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Alternative Approaches to Water Management in the Klamath Basin

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Introduction

Alternative approaches to managing the competing demands on resources in the Klamath Basin are varied and numerous. Components for a long-run strategy to protect fish and other species along with agricultural interests in the basin are likely to include restoration of riparian vegetation, screening irrigation canals, reductions of nutrient flows, reforestation, dam removal, reduced fish harvest pressure, etc. Indeed, many of these actions have been recommended as components in the recent and prior Endangered Species Act (ESA) biological opinions.

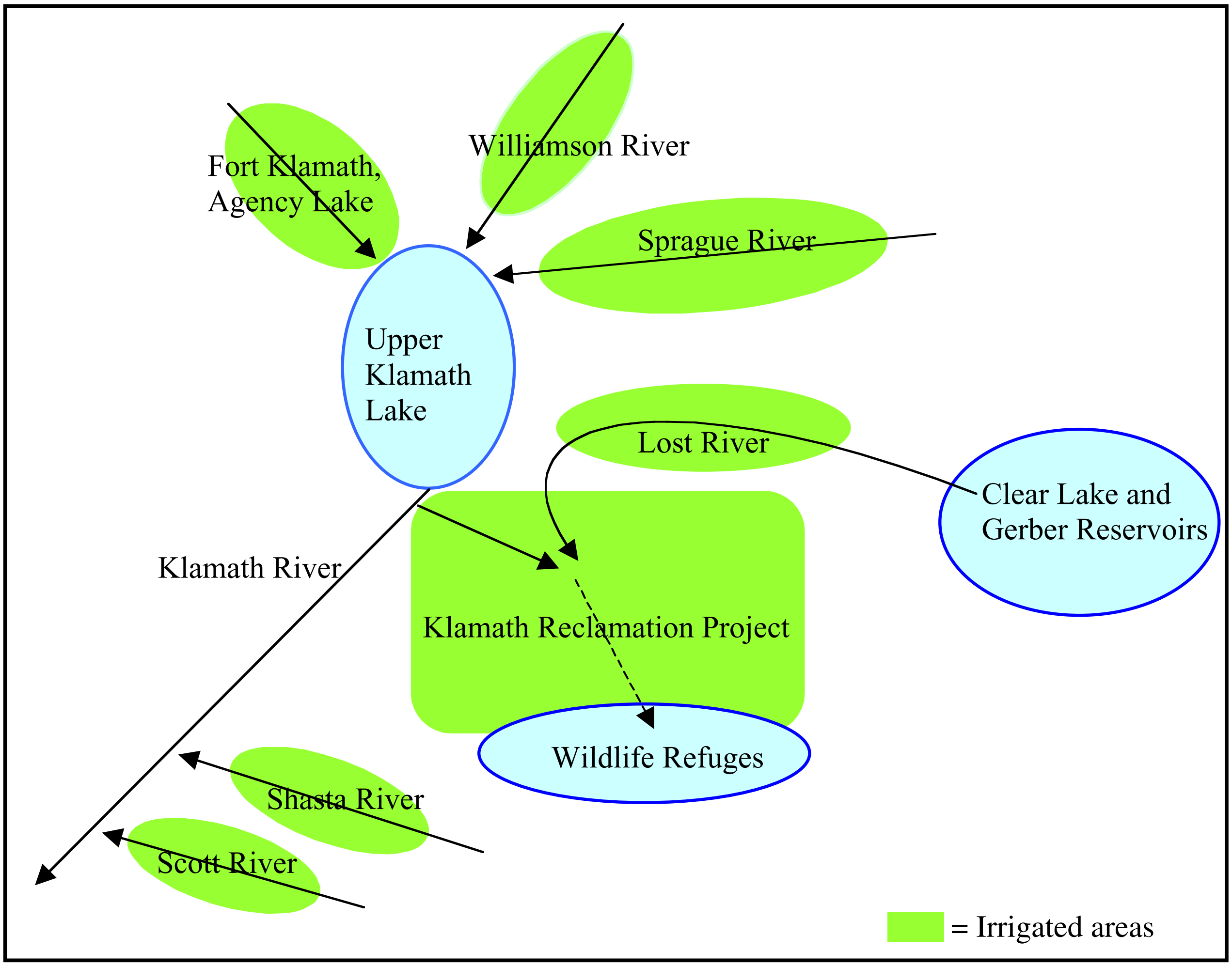
In addition to these broad actions, however, alternatives for the management and allocation of irrigation diversions in the basin may have advantages over current approaches. The aim of this chapter is to evaluate several of these alternatives compared to the actions taken in 2001. Alternatives will be evaluated based on their direct cost to the agricultural sector. To the extent that more cost-effective approaches can be identified, these may shed light on ways that future shortages can be managed to minimize the costs—provided that there is public support and the institutional capacity to carry them out.

The focus of attention here is on alternatives that deal directly with the *quantity* of irrigation water available, and the allocation of that water among competing uses. In addressing these issues, economic data and estimations of net gains and losses from allocating water on different soils in different locations must be estimated. In particular, the cost of short-run curtailment of irrigation supplies form the basis of comparisons of alternative responses to shortages like the one experienced in 2001. Importantly, the analysis is framed not within the boundaries of the Klamath Reclamation Project (KRP or "project"), but includes all irrigated areas within the basin which could reasonably be considered interconnected for purposes of satisfying the mix of competing ecological and agricultural demands.

Armed with data and estimates of short- and long-run marginal values for water, two additional mitigation options are evaluated below: supplemental groundwater pumping and adoption of efficient irrigation technology.

Two key characteristics of irrigated agriculture in the Klamath Basin are central to our investigation of alternative, cost-effective responses to water shortages. First, the acreage that was cut off from water in 2001 represents the large majority of the KRP but amounts to only 35 percent of the total irrigated area in the basin. This fact raises the possibility that other distributions of water curtailment may have been more cost-effective than one concentrated on the KRP. Cutting off water to other, less productive land is one possibility. In principle, given the infrastructure necessary to gauge and meter water deliveries, partial reductions of irrigation deliveries, or "deficit irrigation" represents another alternative.

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



The second characteristic of irrigated land in the basin is its highly variable productivity across different soil classes and locations. The productivity of those lands when irrigated—as reflected in their market values—varies by a factor of 10. The shares of irrigated land by soil classes II, III, IV, and V are 12, 40, 42, and 6 percent respectively.

Given this high variation in productivity, and the wide range of ways to comply with a 35 percent reduction in irrigation, first principles of economics tell us that a decentralized response to water shortage, one that accounts for the highly differentiated marginal losses and gains across different plots, will achieve the desired reduction in irrigation withdrawals at a much lower cost. If water is withheld from its highest value uses, while irrigation continues in locations where the net benefits are minimal, this inefficient arrangement will produce a high overall cost compared to an efficient (cost minimizing) allocation.

Alternative scenarios or policies of this kind will necessarily produce different economic and social effects in which some individuals may be more or less affected by these changes. Whether those alternatives are viewed positively or negatively will depend on many factors including the magnitude of the overall effects of any given scenario. The aim of the current analysis is first of all to identify ways in which the overall cost of irrigation restrictions could be reduced by promoting efficiency in water allocation. To the extent that an alternative response to a water shortage may also generate different consequences for individuals, or other undesirable social or environmental side-effects, we will want to take note of those differences as part of an overall assessment of the quantitative and qualitative differences between alternative courses of action. Still, our primary focus will be on comparisons of the cost-effectiveness of alternatives. In principle, if an alternative approach substantially lowers the overall cost of a water shortage, other ancillary effects may be mitigated with complementary actions.

An economic description of irrigated agriculture in the Klamath Basin

In this section economic data on irrigated agriculture, the value of applied water, and the cost of withholding water are compiled and presented. I begin by describing the data, how water values and losses were estimated, and including corroboration of the estimates based on comparisons with estimates using other methodologies. With these data, an economic portrait of irrigated agriculture in the basin is generated, one that will enable us to evaluate a range of alternative management and mitigation options.

To evaluate alternative management actions, two different measures of the value of water in irrigation are needed. The first of these is a measure of the "long-run" efficient use of water in irrigated agriculture. This measure reflects the net revenue or income generated when irrigation water is applied regularly to an acre of land of a given soil class. This measure of value will be reflected in, and relevant to, market sales and prices of land or water rights, or in making investments in irrigation infrastructure or other capital assets. It reflects the efficient, planned use of water in combination with capital equipment and other inputs. Given efficient capital and land markets, we expect that the sale price of agricultural land reflects 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 the land and its purchase price (P) is based on the interest rate (r) such that P = rY, which is the capitalization relationship for a permanent annuity. Using this relationship we can infer the value of irrigation water by comparing the sales prices of irrigated and nonirrigated lands. For example, if the right to irrigate an acre of land is expected to increase income by $60 per year, the purchase of that right, or the difference between the purchase price of irrigated versus nonirrigated land can be expected to reflect the capitalized value of these annual benefits, or raising the price by $1,000 ($60/0.06). Detailed data on land values for irrigated and nonirrigated lands at different locations and for different soil classes are presented below.

The second important measure of the value of irrigation water reflects short-run losses from unanticipated reductions in available water. This measure of value is a function of the "fixed costs" associated with production. In the short run, some fixed costs will have been incurred by irrigators who expect to apply water whether water is eventually made available to them or not. Given these committed expenses (equipment, contracts, maintenance, etc.), the cost of having water withheld will differ from (be higher than) the long-run values discussed above:

short-run changes or “surprise” adjustments in the amount of water available will generate per acre losses that exceed those reflected in the long-run marginal value of water defined above.

To illustrate, assume that 2 acre-ft of water will enable a farmer to earn income or net revenue (NR) equal to total revenues (TR) minus variable cost (VC) minus fixed cost (FC); the sudden loss of that water will cause the farmer to incur a loss of TR - VC. Under normal circumstances the irrigator expects to earn NR = TR - VC - FC. Thus, the difference between the net revenue when water is delivered, and the net loss NL = TR - VC, is accounted for by the fixed costs. If, in some circumstance, production involved zero fixed costs, then the two measures of the value of irrigation water outlined above would be equal. Since fixed costs are an integral part of agriculture in the Klamath Basin, and because the kinds of water shortage that occurred in 2001 were short-run and unanticipated, it is the short-run measure of loss that will be relevant to many considerations of mitigation and future management.

Economic value of water in the Klamath Basin

Both measures of the value of water introduced above are estimated for each location and soil class in the Klamath Basin, based on disaggregated agricultural and market data. These estimates are also compared to alternative estimation techniques and sources for validation purposes. The primary data source comes from the Klamath County Assessor’s office (Klamath County Assessor 2001) where data on irrigated land areas by soil class, cropping pattern, and market value (as distinct from the assessed values used for tax purposes) are available. These data were supplemented with additional data from the county assessors in Modoc and Siskiyou counties in California, from the Bureau of Reclamation office in Klamath Falls, and from the Oregon State University (OSU) Extension Service for crop budget data.

Crops and crop rotations vary by location and soil type. For the basin overall, 54 percent of irrigated land is pasture, 22 percent alfalfa, and 5 percent other hay. These are followed by 15 percent cereal grains, 3 percent potatoes, and 0.5 percent peppermint. Other crops such as sugarbeets, peppermint, onions, and strawberries account for only fractions of 1 percent each. Alfalfa, cereals, potatoes, and peppermint are grown on type II and III soils; pasture is grown on virtually all type IV and V soils.

The long-run value of irrigation water

The long-run value of irrigation water on a per-acre basis can be estimated based on comparisons of the market value of irrigated land with the market value of similar nonirrigated land. The difference between average values of irrigated land of a given soil class and the average value of similar nonirrigated lands (typically considered class VI due to the lack of irrigation) will generally reflect the value of applied water. The difference in purchase price between irrigated and nonirrigated lands will reflect the present discounted value of the expected annual net returns from irrigation in current and all subsequent years. On an annual basis, the value of irrigation water can be estimated as this difference between the purchase price on irrigated versus nonirrigated land, multiplied by the market interest rate.

Data on irrigated land areas for the Klamath Basin are presented in Table 1. These data indicate that irrigated acreages range from class II to V, with most irrigated lands being class III and IV soils. Importantly, we see that most of the areas within the KRP that did not receive water in 2001 were high productivity class II and III soils. By contrast, many of the areas outside the KRP that received water in 2001 are class IV and V soils (e.g., in areas above Upper Klamath Lake and in the Scott and Shasta valleys).

In Table 2, average land values by soil class indicate the extreme variability in productivity of irrigated land across locations. These vary from class II irrigated areas in the KRP that sell for $2,600 per acre to class V lands that sell for between $300 and $600 per acre. These estimates of average market values reflect transactions and market information prior to the events of 2001.

By combining the data in Tables 1 and 2 we can estimate the total value of irrigated land in the basin. This figure is $654 million. We expect these market prices for land to reflect the capitalized value of the annual income generated from current use. Using an interest rate of 6 percent, this asset value suggests annual income from irrigated agriculture in the region of $39 million, which is remarkably close to the $38 million figure from the U.S. Bureau of Economic Analysis for farm income in the region is reported in the On-farm Economic Analysis chapter.

As explained above, an estimate of the long-run value of irrigation water can be computed based on the difference between the value of irrigated and the value of similar nonirrigated lands. From Table 2 we see that the difference between the market value of class II and class VI nonirrigated lands is $2,300. For class III and IV soils the computed values are between $1,000-1,500 and $700, respectively. Notice that for some areas, especially class V soils outside the KRP, the data on average market value suggest very low values to irrigation; for example, the difference between class V irrigated and class VI nonirrigated land ranges from $0 to $200 per acre. In the case of these class V soils, average values that suggest a zero marginal value for irrigation water may reflect shortcomings in the data for these particular regions. However, the preponderance of the evidence indicates that applying water to class V soils in these regions generate low net returns 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 will add about $1,000 per acre to the value of land.

In general these data and estimates of long-run value are corroborated and validated by other sources and from estimations made using alternative methodologies. A local farm appraiser with many years of experience in the region estimates differences between irrigated and nonirrigated lands to be between $900 and $1,000 (Hank Caldwell, personal communication). When these estimates, based on land sales, are used to estimate the annual value of applied water (multiplying by the market interest rate), we arrive at the marginal values for water per acre per year presented in Table 3 (using a 6 percent interest rate). When compared to estimates for similar soil classes in Malheur County, Oregon, based on a more detailed statistical approach (Faux and Perry 1999), the values found in that location are nearly identical to the soil class averages in Table 3 with the exception of the class V soils in the Klamath area, which are significantly lower than those in Malheur County. Some difference between the two locations is expected due to the higher elevation and shorter growing season in the Klamath area.

Two other data sources provide estimates that are generally consistent with those presented here. The Oregon Water Trust purchases water from irrigators in Oregon to augment instream flows and protect fish habitat. Data on these actual transactions over the past several years, presented in Table 4, are of two types: one for permanent purchases of water rights, the other for 1-year leases. These data are also presented on a per acre-foot per year basis, also using a 6 percent interest rate for the permanent purchases. Given the organization's desire to minimize their costs, we should assume that these transactions most often involve irrigators of class IV and V soils. Detailed data on soil class are not available for these transactions. However, for a consumptive use of 2 acre-ft per acre in the Klamath Basin, the average annual value per acre foot for class IV and class 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). They report that for pasture and irrigated hay they bought water rights at prices reflecting $6 to $17 per acre-ft per year, and for wheat (likely to be grown on class II or III soil) a value of $22 per acre-ft per year.

Short-run losses from unanticipated irrigation curtailment

The short-run measure of loss from having irrigation water withheld unexpectedly will reflect the financial changes faced by farmers. If a farmer is expecting to earn net revenues NR = TR - VC - FC, the complete loss of irrigation water will mean a loss of revenue (TR) and the avoidance of variable costs (VC) such as seed, fertilizer, fuel, and pumping costs. Losses, therefore, can be measured as TR - VC.

For each area and soil type in the basin, data on the observed cropping patterns are used in conjunction with OSU crop enterprise budgets to estimate the losses when water is unexpectedly withheld from a planned crop activity (OSU Oregon Agricultural Enterprise Budgets, http://osu.orst.edu/Dept/EconInfo/ent_budget/). These losses range from $509 and $464 for peppermint and potatoes, respectively, to $32 and $33 for hay and pasture. Given the crops and rotations in each zone, these numbers translate into the losses per acre presented in Table 5, which, like the long-run marginal values estimated above, vary by a factor of 10 across location and soil type, from $325 per acre on class II soils in the KRP to $33 per acre on all class V soils.

These values are consistent with the notion that farmers' losses from being denied water will exceed the income normally generated when water is received. This fact implies that farmers will be made worse off in terms of their net wealth when irrigation is withheld.

Some kinds of losses in the Klamath Basin will not be captured by these estimates, for example, the loss of an established perennial crop, dissolution of experienced and trained crews, and loss of contracts with crop processors and purchasers. To validate the estimates presented in Table 5, one source of evidence from the Klamath Basin provides possible corroboration. In the spring of 2001, the Bureau of Reclamation asked farmers to submit bids of the price at which they would willingly leave their land dry. This "demand reduction program" eventually spent $3 million on accepted bids. We would expect these bids to equal or exceed the expected losses from going without water. The average accepted bid in 2001 was $167 per acre; the average loss from Table 5 for those lands in the KRP that were denied water in 2001 (from the right-hand column in Table 5) is a remarkably close $166.

Three striking features emerge from these data. First, the value of irrigation water varies widely between location and soil type. Second, in relative terms the variation across soil class and location are similar for both measures of value: there is a factor of 10 difference across soil classes for both long-run and short-run measures of value.

Third, we observe that 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 (KRP). This observation raises questions about the cost-effectiveness of the way in which irrigation curtailment was implemented in 2001, and about the potential reductions in losses from more cost-effective responses.

An economic model of irrigation water allocation

The data presented above form the basis of a mathematical model that represents irrigated agriculture in the region. The model is intended to reflect the revenues and costs of irrigated agriculture in the region. It is not intended to measure or represent all aspects or consequences of irrigation curtailment that have affected many other individuals in the region. Some of those other consequences or impacts are addressed elsewhere in this report. To the extent that alternative scenarios described here have different direct consequences for farm proprietors, these differences may also carry over and alter indirect and induced effects elsewhere in the economy in similar directions.

Our model of irrigated agriculture is a system of equations representing the land areas, soil types, costs, and revenues discussed above and described in the tables. The model characterizes 16 areas in Oregon and California. Ten of these are portions of the KRP; others include irrigated areas around and above Upper Klamath Lake, and in the Shasta and Scott valleys of California. The model assumes that all areas will either be irrigated or not irrigated at all (the model does not provide for reduced or deficit irrigation on a given acre). Those portions of the KIP that were denied water in 2001 amount to approximately 178,000 acres, or about 35 percent of the 509,000 total acres irrigated in the upper basin overall.

For the analysis of short-run losses, we start from a base case where all areas in the basin (508,833 acres) are irrigated. A cut-off of irrigation for an area A, in zone, i, of soil type j, (A_{ij}) will produce a loss, L_{ij}. These loss estimates are those reported in Table 5 and as explained above. In the scenario replicating the 2001 situation, all the areas that were cut off from irrigation are required to receive zero water. Areas receive full water suffer zero losses; areas receiving zero water suffer losses as indicated. By replicating the actual allocation of water in the basin in 2001, the model produces an estimate of losses for 2001 of $28 million.

This $28 million should be interpreted as a rough approximation of the direct losses to irrigators based on changes in their revenues and costs as a result of receiving no water.[1] As mentioned above, this figure is likely to understate the losses associated with actual events in 2001 for several reasons. First, some additional costs were incurred that are not represented in these estimations, such as those associated with cover crops, canal clearing and maintenance, variable costs that were unavoidable, proprietors and workers that were under- or unemployed, or the loss of established perennial crops such as peppermint (although these represent a very small share of the area under consideration). Thus the $28 million estimate should be seen as a lower bound on direct costs to agriculture; a figure of $35 million or even higher may be a more accurate estimate of the financial losses in agriculture. If the reductions in irrigation from 2001 reflect a permanent shift to very frequent shortages, then the resulting reductions in irrigated land values should also be included as part of these losses. Still, for purposes of comparison with other scenarios, these estimates are useful to the extent that other unmeasured costs will also vary roughly in proportion to the direct costs estimated for each scenario.

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[1] These loss estimates should not be confused with the “impact” estimates in other chapters that attempt to measure the repercussions on the scale of economic activity throughout the local economy. The current analysis focuses on direct measures that can be the basis for benefit-cost analysis. Net returns, income, and value-added are terms that reflect differences between benefits (revenues) and costs. The measure of local impact that is influenced by export dependency (as discussed elsewhere) should not be used to address questions of cost-effectiveness, or translated into “per acre” economic indicators.

Cost-effective allocation of irrigation restrictions

We are particularly interested in evaluating how the losses of the 2001 curtailment would have differed had more flexibility been possible in the way that 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 introduce an optimization algorithm that chooses the most cost-effective way to reduce the irrigated area by the same number of acres. The total losses (TL) are minimized subject to the constraint that the acres irrigated not exceed the actual irrigated area in 2001. Algebraically we can write this procedure as

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

$$\text{subject to} \quad \sum A_{ij} = A^* \text{ where } A^* \text{ is the required acreage to be denied water.}$$

An analogous optimization model was also used to estimate values and changes in values based on the long-run values for irrigation corresponding to Table 3.

Solving this algorithm for the cost-minimizing way to reduce the irrigated acreage by the same amount as in 2001 produces a total loss of only $6.7 million, or a three-fourths reduction in losses as compared to the estimate for the simulation of what actually occurred in 2001. Rather than curtail irrigation in the KRP, the model identifies class V and IV lands throughout the basin as the ones that will minimize losses. In particular, the cost-minimizing solution curtails irrigation on substantial areas along the Sprague and Williamson rivers, Fort Klamath, in the Lost River area (Langell Valley), and in the Shasta and Scott River valleys.

This cost-minimizing scenario involves choosing which acres to irrigate, but not how much water to apply to each. 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 further than the acre-to-acre reallocation reflected in the optimization model above. The costs of installing gauges and metering devices must also be considered. For flood irrigation diversions, the installation of flumes and meters to record volumes can cost $2,500 at each diversion point. Piped diversions may cost $1,000. An inventory of diversion points in the area counts 300, but there are about 850 irrigated farms. If one such device is required for each of the 850 irrigated farms in the Basin, and with about half of the diversions being piped, the average cost of installation would be about $3 per acre. This is a one-time cost, not an annual cost. Therefore, given these estimates, these costs do not appear to significantly alter the net returns to irrigated agriculture in the Basin.

An analysis of irrigation management involving deficit irrigation and fine tuning of water deliveries was undertaken for the Klamath Reclamation Project by Adams and Cho (1999). They only included the project in their model, but their results provide some evidence of the additional potential for cost reductions. First, if one were to impose a uniform reduction in available water of 35 percent to all irrigated land in the basin, the estimates from Adams and Cho suggest that this would cost $32 million, which would be similar to our estimate for the 100 percent curtailment of the KRP from 2001. If, however, it were possible to cost effectively withhold water from 20 percent of irrigated acreage in the basin, and also to introduce an 18 percent reduction in water deliveries to the remaining irrigated acreage, the same total reduction would be achieved as was imposed in 2001. Based on the model above and extrapolating from Adams and Cho, the total cost would be approximately $4.6 million, or an 83 percent reduction in cost.

Comparisons of the cost of these alternative reallocation scenarios are summarized in Table 6. It is important to recognize, however, that any change in the allocation of scarce water will produce a set of 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 output or acres irrigated within irrigation districts would mean that their operating costs would be shouldered by a smaller revenue base.

Implementing cost-effective water management is, of course, more difficult than 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 the critical question facing the region. The on-going process of adjudicating water rights, and the prospect of high-priority water rights being sold to those users with relatively high risk of large losses represent promising future opportunities. Before looking specifically at the implications of markets for water rights, we evaluate several other management and mitigation options below.

Alternative management and mitigation options

The sections below evaluate the economics of several alternative management and mitigation approaches that have been mentioned as ways to ameliorate or avoid future conflicts involving irrigation water. These options represent only a subset of the possible steps that could, and perhaps should, be taken to improve the situation in the Klamath Basin. Analyses of some other options are beyond the scope and resources of the current study. For example, we do not attempt here to evaluate the benefits and costs of actions to improve water quality in lakes and streams, such as restoration of riparian habitats, or modification of land use in sensitive areas. We also do not look at augmenting water storage with new reservoirs.

Supplementing irrigation with groundwater

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

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

Recently the Tulelake Irrigation District projected that with $5 million, a well producing 170 ft^3/s could be developed. Assuming 100 days of pumping and 2 acre-ft per acre in crop use, this volume would serve about 17,000 acres. A key question is how often would this contingent supplementation be required? The drought conditions observed in 2001 and in 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 ensure that irrigation water scarcity will occur much more frequently in the future. If we assume that supplemental water is needed once every 4 years, can the kind of 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 4), the cost per acre when supplementation is offered would be $74 per acre for the investment and depreciation. Assuming pumping requires 100 feet (total dynamic head), and with a commercial rate (or opportunity cost) for energy of 3.5 cents per KWH, the cost per acre would be $9, for a total cost of $83 per acre of supplemental pumping.

If a groundwater pumping activity would permit 17,000 additional acres to be irrigated, which acres would these be? In the absence of groundwater pumping, the efficient allocation would involve irrigating the high-value lands and leaving the lower value lands dry. If we assume that, in the absence of groundwater pumping, irrigation water will be allocated efficiently (for example, as the result of water rights markets as discussed below), then the incremental 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 generally are about $33 per acre, supplemental irrigation with groundwater pumping cannot be justified if it costs $83 per acre, even under the generous assumption that it is needed 1 year out of 4. If an efficient allocation of water in future drought years is not possible, and the most productive lands are, in fact, required to be left dry 1 year out of 4, then the $83 per-acre cost would be justified to avoid losses ranging from $174 to $325 per acre.

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 or groundwater) for irrigation. Depending on the irrigation technology being used, a farmer may need to apply twice the water required by the plants being grown. The quantity of water that is not consumed by the plant will flow back to the stream, percolate down into the ground, or evaporate. It is generally assumed that water which percolates into the subsoil will eventually find its way back into the stream, but this may take hours, days, or years, depending on the soils, geology, and the 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 will vary as well depending on temperatures and humidity, but is often assumed to account for no more than 10 or 15 percent of the water applied.

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

While irrigation efficiency may be an important factor affecting the potential for satisfying agricultural and ecological demands, it should not be assumed that promoting improved irrigation efficiency in agriculture will result in less water being diverted from the stream, and hence more water left for fish or other instream uses. Consistent with this perception, several western states have passed legislation encouraging farmers to invest in improved on-farm irrigation technology (Huffaker and Whittlesey 2000). The reality is more complicated, however, since improved irrigation efficiency will also reduce return flows.

Assume a farmer diverts 400 acre-ft with an irrigation efficiency of 40 percent. This means that his consumptive use is 160 acre-ft, and assuming 10 percent is irretrievably lost to evaporation or deep percolation, we can expect that 200 acre-ft end up as return flow into the river. What happens if this farmer adopts improved irrigation technology that raises irrigation efficiency to 70 percent, if the stream diversion is lowered from 400 to 350 acre-ft? On the face of it, this would appear to be good for fish because it leaves an additional 50 acre-ft in streams or lakes. With higher irrigation efficiency, however, the consumptive use is now 245 acre-ft, and with 10 percent (35 acre-ft) still irretrievably lost, the return flow is only 70 acre-ft. Adding 70 acre-ft to the 50 that are no longer diverted implies a lower stream flow of 120 instead of the 200 that occurred before the adoption of the new technology. In general it is quite possible that investment in irrigation efficiency can substantially *reduce* water left for streams or lakes, depending on what changes the farmer may make in his farming practices and on how other irrigators downstream may respond to changes in the availability of stream flows at different times—especially in settings where surface water is already over-appropriated via existing senior and junior right holders.

This issue is especially relevant to the Klamath Basin where water that is "wasted" in irrigation due to inefficient irrigation technology frequently provides an ecological benefit elsewhere. In areas above Upper Klamath Lake, return flows from irrigation return to streams, Upper Klamath Lake, and either the KRP or instream flows below Link River Dam. Return flows in the Lost River watershed and the project are believed to be reused by other irrigators as these waters seep into canals, wells, and subsurface irrigation. In addition, the return flows within the project serve to supply water to the wildlife refuges at Tule Lake and Lower Klamath Lake. Return flows in the Shasta and Scott River areas supplement streamflows 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 the critical months, then there may be potential gains from improved irrigation efficiencies—but not without a cost. Ultimately the cost of making more water available for fish by encouraging adoption of improved irrigation efficiency must be compared to the cost of the alternatives.

Indeed, improved irrigation efficiency does not necessarily mean more economic efficiency or higher net revenues. Even in cases where improved irrigation efficiency makes more water available for fish, this may not benefit the farmer. 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, there may be some gains to farmers for using sprinkler irrigation due increased yields, lower labor and pumping costs, or the possibility of switching to a higher value crop. The costs of improved irrigation efficiency will be primarily the capital costs of the new irrigation technology and their associated maintenance costs. Sprinkler systems can cost $400-1,200 per acre to install. The annualized cost for these investments would then amount to $24-72 per acre per year. Given the net revenues for class IV and V soils reported in Table 3, the costs of these investments would be prohibitive unless they also make possible additional cost savings or added revenues.

One cannot, however, assume that farmers will divert less water when irrigation efficiency improves; they may change the crops they grow or other practices so that the amount of water applied stays the same, but the consumptive use increases. Indeed, low irrigation efficiency may be good for fish since return flow is wasted water for the farmer, but it mostly represents water that ends up back in the stream either on the surface or through aquifers, delayed, however, by hours, months, or perhaps years depending on the soils and geology. If return flows occur over a period of months, much of the water returns to the stream in seasons when maintaining instream flow is not critical. In this situation, reducing irrigation diversions when instream flows are critical to fish will have a positive impact because the concurrent reduction in return flows will be slight, making the net effect on instream flow larger.

Even under the generous assumptions that improved irrigation efficiency makes additional water available for fish, we will want to ask, at what cost? Hoffman and Willett (1999) compared grated pipe irrigation with wheel-line, center pivot, and linear move techniques for irrigation systems in the Kittitas Valley, Washington. When the costs of these alternative technologies were compared to the amount of "saved water", the cost per acre-foot of water ranged from $40 for center pivot to $61 for linear move. These estimates do not offer encouragement that technology adoption in irrigation can represent a cost-effective way to resolve water conflicts in the Klamath basin, at least not on a large scale.

Land retirement

The 2001 events in the Klamath Basin and the conflicts between ecological and agricultural uses of water has 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 are likely to be determined by evolving interpretations of tribal rights, interpretations of the Endangered Species Act, and competitive forces in national and international agricultural markets.

Nevertheless, some of the economic data assembled here may provide some perspective and insight relevant to this question.

Although the relative magnitude of benefits versus costs cannot be assumed to be the sole factor in determining outcomes, such comparisons can be instructive and illuminating. In the current context, one may wish to ask whether the value of water used in agriculture is higher or lower than water used for the protection of species or for other instream uses such as recreation. Several studies in the West have estimated the value of increasing instream flow to enhance salmon populations in northern California from $33 to $53 per acre-foot (Colby 1989). In addition, the actions of the Oregon Water Trust, discussed above and described in Table 4, indicate a willingness by environmental interests to pay between $9 and $23 per acre-foot for water to protect instream habitat for fish.

In the case of permanent retirement of agricultural lands, it is the long-run value of water that is relevant, and this is presented in Table 3. What is most noteworthy from these economic data (presented on a per-acre basis rather than per-acre-foot basis, but where 2 acre-feet per acre is typical in the region) is that the value of water in agriculture can be shown to be both higher and lower than the range of ecological values summarized above depending on the location and soil class in question. The value of water applied to pastures on class V soils in the basin are in the range where land retirement to augment instream flows may appear reasonable based on estimates of value. Organizations like the Oregon Water Trust have purchased water rights in this price range to augment instream flows. These low values are not surprising given the high altitude and relatively low-value crop activities on some of these lands.

More striking, however, is the other end of the productivity spectrum. Those areas in the basin characterized by class II and III soils generate values from the application of water in the range of $60 to $144 per acre, or $30 to $72 per acre-foot. This range is 3 to 15 times higher than that reported above for ecological values. Admittedly these are imprecise measures intended only to provide an order-of-magnitude comparison, but on this basis we find that more than half of the agricultural land in the basin generates net revenues from the application of water that exceed the range currently in evidence for instream, ecological uses.

An incremental approach to retirement of some irrigated lands in order to augment stream flows, say by environmental organizations or government programs, would presumably involve purchases of class V lands in the upper reaches of the river system. From Table 2 we expect that the purchases of these irrigated lands would cost $300-600 per acre, or $150-300 per acre-foot of water. For arrangements involving the purchase of water rights for instream uses, but leaving the land available for nonirrigated purposes (nonirrigated land in these areas is valued at $200-400 per acre), the cost of permanent augmentation of instream flows would be lower, in the range of $50-100 per acre-foot. These one-time purchase costs correspond to an annualized cost of $3-6 per acre-foot per year.

Once the adjudication of water rights in the area is complete, voluntary sales of water rights by irrigators to environmental groups or the government will be possible. Consequences of these changes may affect others in the basin by concentrating the burden of maintenance and overhead costs on the remaining irrigators.

Markets for water rights

In the face of continued uncertainty about the total amount of water available for irrigation in the Klamath Basin, 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. Our analysis of short-run water values above indicates that most of these water users are within the KRP, where losses from water curtailment exceed $300 per acre. By contrast, many irrigators in other areas face losses of perhaps $33 per acre. The possibility that the most vulnerable irrigators (those facing losses of more than $300) could buy or swap water rights of different priority dates would bring about a reduction in uncertainty and vulnerability in those areas where it is the most costly.

With differences in losses of, say, $250, the willingness to pay for a swap of priority dates would depend on the expected frequency with which the junior right holder would not receive water. If the senior right holder expects always to receive water, and the junior right holder expects to be denied water 1 year out of 3, then the higher priority right would be worth up to $83 per year more to the high-loss producer than the low-loss producer. The permanent swap characterized here would be worth up to $1,389 ($83/0.06) to the high-loss producer.

In general, there can be serious obstacles to the sale or exchange of water right across locations in a given water system due to potential “third-party effects,” legal prohibitions, or other institutional constraints. In the case of the Klamath Basin, there appears to be reason for optimism. Temporary sales or transfers of water among irrigators appear to be prohibited under state law for most circumstances. However, the permanent sale of a water right, or the exchange of water rights carrying different priority dates, seems to be permissible under Oregon law. Given the distribution of water values within the basin, most efficiency-augmenting transfers would generally move senior water rights from upstream to downstream. This would reduce the likelihood of the kind of “third-party effect” whereby an intermediate priority date water right holder located in between the other two right holders might find him- or herself unable to obtain water. If the ownership of water rights evolved so that most senior water rights were in the KRP area, basin-wide 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, it would appear to produce the unintended but desirable side effect of leaving more water instream 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 also have an ameliorating effect on stream and lake contamination from agricultural chemicals and animal waste.

The exception to the idea that more senior water rights would move downstream and avoid most third-party complications involves the Scott and Shasta rivers. The analysis above suggests that perhaps 3,500 acres in those valleys would be a less efficient allocation of high-priority water rights, but there is no physical way to move water from those tributaries upstream to the KRP and they are also rights within the jurisdiction of California. Alternative institutional arrangements may be possible, however, to achieve the desired outcome. This might include government or nongovernmental organization purchases of these water rights to augment instream flow in the Scott and Shasta rivers. To the extent that these actions have ameliorating effects on fish habitat, subsequent requirements for instream flows at Link River dam may be able to be relaxed somewhat to fulfill ESA or future tribal requirements.

A scenario where adjudicated water rights were shuffled via market transactions within the basin in such a way to minimize financial risks to the agricultural sector overall is unlikely to emerge without conducive and supportive institutions to encourage these mutually beneficial transactions. External funding may serve a catalytic role to purchase, and then resell, high priority water rights. Some purchases may be considered as a way of retiring ecologically sensitive areas, to augment and protect instream flow.

In addition to the possibility of these efficiency-increasing transactions, the adjudication of water rights might reduce the losses from water shortages in a secondary way. Junior right holders can be expected to alter their production decisions based on the recognition that they face a relatively high risk of being denied water. Given this fact, they are likely to take precautionary measures that reduce their vulnerability. This may include the purchase of insurance against water loss. But it may also involve actions or contingency plans that will enable these irrigators to reduce their losses, for example by lowering their fixed costs.

There is some evidence to suggest that when a temporary loss of water is anticipated and planned for, the losses faced by the irrigators can be significantly reduced. Recall that in the data from the Klamath Basin, the ratio between the short-run losses from being denied water and the long-run annual value of water was 5:1. But data from the Oregon Water Trust, where contracts for both permanent purchases and 1-year leases were made, suggest a difference of only 2.5:1 ($23 versus $9 per acre-foot). These market transactions may reflect the short-run value of water in situations where irrigators anticipate, plan for, and are in a unique position that allows them to avoid significant fixed costs. We should not assume, however, that these values would be similar to the losses resulting from *unanticipated, nonvoluntary* curtailment of irrigation deliveries. If these data are indicative of how losses can be reduced when water curtailment is anticipated, the adjudication of water rights and "early warnings" to junior right holders may further reduce the costs associated with uncertain water supplies in the basin.

Biological flexibility with contingent arrangements

The adjustments and mitigation measures discussed above involve finding ways for irrigated agriculture to respond to drought conditions in a more flexible, cost-effective way. In face of the two biological opinions in 2001, scarce water in the basin must be allocated among Upper Klamath Lake suckers, Klamath River coho salmon, and farmers. The question raised in this section is, under drought conditions must it be that the farmers always take the hit?

To a significant degree this is a question for biologists and the federal courts. But given the requirement that response to ESA listings be "reasonable and prudent," one might consider more flexible rules for species protection that allow exceptions to a general rule (for lake level or stream flow) under certain circumstances. Indeed, prior responses have in some cases made similar allowances. The idea here is that for a given lake level or stream flow requirement, exceptions might be allowed. The requirement might be relaxed by a specified amount, with the provision that if an exception is granted, it cannot be granted for X years.

To illustrate, consider the possibility that the required lake level in Upper Klamath lake were allowed to be lowered by 1 foot below the desired minimum, say, once every 5 years, and that the instream flow requirement below Link River Dam were allowed to be relaxed by 25 percent, say, once every 5 years. This would represent a set of rules in which water shortages would sometimes impose costs on farmers, but sometimes on fish. Based on the distribution of high and low hydrological years, how often, and to what extent, would severe irrigation restrictions be necessary? Depending on the biological requirements and temporal distribution of low-water years, a flexible allocation mechanism of this kind might make it possible to avoid severe reductions like the one experienced in 2001. Instead, there might be only infrequent, modest restrictions.

Once again, however, the possibility of implementing a proposal of this kind would depend on the judgment of biologists and court interpretations of the ESA as to whether such an approach could be considered reasonable and prudent.

Concluding comments

The legal and political institutions and infrastructure that currently exist in the Klamath Basin were developed over the past 100 years to fit the circumstances of that period, in which per capita income was low and the abundance of natural resources was relatively high. For these historical reasons, some institutions and infrastructures have not kept pace with change. In particular, the current lack of adjudicated water rights and water metering devices are two key obstacles to the introduction of alternative management approaches to allocate water in the basin in a way that would promote efficiency, reduce uncertainty, and avoid calamities like the one experienced in 2001.

Of the alternatives evaluated here, cost-effectiveness and future flexibility are promoted most directly by a mechanism that would allow scarce water for irrigation to find its way to the highest value use. Centralized control or management by government agencies has a poor track record in this regard, although there may be ways that substantial improvements in cost-effectiveness can be achieved administratively. Even privately owned and metered water can face impediments to contractual transfers of water that raise efficiency, given the legal restrictions on such transfers, potential third-party effects, or physical obstacles such as distance, timing, or moving water uphill. The cost of installing control and metering devices on some flood-irrigated land may reduce net returns to zero, and make these lands prime candidates for land retirement.

In the current context, 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 bought and sold across different locations within the basin, this will make it 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 find themselves developing contingency arrangements to reduce their fixed costs, planting crops more tolerant to deficit irrigation, or diversifying their farm activities. Insurance policies for curtailment of water deliveries may become available. Other mechanisms not evaluated here that also reduce uncertainty, promote flexibility, and encourage cost-effective responses, may also contribute to improved water management in the Klamath Basin.

References

Adams, R. M., and S. H. Cho. 1998. Agriculture and endangered species: an analysis of trade-offs in the Klamath Basin, Oregon. Water Resources Research 34:10, 2741-2749.

Colby, B. G. 1989. Estimating the value of water in alternative uses. Natural Resources Journal 29:511-527.

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.

Hoffman, T. R., and G. S. Willett. 1999. The economics of alternative irrigation systems in the Kittitas Valley of Washington State. Extension Bulletin No. 1875, State of Washington.

Huffaker, R., and N. Whittlesey. 2000. The allocative efficiency and conservation potential of water laws encouraging investments in on-farm irrigation technologies. Agricultural Economics 24:47-60.

Niemi, E., A. Fifield, and E. Whitelaw. 2001. Coping with competition for water: irrigation, economic growth, and the ecosystem in Upper Klamath Basin. ECONorthwest, Eugene, Oregon.

Jaeger, W. K., and R. Mikesell. Increasing streamflow to sustain salmon and other native fish in the Pacific Northwest. Contemporary Economic Policy. (In press, 2002 expected publication date.)

Klamath County Assessor. 2001. Klamath County Assessor's Certified Farm Use Study, 2001-2002. Klamath Falls, Oregon.

OSU Agricultural Enterprise Budgets**, http://osu.orst.edu/Dept/EconInfo/ent_budget/.**

Table 1. Irrigated acreage in the Klamath Basin.

Name	Soil Class:	II	III	IV	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
Spraque 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 (nonproject)		4,541	6,425	6,354	0	17,320
Langell Valley (nonproject)		3,145	6,611	5,209	535	15,500
Poe Valley (nonproject)		525	697	778	0	2,000
West of 97 to Keno (nonproject)		2,388	9,048	11,367	198	23,000
Lower Klamath Lake (non-project)		69	4,614	309	7	5,000
Klamath Irrigation Project Areas						
Merril-Malin area		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[1]		*2,569*	*3,635*	*3,596*	*0*	*9,800*
Langell Valley		*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 & Scott Valleys		8,000	41,100	35,000	0	84,100
Totals:		59,103	201,620	217,920	30,190	508,833

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[1] Italics indicate portions of the KIP that received water in 2001.

Table 2. Average market values for irrigated land by location and soil class (per acre).

Soil Class:	II	III	IV	V	Nonirrigated (class VI)
Areas above Upper Klamath Lake:					
Fort Klamath Valley[1]	--	1,100	850	600	400
Modoc Point to Chiloquin	1,700	1,100	850	600	400
Spraque 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 (nonproject)	2,100	1,450	750	370	200
Langell Valley (nonproject)	2,100	1,450	750	370	200
Poe Valley (nonproject)	2,600	1,400	1,000	500	300
West of 97 to Keno (nonproject)	1,700	1,100	850	600	400
Lower Klamath Lake (non-project)	2,600	1,900	1,000	301	300
Klamath Irrigation Project Areas					
Merril-Malin area	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	*2,100*	*1,450*	*750*	*370*	*200*
Langell Valley	*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 & Scott Valleys	2,000	1,650	1,050	--	300

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

Table 3. Marginal value of applied water in irrigated agriculture (per acre per year).

Soil Class:	II	III	IV	V	Average (weighted)
Areas above Upper Klamath Lake:					
Fort Klamath Valley[1]	--	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 (nonproject)	114	75	33	10	70
Langell Valley (nonproject)	114	75	33	10	67
Poe Valley (nonproject)	138	66	42	12	76
West of 97 to Keno (nonproject)	78	42	27	12	38
Lower Klamath Lake (non-project)	138	96	42	0	93
Klamath Irrigation Project Areas					
Merril-Malin area	138	63	42	12	64
Poe Valley	138	66	42	12	76
Midland-Henley-Olene	138	66	42	12	73
Bonanza-Dairy-Hildebrand	*114*	*75*	*33*	*10*	*70*
Langell Valley	*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	--	
Shasta & Scott Valleys	102	81	45	--	68
Weighted average:					60
Unweighted average:	103	68	37	9	
Comparison with estimates for Malheur County, Oregon[2]	105	67	35	32	

Based on comparison of market price data for irrigated versus nonirrigated land.

[1] These values reflect agricultural use. Recreational demand has increased land values in this area.

[2] Based on hedonic price analysis from Faux and Perry (1999).

Table 4. Recent water rights transactions to augment streamflows.

Oregon locations	Current use	Contract type	Consumptive use (af/year)	Price paid	Cost/af [1]
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:	**$ 9.16**
Deschutes River, Buck Hollow Creek	Hay	one-year lease	196.80	$ 6,630	$33.69
Deschutes River, Buck Hollow Creek	Hay	one-year lease	196.80	$ 6,630	$33.69
Deschutes River, Buck Hollow Creek	Hay	one-year lease	196.80	$ 6,630	$33.69
Grande Ronde River, Crow Creek	Hay	one-year lease	194.00	$ 1,600	$8.25
Umatilla River, E. Birch Creek	Hay	one-year lease	238.50	$ 2,500	$10.48
Deschutes River, Trout Creek	Hay	one-year lease	1135.50	$ 23,843	$21.00
Deschutes River, Trout Creek	Hay	one-year lease	270.00	$ 4,680	$17.33
John Day River, Hay Creek	Hay	one-year lease	248.80	$ 14,500	$58.28
Rogue River, S.F. Little Butte Creek	NA	one-year lease	83.34	$ 1,438	$17.25
Deschutes River, Buck Hollow Creek	Hay	one-year lease	196.80	$ 6,630	$33.69
Grande Ronde River, Crow Creek	Hay	one-year lease	197.70	$ 5,272	$26.67
Deschutes River, Tygh Creek	Pasture	one-year lease	94.50	$ 945	$10.00
Rogue River, S.F. Little Butte Creek	NA	one-year lease	83.34	$ 1,438	$17.25
Grande Ronde River, Crow Creek	Hay	one-year lease	197.70	$ 5,136	$25.98
Deschutes River, Tygh Creek	Pasture	one-year lease	94.50	$ 945	$10.00
Rogue River, S.F. Little Butte Creek	NA	one-year lease	83.34	$ 1,438	$17.25
Umatilla River, Couse Creek	Wheat/Pea	one-year lease	1065.9	$ 23,800	$22.33
Deschutes River, Buck Hollow Creek	Hay	one-year lease	196.80	$ 5,000	$25.41
Grande Ronde River, Crow Creek	Hay	one-year lease	197.70	$ 5,136	$25.98
Rogue River, S.F. Little Butte Creek	NA	one-year lease	83.34	$ 1,438	$17.25
Umatilla River, Couse Creek	Wheat/Pea	one-year lease	1065.9	$ 23,800	$22.33
Umatilla River, Couse Creek	Wheat/Pea	one-year lease	1065.9	$ 23,800	$22.33
				Average:	**$23.19**

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

Source: Oregon data from Oregon Water Trust; Washington data from Washington Water Trust.

Table 5. Losses per acre from irrigation curtailment.

Soil Class:	II	III	IV	V	Average (weighted)
Areas above Upper Klamath Lake:					
Fort Klamath Valley	--	33	33	33	33
Modoc Point to Chiloquin	250	203	33	33	134
Sprague River Valley	--	219	33	33	35
North Country	--	33	33	33	33
Areas east and south of Upper Klamath Lake					
Swan Lake Valley	175	122	33	33	76
Bonanza (nonproject)	307	275	33	33	195
Langell Valley (nonproject)	179	36	33	33	64
Poe Valley (nonproject)	236	132	33	33	121
West of 97 to Keno (nonproject)	178	123	33	33	83
Lower Klamath Lake (non-project)	325	61	33	33	63
Klamath Irrigation Project Areas					
Merril-Malin area	318	284	33	33	217
Poe Valley	236	132	33	33	121
Midland-Henley-Olene	292	279	33	33	205
Bonanza-Dairy-Hildebrand	*307*	*275*	*33*	*33*	*195*
Langell Valley	*179*	*36*	*33*	*33*	*64*
Lower Klamath Lake	325	61	33	33	63
Malin Irrigation District	308	227	33	33	227
Shasta View District	324	284	232	33	281
West of 97 to Keno	178	123	33	33	83
Tule Lake / California portion	174	174	33	33	136
Shasta & Scott Valleys	238	188	33	--	128

Table 6. Cost estimates for reduced irrigation diversions in the Upper Klamath Basin under alternative approaches.

Estimated losses from actual 2001 cut-off in KRP	$28-35 million
Losses with cost-minimizing acre-acre transfers	$6.7-9.0 million
Losses with basin-wide uniform 35% reductions in applied water	$32 million
Losses with acre-acre transfers and deficit irrigation	$4.8 million