per 1,000 cubic meters)
Local run-off and ground water	3 - 10
Owens Aqueduct	15 - 20
Colorado River Aqueduct	28 - 45
California Water Plan	60 - 160
Sea water demineralization	85 - 170
Reclaimed water (including subsequent repumping)	20 - 30

The price charged by the Metropolitan Water District for Colorado River water is increasing. For the present fiscal year it varies from $13.80 per 1,000 cubic meters for untreated water used for agriculture or replenishment, to $32.40 for softened and filtered water for municipal use. In addition, however, the Metropolitan Water District receives revenue from taxes levied against member agencies. The true total cost is presently about $36 per 1,000 cubic meters, but it may vary between $28 and $45.

To determine the true total cost of water from northern California is almost impossible. Initially this water will probably cost in excess of $160 per 1,000 cubic meters, but after deliveries approach the full capacity of the system, total costs may drop as low as $60.

The demineralization of sea water in presently operating plants costs in excess of $300 per 1,000 cubic meters. A large plant proposed by the Metropolitan Water District in conjunction with nuclear power production is expected to lower this cost to $57 at sea level or about $70 at the Diemer filtration plant. These figures, however, are based on charging all possible costs against electric power production and amortization of capital costs at 3.5 percent interest for 30 years. With more equitable allocation of costs, with realistic interest rates, and with recognition that mechanical equipment of this type will be obsolescent in 20 years or less, the true cost of demineralization will range from $85 to $170 per 1,000 cubic meters.

For waste-water reclamation, true total cost data are more realistic and better documented. Total costs at the Whittier Narrows Water Reclamation Plant run about $12 per 1,000 cubic meters, and the total cost of spreading for ground-water recharge is about $4. To this expense should be added about $4 for repumping into a water system, or a total of $20. Rendering Hyperion effluent suitable for ground-water injection is estimated at $20, to which $8 should be added for actual injection and subsequent repumping, or $28 per 1,000 cubic meters for the true total cost of this water supply.

It is apparent, therefore, that the true total cost of potable good-quality water reclaimed from waste water is slightly cheaper than Colorado River water and considerably less costly than northern California or demineralized sea water. Moreover, with more than 25 percent of the imported water recoverable through ground-water recharging, southern California's foreseeable water needs can be met with existing (including northern California water) facilities.