A STUDY OF ADDITIONAL DRAINWATER REUSE FOR THE SUTTER BASIN

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ABSTRACT

Farmers in the Sutter Basin, in the Sacramento Valley of California, do not have sufficient irrigation supply to meet crop needs during peak irrigation demand and during years with surface water allocation restrictions. To help meet these needs, Reclamation District 1500 examined the viability of expanding its existing drainwater reuse system.

Drought and reduced surface water allocations, which are partly attributed to ever-more-stringent environmental concerns and regulations, have markedly increased the hard-to-quantify socioeconomic value of a reliable water supply. Basin farmers have a sense of urgency to establish a supplemental irrigation supply. Expanding the drainwater reuse system for a supplemental irrigation supply will increase water delivery reliability in the Sutter Basin. Approximately 68,000 irrigated acres and over 500 miles of surface drainage channels encompass the study area, where rice is the predominate crop. This study highlights the need to identify supplemental irrigation sources in the absence of extensive master planning data. This study relied on stakeholder input to identify operational and management constraints and to develop specific evaluation criteria. Drainwater availability was inversely proportional to downstream irrigation demand in the Sutter Basin, which required special engineering consideration. The study found that drainwater quality concerns can be mitigated by (a) reusing drainwater upstream of the connate water zone, (b) blending drainwater with surface diversion water, and (c) implementing water quality monitoring program tailored to the recommended alternative. Two service-area-scale drainwater reuse alternatives are recommended to collectively provide up to 20,000 acre-feet of supplemental irrigation supply annually. Project implementation would help offset surface diversion shortages and increase water delivery reliability in the Sutter Basin.

INTRODUCTION

This study examines drainwater reuse in the Sutter Basin (Basin), which is located in the Sacramento Valley of California (see Figure 1). Approximately 68,000 irrigated acres and over 500 miles of surface drainage channels exist in the study area. The combination of natural topography and constructed levees in the study area requires that all excess surface water be collected and discharged from the Basin into natural waterways: this is managed by Reclamation District 1500 (RD 1500).

Currently, Basin farmers do not have sufficient irrigation supply during peak irrigation demand and during years with surface water allocation restrictions. These shortages have worsened since 2004 when the annual full allocation for Sutter Mutual Water Company (SMWC), a Sacramento River Settlement Contractor, was reduced to 226,000 acre-feet. SMWC provides approximately 75 percent of surface irrigation water in the Basin

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depending on the water year. Furthermore, SMWC's State Ranch Bend service area, which is isolated from other conveyance networks, consistently has water shortages where gross irrigation demand exceeds delivery capacity. Also, the Basin has what is commonly referred to as tailender problems: flexibility and reliability of irrigation deliveries are compromised toward the downstream end of irrigation laterals. All surface drainage water must be pumped out of the Basin. This can be costly.

This study highlights the need to identify supplemental irrigation sources in the absence of extensive master planning data. The study did not include extensive data collection, nor was it a comprehensive appraisal of conveyance infrastructure; and the irrigation delivery system was not specifically assessed. Also, this study did not address reducing connate water inflows as discussed in previous reports (Cal Poly ITRC 1999 and 2000). This study addresses the need to expeditiously identify a supplemental water supply.

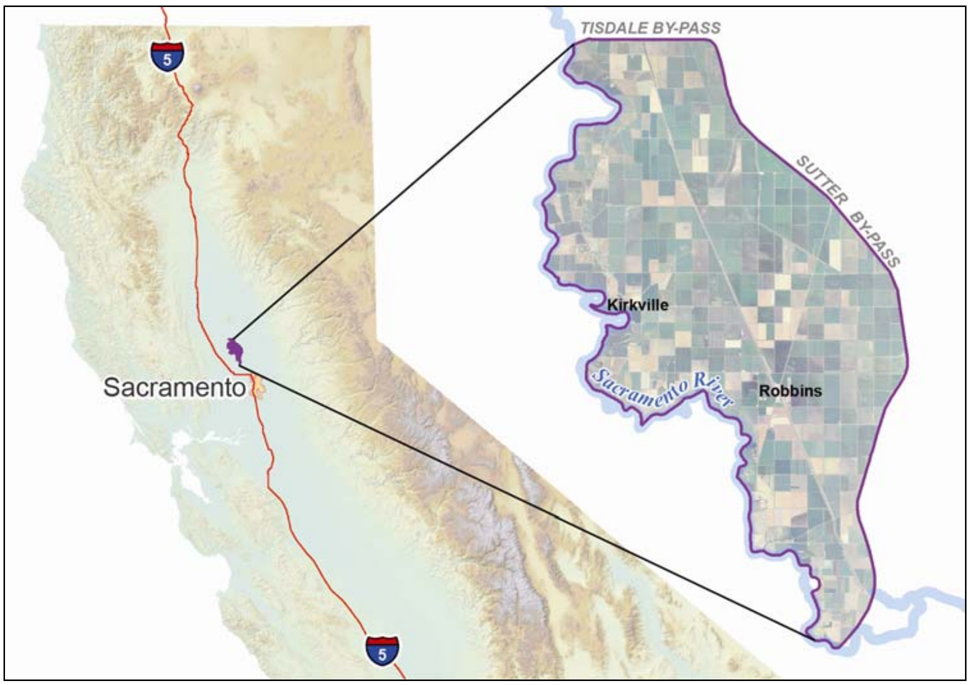

Figure 1. Sutter Basin vicinity map

EXISTING CONDITIONS

Drainage Overview

RD 1500 collects and manages drainwater from all land in the Basin. Drainwater is conveyed out at one location: the Karnak Pumping Plant at the southernmost end of the Basin. Drainwater either flows by gravity or is pumped out of the Basin at this location depending on the water levels in RD 1500's main drain and the Sacramento River. Pumping of drainwater outflow is typically required during the irrigation season. Average Basin outflows are summarized in Figure 2. Drainwater outflow includes drainwater during the irrigation season, runoff during the rainy season, and groundwater flows into some of the drains, particularly in the connate water zone as found in previous studies (U.C. Davis, 1970 and 1972).

The main drain, which flows generally north to south, bisects the Basin. Drainwater is conveyed to the Karnak Pumping Plant via the main drain. An elaborate network of both drain laterals and sublaterals conveys drainwater to the main drain from both the east and west. A few row-crop fields in the Basin have tile drains to facilitate root zone drainage, but overall tile drains are not prevalent. Under special conditions farmers use private pumps to reuse drainwater from the RD 1500 drain network but the practice is not common.

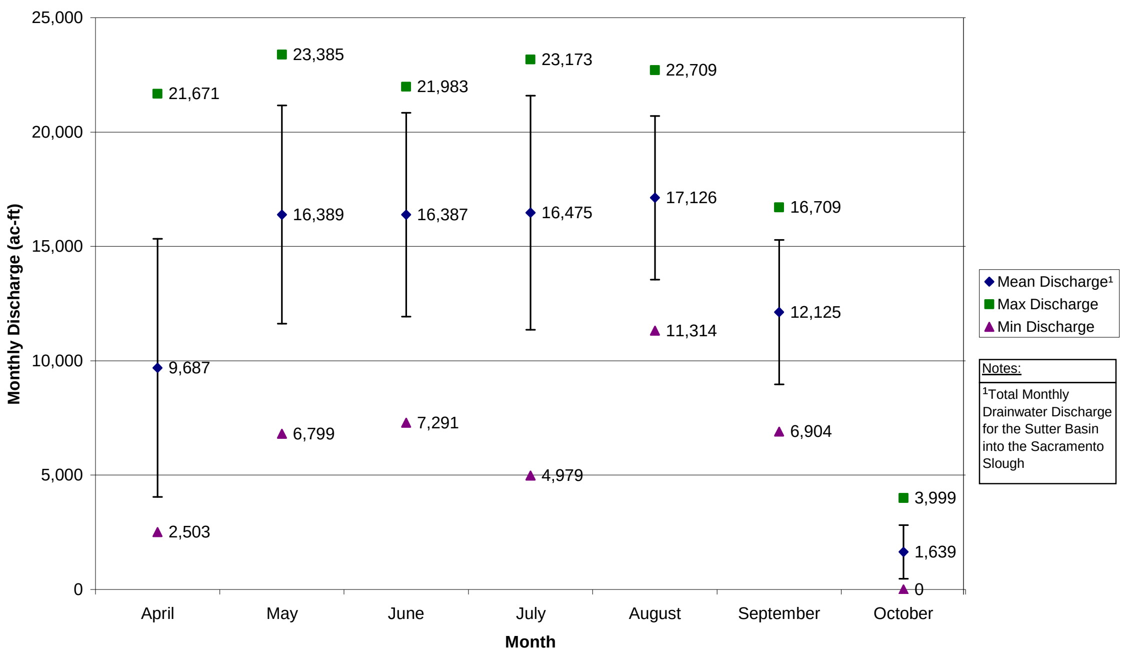

Figure 2. Basin drainwater discharge, April through October (1991 – 2000).

Water levels in drainage laterals are controlled using flashboard risers. Drainwater is checked up during the irrigation season to provide backwater hydraulic gradients for the existing drainwater recycling pumps. Even though high drainwater levels might reduce connate water inflow, drainwater levels should not be raised too high because the high water table can damage row and field crops. Once the flashboard checks are installed, they are seldom adjusted during the growing season. Checks are removed after the growing season to facilitate drainage and leaching of the root zone and maximize drainage capacity for flood control.

Table 1. Overview of Sutter Basin Water and Drainwater Entities.

	SMWC	PMWC	Rimlanders	RD 1500
Service Area (acres)	51,200[a]	3,000[b]	13,800	68,000[c]
Average Annual Surface Water Diversion(acre-feet)	200,562[d]	5,659[e]	Not Available	154,896[f]
Average Annual Drainwater Reuse Volumes (acre-feet)	15,000[g]	8,000[h]	Not Available	
Crops[i]	Rice	Rice	Not Available	
	Grain	Safflower		
	Tomatoes	Wheat/Barley		
	Safflower	Tomatoes		
	Sunflower	Wild Rice		
	Other	Other		

Notes:
a. From SMWC records
b. From PMWC records
c. Source: "Reclamation District No. 1500 resource study" performed by the NRCS in 1996
d. Average annual diversion of Sacramento River water for years 2000 through 2007
e. Average annual diversion of Sacramento River water for years 2002 through 2007
f. Average annual discharge of drainwater into the Sacramento River for the years of 1991 through 2000
g. From "Reclamation District No. 1500 resource study" performed by the, NRCS in 1996
h. Average annual drainwater recycled volume from PMWC records for years 2002 through 2007
i. Prioritized by most acreage

Irrigation Overview

Two water companies serve the Basin: SMWC and Pelger Mutual Water Company (PMWC). Additionally, some farmers have independent irrigation water sources and are referred to as Rimlanders. The primary source of irrigation water in the Basin is the Sacramento River. Four main pumping plants and several smaller, private pumps discharge surface irrigation water into the Basin from the Sacramento River. Groundwater wells, particularly on the west side of the Basin, are used as needed during times of limited surface water supply. Table 1 summarizes the acreages and diversion data for water and drainwater entities in the Basin.

Sutter Mutual Water Company. SMWC delivers water to approximately 51,200 acres. Three pumping plants on the Sacramento River serve three SMWC service areas. Average annual diversions are presented in Table 1. The Tisdale Pumping Plant discharges water to the Tisdale Canal with distribution to the West, East, and Central Canals and their laterals. This is the largest service area totaling 42,900 acres on both the west and east sides of the main drain. The State Ranch Bend Pumping Plant supplies water to the State Ranch Bend main canal and its laterals. This service area is approximately 5,700 acres. The Portuguese Bend Pumping Plant discharges water to the Portuguese Bend main canal and service area of 2,600 acres. Total diversions from the Sacramento River are summarized in Figure 3. On average, nearly 90 percent of irrigation diversions occur from May through August. The greatest year-to-year variations in SMWC irrigation deliveries occur in May and June.

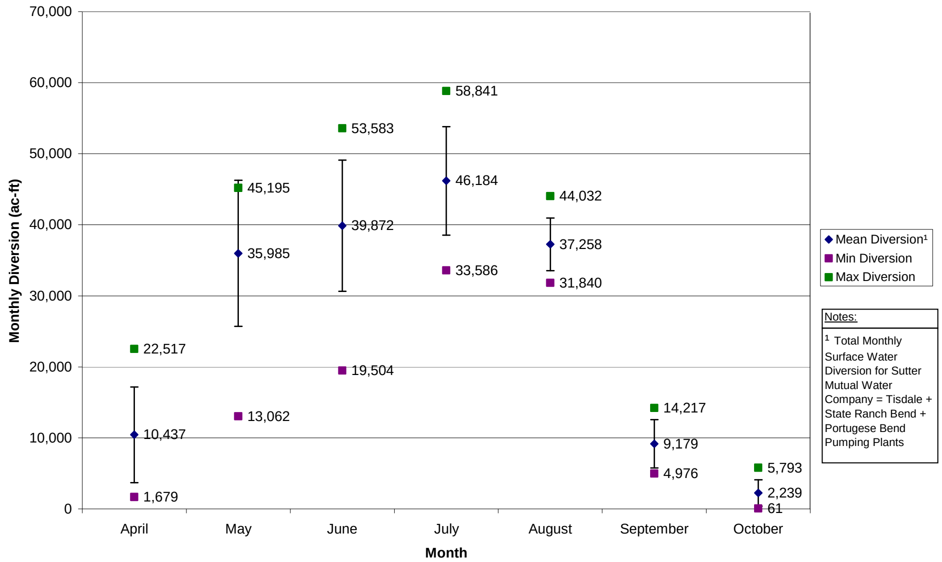

Figure 3. SMWC diversions (1991 through 2000).

The State Ranch Bend service area requires special consideration because it consistently experiences irrigation demands that exceed the irrigation delivery capacity. The bottle-neck is the State Ranch Bend pumping plant: it cannot pump enough water to meet peak irrigation demands. The State Ranch Bend conveyance infrastructure has capacity for additional flow, however.

SMWC operates eight drainwater recycling pumps in the Basin. These recycling pumps convey drainwater directly into adjacent irrigation canals. Additionally, SMWC utilizes portable drainwater recycling pumps to relieve problem areas. Currently, the approximated volume of recycled drainwater is 15,000 to 36,000 acre-feet annually (NRCS, 1996 and SMWC records).

<u>Pelger Mutual Water Company.</u> PMWC delivers water to approximately 3,000 irrigated acres. A pumping plant on the Sacramento River discharges water to the PWMC water distribution system. PMWC operates six permanent and one portable drainwater recycle pumps. These recycle pumps convey drainwater directly into adjacent irrigation canals. Currently, the approximated volume of recycled drainwater is 5,400 to 10,000 acre-feet annually.

<u>Rimlanders.</u> Rimlanders are individual land owners who pump their own irrigation water, primarily directly from the Sacramento River. They do not purchase surface irrigation water from a water purveyor. Water reuse specifically for Rimlanders was not evaluated in this study. However, drainwater from Rimlander’s fields that enters the drainage channel network is managed by RD 1500 and is therefore available for reuse.

Basin Characterization

The Basin was divided into three sub-basins and average drainwater flow data were evaluated. The estimated average Basin-wide drainwater ratio during the irrigation season (May through August for years 1991 through 2000) was 250 acres per 1 cubic foot per second (cfs) drainwater. Drainwater flow measured at three locations on July 22, 2008 verified this approximation.

Cropping Patterns and Effects on Drainwater Availability. Rice has been the predominant crop in the Basin over the past several decades as listed in Table 1. Cropping patterns are subject to change, which can impact the timing surface drainage flow and drainwater availability. However, Figure 4 shows no direct correlation between total irrigation diversions and drainwater outflow, and no direct correlation between rice acreage and total drainwater outflow for the available data. Therefore, no service area drainwater flow adjustments were made as a result of cropping patterns.

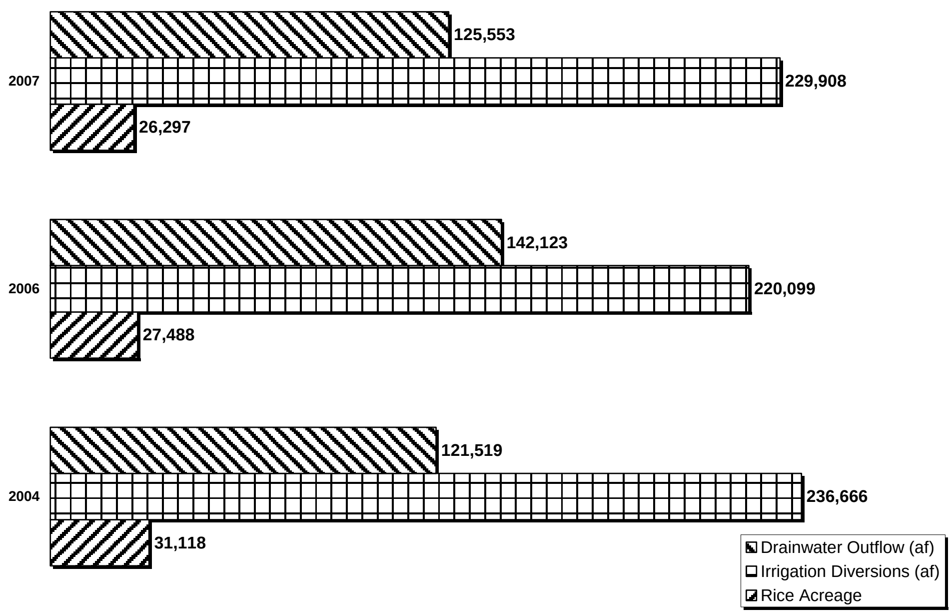

Figure 4. Drainwater Outflow during the Irrigation Season compared to Irrigation Diversions and Rice Acreage.

Drainwater Quality. The Basin water quality target for irrigation deliveries is 750 milligrams per liter (mg/L) maximum total dissolved solids (TDS). Previous studies highlighted drainwater quality concerns for reuse, especially lower in the system (NRCS, 1996; Tanji et al, 1975; Henderson et al, 1972). Limited reconnaissance-level water quality measurements in July 2008 indicated that drainwater is of sufficient quality for reuse, particularly if the drainwater source is upstream of the connate water zone and if drainwater is blended. Blending drainwater with water diverted from the Sacramento River further reduces the salinity.

Drainwater Reuse and Connectivity between Water Purveyors. Physical features of the Basin create connectivity between the operations of irrigation delivery systems and the drainage network. Examples of this connectivity follow:

- All surface water runoff (both precipitation and irrigation origin) enters the RD 1500 drainage system
- Independent water users contribute drainwater to RD 1500 drainage channels
- Drainwater levels affect growing conditions in adjacent fields
- Some drains have bidirectional flow, depending on point-source magnitudes and flashboard riser check elevations

These interdependencies influenced reuse categories and alternatives, which are discussed in the following section.

ALTERNATIVE DEVELOPMENT AND EVALUATION

Basin farmers have a sense of urgency to establish a supplemental irrigation supply. Although drainwater reuse in the Basin is not a new idea, and in fact it is currently practiced, limited data were available. There were few data available on lateral drainwater flows, channel elevations and cross sections, and drainwater quality variability. Stakeholder input and a logical approach to identifying drainwater reuse options were therefore critical in this study. Drainwater reuse categories were identified initially, followed by more detailed alternatives. In addition to field visits and staff interviews, collaborative ideas were shared during two stakeholder workshops.

After initial data collection and research, drainwater reuse categories were developed and presented at a stakeholder workshop. The preferred drainwater reuse category was that of the service-area magnitude: that is, a drainwater reuse system of a magnitude that would convey drainwater from a source to multiple field groups for irrigation. This magnitude is smaller than a previously studied Basin-wide centralized pump-back system, which became infeasible and cost prohibitive. See the drainwater study by Laugenour and Meikle (1997) for more information on centralized pump-back system alternatives. At the same time, the preferred category is larger than localized drainwater reuse like the existing drainwater reuse systems where drainwater is pumped from the source directly to an adjacent field or canal. The evaluation criteria in the following subsection highlight considerations that may be pertinent to other drainwater reuse studies.

Constraints and Evaluation Criteria

At the north end of the Basin, there is ample downstream irrigation demand and elaborate conveyance infrastructure to make irrigation deliveries. Conversely, there is little drainwater available for reuse at the head of the irrigation system. The opposite is true at the southern end of the Basin where there is substantial drainwater available for reuse but a small amount of acreage and limited conveyance infrastructure. Balancing this inversely proportional relationship, which is illustrated in Figure 5, between drainwater availability and irrigation demand without an extensive and costly centralized pump-back system was required when developing alternatives.

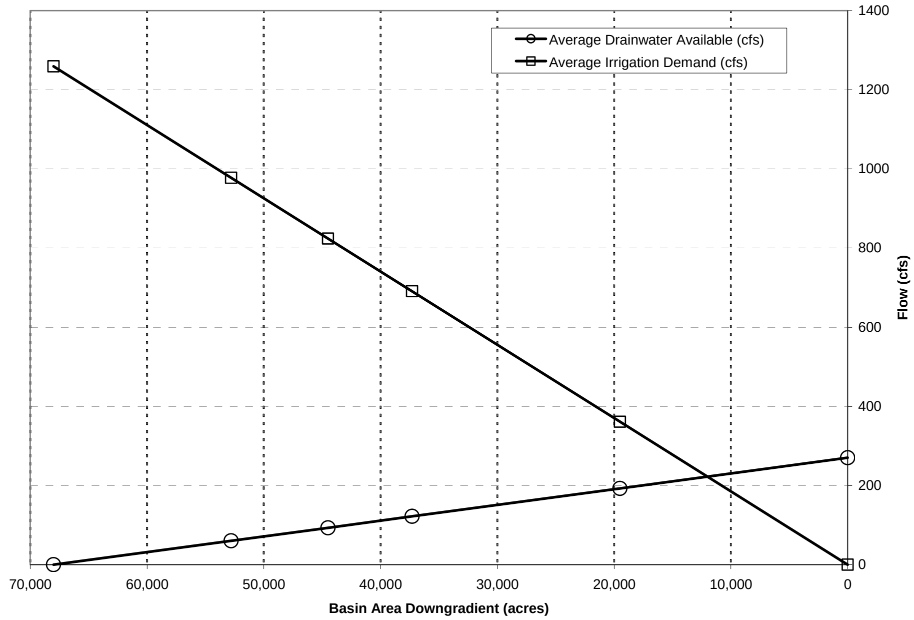

Figure 5. Inverse relationship between irrigation demand and available drainwater.

Other criteria included providing drainwater reuse to multiple service areas; identifying a reliable drainwater source; verifying adequate irrigation demand for sustained reuse deliveries; providing equitable irrigation deliveries; and minimizing drainwater outflow pumping costs.

Generally, reusing drainwater makes surface diversion water available for delivery elsewhere. This increases reliability of irrigation diversions for all Basin users. Therefore, when drainwater is pumped back into an irrigation lateral there should be sufficient downstream irrigation demand such that the drainwater can be consistently reused during the irrigation season. This maximizes the benefit of the available drainwater. Presumably, cropping patterns, cultural practices, year-to-year weather variations, evapotranspiration demands, and on-farm irrigation efficiency can influence the correlation between drainwater reuse demand and service area.

Furthermore, equity of irrigation deliveries, including water quality, should be considered. Irrespective of the Basin water quality target of a maximum of 750 mg/L TDS, if one water user exclusively receives reused drainwater and another water user receives only river diversion water, a certain degree of inequity is perceived. Therefore, two criteria relating to water quality equity were established for this study: (a) all deliveries shall have a water quality less than or equal to 750 mg/L TDS, and (b) the maximum quantity of reused drainwater for any given field during the irrigation season shall not exceed 50 percent of the gross irrigation demand. The resulting maximum reuse factor was approximately 1 cfs continuous drainwater reuse per 100 acres. For example, a Basin drainwater reuse system with a capacity of 20 cfs should directly serve a minimum of 2,000 acres; the remainder of the irrigation demand should be supplied by surface water diversions.

Conveyance hydraulics were evaluated to determine which existing drainwater channels could be utilized for a new reuse system. The following conveyance factors were studied:

- Identifying drain reaches that can “backflow” by gravity depending on water levels
- Determining flow capacity
- Identifying drain reaches that require a pump station and pressurized pipe flow to re-enter the irrigation delivery system
- Identifying drain reaches that require regraded and/or reshaped channels
- Identifying the approximate typical cross section of regraded and reshaped channels required for the corresponding design flow
- Identifying existing infrastructure that needs to be modified or replaced

Hydraulic calculations were largely dependent on generalized engineering assumptions.

Results

A second stakeholder workshop was held to evaluate drainwater reuse alternatives. Two recommended alternatives resulted from the workshop. The first preferred alternative was selected for conveying 40 cfs of drainwater to the east of the main drain. This alternative was favorable for the following reasons:

- Operation of existing drainwater channels would be modified allowing drainwater to flow against natural topography toward the irrigation canal
- Drainwater would be pumped into the irrigation delivery system: there are multiple downstream laterals for irrigation deliveries
- The alternative features a comparatively short cross-connection between the main drain and the irrigation canal
- There is a reliable drainwater supply of sufficient quantity to sustain continuous reuse during the irrigation season
- Blending drainwater with a large quantity of surface diversion water results in a high degree of irrigation delivery equity

The second preferred alternative was selected for conveying 40 cfs of drainwater west of the main drain. This alternative was favorable because the drainwater would be blended with surface diversion water at the head of a distribution system. The supplemental irrigation source would alleviate water shortages and increase flexibility in the service area. Both of the preferred alternatives are mostly upstream of the area where salty connate water might cause a quality problem. Implementing both alternatives would provide up to 20,000 ac-ft of supplemental irrigation supply annually.

Drainwater quality concerns can be mitigated by (a) reusing drainwater upstream of the connate water zone, (b) blending drainwater with surface diversion water, and (c) implementing water quality monitoring program tailored to the recommended alternative. It is recommended that the monitoring program include an investigation of the long-term salinity build-up in the root zone.

DISCUSSION

Drainwater Reuse Challenges

Drainwater reuse comes with numerous challenges. While some challenges discussed below are specific to this Basin, many of them are common in some form with other drainwater reuse systems in other locations.

Identifying cost-effective drainwater conveyance is important. Drainwater often needs to be conveyed from the source to areas with adequate irrigation demand throughout the growing season. Elaborate new conveyance systems can become cost prohibitive; and oftentimes land is taken out of production. This study focused on using existing drainwater channels for conveyance to the extent possible. Both hydraulic control structures and operational strategies will be modified and a lift station will be installed to convey drainwater against natural topography so that it can be blended with surface diversion water. While the flat topography made this possible in this instance, the reader is encouraged to examine atypical conveyance strategies for similar drainwater reuse opportunities.

Controlling operation and maintenance cost is important to Basin farmers. The recommended drainwater reuse plan minimizes both the number of new pumps required and the lift head. This will keep energy consumption as low as possible. Regardless of the preferred alternative, a new drainwater reuse system will require ongoing flow rate, water level, and water quality measurements.

Maintaining equitable irrigation deliveries in terms of water quality must be accounted for when studying potential drainwater reuse systems. In this instance, blending drainwater with diversion water in irrigation canals will help keep water quality equitable, exceeding Basin standards for all. Additional drainwater reuse should be coupled with additional, ongoing water quality measurements to ensure the aforementioned equity.

Identifying a reliable drainwater supply was critical for delivering consistent and reliable reuse. Cropping pattern changes and shifts in cultural practices can presumably influence irrigation demand, drainwater flow magnitudes, and the timing of drainwater availability. Reliable drainwater sources were identified on RD 1500’s main drain, which collects surface drainwater from all drain laterals and offsets localized drainwater flow fluctuations.

Drainwater Reuse Benefits

Reusing drainwater can increase water delivery equity by reducing tailender problems, or alleviating water-shortage problems that are specific to certain service areas. In this case, reusing drainwater in the State Ranch Bend service area will allow the SMWC to deliver the volume of water needed to match peak irrigation needs.

Furthermore, drainwater reuse leaves available surface diversion water for use elsewhere. The benefit is especially critical and becomes more economically valuable when surface water allocations are reduced.

The benefits of increasing water delivery reliability through drainwater reuse should not be overlooked. With the recent increasing uncertainty of water supply because of drought and reduced allocations, the hard-to-quantify socioeconomic value of a reliable water supply has increased markedly. A reliable water supply goes beyond localized farmer profit; at some point it begins to influence food security. Expanding the Basin drainwater reuse system as supplemental irrigation supply will increase water delivery reliability.

CONCLUSION

Expediting the process of identifying drainwater reuse opportunities without extensive data was highlighted in this study. Stakeholder participation was a critical study component. Basin drainwater quality concerns can be mitigated by (a) reusing drainwater upstream of the high-in-TDS connate water zone, (b) blending drainwater with surface diversion water, and (c) implementing a specific water quality monitoring program in the final design.

Expanding the existing drainwater reuse system will help reduce diversion irrigation supply shortages while increasing irrigation delivery equity. There are potentially other means of improving Basin water use efficiency. This study was not intended to replace a comprehensive basin-wide master plan; in fact, such a plan is recommended to identify other ways to improve serviceability to Basin farmers. This will help categorize areas where water use efficiency can be increased; or highlight operational changes that can further improve the reliability of water sources, the flexibility of irrigation deliveries, and service equity. In the meantime, additional drainwater reuse of approximately 20,000 acre-feet annually can increase serviceability to Basin irrigators.

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