Agricultural water conservation in simplified perspective

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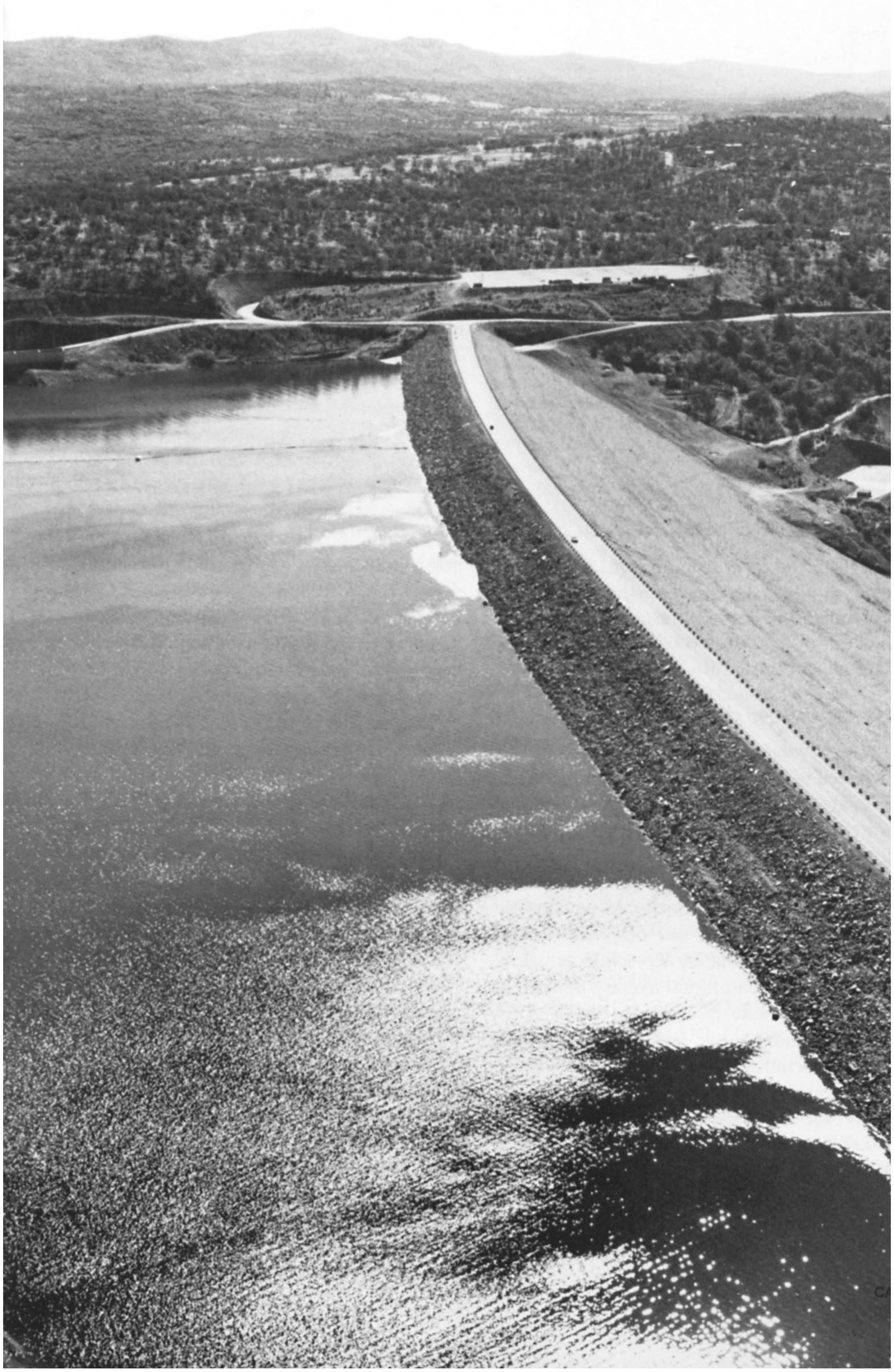
If California is to conserve water, it must curtail irrecoverable losses to the air and to saline sinks.



Poorly distributed rainfall, both seasonally and geographically, and increasing competition for limited amounts of water, make California's water issue highly complex. A few decades ago, the benefits of large-scale water developments seemed to overshadow their impacts on environmental and special-interest issues. Today, however, the need to further develop, possibly redistribute, or conserve California's water is debated in a context of conflicting environmental, instream, private-enterprise, social, emotional, and legal concerns.

All competitive demands for water warrant consideration, but they must be put into the perspective of the state's water budget as a whole. Since irrigated agriculture uses 85 percent of California's applied water (and therefore, often unjustly, bears the brunt of accusations of water waste), we will focus on the effects of agricultural conservation actions on California's water budget.

Concepts

Two basic concepts concern the destination of water:

- Water that remains on or below the land surface after initial use is usually recoverable for reuse and thus is not truly lost. Water passing to the air, by evaporation or transpiration, or to highly saline bodies is irrecoverable and truly lost from the state (although it remains part of the hydrologic cycle, returning later as precipitation somewhere).
- Reducing recoverable water "losses" and reusing agricultural, municipal, and industrial wastewaters generally save water on the farm or locally but not for the state, except where return-flow waters enter saline sinks. Reducing irrecoverable water losses saves water for the farm or locale where the reduction is made and for the state.

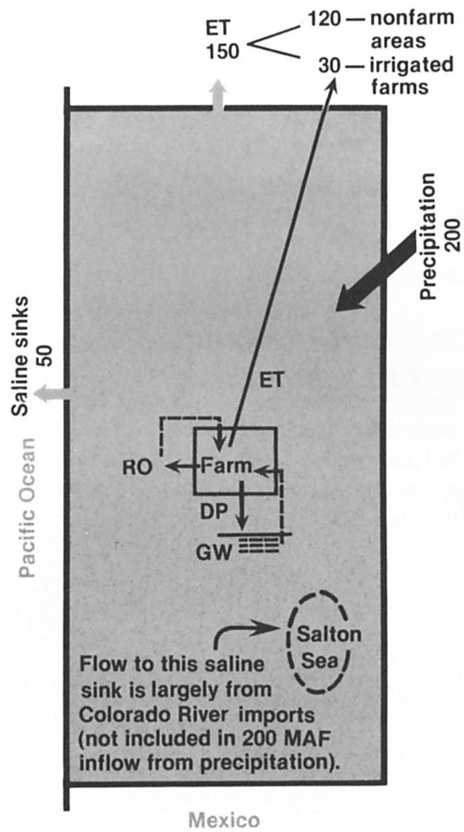
State water balance

The relation of these concepts to the water balance of the state can be seen in the diagram, an oversimplified depiction of California's surface water budget. In very approximate terms, the average annual amount of water entering the state as precipitation is 200 million acre-feet (MAF). (1 MAF = 1,233.5 hm^3.) Of this, about 150 MAF are lost to the atmosphere, roughly 120 MAF as evaporation from lakes and evapotranspiration (ET) from forests and unirrigated rangeland, and 30 MAF as ET from irrigated agriculture; and about 50 MAF flow to saline bodies (mainly the Pacific Ocean) and to geological formations from which the water cannot be recovered. (These rounded "average" values vary from year to year. However, our concern here is not so much the precision of these numbers, as the *destinations* of the annual incoming water.)

Irrecoverable water. The total water inflow (200 MAF) is accounted for solely in terms of irrecoverable water losses (150 MAF to the air and 50 MAF to, mainly, the ocean). Obviously, then, if the state wishes to conserve water, it must curtail irrecoverable water losses to the air and to highly saline sinks. Such curtailment, however, will not increase the total supply of water, because the roughly 200-MAF-per-year income is fixed. (Inflow could only be increased by cloud-seeding or importing additional surface flows.) It will mean that more of the increasingly competitive demands for water can be met each year, but this, as we will explain later, can entail some adverse effects in reducing certain irrecoverable losses and redistributing the saved water among competitive uses. Our purpose here is not to advocate specific actions for reducing irrecoverable water losses (particularly if no consideration is given to the results of such reductions) but to point out where the true statewide water losses occur.

The diagram represents an inland farm from which a certain amount of water is irrecoverably lost as ET, contributing to the 30 MAF of statewide agricultural ET. Curtailment of ET from the farm would reduce water demands both for the farm and for the state, but that reduction in ET can also reduce crop yield, a risk that many farmers may not take, in spite of other possible incidental benefits. Nevertheless, research is needed to determine whether crop ET can be reduced without seriously curtailing yield or net income by use of short-season varieties, properly timed deficit irrigation, and changes in cropping patterns.

Recoverable water. Many people believe that the state or a hydrologic basin can reduce its water losses by curtailing (1) leakage, spillage, and seepage during storage and transport, and (2) surface runoff and deep percolation below the root zone during irrigation. These are all recoverable water "losses" and, although their reduction does curtail on-farm or local water demands, it does not save water for the state or the basin. Flows of runoff or deep percolation from the inland farm (or farming area) in California (downward arrow to GW in diagram) remain within state boundaries and can be recovered and reused (dashed lines) by that farm or by others, although often at the expense of energy and some degradation in water quality. Thus, reductions in these flows (by improving irrigation application efficiency, for example) would not reduce the amount of water leaving state boundaries, but would reduce the amount of water that must be diverted to the farm from streams or pumped from groundwater aquifers (thereby benefiting streamflow between the points of diversion and return, and the level of aquifers, particularly in late summer).



Annual average surface water balance for California. Numbers are approximate millions of acre-feet (MAF) per year. (ET = evapotranspiration; RO = runoff; DP = deep percolation; GW = groundwater.)

State water deficit

The hydrologic balance for California depicted in the diagram is greatly oversimplified, and no mention has been made of ground water reserves and withdrawals. Ideally, average annual amounts of groundwater should remain the same: that is, replenishment over several years should equal withdrawal, in which case our simplified budget would be approximately correct. In actuality, based on 1974 data, total average annual inflow to the state is currently about 206.6 MAF, including river inflows from Oregon and importation from the Colorado River. Total outflow is about 208.8 MAF. This 2.2 MAF deficit represents, roughly, the annual average overdraft of groundwater basins. Within this decade, when the Central Arizona Project takes its full entitlement of Colorado River water, the current 4.7 MAF inflow from that source to California will be cut by about 0.3 MAF, thus further increasing the annual state deficit.

The State Department of Water Resources (DWR) estimated in 1974 that, with full use of foreseen supplies, California's annual water deficit, projected to year 2020, may range from 2.6 to 9.6 MAF, depending on population growth and urban spread, irrigated agricultural acreage, conservation of water, and other factors. More recent figures show an annual state net water deficit of 2.7 MAF in 1980 and 3.8 MAF in 2000 (excluding water conservation, groundwater overdrafting, and new sources of water availability).

Although a farmer's major motive for conserving water may be to maintain or increase profits, the overall concern of the state's water agencies should be reduction of present and projected water deficits. DWR is also concerned with the equitable distribution of water within the state. Many conservation actions that reduce recoverable losses and involve water reuse will make water available for redistribution (although institutional constraints will often be involved), but that will not necessarily reduce the state water deficit.

DWR recently estimated the statewide annual potential for water saving by the year 2000 to be about 1.8 MAF, of which 1.0 would be from urban and 0.8 from agricultural conservation. The latter saving includes roughly 0.40 MAF in the Imperial Valley (by improving conveyance and irrigation efficiencies); 0.25 MAF in the San Joaquin Valley (mainly brackish water reuse); and 0.15 MAF (by improving irrigation efficiencies in north coastal and desert basins). Rather than debate the accuracy of the above estimates and projections (DWR will soon publish updated figures), our concern here is to determine if the estimated savings will indeed reduce the state water deficit.

With respect to the urban savings, reductions in household water use (by low-flow shower heads and toilet tanks, and the like) will benefit the owner if water is paid for by metered volume, but it will not reduce the state deficit if drainage water from the house is already being reclaimed and reused. If, on the other hand, that water flows irrecoverably to the ocean (as has been the case with large volumes of sewage outflows from the Los Angeles and San Francisco metropolitan areas), reducing that volume of outflow would lower the state water deficit. Similarly, curtailing surface runoff to street gutters from garden, park, and other landscape irrigation is indeed laudable, but if all of the water enters the sewage system for reclamation and reuse it will not reduce the state water deficit.

On the other hand, most consumptive water use in urban and suburban areas is in the form of irrecoverable ET loss from gardens and other landscaping. Reducing that loss would reduce both the urbanite's water bill and the state water deficit. It is not clear, however, how much of the estimated 1 MAF of urban conservation can be attributed to reduced irrecoverable water losses from landscaping. The concepts of urban water losses are therefore quite similar to those of agriculture, although the amount of irrecoverably lost water is far greater in the latter. (We are not advocating drastic curtailment of landscape vegetation, but merely pointing to the irrecoverable losses of water and the need to determine their magnitudes. There is increasing interest in using landscaping plants with lower ET rates.)

With respect to the 0.8 MAF of estimated agricultural savings, a true reduction in the state water deficit will result if conservation measures now being used and others proposed in the Imperial Valley prevent 0.4 MAF of somewhat salty, but usable, Colorado River water from flowing to the highly saline Salton Sea, from which it is not feasibly recoverable (both because the salt content is high and because it eventually evaporates). In the San Joaquin Valley, saving 0.25 MAF by irrigation with usable brackish water reduces demand for fresh water from, for instance, the California Aqueduct or deep wells. If, however, constant irrigation with brackish water (even when partly diluted and used on salt-tolerant crops) causes continual accumulation of salts in the soil, then substantial volumes of good-quality water may later be required to leach the soil profile, particularly in the southern San Joaquin Valley where rainfall is relatively scant and unreliable. If that is the case, then in the long run, the net saving of water for the state may be less than some anticipate—an important matter that requires further evaluation.

If the brackish water to be reused (after dilution, desalination, or both) is from agricultural drainage that would otherwise be lost to evaporation (as in salt ponds to reduce drainage volume) or would flow out of the state (possibly through a completed San Luis Drain flowing through the Delta to San Francisco Bay), then less water would be lost from the state. On the other hand, if this brackish water is used to irrigate salt-tolerant crops on new rather than existing acreage, it would expand the area from which irrecoverable ET losses from the state could occur, thereby increasing the state water deficit to the extent that fresh-water leaching is needed on this new land. In any case, on-farm reuse of drainage water may be advantageous in that it reduces the capacity of drainage facilities required.

In the north coastal and desert basins, the estimated 0.15 MAF savings from improved irrigation efficiency will conserve water locally but will not affect the statewide deficit unless water now flows to the ocean and other highly saline sinks because of inefficient irrigation.

Storage of water in reservoirs, such as Shasta Dam in northern California, is a form of conservation, preventing loss to saline bodies, mainly the Pacific Ocean.

Transpiration from full green cover of sugarbeets contributes the major part of water irrecoverably lost by evapotranspiration (about 36 inches per season in the San Joaquin Valley). In contrast, evapotranspiration from adjacent field of dry hay is negligible.

Reduced irrecoverable losses

If, for the sake of argument, the annual 150-MAF ET loss could theoretically be curtailed to, say, 149 MAF (through reduced ET from the watershed and from agriculture), and if the saline-sink loss of 50 MAF were reduced to 49 MAF, then total annual outflow would be 198 MAF. What would happen to the "saved" 2 MAF? Ideally, it should reduce the present 2- to 3-MAF deficit caused by groundwater overdrafting. This could be achieved in three ways: (1) lower agricultural ET losses from areas where the sole or major water source is an overdrafted aquifer would curtail the amount of groundwater pumped; (2) less nonagricultural ET (the largest source of evaporative loss) through vegetation management on watersheds could increase their runoff yield for water needs such as groundwater recharge; and (3) reduced outflows to saline sinks, mainly the ocean, would enable greater diversion of water either to recharge inland overdraft aquifers or to provide an alternative water source to groundwater pumping.

There are, however, several major "bones of contention." The first option is likely to cause crop yield losses, because transpiration and plant growth are closely related. The second option, though partially researched, involves many complexities, such as inaccessibility of most watershed areas, soil erosion, timber yield, and treatment costs. The third option would require decreases in some river flows with consequent adverse impacts on various instream needs (such as fish migration and recreation) and on marine ecology at outflow points. Apart from environmental impacts, physical, economic, and institutional constraints hinder the further diversion and transport of water, its use for recharging subsurface aquifers, and its sale in a free market system.

Thus, these decreases in irrecoverable water losses, while helping to meet inland water needs such as groundwater recharge or other competitive demands by agricultural, municipal, and industrial users, would necessitate evaluation of important trade-offs.

Agricultural water conservation

Water savings resulting from conservation must be evaluated in light of the two basic concepts mentioned earlier. "Water conservation" can take many forms, and it means different things to different people. In the context of California's water resources, a few examples of conservation, illustrating reductions in irrecoverable and recoverable losses as well as wastewater reuse, include:

- Storage and conveyance

  On-stream and off-stream surface reservoirs. Prevent excessive irrecoverable outflow to the ocean in winter and spring and permit timely water release in summer.

  Groundwater recharge. Provides storage capacity and prevents irrecoverable evaporation losses.

  Lining farm ponds, canals, and ditches. Reduces recoverable water "losses"; improves storage and conveyance efficiency.

- Irrigation systems that reduce recoverable runoff and deep percolation. Changing from a conventional flood or furrow system to drip or some form of sprinkler irrigation can improve irrigation application efficiency only if the new system is suited to the site and crop conditions and is properly managed.

- Irrigation management to reduce recoverable "losses."

  Irrigation scheduling by instrumentation and computerized services to supply water in amounts and at times when required to meet ET needs but prevent excessive runoff and deep percolation.

  Elimination of final irrigation, especially if moisture in lower soil profile is adequate.

  Determination of correct leaching requirement to reduce deep percolation.

- Irrigation management to reduce irrecoverable losses.

  "Spot" irrigation, such as by drippers, of young orchards to reduce soil surface evaporation from intervening uncropped areas.

  Reduced irrigation frequency to curtail the opportunity for evaporative losses.

  Deficit irrigation whereby total water supply is inadequate to meet potential ET for this crop.

- Cultural and crop management practices to reduce irrecoverable losses.

  Mulching to reduce evaporation.

  Weed control to reduce unproductive transpiration.

  Foliar antitranspirant spray to reduce transpiration.

  Changing cropping patterns to reduce total annual ET.

  Planting salt-tolerant crops to enable use of brackish water that might otherwise be irrecoverably lost.

  Selection and breeding of crops for low seasonal ET.

- Wastewater reuse to reduce demand for fresh water.

  Tailwater system to capture and reuse agricultural runoff.

  Brackish water for salt-tolerant crops.

  Municipal and industrial wastewater, such as reclaimed sewage, food processing effluent, and thermally polluted water from power plants. (Unless these wastewaters would otherwise be lost to an irrecoverable sink, such as effluent outflows to the ocean from coastal metropolises, reuse will not reduce net water demand for the state.)

- Institutional actions.

  Pricing water to more closely represent its true cost at the farm head-gate and its real value in relation to other demands for water.

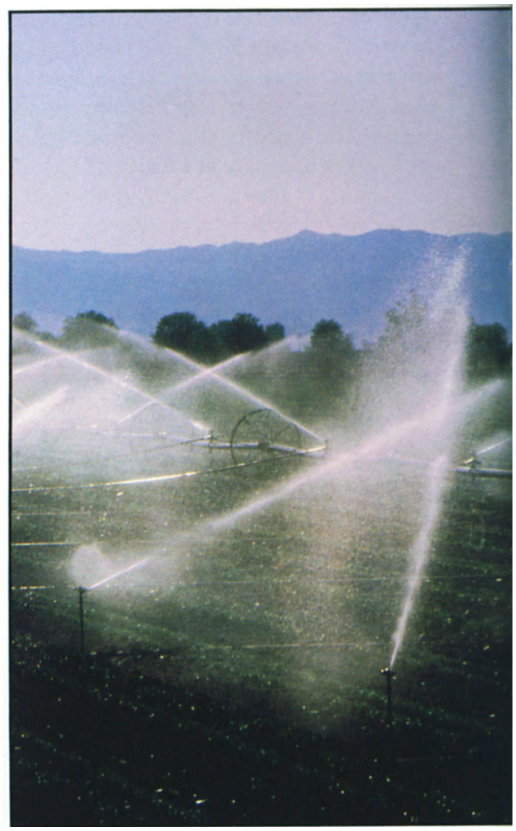
  Other financial incentives, such as tax credits.

  Changes in water rights laws to enable more efficient state-wide use of water resources, as through water transfers in response to market demands.

  Regulation by local or state agencies in extreme situations of water scarcity, for example, to limit groundwater pumping, prevent expansion of irrigated acreage, or allocate water at less than historical rates of use.

Thus, water conservation can be in the form of "water development" to reduce irrecoverable flows to the ocean and in the form of a reduction in net water demands through curtailment of irrecoverable ET losses to the atmosphere. We emphasize that the statewide water deficit can be reduced only through one or both of these forms of water conservation. The specific form of conservation chosen, however, must consider the trade-offs.

Tracy Borland



Well-managed sprinkler systems reduce runoff and deep percolation, but some water is irrecoverably lost by evaporation.

Effects

Conservation actions, such as those in the preceding list, might be chosen or enacted after careful site-specific consideration of their possible effects on true water savings at farm, local, and statewide levels and incidental effects that might occur on or off the farm. The incidental effects (benefits or costs other than the saving of a quantity of water) of agricultural water conservation actions have been identified, and methods for their economic valuation have been described in a recent report from the University of California to the State Department of Water Resources. (An executive summary of the report, "Incidental Effects of Agricultural Water Conservation," may be obtained from the Office of Water Conservation, Department of Water Resources, P.O. Box 388, Sacramento, California 95802.)

Some examples of on-farm incidental effects are possible adverse impacts on crop yield, energy savings from reduced pumping, fertilizer savings, and influences on crop

Tracy Borland

Drip irrigation is one means of reducing irrecoverable water losses by evaporation.

Herbert Schulbach

Tailwater recovery system permits reuse of runoff water collected in sump at lower end of irrigated field.

pathogen and pest infestations. Off the farm, conservation actions might affect mosquito breeding sites, drainage volume for disposal, surface- and ground-water quality, instream needs, and wildlife.

Why conserve?

Why should a California farmer take special actions to conserve water? Many growers have been conserving agricultural water for years, although this primarily has been recoverable rather than irrecoverable water. Thus, the high hydrologic efficiency (96 percent) of the Tulare Basin indicates efficient use of existing supplies through multiple reuse of water. Obviously, in areas and times of water scarcity, as during the 1976-77 drought, a real incentive exists to apply and reuse water judiciously, although some growers also increase their dependence on already depleted groundwater aquifers. In normal years, however, there is little incentive to conserve water if the cost of irrigation (including water, equipment, energy for pumping and pressurizing, labor, and maintenance) is only a small proportion of the total annual cost of producing a crop.

Farmers can cut down on the quantity of water they purchase or pump by reducing recoverable and irrecoverable losses, but they can decrease the state's deficit only by curtailing irrecoverable losses. Today's growers will probably be unwilling to achieve the latter by reducing transpiration from existing cropped acreage at the risk of a yield reduction. They are more likely to take water conservation actions, however, if their net farm profits increase through savings in production costs associated with water management. This could mean, in some cases, replacement of the goal of yield maximization with a goal of profit maximization. Most growers are primarily interested in the business of farming.

From a state water planner's viewpoint, it is necessary to meet present deficits (particularly those involving groundwater overdraft) to meet future contractual commitments, and to allow for increasingly competitive water demands as well as the probability (based on tree ring studies) of extended droughts. Because no additional water is likely to flow into California, equitable distribution and conservation of water in the state are becoming increasingly important. This necessitates adequate surface- and groundwater storage and curtailment in water demand, particularly by reducing irrecoverable losses.

Jack Kelly Clark

Fresh water flowing from Big River into the Pacific Ocean at Mendocino, California, is irrecoverably lost to the state, but such water has other values.

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