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OVERVIEW OF THE IMPERIAL IRRIGATION DISTRICT EFFICIENCY CONSERVATION DEFINITE PLAN

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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 their total annual water use.

In 2007, IID completed their Efficiency Conservation Definite Plan (Definite Plan) that outlined strategies for both delivery system and on-farm water savings, and evaluated various alternatives for implementing a program of integrated system and on-farm conservation measures. This paper summarizes the pertinent terms of the QSA as they affected development of the Definite Plan and presents a broad overview of the seven main work elements involved with developing the Definite Plan:

1. Outreach and Public Involvement
2. On-Farm Water Conservation Opportunities and Costs
3. Delivery System Modifications to Conserve Water and Support Improved On-Farm Water Management
4. Delivery/On-Farm System Conservation Program Interrelationships
5. Incentive Programs for On-Farm Conservation
6. Decision Support System for Evaluating Alternatives
7. Alternatives for Implementing Efficiency Conservation

The paper concludes with observations regarding some of the challenges and insights realized in developing the Definite Plan.

INTRODUCTION

A combination of factors forms the framework within which IID's Definite Plan was developed. These fall into three general categories: the *legal obligations* manifest in the QSA, the *physics and economics* of conserving water within the IID delivery system and

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on-farm, and the *institutional and political* landscape of the Imperial Valley and the Colorado River Basin, including the export areas. Development of the IID Definite Plan considered factors in all three categories. The QSA terms were negotiated prior to development of the Definite Plan and were accepted, a priori, as bounding conditions for plan development. The physics and economics of water conservation are foundational and led to highly detailed technical evaluation of IID's water delivery and on-farm irrigation systems. The sociology and politics of water management are essential to any successful water management initiative. In this case, emphasis was placed on involving IID growers in plan development, due to the importance of their participation in implementing the Efficiency Conservation Program (ECP) that would evolve from the Definite Plan.

When IID negotiated the QSA, its staff and consultants performed high-level analyses to determine the amount of water that could feasibly be conserved in IID and the cost of conserving it. However, those analyses did not provide a detailed plan that IID could follow to actually implement conservation measures. Decisions that were left open at the time of QSA negotiation, among others, included the mix of on-farm and distribution system water savings that IID should target to produce the conserved water for transfer and how the on-farm and distribution system conservation programs should be designed to work synergistically. The Definite Plan was developed to address these and a variety of technical issues, thereby providing a concrete basis for producing conserved water for transfer on the stipulated schedule and within the financial constraints of the QSA.

Owing to the nature of water rights and the large number of parties involved, the QSA is a complex package of agreements. However, there are just a handful of critical contract terms that governed formulation of the Definite Plan:

- The water to be transferred under the QSA must be produced by efficiency conservation, not by land fallowing or other means[4].
- IID must meet or exceed the conserved water transfer schedule (Figure 1). Water transfers begin in 2008 when just 4,000 acre-feet must be transferred, and gradually increase to the ultimate transfer amount of 303,000 acre-feet annually by 2026.
- Of the 303,000 acre-feet of total water savings, no less than 130,000 acre-feet must be produced by on-farm water savings. Thus, at program build out in 2026, on-farm savings could range from 130,000 to 303,000 acre-feet, and distribution system savings could range from zero to 173,000 acre-feet.
- Participation in the on-farm conservation program by IID landowners and growers must be voluntary; landowners and growers cannot be conscripted into the program, such as through an involuntary water allocation process. Furthermore, landowners and growers must be allowed to choose their own means of conserving water on-farm.

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[4] Under the QSA, land fallowing is allowed for a temporary period to generate water for transfer and for Salton Sea mitigation. Fallowing began in 2003 and must end by no later than 2017. Due to concerns about negative economic impacts, there is strong interest in the Imperial Valley to end fallowing as early as possible.

- Water savings, both on-farm and in the IID delivery system, must be verifiable.

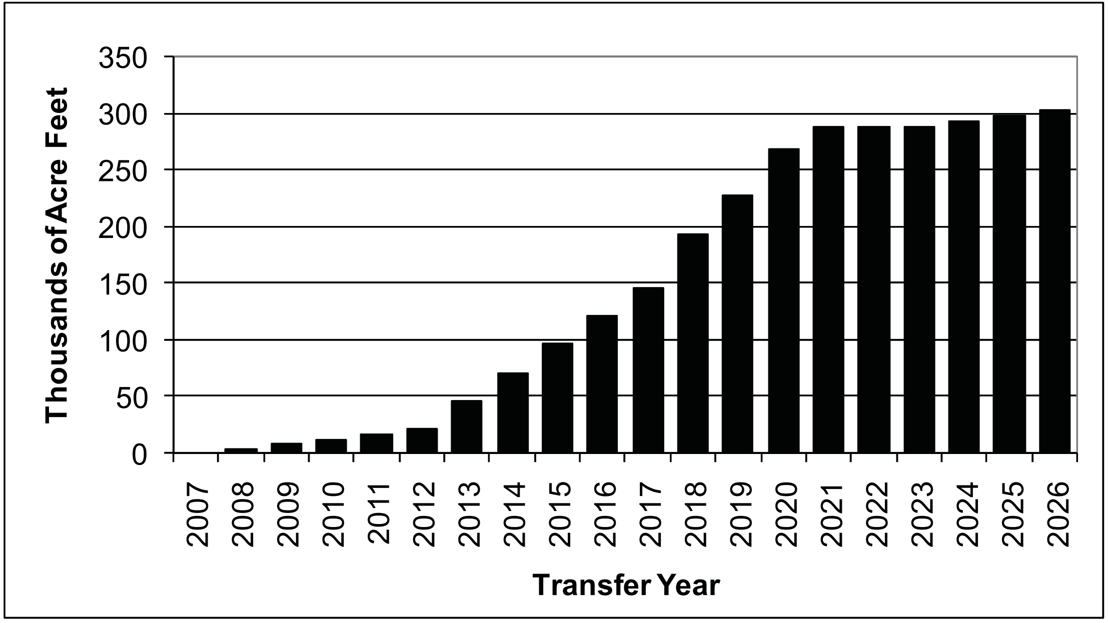

Figure 1. QSA water transfer schedule.

In addition to these requirements, IID established a number of criteria, or guiding principles, for development of the Definite Plan to ensure that it would be effective and implementable:

- The Definite Plan must be technically viable. It must rely on conservation measures and technologies that are proven and currently available, while allowing for the probability that new technologies will be developed during the life of the QSA.
- The on-farm and delivery system conservation programs must be integrated, recognizing that how water is used on-farm depends in part on how it is delivered, and, conversely, how the delivery system performs is influenced by the provisions allowed to water users for starting and ending their water deliveries.
- Implementing the conservation program involves risk due to the uncertainty in the costs and water savings associated with implementing conservation measures. These risks must be understood and shared fairly between IID and participating landowners and growers. This can be viewed as a condition that must be satisfied to attract a sufficient number of growers into voluntary participation.
- The overall conservation program must be cost-effective, meaning that its costs cannot exceed its revenues over the long term. Because of the voluntary nature of the on-farm program, and other factors, it is impossible to predict program costs with certainty. Also, program revenues are subject to re-determination according to provisions of the QSA. Contingencies should be provided to deal with these uncertainties.

Several key features were built into the process of formulating the Definite Plan in order to achieve these criteria. The process was designed to be participatory, in order to tap into the experience and views of IID staff, landowners and especially growers, who will be the ones responsible for implementing on-farm conservation. Additionally, the process was technically rigorous to ensure that the on-farm and distribution system components would work together, and would achieve the targeted program savings at the least cost. All available data were considered.

The Definite Plan was developed by a consulting team comprising engineers, economists, and other specialists from several different consulting firms, working under the direction of IID's executive program manager, Dr. John Eckhardt. Davids Engineering of Davis, California, and Keller-Bliesner Engineering of Logan, Utah, were the lead consulting firms. Western Resource Economics, also based in Davis, and CONCUR, based in Berkeley, California, contributed key members of the Team. The Irrigation Training and Research Center, California State Polytechnic University, San Luis Obispo, California provided detailed delivery system analyses.

The seven main work elements involved with development of the Definite Plan are as follows:

1. Outreach and Public Involvement
2. On-Farm Water Conservation Opportunities and Costs
3. Delivery System Modifications to Conserve Water and Support Improved On-Farm Water Management
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An overview of each element is presented in the following sections, along with concluding remarks. Detailed descriptions can be found in the six accompanying papers[5].

OUTREACH AND PUBLIC INVOLVEMENT

A key facet of the Definite Plan initiative was the Public Involvement Plan, an effort intended to involve a broad cross-section of growers and farm landowners in the development of the Plan. It also aimed to ensure that the broader community was aware of and had input into the initiative. Specific objectives included:

- Foster the awareness and active involvement of Valley growers and farm landowners.
- Help the Definite Plan Team focus its needs for information gathering, analysis, and synthesis to assure the success of the program.

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[5] Work Elements 5 and 7 are covered in one accompanying paper; the other elements each have a paper dedicated to them.

- Reinforce the Definite Plan as a well-structured, transparent process that uses best readily available information.
- Identify on-farm conservation opportunities and incentives that can be embraced by growers and farm landowners.
- Inform the broader community of the approach, goals, and emerging direction.

The Definite Plan incorporated two distinct efforts: an extensive Grower Participation Plan (GPP) and a more streamlined Public Outreach (PO) effort. Below is a brief description of each.

The intent of the GPP was to elicit input to inform the technical analyses, seek feedback on evolving approaches and work products, and build legitimacy for the overall effort and final work products. In particular, the Team sought grower input into and feedback on three specific areas: Economic Incentives; On-Farm Technical Demonstration Projects; and On-Farm System Costs, Performance, and Service Requirements. The Team also sought grower feedback on the linkage between on-farm efficiency conservation measures and the IID delivery system. A key piece of the effort was the creation of an On-Farm Technical Advisory Committee, a standing body of 12 growers who met regularly with the Team to review and comment on the evolving analysis. Other facets included on-farm demonstrations, a grower/landowner survey, and one-on-one meetings.

The general PO effort, while more limited in scope, was nonetheless an important component of the effort. The Valley's economy is grounded in agriculture; what occurs on the farm is of interest and importance to the broader community. Accordingly, the Public Outreach effort was intended to – at strategic junctures – provide updates to and seek feedback from the general public and those growers who elected not to participate in grower-specific activities. Specific strategies included issuing bi-monthly project newsletters, developing and maintaining a project web site, and conducting periodic public workshops and other outreach activities.

ON-FARM WATER CONSERVATION OPPORTUNITIES AND COSTS

The IID water balance developed as a component of the Definite Plan was used to establish the total *potential* on-farm (and delivery system) water savings within IID. The water balance revealed that 2.55 million acre-feet (maf) were delivered to IID farms, on average, over the period 1998 through 2005. Of that amount, 1.80 maf were consumed as crop ET, with the residual split nearly evenly between tailwater (433,000 acre-feet) and tilewater[6] (417,000 acre-feet). Tilewater is generally considered a requirement to maintain favorable salinity levels in the crop root zone. It is generally not targeted for conservation, except on the relatively few fields with permeable soils where more tilewater occurs than is needed to maintain acceptable rootzone salinity. Tailwater occurs almost entirely from surface-irrigated fields, which are dominant in IID. It is the primary target of the on-farm water conservation program.

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[6] Tilewater is applied irrigation water that infiltrates and drains through the soil carrying away potentially damaging salts. It is called "tilewater" because most fields in IID have buried tile drains beneath them that collect and remove it.

While the water balance reveals the volume of tailwater that could potentially be conserved, it was recognized at the outset that only some portion of the tailwater could be saved economically, within the financial limits of the QSA. One of the main objectives of the on-farm analysis was to determine the volume of *practical* water savings. This involved identifying the technically sound conservation measures that can be implemented to conserve tailwater. These measures fall broadly into two categories: ones that work to *reduce the production of tailwater* from irrigated fields, and ones that *reuse tailwater*. For example, irrigation scheduling, with emphasis on selecting not only the appropriate time to irrigate, but also selecting a combination of delivery rate and duration, has the potential to reduce tailwater production. Conversion from surface to drip or sprinkle irrigation also has the potential to reduce (or nearly eliminate) tailwater. Tailwater recovery, whereby water is captured from a field and reapplied to either that field or another one, is an example of tailwater reuse. Once the various conservation measures were identified, their adaptability to various combinations of IID crops and soils was defined.

Costs were developed for each conservation measure relative to field and crop characteristics, with field size and crop type being the main keys. This was approached on an incremental basis by identifying the additional costs, above those involved with existing irrigation practices, associated with adopting the various conservation measures. All costs were addressed, including capital, operation and maintenance costs. Cost savings associated with conservation measures that growers would likely take into account were also estimated. These include the reduced costs of water, fertilizer (which in IID is commonly applied in the irrigation water, or “water run”), and, for selected conservations like drip irrigation, crop yield increases.

It was also necessary to estimate the amount of water that could be saved by the various conservation measures so that their cost-effectiveness, or cost per acre-foot of water saved, could be estimated. This proved to be the most challenging aspect of the on-farm analysis, due to two primary factors. First, it was recognized that the decision to adopt conservation measures would be made by growers and landowners on a field by field basis, given each field’s unique conservation implementation costs and water savings. Profiling of IID historical water use at each field revealed wide variability in water use, even within families of fields with the same crop and soil types. This suggested wide variability in potential conservation among fields, and therefore conservation cost-effectiveness. This strongly suggested that the analysis should include each field explicitly, rather than all fields being represented by proxy using a set of typical, representative fields. Moreover, each crop season at each field has its unique characteristics. Thus individual crop-seasons were used as the basic element of the on-farm analysis.

Addressing crop-season explicitly led to the second challenging factor, which was error and uncertainty in some historical records of water delivery to some fields at some times. Relative to other irrigation districts in the western United States, especially those with open canal delivery systems, IID’s water measurement methods and protocols are excellent and have been adequate for supporting IID’s water operations and volumetric water charge system. However, at any particular farm delivery gate and time increment, errors can exist for a number of reasons. These include mistakes in the manual observation and recording of delivery rates by IID operators (zanjeros), variability among gates in their hydraulic characteristics, and "moving" water, the name given to water recorded as delivered to a field at one gate but actually used on a field at another gate[7]. Various techniques were employed to correct and compensate for error in IID's delivery records to the extent possible. The main one was to rely most heavily on the results for fields with the highest quality delivery records. The remaining error that could not be corrected or compensated for was considered in the contingencies applied during data interpretation.

Estimates of the amount of water that each field (during each crop season) would use if a particular conservation measure was adopted were based on a relative shift in irrigation performance, with the ratio of consumptive use to delivered water, called the consumptive use fraction (CUF) used as the indicator of performance. For groups of fields with the same crop and soil characteristics, called families, existing CUF distributions were plotted depicting recent historical performance. For each CUF family and applicable conservation measure, the CUF distribution was shifted relative to the historical distribution, and the new CUF denoted for each field within the distribution. This CUF shift was used to compute the amount of water that *would be* delivered if the conservation measure was applied. The difference between historical water use and predicted water use based on the CUF shift represents water savings.

Data tables were developed containing cost data and performance shift characteristics for all fields and possible conservation measures in IID. These were used in the Demand Generator, a component of the Imperial Irrigation Decision Support System (IIDSS), for development and testing of incentive payment structures and program alternatives.

DELIVERY SYSTEM MODIFICATIONS TO CONSERVE WATER AND SUPPORT IMPROVED ON-FARM WATER MANAGEMENT

IID's water delivery system consists of an extensive network of more than 1,600 miles of open, branching main and lateral canals. They are sloping, upstream-controlled channels designed to convey the large intermittent water deliveries needed for effective surface irrigation. The 1998 through 2005 IID water balance revealed that, on an annual average, 2.88 maf[8] are diverted from the Colorado River into the delivery system, of which 2.55 maf are delivered to IID farms. The difference of 330,000 acre-feet represents system loss, including 3,000 acre-feet of main canal spillage, 121,000 acre-feet of lateral canal spillage, 86,000 acre-feet of seepage and 22,000 acre-feet evaporation (net of precipitation). There is no practical way to reduce evaporation, so it was not targeted.

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[7] Moving water occurs for various reasons, and, from a water administration perspective, is inconsequential since the correct volume of water is recorded and billed to the customer. But the errors introduced in the record, over-recorded delivery at one gate and under-recording at another, are problematic from an analytic perspective.

[8] Does not include All American Canal loss. Measurement is taken at just upstream of Mesa Lateral 5 at the beginning of the IID deliveries.

Main canal spillage is highly intermittent and is generally associated with precipitation events (when ordered water is refused due to rain, causing the main canal to spill), so it is not a prime conservation target either. Canal seepage and lateral canal spillage were the two primary conservation targets within the IID delivery system.

In general, as a result of past conservation programs, IID has identified and lined lateral and sub-main canals with high seepage characteristics. The remaining unlined canals were reviewed, revealing that only a very few of these reaches could be lined cost-effectively, and the savings would be small (<3,000 acre-feet). Thus, lateral canal lining was not a significant component of delivery system conservation.

Various reaches of IID's main canals have had interceptor drains installed along them on the down-gradient side, parallel to the canal. Originally, all of these were open drains that intercepted seepage from the main canal to prevent water-logging of adjacent, down-gradient fields. All of the intercepted water, most of it high quality, was discharged to the Salton Sea through the IID drainage system. In the 1960s and 1970s, IID converted some of these drains along the upper reaches of the East Highline (EHL) Canal to buried interceptor pipelines to capture the seepage and return it to the canal. As part of the Definite Plan development, remaining open interceptor drains along the EHL, All-American, and Westside Main canals were investigated. It was found the drains capture essentially all of the seepage that occurs from the canals, and therefore there is no need to convert these drains to buried pipes. Instead, intercepted flows can be captured and returned to the canals by simply installing check structures and pumping plants along the drains. Between 40,000 and 50,000 acre-feet of seepage can be conserved in this manner for about $15 per acre-foot, making it by far the cheapest conservable water.

Spillage occurs from the ends of IID lateral canals because it is practically impossible with upstream controlled system for operators to exactly match the flow put into the lateral canal with the water deliveries and losses from the lateral canal. This is due primarily to the inherent nature of open canal operation, where the point of water control (at the head of the lateral canal) is typically distant from the point(s) of delivery. Any error in the delivery of water into the lateral canal, or change in delivery demand, results in a supply–demand mismatch. To mitigate the risk of shorting delivery to users, operators typically order a little more water into a lateral canal than needed to meet deliveries, sometimes resulting is spillage. Spillage also results when delivery gates are not opened at the correct time, or when deliveries are shut off before a corresponding cut can be made at the head of the lateral canal, or for a variety of other reasons.

The approach to reducing spillage from a sloping canal system involves just a few kinds of system improvements, which fall into the categories of either reducing the production of spillage or capturing it. Fortunately, the same kinds of improvements that can be applied to reduce lateral canal spillage also allow the lateral canals to be operated with greater sensitivity to changes in on-farm demands, thereby enhancing on-farm water management. The types of system improvements considered for the Definite Plan are as follows:

- Real-time, remote monitoring of lateral canal spillage and other system conditions, with the information provided to zanjeros in the field.
- "Zanjero" (lateral canal-level) regulating reservoirs, which put regulating capacity closer to the points of water delivery and under the zanjero's control, thereby enabling a closer match between water supply and demand.
- Main canal reservoirs to enable more flexible delivery of water into lateral canal headings, as requested by the operators.
- System inter-connections and interceptor canals, which collect and reuse lateral canal spillage, some by gravity, others by pumping.
- Upgraded spill structures.
- Non-leak lateral canal check gates.

Alternative combinations of these improvements were formulated, ranging from capital-intensive, hardware oriented formulations to ones structured more around improved system management (but also involving significant capital cost). It was discovered early on that intensive, hardware oriented formulations are not affordable within the financial capacity of the QSA, leading to a focus on improved delivery system management, especially of lateral canals.

DELIVERY/ON-FARM SYSTEM CONSERVATION PROGRAM INTERRELATIONSHIPS

Achieving on-farm water conservation generally implies increasing water ordering and delivery flexibility so that growers can order water precisely according to their irrigation schedules, have it delivered as ordered, and adjust the delivery if needed before or during the irrigation event. This is especially true for surface irrigation methods like those used extensively in IID. Yet with an open channel delivery system, providing more delivery flexibility makes it more difficult to match system water supply with on-farm demand, thereby increasing the probable frequency, rate and duration of spillage, and therefore the spillage volume. Development of Definite Plan alternatives accounted for this interrelationship, and the tradeoff it denotes, to ensure that *net water savings* would be sufficient to achieve QSA requirements.

The interrelationship between system and on-farm water conservation was handled analytically using the concept of "rejected water", which is water ordered into the system by growers with the expectation of its need, but not delivered because the actual need for water turned out to be different than expected[9]. Rejected water typically occurs in two ways, including reduction of the delivery rate during an event and early shutoff at the end

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[9] This is the central challenge of upstream-controlled irrigation delivery systems serving surface-irrigated fields when high levels of efficiency are being sought. No matter how well an irrigator schedules the delivery of water based on anticipated field conditions, there will likely be too much or too little water relative to actual needs, which cannot be known until the irrigation event is in progress or nears completion. Because the cost and inconvenience of not finishing a planned irrigation on time is appreciable, in terms of management and labor requirements, growers tend to order more water than will probably be needed, and to reject the unneeded portion, if permissible under the rules for water delivery. If the unneeded water cannot be rejected (to the delivery system), then it will be discharged as tailwater.

of the event. When these changes can be anticipated, water can be cut from the lateral canal heading in advance and lateral canal spillage minimized. In the Definite Plan analysis, this was called “upstream” rejected water because it is held in the main canal upstream of the delivery. Conversely, if the rejection cannot be anticipated, it unavoidably passes downstream and is either spilled or intercepted and stored for reuse. This is called “downstream” rejected water. Rejected water occurs now in IID corresponding to the level of delivery flexibility currently provided; rejected water is expected to increase as delivery flexibility is increased to enable on-farm efficiency conservation under the Definite Plan.

Rejected water characteristics (or functions) were assigned to each of the on-farm conservation measures included in the on-farm analysis, reflecting the degree of delivery flexibility needed to achieve each measure’s characteristic performance. The rejected water functions were used in the Demand Generator (see section below titled Decision Support System for Evaluating Alternatives) to estimate rejected water volumes under various on-farm conservation scenarios. These volumes were passed to the MODSIM model for system analyses.

INCENTIVE PROGRAMS FOR ON-FARM CONSERVATION

The success of the Definite Plan depends heavily on the effectiveness of its on-farm incentive program. As a voluntary program, the incentive structure and payments must be attractive enough to entice widespread grower participation. Three approaches or incentive payment options were considered: those that pay for performance or results (such as measured reductions in delivered water or tailwater); those that pay for actions (such as implementing specific on-farm conservation measures); and hybrids, where a portion on the payment is based on results and a portion on actions.

Within each approach, many formulations of payment rates, water use baselines, and other payment parameters were evaluated. An analytical tool called the Demand Generator was developed to simulate the adoption of on-farm conservation measures under different incentive approaches. The Demand Generator evaluated the costs, payments, and other benefits that each field and crop-season in IID’s historical database would face under an incentive approach, and selected the grower’s preferred decision based on highest expected net return.

The analysis indicated that four incentive approaches appeared to be feasible (i.e., they could generate enough participation to achieve the needed savings within the financial constraints of the program). These four included two that paid growers solely based on the conservation measures they implemented (so-called “pay-for-measures” approaches), and two hybrid approaches (including both a pay-for-measures payment and a results-based payment).[10]

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[10] None of the purely performance-based incentive programs appeared viable for a combination of reasons, including: establishing accurate field-level water use baselines, likelihood of significant enrollment bias, concerns about perceived fairness of payments, and large payments to growers for fields that may have little or no real conservation.

DECISION SUPPORT SYSTEM FOR EVALUATING ALTERNATIVES

Over recent years, IID has been developing a set of analytic tools to enable evaluation of its water delivery system. Collectively, these tools are referred to as the Imperial Irrigation Decision Support System (IIDSS). Prior to development of the Definite Plan, the main IIDSS tool was a MODSIM (Labadie, 2006) link-node model of the IID delivery system. It was developed to support evaluation of environmental effects, especially changes to flows and water quality in IID's canals and drains that could be expected under a broad range of alternative water conservation programs.

A number of factors encountered in developing the Definite Plan required that IIDSS be updated and expanded. The primary factors were as follows:

- The need to simulate on-farm decisions on all of the more than 5,500 fields served by IID, not just a sample of them. This results from the voluntary nature of the on-farm conservation program, and the realization that growers will select from among all their fields the ones that will maximize their net financial benefit, not necessarily the ones that maximize water conservation.
- The need to design and test a wide range of possible on-farm conservation incentive structures under a consistent set of assumptions and conditions.
- The need to account for the interaction between the more than 5,500 farm delivery gates and the IID delivery system, through the tracking of changes to delivered water, rejected water and system spillage resulting from adoption of conservation measures. This is necessary to ensure that net water savings are sufficient to meet the QSA water transfer schedule.
- The need to account for changing land use in IID and its effects on irrigated agriculture and the IID delivery system, especially urbanization in and around the cities of El Centro, Imperial and Brawley.

The principal components of IIDSS, created or upgraded to support development of the Definite Plan are as follows:

- A GIS of IID's water delivery system, which consists of more than 1,600 miles of main and lateral canals linking over 5,500 water delivery points.
- The Demand Generator for assembling time series of demands and analyzing the effects of various on-farm conservation incentive programs on those demands.
- Geo-MODSIM (Triana and Labadie, 2007), the link-node network solver program which assembles the network from the GIS representation of the system, simulates routing water through the canal system to delivery points, and computes total IID water demand while accounting for predicted spills, seepage and evaporation losses associated with various alternative canal and operation configurations.

- Various databases of gaged flows, delivery details, field characteristics, and conservation measure attributes.
- A set of alternative comparison tools, which assist in summarizing results and facilitating the spatio-temporal analysis of large amounts of simulated data.

These tools were indispensable in the design and testing of alternative on-farm conservation incentive structures, and accounting for the effects of delivery system and on-farm conservation measures on system performance.

ALTERNATIVES FOR IMPLEMENTING EFFICIENCY CONSERVATION

Building blocks for alternatives formulation were the promising, incentive-driven approaches for achieving on-farm water conservation, and the set of delivery system projects for reducing losses and improving delivery flexibility. Alternatives were defined primarily by the volumes of water targeted for on-farm and system savings, respectively, to provide the 303,000 acre-feet of annual conservation savings at program buildout. Seven conservation mix alternatives were formed, ranging from a “maximum on-farm” alternative designed to produce 280,000 acre-feet from on-farm conservation and 23,000 acre-feet from system savings, to a “maximum delivery system” alternative designed to produce 158,800 acre-feet on-farm and 144,200 acre-feet from system savings.

For each of the seven mixes of on-farm and system savings, the four most promising incentive structures were evaluated to achieve the on-farm savings component. It was found that, from among the resulting 28 unique alternatives, half were economically viable, meaning that their costs were less than the available net revenue, and half were not. There were appreciable cost differences among the viable alternatives, with some being well below the cost threshold, and others only marginally below. Analysis of the alternatives suggested an optimal mix of between roughly 180,000 and 210,000 acre-feet of on-farm water savings combined with 93,000 to 123,000 acre-feet of delivery system conservation savings.

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.

CONCLUDING REMARKS

The extensive analyses and rigorous processes used to formulate the Definite Plan revealed a number of important and interesting findings. Some of the more important findings and observations are summarized briefly below.

- Improved measurement of water delivered to fields is critical for implementing an effective on-farm conservation program. It is essential to verify savings at the field level and to establish water use for incentive payments under some incentive approaches.

- For small incremental cost, the improved measurement options examined may also provide automated flow regulation and control, reducing operator level and improving water delivery to the farms.
- Changes in delivery system management, supported by key automation elements with real-time data in the hands of system operators, allow prevention of nearly as much lateral canal spillage as much more expensive hardware only solutions. The key lies in operator training and a paradigm shift in system operation.
- The uncertainty in potential conservation of certain actions and the response of growers to incentive programs, suggests a test-period to further refine conservation savings estimates and test response of delivery system operators and farmers to the changes.
- The voluntary nature of the on-farm program suggests an adaptive management approach to implementation, with sufficient flexibility to accommodate unforeseen issues and new advances in irrigation technology over the life of the program.
- The analysis described in this paper and the companion papers focused primarily on quantitative evaluation of options and alternatives. However, other aspects of a conservation program were also of great interest during the Definite Plan process.

    - "Equity" among growers was an important concern throughout the Definite Plan development: the distribution of program costs and benefits among growers and whether all categories of growers would have an opportunity to participate. Growers expressed an interest in understanding the potential for different approaches to pay for existing, ongoing conservation. Opinions varied about whether and to what extent already-implemented conservation should be compensated.
    - Beyond a simple comparison of costs to benefits, the Definite Plan analysis also suggested a strong need for "financial headroom" – the difference between the projected cost of implementation and the available revenue – as a buffer to address implementation uncertainties, ensure IID can meet its water transfer obligations within the financial means of the program, provide adequate incentive to cover the farmer-perceived risk and encourage adequate participation and, if desired, provide some compensation for existing conservation.

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