Irrigation District Sustainability — Strategies to Meet the Challenges

A USCID Irrigation District Specialty Conference

Reno, Nevada
June 3-6, 2009

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

Edited by

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ORLAND UNIT WATER USERS ASSOCIATION REGULATING RESERVOIR, AN EXAMPLE OF VERIFICATION-BASED MODERNIZATION PLANNING

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ABSTRACT

The Orland Unit Water Users Association (OUWUA or Association) desires to modernize its delivery system to increase delivery flexibility and conveyance efficiency. The Association recognizes the need to improve the level of service and increase water supply reliability to reduce the incidence of growers converting to groundwater. Regulating reservoirs are an important part of the Association's modernization plans, and once constructed, will provide the benefit of reducing system losses. Combined with the Association's current conjunctive water management plans, regulating reservoirs may enhance water supplies available for regional initiatives.

This paper describes the results of a Feasibility Investigation conducted to develop firm estimates of the benefits of the regulating reservoir, near-final designs, specifications and costs. Verification-based modernization planning, a technique that fuses traditional facilities planning with water conservation verification procedures, was applied to develop estimates of the expected benefits in the context of a water balance with and without the project.

INTRODUCTION

The Orland Unit Water Users Association (OUWUA or Association) recognizes the need for system modernization to improve water use efficiency and is aggressively following a conceptual modernization plan. OUWUA is utilizing a strategy of re-routing flow fluctuations along main canals to points where these flows can be re-regulated. These re-regulating points are either regulating reservoirs or discharge points to the Tehama-Colusa Canal (TCC) where OUWUA receives credit to offset its Stony Creek diversions[3]. The conceptual modernization plan focuses on facilitating the routing of these flow fluctuations by improvement of main canal structures and regulating reservoirs, and installation of SCADA technology.

Primary goals identified by the OUWUA include replacing obsolete structures, increasing water delivery flexibility, and increasing conveyance efficiency. Among other benefits,

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[3] Upon completion of Black Butte Reservoir in 1964, the United States and the Orland Unit Water Users' Association entered into a contract providing for the exchange of water. In present Black Butte water accounting, OUWUA discharges into the TC Canal are credited against (CVP) supplies diverted from Black Butte Reservoir.

the improved levels of service made possible through modernization will ensure continued use of renewable surface water supplies, reducing the incidence of farmers converting to readily available groundwater supplies. This, in turn, will protect local groundwater supplies for use in dry periods, when needed.

Regulating reservoirs are an important part of OUWUA's modernization plans, in that they minimize system spillage while enabling system operators to provide additional delivery flexibility to growers. By providing improved surface water service, these reservoirs help the Association accomplish its conjunctive water management goals, through which local and regional water supply reliability may be improved.

Proposition 50, the Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002 passed by California voters provides funds to assist agencies improve water use efficiency. This grant program implements California Water Code Chapter 7, Section 79550 (g) of Proposition 50 and provides the funds for this application of verification-based modernization planning.

Verification-based modernization planning is "a tool to improve the irrigation system modernization planning process and to effectively monitor the post-project effects on system performance" (Burns, J.I., et al., 2000). The aforementioned Proposition 50 grant program requires monitoring of post-project system performance with annual reports for five years following project completion. Thus, the verification-based modernization planning was used to provide a foundation and framework for future monitoring of post-project performance.

PHYSICAL AND INSTITUTIONAL SETTING

The Orland Project (or Project), constructed between 1907 and 1918 and operated and maintained by the Orland Unit Water Users Association (OUWUA or Association), irrigates about 20,000 acres in northern Glenn County (Figure 1). The Project diverts roughly 100,000 acre-feet (AF) of water from Stony Creek in most years, shortages occur only in the driest years. One hundred and forty miles of mostly concrete lined canals distribute water into six "beats" (ditch tender service areas) (Figure 2). Beats One, Two, Three and Four are served by the Southside system via direct Stony Creek diversions at Black Butte Dam into the South Canal. The Southside system serves roughly two-thirds of the Project area. Beats Five and Six are served by the Northside system via direct diversions from Stony Creek into the North Canal at the North Diversion, a diversion dam located approximately four miles downstream of Black Butte Dam.

Beats One, Two and Three are independent units receiving water at diversion points on the South Canal. The South Canal terminates at the head of Beat Four and becomes Lateral 40 with all remaining water designated for Beat Four deliveries. Beats Five and Six serve roughly one-third of the Project on the north side of Stony Creek. Beat Five receives water from the North Canal via sub-lateral turnouts with the remaining water passing through to Beat Six. Beat Two covers the largest area and serves the most water users (Table 1)

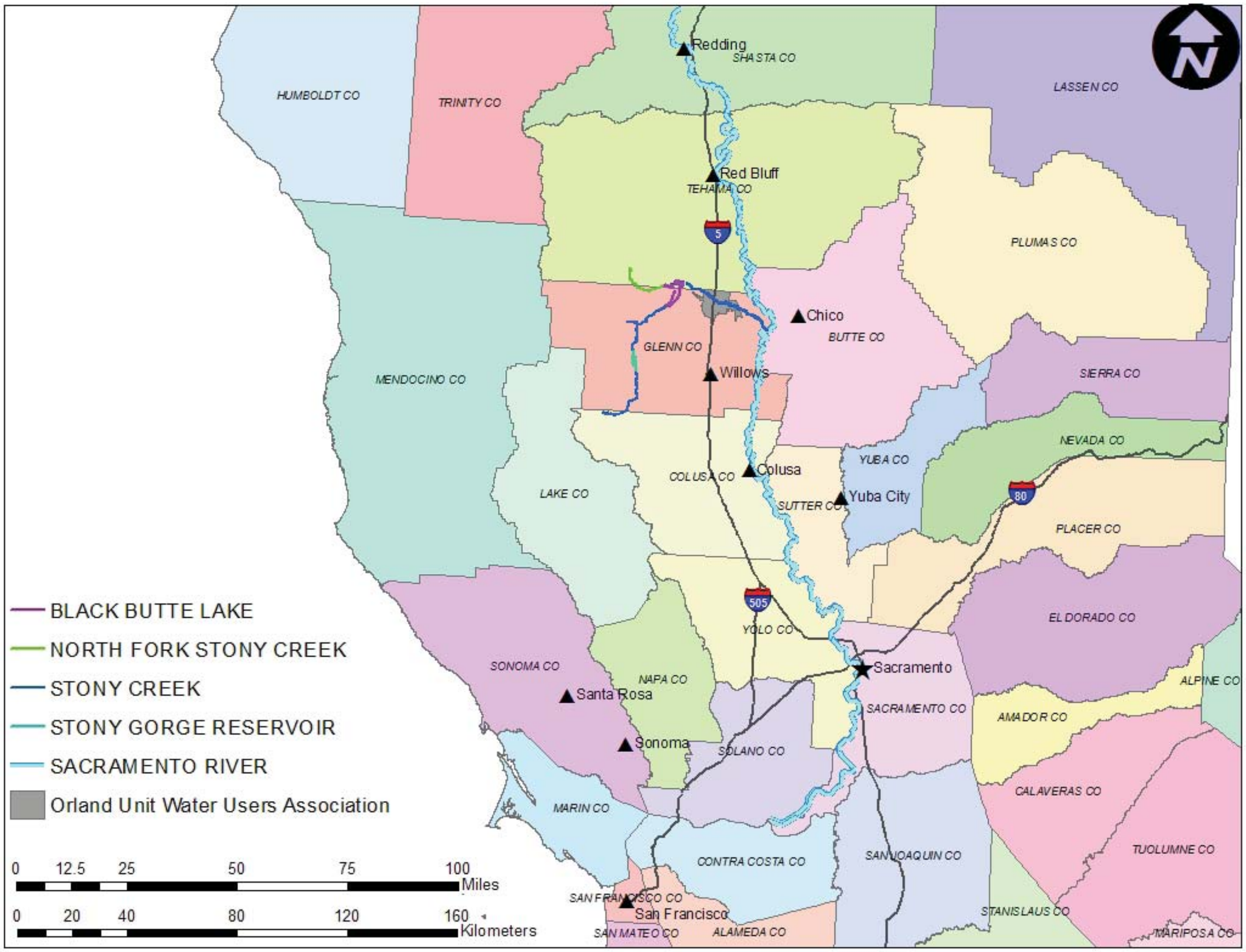

Figure 1. Location of the Orland Project in Northern California

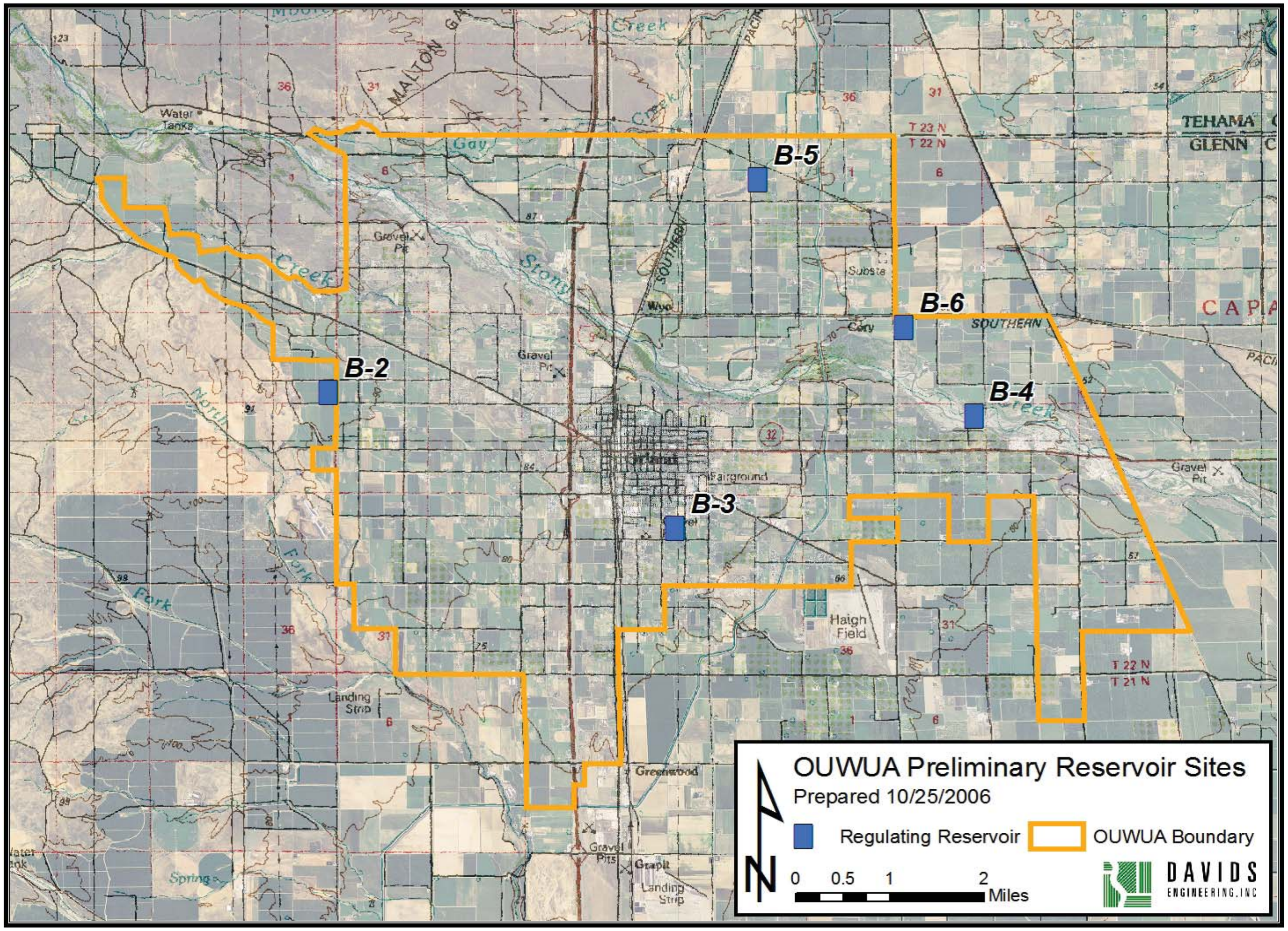

Figure 2. OUWUA Boundaries, Beats and Preliminary Reservoir Sites

Table 1. Irrigated Area, Water Users, Canal Branches and Lengths for OUWUA Beats

Beat No.	Irrigated Area, acres	Number of Water Users	Number of Canal Branches	Total Canal Length, miles	Average irrigated field size, acres
Beat 1	1,323	70	6	17.6	19
Beat 2	4,492	179	11	24.6	25
Beat 3	2,091	200	19	21.6	11
Beat 4	2,586	128	16	27.3	20
Beat 5	2,031	80	9	15.7	25
Beat 6	3,455	125	9	19.7	28

Irrigation water is distributed in open, upstream controlled canals and ditches on a rotation pattern—specifically, a "head" of water is passed from one grower to the next on a 24/7 basis throughout the irrigation season. Rotational irrigation deliveries generally result in over-irrigation in the spring and fall and under-irrigation in the summer. Consequently, yields are less than optimum, causing an increasing number of growers to convert from surface irrigation with Project water to drip irrigation systems supplied by private groundwater wells.

Because parcel sizes are generally small (averaging 20 acres) and canal flows are large (six to 12 cfs), water is typically passed from one grower to the next every few hours. These frequent flow changes cannot be made with perfect timing and accuracy, resulting in high canal spillage due to the lack of regulating storage in the distribution system.

The Army Corps of Engineers (USACOE), the operating entity of Black Butte Dam, receives water orders from OUWUA for the North and South Canal and regulates the flows downstream from the Black Butte Reservoir accordingly. OUWUA is currently restricted to two orders per day-- at 7 am and 1 pm during the irrigation season. Due to the inability to reduce Black Butte heading flows in the late afternoon or evening, water is sometimes spilled throughout the night when an irrigation "run" is finished, or when an irrigator is unable to take the water.

This paper describes the selection of the proposed regulating reservoir site, the proposed reservoir operational procedures, the water savings estimate developed using the verification modernization planning method and the regulating reservoir and lateral improvements design.

RESERVOIR SITE SELECTION-CRITERIA AND SELECTION

Five potential regulating reservoir sites were identified. Available information and data related to these five sites were collected and reviewed. All five potential sites were inspected and discussed at length with OUWUA staff. Sites were evaluated with respect to the following criteria: (1) site size and suitability for a reservoir, (2) access and ease of construction, (3) suitability of site soils and materials for construction, (4) availability of grid power, (5) potential for water savings, (6) existing land use/zoning and cost, (7) landowner's willingness to cooperate and (8) potential for environmental impact.

The five potential sites were scored from 1 (worst) to 5 (best) for each criteria based on discussions with OUWUA staff, site inspections and additional information collected. The potential reservoir site located in the area identified by OUWUA as Beat Two emerged with the highest score after the sites were ranked with equal weight on the seven criteria. The existing land use for all sites was agriculture and no obvious environmental problems were noted. The environmental review of the highest scoring site, located within Beat Two, was supported by a biological and cultural resources evaluation. No special status plant or wildlife species were observed in the area proposed for the Beat Two reservoir. The cultural resources review found that no previously recorded cultural resources were located in the area proposed for the Beat Two reservoir.

OPERATIONS PROCEDURES AND BENEFIT ZONES

Two "head" sizes (delivery flow rates) of 11.5 and 6 cfs are distributed to users in a rotational delivery system. Rotation intervals vary from 12 days in the middle of the irrigation season to14 days early and late in the irrigation season. Delivery durations, based on the head size and irrigated acreage, vary from less than 0.5 to more than 24 hours. On average, water is moved from user to user 15 times each day with the movement of water handled by the users themselves about 95 percent of the time. Nighttime operations are usually limited to handing water from one user to the next by the water users themselves. Should a head need to be moved from one lateral to another at night, the last user is often asked to keep the head until daylight. Analysis of historical spillage records identified the following three main causes of spillage:

1. moving heads between growers (head movement spillage),
2. level fluctuations at the heads of laterals (heading fluctuation spillage) and
3. inability to respond in a timely manner to changes in demand (responsiveness spillage)

Based on this detailed review, procedures for system operation with the proposed regulating reservoir in place were formulated with the objectives of reducing system spillage and increasing delivery flexibility. Existing operations procedures and those recommended under future conditions with the regulating reservoir are summarized in Table 2.

Six benefit areas were defined to quantify reservoir benefits (Figure 3). In each benefit area each of the three spillage causes are addressed to differing extents. In benefit area one, all spillage, regardless of the cause, would be intercepted by the proposed reservoir and significant additional flexibility would be available to growers with turnouts without increasing delivery system spillage. Proposed automation will minimize the spillage due to all causes from benefit area two, but, due the location of this benefit area downstream of the reservoir, some spillage is unavoidable. In benefit areas three and four, head movement spillage cannot be captured, and flow settings at a lateral heading must be changed to convey responsiveness spillage to the reservoir. Benefit areas five and six are operationally the most distant from the reservoir, making it more difficult to convey responsiveness spillage from these areas to the reservoir.

Table 2. Summary of Operations Procedures under Existing Conditions and Future Conditions with the Proposed Regulating Reservoir

Operations Procedures	Existing Conditions	Future "With-reservoir" Conditions
Water Ordering and Delivery		
Delivery Date and Time	Date and time fixed by rotation with very limited flexibility under extraordinary circumstances.	Date and time fixed by rotation with increased flexibility under defined criteria.
Delivery Flow Rate	Two basic flow rates--6 and 11.5 cfs, small numbers of other flow rates in special circumstances	Two basic flow rates--6 and 11.5 cfs, increased numbers of other flow rates in wider circumstances
Duration	84% of durations 10 hours or less	Expect longer durations as lower flow rates become more common.
Moving water between growers	Growers inform next grower when to start receiving delivery.	Same as existing with potential for limited arranged demand.
Night operations	Significant on-farm spillage when heads end at night and must be moved to a grower on another lateral.	On-farm spillage reduced significantly in primary benefit zone where ditch tender can remotely reduce flow at lateral heading and have the flow passed to the proposed reservoir. Reduced to a lesser extent in secondary and tertiary benefit zones due to greater distance and less direct operational connection to proposed reservoir.
Spillage Causes		
Head Movement Spillage		Reduced on Lateral 210
Heading Fluctuation Spillage		Reduced on laterals taking water from Lateral 210
Responsiveness Spillage		Eliminated in primary benefit zone and reduced to greater and lesser extents in secondary and tertiary benefit zones, respectively.
Ditch Tender Ordering Procedures	Total heads required to meet demand as daily order from South Canal	Total heads required to meet demand, determine planned reservoir outlet flow and subtract from total heads to equal order from South Canal
Lateral Operations	Fully manual operations	Mix of manual and automatic operations
Checks	Manually set checks with boards	Lateral 210 automatic level control checks
Headings	Manually set heading openings	Selected headings remotely controlled

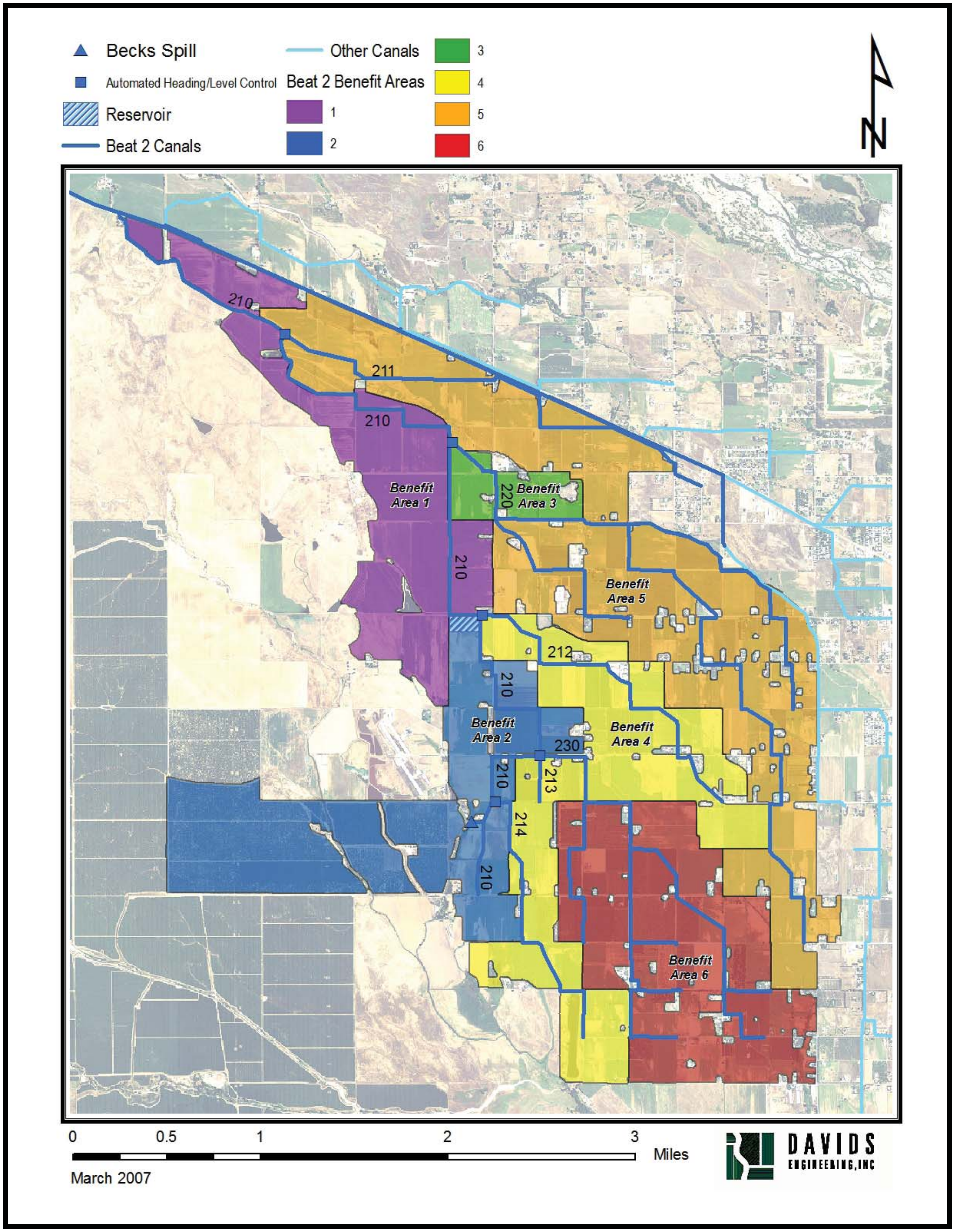

Figure 3. Operations Benefit Zones in Beat 2

WATER CONSERVATION ESTIMATE

The verification-based modernization planning process estimates water savings by preparing a water balance for the area within which canal operations and delivery flexibility would be enhanced by the reservoir. This area, or "benefit zone" was defined earlier as all of Beat 2. The water balance diagram for Beat 2 is presented in Figure 4. The water balance was prepared for the 2006 irrigation season, which ran from early May through late October, and computes flows on a monthly time step. The water balance results are tabulated in Tables 3 and 4.

Based on the water balance, selected flow paths are targeted for conservation. These flow paths, in decreasing order of priority, are measured flows at Beck's Spill (location where spillage from Beat 2 is measured), unmeasured spillage to irrigated lands and tailwater from irrigated lands. With the project, water that would have either spilled through Beck's spill or to irrigated lands would be stored in the proposed regulating reservoir. In addition, growers would be able to reduce tailwater by shutting off delivery when irrigation is complete, with the remaining unused water being conveyed to, and stored in, the reservoir.

The total spillage volumes for the 2005 and 2006 irrigation seasons at Beck's Spill were 2,900 and 2,600 acre-feet, respectively. Verification-based planning requires estimating the changes to the targeted flow paths. The 2006 pre-project record was considered representative of future spillage magnitudes if the project is not constructed, and thus assumed to be the without-project spillage volume. With-project spillage volumes were estimated using a spreadsheet model to simulate reservoir operations on a 15-minute time-step, based on the operations procedures

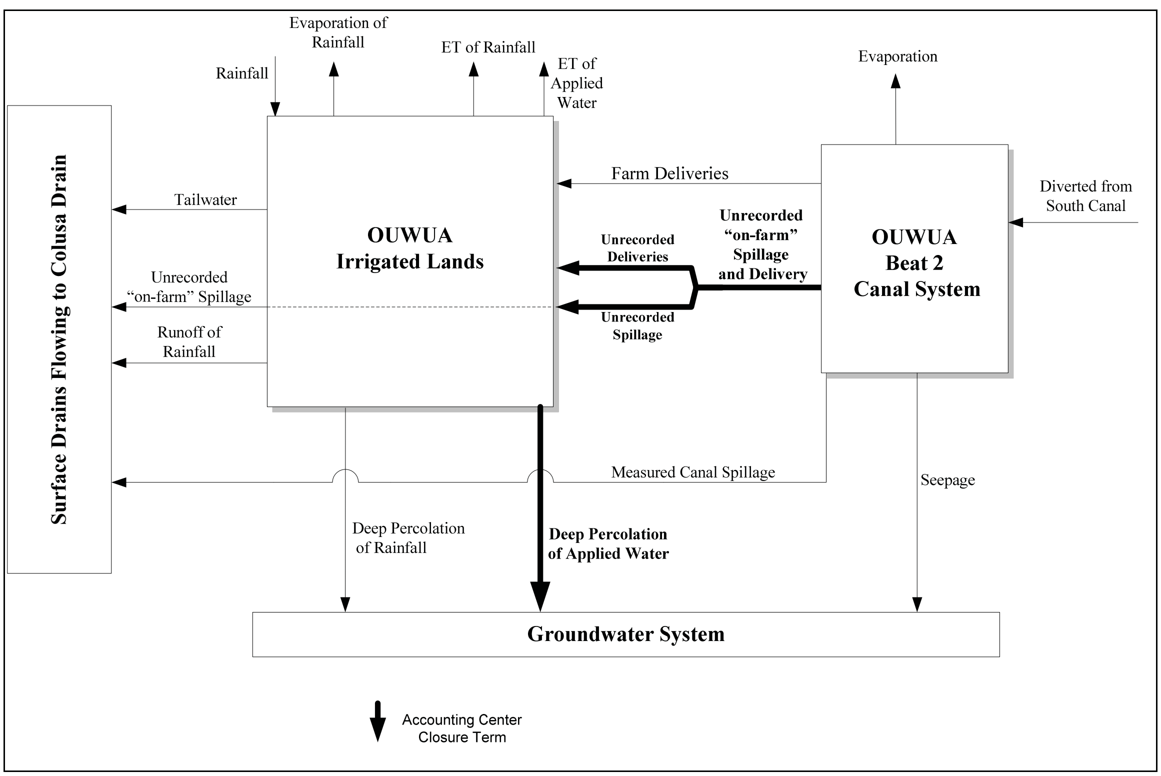

Figure 4. OUWUA Beat 2 Water Balance Schematic

Table 3. Summary of 2006 OUWUA Beat 2 Canal Water Balance

		Inflow	Outflows						
Source/Equation		OUWUA Water Order Database	OUWUA Water Order Database	Measured Flows at Beck's Spill	Estimated based on Concrete Lined Seepage Coefficient (0.24 $ft^3/ft^2/day$)[1]	Water Surface Area * ETo*1.1	OUWUA Water Order Database	Closure--Combination of Unrecorded Spillage and Deliveries to Irrigated Lands--Estimated as Equal Amounts of Spillage and Delivery	
Month	No. of Days	Beat 2 Diversion, (AF)	Recorded Deliveries, (AF)	Measured Spill, (AF)	Seepage, (AF)	Evaporation, (AF)	Recorded Spill (not including Beck's Spill) , (AF)	Unrecorded Deliveries to Irrigated Lands, (AF)	Unrecorded Spillage to Irrigated Lands, (AF)
5	28	3,201	2,143	290	109	8	21	315	315
6	30	4,409	2,842	472	130	11	104	425	425
7	31	4,260	2,991	324	129	11	37	384	384
8	31	3,933	2,560	507	127	10	40	344	344
9	30	3,356	2,148	564	114	8	17	252	252
10	26	2,120	1,259	443	76	4	13	162	162
Total	**176**	**21,279**	**13,943**	**2,600**	**685**	**52**	**232**	**1,882**	**1,882**
Percentage of Diversion			66%	12%	3%	0%	1%	9%	9%

[1]Published seepage rates from lined canal ponding tests vary substantially. Two examples are 0.07 $ft^3/ft^2/day$ for 3- to 4-inch concrete liner with good joint filler (USBR, 1994) and 0.24 $ft^3/ft^2/day$ for "weathered and aged" concrete lining (Worstell, 1976). Much of the lining in Beat 2 fits the "weathered and aged" description, thus, 0.24 $ft^3/ft^2/day$ was selected as the seepage coefficient.

Table 4. Summary of 2006 OUWUA Beat 2 Irrigated Lands Water Balance

	Inflows		Outflows								
Source/ Equation	(Recorded Deliveries) + (Unrecorded Deliveries to Irrigated Lands)	Orland CIMIS Station #61	Applied Water Balance Closure (IL)	Rainfall Water Balance Closure	(District Deliveries) * (Estimated Tailwater percent)		Rootzone Model	Rootzone Model	Rootzone Model	Rootzone Model	Rootzone Model
Month	District Deliveries, (AF)	Rainfall (AF)	Deep Percolation of Applied Water, (AF)	Deep Percolation of Rainfall, (AF)	Tailwater, (AF)	Storage Change of Applied Water, (AF)	Rainfall Runoff, (AF)	ET of Applied Water, (AF)	ET of Rainfall, (AF)	Evaporation of Rainfall, (AF)	Storage Change of Rainfall, (AF)[1]
May-06	2,458	261	417	62	492	376	26	1,173	821	26	-675
Jun-06	3,267	40	461	4	653	149	4	2,004	48	4	-19
Jul-06	3,375	0	460	0	675	-6	0	2,245	2	0	-2
Aug-06	2,904	0	242	0	581	-9	0	2,091	0	0	0
Sep-06	2,400	0	196	0	480	15	0	1,710	0	0	0
Oct-06	1,421	16	94	1	284	-108	2	1,151	12	2	0
Total	**15,825**	**317**	**1,870**	**67**	**3,165**	**417**	**32**	**10,374**	**883**	**32**	**-696**
Percentage of Deliveries			12%		20%	3%		66%			

[1]Negative values refer to volumes removed from storage.

described earlier. The simulations indicate that the annual spillage volume at Beck's spill could be reduced by 1,871 acre-feet.

Unrecorded spillage to irrigated lands from the Beat 2 canal system was estimated to be 1,882 acre-feet. The reservoir and related automation has been designed to capture on-farm spillage from the operational benefit zones. The unrecorded on-farm spillage volume in each benefit zone was assumed proportional to the irrigated area in the zone, and the on-farm spillage volume from each benefit zone that could be conveyed to the reservoir was estimated. Totaling the estimates from each benefit zone resulted in a with-project spillage reduction of 945 acre-feet.

On-farm water savings are expected to be modest, resulting from improved surface irrigation practices and from the more rapid conversion from surface irrigation to pressurized irrigation enabled by the proposed reservoir. Together these effects are estimated to reduce tailwater from an estimated 20 percent of deliveries to farm to 16 percent.

The approximately 10-acre area of the proposed reservoir site is part of a 50-acre field that received a total recorded delivery of 116 acre-feet, or 2.29 acre-feet per acre in 2006. With the project, the delivery to this field can be expected to be reduced by the average delivery per acre multiplied by ten acres or 23 acre-feet.

The total estimated spillage and delivery reduction are 3,500 acre-feet. However, evaporation, seepage and spillage at the reservoir are new losses that will occur from the proposed regulating reservoir. These losses are estimated to be 28, 29 and 8 acre-feet, respectively. Subtracting the total new losses from the spillage and delivery reduction and rounding to the nearest one hundred acre-feet provides an expected value of project savings of 3,400 acre-feet (Table 5). Based on confidence intervals estimated for the OUWUA Beat 2 water balance, a 95 percent confidence interval of 30 percent is established for these savings. This can be interpreted as being 95 percent confident that the project savings will fall between 2,380 and 4,420 acre-feet with an expected value of 3,400 acre-feet.

Table 5. Estimated Total Project Water Savings with Confidence Intervals

Targeted Flow Path	Without Project, (AF)	With-project, (AF)	Flow Path Reduction, (AF)	CI[1]
Spillage at Beck's Spill	2,600	729	1,871	7%
Unrecorded Spillage to irrigated lands	1,882	937	945	96%
Tailwater from irrigated lands	3,165	2,504	661	64%
Reduced Deliveries (Reservoir area)	23	0	23	10%
Total Conserved Water			3,500	25%
New Flow Paths with Reservoir				
Reservoir Evaporation	0	28	-28	30%
Reservoir Seepage	0	29	-29	50%
Reservoir Spillage	0	8	-8	10%
Total New Flow Paths (Losses)			-65	0%
Total Conserved Water (Rounded to the nearest 100 acre-feet)			3,400	30%

[1]Confidence Interval

REGULATING RESERVOIR AND LATERAL IMPROVEMENTS DESIGN

Achieving spillage reduction estimates while simultaneously improving, or maintaining, existing service levels requires an integrated lateral and reservoir control strategy. Flow changes must be passed down Lateral 210 to the reservoir and from the reservoir to Beck's Spill without significantly changing delivery flows to growers along the way. Four improvement scenarios were defined targeting water savings in various combinations of the benefit areas. Estimated costs for the improvements necessary under each scenario were combined with water savings estimates for the targeted benefit areas to compute the annual cost of the water savings generated. Scenarios 2 and 4 cost the same per acre-foot of spillage and tailwater reduction, however, the estimated spillage and tailwater reduction for Scenario 4 was 700 acre-feet per year more than Scenario 2 (Table 6).

Table 6. Summary of Economic Analysis of Improvement Scenarios

Scenario	Benefit Areas	Capital Cost + Contingency ($)	Annual Cost ($/yr)	Annual Spillage and Tailwater Reduction (AF)	Unit Cost ($/AF)
Scenario 1	2	$ 2,074,160	$ 143,183	2,200	$ 65
Scenario 2	2,4, and 6	$ 2,146,710	$ 149,106	2,700	$ 55
Scenario 3	1 and 2	$ 2,441,734	$ 173,191	2,600	$ 67
Scenario 4	all	$ 2,586,834	$ 185,036	3,400	$ 54

Scenario 4, identified as the preferred improvement configuration, requires a reservoir of at least 35 acre-feet and upgrade of 23 check structures on Lateral 210. The regulating reservoir site and grading plan includes horizontal coordinates, critical water surface and embankment elevations and earthwork quantities. Improvements for check structures were required to maintain delivery flow rates within plus/minus five percent while passing 12 cfs (one head) more or less down the lateral to the reservoir. Long crested weirs, flap gates and automated gates were all options that could meet the requirement for maintaining delivery flows while passing flow changes down the lateral. Flap gates or long crested weirs were preferred because of OUWUA's staff experience in their construction, maintenance and operation. Flap gates are less expensive to construct, so they were used where there was sufficient head available. These criteria resulted in selection of six 2-bay long crested weirs, 14 single bay long crested weirs, one flap gate and one automated slide gate.

Automated overshot gates with flow measurement and the capability to remotely program the time for a flow set point change will be installed at the head of Lateral 210 and at the headings of four sub laterals branching off Lateral 210. Similar automated overshot gates will be used at a flow control point in Lateral 210 at the reservoir inlet and for the two reservoir outlets.

A Doppler flow measurement device is planned for just downstream of the reservoir to allow the flow at this location to be controlled by changing the reservoir outlet gate. A ramp flume, or Replogle flume, will improve measurement accuracy at Beck's Spill.

Estimated construction costs for the preferred improvement scenario were $2.59 million. This cost does not include project management and engineering services during construction.

SUMMARY

A verification-based modernization planning process estimated that a regulating reservoir and associated lateral improvements would save 3,400 acre-feet with a confidence interval of 30 percent at an estimated cost of $54 per acre-foot. These estimated benefits, based on a proposed operations plan with the improvements, were derived from measured spillage data and a water balance of the defined benefit areas within Beat 2. Near-final designs and cost estimates were prepared for the regulating reservoir and associated lateral improvements and utilized to select a least-cost preferred alternative.

Five preliminary regulating reservoir locations were evaluated against defined criteria resulting in the selection of a location in Beat 2 for detailed analysis. Existing operations were characterized leading to proposed operations with the regulating reservoir and defined benefit areas within Beat 2. The regulating reservoir and associated lateral improvements were selected and approved for implementation funding to save 3,400 acre-feet with a confidence interval of 30 percent at an estimated cost of $54 per acre-foot. Final designs are nearly complete, environmental approvals and permits have been obtained and construction is expected to begin later this year.

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