Water Allocation Alternatives
for the Upper Klamath Basin

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Alternatives for managing water resources in the Upper Klamath Basin are varied and numerous. A long-run strategy to protect fish and other species, while at the same time providing water for agriculture and other interests, likely will include restoring riparian vegetation, screening irrigation canals, reducing nutrient loads, reforestation, dam removal, continued controls on fishing, etc. Indeed, many of these actions have been recommended in recent and earlier Biological Opinions pursuant to the Endangered Species Act (ESA).

In addition to these broad actions to improve water *quality* and fish habitat, however, alternatives involving water *quantity* and its allocation also may have advantages over current and past approaches. The aim of this chapter is to appraise the merits of several water allocation alternatives from an economic perspective. The estimated impacts of an irrigation curtailment used in this chapter are model based. For a discussion of reported economic outcomes in 2001, see Chapter 14 ("Outcomes").

Our effort is set in the context of the 2001 irrigation curtailment and the prospect that water shortages may occur again in the future. Alternatives will be evaluated primarily on their direct cost to the agricultural sector in the Upper Klamath Basin. However, this should not be interpreted as implying that agricultural interests are paramount, nor that the value of water allocated to other uses, such as environmental and tribal interests, tourism, or commercial and recreational fisheries, is unimportant or peripheral.

Unlike Chapter 12 ("Crop Revenue"), this analysis focuses not only on the Klamath Reclamation Project, but on the entire Upper Basin. In that chapter, Burke considered alternative ways of allocating water within the Project that could reduce the losses to gross farm crop sales resulting from an irrigation curtailment. Here we look instead at all irrigated areas within the Upper Klamath Basin that could reasonably be considered interconnected for purposes of satisfying the mix of competing ecological and agricultural demands. Our definition of the Upper Klamath Basin is broader than many; we include the combined Klamath River–Lost River watershed and also the Shasta and Scott rivers (Figure 1, following page). Thus, the Shasta and Scott valleys are included in this analysis.

Clearly, it is important to recognize the relationships between past, current, and future competing demands for water among agricultural and nonagricultural uses. However, it is beyond the scope of this chapter to quantify and compare the long-term costs and benefits of irrigated agriculture in the region. Nor do we attempt to place a value on in-stream uses of water, declining fish populations, or the consequent inability of the Klamath and downriver tribes to avail themselves of their legally recognized fishing rights. We recognize that by using the late 1990s as our benchmark for comparison, we are implicitly selecting as "normal" a

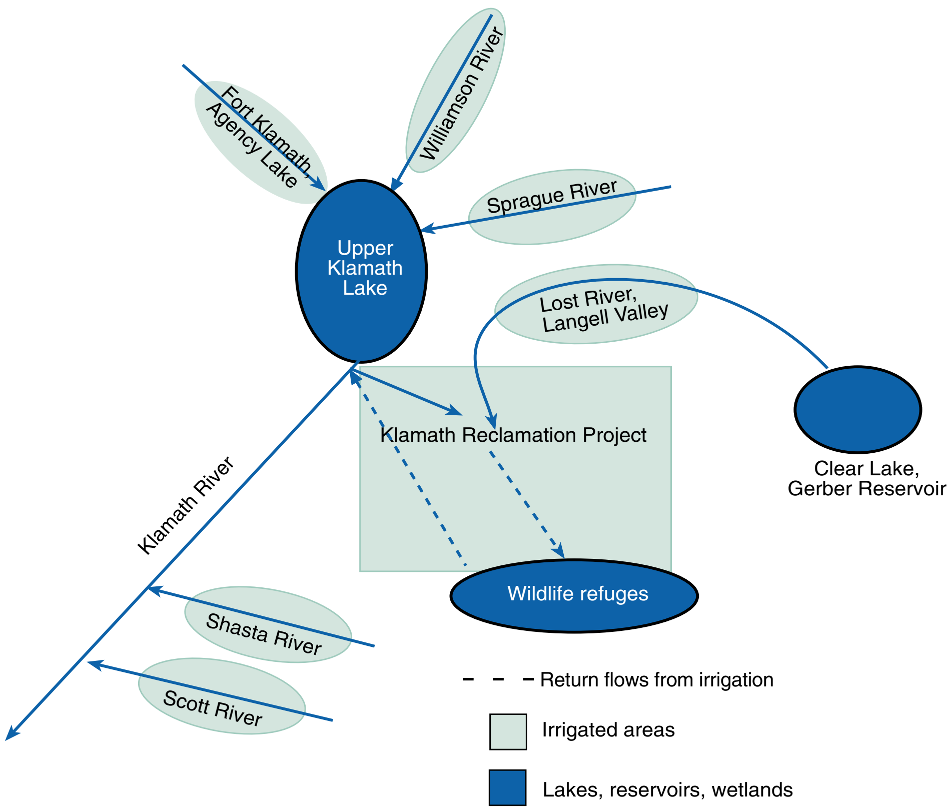

Figure 1. Key features and irrigated areas in the Upper Klamath Basin and Klamath River system.

situation that reflected decades of water allocation decisions and outcomes that may have benefited some groups more than others.

As competing demands on water resources in the Klamath Basin continue to grow, there are likely to be additional constraints on irrigation diversions. In addition to limitations imposed under the Endangered Species Act, changes in water allocation may result from the resolution of tribal water claims in the ongoing adjudication process. Moreover, relicensing of the Iron Gate Dam by the Federal Energy Regulatory Commission (FERC) in 2006 will require giving equal consideration to power and nonpower benefits (such as recreational use and the provision of fish and wildlife habitat) under the Electric Consumers Protection Act of 1986 (see Chapter 6, "Coho Salmon"). Whether this requirement will influence required summer flows in the Klamath River mainstem is unclear.

In the midst of these conflicts, future droughts are likely to give rise to future water scarcity. More cost-effective approaches to the allocation of scarce irrigation water may represent ways to minimize the costs of future shortages—provided there is public support and the institutional capacity needed to carry them out (see Chapter 18, "Policy").

Thus, our focus is on alternatives that deal directly with the *quantity* of water available and the allocation of that water among competing uses. In addressing these issues, we estimate the net gains and losses from allocating water to different soils in different locations. Thus, the cost of short-run curtailment of irrigation supplies forms the basis for comparing alternative responses to shortages.

An economic description of agriculture in the Upper Basin is the starting point for this analysis and for interpretation of the results. Two key characteristics of irrigated agriculture in the Upper Klamath Basin emerge as crucial to the analysis. First, the acreage within the Klamath Reclamation Project that did not receive water in 2001 represents only about 35 percent of the total irrigated area in the Upper Basin. Second, the irrigated soils throughout the Upper Klamath Basin range in productivity classification from Class II to Class V (see Chapter 7, “Soil Resources”). These differences give rise to large variations in the economic gains from irrigation based on differences in the market values for irrigated and nonirrigated lands.

In the face of limits on irrigation, allocating water in ways that reflect these productivity differences will promote “economic efficiency” (produce the highest value of agricultural output with a given amount of water) and thus help minimize the overall cost of water scarcity. If water is withheld from its highest value uses, while irrigation continues in locations where the benefits are minimal, there will be a high overall cost compared to an efficient, cost-minimizing allocation. A decentralized response to water shortage, one that accounts for the very different marginal losses and gains across plots, will achieve the desired reduction in irrigation withdrawals at a much lower cost.

Thus, this analysis will consider alternatives that meet this criterion. For example, if irrigators can transfer water, create water banks, or buy and sell water rights, those with the most to lose

Gross versus net economic indicators

As explained in the Preface to the economics chapters, we use two main types of dollar measures to describe agriculture in the Upper Klamath Basin in economic terms and to measure the effects of events in 2001. Each measure is intended for a specific use. To avoid confusion, differences between these measures are reiterated here.

The first monetary measure is intended to reflect the benefit or economic value of a resource. “Net revenue” and “income” are economic measures of this kind. They are intended to reflect the *net* gains from farming. Thus, they include revenue from the sale of a crop minus the cost of the inputs used to produce it. These measures represent the net financial benefit to the farm owner or operator. This chapter uses this type of measure to look at the net gain associated with a particular activity, piece of land, or quantity of irrigation water.

The second monetary measure is referred to as “gross farm revenue” or “gross farm sales.” This measure is intended to indicate the scale of the farm economy, but it does not accurately reflect the gains accruing to an individual, group, or specific resource because it does not subtract the cost of inputs. As a result, a region’s gross farm revenue or sales always is higher than its net revenue or net farm income. This type of measure is used extensively in Chapter 12 (“Crop Revenue”) to evaluate changes in the scale of agriculture in the Project. Similarly, “regional economic output” is a measure of changes in the gross value of goods and services produced in the regional economy. This measure is emphasized in Chapter 13 (“Regional Economic Impact”).

Each of these monetary measures is appropriate for addressing particular questions. Gross farm revenue and regional economic output are useful for describing changes in the scale of economic activity in agriculture or in the region. In this chapter, however, we are interested in assessing the value or return on an investment, as well as the willingness of individuals to pay for, or be compensated for, gains or losses in resource availability. For these purposes, “net revenue,” “loss,” or change in “income” are the appropriate measures. In general, we expect such measures to correspond to the market price—the amount that individuals should be willing to pay to acquire a given quantity of land, water, or other resource.

from a water cutoff could assure themselves of a more reliable supply. Partial reductions in irrigation deliveries, or "deficit irrigation," represent another way to achieve efficiency.

The aim of this analysis is, first of all, to identify ways in which the overall cost of irrigation restrictions could be reduced by promoting economic efficiency in water allocation. Alternative scenarios or policies of this kind will produce economic and social consequences that affect individuals in different ways. Whether those alternatives are viewed positively or negatively will depend on many factors, including the overall cost of any given scenario.

We recognize that some alternative responses to a water shortage may generate undesirable social or environmental side effects. Before implementing any alternative, those consequences should be considered as part of an overall assessment of the quantitative and qualitative differences between alternative courses of action. In principle, if an alternative approach substantially lowers the overall cost of a water shortage, other actions could be taken to offset possible negative consequences.

The economic value of irrigation water

In this section, data on irrigated areas, land prices, crops, and yields are used to estimate the economic value of applied irrigation water, as well as the cost of withholding water. These data generate an economic portrait of irrigated agriculture in the Basin, one that provides a basis for evaluating a range of water allocation options.

For these purposes, it is crucial to look at the differences in irrigated agriculture across locations and soil classes rather than simply characterizing the entire region based on average values. We must take into account how these agronomic differences translate into differences in revenues, costs, and the economic value of water used in irrigated crop production (i.e., water used in combination with other inputs such as equipment, energy, labor, and land).

Understanding long-run versus short-run value

For this analysis, when measuring the value of water, we need to distinguish long-run value from short-run value. The "long-run" value of water in irrigated agriculture reflects the net revenue (income) generated when irrigation water is applied regularly to an acre of land of a given soil class over time. It reflects the efficient, planned use of water in combination with equipment, labor, and other inputs. We expect this measure of value to be reflected in market sales and prices of land or water rights. It is especially relevant to decisions about investing in irrigation infrastructure or other capital assets.

Given efficient capital and land markets, we expect the sale price of agricultural land to reflect the present value of the income that can be generated annually by farming it. The relationship between the annual income (Y) made possible by farming a piece of land and its purchase price (P) involves an interest rate (r). As with a financial asset such as a stock or annuity, an asset with a face value of P can be expected to generate annual dividends of r times P. (We can write this relationship as $Y = r * P$.)

This relationship allows us to infer the value of irrigation water by comparing the sales prices of irrigated and nonirrigated lands. For example, if the difference between the purchase prices of similar irrigated and nonirrigated land is $1,000, we can infer that the difference reflects the benefits resulting from irrigation. Then, we can use the formula above to estimate that the annual net benefits of irrigation equal r * $1,000. For a 6 percent interest rate, this suggests that $60 per year is the net benefit of irrigation water in this example (0.06 * 1,000).

In addition to long-run values, a "short-run" measure of the value of irrigation water is important. This value more accurately reflects the losses suffered by growers who go without water unexpectedly or temporarily.

The short-run losses associated with reductions in water availability can be expected to exceed the long-run measures discussed above. The difference between the short-run and long-run measures arises from the fact that some production costs are "fixed costs" and cannot be avoided in the short run.

In the short run, growers are likely to incur some fixed production costs whether water is available or not. Examples include equipment that would be idled without water, insurance, and depreciation. Given these fixed costs, the short-run cost of having water withheld is higher than the long-run values discussed above. In other words, short-run changes or "surprise" adjustments in the amount of water available will produce per-acre losses that exceed the long-run value of water reflected in land prices.

Consider how this works. A farmer's net revenue (NR) is equal to total revenues (TR) minus variable costs (VC) and fixed costs (FC). Thus, NR = TR – VC – FC. Giving up farming in the long run means giving up NR. Giving up farming in the short run means losing TR and eliminating VC, but the farmer still has fixed costs, which now are not offset by revenues. The loss then is NR + FC, which also is equal to TR – VC.

Suppose a farmer's total revenue (per acre) with irrigation is $750. If variable costs are $300, and fixed costs are $200, the farmer's net revenue is $250. If irrigation water is withheld in the short run, total revenue and variable costs fall to zero. Fixed costs of $200 remain, however, so that net revenue becomes –$200. The difference between net revenue with irrigation ($250) and net revenue without irrigation (–$200) is $450, which equals NR + FC or TR – VC. This is the farmer's net loss, which represents the short-run value of irrigation water, or the cost of withholding water.

If production involved zero fixed costs, then the short-run and long-run values of water should be equal. A grower who anticipates a 1-year pause in irrigation (for example, a voluntary agreement to leave water in-stream for 1 year) may avoid some of the fixed costs (for example, by renting equipment to other growers). Nonetheless, he or she likely still will incur some fixed costs. In this case, the costs of irrigation curtailment should be lower than in the short-run, "surprise" scenario, but higher than the long-run values of irrigation water. This kind of anticipated short-run cost is relevant to the discussion of water markets and water banks later in this chapter.

Because the water shortage that occurred in 2001 was short-run and unanticipated, the measure of short-run loss is the relevant measure for assessing the overall cost of irrigation curtailment. For other considerations, such as the development of additional storage capacity, improved irrigation efficiency, or permanent retirement of irrigated land, the long-run value of water is more relevant.

It also is important to recognize that the value of an "incremental" or marginal change in the amount of water available often differs from the "average value" of water. Irrigation water may have a very high *average* value when applied to the most productive lands in a given region, but the *marginal* value of an additional unit of water may be quite low. This situation occurs when adequate water already has been applied to existing high-productivity lands, while the additional lands that could be irrigated are much less productive.

Value of irrigation water in the Upper Klamath Basin

Based on available market, crop, and farm enterprise data, we have estimated both short-run and long-run values of water by soil class for each location within the Upper Klamath Basin. The primary data source is the Klamath County Assessor's office (Klamath County Assessor 2001). Data from this source include irrigated land areas by soil class, cropping pattern, and market value (as distinct from the assessed values used for tax purposes). These data were supplemented with additional data from the county assessors in Modoc and Siskiyou counties in California, the U.S. Bureau of Reclamation office in Klamath Falls, and the Oregon State University (OSU) Extension Service (for crop budget data).

Soils in the Upper Basin range from Class II to VI. Higher numbers indicate progressively greater limitations and narrower choices for practical use (see Chapter 7, "Soil Resources").

Crops and crop rotations vary by location and soil class. For the Upper Basin overall, 54 percent of irrigated land is pasture, 22 percent is alfalfa, 15 percent is cereal grains (barley and wheat), and 5 percent is other hay. These are followed by 3 percent for potatoes and 0.5 percent for peppermint. Other crops, such as onions, each account for less than 1 percent of the area planted, although they may represent a larger share of total revenue. Alfalfa, cereals, potatoes, and peppermint are grown on Class II and III soils; pasture is grown almost exclusively on Class IV and V soils.

Long-run value of irrigation water

Data on irrigated land areas for the Klamath Basin are presented in Table 1. These data indicate that irrigated soils range from Class II to V, with most being Class III and IV.

Table 1. Irrigated acreage in the Upper Klamath Basin by location and soil class.

	Irrigated acres				
	Class II	Class III	Class IV	Class V	Totals
Areas above Upper Klamath Lake					
Fort Klamath Valley	0	1,800	8,025	26,055	35,880
Modoc Point to Chiloquin	2,710	6,475	7,215	335	16,735
Sprague River Valley	0	640	54,120	910	55,670
North Country	0	5,410	16,865	1,530	23,805
Areas east and south of Upper Klamath Lake					
Swan Lake Valley	2,620	8,310	14,930	0	25,860
Bonanza (non-Project)	4,541	6,425	6,354	0	17,320
Langell Valley (non-Project)	3,145	6,611	5,209	535	15,500
Poe Valley (non-Project)	525	697	778	0	2,000
West of 97 to Keno (non-Project)	2,388	9,048	11,367	198	23,000
Lower Klamath Lake (non-Project)	69	4,614	309	7	5,000
Klamath Reclamation Project areas					
Merrill-Malin	2,030	13,965	6,205	0	22,200
Poe Valley	4,424	5,873	6,562	0	16,859
Midland-Henley-Olene	7,625	18,555	11,890	0	38,070
Bonanza-Dairy-Hildebrand [a]	*2,569*	*3,635*	*3,596*	*0*	*9,800*
Langell Valley [a]	*3,315*	*6,969*	*5,491*	*565*	*16,340*
Lower Klamath Lake	211	14,021	941	23	15,195
Malin Irrigation District	300	2,905	120	0	3,325
Shasta View District	1,000	3,100	1,100	0	5,200
West of 97 to Keno	387	1,467	1,843	32	3,730
Tule Lake/California portion	13,244	40,000	20,000	0	73,244
Shasta and Scott valleys	8,000	41,100	35,000	0	84,100
Total	**59,103**	**201,620**	**217,920**	**30,190**	**508,833**

[a]Portions of the Project that received surface water in 2001.

Note: Figures in this table may differ slightly from those in other chapters due to different data sources and geographical categories.

Sources: County assessors in Klamath, Modoc, and Siskiyou counties (personal communications)

Table 2. Average market values for irrigated land by location and soil class.

	Market value of land ($ per acre)				
	Class II	Class III	Class IV	Class V	Nonirrigated (Class VI)
Areas above Upper Klamath Lake					
Fort Klamath Valley[a]	—	1,100	850	600	400
Modoc Point to Chiloquin	1,700	1,100	850	600	400
Sprague River Valley	—	1,000	750	300	200
North Country	—	750	750	250	200
Areas east and south of Upper Klamath Lake					
Swan Lake Valley	2,100	1,450	750	370	200
Bonanza (non-Project)	2,100	1,450	750	370	200
Langell Valley (non-Project)	2,100	1,450	750	370	200
Poe Valley (non-Project)	2,600	1,400	1,000	500	300
West of 97 to Keno (non-Project)	1,700	1,100	850	600	400
Lower Klamath Lake (non-Project)	2,600	1,900	1,000	300	300
Klamath Reclamation Project areas					
Merrill-Malin	2,600	1,350	1,000	500	300
Poe Valley	2,600	1,400	1,000	500	300
Midland-Henley-Olene	2,600	1,400	1,000	500	300
Bonanza-Dairy-Hildebrand[b]	*2,100*	*1,450*	*750*	*370*	*200*
Langell Valley[b]	*2,100*	*1,450*	*750*	*370*	*200*
Lower Klamath Lake	2,600	1,900	1,000	300	300
Malin Irrigation District	2,600	1,900	1,000	300	200
Shasta View District	2,600	1,350	1,000	300	200
West of 97 to Keno	1,700	1,100	850	600	400
Tule Lake/California portion	2,600	1,800	1,100	—	300
Shasta and Scott valleys	2,000	1,650	1,050	—	300
Average	**2,278**	**1,402**	**895**	**421**	**276**

[a]Values based on agricultural use. Recreational demand has increased land values in this area.

[b]Portions of the Project that received surface water in 2001.

Sources: County assessors in Klamath, Modoc, and Siskiyou counties (personal communications)

In Table 2, average land values by soil class indicate the extreme variability in productivity of irrigated land across locations. Land values vary from Class II irrigated areas that sell for $2,600 per acre to Class V lands that sell for between $250 and $600 per acre. We expect these market prices for land to reflect the capitalized value of the annual income generated from current use. Our data on average market values reflect transactions and markets during a number of years prior to the events of 2001.

These land-value data also provide an indication in relative terms of the economics of farming in the Upper Klamath Basin. The value of farm real estate in 1998 averaged $960 per acre in Oregon and $974 per acre in the U.S. In the Upper Klamath Basin, the market value of Class II lands is double these levels, and it is 50 percent higher for Class III lands. This suggests that the income-generating capacity of an acre of these lands is significantly higher than the average for Oregon or for the nation as a whole. Indeed, the market values on Class II and III soils are comparable to those in Iowa, one of the most productive agricultural areas in the country. By contrast, the value of irrigated Class V land in the Upper Klamath Basin ($421 per acre) is at the low end of state-averaged land values, comparable to those in North Dakota, where dryland farming predominates.

By combining the data in Tables 1 and 2, we can estimate the total value of irrigated land in the Basin at $654 million. Using an interest rate of 6 percent, this asset value suggests an annual income from irrigated agriculture in the region of $39 million. This figure is very close to the $38 million figure for farm labor and proprietors' income (1997) reported by the U.S. Bureau of Economic Analysis.

As explained above, the long-run value of irrigation water can be estimated by looking at the difference between the values of irrigated land and similar nonirrigated land. From Table 2, we see that the difference between the per-acre market value of Class II irrigated and Class VI nonirrigated lands in much of the Project is $2,300 ($2,600 – $300). The difference between irrigated Class III soils and nonirrigated Class VI soils ranges from $550 to $1,700 per acre. For Class IV soils, the difference averages $620 per acre.

Notice that for some locations, and especially for Class V soils outside the Project, the differences in land values suggest very low values to irrigation. For example, the difference in market value between Class V irrigated and Class VI nonirrigated land ranges from $0 to $200 per acre. This suggests that applying water to Class V soils in these regions generates low net revenues as irrigated pasture.

Even ignoring the extreme low estimates of $0 and $50 per acre, these data indicate that the value of applied water varies by a factor of 23 between the most productive lands ($2,300 per acre) and least productive lands ($100 per acre). On average, the data suggest that irrigation water adds about $1,000 per acre to the value of land. This interpretation is corroborated by a local farm appraiser with many years of experience in the region, who estimates differences between irrigated and nonirrigated lands to be between $900 and $1,000 (Caldwell 2001).

When these estimates are used to estimate the annual value of applied water (multiplying by a 6 percent interest rate), we arrive at the marginal per-acre annual values for water presented in Table 3. Average values range from $9 for class V soils to $103 for Class II soils. The lowest value is $0 for Class V soils in the Lower Klamath Lake area. The highest value is $144 for Class II soils in the Malin and Shasta View irrigation districts.

We can compare these values to estimates for similar soil classes in Malheur County, Oregon, which were developed using a more detailed statistical approach (Faux and Perry 1999). The Malheur County values are nearly identical to the soil class averages in Table 3, with the exception of the Class V soils. Klamath-area Class V soils seem to be significantly lower in value than those in Malheur County. One reason for this difference may be the higher elevation and shorter growing season in the Upper Klamath Basin.

Table 3. Marginal value of applied water in irrigated agriculture by location and soil class.[a]

	Marginal value of water ($ per acre per year)				
	Class II	Class III	Class IV	Class V	Weighted average
Areas above Upper Klamath Lake					
Fort Klamath Valley[b]	—	42	27	12	17
Modoc Point to Chiloquin	78	42	27	12	41
Sprague River Valley	—	48	33	6	33
North Country	—	33	33	3	31
Areas east and south of Upper Klamath Lake					
Swan Lake Valley	114	75	33	10	55
Bonanza (non-Project)	114	75	33	10	70
Langell Valley (non-Project)	114	75	33	10	67
Poe Valley (non-Project)	138	66	42	12	76
West of 97 to Keno (non-Project)	78	42	27	12	38
Lower Klamath Lake (non-Project)	138	96	42	0	93
Klamath Reclamation Project Areas					
Merrill-Malin	138	63	42	12	64
Poe Valley	138	66	42	12	76
Midland-Henley-Olene	138	66	42	12	73
Bonanza-Dairy-Hildebrand[c]	*114*	*75*	*33*	*10*	*70*
Langell Valley[c]	*114*	*75*	*33*	*10*	*67*
Lower Klamath Lake	138	96	42	—	—
Malin Irrigation District	144	102	48	6	104
Shasta View District	144	69	48	6	79
West of 97 to Keno	78	42	27	12	38
Tule Lake/California portion	138	90	48	—	87
Shasta and Scott valleys	102	81	45	—	68
Unweighted average	**103**	**68**	**37**	**9**	**—**
Weighted average	**—**	**—**	**—**	**—**	**60**
Estimates for Malheur County, Oregon[d]	105	67	35	32	—

[a]Based on comparison of market price data for irrigated versus nonirrigated land.
[b]These values reflect agricultural use. Recreational demand has increased land values in this area.
[c]Portions of the Project that received surface water in 2001.
[d]Based on Faux, J. and G.M. Perry. 1999. "Estimating irrigation water value using hedonic price analysis: A case study in Malheur County, Oregon." *Land Economics* 75:440–452.

Two other data sources provide estimates that generally are consistent with those presented here. First, the Oregon Water Trust purchases water from irrigators in Oregon to augment in-stream flows and protect fish habitat. Data on these transactions over the past several years are presented in Table 4. There are two types of transaction: permanent purchases of water rights and 1-year leases. These data also are presented as the annual value (per acre-foot), using a 6 percent interest rate in the case of the permanent purchases.

Detailed data on soil class are not available for these transactions. However, given the organization's desire to minimize costs and to target small tributaries in upper basins, we expect that most of these transactions involve Class IV and V soils. For a consumptive use of 2 acre-feet per acre (the average irrigation use in the Upper Klamath Basin), the average annual value per acre-foot for Class IV and V soils is $11.50, which is close to the $9.16 average paid by the Oregon Water Trust.

Additional information on transactions by the Oregon Water Trust (reported in Niemi et al. 2001) is remarkably consistent with Faux and Perry (1999). Niemi et al. report that for water rights previously associated with pasture and irrigated hay, Oregon Water Trust paid growers $6 to $17 per acre-foot per year. For water previously used in producing wheat (likely to be grown on Class II or III soils), purchase prices were $22 per acre-foot per year. Similarly, Landry (1995) surveyed water rights transfers in Oregon in the early 1990s and found that the average price corresponded to an annualized value of $22 per acre-foot per year.

Second, the U.S. Bureau of Reclamation manages the annual leasing of lands within the Upper Basin's national wildlife refuges. Using a sealed bidding process, irrigators compete for use of these relatively high-productivity lands. These data, therefore, are on a per-acre basis and are primarily for Class II, III, and IV lands. In 2000, the successful bids averaged between $51 per acre for "area K" grain production to $83 per acre for "Sump 3" lands (where only one-third of the land may be planted with row crops; the rest typically is planted with grains). These prices are comparable to those for Class III and IV lands in Table 3. Assuming 2 acre-feet per acre, they also are close to the range of prices paid by Oregon Water Trust under 1-year leases.

Short-run losses from irrigation curtailment

As defined above, the short-run losses from curtailed water deliveries reflect the financial changes faced by farmers. These losses cannot be inferred from market prices for farmland alone.

Short-run losses vary, depending on the crops grown and other circumstances faced by individual farmers. Average values reflect expected net revenues from crop sales as well as fixed costs. Losses facing individual farmers may be higher or lower than the estimated averages due to fluctuations in crop prices or other differences. Losses are likely to be higher for growers of perennial crops.

Average values for short-run losses can be estimated by combining information on long-run irrigation values and fixed costs. Fixed costs are crop-specific and must be estimated based on the crop rotations common to each location and soil class. Using data on observed cropping patterns in conjunction with OSU crop enterprise budgets, we have estimated fixed costs for all locations and soil classes in the Upper Klamath Basin. The per-acre loss associated with withholding irrigation water is the sum of (a) net revenues or marginal values of applied water (from Table 3) and (b) nonland fixed costs from the OSU crop enterprise budgets. (See "References.") These losses include the amortized fixed cost of establishing perennial crops such as peppermint and alfalfa.

Table 4. Recent water rights transactions to augment stream flows.

Location	Current use	Contract type	Consumptive use (acre-feet/year)	Price ($)	Cost per acre-foot per year[a] ($)
Rogue River, Sucker Creek	Fallow	Purchase	67.80	8,800	7.79
Rogue River, Sucker Creek	Fallow	Purchase	107.62	13,627	7.60
Rogue River, Sucker Creek	Fallow	Purchase	57.47	8,138	8.50
Deschutes River, Squaw Creek	Pasture	Purchase	417.19	42,900	6.17
Deschutes River, Squaw Creek	Pasture	Purchase	308.08	44,352	8.64
Deschutes River, Squaw Creek	Pasture	Purchase	48.14	7,425	9.25
Deschutes River, Squaw Creek	Pasture	Purchase	8.46	870	6.17
Deschutes River, Squaw Creek	Pasture	Purchase	96.27	13,860	8.64
Rogue River, Little Butte Creek	Hay	Purchase	173.95	20,000	6.90
Hood River, Fifteenmile Creek	Wheat	Purchase	71.76	26,307	22.00
Average (purchases)					**9.16**
Deschutes River, Buck Hollow Creek	Hay	1-year lease	196.80	6,630	33.69
Deschutes River, Buck Hollow Creek	Hay	1-year lease	196.80	6,630	33.69
Deschutes River, Buck Hollow Creek	Hay	1-year lease	196.80	6,630	33.69
Grande Ronde River, Crow Creek	Hay	1-year lease	194.00	1,600	8.25
Umatilla River, East Birch Creek	Hay	1-year lease	238.50	2,500	10.48
Deschutes River, Trout Creek	Hay	1-year lease	1,135.50	23,843	21.00
Deschutes River, Trout Creek	Hay	1-year lease	270.00	4,680	17.33
John Day River, Hay Creek	Hay	1-year lease	248.80	14,500	58.28
Rogue River, South Fork Little Butte Creek	NA	1-year lease	83.34	1,438	17.25
Deschutes River, Buck Hollow Creek	Hay	1-year lease	196.80	6,630	33.69
Grande Ronde River, Crow Creek	Hay	1-year lease	197.70	5,272	26.67
Deschutes River, Tygh Creek	Pasture	1-year lease	94.50	945	10.00
Rogue River, South Fork Little Butte Creek	NA	1-year lease	83.34	1,438	17.25
Grande Ronde River, Crow Creek	Hay	1-year lease	197.70	5,136	25.98
Deschutes River, Tygh Creek	Pasture	1-year lease	94.50	945	10.00
Rogue River, South Fork Little Butte Creek	NA	1-year lease	83.34	1,438	17.25
Umatilla River, Couse Creek	Wheat/Pea	1-year lease	1,065.9	23,800	22.33
Deschutes River, Buck Hollow Creek	Hay	1-year lease	196.80	5,000	25.41
Grande Ronde River, Crow Creek	Hay	1-year lease	197.70	5,136	25.98
Rogue River, South Fork Little Butte Creek	NA	1-year lease	83.34	1,438	17.25
Umatilla River, Couse Creek	Wheat/Pea	1-year lease	1,065.9	23,800	22.33
Umatilla River, Couse Creek	Wheat/Pea	1-year lease	1,065.9	23,800	22.33
Average (1-year leases)	—	—	—	—	**23.19**

[a]Assumes a 6 percent discount rate to compute annualized cost of permanent acquisitions.

Source: Oregon Water Trust

Nonland fixed costs range from $25 for pasture to $207 for alfalfa. When net revenues are included, the short-run loss estimates range from $206–$312 on Class II lands to $25–$37 on Class V lands (Table 5). Like the long-run values of irrigation water estimated above, per-acre losses vary greatly (in this case, by more than a factor of 12) across location and soil class.

To validate our loss estimates, we can compare them to two sources of market data involving short-run transactions or temporary transfers—land rentals and annual water leases. In these situations, however, landowners are likely to make arrangements to avoid leaving equipment idle (e.g., they may rent it out or use it on other lands). They will want to cover their forgone net revenue and the cost of the land (the capital tied up in land ownership), but nonland fixed costs may be zero or very low if their equipment and vehicles are fully utilized elsewhere.

Table 5. Estimated per-acre losses from irrigation curtailment by location and soil class.

	Losses ($ per acre)				
	Class II	Class III	Class IV	Class V	Weighted average
Areas above Upper Klamath Lake					
Fort Klamath Valley	—	67	52	37	42
Modoc Point to Chiloquin	232	182	52	37	131
Sprague River Valley	—	210	58	31	59
North Country	—	58	58	28	56
Areas east and south of Upper Klamath Lake					
Swan Lake Valley	236	162	58	35	110
Bonanza (non-Project)	309	260	58	35	199
Langell Valley (non-Project)	242	106	58	35	115
Poe Valley (non-Project)	297	158	67	37	159
West of 97 to Keno (non-Project)	206	134	52	37	100
Lower Klamath Lake (non-Project)	307	159	67	25	155
Klamath Reclamation Project areas					
Merrill-Malin	312	232	67	37	193
Poe Valley	297	158	67	37	159
Midland-Henley-Olene	297	247	67	37	201
Bonanza-Dairy-Hildebrand [a]	*309*	*260*	*58*	*35*	*199*
Langell Valley [a]	*242*	*106*	*58*	*35*	*115*
Lower Klamath Lake	307	159	67	25	155
Malin Irrigation District	295	243	73	31	242
Shasta View District	299	217	211	31	232
West of 97 to Keno	206	134	52	37	100
Tule Lake/California portion	259	211	73	25	182
Shasta and Scott valleys	273	228	70	—	167
Unweighted average	**274**	**173**	**69**	**33**	—

[a]Portions of the Project that received surface water in 2001.

The loss estimates in Table 5 correspond very closely to observed market prices from the active land rental market in the Upper Klamath Basin, where per-acre rental prices are $200 to $300 for row crops, $125 for alfalfa, and $30 to $50 for pasture (Todd 2002). We also can compare them to the annual water leases from farmers by the Oregon Water Trust. As shown in Table 4, these leases indicate an average value of $23 per acre-foot of consumptive use on pasture and hay fields. Assuming 2 acre-feet per acre, this value corresponds to an implicit price of $46 per acre, about 35 percent higher than the $33 short-run loss estimate for Class V soils.

Estimates of short-run costs exceed the long-run estimates of the economic value of water (compare Tables 3 and 5) by more than a factor of 2. This result is consistent with the expectation that a large-scale, unexpected curtailment of irrigation is more costly to growers than small-scale individual transactions that are anticipated and planned.

It is important to recognize that certain kinds of losses in the Upper Klamath Basin are not captured by these estimates. Examples include dissolution of experienced and trained crews and loss of contracts with crop processors and purchasers.

Implications of these data

Two striking features emerge from these data.

- The value of irrigation water varies widely across locations and soil types in the Upper Klamath Basin.
- In relative terms, the variations across soil class and location are large for both long-run and short-run measures of the value of irrigation water. Per-acre values differ by a factor of 12 or more across soil classes in both cases.

The limitation on irrigation water imposed in 2001 represented only about 35 percent of the water normally applied throughout the Basin, yet the reductions were made by imposing 100 percent reductions on a subset of irrigators—those within most of the Klamath Reclamation Project. Most of the areas within the Project that did not receive water in 2001 were high-productivity Class II and III soils. By contrast, many of the areas outside the Project that did receive water in 2001 are Class IV and V soils. Examples include areas north and east of Upper Klamath Lake and in the Scott and Shasta valleys.

This observation raises questions about the cost-effectiveness of the way in which irrigation curtailment was implemented in 2001 and suggests ways to reduce losses with more cost-effective responses.

The role of government farm payments and other subsidies

In examining the economic value of water based on its use in agriculture, it should be recognized that in the Upper Klamath Basin, as in the nation as a whole, there are significant government payments to farmers via commodity support and other programs. In the Klamath Basin, payments are made to eligible farmers based on their past production of any one of three crops—wheat, barley, or oats. Payments are made under the Agricultural Marketing Transition Act, the Market Loss Assistance program, and the Loan Deficiency Payments program.

These government payments averaged about $5 million per year from 1990 through 1999 in the three counties, according to the Bureau of Economic Analysis (www.bea.gov). Payments represented about 15 percent of total farm labor and proprietors' income.

While these transfers affect land values and other economic data in the region, the magnitude of the effects may not be large. Although the three eligible crops are grown on about 30 percent of the land within the Project (2000 data), and about 15 percent of the land in the Basin overall, they represent only 17 percent of revenues from the Project and are grown almost exclusively on Class II and III soils. Current payments are based on levels of production of these three crops prior to the mid-1990s, so they do not influence current cropping decisions.

To consider the effects of these subsidies on farm values or agriculture generally in the region, one needs to ask: "What would be different if these subsidies were unavailable?" Without these subsidies, or since the mid-1990s (after which payments no longer were tied to current production), farmers are likely to have reduced the acreage allocated to the three eligible crops, while increasing production of other crops that can be grown profitably in rotations on the same Class II and III soils.

With these substitutions to other crops, changes in net returns per acre might be small. Land rental rates paid by farmers to landowners might decline, but because the net benefits of farm subsidies tend to become capitalized into land values or land rental rates, the effects on the more than 50 percent of farm operators who rent land likely would be negligible. Moreover, in terms of overall irrigated agriculture in the Upper Klamath Basin, these programs likely have no effect because the economically marginal lands (Class V) used for pasture and hay are unaffected.

These government payments may have a small positive effect on estimates of the long-run value of irrigation water presented in Table 3. Without these payments, the values on Class II and III lands might be $19 per acre lower on average ($5 million annually spread over 260,000 acres).

Irrigators in the Project also benefit from a 50-year BOR contract with PacifiCorp for electricity provided at 80 to 90 percent below market rates (as low as $0.003 per kwh). This implicit subsidy amounts to an average of $6 to $9 per acre per year, or between $1.2 million and $1.75 million annually for the Project overall.

These subsidies have a modest effect on the net returns to agriculture in the Project. They amount to 8 to 12 percent of the average long-run value of irrigation water for those portions of the Project not receiving water in 2001 (based on figures in Table 3).

The current energy contract ends in 2006. The elimination of these energy subsidies likely would reduce the long-run net returns to agriculture on Project lands by $6 to $9 per acre per year.

Economic costs of irrigation curtailment

The data presented above form the basis for a mathematical representation, or model, of irrigated agriculture in the Upper Klamath Basin. This analysis differs from the estimates in Chapter 12 ("Crop Revenue"). That analysis reflects only the Klamath Reclamation Project, and she estimates changes in gross revenues rather than changes in net revenues. It also differs from the analysis in Chapter 13 ("Regional Economic Impact"), which focuses on changes in the scale of economic activity throughout the region.

This analysis does not attempt to represent all potential consequences of irrigation curtailment that might affect individuals in the region. Nor does it attempt to quantify the "benefits" of irrigation curtailment arising from increased stream flow, improvements in aquatic habitat, and possible (but uncertain) improvements in fish populations, fish harvests, or other related changes. Putting a dollar value on all of these impacts within and outside the Upper Klamath Basin would represent an impossible task—in part because the biological relationships are so uncertain.

Our model is essentially a system of accounting equations representing the land areas, soil types, costs, and revenues discussed above and described in Tables 1–5. The model characterizes 16 areas in Oregon and California. Ten of these are portions of the Project; others include irrigated areas around and above Upper Klamath Lake and in the Shasta and Scott valleys of California.

Typically, there are about 509,000 total irrigated acres in the Upper Basin. The model assumes that each acre is irrigated fully or not at all. (It does not allow for reduced, or deficit, irrigation on a given acre nor for groundwater supplementation.)

For the analysis of short-run losses, we start from a base case in which all of these acres are irrigated and earn “normal” net revenues. We want to evaluate the losses from curtailment of irrigation on some portion of those lands.[1]

Losses from the 2001 curtailment

Our first scenario replicates the 2001 situation, but without supplemental groundwater or the midseason delivery of canal water. All of the areas that were cut off from irrigation are required to receive zero water. These areas are estimated to equal 177,823 acres, or about 35 percent of the 509,000 total irrigated acres in the Upper Basin. Areas receiving full water suffer zero losses; areas receiving zero water suffer losses as indicated in Table 5.

By replicating the actual allocation of water in the Basin in 2001, the model produces an estimate of losses of $33 million in net revenues. This loss corresponds to a decline in gross farm revenues of $87 million (which is about 17 percent higher than the $74.2 million estimated in Chapter 12 (“Crop Revenue”) by Burke, who included some groundwater-based irrigation). Wage payments to farm labor were estimated to have been reduced by $8.2 million. The reductions in net revenues and farm wages amount to 48 percent of the reduction in gross farm revenues.

This estimate will overstate actual direct losses if some of the 177,823 acres assumed to have been cut off from irrigation were cropped using publicly or privately provided groundwater or the midseason canal flows allowed by the BOR. (In Chapter 14, “Outcomes, by Jaeger, actual Project acreage in 2001 is reported to have been 102,338 acres below normal.) This change was primarily the result of supplemental public and private groundwater irrigation.

Conversely, this estimate will understate actual direct losses if additional costs were incurred by growers. Examples might include costs associated with groundwater pumping, planting cover crops, clearing canals of weeds, losses from early “distress” sales of livestock, and idled or underemployed farm labor. If we assume that half of the farm labor normally employed on the cutoff acres was unable to find other employment, the estimate of losses would rise from $33 million to about $37.5 million.

Losses under efficient water allocation

We are particularly interested in evaluating how the losses of the 2001 curtailment would have differed if there had been more flexibility in how water was allocated. We expect that the losses could have been significantly lower had a cost-effective, loss-minimizing approach been possible—one that cut off water from those lands that would suffer the least.

To estimate these differences, we ask the model to choose the most cost-effective way to reduce the total irrigated area by the same number of acres. In other words, the total loss (TL) to the region is minimized, while still reducing irrigated acreage by 177,823 acres, as was assumed in the 2001 scenario.[2]

This cost-minimizing scenario generates an estimated cost of only $9.5 million, or about 71 percent lower than the $33 million cost under a scenario replicating the curtailment in 2001. Rather than curtail irrigation only on the Project, the model identifies Class IV and V lands throughout the Basin as the ones where irrigation can be eliminated with the least amount of loss. In particular, substantial areas along the Sprague and Williamson rivers, Fort Klamath, and in the Horsefly and Langell Valley areas would be cut off. No lands in the Shasta or Scott river valleys would be affected.

These scenarios involve choosing which acres to irrigate, but not how much water to apply to each. Since water scarcity has only recently become a direct concern for irrigators in the Basin, precise measurement of applied water

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[1]A curtailment of irrigation for an area A, in zone i, of soil type j, (A_{ij}) will produce a loss, L_{ij}.

[2]Algebraically, we can write this procedure as:

Minimize: $TL = \sum L_{ij} A_{ij}$

subject to: $\sum A_{ij} = A^*$

where A* =177,823, the acreage not receiving water

Table 6. Estimated loss in net farm revenues from restricting irrigation diversions in the Upper Klamath Basin under alternative allocation methods.

Losses from 2001 restrictions on the Project (177,823 acres without water)	$33–37.5 million
Losses for equivalent restrictions but with cost-minimizing acre-to-acre transfers	$9.5–12 million
Losses for equivalent restrictions but with acre-to-acre transfers and deficit irrigation	$6.3–7.6 million

has not been practiced. If gauges and volume meters were available throughout the Basin, one could "fine tune" the allocation of water to include partial reductions in the applied water for some fields. Such "deficit irrigation" may lower the cost of irrigation reduction even more than the "acre-to-acre" reallocation reflected in the model above.

The cost of installing gauges and metering devices must be considered. For flood irrigation diversions, the installation of flumes and meters can cost $2,500 at each diversion point. For piped diversions, the cost may be $1,000. An inventory of diversion points in the area counts about 300, but there are about 850 irrigated farms. If one metering device is required for each irrigated farm, and if about half of the diversions are piped, the average cost of installation would be about $3 per acre. Given an additional 10 percent cost for annual maintenance and depreciation, the cost of metering amounts to less than 50 cents per acre per year. Therefore, these costs do not seem to significantly weaken the case for metering water in the Basin.

An analysis of irrigation management involving deficit irrigation and fine tuning of water deliveries was undertaken for the Project by Adams and Cho (1998). They included only the Project in their model, but their results provide some evidence of the additional potential for cost reductions provided by this method. They find that for small percentage reductions in irrigation deliveries (less than 20 percent), the cost is about $17 (per "acre equivalent"), compared to the $30 to $35 short-run loss for leaving an acre of pasture completely dry.

With a combined approach that would leave 100,000 acres of pasture dry and require deficit irrigation (of 18 percent) on other acres, the same reduction in total diversions as was imposed in 2001 could be achieved at a cost of $6.3 million, or 80 percent less than the estimated actual cost. If half the labor reduction is assumed to be left idle, the estimate rises to $7.6 million. A summary of these cost estimates for different water allocation alternatives is presented in Table 6.

Two caveats remain. First, it is important to recognize that any change in the allocation of scarce water will produce consequences for many individuals that differ from the circumstances of 2001. Some would see these changes as improvements, others would not. For example, reductions in irrigated acres would cause operating and maintenance costs for the affected irrigation districts to be shouldered by a smaller production base. Second, implementing cost-effective water management is more difficult than simply estimating the cost savings that might result. How the legal, administrative, and political institutions might be realigned to facilitate cost-effective responses to scarcity is a critical question facing the region.

Ways to reallocate water among irrigators

> "Water is becoming increasingly scarce in the United States. Demand is rising along with population, income, and an appreciation for the services and amenities that streams, lakes, and other aquatic ecosystems have to offer…. Ordinarily, Americans count on prices and markets to balance supply and demand and allocate scarce resources…. As conditions change, markets enable resources to move from lower- to higher-value

uses. Market forces, however, have been slow to develop as a means of adapting to water scarcity" (Frederick 1999).

The analysis presented in this chapter suggests that about 80 percent of the cost of the 2001 irrigation curtailment in the Upper Klamath Basin was due to inefficiencies in the way irrigation water was allocated. In other words, only 20 percent of the cost was directly attributable to water scarcity arising from the drought and ESA-related requirements.

The situation facing growers in 2001 contained the two characteristics that economists recognize as working against producers in any industry: a high degree of uncertainty and few options or flexibility. Not only was irrigation interrupted on the most productive, highest value acreages in the Basin, but there existed no mechanism—such as a market—to reallocate other irrigation water between low-value and high-value uses.

This is not to suggest that water markets could have been introduced on short notice as the 2001 situation became apparent. In the future, however, if similar water scarcities arise, the ability of irrigators to transfer water rights via markets could transform a potentially very high-cost event into a much less significant one.

Water markets

Water markets or water banks represent the option to buy needed water or to sell water to others. The willingness to buy or sell water will reflect differences in land productivity, crops, and fixed costs. Growers who have the most to lose from a cutoff of water are likely to benefit most from the ability to buy additional water in such circumstances. Likewise, irrigators of low-productivity lands or those with low fixed costs may decide they would be better off selling their water to others.

Although water markets and water rights transfers are a relatively recent phenomenon in the western U.S., there is growing evidence of their use and beneficial effects. In Texas' Rio Grande Valley, transfers of 74,966 acre-feet occurred prior to 1990. The net benefit of these transfers has been estimated at more than $1 trillion (Griffin 1998). Active water markets have long existed in Colorado, Utah, and New Mexico, and more recently in Arizona, Wyoming, and California (Howe 1998).

The thousands of applications documented in Colorado, Utah, and New Mexico include permanent sales of water rights as well as temporary transfers to accommodate short-term needs, such as those that occur during drought. Approved trades in these states include many transfers among irrigators and from agriculture to nonagricultural uses, and a few from nonagricultural uses to agricultural ones. Colorado long ago adopted a water court system in which proposed water transfers may be challenged by parties who believe they will be "injured" by the transfers.

In California, during the early 1990s, federal and state legislation helped clarify water rights in order to facilitate rights transfers, although these changes have not yet achieved their full intent involving long-term transfers (Archibald and Renwick 1998). Nevertheless, California has developed informal intraseasonal spot markets and annual lease markets, both of which have been dominated by trades within agriculture. A state-run "water bank" has handled 40 percent of all water transfers since 1992, demonstrating that annual lease arrangements could benefit the willing buyers and sellers in these markets (Howe 1998). This water market activity has averaged 122,000 acre-feet in each drought year during the early 1990s. In the case of the 1991 water bank, the statewide net benefit was estimated to be $104 million, including $32 million in benefits to agriculture (Howitt 1998).

Existing Oregon water law is quite conducive to water markets. Water right transfers have been common in the state since the 1980s. Oregon law allows water rights to be transferred between beneficial uses, including in-stream flow, following an application and approval process through the Oregon Water Resources Department (OWRD).

The number of applications rose from about 100 to more than 200 per year between the 1980s and 1990s. Currently, OWRD receives more than 250 applications per year for out-of-stream uses and 5 applications for transfers to in-stream uses such as protection of fish habitat. The total includes about 50 temporary transfers. About half of commercial water right transfers convey water rights from one agricultural use to another, according to a survey conducted in the early 1990s (Landry 1995). The average sales price in these water markets was $360 per acre-foot, which corresponds to an annual value of about $22 per acre-foot (using a 6 percent interest rate).

Potential effects of water markets in the Upper Klamath Basin

There is continued uncertainty about the total amount of water available for irrigation in the Upper Klamath Basin. It also is possible that future curtailments may be implemented in ways that do not promote efficiency, as they were in 2001. In the face of these circumstances, irrigators may wish to increase their options in such situations.

The suggestion that water markets could play a central role in solving Klamath water conflicts frequently is met with two kinds of objections. First, growers in the region typically dismiss it as an idea that "can't work" and will "never happen." Second, they are concerned that so much water might be transferred from irrigation to other uses that the scale of the local farming economy would be greatly reduced, thus threatening the viability of their rural communities. These issues are discussed in this and the following section.

Permanent market transfers or "swaps" of water rights with different priority dates may be advantageous to some growers. The financial risk associated with not receiving water varies among irrigators, depending on their crops, soils, and production technologies. Our estimates of short-run losses from losing access to water vary from $25 to $312 per acre. Efficiency suggests that the highest priority water rights will have the highest financial value when held by those irrigators with the highest risk of loss.

Consider an example. If a senior water right is held by a grower facing losses of only $25 per acre (due to lower productivity land), while a junior water right is held by a grower facing losses of $300 per acre (due to having highly productive land and higher risk crops), there are obvious gains from an exchange of assigned priority rights between these two growers. Assume the high-loss, junior-right holder expects to lose access to water 1 year out of 4. He likely would be willing to pay up to $300 every 4 years to avoid that loss. The low-loss, senior right holder, on the other hand, could exchange his senior right for a junior right and face only a $25 loss once every 4 years.

Thus, after taking into account the changes in their expected losses over time, the high-loss grower should be willing to pay up to $1,250 for a permanent trade of priority dates, while the low-loss grower should be willing to accept anything higher than $104. The combined gain from this swap is $1,146 per acre.[3]

Oregon law allows for these kinds of water rights transfers, both permanent and temporary, provided there are no adverse "third-party effects." When a water right transfer changes the point of diversion, it is possible that holders of water rights between the two points of diversion will be affected adversely. Such transfers would be prohibited by the OWRD.

There is reason for optimism that water right transfers would be allowed in the Upper Klamath Basin. Most transfers would move senior water rights from upstream to downstream, where they could be used on more productive land. This would reduce the likelihood of this kind of "third-party effect" because more water would be flowing past intermediate diversion

[3]The present value of these changes in seniority is computed by annualizing the expected losses (dividing by 4), and then applying the formula for a perpetuity (dividing by the interest rate). Using 6 percent, we calculate for the high-loss grower an increase in the present value of his water right of $(300 \div 4) \div 0.06 = \$1{,}250$; for the low-loss grower, there will be a loss in present value terms of $(25 \div 4) \div 0.06 = \$104$.

points rather than less. If the ownership of water rights evolved so that most senior water rights were in the Project area, basinwide management of water allocation would involve restricting water diversions among the junior-right holders in the upper reaches of the Basin to ensure adequate supplies for the senior-right holders below.

Were such a reallocation of priority rights to occur, an unintended, but desirable, side effect would be more water left in-stream in the upper portions of the Basin and in Upper Klamath Lake. Additionally, in years when water supplies were inadequate to provide water to junior-right holders, the curtailment of water deliveries in these upper reaches would reduce stream and lake contamination from agricultural chemicals and animal waste by reducing agricultural runoff in the upper portions of the watershed.

For the Upper Klamath Basin overall, the exception to the idea of fully functioning water markets and transfers of water rights involves the Scott and Shasta valleys in California. There are multiple obstacles to including those areas in any realistic scenario. First, there is no physical way to move water from those tributaries upstream to the Project. Second, it is unclear whether individual water transfers between right holders in different states would be allowed under the laws of either California or Oregon.

Nevertheless, other mechanisms for including Scott and Shasta valley irrigation as part of a comprehensive solution are possible. For example, government agencies or nongovernmental organizations might take actions to augment in-stream flows in the Scott and Shasta rivers. To the extent that these actions improve fish habitat, it might be possible to relax requirements for in-stream flows below Iron Gate Dam.

In addition to the possibility that these transactions might increase economic efficiency, the adjudication of water rights might reduce the losses from water shortages in a secondary way. In the long run, junior-right holders can be expected to alter their production decisions based on the recognition that they face a relatively higher risk of not receiving water. Given this fact, they are likely to take precautionary measures that reduce their vulnerability. For example, they might be able to choose a different combination of fixed and variable costs of production, or they might prepare contingency plans to minimize their losses in the event of drought. An example is the purchase of insurance against water loss.

One variation on the water market theme may be appealing to irrigators and a good fit for the current administrative structure of the Project. This variant is called a "water bank." It can be thought of as a cooperative arrangement among growers for the distribution of water and payments for its use.

In the case of the Project, a water bank might work as follows. Each grower could be entitled to a proportional share of the available water based on the size of his or her farm. In a drought year, when the total amount of water available is limited, these shares may not represent enough water to fully irrigate each acre of land. In that case, farmers may offer to forgo irrigation and "deposit" their water in the water bank. Other irrigators may be willing to pay the bank in order to obtain additional water. The bank acts as a clearinghouse between buyers and sellers of water, all of whom are growers in the Project.

What if all growers wanted additional water? In that situation, the Project, or a district within the Project, may be willing and able to look elsewhere for additional water, for example, by buying water from irrigators above Upper Klamath Lake.

A well-functioning water bank can achieve an efficient allocation of water similar to a water market. However, a water bank may be better suited to the existing collective arrangements and operations of the Project; it may facilitate the necessary coordination within the Project better than a decentralized water market.

Without conducive and supportive institutions, it is unlikely that adjudicated water rights will be transferred via water markets or water banks to reduce financial risks to the agricultural sector overall. External funding might serve as a catalyst to purchasing, and then reselling, high-priority water rights.

Reallocation of water from agriculture to nonagricultural uses

How water will be allocated in the future between irrigators within the Project, irrigators outside the Project, and nonagricultural uses is a central concern for everyone in the region. The events of 2001 have raised the level of concern, apprehension, and uncertainty about future water allocation in the Basin.

The events of 2001 and the conflicts between ecological and agricultural uses of water have led some to question whether agriculture is compatible with competing ecological goals. This is a complex question that does not have a simple "yes" or "no" answer, certainly not one based solely on the existing methods for valuing and comparing benefits and costs. Moreover, the eventual outcomes for water allocation in the Basin will be based in part on legal determinations involving tribal rights, the Endangered Species Act, Bureau of Reclamation obligations, and competitive forces in national and international agricultural markets. Although it is not possible to predict the future path of water allocation within the Upper Klamath Basin, it can be expected to evolve in response to changes in the legal, economic, demographic, and political setting.

Economic forces also can be expected to be at work, by influencing legal and political processes, and by creating individual and collective incentives to allocate water in ways that reflect the most valuable uses of that water to society. In that context, some observations about the allocation of water between agricultural and nonagricultural uses are possible, based on the economic description of agriculture in the Upper Klamath Basin and the estimates of the value of water when used on various classes of agricultural land.

When water rights adjudication in the Basin is complete, Oregon water law allows purchases of water rights from individual irrigators to augment in-stream flows, so long as there are no direct "third-party" effects that limit the legal diversions by other water rights holders. Whether and how much water might be returned to in-stream flows is unclear. However, there is little evidence to suggest that such transactions will result in the complete demise of agriculture in the Upper Klamath Basin. The following evidence should dispel such fears.

First, while there are examples of large transfers of water from agricultural to nonagricultural uses via water markets (for example, in Texas' Rio Grande Valley, where 99 percent of water rights transfers were from agricultural to nonagricultural uses), much of the agricultural water that was sold would otherwise have been unused by its owners (Griffin 1998). In addition, nearly all of these transfers were near large urban centers and went to municipal uses or to accommodate urban sprawl. In the Upper Klamath Basin, there are no comparable circumstances in which water is unused, nor is there large unmet urban demand for water nearby. Long-distance conveyance seems impractical at this time.

Second, the estimates presented above of the long-run agricultural value of water rights, especially on the highly productive "prime" Class II and III farmlands, seem to be more than environmental groups have been willing to spend, except in exceptional circumstances. Most of the Class II and III soils are estimated to generate between $75 and $144 per acre per year, or between $37 and $72 per acre-foot of water. Purchases of water rights for in-stream flow, for example by the Oregon Water Trust, tend to be in the range of $6 to $22 per acre-foot. Thus, the agricultural value of water on these soils is 1.5 to 12 times higher than the prices that have been paid elsewhere in the region.

This evidence suggests that, given scarce funding for the improvement of aquatic ecosystems and fish habitat, available funds are likely to be targeted where they can do the most good (in terms of improving fish habitat) at the lowest cost. Some of the Class IV and V soils in the Upper Klamath Basin, where estimates of the value of water are within the range of $6 to $22 per acre-foot, might be candidates.

This economic evidence may or may not be a good predictor of the course of legal challenges and political support for ESA-related restrictions on irrigation diversions. It also is not clear whether the introduction of water markets would alter the political balance among interest groups in any predictable way. To the extent that market transactions are used to improve stream flow and aquatic habitats in the region, the status of threatened and endangered species may improve, and pressures for additional legal or political challenges may abate. Moreover, market transfers involve direct compensation to those water right holders who willingly sell their water rights. Generally speaking, a water market also will put the agricultural economy in a better position to reduce the economic effects of any future restrictions on irrigation, both in terms of individual farmers and the overall agricultural community.

It is important to recognize that with water markets, land retirement would have a smaller effect on the agricultural economy than if land were taken out of production arbitrarily or by some other procedure that did not take account of market values. When irrigation water rights are bought by environmental interests to protect fish, a market approach will encourage and facilitate the purchase of those water rights with the lowest agricultural value. These rights are likely to be those associated with Class IV and V soils, where net revenues may be only 7 percent of those on the most productive soils. As a result, the retirement of those lands will have the smallest effect on the region's agricultural economy.

For example, we estimate that if 20 percent of the lowest value irrigation water rights were purchased for in-stream use, total net farm revenues for the Basin would be reduced by only about 10 percent.

A change of this magnitude would have a very modest effect on the agricultural economy overall. For example, this change is less than the typical year-to-year percentage change (positive or negative) in gross farm sales in Klamath County, and it is about half as large as the typical year-to-year change in revenues for Oregon counties such as Sherman and Gilliam, where rainfed agriculture predominates.

None of the foregoing analysis is intended to provide an answer to the question of which uses for water in the Klamath watershed produce the highest social value. In addition to agriculture, other individuals and groups with interests in how water is allocated in the Upper Klamath Basin include the commercial fishing industry, recreational users, and Native American tribes throughout the Basin and in coastal communities, as well as urban, regional, and national groups who value the protection of species and aquatic ecosystems. As much as one would like to quantify these different (and difficult-to-measure) values in order to compare them to agricultural values (including the values associated with the protection of farm communities), it would be an extremely costly endeavor unlikely to achieve a credible result.

Biological flexibility

The mechanisms for water transfers discussed above involve introducing flexibility in the ways in which irrigators are able to respond to water scarcity. It is reasonable to consider how flexibility in the biological requirements for lake elevation in Upper Klamath Lake and stream flow below Iron Gate Dam can be part of a cost-minimizing way to allocate water among competing uses. In the event of a drought, is there room for flexibility in the ESA requirements?

Several recent Biological Opinions have been responsive to drought conditions in considering how much water would be required to support fish populations. However, the limited flexibility in the 2001 decisions raised questions about how biological flexibility might best be managed, while at the same time offering reasonable and prudent protection for fish. A rule-based, long-term approach that incorporates drought-year compromises by both in-stream and irrigation uses might be a way to avoid large negative consequences for either agricultural or environmental interests.

Given the language contained in the Endangered Species Act, to a large extent this is a question for biologists and court interpretations. (See Chapter 5, "Suckers," and Chapter 6, "Coho Salmon," for discussion of the biology of these issues.) The ESA indicates that costs should not be taken into account when devising plans to protect endangered species; yet, it also instructs that responses should be "reasonable and prudent."

More flexible rules for species protection that allow exceptions to a general rule (for lake elevation or stream flow) under certain circumstances would seem to be consistent with the directive for "reasonable and prudent" approaches, so long as these rules would not compromise the protection of the species. To illustrate, consider the possibility that the required lake elevation in Upper Klamath Lake could be lowered by 1 foot below the desired minimum, say, once every 5 years (but no more frequently, regardless of whether multiple droughts occurred within a 5-year period) and that the in-stream flow requirement below Iron Gate Dam could be relaxed by 25 percent, say, once every 5 years. Given these rules, water shortages sometimes would restrict irrigation diversions by farmers, and they sometimes would reduce flows or lake levels for fish.

Based on the distribution of hydrologic year-types, how often, and to what extent, would severe irrigation restrictions be necessary? Depending on the biological requirements and frequency of low-water years, a flexible allocation mechanism of this kind might make it possible to completely avoid severe irrigation reductions like the one experienced in 2001. Instead, there might be only infrequent, modest restrictions.

Although the U.S. Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), and the Bureau of Reclamation (BOR) have at times made provisions for relaxing the biological requirements in drought years, they have not established a regular, long-term directive that would rule out sequential, or closely timed, reductions in lake level or stream flow that might place fish in jeopardy.

The BOR proposals for managing lake elevation in Upper Klamath Lake and stream flow below Iron Gate Dam, for example, allowed for relaxing lake elevation and stream flow requirements in dry years and critically dry years. The BOR proposal, however, would relax biological requirements in all dry or critically dry years, even if they occurred consecutively. The alternative suggested here would allow for relaxed biological water requirements only if those requirements had not been relaxed in the previous 5 (or some other number of) years. To avoid considering every year to be a special case, rule-based limits on the frequency of compromises must be upheld.

In principle, arrangements of this kind recognize the uncertainty of future water availability, and they also implicitly recognize that small reductions in water supplied to several uses might be preferable to large reductions in supply to any one group. This approach is yet another way in which flexibility, if managed effectively, can promote better use of a scarce resource. Once again, however, the possibility of implementing a proposal of this kind would depend on scientific and court interpretations of the ESA as to whether such an approach could be considered "reasonable and prudent" and not likely to jeopardize the continued existence of species listed as threatened or endangered under the ESA.

Increasing the water supply

Many observers would like to see the quantity of water in the Basin increased in some way. Proposals include using groundwater in times of drought, building new reservoirs, and "saving water" through the adoption of technologies with higher irrigation efficiency.

These solutions are appealing because they avoid making hard choices to resolve the conflict over existing scarce water; they simply make more water available so that all users can have what they want. In practice, these solutions rarely work. The options for increasing supplies tend to be very expensive relative to the value of their intended use, and they often are environmentally damaging (Frederick 1999).

The sections below evaluate the economics of two approaches that have been suggested as ways to increase the amount of available water. Analyses of other options are beyond the scope and resources of the current study. For example, we do not look in detail at augmenting water storage with new reservoirs.

Supplementing irrigation with groundwater

In drought years, might it be feasible to supplement irrigation diversions by pumping groundwater, or by using groundwater to augment in-stream flow so that additional irrigation diversions could be permitted? There are important hydrological concerns about doing so on a large scale, as there is evidence that such pumping would have adverse effects on local aquifers, private wells, public drinking water supplies, and subsurface irrigation in nearby areas (see Chapter 2, "Klamath Reclamation Project"). For these reasons, there may be legal obstacles as well.

Our goal here, however, is to provide an approximate picture of the economic costs and benefits to farmers of such an approach. The question is whether the installation of high-volume groundwater pumps can be an economically viable way to respond to drought conditions in the Upper Klamath Basin. We are not asking whether such pumps can be economically justified to permanently augment irrigation supplies, but rather whether they could be used as a source of supplemental irrigation water in times of extreme need.

In 2001, for example, the Tulelake Irrigation District projected that, with $5 million, wells producing 170 cfs could be developed. Assuming 100 days of pumping and 2 acre-feet per acre, this volume would serve about 17,000 acres.

A key question is how often this supplementation would be required. The drought conditions observed in 2001 and 1992 represent extreme conditions that occur only 5 percent of the time based on data from the past 41 years. Changes in forests, climate, and biological requirements may mean that irrigation water scarcity will occur much more frequently in the future. If we assume that supplemental water is needed once every 5 years, can the costs estimated by the Tulelake Irrigation District be economically justified? It depends on how the available water is otherwise allocated.

Based on the $5-million investment cost and a 5 percent annual cost for maintenance and depreciation (given usage only 1 year in 5), the cost when supplementation is offered would be $162 per acre for the investment and depreciation. Assuming pumping requires 100 feet (total dynamic head), and with a commercial rate for energy (or opportunity cost) of $0.035 per kwh, the energy cost per acre would be $9. Thus, the total cost of supplemental pumping would be $171 per acre.

If a groundwater pumping activity permits 17,000 additional acres to be irrigated, which acres would these be? In the absence of groundwater pumping, efficient water allocation would involve irrigating high-value lands and leaving lower value lands dry. If we assume that efficient allocation occurs (for example, via water markets), then the additional areas irrigated as a result of groundwater pumping would be lower value lands. Since one-half of the acreage normally irrigated is Class IV and V soils, where losses due to an irrigation cutoff generally are $33 to $70 per acre, supplemental irrigation with groundwater pumping cannot be justified if it costs $171 per acre.

If an efficient allocation of water in drought years is not possible, and the most productive lands are required to be left dry 1 year out of 5, then the $171 per-acre cost would be justified to avoid per-acre losses ranging from $173 to $312 for Class II and III soils. However, this conclusion requires one to assume that surface water will be allocated in a highly inefficient manner during future water shortages, as it was in 2001.

Improving irrigation efficiency

Irrigation efficiency is defined as the ratio of the amount of water actually consumed by the crop to the total amount of water diverted (from surface water or groundwater) for irrigation. Depending on the irrigation technology used, a farmer may need to apply twice as much water as the plants need. The water that is not consumed by plants flows back to the stream, percolates down through the soil, or evaporates.

It generally is assumed that water that percolates into the subsoil eventually finds its way back into the stream. This may take hours, days, or years, depending on soils, geology, and distance to the stream. The benefits to fish of changes in irrigation diversions vary greatly, depending on what is assumed about the amount and timing of changes in these return flows.

Evaporation varies as well, depending on temperature and humidity, but it often is assumed to account for no more than 10 to 15 percent of the water applied.

Surface (flood) irrigation efficiency may be less than 50 percent; sprinkler efficiency may be higher than 70 percent. In the Upper Klamath Basin, surface irrigation is most common, especially on the less productive lands. For most high-productivity lands, sprinkler irrigation is used. Conveyance efficiencies (typically canals for transporting water) of 70 to 80 percent are common in the Northwest, although efficiencies for unlined canals can be as low as 20 percent. Overall efficiencies, including conveyance and irrigation delivery, average less than 50 percent, and in some cases are as low as 20 percent (Butcher et al. 1988).

Several western states have passed legislation encouraging farmers to invest in improved on-farm irrigation technology (Huffaker and Whittlesey 2000). However, while irrigation efficiency may be an important factor affecting the potential for satisfying agricultural and ecological demands, it should not be assumed that improved irrigation efficiency in agriculture will result in less water being diverted from the stream. Thus, it does not necessarily leave more water for fish or other in-stream uses. Reality is more complicated, since improved irrigation efficiency also reduces return flows.

Assume a farmer diverts 400 acre-feet with an irrigation efficiency of 40 percent. This means that his consumptive use is 160 acre-feet, and return flows are 240 acre-feet. What happens if this farmer adopts improved irrigation technology that raises irrigation efficiency to 70 percent? With higher irrigation efficiency, the farmer may alter production methods or even switch to different crops that take advantage of the improved irrigation technology. As a result, consumptive use may increase. Assume, for example, that consumptive use increases from 160 to 175 acre-feet. With 70 percent irrigation efficiency, the stream diversion would be lowered from 400 to 250 acre-feet (175 ÷ 0.7). On the face of it, this would seem to be good for fish because it leaves an additional 150 acre-feet in streams or lakes.

However, the return flow now is only 75 acre-feet (250 – 175) instead of the previous 240 (400 – 160), a decrease of 165 acre-feet. Return flow has decreased by 165 acre-feet, while diversion has decreased by only 150 acre-feet. Thus, stream flow is reduced by 15 acre-feet as a result of the adoption of the new technology.

This hypothetical example illustrates the possibility that investment in improved irrigation efficiency can substantially *reduce* the amount of water left for streams or lakes. The actual outcome depends on what changes the farmer makes in farming practices and on how irrigators downstream respond to changes in the availability of stream flows at different times—especially where surface water is overappropriated via existing senior- and junior-right holders.

This issue is especially relevant to the Upper Klamath Basin, where water that is "wasted" due to inefficient irrigation technology frequently provides ecological benefits elsewhere. In areas above Upper Klamath Lake, return flows from irrigation return to streams or to Upper Klamath Lake, either reentering the Project for irrigation or providing in-stream flows below Iron Gate Dam. Return flows in the Lost River watershed and the Project are believed to be reused several times by other irrigators as these waters are collected in lateral canals or seep into canals, wells, and subsurface irrigation throughout the Project. Because of this recycling of water across the Project, overall irrigation efficiency is estimated to be above 90 percent.

In addition, return flows within the Project supply water to Tule Lake and Lower Klamath national wildlife refuges. Return flows in the Shasta and Scott river areas supplement stream flows and augment habitat for coho salmon. Overall, it is hard to make the case that improved irrigation efficiency will make more water available for fish and wildlife habitat.

If, however, return flows are very slow, so that "wasted" irrigation water does not return to lakes and rivers during critical months, there may be potential gains from improved irrigation efficiencies—but not without a cost. Ultimately, the cost of making more water available for fish through improved irrigation efficiency must be compared to the cost of the alternatives.

Even in cases where improved irrigation efficiency makes more water available for fish, the farmer may not benefit. For some crops, especially low-value crops, the cost of improved irrigation technology may be higher than the net revenues from production. For high-value crops, sprinkler irrigation may provide some gains to farmers due to increased yields, lower labor and pumping costs, or the possibility of switching to a higher value crop.

The principal costs of improved irrigation efficiency are the capital costs of the new technology and associated maintenance costs. Sprinkler systems can cost from $400 to $1,200 per acre to install. The annualized cost for these investments would amount to $24 to $72 per acre per year. Given the net revenues for Class IV and V soils reported in Table 3, the cost of these investments would be prohibitive unless they enable irrigators to increase revenues or lower costs in other ways.

Concluding comments

The legal and political institutions and infrastructure that currently exist in the Upper Klamath Basin were developed over the past 100 years to fit the circumstances of that period—one in which per-capita income was low and natural resources were relatively abundant. For these historical reasons, improvements in the institutions and infrastructure necessary for efficient water allocation have not kept pace with other changes in the region. In particular, the current lack of adjudicated water rights and the absence of water-metering devices are two key obstacles to managing water in a way that would reduce uncertainty, promote efficiency, and avoid costly events like the one experienced in 2001.

Costs are minimized most directly by flexible mechanisms that allow scarce irrigation water to be transferred among growers so that it finds its way to the highest value uses through voluntary exchange. The analysis above suggests that more than 80 percent of the costs of the 2001 water situation could have been avoided had water markets or other transfer mechanisms been available at that time. Given the high value of agriculture within the Project, and the presence of large areas of significantly lower value agriculture in other parts of Klamath County, a cost-minimizing approach to reducing irrigated acreage would involve full irrigation for the Project and curtailed irrigation in other, less productive areas. Indeed, a comparison between the $6.3 million in estimated cost for a cost-minimizing irrigation curtailment equivalent to the one imposed in 2001 and the $27 to $46 million in estimated losses in 2001 (Chapter 14, "Outcomes") is sobering.

This analysis suggests that in the Upper Klamath Basin, the absence of water transfer mechanisms such as water markets or water banks magnified the costs of drought and ESA determinations fourfold. The cost of future water shortages could be reduced if mechanisms for transferring water rights were put in place. In addition, the incorporation of rule-based biological flexibility into the species-related decisions also could lessen the prospect of costly restrictions on irrigators during future droughts.

The completion of the adjudication process promises to create a new opportunity for the reallocation of water rights among groups and users with different interests and risks. Whatever the outcome of tribal water right claims or future ESA rulings and Biological Opinions, if water rights can be transferred across different locations within the Basin, it will be possible for water available to irrigators to be allocated with the greatest certainty to those users with the most to lose from not getting their water. Users with junior water rights may develop contingency arrangements to reduce their short-run losses, plant crops more tolerant of deficit irrigation, or diversify their farm activities.

Other mechanisms, such as insurance against curtailed water deliveries, may develop as ways to reduce uncertainty, promote flexibility, and encourage cost-effective responses. When combined with long-term actions to address water quality issues throughout the Basin, there is reason for optimism that a sustainable balance can be found among the competing demands for the Basin's water.

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