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On-farm economic analysis

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Objectives of the on-farm economic analysis

The objectives of this chapter are two-fold:

1. To present an estimate of the impact the 2001 biological opinion had to on-farm crop revenue.
2. To suggest alternative water allocation mechanisms that could increase on-farm crop revenue without increasing the water allocated to irrigation.

This analysis focuses on the irrigated land within in the United States Bureau of Reclamation Klamath Basin Project (the Project).

Background of the Project

Authorized by the United States Bureau of Reclamation in 1905, the Project encompasses over 200,000 acres on approximately 1,400 farms. The farms receiving irrigation water from the Project annually generate on-farm crop revenue of approximately $100 million. The primary crops irrigated within the Project are alfalfa hay, pasture, small grains (barley), potatoes, and wheat.

Construction of the Project joined two separate watersheds, namely:

1. The Klamath River watershed, which originates at Upper Klamath Lake in Oregon and supplies water to Lower Klamath Lake as well as the Klamath River.
2. The Lost River watershed, formerly a closed system, comprised of Gerber Reservoir in Oregon and Clear Lake and Lower Tule Lake, both in California.

The two watersheds are joined by two physical structures. The Lost River Diversion Canal joins the Lost River to the Klamath River. The second structure joining the two watersheds is a pipe, through which irrigation runoff is pumped from Tule Lake to Lower Klamath Lake.

Because the Project lands receive water from two watersheds, farmers within the Project may receive different restrictions on their diversions. The reason for receiving different restrictions on diversions is simply because the hydrology of the two watersheds may be different in any one year. The importance of this fact will become clear later on in this chapter when estimates of on-farm crop revenue are made under varying quantities of irrigation water deliveries.

Section overview

In addition to this introduction this chapter contains five other sections. The first section presents agricultural economic and statistical data about the Project. The second section describes the model used to estimate the response of on-farm crop revenue to various levels of irrigation diversions. The results of the model are presented in the third section. The structure of the results section aligns with the objectives of this chapter. The first subsection in the results section presents a discussion of the impact of the 2001 biological opinion to on-farm crop revenue. The second subsection in results describes how changes in policies could make the existing water “go farther,” measured in terms of increases in on-farm net revenue. The fourth section quantifies the impacts of various combinations of biological opinions and hydrologic year types on irrigation diversions. The fifth and final section summarizes the findings and discusses possible improvements on the analysis.

Klamath project agricultural economic statistics

Crop mix and acreage

The acres planted in the Project by crop and watershed for the years 1987 through 1998 are shown in Table 1. Total acres and the mix of crops planted have changed little over this 12-year period. The Klamath River watershed comprises most of the land in the Project, approximately 170,000 acres or 87 percent of the total Project acres. Alfalfa hay, irrigated pasture, and feed grains make up approximately 75 percent of the Klamath River watershed crops. Potatoes (categorized as vegetables) make up most of the remaining 25 percent of the crops grown in the Klamath River watershed. Hay and pasture are the primary crops grown in the Lost River watershed.

Sugarbeets, which came into production in 1990 in the Project, will likely not be grown any longer due to the closing of a processing plant. The number of acres in production over this period of time is relatively unchanged because irrigation insulated farm managers from natural droughts. The years 1992 and 1994 were dry; however only 1992 shows a reduction in total acres in production and the greatest reduction in acreage in 1992 occurred in the Lost River watershed. The data for 1988 is incomplete, which is why the total acres in production in that year are noticeably low.

On-farm crop revenue

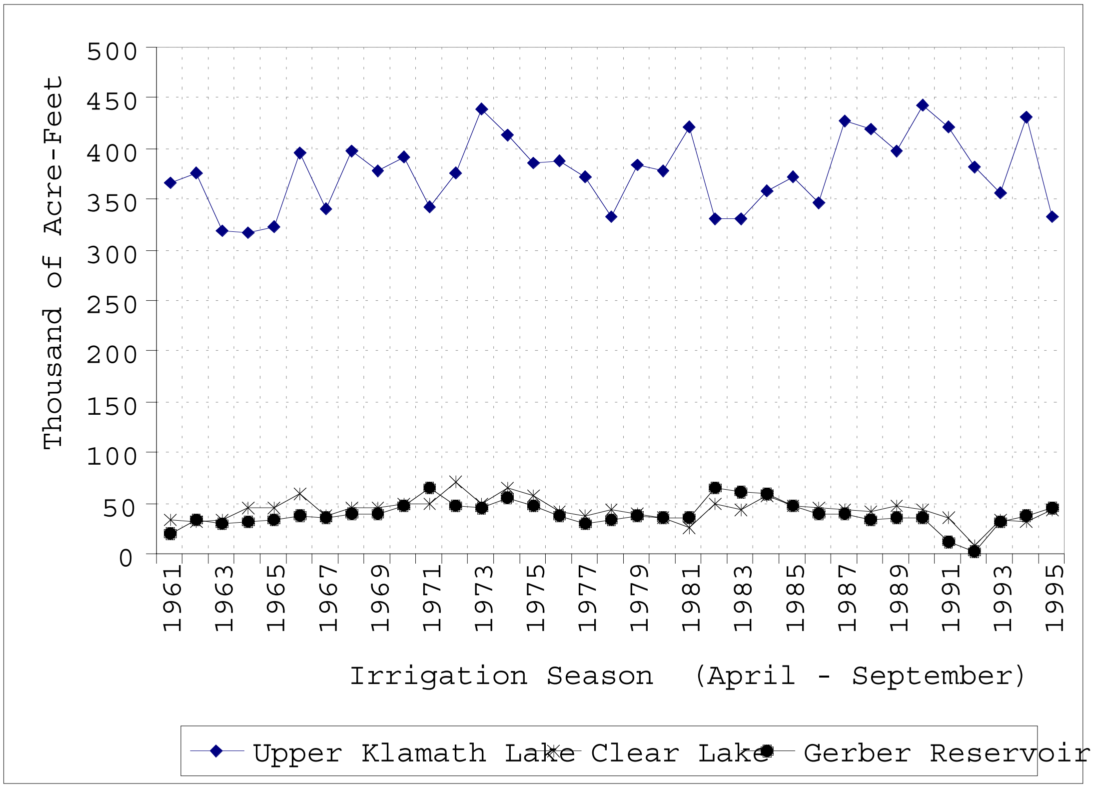
The nominal on-farm crop revenue generated on Project lands from 1987 through 1998 is shown in Table 2. Generally, the total on-farm crop revenue is near $100 million per year. Farms in the Klamath River watershed generate approximately 90 percent of the total on-farm Project revenue. Potatoes generate 30 percent of the total on-farm crop revenue on roughly 16 percent of the total land in the Project. Volatility in revenue is due to fluctuations in crop prices and yields rather than a change in the quantity of land in production. Table 3 shows the historical prices by crop. Notice that the price of potatoes (categorized as vegetables) ranged between $46 per ton to $133 per ton. It is not a coincidence that the year with the highest revenue, 1995, is the same year that the price of potatoes was higher than any other year in the time series. The prices for 2001 are estimates, used in the analysis of this chapter.

Irrigation diversions

Figure 1 shows the releases of water into the Project by source for the years 1961 through 1995. Recall that Gerber Reservoir and Clear Lake provide water to the Project’s lands that are within the Lost River watershed. Releases from these sources make up a significantly smaller portion of the total water released into the Project. Most Project water comes from releases from Upper Klamath Lake, between just over 300,000 acre-ft in 1964 to nearly 450,000 acre-ft in 1990.

Historically, the quantity of water released in any irrigation season does not necessarily reflect whether that hydrologic year was dry. Particularly, prior to the listing of the sucker fish, farmers in the Project were not competing with the environment for water and, therefore, received enough water to irrigate all their lands. This can be seen by examining the two driest years on record for this time period—1992 and 1994. Notice that releases into the lands of the Upper Klamath Lake watershed were also not noticeably low in 1992 and 1994. And releases into the lands of the Lost River watershed (from Gerber Reservoir and Clear Lake) were close to normal in 1994. The only indication that 1992 was a critically dry year is the fact that little water was released into the Lost River watershed—simply because there was little water to release.

Figure 1. Irrigation diversions into the Project by source.



Source: U.S. Bureau of Reclamation reservoir operations model entitled Klamath Project Operations Model (KPOP-SIM).

Water rights and allocations within the Project

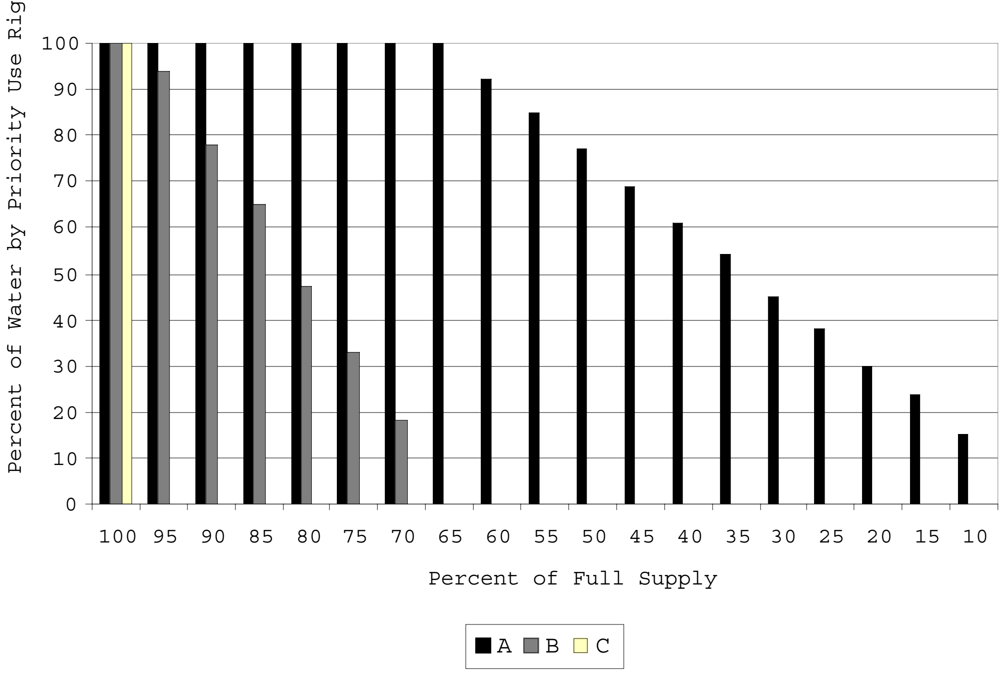
The water rights attached to Project lands fall into one of three categories, called a priority use right. The three categories are referred to as "A," "B," and "C." Legally, the priority use right dictates how water is allocated throughout the Project. The A priority rights holders, or users as they are sometimes referred to, have the most senior rights to water, followed by B users and finally C users. Seniority of right in this case means that, when water is allocated among the users, the A users receive all the water they can beneficially use before either the B or

C users receive any water. Once the A users receive all the water they can beneficially use, deliveries begin to the B users until the B users receive all the water they can put to beneficial use. Lastly, the C users receive their allocation.

The drought of 2001 combined with the new biological opinions—calling for higher water levels in Upper Klamath Lake and greater in-stream flow in the Klamath River—created a situation where the Bureau of Reclamation had to forgo irrigation deliveries to all three of the priority use right categories. In the future the priority use right system may be used to allocate irrigation diversions. Specifically, the Bureau may have to determine how to allocate water to Project lands when irrigation diversion are less than a full supply and greater than zero. "Full supply" is defined as the amount of water required to irrigate all of the Project lands.

Figure 2 details how a percent reduction in full irrigation diversions would translate into a percent reduction in irrigation diversions by priority use right. Figure 2 shows that the C users lose all their diversions almost immediately. At 95 percent of full diversions the C users receive zero diversion. The B users receive less and less of their diversion until full diversions are down to 65 percent, at which time the B users receive no water. The first reduction in delivery to the A users occurs when diversions are 65 percent below full.

Figure 2. Percent of full irrigation diversions allocated by priority use right for various percent reductions in full supply.



The percent of land categorized by priority use right and state is given in Table 4. Land that holds an A priority use right comprises 67 percent of the total land in the project. The lands that hold B and C priority use rights comprise 30 percent and 3 percent of the land, respectively. Nearly all of the B land is in Oregon and nearly all of the C land is in California. The result of this distribution of priority use rights means that if the Project lands suffer a reduction in irrigation diversions of between 95 percent and 65 percent, most of the reduction will be felt in Oregon (ignoring the small percentage of C lands that are in California).

The model

This section of the chapter describes the model that was used to estimate the change in on-farm crop revenue resulting from a change in irrigation diversions. This section begins with background detailing how the model came to be built, followed by a description of the use of economic theory in the model. A description the model's uses and shortcomings conclude this section.

Historical background of model development

The model was developed from 1996 through 1998 at Oregon State University (OSU) and the University of California, Davis (UCD) with a grant from the U.S. Department of Agriculture (USDA). The purpose of the grant was to study the economic and hydrologic impacts occurring in the Project resulting from changes to irrigation diversions and water allocations (see Burke 1999).

Model development required coordination with staff members at the U.S. Bureau of Reclamation (USBR) office in Klamath Falls, Oregon. At the time of the model development, the USBR was preparing to write an Environmental Impact Statement (EIS) for the Klamath Basin. It became apparent that the model being developed by OSU and UCD would have usefulness in the EIS process. Therefore, the USBR contracted to continue the effort. Furthermore, in September 2000, the USBR funded an effort to incorporate the model into the existing reservoir operations model (KPOP-SIM) currently in use in the Klamath Falls USBR office.

The model

The model is a combined hydrologic and economic model. The economic model is a short-run model that assumes farm managers maximize their net on-farm crop revenue through cropping decisions and irrigation technology improvements that are constrained—in part—by available water, fixed capital, and cultural practices. The input to the economic model includes, historical crop patterns, per acre average yield of crops grown in the Project, variable costs of crop production, available water, and crop prices. The output of the model includes estimates of cropping patterns within an irrigation district given a set of inputs. Of primary interest for this analysis is the input that quantifies the amount and allocation of available irrigation diversions to farm manager and/or irrigation districts.

Irrigation diversions enter into the model in two ways: first, how much total irrigation diversions are available to the Project, and second, how will the available diversions be allocated? The answer to the first question comes from the analysis that translates the available diversions into a percentage of full water supply available to the Project. This analysis depends on the time-series of diversion data presented in Figure 1. The second way diversions enter into the model is by allocating the available irrigation diversions among the water districts as shown in Figure 2.

The model assumes that the farm managers and/or irrigation districts will be informed about how much water is available to them as a percentage of full supply. The model also assumes the farm manager receives this information in a timely manner so that business decisions can be made with full information about resource availability. Once the percentage of full supply of water is known, the model is run with various assumptions about how the available water is allocated among irrigation districts and/or farms.

An allocation method can take many forms. Two examples of how to constrain limited irrigation diversions are (1) directly, by constraining the water deliveries to farms and irrigation districts, or (2) indirectly, by constraining the amount of land that is in production. For example, if the irrigation diversion were determined to be 50 percent of full supply, either the water deliveries could be measured to assure only 50 percent of full supply was delivered, or the quantity of land in production could be reduced by 50 percent. The first allocation method—directly measuring water deliveries—has the advantage of increasing the flexibility of the farm manager (to allocate water as he or she sees fit). The disadvantage of directly measuring water deliveries is that the measurement devices needed to manage deliveries to the A, B, and C users are not currently in place in the Project.

The indirect method of assuring the appropriate quantity of water is delivered—by constraining the number of acres of land in production—has the advantage of being a "manageable" method in the Project today, but reduces the farm manager's flexibility regarding the use of their resources and results in lower overall on-farm crop revenue within the Project. A comparison of the impact these two allocation methods have on on-farm crop revenue will be presented in the Results section of this chapter.

Model uses and shortcomings

Uses and shortcomings of the model are discussed in this section. Two model shortcomings are (1) the model assumes the availability of a timely and accurate estimate of the percent of full irrigation diversion available in the coming growing season, and (2) the model is a short-run model.

In the above description of the percent of full irrigation diversions available to irrigation districts and/or farms, the assumption was that the percent of full supply information would be available when farm managers are making production plans for the upcoming year. There is a significant amount of controversy around this assumption.

The controversy takes two forms. First, many of the Project farm managers feel they receive little information regarding the availability of irrigation supplies, and the information that is available is too late to be of help in making production decisions, i.e., planting decisions and securing operating lines of credit. Some farm managers in the Project feel this information is needed as early as November or December of the year preceding the growing season. Some farm managers feel that the information could come later, in the spring of the planting season, and still be used in planting decisions. The advantage to announcing the available supplies earlier rather than later is that the farm manager has more time to make decisions. The drawback of making the estimate earlier—about how much water will be available during the coming growing season—is that less data about the hydrology of the coming year are available simply as a consequence of time. Therefore, the estimate of water availability may be far below the amount of water that will ultimately be available. Regardless of the timing of the announcement, or the information content, what is important to point out in this analysis is that the model assumes something that is not currently occurring—that is, the farm manager gets full information in a timely manner. Therefore, the model suggests a best-case correspondence between water availability and on-farm crop revenue.

The second form of controversy surrounding the assumption of timely information about water availability is that the estimate of available irrigation diversions is correct. The hydrology of the Project is complex. Many factors contribute to the available supplies including, but not limited to summer precipitation, average temperature during the growing season, and timing of the run-off from the winter snow pack. An above-average snow pack year may result in a below-average water year if above-average temperatures in the spring lead to early snow melt. Conversely, impacts of a relatively dry winter could be offset by above-average summer rains. These events have happened in the Project, making forecasting available irrigation diversions a difficult task. In order to quantify the value of accurate forecasts, one of the scenarios, discussed below, addresses the impact of an incorrect estimate of irrigation diversions on crop yield, and therefore on on-farm crop revenue.

Lastly, implications of the short-run nature of the model will be described. The model assumes that farm managers are operating to cover their variable costs of production. Fixed costs are not a factor in the results generated by the model. The benefit of this type of model is that it estimates the on-farm response to short-run, i.e., seasonal, changes in inputs. The model was developed this way because, at the time, a paradigm shift was not what was being modeled in the Project. Rather the model was developed to estimate the impacts to occasional annual shortages in available irrigation diversions. The disadvantage of not including fixed cost in the model is that the "break-even point"—the point past which it is no longer economically feasible to remain in farming for the long-term—is not determined.

Finding this break-even point is a difficult task. The information necessary to determine the break-even point of a farm operation varies by farm. Primarily, such an analysis involves the level of long-term debt being carried by the farm manager (not to be confused with annual operations debt). For the purposes of this analysis, the short-run analysis is used to understand the link between on-farm crop revenue in the short run; the analysis is not used to predict how many farms, or how many acres, could remain in production in the long run under a paradigm shift involving available irrigation diversions at perpetually reduced levels, compared to historical levels, based on new biological opinions.

The results

The results are separated into two subsections, which describe:

- The estimated impact of the 2001 biological opinions to on-farm crop revenue in 2001.
- Policy changes that could mitigate the impact of reduced irrigation deliveries to on-farm crop revenue, e.g., ways to make the available water "go farther."

The impacts are measured on the on-farm crop revenue in the Project.

Impact of the 2001 biological opinions on 2001 on-farm crop revenue

Two events significantly impacted the level of on-farm crop revenue generated in the Klamath Project in 2001. First, a record drought reduced the supply of water available to all water users in the basin. Secondly, a revised biological opinion for the level of Upper Klamath Lake, combined with a new biological opinion about Klamath River flows led the Bureau of Reclamation to announce in April 2001 that there would be no irrigation diversions for the year.[1]

The results presented below disaggregate the estimated effects to on-farm crop revenue of these two events namely, the drought and the 2001 biological opinions for the lake and river. To

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[1] Subsequent to the announcement that irrigation deliveries would be zero in 2001, the Bureau released 70,000 acre-ft of water in mid-season.

disaggregate the effects the model was run three times using three different assumption sets. The in-stream flow requirement, lake-level minimum, and hydrologic year (representing inflows) used in the model are seen in Table 5. The assumption set labeled "*Baseline*" estimates on-farm crop revenue in a year with *near normal water supplies* (1986 was used as a proxy) and the *biological opinion in effect for 2000 on the lake levels.* Although there was no biological opinion on the river flow minimums in 2000, there were *minimum FERC flows, which the Bureau has managed to in the past; therefore those FERC minimums are used as the river constraint.*

The second assumption set shown in Table 5, labeled "Drought-Only (revised FERC minimum flow)," estimates the on-farm crop revenue using the biological opinion for the lake that was used last year (2000), the revised minimum FERC flows, and a hydrologic year that is classified as "critically dry" (1992 was used as a proxy). The only difference between the baseline assumption set and this Drought-Only (revised FERC minimum flows) assumption set is the hydrologic year that was used as a proxy, 1992, versus the near-normal year of 1986.

The third and final assumption set shown in Table 5, "Drought and 2001 Biological Opinions," estimates the on-farm crop revenue using this year's biological opinions and the hydrology from 1992. The lake level minimums used in this assumption set are colloquially referred to as "4140" due to the level requirement in the July through September timeframe that is highest, namely, the August requirement of 4,140.79 ft above sea level. The flow requirements are much greater than the 1992 operations. The 2000 actual flows are used here because they are close to the flow requirements under the 2001 river flow biological opinion.

Table 6 presents the estimates of on-farm crop revenue under all three assumption sets and disaggregates the results in order to gain visibility into the impact to on-farm crop revenue from (1) the drought and (2) the new biological opinions.

If the river were operated according to the revised FERC minimums, then the estimate of full irrigation diversions available to the Upper Klamath River users is 55 percent while the Lost River users would have had 35 percent of their full suppl —generating 70 percent of on-farm crop revenue using full-supply revenue as a basis. Model results for the combined effect of the drought and the 2001 biological opinions suggest that, while the Upper Klamath Lake users would have received no water, the Lost River users could have received 25 percent of their supply, generating 25 percent of total on-farm crop revenue.

On-farm crop revenue is not zero when irrigation diversions are zero because of the availability of groundwater within the Project lands. For the purposes of this analysis, the level of groundwater pumping is based on historical levels (45,000 acre-ft) and therefore does not include new sources made available this year with emergency funds from the state of California groundwater pumping at historical levels (see text box entitled Tulelake Well Program below). Additionally, the USBR delivery of 70,000 acre-ft of surface water in mid-season in 2001 is ignored, assuming farm managers did not plan on the late delivery and therefore did not plant. The comparative analysis shown in Table 6 estimates the impact of the 2001 biological opinions to on-farm crop revenue. The difference in on-farm crop revenue due to the drought alone is estimated to be a $29.7 million loss. The difference in on-farm crop revenue due to both the drought and the new biological opinions is a loss of $74.2 million. Taking the difference of these differences produces an estimate of the cost of the 2001 biological opinions to on-farm crop revenue in the Klamath Project in 2001: *the effect of the 2001 biological opinion to on-farm crop revenue is $44.5 million.*

It should be noted that in 1992, a critically dry year, the shortage in irrigation diversion was mitigated by allowing the Klamath River flows to fall significantly below the FERC minimums. The flows ranged between 400 and 900 ft^3/s compared to the FERC minimum flows that range between 900 and 1,900 ft^3/s. If the 2001 river flows had been managed as in 1992, the irrigation diversion shortage could have been eliminated.

Policy options that can increase on-farm crop revenue without increasing irrigation diversions

This subsection will cover three topics:

- The general relationship between irrigation diversions and on-farm crop revenue.
- How greater flexibility in the method by which water is allocated could increase on-farm crop revenue using the same quantity of water.
- How greater flexibility in the timing of the measurements of lake levels could potentially save on-farm crop revenue.

The first of the above points—the general relationship between irrigation diversions and on-farm crop revenue—acts as a background to the subsequent discussion regarding water allocation methods and flexibility in the timing of lake levels.

General relationship between irrigation diversions and on-farm crop revenue

The general relationship between irrigation diversions and on-farm crop revenue on Project lands is illustrated in Figure 3. The horizontal axis displays the percent of full supply of irrigation diversions. The left-hand vertical axis displays on-farm crop revenue. The right-hand vertical axis displays percent of on-farm crop revenue, based on water allocations at 100 percent of full supply.

Tulelake Well Program

The California Department of Water Resources, the Governor’s Office of Emergency Services, and Tulelake Irrigation District are currently developing supplemental groundwater resources in the California portion of the Upper Klamath River Basin. At this time a total of 10 wells have been drilled in Siskiyou and Modoc counties for the purpose of providing supplemental water for irrigating 20,000 acres of cover crops in an effort to preserve valuable agricultural topsoil and to augment surface water supplies for future water shortages (see table below). Groundwater development was initiated May 4, 2001, when Governor Davis allocated $5 million to the program in his Klamath Basin Drought Emergency Proclamation.

TULELAKE IRRIGATION DISTRICT

WELL SUMMARY TABLE

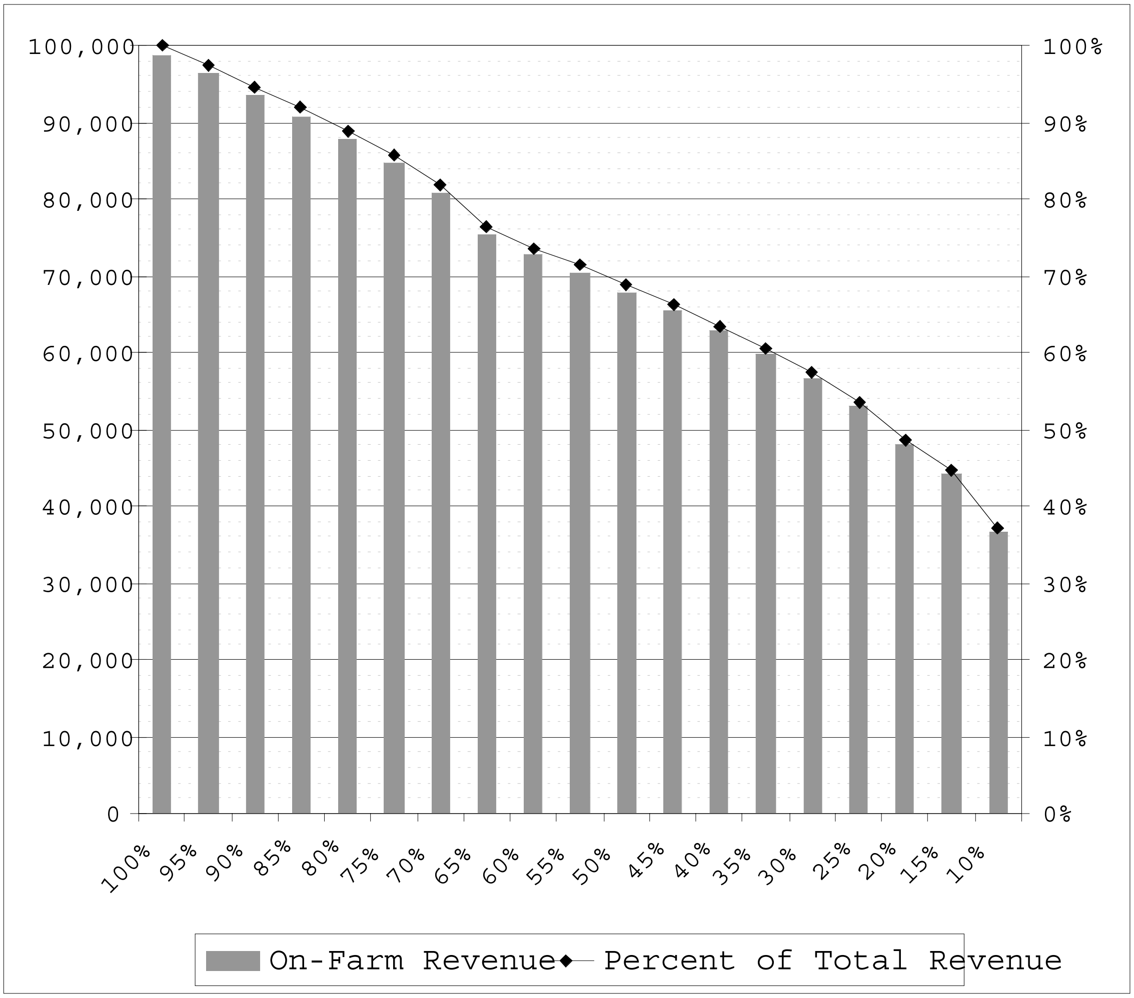
October 12, 2001

TID	DATE STARTED	DATE COMPLETED	COMPLETED DEPTH	PRODUCTION ZONE	PUMP TEST YIELD	START DELIVERIES	STATUS
#1	**5/26/2001**	**6/8/2001**	**740 ft**	**245’ - 685’**	**9,300 gpm**	**6/27/2001**	**pumping**
#2	**7/27/2001**	**8/3/2001**	**1,545 ft**	**1,260’ - 1,540’**	**12,000 gpm**	**8/25/2001**	**pumping**
#3	**6/9/2001**	**6/28/2001**	**1,680 ft**	**1,153’ - 1,680’**	**9,000 gpm**	**7/24/2001**	**pumping**
#4	**6/28/2001**	**7/8/2001**	**1,4432 ft**	**1,211 - 1,433**	**10,000 gpm**	**8/15/2001**	**pumping**
#5	**7/14/2001**	**7/20/2001**	**1,566 ft**	**935’ -1,556’**	**9,500 gpm**	◦	**pumping**
#6	**6/6/2001**	**6/29/2001**	**2,380 ft**	**822’ - 2,358’**	**6,000 gpm**	**7/13/2001**	**waiting for pump**
#7	**6/29/2001**	**7/8/2001**	**2,030 ft**	**814’ - 1,687’**	**4,000 gpm**	**9/21/2001**	**pumping**
#8	**8/16/2001**	**8/29/2001**	**1,810 ft**	**1,240’ - 1,800’**	◦	◦	**waiting for pump**

When irrigation diversions are 100 percent of full supply, on-farm crop revenue is near $99 million, and by construction, the percent of revenue is 100 percent. When irrigation diversions are 95 percent of full supply, on-farm crop revenue is $98 million and the percent of revenue is just under 99 percent. Therefore, the first 5 percent reduction in irrigation diversions causes a 1 percent reduction in on-farm crop revenue. The next 5 percent reduction in irrigation diversions, to 90 percent of full supply, causes a 2 percent decrease in on-farm crop revenue.

The rate of decrease in on-farm crop revenue increases slightly with each 5 percent decrease in irrigation diversions until the total decrease in irrigation diversions is 65 percent, at which point the percent decrease in on-farm crop revenue from 70 percent to 65 percent of full irrigation diversion is 3 percent. After 65 percent of full irrigation diversions, the percent decrease in on-farm crop revenue for each 5 percent decrease in irrigation diversions is close to 2 percent, until irrigation diversions are 20 percent of full supply, at which time the percent decrease in on-farm crop revenue for each 5 percent decrease in irrigation diversions is between 3 and 4 percent.

Figure 3. Relationship between irrigation diversions and on-farm crop revenue.



The reason the rate of change in on-farm crop revenue increases at 65 percent of full irrigation diversions and then decreases after 65 percent of full irrigation diversions is due to the A, B, C priority-use right water-allocation method. Near the 65 percent point in irrigation diversion, the allocation of water to the B users is completely suspended while the A users are still receiving a full supply (refer back to Figure 2). Assuming some heterogeneity of land quality, this allocation method forces the highest-quality B land completely out of production, while the lowest-quality A lands are all still in production.

Caution should be exercised in interpreting the information shown in Figure 3. Recall that the model generating this data is a short-run model. The implication of a short-run model is that the fixed debt costs of the on-farm operation are being covered. This may not be the case if year after year the percent of irrigation diversions to farmer managers is below historical levels. The data presented in Figure 3 is helpful in understanding the 1-year impact of a reduction in irrigation diversions, assuming operations will return to near-normal conditions in the following years.

Increasing on-farm crop revenue with policy changes that reallocate existing irrigation diversions

The current water allocation method in the Project follows the A, B, C priority-use right method already described in this chapter. The results that will be presented in this subsection of the chapter answer the question *"What if there were greater flexibility in the method of allocating water?"* Estimates of on-farm crop revenue under two different allocation methods will be presented. Those methods assume:

1. Water measurement devices (meters) are installed so that the water-allocation methods constrain water deliveries directly, instead of constraining the number of acres in production. For example, if the amount of water available to a B user is 50 percent of their full supply then they will receive 50 percent of their full water supply rather than only being permitted to plant 50 percent of their acres.
2. Prorating equally any reduction in irrigation diversions across all users, regardless of the A, B, and C priority-use right distinction.

The percent of on-farm crop revenue generated under the above two allocation methods when irrigation diversions range from 100 to 10 percent of full supply is shown in Figure 4. For reference, the baseline percent of on-farm crop revenue, originally shown in Figure 3**,** is included in Figure 4. The percent of on-farm crop revenue is higher under either of the alternative water allocation methods than under the baseline method for any level of irrigation diversion. When meters are used so that reductions in water deliveries can be managed by measuring water rather than fallowing land, the percent of total on-farm crop revenue is between just slightly higher than baseline to 2 percent above baseline. Since meters generate higher on-farm crop revenue, an analysis could be developed to determine how long a meter-installation program would take to pay back. Since a 1 percent change in revenue is roughly equal to $1 million in the Project, if the meter-installation project cost less than $2 million, the payback could be between 1 and approximately 5 years, depending on the percentage of irrigation diversions.

In this example, the smallest decrease in on-farm crop revenue occurs when shortages in irrigation diversions are proportionally allocated across the Project, without regard to A, B, C priority-use right designation. For example, when irrigation diversions are 70 percent of full supply, on-farm crop revenue is 90 percent of total under the proportional water allocation method, versus 80 percent under the baseline water allocation method.[2] Specifically, under the baseline water allocation method, the B user's water allocation is near zero and yet the A users are receiving 100 percent of their water supplies when irrigation diversions are near 70 percent of normal. Presuming the lowest value land is removed from production first, this allocation

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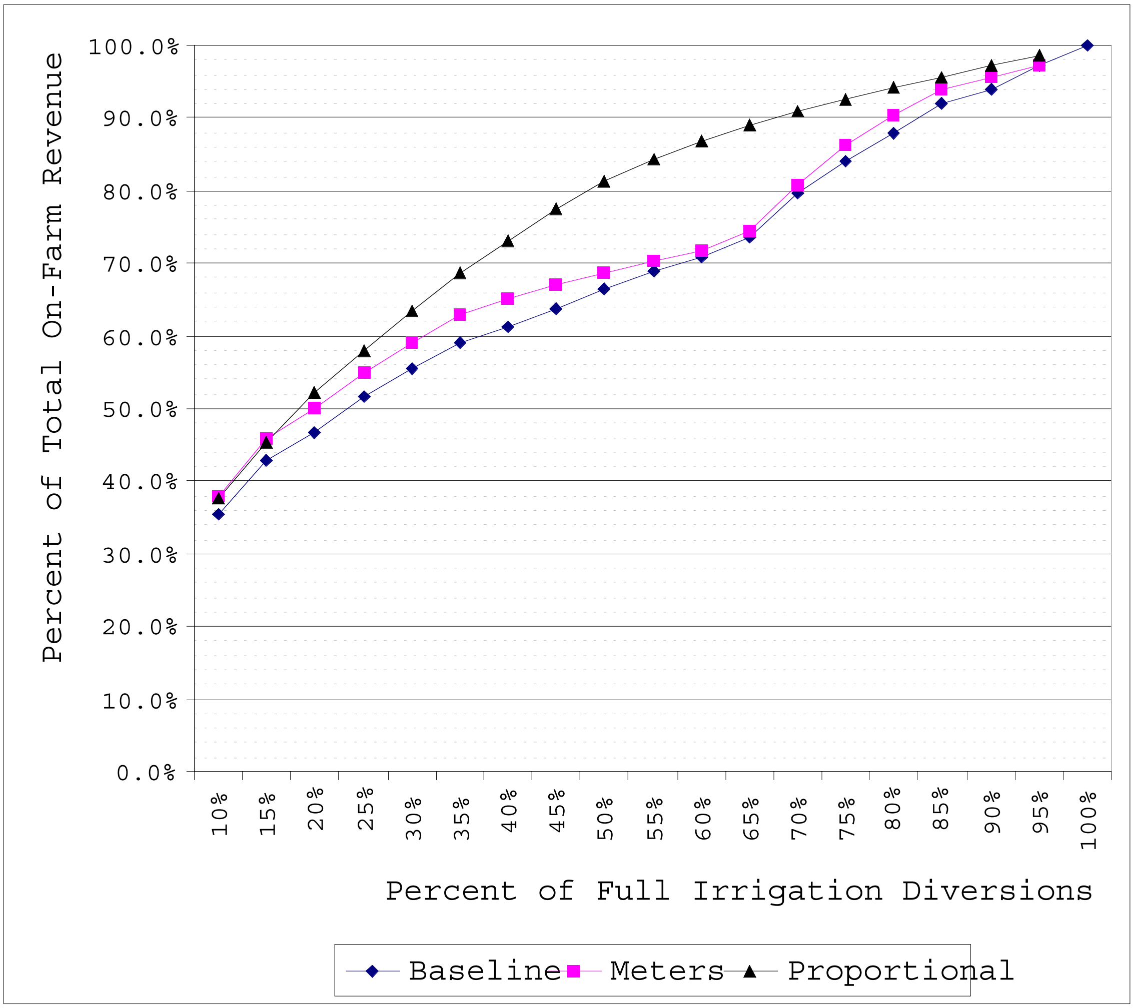
[2] The overall impact of such a water allocation approach is to reduce the return flow out of the Project (through the Klamath Straits drain). Increasing overall Project efficiency may have a detrimental effect on both the Lower Klamath Lake and Tule Lake national wildlife refuges. Both refuges are dependent on the return flows of the Project to maintain wildlife habitat.

method forces the highest value B land from production before the lowest value A lands are removed from production. For an intuitive numerical example of this result see the text box below entitled "How water allocations can affect total on-farm crop revenue."

Figure 4. Percent of on-farm crop revenue under various water allocation methods and a range of irrigation diversions.



How water allocations can affect total on-farm crop revenue

Assume the relationship between irrigation diversions and on-farm crop revenue follows the pattern:

Percent of Irrigation Diversion	Percent of On-farm crop revenue
100%	100%
50%	70%
0%	20%

Now assume there are three farms, farm A, farm B, and farm C. Farm A holds an A priority-use right to water. Farm B holds a B priority-use right to water. Farm C holds a C priority-use right to water. Assume the quantity of water used on each farm is the same and each farm produces $100 of on-farm crop revenue when irrigation diversions are 100 percent. Therefore, total revenue from all the farms is $300. A comparison of the revenue generated under the A, B, C priority-use right water-allocation method and the proportional method is presented in Table 1 assuming irrigation diversions must be cut to 50 percent of full. Total on-farm crop revenue under the A, B, C priority use right method is $190, or 63 percent of total. Total on-farm crop revenue under the proportional method is $210, or 70 percent of full. Simply because the "pain is shared" in the reduction of irrigation diversions, the decrease in on-farm crop revenue can be lessened by 7 percent.

Table 1. On-farm crop revenue under two water allocation methods.

Farm	Full irrigation deliveries	A, B, C priority-use right	Proportional
A	$100	$100	$70
B	$100	$70	$70
C	$100	$20	$70
Total	$300	$190	$210
% of Full	100%	63%	70%

The results suggest another method of water allocation that could mitigate the effects of decreases in irrigation diversions even more than the proportional allocation, namely, a water market. The proportional allocation method mitigates for some of the loss to total on-farm crop revenue by more closely equating the value of the land in production than the A, B, C allocation method. A water market moves even further in that direction by equating the value of the water in production. Allowing willing sellers to offer water to potential buyers, both parties could be made better off. Increasing the flexibility of water allocation methods, to better equate the value of water on the margin, increases the output of the Project.

Increasing on-farm crop revenue with policy changes that increase the flexibility of when lake levels are measured

The level of Upper Klamath Lake is measured on the dates listed in Table 5. For example, under all four of the assumptions sets shown in Table 5, the lake level must be 4,139 ft above sea level at the end of September. If, as the end of September nears, there is a concern that the lake level will not be met, irrigation diversion may be stopped until the lake measurement is taken. The nervousness about meeting the lake level requirements during the height of the growing season has been captured in a colloquialism: local stakeholders refer to this period as the "nervous narrows." The need to stop irrigation deliveries for a time to meet lake levels may arise for whatever reason—hotter than normal summer temperatures, lower than average summer precipitation, etc.—the question is, how will on-farm crop revenue be impacted?

The results presented in Table 7 assume a mid-season cessation of irrigation diversions beginning on August 15 and resuming August 31. The reduction of on-farm crop revenue as a result of the cessation is approximately $12.5 million. The reduction in on-farm crop revenue is based on the impact the cessation has on crop yield. The data on the change in crop yield was obtained from field trials performed at the University of California, Davis, Intermountain Research and Extension Center.

The reduction in on-farm crop revenue from potatoes (classified as vegetables) accounts for most ($9.8 million) of the total reduction. Potatoes, as a row crop, are relatively more sensitive to cessations in watering earlier in the season rather than later because they must become established. Once established, a reduction in irrigation water has less of an impact on the crop yield. If the 2-week cessation occurred from September 1 through 15 instead of August 15 through 31, the impact on on-farm crop revenue could be decreased**.** Table 8 shows the difference in on-farm crop revenue under irrigation cessations beginning August 15 and September 1. More than $8.2 million of on-farm crop revenue could have been saved in potatoes (nearly $8.9 million in total) if the 2-week cessation was moved back 2 weeks.

To the extent there is flexibility in the determination of the date when the lake levels must be taken, there is potential to save on-farm crop revenue. Each year, the impact a cessation in irrigation would have on crop yield may be different, however if the agencies involved can increase their operational flexibility without serious injury, a marginal gain may be available.

Effects of various combinations of biological opinions to irrigation diversions

In order to gain more insight into the impact the lake levels and in-stream flow regimes may have on irrigation diversion in the Project, Figure 5 and Figure 6 show the percent of full supply for five historical hydrologic traces under four different combinations of lake level and in-stream flow regimes for Upper Klamath Lake and Lost River, respectively. Two lake levels are examined, namely:

- 4,139 ft above sea level.
- 4,140 ft above sea level.

The three in-stream flow regimes examined are:

- The 1992 operations (a critically dry year when FERC minimums were violated).
- The 2000 operations (hydrologically, an above-average year that closely approximates the 2001 biological opinion).
- The flows recommended by Dr. Hardy in the Phase I analysis of in-stream flow required for habitat restoration.[3]

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[3] Dr. Hardy is an associate professor at Utah State University. He is under contract with the Bureau of Indian Affairs to assess the river flow required to improve habitat in the Klamath River.

The lake levels and flow regimes are combined into four sets of data (although six sets are possible, only four are presented here) of the lake levels and in-stream flow regimes. These four data sets are then combined with five different hydrologic year traces. There is one of each hydrologic year trace classified as critically dry, dry, and below average and two hydrologic year traces classified as above average shown in these figures.

The USBR defines the hydrologic year types in its annual Environmental Assessments. Above-average years are any years where snow pack and spring in-flows are greater than the average. A below-average year type is any year where the snow pack and spring in-flows are one standard deviation below average. A dry year is defined where the snow pack and spring in-flow are two standard deviations below average. Critically dry years are any years the snow pack and spring in-flows are more than two standard deviations below normal.

Figure 5 shows the percent of full irrigation diversions that may be available to the Upper Klamath Lake users under four various combinations of river and lake biological opinions and hydrologic year types. Under the lake level requirement of 4,139 ft above sea level, three different river flow requirements were tested. The results are (1) under no flow requirement irrigation diversions are 100 percent regardless of year type; (2) under the 2001 biological opinion the above and below average year types have 100 percent of irrigation diversions; however in dry and critically dry years irrigation diversions are 65 percent and 10 percent, respectively; (3) when river flow requirements follow Dr. Hardy's report only one above-average year, 1982, has full irrigation deliveries and one above-average year, 1986, has 40 percent deliveries, the below-average year has 10 percent, and there are no irrigation diversions in dry and critically dry years.[4]

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[4] The reason 2 above-average years can result in different estimates for the percent of irrigation diversion occurs as a result of the methods of classifying year types. Recall that the estimate of how much water is available is made based on the inflows into Upper Klamath Lake (and Gerber and Clear lake reservoirs) in the spring, before the summer precipitation and temperature are known. After the spring announcement two factors can and have influenced the amount of agricultural demand for irrigation (or the supply of water). Namely, (1) summer precipitation can make up for below-average spring inflows into the Project reservoirs, and (2) cooler summer temperatures may decrease the demand for irrigation water. Combined, these factors can change a hydrologic year that appears below average in the spring (based on inflow data) into a hydrologic year when all demands are met. Conversely, a hydrologic year that appears to be above average in the spring may emerge into a hydrologic year when all demands are **not met**. An example of this situation can be seen by examining the results when the

Under the lake level requirement of 4,140 ft above sea level, one river flow requirement was tested: 2001 biological opinion, which shows 100 percent deliveries in above- and below-average years but no irrigation diversions in dry or critically dry years.

Figure 6 presents the same analysis as in Figure 5 for the Lost River watershed. In all cases when the hydrologic year type is critically dry, the percentage of full supply is between 25 and 30 percent. In the Lost River watershed, a relatively larger portion of full supply is met with groundwater. The model assumes groundwater is static over year types, therefore the result seen in Figure 6, that even in critically dry years at least 25 percent of full supply is available, is driven by the availability of groundwater.

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hydrologic year is 1986, an above-average year. This result shows the complexity of the hydrology in the Project lands and illustrates the difficulty of predicting available irrigation diversions.

Figure 5. Percent of full water supply under various biological opinions, Upper Klamath Lake.

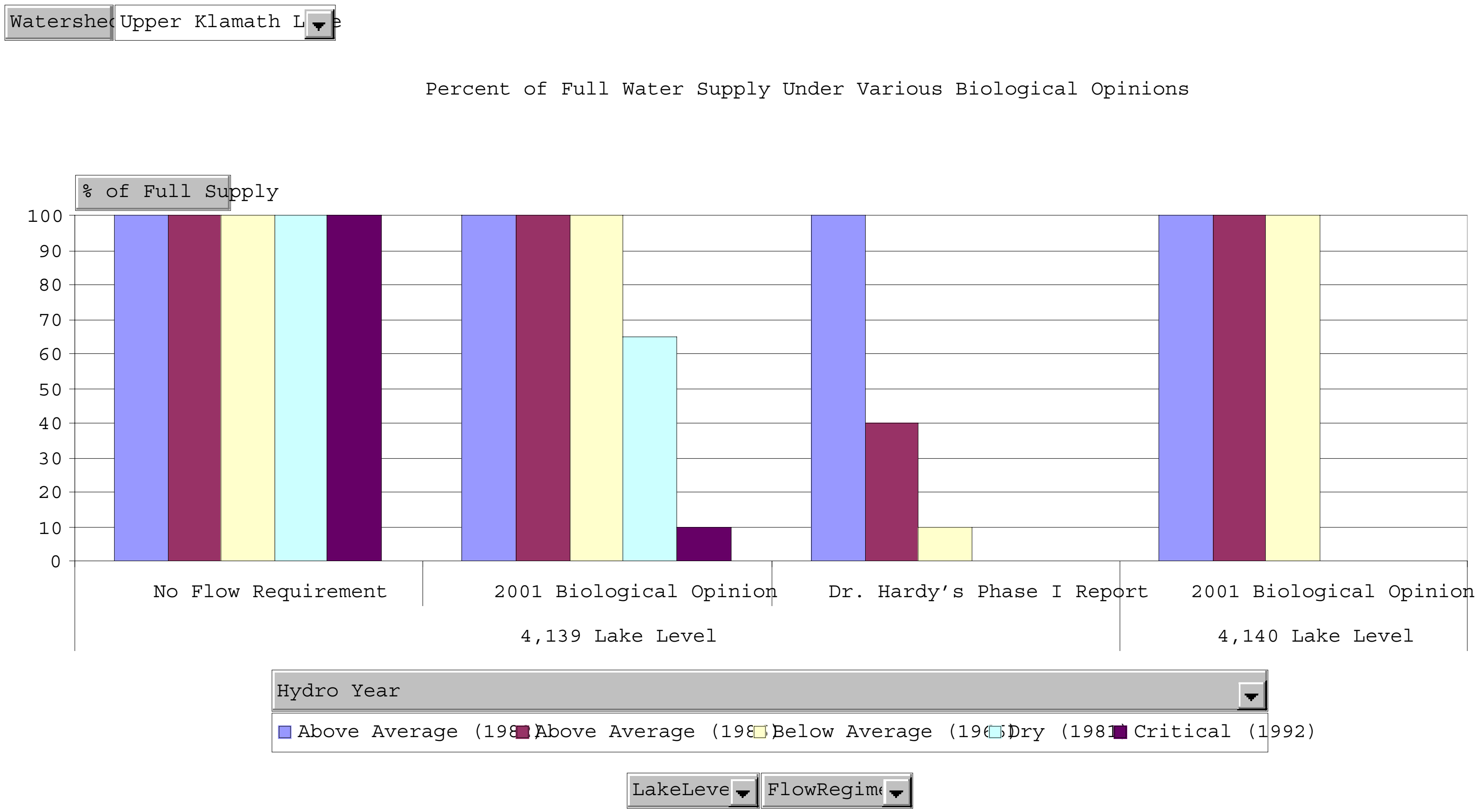
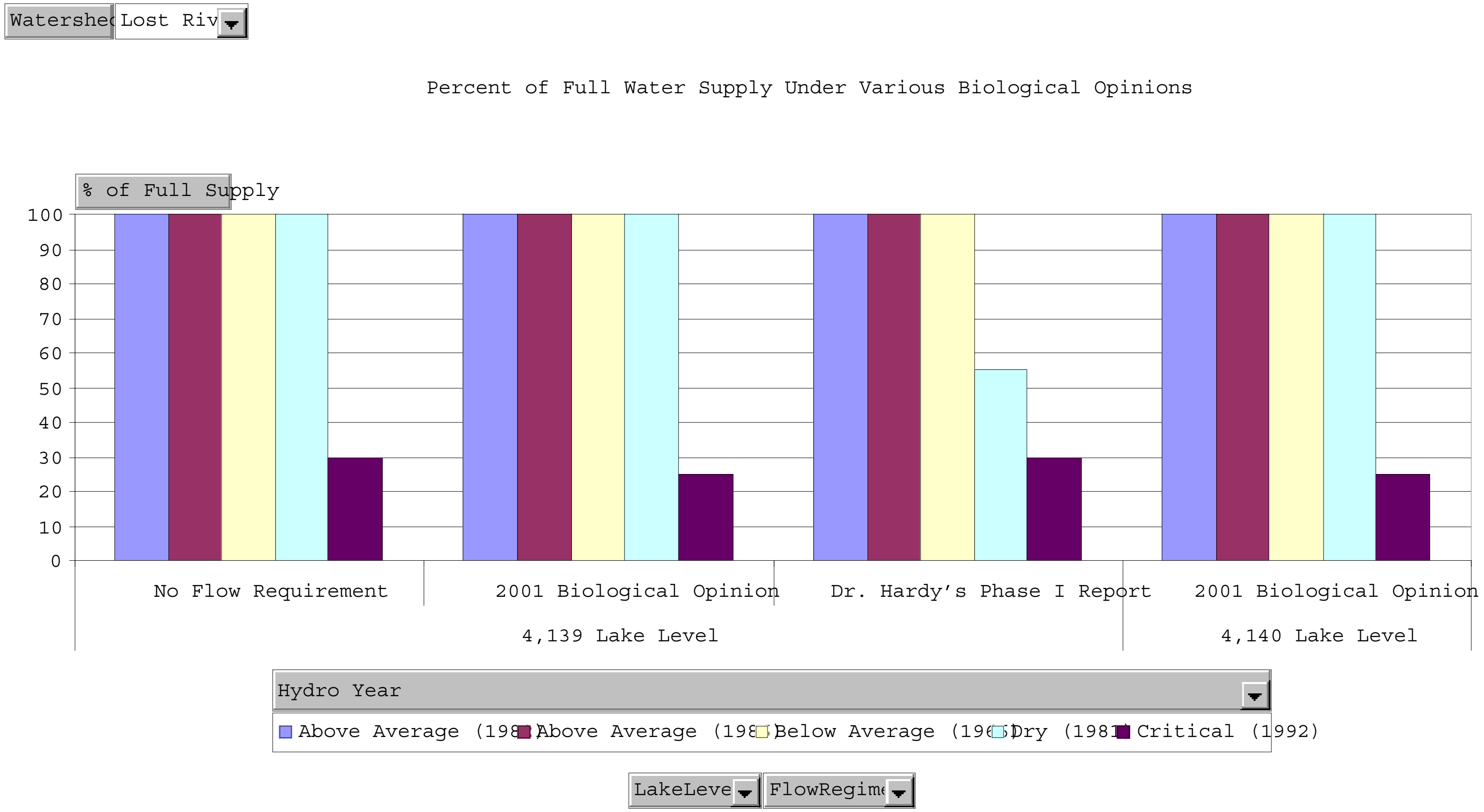


Figure 6. Percent of full water supply under various biological opinions, Lost River.



Summary and conclusions

This section of the analysis presents an estimate of the impact of the 2001 biological opinion to on-farm crop revenue in the Project. The impact is estimated to be between $44.5 million and $74.2 million. In addition, this section presents the estimate of impacts to on-farm crop revenue in the Project from policy changes regarding water allocation methods and flexibility in the timing of lake level measurements. Changing water allocation methods through the installation of measurement devices had a 1-year increase in on-farm crop revenue of between 0.3 and 2.4 percent. Using a proportional method to allocate water instead of the existing A, B, C priority-use right method could save as much as 10 percent of total on-farm crop revenue, depending on the percent of full irrigation diversions. Increasing the flexibility of when lake level measurements are taken could potentially save $8.9 million, or roughly 9 percent of total on-farm crop revenue.

The irrigation diversion available to the Project under various hydrologic year-types and biological opinions was estimated. Under both below- and above-average year hydrologic conditions, at the 2001 biological opinions for Upper Klamath Lake and Klamath River, the estimated full supply of water available to the Project would be 90 to 100 percent for the Klamath River watershed and approximately 100 percent for the Lost River watershed. If the year type is dry or critical—under the same biological opinions—the Klamath River users receive 5 percent and no water, respectively.

If the Hardy flows replace the 2001 biological opinion for in-stream flows in Klamath River, the percentage of full supply water available in the Klamath River watershed in above-average years would be between 100 and 40 percent. In a below-average year the percentage of full supply would be 5 percent. In dry and critical years there would be no water available for irrigation diversions.

The model used to estimate the change in on-farm crop revenue is a short-run model. The results cannot be used to extrapolate the number of farms that may be forced out of business in the long run if the water allocation paradigm in the Project changes significantly from historical delivery patterns. Further extension of this work would include incorporating a long-run analysis in order to fully understand the impacts of changing water allocations in the long-run.

References

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