time to avert the no-profit, depleted state. Given the political environment today, however, it is by no means clear that significant new water development will bail out users of depleted groundwater basins.

In sum, farmers' resistance to controls over groundwater extraction is understandable. State-level management would be particularly onerous, since many basins may not need regulation for years. For some basins intervention is needed. The boundaries of the control agency should correspond as closely as possible to the boundaries of the aquifer. Personnel imposing the controls should be elected by representatives of the basin's water users, if controls are to be approved and if confidence in their administration is to be high.

Luckily, most California groundwater basins will eventually arrive at optimal steady state at a level high enough to sustain a prosperous overlying agriculture. By contrast, the Ogallala, a California-size aquifer stretching from Texas to South Dakota, is threatening to run dry. Regulatory agencies are attempting to curb each farmer's urge to pump what remains. A Kansas farmer was quoted recently by the *Wall Street Journal* (August 6, 1980): "It's a shame we didn't have water management back in the year 1950. We could have put controls on and instead of lasting 40 years, the Ogallala would have lasted 80."

Water can be managed wisely in California so that users of basins in critical overdraft conditions can realize the most from the resource. Local cooperation to maximize long-term benefits from a basin, including the associated land values, is essential. Other basins far from the critical stage now should, nevertheless, be monitored periodically. The key to California's water management is enough flexibility so that each basin can be assessed independently. Water analysts can contribute to the decision-making process, which should probably remain basically a local matter.

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Is overdrafting groundwater always bad?

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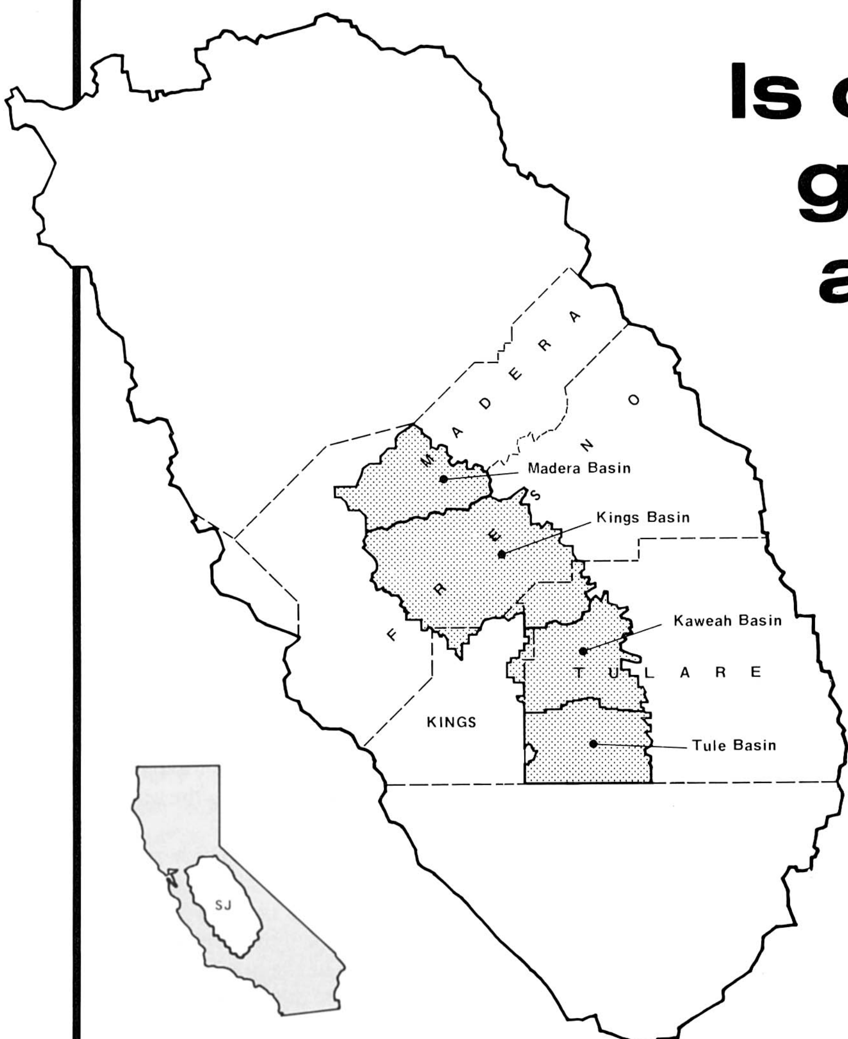

San Joaquin Valley hydrological study areas.

Like money in the bank, groundwater can be spent now or saved for the future. Unlike a normal bank account, however, overdrafting a groundwater source does not result in a negative balance requiring instant attention, but only indicates that withdrawals exceed deposits and the balance is declining. In nearly all basins, overdrafting initially contributes more to the community overlying the basin than it costs. As the level of the aquifer drops, however, overdrafting costs increase. Thus, a depth will inevitably be reached at which costs will exceed benefits. Clearly, overdrafting should not exceed this depth.

Continuing our banking analogy, the groundwater stock can be compared with capital that can be either invested in business (growing crops) or saved to draw interest. "Interest" accrued by the decision not to overdraft is collected in the future through savings in pumping costs. Overdrafting, of course, lowers the water table so that, as time goes on, pumps must draw more deeply at increased cost.

Setting aside other bad features associated with overdrafting, such as land subsidence and water quality deterioration, let us consider only the economic choice between using capital and reserving it. In reserving it, the farmer must use less water on existing cropland, cut back on irrigated acreage, or import costly surface water. He would probably cut back on the least profitable irrigated crop. In the decision procedure, net return on the area's least profitable irrigated crop must be balanced against future savings in pumping costs. Money in hand today, however, is worth more than money received in the future, not just because of devaluation of the dollar, but because today's dollar can be invested at the going rate of interest. Economists use a discount rate to determine the "present value" of a sum to be received in the future. Using, for example, 8 percent, the rate a conservative investor can receive on government bonds, $100 received next year is worth $92.59 today, since $92.59 invested at 8 percent will be worth $100 in a year. The formula allowing for continuous compounding and for various time spans, becomes more complicated, but the principle is the same. Putting alternative investment strategies into present value terms allows clear comparisons to be made.

Again, using the banking analogy, the "steady state" of a groundwater source is the point at which deposits (recharge) equal withdrawals. A hydrologic system is in a steady state if net withdrawals equal the average rate of natural recharge. This state can be attained at various groundwater levels; the more overdrafting, the deeper the level. When the aquifer has been sucked almost dry and pumping has to equal annual recharge, this, too, is a steady state, but one with very high pumping costs.

Sooner or later all groundwater aquifers must reach steady state, although, it is hoped, not when empty. The management decision to be made for each aquifer is when and at what depth to stop overdrafting. Irrigated agricultural production dependent on a steady state groundwater source will have to stabilize at exactly the level sustainable by withdrawals, balanced with natural and artificial recharges.

The calculation of the optimum level for steady state of a particular aquifer depends on several variables, including the present depth to groundwater, the discount rate chosen, and the profitability of irrigated agricultural production in the area relative to costs of energy for pumping. Absolute values of net returns received for farm products or prices paid for energy are not important in the decision-making process; it is their comparison that is relevant.

TABLE 1. Optimal Economic Steady State for Four San Joaquin Valley Groundwater Basins.

	Madera	Kings	Kaweah	Tule
Return, dollars*	36.50	37.15	39.44	40.07
User cost, dollars†	16.45	19.88	21.81	19.88
Average depth to groundwater level, feet, 1979	84.9	77.9	85.7	129.4
Current average rate of overdraft (drop in depth to water), feet/year	2.5	1.6	3.9	4.2
Depth of optimal steady state, feet	176	178	155	177
Years to steady state at current rates of overdraft	36	62	17.7	11.5

*Net return of an additional acre-foot of water when applied to the least profitable crop in the area. Calculated from an economic computer model of the region.

†Present value of future savings in pumping costs of extracting an additional acre-foot of water. Calculation was made using average basin depth to groundwater, average regional pump efficiency of 55 percent, net efficiency of application incorporating specific yield of the aquifer and proportion of applied water that percolates back, discount rate of 8 percent, and future energy price of $0.06/kilowatt-hour.

Is overdrafting bad? Not as long as the net revenue from the least profitable crop exceeds the present value of future savings in additional pumping costs. (We are still ignoring environmental effects of overdrafting.)

To illustrate that overdrafting under certain circumstances is not always detrimental, we have selected for study four groundwater management basins out of thirteen defined as subject to critical overdraft conditions, according to the recent California Department of Water Resources report (Bulletin No. 118-80). The basins, adjacent to one another on the east side of the San Joaquin Valley, are Madera, Kings, Kaweah, and Tule.

Results of our computations for the four basins (table 1) must not be taken as definitive, because they are based on provisional aggregate data. Effects of water quality degradation and land subsidence have been omitted from the costs. The provisional results, however, demonstrate the ease with which the steady-state target can be computed, given the data, the relative sensitivity of the optimal steady state to the agriculture/energy price ratio, and the discount rate selected. From the results, the approximate degree of urgency for basin management can be estimated in terms of years to steady state at the current rate of overdraft.

Although there is not much difference among basins in the value of an additional acre-foot of water applied to the least profitable crop, there is considerably more variation in the value of water remaining underground.

Kaweah Basin is the only one to differ in optimal depth to steady state with a permanent 155-foot basin, compared with 177 in the other districts. Since Kaweah is bounded on two sides by Tule and Kings basins, the hydrologic interconnections may cause problems in achieving these levels in the long run. Given the time to steady state, however, it is clear that Kings Basin will not cause problems for Kaweah.

The number of years to steady state shows that Tule and Kaweah will soon face long-term economic costs and should start planning immediately for steady state "no overdraft" adjustment. Madera and Kings basins have, respectively, 36 and 62 years before current levels of overdrafting become uneconomic. This long period in which current levels of overdraft are economically beneficial to the regional agricultural economy should allow plenty of time to formulate plans for future steady-state adjustments. In such regions, the costs of detailed hydrologic planning are better deferred, and an audit of the situation in about five years should suffice for the time being.

The steady-state depths and times on which these conclusions are based, however, depend on two key factors—the discount rate and the agriculture/energy price ratio. In table 2 sensitivity of the results to changes in the relative energy price (up 50 percent from 1979 prices, 100 percent, 150 percent) and discount rates of 5 and 10 percent are analyzed. As expected, lower discount rates and higher energy costs shorten the time to steady state.

At a 5 percent instead of 8 percent discount rate, both Tule and Kaweah have already gone past the point of optimal steady state. When the effect of 7.5 cents per kilowatt-hour is combined with a 5 percent discount rate, all the basins should stabilize at a very shallow depth. Given the current rate of inflation, however, and escalating energy prices, a much more likely combination is a high discount rate and high energy prices. The effect of 7.5 cents per kilowatt-hour dominates the offsetting effect of the shift to the 10 percent discount rate, significantly reducing the time to steady state. Tule Basin would reach optimal steady state in only 2.9 years.

Without regional management and regulation in the critical overdraft basins, such as Tule, individual pumpers are economically inclined to pump beyond the steady-state point optimal for the basin. In fact, each farmer would keep pumping until a steady-state depth of no profit is reached—that is, overdrafting would continue to the water table depth at which individual pumping costs equal the value of water used on the least profitable crop. At this point the farmer would cut back on rates of groundwater extraction, the basin would be in hydrologic steady state, and crop acreage would be reduced by the same amount as under regional management, but at a later date. The problem is, however, that pumping costs would be so high that marginal crops (the least profitable crops) would be generating no profit.

By contrast, under regional management, overdrafting would be stopped at a higher water level, hydrologic steady state would be reached sooner, pumping costs would be lower, and marginal crops would still show a profit. Long-range benefits to the basin and to individual farmers far outweigh short-term profits extracted by pumping beyond the optimum point.

On the other hand, Kings Basin under high discount rate and high energy cost assumptions still has 38 years before reaching the steady-state level optimal for all farmers drawing from that aquifer. Basins in such an enviable position can delay costly regulatory actions, at least for a time.

Several economic and hydrologic problems with overdrafting have been simplified in this analysis. For example, it is difficult to attach dollar values to some of the environmental factors. Land subsidence resulting from the drawdown of the water table causes problems with overlying roads, canals, and well linings. These costs are not major when compared with increased pumping costs for all future periods. There are, however, serious concerns about the permanent loss of storage capacity as an emptying aquifer partially caves in. Salinity appears to increase as water stocks diminish. In some areas, sea water intrusion in drawdown aquifers is a problem.

Obviously, water managers must find a way to add environmental and water quality deterioration costs associated with overdrafting into their computation of the optimum steady-state level of an aquifer. One way would be to shorten times and raise optimal steady-state depth computations (say 10 or 15 percent). A safety margin should also be built into the optimal steady-state target level to allow for drought years when natural recharge is below normal.

Conclusion

Overdrafting groundwater is not always bad, nor is it all bad. Overdrafting can be economically beneficial in some areas even for many years to come, but ultimately a point will be reached at which long-term costs of overdraft exceed short-term benefits in present value terms. This critical point varies greatly from basin to basin, and the urgency with which basin management and overdraft controls are needed varies accordingly.

At present groundwater levels and pumping costs in the San Joaquin Valley, it is clearly essential to define basins of workable size for management and determine if and when overdraft will become costly to water users. Groundwater management plans, however, should not require that overdrafting cease or that large amounts of money be spent on detailed regulation programs for basins many years away from reaching optimal steady-state depths. In other basins, rapidly approaching the critical steady-state point, effective and equitable groundwater management must be quickly established.

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TABLE 2. Sensitivity of Steady State to Changes in the Discount Rate and in Energy Costs

Discount rate = 5%				Discount rate = 10%			
Cost/kilowatt-hour	User cost	Depth to steady state	Time to steady state	Cost/kilowatt-hour	User cost	Depth to steady state	Time to steady state
$	*$*	*ft*	*yr*	*$*	*$*	*ft*	*yr*
Madera				**Madera**			
0.045	19.19	201.2	46.2	0.045	10.05	307.5	88.3
.060	25.59	95.7	4.3	.060	13.40	202.6	46.7
.075	31.99	31.6	−21.2*	.075	16.76	138.1	21.1
Kings				**Kings**			
0.045	19.69	203.0	77.7	0.045	10.32	312.0	145.4
.060	26.26	95.5	10.9	.060	13.75	205.2	79.1
.075	32.82	30.3	−29.6*	.075	17.19	139.6	38.3
Kaweah				**Kaweah**			
0.045	25.03	167.5	21.0	0.045	13.11	306.1	56.7
.060	33.38	53.2	−8.4*	.060	17.48	192.6	27.5
.075	41.72	−0.0†	−26.1*	.075	21.85	123.0	9.6
Tule				**Tule**			
0.045	23.19	196.3	16.1	0.045	12.15	324.7	46.9
.060	30.92	80.3	−11.8*	.060	16.20	209.4	19.2
.075	38.65	9.9	−28.7*	.075	20.25	141.6	2.9

*Negative values indicate the number of years ago that optimal water for steady state was exceeded at current overdraft.
†At this low discount rate and high relative energy cost, no drawdown of the water level is justified.