Urbanization of Irrigated Land and Water Transfers

A USCID Water Management Conference

Scottsdale, Arizona
May 28-31, 2008

USCID
The U.S. society for irrigation and drainage professionals

Edited by

Robert S. Gooch
Salt River Project

Susan S. Anderson
U.S. Committee on Irrigation and Drainage

Published by

U.S. Committee on Irrigation and Drainage
1616 Seventeenth Street, #483
Denver, CO 80202
Telephone: 303-628-5430
Fax: 303-628-5431
E-mail: stephens@uscid.org
Internet: www.uscid.org

IMPERIAL IRRIGATION DISTRICT EFFICIENCY CONSERVATION DEFINITE PLAN — DELIVERY/ON-FARM SYSTEM CONSERVATION PROGRAM INTERRELATIONSHIPS

Bryan P. Thoreson, Ph. D., P.E.[1]
John R. Eckhardt, Ph. D., P.E.[2]
Grant G. Davids, P.E.[3]
Andrew A. Keller, Ph.D., P.E.[4]
Byron Clark, P.E.[5]

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. This paper, one of seven detailing the findings of the ECDP, describes the interrelationships between the delivery system capabilities, or service levels, and on-farm water conservation actions.

To achieve high combined delivery system and on-farm efficiencies, the delivery and on-farm systems must work in concert. Achieving the highest on-farm efficiencies requires the delivery system to accept water originally intended for delivery but rejected and to reroute the water to another delivery or store it temporarily in a reservoir, with the ultimate effect of reducing overall diversions. The amount of water ordered that would be expected to be returned to the system following implementation of on-farm conservation measures (termed dependent savings) was estimated and passed to the delivery system part of the Imperial Irrigation Decision Support System (IIDSS). Within IIDSS, the quantity of dependent savings that could be rerouted or stored was estimated and used to quantify net water savings. Incorporation of these interrelationships between on-farm conservation and net reductions in diversions at the district level was critical to evaluating conservation program alternatives.

---

[1] Project Manager, Davids Engineering, Inc. 1772 Picasso Avenue, Suite A, Davis, CA 95618, 530-757-6107; bryant@de-water.com

[2] Executive Program Manager, QSA-IID/SDCWA Water Transfer, Imperial Irrigation District, 333 East Barioni Boulevard, Imperial, CA 92251, 760-339-9736; jreckhardt@iid.com

[3] President, Davids Engineering, Inc. 1772 Picasso Avenue, Suite A, Davis, CA 95618, 530-757-6107; grant@de-water.com

[4] Vice President, Keller-Bliesner Engineering, LLC, 78 East Center, Logan, UT 84321, 435-753-5651; akeller@kelbli.com

[5] Project Manager, Davids Engineering, Inc. 1772 Picasso Avenue, Suite A, Davis, CA 95618, 530-757-6107; byron@de-water.com

INTRODUCTION AND BACKGROUND

Water use in the West is changing, and nowhere is that being felt as acutely as the Imperial Irrigation District (IID), a 450,000-acre district in Southern California where longstanding agricultural water users are under intense pressure to transfer water to the region's ever-thirsty and ever-expanding urban areas. Four years ago, the IID agreed to launch a massive conservation program that would free up roughly 10 percent of its water for transfer to San Diego and others. The heart of the agreement called for the District to generate more than 300,000 acre-feet through a combination of District and voluntary on-farm efficiency conservation savings. In 2007, IID completed their Efficiency Conservation Definite Plan (Definite Plan) that outlined strategies for both delivery system and on-farm water savings. This paper, one of seven detailing the findings of the Definite Plan, addresses on-farm conservation.

Achieving the highest on-farm efficiencies, particularly with surface irrigation, requires the ability to adjust the irrigation flow rate and time of application to match the soil intake characteristics at the time of the irrigation (Merriam, 1964). These intake characteristics vary from irrigation to irrigation and cannot be predicted in advance with certainty. This variability requires even the best managers to make changes to the stream size and duration of each irrigation event based on field observations to achieve the highest efficiencies (Walker and Skogerboe, 1987).

To prevent increased lateral spills potentially resulting from reduction of delivery flow rates and early shutoffs, flow at lateral headings must be reduced in a timely manner and the water re-routed to storage or another farm delivery. Especially for management improvements, the high on-farm efficiencies necessary to generate the required conservation volumes demand unprecedented levels of integration between IID's water delivery system and IID's growers.

The need for these increased levels of integration and determination of the volume of increased canal system reservoir storage required were important factors driving the development of the Imperial Irrigation Decision Support System (IIDSS), described in an accompanying paper (Keller, et al, 2008). IIDSS was configured to model the effects on the delivery system resulting from anticipated changes in delivery rates and durations associated with on-farm actions (termed conservation measures, or CMs) taken to achieve water savings.

This paper briefly outlines the constraining physical and institutional settings, describes the range of conservation measures considered and their anticipated effects on the delivery system, the modeling of these effects in the IIDSS, the modeling results and conclusions.

PHYSICAL AND INSTITUTIONAL SETTING

IID is located in Southeastern California. The land slopes gradually northward from the Mexican border to the south shore of the Salton Sea. Water for IID is released, per IID's water order, from Hoover Dam and routed down the Colorado River to Imperial Dam near Yuma. At Imperial Dam, water is diverted into the All American Canal (AAC) for delivery to IID's service area. Water released at Hoover Dam requires between three and four days to arrive in IID's service area. Because little storage capacity exists within IID's service area and between Hoover Dam and IID's service area, any adjustments to the flow released from Hoover Dam must be small. This restricted capability for adjustment coupled with IID's practice of accepting water orders up to noon for delivery on the following day leads to the need for a mechanism of matching daily demand to the volume of water approaching the district.

IID matches the demand to the orders by ordering sufficient water to satisfy about 80 percent of the predicted demand. The IID then selects, based on defined criteria, orders to *carry over* until the next day to reduce the demand to match the ordered supply. This 20% under-ordering strategy has enabled IID to accept all the water ordered from Hoover Dam, except for rare instances of rain in great enough amounts to lead growers to cancel orders.

To maximize on-farm efficiency, growers must supply water to the crops at the right time and in the correct amount. IID provides growers the opportunity to order water any day they select and four out of five times (80% of the time); they will receive the water on that day. The volume of water is determined by the combination of the duration and rate. Growers select any rate they desire that does not exceed the capacity of the delivery gate to the field and are allowed to adjust the rate downward with three hours notice. Delivery rates can also be adjusted upward if water is available. IID requires growers to specify the order durations in 12-hour blocks.

Less than perfect estimates of the volume of water required and less than perfect measurements of the volume supplied result in the need to sometimes shut off water early and sometimes keep water longer. IID allows grows to shut off early when a three-hour notice is provided so that the water can be diverted to storage or another delivery. In addition, growers are often allowed to run two to three hours long, or up to 12 hours long if a finish head is requested not less than 15 hours before the delivery is scheduled to end.

These parameters within which growers are allowed to order and manage water with IID influence the effectiveness of the various conservation measures that may be applied to conserve water on farm. Without proper coordination with the delivery system, conservation measures operating within the framework of these rules and regulations, have the potential to conserve water on farm only to then spill it from the delivery system.

CONSERVATION MEASURES AND REJECTED WATER FRACTIONS

Conservation measures likely to be considered when water conservation incentives are offered were identified through consultation with Imperial Valley growers. The range of potential conservation measures identified includes measures that are currently in use in the Valley as well as those that may be considered in the future (Clark, et al, 2008).

Tailwater is the primary flow path targeted for reduction; however, adoption of conservation measures will potentially affect all on-farm flow paths, including delivered water, tailwater, tilewater, and crop evapotranspiration. Additionally, reductions in delivered water may occur within the normal delivery schedule or may require additional flexibility to shut off or reduce flows during an irrigation event. Conservation measures are characterized with respect to the amount of savings dependent on additional flexibility from the system.

Dependent savings is the portion of delivered water savings that results from changes to delivery flow or duration that are provided outside of IID's normal provisions for water delivery. Dependent savings for each CM were parameterized as a fraction of total savings, f_{DS}. Dependent savings ($DW_{sav,dependent}$) were estimated for each field-season and CM combination according to Equation 1.

$$DW_{sav,dependent} = f_{DS} DW_{sav} \qquad \text{(Eq. 1)}$$

Values of f_{DS} were developed for each CM based on the baseline irrigation method and are listed in Table 1. The derivation of these values is based on the mechanisms by which each conservation measure conserves water. First, if the conservation mechanism does not require delivery adjustments, the dependent savings fraction is estimated to be zero. Scientific irrigation scheduling, which as defined for the Definite Plan, simply leads to better initial estimates of the delivery flow rate and duration required, is an example of a CM that does not depend on delivery adjustments. Second, if the conservation mechanism requires delivery adjustments and includes on-farm storage, the fraction of savings that cannot be stored is estimated. Pressurized irrigation systems require a fixed flow rate and are anticipated to be operated in 12-hour and/or 24-hour blocks, thus, not requiring any additional flexibility.

DELIVERY SYSTEM IMPACTS DUE TO ON-FARM CONSERVATION MEASURES

Lateral spillage[6] makes up the largest portion of IID delivery system losses, accounting for over half the total system losses and making up 70 percent of the potential conservable system losses. Some spillage is unavoidable and must be intercepted to be conserved. Other spillage can be reduced by improving system operations.

Observation of 15-minute recorded spillage hydrographs indicates that spillage is comprised of two components: an underlying base flow component and a variable component. The base component is related to the number of delivery gates and the existence of one or more service pipes (a service pipe supplies non-potable water to a farmstead). The variable component tends to cycle in association with the lateral

---

[6] There are four general types of spills, or operational discharges, within the IID distribution system whereby excess delivery system water is discharged to drains: lateral spills, main canal spills, reservoir spills, and interceptor system spills. This discussion focuses on the first of these, lateral spills, which are by far the most numerous and significant in terms of total spill volume.

Table 1. Dependent Savings Fractions for CMs

	Dependent Savings Fractions			
Conservation Measure	**Row**	**Flat**	**Drip**	**Sprinkle**
Scientific irrigation scheduling	0.00	0.00	0.00	0.00
Scientific irrigation scheduling and event management	0.33	0.41	NA	NA
Minor management and physical improvements	0.00	0.00	0.00	0.00
Tailwater recovery systems with minimal storage	0.40	0.40	NA	NA
Tailwater recovery systems with minimal storage, extended delivery[7]	0.20	0.20	NA	NA
Tailwater recovery systems with small pond	0.30	0.30	NA	NA
Tailwater recovery systems with small pond, extended delivery	0.10	0.10	NA	NA
Tailwater recovery systems with big pond	0.20	0.20	NA	NA
Tailwater recovery systems with big pond, extended delivery	0.00	0.00	NA	NA
Drip irrigation without reservoir	0.00	0.00	NA	NA
Drip irrigation with reservoir	0.00	0.00	NA	NA
Sprinkle irrigation without reservoir	0.00	0.00	NA	NA
Sprinkle irrigation with reservoir	0.00	0.00	NA	NA
Center-pivot irrigation, non-cropped corners	0.00	0.00	NA	NA
Center-pivot irrigation, cropped corners	0.00	0.00	NA	NA
Level basin irrigation, normal delivery	0.00	0.00	NA	NA
Level basin irrigation, flexible delivery	0.74	0.74	NA	NA

NA = Not Applicable

operational schedule, increasing a couple of hours before delivery setup and falling a few hours after. The early rise before the normal delivery setup time is associated with *rejected water* that results from irrigations finishing in less time than the 12 or 24-hour water order period. This is the volume of water that is returned to the delivery system from the farm due to delivery rate and duration adjustments during an irrigation event. The dependent savings discussed earlier result in *rejected water* in the lateral. To conserve this water, it must be prevented from spilling from the lateral. Starting, ending, and changing deliveries also contribute temporary flows to spills, which settle out a few hours after lateral setup is complete.

For example, a grower orders 15 cfs for 24 hours, but realizes after 18 hours that irrigation has proceeded faster than expected (perhaps because the estimated volume required was slightly high) and the irrigation will be complete in 21 hours. The grower calls IID and asks for his order to be turned off after 21 hours. In this example, three hours of 15 cfs of flow is *rejected water*. By requesting that his delivery be shut off three hours early, the grower has conserved this water. To ensure the water is conserved and not spilled, the delivery system must be capable of routing the *rejected water* to storage

---

[7] Extended delivery is an operational strategy of reducing the flow rate and extending the duration to more effectively use the tailwater generated as a supply during the irrigation event.

or to another delivery. Characterization of *rejected water* according to the delivery system's ability to store and ultimately re-route *rejected water* to another delivery leads to two types: downstream and upstream.

Rejected water resulting from early order completion can be retained in the main canal if the water flowing into the lateral can be reduced in a timely manner. This is referred to as *upstream rejected water*. By keeping the water in the main canal system the options and likelihood of being able to store the rejected water and use it for another delivery are greatly enhanced. This is the purpose of the 3-hour notification rule described earlier. If the lateral heading cannot be reduced in a timely manner, the *rejected water* flows past the rejecting delivery gate and on downstream where it is diverted through lower open delivery gates, spills, or is intercepted, stored, and routed for use elsewhere. This latter type of rejected water is referred to as *downstream rejected water*.

On-farm conservation is anticipated to result in more of both types of *rejected water* than exists under current conditions. *Rejected water* occurs given the existing level of on-farm conservation. The average annual (WY1998 - WY2005) downstream rejected water was 21,000 AF. The average upstream rejected water was 76,000 AF/year. These existing levels of *rejected water* are expected to increase as the intensity of on-farm conservation increases.

To be conserved and not spilled, *rejected water* must be intercepted downstream or cut out upstream. Either generally requires storage so that the supply of *rejected water* can be matched with demand. Furthermore, *rejected water* routed downstream in tapered laterals could overtop the laterals if the downstream capacity is insufficient to carry the rejected flow on top of the normal flows. Hence, understanding the nature and fate of *rejected water*, and determining how it might be conserved by various system configurations was an important analytical aspect in the development of IID's Definite Plan. This understanding was developed through modeling in IIDSS.

DELIVERY SYSTEM MODERNIZATION OPTIONS TO CAPTURE AND REUSE REJECTED WATER

Two modernization and improvement scenario bookends were formulated including specific technical actions for the entire IID distribution system. The first scenario focused on spillage reduction with little change in delivery flexibility. The second, termed the maximum delivery system with delivery flexibility option, considered both spillage reduction and improved flexibility of water delivery including facilities to capture and reuse *rejected water*.

When it became evident that even the low bookend was not economically feasible, a least-cost option was developed by selectively removing high capital cost components from the low bookend while retaining key Supervisory Control and Data Acquisition (SCADA) and automation technologies.

This least-cost bookend was termed “Integrated Information Management” (IIM). IIM focuses on utilizing SCADA technology to set up an extensive real-time monitoring system for lateral canal spill and to automate all the lateral headings. Reservoir capacity would be increased by 2,266 acre-feet with three new and two upgraded main canal reservoirs and up to 27 additional small zanjero-controlled reservoirs to be located as needed for efficient lateral operation throughout the system. Water conservation would result from system operators (primarily zanjeros) making lateral heading flow adjustments based on real-time spill data, thereby reducing lateral spillage while maintaining farm deliveries. New and existing regulating reservoirs would absorb the inherent fluctuations in main and lateral canal flows, thereby minimizing lateral spillage and achieving steady main canal water levels. This option minimizes hardware and construction costs by relying on improved management through better information and control. A major change in system operation would be required. The final recommended configuration of components that make up IIM is reported by Bliesner, et al. (2008).

IIDSS MODELING OF REJECTED WATER

Downstream rejected water volume for each delivery is calculated as the delivered flow rate times the duration between the actual and scheduled delivery end time. Water must be ordered in 12- or 24-hour blocks. Thus, given the scheduled order duration, if the reported end time is less than the scheduled end time, the scheduled end time minus the reported end time equals the hours the order was rejected (turned back to the lateral). Multiplying the recorded delivery flow rate with the hours the order was rejected provides an estimate of the downstream rejected water volume. The maximum time an order can be rejected is assumed to be 6 hours. Any time a delivery gate closure occurs more than 6 hours early it is assumed the zanjero (lateral canal operator) would cut the flow at the lateral heading.

Upstream rejected water volume for each delivery is calculated as the ordered volume minus the delivered volume minus the downstream rejected volume. The ordered and delivered volumes are from the detailed delivery records. Upstream rejected water volume for each delivery is calculated as the ordered volume minus the delivered volume minus the downstream rejected volume. The ordered and delivered volumes are from the detailed delivery records. For 12-hour AM orders[8] and 24-hour deliveries, IID brings into the main canal system 24 hours of water at the ordered flow rate. For 12-hour PM orders, IID does not bring in any water, thus the 12-hour PM orders are met with the unused portion of 12-hour AM orders. Accordingly, for the upstream rejected water volume calculation, zero is used for the ordered water in the case of 12-hour PM orders. Because the delivered plus downstream rejected water volumes can be greater than the ordered water, the calculated upstream rejected water can at times be negative.

MODSIM is the network solver component of IIDSS. The time series of delivery gate demands that are input to MODSIM consist of two time series for each gate. The first

---

[8] 12-hour orders are either AM orders, starting in the morning (nominally at 6 am) and end in the evening 12 hours later, or PM orders, which start in the evening and end 12-hours later the following morning.

time series is used by MODSIM in its first pass through the delivery system network (see accompanying paper by Keller, et al. (2008), MODSIM Network Model, for a full description of MODSIM and the 3-pass approach used for simulating the IID delivery system). This first time series is called “ordered” water and is calculated as the sum of the delivered water volume plus the downstream rejected water volume estimated as described above. The second time series is the delivered water volume and is used for the second and third passes in MODSIM. Upstream rejected water is summed to the lateral headings and entered as a time series demand at the lateral heading.

It is assumed that the historical rejected water associated with each delivery gate will persist and that any additional rejected water resulting from program on-farm conservation will be added to it. Depending on the delivery system configuration, some portion of downstream rejected water may be reduced by cutting it out at the head of the lateral. When this occurs the cut portion of downstream rejected water is added to the upstream rejected water. Thus, under conservation the downstream rejected water, $R_{d/s}$, is calculated as follows:

$$R_{d/s} = (\text{Historical } R_{d/s} + \text{On-farm Conservation } R_{d/s}) * (1 - \text{cut fraction}) \qquad \textbf{(Eq. 2)}$$

In Equation 2 the cut fraction is the fraction of the rejected water that can be cut at the lateral heading. The upstream rejected water with conservation is equal to the historical upstream rejected water plus the cut portion of the downstream rejected water. Thus, under conservation the upstream rejected water, $R_{u/s}$, is calculated as follows:

$$R_{u/s} = \text{Historical } R_{u/s} + (\text{Historical } R_{d/s} + \text{On-farm Conservation } R_{d/s})*\text{cut fraction} \qquad \textbf{(Eq. 3)}$$

The fraction of rejected water that can be cut out at the lateral heading (cut fraction) is dependent of the delivery system configuration. (See Bliesner, et al. 2008 for details on the various delivery system configurations.) Under the IIM configuration for “long” laterals (laterals longer than two miles and with more than four delivery gates), the cut fraction is estimated to be 58 percent. For “short” laterals (laterals less than two miles in length and with four or fewer delivery gates), the cut fraction under IIM was estimated to be 74 percent. These cut fractions were calculated as the portion of historical spill above 0.5 cfs with a duration longer than 3 hours for “long” laterals and longer than 1 hour for “short” laterals. The 3 hours and 1 hour are the average water travel times for “long” and “short” laterals respectively. The logic for these spill reductions under IIM is that if the spill is known in real time and the lateral heading is automated, the heading can be adjusted to cut the spill down to the target 0.5 cfs. Because of the water travel time in the lateral it takes 1 to 3 hours after the heading is adjusted before the cut at the lateral heading affects the spill.

RESULTS

Existing Rejected Water

The average annual (WY1998 - WY2005) *downstream rejected water* was 21,000 AF. Figure 1 shows a histogram of the *downstream rejected water* that was greater than zero (95 percent of all deliveries had no *downstream rejected water*). The *downstream rejected water* is less than 1 cfs-day (2 AF) for 55 percent of the deliveries with *downstream rejected water*.

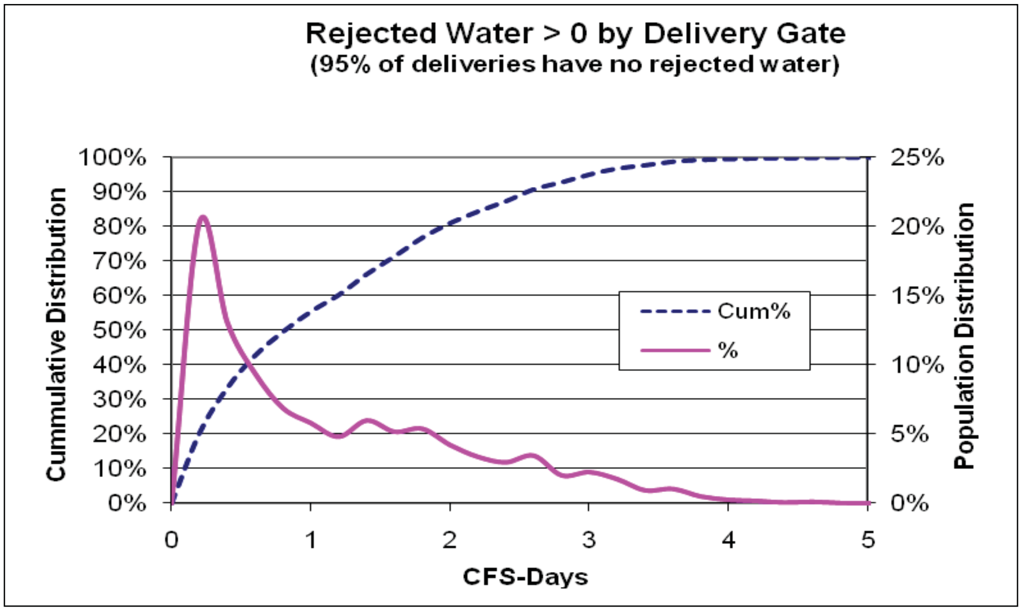

Figure 1. Histogram of Downstream Rejected Water Greater Than Zero

The average *upstream rejected water* was 76,000 AF/year. Figure 2 shows a histogram of the *upstream rejected water* that was not zero (34 percent of all deliveries had no *upstream rejected water*). The *upstream rejected water* is less than ±1 cfs-day (2 AF) for 83 percent of the deliveries with *upstream rejected water*.

The high *upstream rejected water* estimate is a result of considering the 12-hour AM orders as equivalent to 24-hour orders and 12-hour PM orders are equivalent to zero order. Thus, every 12-hour order results in either a positive or negative upstream rejected water estimate. This reflects how IID operators order water from the Colorado River, including the AM 12-hour deliveries in the order and handling the rejected water from these orders by allocating the water to PM orders to the extent possible. The rejected water from AM orders not allocated to a nearby PM order is returned to the main canal and routed to the nearest downstream reservoir.

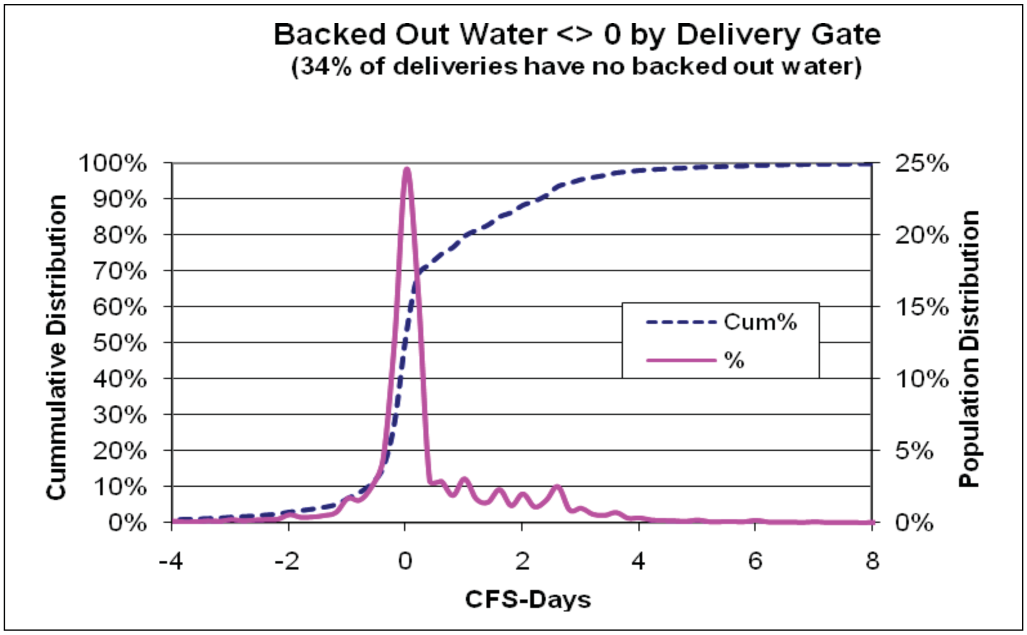

Figure 2. Histogram of Upstream Rejected Water not Equal to Zero.

Rejected Water with On-farm Conservation

The evaluation of on-farm conservation measures (CMs) and the savings that can be achieved with each measure (Clark, et al. 2008) indicated that to achieve the desired level of on-farm savings, those CMs that produce very little rejected water would dominate the on-farm mix. The various on-farm and system alternatives developed and analyzed with IIDSS runs showed about 8,700 acre-feet as the maximum increase in rejected water at a gross on-farm savings of about 143,000 acre-feet (Figure 3). From that point, as gross on-farm savings increase to 205,000 acre-feet, the increase in rejected water decreased to

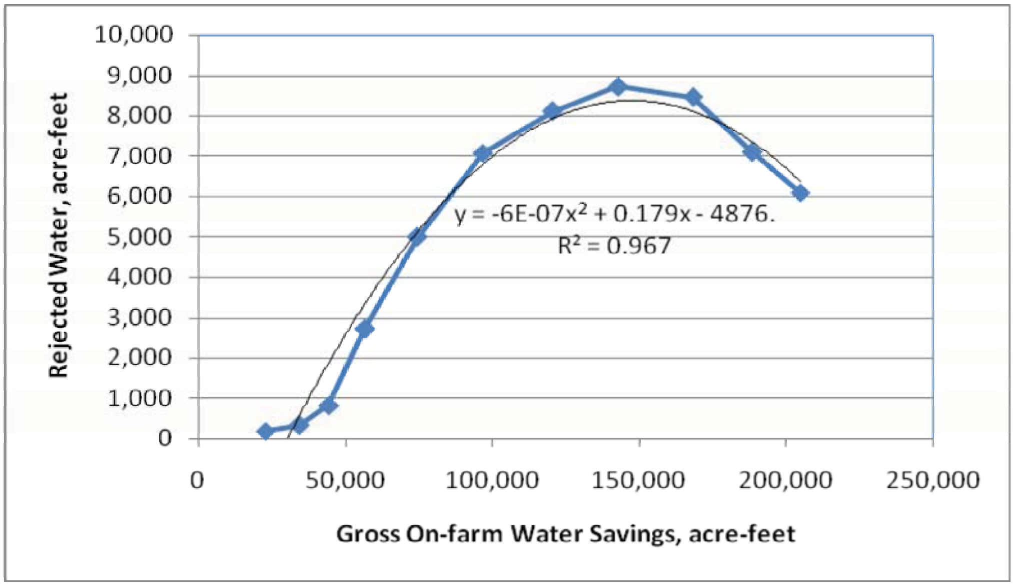

Figure 3. Rejected water as a function of gross on-farm water savings.

about 6,000 acre-feet. At the on-farm savings level of around 180,000 acre-feet for the least cost alternative (Hatchett, et al., 2008), only a small increase in the *rejected water* volume was observed. More than half of this increase was captured and saved by the IIM system improvement option and the remaining volume that was not captured was reduced from on-farm savings.

The maximum delivery system with delivery flexibility option did not provide any additional delivery system savings. However, it did provide the ability to intercept and use rejected water from implementation of on-farm conservation, thus providing for more flexible delivery and better on-farm irrigation performance. The net cost attributable to providing shutoff flexibility was found to be $54,000,000 per year. Table 3 shows the cost per acre-foot of several levels of rejected water based on this flexibility cost allocation.

Table 3. Cost to Capture On-Farm Rejected Water for
Delivery Shutoff Flexibility Option

Rejected Water Volume, AF	**Cost, $/AF**
35,000	$1,543
70,000	$771
100,000	$540

CONCLUSIONS

Considering the implications of on-farm conservation actions on the delivery system is critical to ensure that on-farm conservation is not eroded by increased delivery system spillage. When computing water conservation, care must be taken to ensure that on-farm savings that spilled from the delivery system are discounted from the on-farm savings total.

Enabling full delivery shutoff flexibility and capturing all rejected water is very costly. Other delivery system improvements capture a portion of the rejected water at a fraction of this cost. For example, the IIM option is capable of capturing almost 60 percent of rejected water, provided that growers give IID three-hour advance notification of early delivery shutoffs (Bliesner, et al., 2008). Also, the evaluation of on-farm incentive approaches (Hatchett, et al., 2008) suggests adoption of on-farm conservation measures (CMs) that produce very little rejected water at the level of water conservation required. Furthermore, if delivery gate automation is provided, the fraction of the rejected water that can be captured and reused will be increased. An operating guideline that requires a three-hour notice of early shutoff in conjunction with these other options is cost effective and will provide reasonable delivery flexibility.

REFERENCES

R. D. Bliesner, J. R. Eckhardt, C.M. Burt and B. Freeman. 2008. Imperial Irrigation District Efficiency Conservation Definite Plan: Modifying the Delivery System to Conserve Water and Support More Efficient On-Farm Irrigation. In *Urbanization and Water Transfers.* Proceedings from a USCID Water Management Conference, Scottsdale, AZ.

Clark, B., J. R. Eckhardt, J. Keller and G.G. Davids. 2008. Imperial Irrigation District Efficiency Conservation Definite Plan: On-Farm Conservation Opportunities and Costs. In *Urbanization and Water Transfers.* Proceedings from a USCID Water Management Conference, Scottsdale, AZ.

Hatchett, S., R. D. Bliesner, J. R. Eckhardt and G.G. Davids. 2008. Imperial Irrigation District Efficiency Conservation Definite Plan: Alternatives for Implementing Efficiency Conservation. In *Urbanization and Water Transfers.* Proceedings from a USCID Water Management Conference, Scottsdale, AZ.

Keller, A. A., B. P. Thoreson, E. Triana, and J. R. Eckhardt. 2008. Imperial Irrigation District Efficiency Conservation Definite Plan: Decision Support System for Evaluating Alternatives. In *Urbanization and Water Transfers.* Proceedings from a USCID Water Management Conference, Scottsdale, AZ.

Meriam, J. L. 1964. The Advantages of Flexibility in Irrigation Water Delivery. Presented at the January 27-28, 1964, meeting of the California Irrigation Institute, Fresno, California.

Walker, W.R. and G. Skogerboe. 1987. Surface Irrigation: Theory and Practice. Published by Prentice-Hall, Inc., a division of Simon and Schuster. Englewood Cliffs, New Jersey. 386 pp.