ALTERNATIVES FOR IMPLEMENTING EFFICIENCY CONSERVATION IN THE IMPERIAL IRRIGATION DISTRICT

Stephen Hatchett, Ph.D.[1]
Ronald Bliesner, P.E.[2]
John R. Eckhardt, Ph.D., P.E.[3]
Grant Davids, P.E.[4]

ABSTRACT

In 2003 the Imperial Irrigation District (IID), a 450,000-acre water district in Southern California, entered into a package of decisions and agreements known collectively as the Quantification Settlement Agreement and Related Agreements (QSA). As part of these agreements, IID agreed to a long-term transfer of water to the San Diego County Water Authority (SDCWA) and the Coachella Valley Water District (CVWD). According to the terms of the agreements, the water must come from conservation within IID. The transfer begins small but by 2026, IID must conserve and transfer 303,000 acre-feet of water each year or nearly 10% of its total annual water use.

In 2007, IID completed the Efficiency Conservation Definite Plan that outlined strategies for both delivery system and on-farm water savings. IID examined a large number of alternatives to generate the savings. Alternatives differed largely according to two features: the mix of on-farm versus delivery system savings, and the structure of the on-farm incentive program. Seven different mixes of on-farm and delivery system savings were evaluated, ranging from the maximum practical delivery system savings to generating nearly all savings on-farm. Four different incentive program approaches appeared to be viable ways of inducing sufficient on-farm enrollment. The incentive approaches differed in the way that growers would be paid for their participation.

The resulting alternatives varied significantly in their performance and cost-effectiveness. Costs included system conservation measures, payments to growers to implement on-farm measures, measurement and monitoring, and administration. System delivery savings of between 93,000 and 123,000 acre-feet per year provided the most cost-effective mix of savings. The complementary on-farm savings were 180,000 to 210,000 acre-feet per year, with average payments to growers between $245 and $300 per acre-foot saved.

This paper, one of seven detailing the findings of the Definite Plan, describes the development and analysis of alternatives to implement the conservation program, and summarizes important findings on how best to design on-farm conservation incentives to achieve cost-effective, real water savings without encouraging fallowing.

[1] Western Resource Economics, 364 Sandpiper Drive, Davis, CA, 95616; steve@wrecon.com
[2] President, Keller-Bliesner Engineering, LLC, 78 E. Center, Logan, UT 84321; bliesner@kelbli.com
[3] Executive Program Manager, QSA-IID/SDCWA Water Transfer, Imperial Irrigation District, 333 East Barioni Boulevard, Imperial, CA 92251; JREckhardt@IID.com
[4] President, Davids Engineering, 1772 Picasso Ave. Suite A, Davis, CA 95618; grant@de-water.com

INTRODUCTION

The objective of alternatives development is to identify the combinations of on-farm conservation and delivery system conservation that can best meet IID's requirements for implementation of the Quantification Settlement Agreement (QSA) and related agreements. Alternatives comprise different combinations of system delivery options, on-farm conservation volumes, and incentive program designs. These components are initially evaluated independently in order to screen out those that clearly cannot meet the requirements. Then the components are combined to evaluate different mixes of on-farm and system conservation. The most important requirement is that components be able to work within an alternative to produce the required level of savings within the financial constraints. The evaluation focuses on quantitative comparisons of options and alternatives, but includes other important criteria such as implementation considerations and verification of water savings.

The on-farm component of the Efficiency Conservation Definite Plan (Definite Plan) is a voluntary, incentive-driven program to implement irrigation conservation measures. The incentive program must induce sufficient voluntary participation by growers and landowners to meet the on-farm conservation component over the life of the water transfer agreement. At full implementation, it must provide a minimum of 130,000 acre-feet (AF) of annual, on-farm savings. Potentially, all 303,000 AF of annual savings could be provided by on-farm conservation.

Delivery system savings can range from 0 up to 173,000 AF per year. Because of the emphasis on on-farm water savings, delivery system conservation options should be low-cost and/or include elements that support on-farm conservation. The evaluation considered both stand-alone system options and integrated options aimed at improving system management and supporting on-farm conservation.

ALTERNATIVES DEVELOPMENT

Defining Efficiency Conservation

According to the QSA, at least 130,000 of the 303,000 acre-feet of conservation must come from contracted, on-farm efficiency conservation. Based on IID's understanding and intent when it signed the QSA, the following requirements were to be met by the Efficiency Conservation Plan[5]:

- All savings must be generated through efficiency conservation, defined as a reduction in losses associated with delivery and use of irrigation water. Water savings generated through actions such as fallowing, crop-shifting or deliberate deficit irrigation cannot be counted towards satisfying the terms of the QSA.

[5] The Definite Plan evaluation team did not attempt to interpret the terms of the QSA – it simply followed these requirements as specified by IID.

- Grower participation is voluntary and incentive-driven. IID must provide sufficient incentive to compensate for the costs and uncertainties of changing irrigation practices.
- Growers choose the means of generating on-farm efficiency conservation.
- Water savings must be verifiable.
- The program must be financed through net revenues derived from the water transfers and related QSA provisions.

Verifying conservation will occur at two levels. First, IID's aggregate quantity of water diverted from the Colorado River must fall within its quantified allotment minus the amount transferred. Second, the on-farm savings must be verified as efficiency conservation rather than fallowing or other ET reduction. Therefore, IID must verify that participating growers have saved water relative to some reference level, or baseline, of water use.

But what is the appropriate reference level of field-level water use against which to measure savings? A number of ways to measure savings were considered, and they fall largely into three different categories: 1) measure a field's current water use relative to what the field would have used without the implemented conservation[6]; 2) measure a field's current water use relative to what that field had used in the past; or 3) measure a field's current water use relative to an aggregate (rather than field-specific) baseline.

Each of these ways of measuring savings has practical advantages and disadvantages. Also, each can provide growers with different incentives regarding which fields and crops to enroll in the program. The Definite Plan used the second approach to estimate savings, using historical water use records by field for the period 1998-2005. For each on-farm program evaluated, the water use on fields adopting conservation measures was compared to the water use on the same field in the historical database.

On-Farm Program Incentive Options

Measurement of savings is required to verify conservation, but it can also be used as the entire or partial basis for the incentive payment. The Definite Plan considered four ways to structure incentive payments to growers:

- **Pay for Conservation Measures**. Payment is based solely on the action taken by the grower. The grower is paid based on the conservation measure implemented (not on the measured amount of water saved). Water users could select from a set of approved practices or could submit their own proposals for on-farm practices that best suit their individual operations. Water users would be responsible for performing practices as specified in an agreement and would be paid on that basis, rather than based on achieving certain water use levels. Payments can be ***uniform*** per acre to all who implement a conservation measure or they can be

[6] One way to implement this approach is simply to create a schedule of assumed savings by conservation measure, crop, and perhaps soil: for example, assume that conservation measure X (say, irrigation scheduling) reduces seasonal application rate on alfalfa by Y acre-feet per acre.

scaled to account for cost differences according to field size. This approach can assure that measures are implemented at a relatively low cost to the program, but it does not provide good incentive for growers to operate the measures well to achieve optimum savings.

- **Pay for Delivered Water Savings**. Payment is based solely on the result achieved (measured or estimated water savings). Regardless of the conservation measure implemented or its cost, the grower receives payment based on water use. The payment could depend on the amount saved relative to a reference level or the payment could depend on achieving a target rate of water use. This approach provides good incentive to hold water use low, but it can encourage fallowing or other ET-reduction activities. Also, depending on the choice of baseline, it may penalize growers who had been low water users in the past. Similarly, it can pay large amounts to growers that may have to do and spend very little to reduce water use.
- **Pay for Tailwater Savings**. Payment is based solely on the result achieved (measured or estimated reduction in tailwater volume or fraction). Regardless of the conservation measure implemented or its cost, the grower receives payment based on tailwater reduction. This approach has similar advantages and disadvantages to the Delivered Water Savings approach, plus it requires additional measuring devices for tailwater leaving the field.
- **Hybrid**. Payment is based on a combination of the action taken and the result achieved. Its purpose is to capture the best features of the two approaches above by basing a substantial part of the payment on actual cost of the implemented conservation measure (using either a ***uniform*** or a ***scaled*** payment as described above), plus an additional payment based on achieving verified water savings.

Payment based on water savings initially seemed the most likely to generate cost-effective savings because the payment is most closely tied to the overall program goal of reducing aggregate water use. As the Definite Plan evaluation team (team) began to analyze it using the historical database of field deliveries, several significant problems became apparent. First, the data showed a very wide range of apparent water use for a given crop and soil. Much of this variation appears to be real, but several data issues compounded the problem: recording errors, multiple-field gates, and moving water between gates introduced significant additional noise into the estimates of historical water use by field[7]. Under a pay-for-savings incentive, the same unit price is paid for all water saved, so large variation in savings per acre causes very large payments to some fields.

The team evaluated many combinations of unit payment amounts, baselines, and payment limits in an attempt to formulate pay-for-water options that were financially feasible, but it was unsuccessful for the reasons described above. Therefore, the payment for delivered

[7] We did not detect any overall or systematic bias resulting from data errors. Total field water use matched well with District-level water balances, so positive and negative errors tended to balance. Nevertheless, use of the historical data as a basis for payments presents a substantial risk of enrollment bias for the on-farm incentive program – growers could choose to enroll fields that have data errors in their favor and omit fields that do not.

water savings and for tailwater savings were eliminated as feasible options for an incentive program. The team did recommend exploring ways to create a more consistent and accurate water use baseline, and IID will be developing such “certified gate histories” as part of the implementation phase.

Four incentive options were carried forward for further evaluation and for inclusion in comprehensive Definite Plan alternatives. These were:

- **Uniform Payment for Conservation Measures (Uniform PFM)**: Growers are paid based on what they agree to implement, and each field receives the same payment per acre for a given conservation measure.
- **Scaled Payment for Conservation Measures (Scaled PFM)**: Growers are paid based on what they agree to implement, but the size of the payment for a given conservation measure varies to account for economies of scale gained on larger fields, and possibly other factors.
- **Uniform PFM Hybrid**: The incentive payment would consist of two components. The larger portion would be a *uniform* payment based on the conservation measure implemented, and the smaller portion of the payment would be contingent on achieving a measurable level of performance.
- **Scaled PFM Hybrid**: The incentive payment would consist of two components. The larger portion would be a *scaled* payment based on the conservation measure implemented, and the smaller portion of the payment would be contingent on achieving a measurable level of performance.

Evaluation and Comparison of Incentive Options

The team evaluated and compared incentive approaches using both quantitative and qualitative criteria. The primary evaluation focused on quantitative analysis to estimate costs, payments, and other benefits to growers and landowners; to predict their selection of conservation measures based on the costs and benefits; and to estimate the resulting program savings, costs, and incentive payments. Other, qualitative criteria were also used to compare incentive program approaches that appeared to be feasible.

The evaluation of incentive approaches relied primarily on an analytical tool developed for the Definite Plan effort. The Demand Generator is a module of the IID Decision Support System (IIDSS), and is described in more detail in the companion paper titled “Decision Support System for Evaluating Alternatives.”[8] The Demand Generator allows the user to define the features of an incentive approach. The Demand Generator then evaluates the costs, payments, and other benefits that each field in IID’s historical database would face under that incentive approach and selects the grower’s preferred decision.

The Demand Generator then modifies historical farm water orders to simulate the change in water demands anticipated from the adoption of its predicted selection of on-farm

[8] Keller, Andrew et al. 2008.

conservation measures. These modified farm water orders and system delivery changes for an alternative are input to MODSIM, which simulates the flow of water throughout IID's canal delivery system, predicting spills, seepage, and evaporation losses associated with various alternative canal and operation configurations.

The Demand Generator can evaluate each of the candidate incentive approaches described above. The user selects the incentive approach and then chooses the necessary payment rates and other parameters and decision criteria needed to implement the incentive approach. For each approach, the user decides on a target level of average annual savings, and then adjusts parameters of the approach (e.g., payments per acre or per acre-foot of savings) as needed to achieve the target.

Figure 1 shows a comparison of the cost performance of these four incentive options for a target annual savings of 200,000 acre-feet. The figure shows the average implementation cost and the average payment to growers per acre-foot saved. Average payments exceed implementation costs because payments are somewhat standardized whereas costs vary from field to field. Fields which have costs higher than payments will not adopt a conservation measure, but fields having costs lower than payments will adopt.

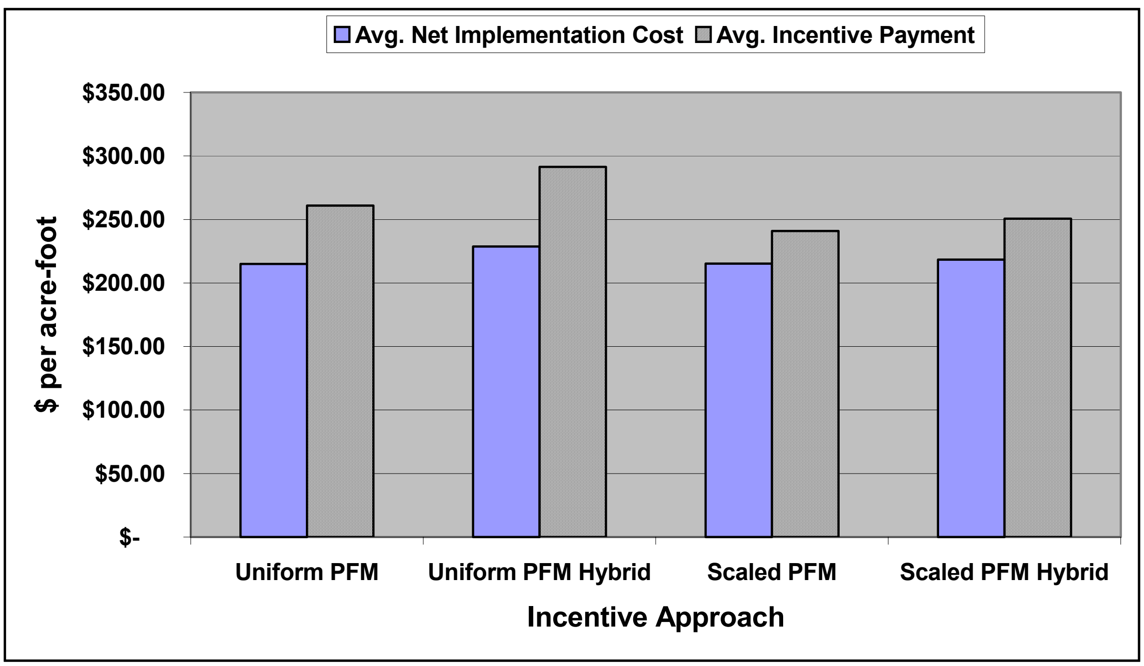

Figure 1. Comparison of net implementation costs and average incentive payments by incentive option at 200,000 AF per year, in $ per net AF saved

<u>Alternatives Definition and Evaluation</u>

Alternatives are defined as combinations of system and on-farm conservation options that meet the overall financial and water savings goals while satisfying the other efficiency conservation requirements described earlier. One approach for selecting among a combination of options is optimization: scaling or parameterizing the possible options and then using an algorithm that chooses the level of each to provide the "best" overall result. For the Definite Plan, a pure optimization approach was impractical for two reasons. First, a continuous range of delivery system options was not realistic. The screening and analysis of system options defined a set of discrete options that were feasible and cost-effective, and that provided the service level to support on-farm conservation. Second, the on-farm incentive options were structurally and conceptually different (they could not be nested within a more general mathematical formulation) and contained discontinuous and nonlinear payment formulas.

Therefore the analysis of alternatives was performed by developing a set of delivery system options and then formulating an on-farm program at a scale needed to generate the overall conservation target of 303,000 acre-feet per year.[9] Table 1 shows the resulting set of combinations.

Table 1. Definite Plan Conservation-Level Alternatives

Conservation Mix Alternative	**On-farm Conservation, ac-ft**	**System Conservation, ac-ft**
1. Maximum on-farm	280,000	23,000
2. On-farm plus seepage interception	258,100	44,900
3. On-farm, seepage interception and least cost canal lining	255,720	47,280
4. System water for CVWD*	200,000	103,000
5. Least-cost combination	182,340	120,660
6. Maximum delivery system	158,800	144,200
7. Maximum delivery system with delivery flexibility	158,800	144,200

*The QSA includes up to 103,000 acre-feet of water per year (of the total 303,000) to be transferred to the Coachella Valley Water District (CVWD).

Each of these seven combinations was evaluated using the four incentive options, resulting in 28 alternatives.

The name of each alternative in Table 1 indicates the general parameters used to construct it. For most alternatives, the description also determined the split between system and on-farm savings. For the Least-cost combination, however, the exact savings split between system and on-farm savings was the result of a least-cost analysis. First, each of the four feasible on-farm incentive structures were evaluated in increments over the range of savings levels, with each increment achieving the targeted on-farm savings at the lowest cost to the program. Next, the cost and savings of the discrete delivery system

[9] The delivery system option development is described in the companion paper: "Modifying the Delivery System to Conserve Water and Support More Efficient On-Farm Irrigation" (Bliesner et al., 2008). Note that the delivery system options were developed to save water on their own and to provide the service level needed to support the complementary savings from the on-farm program.

options were compared with the cost and savings of increments of on-farm savings. By ranking the options and on-farm increments in order of increasing cost per acre-foot saved, a marginal cost curve was constructed.

Figure 2 illustrates the results graphically for the Least-cost Combination alternative. The Figure shows the total annual savings along the horizontal axis as savings increments are added in order of increasing unit cost. The points denote on-farm increments or system savings options; the thin, stepped line is the marginal cost; and the dark line is the average cost. The red, horizontal line denotes the financial feasibility limit: the expected revenue received per acre-foot of saved water minus the estimated cost of administration and measurement. The average cost curve in Figure 2 indicates the minimum average cost (not including administration and measurement cost) to achieve any target level of savings.

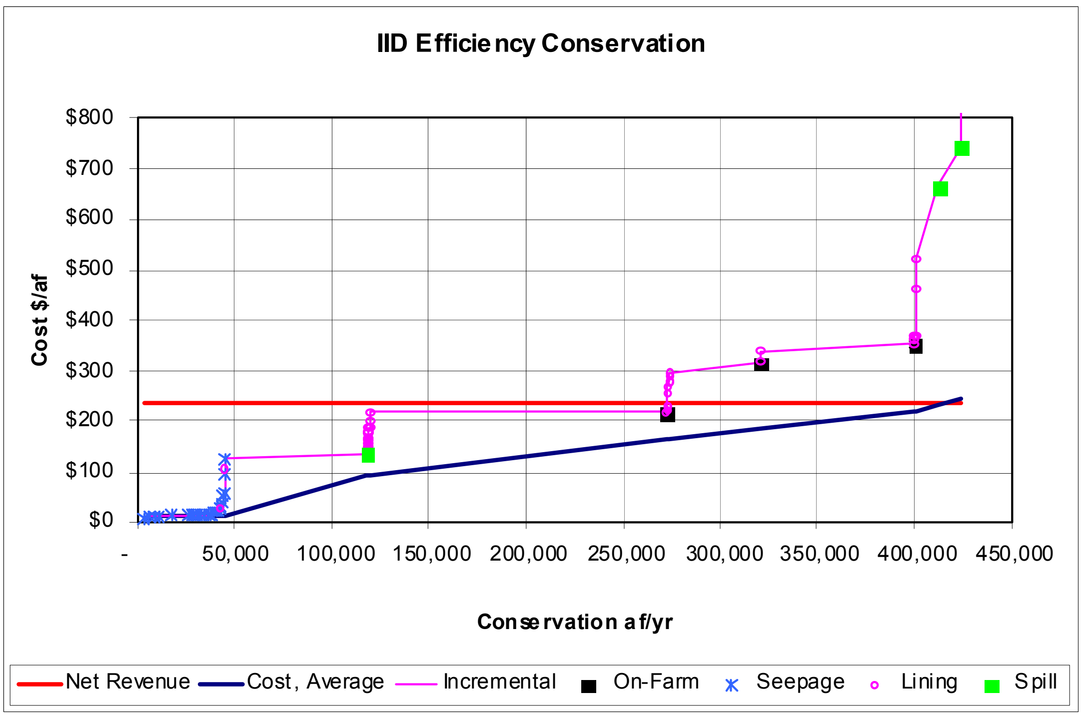

Figure 2. Incremental and average cost for the Least-cost Combination alternative

This approach was used for each of the four Least-cost Combination alternatives (one for each incentive option). The least-cost approach was used not because IID's intent was to minimize payments to growers, but because all of the incentive structures were close to or beyond the financial feasibility target. The incentive programs needed to be designed for the lowest program cost in order to provide a prudent amount of "financial headroom" to meet uncertainties in future conditions.

RESULTS

The graph of the alternatives presented in Figure 3 – each with the common measurement, administration and contingency costs of $67 per acre-foot already added in – shows a wide range of costs for conserving 303,000 acre-feet. General findings are summarized as follows:

- Fourteen of the 28 alternatives analyzed had costs at or below the available revenue (estimated for the Definite Plan to be $300 per-acre foot saved) and could be considered for evaluation and possible adoption as the recommended approach. Most of the Scaled Pay-for-Measures incentive alternatives fell below the $300 threshold.
- Fourteen of the 28 alternatives exceeded the $300 threshold and were not considered viable alternatives for consideration in Definite Plan implementation. More than half of the Uniform Pay-for-Measures Hybrid alternatives exceeded the $300 limit. Uniform Pay-for-Measures fared second worst, with the cost of four of its seven alternatives exceeding the available revenue.
- A number of alternatives provided significant "headroom" between the alternative's cost and the available revenue. Most promising were some of the Least-cost combination and System Water for CVWD (conservation mixes #5 and #4) alternatives, whose costs for most of the incentive options were between $243 and $268 per acre-foot – well below the $300 threshold.
- Including a hybrid component with some of the incentive pay-for-measures approaches raised the cost across-the-board, but hybrid approaches provided better assurance that conservation measures would be operated to their potential.
- IIM is Integrated Information Management, a combination of automated lateral headings and spill monitoring to reduce canal spills. Configurations encompassing the IIM inter-related delivery system component (see Table 2 below) combined with seepage interception (Least Cost, conservation mix #5) or IIM plus seepage interception and canal lining (System Water for CVWD, conservation mix #4) had the lowest costs.

Based on these findings, five integrated alternatives were judged to be particularly strong candidates. These were: Least-Cost (conservation mix #5) with Uniform PFM, Scaled PFM and Scaled Hybrid; and System Water for CVWD (conservation mix #4) with Scaled PFM and Scaled Hybrid.

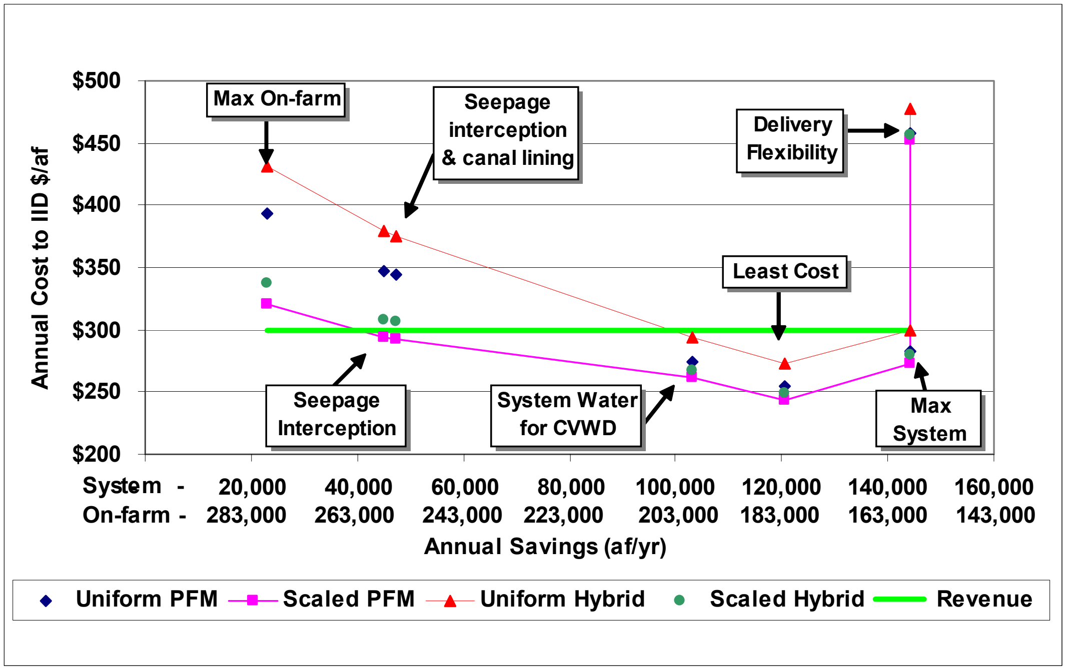

Figure 3. Comparison of Integrated Alternatives

Analysis of the alternatives suggested an optimal mix of between roughly 180,000 to 210,000 acre-feet of on-farm water savings combined with 93,000 to 123,000 acre-feet of delivery system conservation savings. Table 2 summarizes the range of conservation savings by component and average water savings costs over this preferred range.

Table 2. Component Savings and Average Costs Over Preferred Range of Savings

Conservation Component	**Low On-farm Savings, acre-feet**	**High On-farm Savings, acre-feet**	**Average Cost at 180,000 acre-feet on-farm savings, $/acre-foot**	**Average Cost at 210,000 acre-feet on-farm savings, $/acre-foot**
IIM	75,720*	53,000	$136	$189
Seepage Interception	44,900	40,000	$15	$15
Canal Lining	2,380	0	$202	$0
On-Farm	180,000	210,000	$240	$256
Total or overall avg.	303,000	303,000	$247	$279

CONCLUSIONS AND RECOMMENDATIONS

The analysis found that several alternatives can allow IID to fulfill its water transfer obligations through efficiency conservation within the limits of available revenues. A number of other alternatives either cannot work or are so marginal that they seriously reduce the prospects for success.

Based on this analysis, a set of six recommendations were developed that address: (1) the blend of on-farm and delivery system savings that IID should target; (2) the on-farm incentive approach that IID should employ to attract landowners and growers voluntarily into participation; (3) the improvements that should be implemented within the IID delivery system; (4) the need to improve measurement of farm deliveries; (5) provisions for fulfilling IID's early-year (2008 – 2010) water transfer obligations; and (6) near-term actions to ensure IID has sufficient capacity to meet its water transfer obligations. Importantly, recommendations 1 through 4 are not separable; rather, they form an integrated package that cannot be separated without implication to the viability and performance of the overall efficiency conservation program.

1 ***Recommendation #1: IID should target on-farm savings in the range of 180,000 to 210,000 acre-feet and delivery system savings ranging from 93,000 to 123,000 acre-feet, at program build-out.*** This mix of efficiency conservation savings provides most of the savings through the on-farm program without imposing unnecessarily high costs that jeopardize the overall financial viability of the efficiency conservation program. Importantly, it affords the financial "headroom" that will give IID the flexibility to deal with inevitable program uncertainties.

2 ***Recommendation #2: IID should use the Scaled Pay-for-Measures Hybrid Incentive approach to attract growers voluntarily into the efficiency conservation program and to achieve the targeted on-farm savings.*** The Scaled Pay-for-Measures Hybrid approach offers the best combination of cost-effectiveness, administrative ease, and – importantly – the increased likelihood that on-farm conservation measures will be operated at or near their potentials. No other approach is as effective, and each would increase the risk that IID will not be able to meet its future water transfer commitments within the available budget.

3 ***Recommendation #3: IID should implement seepage recovery and Integrated Information Management to achieve the targeted delivery system savings, and to enable the targeted on-farm savings.*** The analysis showed that extensive physical modification of the IID delivery system is both extremely expensive and unnecessary for a viable efficiency conservation program. The recommended improvements are a more modest combination of physical and operational changes that will provide cost-effective system savings and provide growers with the improved delivery services needed for implementing the on-farm conservation measures.

4 ***Recommendation #4: IID should implement improved measurement of farm deliveries. Consideration should also be given to equipping the farm delivery gates with automatic flow control to hold deliveries steady and radios to enable remote control.*** IID's existing methods of measuring farm water deliveries, while adequate for present water administration purposes, will become inadequate for purposes of verifying on-farm water savings and administering incentive payments based on water use criteria.

5 ***Recommendation #5: IID should rely on selected seepage recovery projects and on-farm and delivery system pilot projects to generate early year – 2008 through 2010 – water savings.*** Main canal seepage recovery systems can be constructed easily, provide the ability to scale savings to match the transfer schedule, and are easily verified. However, to the extent on-farm pilot programs produce verified savings, these could be combined with system savings to fulfill early-year water transfer requirements.

6 ***Recommendation #6: IID should take a series of steps to ensure it is ready to meet its near-term water transfer obligations.*** Decisions on near-term actions will serve two aims: (1) to ensure IID is ready to meet its most immediate water transfer requirements: and (2) to prepare for launching a more comprehensive program. These actions include both concrete steps to generate near-term water; and on-farm demonstration and system pilot projects to refine longer-term program approaches.

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