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Subgroup: Reduce Water Demand

Chapter 2 Agricultural Water Use Efficiency

The Agricultural Water Use Efficiency Strategy describes the use and application of scientific processes to control agricultural water delivery and achieve a beneficial outcome. It includes, 1) an estimation of net water savings resulting from implementation of efficiency measures as expressed by the ratio of output to input; 2) resulting benefits; and 3) strategies to achieve efficiency and benefits.

The estimation of net water savings is the reduction in the amount of water used that becomes available for other purposes, while maintaining or improving crop yield. Net water savings recognizes 1) uptake and transpiration of water for crop water use, 2) the role, benefits, and quantity of applied water that is recoverable and reusable in the agricultural setting, and 3) the quantity of irrecoverable applied water that flows to salt sinks, such as the ocean and inaccessible or degraded saline aquifers, or evaporates to the atmosphere, and is unavailable for reuse. The benefits, in addition to water savings, may include water quality improvements, environmental benefits, improved flow and timing, and often increased energy efficiency.

Box 2-1 BDPAC Working Landscapes Approach

BDPAC Working Landscapes Approach

The working landscape is defined as an economically and ecologically vital and sustainable landscape where agricultural and other natural resource-based producers generate multiple public benefits while providing for their own and their communities' economic and social well-being.

Net Water Savings & Applied Water Reduction

In California agriculture, water is seldom used only once. Applied water is often reused multiple times on the same farm or in the same region. Reuse of agricultural recoverable flows is a prominent characteristic of California agriculture. Water may be used *only one time* in the salt sink areas of the state. Therefore, in agriculture it is necessary to focus on the net water savings and not on applied water reductions. Net water savings can be achieved by reducing irrecoverable flows. Reduction of applied water that results in reduction of recoverable flows often does not save water; nevertheless, reduction of applied water may have other benefits such as improvements in water quality, flow and timing, and energy conservation. Reuse of applied water is the main reason why, in the agricultural setting, the quantity of saved water is much smaller than in the urban setting. In the urban setting, applied water is used only once, and any reduction of applied water will result in water savings.

The strategy to achieve agricultural water savings and benefits primarily includes improvements in technology and management of water, both on-farm and at the irrigation district level. The strategy may be dependent on an array of factors such as labor, market, demographics, changes in government policies, funding availability, environmental stresses, desire to increase yield, education, energy, water supply development, water delivery systems, legal issues, economics, and land use issues. More detailed cultural practices that contribute to agricultural water use efficiency are included in Chapter 20, Agricultural Lands Stewardship. This narrative presents the

costs and benefits of efficiency improvements in on-farm irrigation equipment, crop and farm water management, and water supply management and distribution systems.

Agricultural Water Use Efficiency Efforts in California

Agriculture is an important element of California's economy, with 88,000 farms and ranches generating \$36.6 billion in gross income in 2007, according to the California Department of Food and Agriculture and generating \$100 billion in related economic activity. California farm and closely related processing industries employ 7.3 percent of the state's private sector. In 2000, California irrigated an estimated 9.6 million acres of cropland with about 34.2 MAF (million acre-feet) of applied water.

In California, growers and water suppliers implement state-of-the-art design, delivery, and management practices to increase production efficiency and conserve water. As a result, they continue to make great strides in increasing the economic value and efficiency of their water use. One indicator of agricultural water use efficiency improvement is that agricultural production per unit of applied water (tons/acre-foot) for 32 important California crops increased by 38 percent from 1980 to 2000. Another indicator is that inflation-adjusted gross crop revenue per unit of applied water (dollars/acre-foot) increased by 11 percent by 2000 compared to 1980.

The Agricultural Water Suppliers Efficient Water Management Practices Act of 1990 (AB 3616) and the Federal Central Valley Project Improvement Act of 1992 (CVPIA) established guidance for improving agricultural water use efficiency. As of July 2009, the Agricultural Water Management Council united, through a Memorandum of Understanding (MOU), 79 agricultural water suppliers and four environmental organizations in an effort to improve water use efficiency through implementation of efficient water management practices. The council recognizes and tracks water supplier water management planning and implementation of cost-effective efficient water management practices through a review and endorsement procedure. The signatory agricultural water suppliers voluntarily commit to implement locally cost-effective management practices (see Box 2-1). Agricultural water suppliers represent more than 4.6 million retail irrigated acreage and a total of 5.86 million acres of agricultural land. Sixty-six (66) signatories to the MOU have submitted water management plans, six signatories are not subject to development and submittal of Water Management (WM) Plans, and the remaining seven signatories are in the process of development and submittal of their WM Plans. All submitted WM Plans have council-endorsed plans.

Box 2-2 Agricultural Water Management Efficient Water Management Practices (EWMPs) (From Ag MOU)

The Agricultural Water Management Council has three classifications of EWMPs as follows:

List A - Generally Applicable Efficient Water Management Practices—Required of all signatory water suppliers

1. Prepare and adopt a water management plan
2. Designate a water conservation coordinator
3. Support the availability of water management services to water users
4. Where appropriate, improve communication and cooperation among water suppliers, water users, and other agencies
5. Evaluate the need, if any, for changes in policies of the institutions to which water supplier is subject

List B - Conditionally Applicable Efficient Water Management Practices – Practices Subject to Net Benefit Analysis and Exemption from Analysis

1. Facilitate alternative land use (drainage)
2. Facilitate use of available recycled water that otherwise would not be used beneficially
3. Facilitate the financing of capital improvements for on-farm irrigation systems
4. Facilitate voluntary water transfers that do not unreasonably affect the water user, water supplier, the environment, or third parties
5. Construct improvements (lining and piping) to control seepage from ditches and canals
6. Within operational limits, increase flexibility in water ordering by, and delivery to, the water users
7. Construct and operate water suppliers' spill- and tail-water recovery systems
8. Optimize conjunctive use of surface and groundwater
9. Automate canal-control structures

List C - Practices Subject to Detailed Net Benefit Analysis without Exemption

10. Water measurement and water use report
11. Pricing or other incentives

For detailed information on the Agricultural Water Management Planning and Implementation process, implementation of EWMPs, Net Benefit Analysis and schedules, see the Memorandum of Understanding at AWMC Web site, www.agwatercouncil.org/aboutusmain.htm

It should be noted that in addition to the Efficient Water Management Practices listed above, there are important cultural practices such soil management, cover crops, changes in tillage practices, land management practices, winter storm water capture and use, dry farming and rain-fed farming that can reduce applied water and increase water use efficiency.

Growers invest in on-farm water management improvements to stay economically competitive. Likewise, local water suppliers invest in cost-effective, system-wide water management improvements in order to provide quality service at a fair and competitive price. In addition to water savings, efficiency measures can provide water quality and flow-timing benefits. The CALFED Program's Quantifiable Objectives (QOs) and Targeted Benefits (TBs) — which can be local, regional, or statewide — are numeric targets that address CALFED objectives of water supply reliability, water quantity, water quality, flow and timing for ecosystem improvements, and other benefits such as energy efficiency. Due to complexity of QO's and lack of technical information on QO's for different CALFED solution regions, DWR, in consultation with CALFED, has increasingly emphasized TBs and has incorporated TBs into its water management planning and implementation efforts as well as emphasizing TBs through the grant program.

Substantial financial support for research, development and the demonstration of efficient water management practices in agriculture comes from the agricultural industry and State and federal efforts. Support also comes from the early adopters of new technology who often risk their crops, soils, and money when cooperating to develop and demonstrate technology innovations. Further investments in research and demonstration are critical, especially in support of university-based research, field station studies, and cooperative extension demonstration projects.

Improvements in agricultural water use efficiency primarily occur from three activities:

- Hardware – Improving on-farm irrigation systems and water supplier delivery systems
- Water management – Improving management of on-farm irrigation and water supplier delivery systems
- Crop water consumption – Reducing non-beneficial evapotranspiration

Hardware Upgrades

Due to water delivery system limitations, growers are often unable to apply the optimal amount of irrigation water. Water delivery system improvements such as integrated supervisory control and data acquisition systems (SCADA), canal automation, regulating reservoirs, and other hardware and operational upgrades, can provide flexibility to deliver water at the time, quantity, and duration required by the grower. At the on-farm level, many old and most new orchards and vineyards, as well as some annual fruits and vegetables, are irrigated using pressurized irrigation systems. Almost all trees and vines established since 1990 are irrigated using micro-irrigation. Between 1990 and 2000, the crop area under micro-irrigation in California grew from 0.8 million to 1.9 million acres, a 138 percent increase (see Table 2-1 and Box 2-2).

Table 2-1 Trends in irrigation method area (in million acres)

Irrigation method	1990		2000		Change from 1990 to 2000	
	Area	% of total	Area	% of total	Percent change in acreage & reduction of area in Million Acres	
Gravity (furrow, flood)	6.5	67	4.9	51	-16%	-1.6 MA
Sprinkler	2.3	24	2.8	29	5 %	+0.5 MA
Drip/micro	0.8	9	1.9	20	11 %	+1.1 MA
Total	9.6	100	9.6	100		

Source: DWR

A recent report (Orang et al., 2008) providing results of a survey of 10,000 growers in California (excluding rice, dry-land, and livestock producers), indicated that between 1972 and 2002, the area planted to orchard increased from 15 to 31 percent and the area planted to vineyards increased from 6 to 16 percent, while the area planted to vegetables remained relatively unchanged. Meanwhile, the area planted to field crops decreased from 67 to 42 percent. The survey also indicates that the land irrigated by low-volume (drip and micro sprinklers) irrigation has increased by about 33 percent while the amount of land irrigated by surface irrigation methods has decreased by about 31 percent.

Box 2-3 Example of Irrigation Efficiency Improvement

Kern County Water Agency reports significant improvements in irrigation efficiency. An analysis of data in 1986 compared to 1975 showed an 8 percent improvement (from 67 percent in 1975 to 75 percent in 1986). This improvement reduced the total applied water use in the San Joaquin Valley portion of Kern County by about 250,000 acre-feet, enough water to irrigate about 70,000 acres. Since 1986 Kern County has added 61,500 acres of trees and vines. These now make up 37 percent of the total irrigated crop area. Nearly all of this new crop area has low volume drip irrigation systems installed. KCWA estimates the overall on-farm water use efficiency now is about 78 percent. Note that the remaining 22 percent constitutes leaching requirement, irrigation system distribution non-uniformity, and cultural practices, which includes both recoverable and/or irrecoverable flows.

Many growers use advanced irrigation systems for irrigation, fertilizer application, and pest management. Advanced technologies include Geographic Information System (GIS), Global Positioning System (GPS) and satellite crop and soil moisture sensing systems. These technologies allow growers to improve overall farm water management.

The use of pressurized irrigation systems, such as sprinkler, drip, and micro-spray, in addition to being energy intensive, often requires modernization of water supplier delivery systems to provide irrigation water at the time, quantity, and duration required by the grower. Increasingly, water suppliers are upgrading and automating their systems to enable accurate, flexible, and reliable deliveries to their customers. Also, suppliers are lining canals, developing spill recovery and tail water return systems, employing flow regulating reservoirs, improving pump efficiency, and managing surface water conjunctively with groundwater. With the advancement of both water supplier and on-farm water management systems, there is potential to improve irrigation efficiencies at both on-farm and water supplier levels.

Growers continue to make significant investments in on-farm irrigation system improvements, such as lining head ditches and using micro-irrigation systems. Many growers take advantage of mobile laboratory services to conduct in-field evaluation of irrigation systems. Once considered innovative technologies, these are now standard practice. In terms of future improvements, the California Polytechnic State University, San Luis Obispo, Irrigation Training and Research Center estimates that an additional 3.8 million acres could be converted to precision irrigation such as drip or micro-spray irrigation. (Burt, et. al, 2002) While this will not reduce crop water consumption, it can improve the uniform distribution of water and reduce evaporation, thus allowing more efficient use of water. Research on drip irrigation of alfalfa has shown an applied water reduction of two to three percent with yields increasing from 19 to 35 percent, an increase in productivity of 30 percent with the same amount of applied water. Conversion of traditional irrigation systems to pressurized systems and installation of advanced technologies on water supplier delivery systems require more investment in facilities as well as use of additional energy that increases farm production costs and water supplier operational costs. The additional cost of such improvements is a challenge for many water suppliers. [California Farm Water Coalition reports, based on industry contacts, that in the six-year period from 2005 through 2008, San Joaquin Valley farmers invested over \\$1.5 billion in high efficiency irrigation equipments.](#)
Bureau

Water Management

Both on-farm and water supplier delivery systems must be managed to take advantage of new technologies, science, and hardware. Personal computers connected to real-time communication networks and local area networks allow transmission of data to a centralized location. These features enable water supplier staff to monitor and manage water flow and to log data. With such systems, the water supplier staff spends less time manually monitoring and controlling individual sites, allowing them to plan, coordinate system operation, and potentially reduce costs. Such systems improve communications and provide for flexible water delivery, distribution, measurement, and accounting.

Some of today's growers use satellite weather information and forecasting systems to schedule irrigation. Many growers employ ET and soil moisture data for irrigation scheduling. Users generate more than 70,000 inquiries per year to the California Irrigation Management Information System (CIMIS), the Department of Water Resources' weather station program that provides ET data. Universities, water suppliers, and consultants also make this information available to a much wider audience via newspapers, Web sites, and other media.

Growers use many other water management practices. Furrow, basin, and border irrigation methods have been improved to ensure that watering meets crop water requirements while limiting runoff and deep percolation. Growers use organic or plastic mulch to reduce non-essential evaporation of applied water, minimize weed growth, and improve crop growth and productivity value. Agricultural Land Stewardship practices (see Chapter 20) also reduce water use and contribute to sound on-farm water management.

Reducing Evapotranspiration (ET)

Evapotranspiration (ET) is the amount of water that evaporates from the soil and transpires from the plant. Growers can reduce ET by reducing unproductive evaporation from the soil surface, eliminating weed ET, and shifting crops to plants that need less water, or reducing transpiration through deficit irrigation. In addition, some growers deficit irrigate their crops during water short periods and for agronomic purposes (see Box 2-3). Management practices such as mulching, use of cover crops, no-till and minimum tillage, and dust-mulching associated with dry farming reduce unnecessary evaporation from soil surfaces. Some of these management/cultural practices have energy conservation components as well.

Box 2-4 Regulated Deficit Irrigation

Some growers use regulated deficit irrigation (RDI) to stress trees or vines at specific developmental stages to improve crop quality, decrease disease or pest infestation, reduce production costs, while maintaining or increasing profits. Conventional irrigation management strategy has been to avoid crop water stress. Research on RDI began in California in the 1990s on tree and vine crops. Initial results show potential for reducing ET while increasing or maintaining crop profitability and allowing optimum production.

Wine grapes are a clear example: Mild stress imposed through the growing season decreases canopy growth, but produces grapes with higher sugar content, better color, and smaller berries with a higher skin to fruit-volume ratio. This is a very common practice in the premium wine regions of California.

RDI has been primarily used as a production management practice and the extent of its application in California, in terms of crops and acreages under RDI, has not been quantified. Before RDI can be applied to other crops, information on its costs, risks, long-term impacts, and potential benefits including water savings must be determined. Once that is done, practical guidelines for growers on how to initiate, operate, and maintain RDI should be developed and disseminated. (See Volume 4 Reference Guide for details on RDI.)

Potential Costs and Benefits of Agricultural Water Use Efficiency

The CALFED Water Use Efficiency Technical Appendix of the CALFED Record of Decision (ROD) estimated the costs and benefits of water savings. The California Bay Delta Authority (CBDA) sponsored a study in 2004 and a more recent study (CALFED Bay-Delta Program, 2006- Water Use Efficiency Comprehensive Evaluation) that both estimated the costs and benefits of water use efficiency. These two estimates are based on different approaches and assumptions. The ROD's potential costs and benefits were based on district efficiency improvements and, assumed on-farm improvements to achieve on-farm efficiency of 85 percent within each hydrologic region and considered total irrigated crop area, crop water use, irrigation system types, applied water, and depletions within each Water Plan planning area. The 2006 CBDA study (and similarly the 2004) study used cost and performance information for on-farm and water supplier improvements to estimate costs, considered various levels of funding and local

implementation, and accounted for quantifiable objectives developed for the CALFED Bay-Delta Program's Water Use Efficiency Element. In addition, it included an estimate of potential water use reduction from implementing a moderate level of regulated deficit irrigation.

Potential Benefits of Agricultural Water Use Efficiency

The ROD estimates of 2000 estimated that efficiency improvements could result in a water savings (reduction in irrecoverable flows, also referred to as net water savings) ranging from 120,000 to 563,000 acre-feet per year by 2030. It was assumed that the achieved 85 percent on-farm efficiency would be maintained afterward. The study also estimated a 1.6 million acre-foot per year reduction in applied water (combined recoverable and irrecoverable flows) that would provide environmental and crop production benefits-

In the Colorado River Hydrologic Region, water use efficiency measures are being driven by the Quantification Settlement Agreement (QSA). QSA projects will reduce irrecoverable flows by 67,700 acre-foot per year (AFY) at a cost of \$135.65 million by lining the All-American Canal, and by 26,000 AFY (at a cost of \$83.65 million) by lining the Coachella Branch Canal, for a total of 93,700 AFY.

Under the QSA, agricultural water use efficiency measures adopted by the Imperial Irrigation District by 2026 will result in a reduction in delivery of Colorado River water to IID of 487,200 AFY (inclusive of 67,000 AFY reduction from the All-American Canal lining).¹ Water conserved under the QSA will not result in new water supplies for California; rather, it provides a portion of the reduction needed for California water users to reduce their use of Colorado River water by 800,000 AFY— from 5.2 to 4.4 MAF per year. (For details, see Volume 3, Chapter 11, Colorado River Hydrologic Region and following Web site: www.usbr.gov/lc/region/g4000/crwda/index.htm.)

Estimates of water savings and benefits resulting from land retirement, crop shifts, crop idling, and reducing crop transpiration through regulated deficit irrigation were not quantified in the ROD estimates.

The 2006 CALFED study, similar to 2004 CALFED study, called the Water Use Efficiency Comprehensive Evaluation (CALFED Bay-Delta Program, 2006) estimated potential water savings ranging from 34,000 to 190,000 af/year of irrecoverable water and 150,000 to 947,000 af/year of recoverable water. These estimates were based on investment levels (costs) ranging \$15 to \$40 million annually (Table 2-2). The Comprehensive Evaluation also provided the maximum water savings achievable at the field and district levels if cost were no barrier. Water savings at this level is called Technical Potential (Projection Level 6). The Technical potential level savings, at an estimated cost of \$1,592,000,000, are 1,819,000 and 4,338,000 af annually for irrecoverable and recoverable water savings, respectively. The Comprehensive Evaluation also described the potential for additional water savings of 142,000 af annually from regulated deficit

¹ The 26,000 AFY (acre-feet per year) Coachella Branch Canal lining is subtracted from CVWD use; however, CVWD will receive conserved water from IID, and over the term of the QSA, its overall consumptive use will increase by 77 KAFY by 2026 and for the duration of the QSA. For details, see <http://www.iid.com/Media/Colorado-River-Water-Delivery-Agreement.pdf> , p 13. Note: IID/MWD transfer has been fixed at 105 KAFY instead of 110 KAFY.

irrigation (independent of investment level). Technical Potential was defined as the savings and cost of 100% adoption of all agricultural water use efficiency actions/measures statewide, and assumed that all technically demonstrated practices would be implemented regardless of cost. Technically demonstrated practices were determined through literature reviews, demonstrated use, and professional experience. The Comprehensive Evaluation estimated water conservation based on on-farm hardware and irrigation management improvements and district improvements. The study did not include potential savings in the Colorado River Hydrologic Region that are already committed to and funded by efficiency conservation water transfer agreements. Nor, as noted above, will these be included in potential agricultural water use efficiency reductions for the state, because they only account for reductions to meet California’s Colorado River water rights.

On-Farm Water Use Efficiency

On-farm water use improvements were analyzed based on natural replacement from lower to higher performing systems over time as well as various state funding levels. Water supplier improvements were based on the implementation of efficient water management practices and various State funding levels². Table 2-2 presents the 2006 Comprehensive Evaluation’s estimates of potential reductions in recoverable and irrecoverable flows at both the on-farm level and at the water supplier level. The cost information in Table 2-2 represents the State’s investment in water use efficiency actions beyond the estimated locally cost-effective actions.

Table 2-2 On-farm and water supplier recoverable and irrecoverable flow reductions
Estimated to be fully realized by 2030*

TABLE 1.1 CBDA ESTIMATES OF 2030 ON-FARM AND DISTRICT AGRICULTURAL WUE POTENTIAL					
Projection Level (PL)	Local Agency Investment Assumption	CALFED Grant Funding Assumption	Recoverable Flows (1,000 acre-feet/year)	Irrecoverable Flows (1,000 acre-feet/year)	Regulated Deficit Irrigation (1,000 acre-feet/year)
1	Historic Rate	Proposition 50 only	150	34	142
2	Locally Cost-Effective	Proposition 50 only	No change in locally cost-effective rate--results same as PL1		
3	Historic Rate	Proposition 50 + \$15 million/year	565	103	142
4	Locally Cost-Effective	Proposition 50 + \$15 million/year	No change in locally cost-effective rate--results same as PL3		
5	Locally Cost-Effective	Proposition 50 + \$40 million/year (2005-14) \$10 million/year (2015-30)	947	190	142
6*	\$1,592 billion annually		4,338	1,819	142

*Projection 6 estimated the technical potential of agricultural WUE. It assumed 100% adoption statewide. Funding assumptions are based on implementation costs and are not divided between local and public funding.

²The potential savings estimated in the Year Four Report are based on a set of specific assumptions about the distribution and effective use of investments in agricultural water use efficiency. See the CBDA Draft Year Four Water Use Efficiency Comprehensive Report for details on those assumptions.
http://www.calwater.ca.gov/content/Documents/library/WUE/2006_WUE_Public_Final.pdf

Source: CALFED Bay-Delta Program. Water Use Efficiency Element. Water Use Efficiency Comprehensive Evaluation. Final Report. (August 2006).

www.calwater.ca.gov/content/Documents/library/WUE/2006_WUE_Public_Final.pdf.

Note: Detailed tables in the 2006 Comprehensive Evaluation included estimates of non-essential evaporation that should have been removed for the final report. The estimates in the summary table (2.2 of the final report) were correct and are duplicated in Table 1.1 here.

A July 2009 report from the Pacific Institute “Sustainable California Agriculture in an Uncertain Future” is another analysis to quantify agricultural water savings. The report estimates potential water savings from 1) efficient irrigation technologies, 2) improved irrigation scheduling, and 3) regulated deficit irrigation, under three statewide hydrologic scenarios, i.e., wet, average, and dry year conditions. The Pacific Institute’s potential water savings are based on an extensive literature review and empirical research documenting water conservation savings with on-farm irrigation technology improvements, irrigation scheduling, and Regulated Deficit Irrigation. The total potential water savings range between 4.5, 5.5, and 5.9 MAF/Y for wet, average, and dry years respectively. The report does not separate its quantitative estimates between recoverable and irrecoverable water savings, thus the potential water savings are applied water savings only. These numbers are comparable to the CBDA Water Use Efficiency Comprehensive Evaluation (2006), which estimates the technical potential savings of 6.15 MAF for irrecoverable and recoverable savings.

Side Box

Inter-relation between On-farm and regional efficiencies and role of water reuse

It should be recognized that saved or conserved water may or may not constitute new water for use for other purposes. Saved water constitutes new water only if it is prevented from evaporation from soil or flowing to salt sinks such as saline surface or groundwater, or ocean. In California, over-application of irrigation water that flows out of a field in excess of crop water requirements provides irrigation water to another field directly via surface water flows or indirectly via groundwater recharge and pumping. Agricultural flows reused for irrigation seldom need treatment. Much of water in the agricultural setting is being used and reused many times over. It is because irrigation water is reused that on-farm efficiency improvements will not result in regional water savings. Also, on-farm efficiency improvements often do not result in water savings for the region due to reuse of irrigation water. Regional efficiencies are, with few exceptions such as drainage problem areas and salt sink areas, always greater than individual field efficiencies. Indeed, reuse of water may be the least expensive mechanism and easily implemented measure to achieve very high regional efficiencies. The extensive reuse of recoverable flows in the agricultural setting also explains relatively small real water savings (which can be used for other purposes) compared with huge amounts of recoverable flows.

Water Supplier Water Use Efficiency

Water use efficiency estimates at the water supplier level are based on cost and performance of supplier management changes and infrastructure improvements. A regional baseline of water supplier improvements was developed by CALFED based on water availability and knowledge of

local delivery capabilities and practices. In addition, it was assumed that all locally cost-effective efficient water management practices would be implemented. The initial investment for improvements was allocated for management changes that provide an improved level of delivery service – mainly through additional labor and some system automation. Higher levels of water supplier delivery system performance would be achieved through infrastructure improvements such as regulating reservoirs, canal lining, additional system automation, and spill prevention.

On-farm water use efficiency estimates are based on cost and performance information for feasible irrigation systems. Depending on crop type, irrigation systems can include various forms of un-pressurized surface irrigation (furrow and border strip), and pressurized irrigation systems (variety of sprinkler and drip). The performance of any irrigation system also depends on how well it is managed. For a given crop, the irrigation system and management will determine the water use characteristics--how much of the applied water is used beneficially and how much is irrecoverable. Irrecoverable flows include those to transpiration, saline sinks and non-beneficial evaporation. In Table 2-2, the reduction in irrecoverable flows at investment level 1 is due to natural replacement of irrigation systems over the horizon of the projections. Recoverable flows encompass surface runoff and deep percolation to usable water bodies. The recoverable flow results in Table 2-2 are based on the Quantifiable Objectives that express instream flow needs for Bay-Delta tributaries. It is important to note that the assumption that all recoverable flows may end up benefiting instream flows may not be valid. Much of efficiency improvements may increase water use as a result of larger plants, higher yields, and increased irrigated acreage. Although recoverable and irrecoverable flow reductions are reported separately for on-farm and water suppliers, it is not appropriate to assign benefits solely to on-farm or water suppliers due to the strong connection between on-farm recoverable flows and water supplier efficiency improvements.

At the water-supplier level, most benefits may occur as a result of managing recoverable flows through return flows and spill recovery systems. However, since recoverable flows, especially surface return flows, are typically being used by downstream farming operations, the location of the water diversion in the basin is critical for determining if implementing a water use efficiency measure would adversely reduce the supply of downstream agricultural water users. Consequently, many consider the reduction of irrecoverable flows (or net water use) a better estimate of potential agricultural water use efficiency.

A primary environmental benefit of water use efficiency actions is the improvement in aquatic habitat through changes in instream flow and timing. Additional benefits may include water quality improvements by reducing thermal loading, subsurface drainage water, and contaminant loads. Growers may provide and/or receive water quality benefits by complying with pollutant reduction rules under the State's total maximum daily load requirements (TMDL). However, depending on the timing of flow changes, improvements in water use efficiency can cause negative environmental effects, such as reduced runoff to downstream water bodies and increased concentration of pollutants in drain water unless the drainage water contaminants (such as selenium) are isolated and properly disposed of. The Quantifiable Objectives flows in Table 2-2 represent the aggregate instream Bay-Delta watershed flow needs that can potentially be met through water use efficiency actions. When comparing the recoverable flows in Table 2-2 to the Quantifiable Objectives flows and Targeted Benefits, it is important to remember that the instream flow needs are location and time specific – thus an acre-foot to acre-foot comparison is not appropriate.

Potential Costs of Agricultural Water Use Efficiency

The CALFED ROD 2000 estimates the cost of 563,000 acre-feet net water savings at \$35 to \$900 per acre-foot. The total cost of this level of agricultural water use efficiency to year 2030 is estimated at \$0.3 billion to \$2.7 billion, which includes \$220 million for lining the All-American Canal and Coachella Branch Canal.³

The CALFED Bay-Delta Program 2006 Water Use Efficiency Comprehensive Evaluation cost estimate for water use efficiency improvements are summarized in Table 2-2. The water supplier improvements are assumed required to achieve on-farm improvements. The irrecoverable flow reduction estimates range from 34,000 to 620,000 acre-feet per year at a cost of \$2.9 million to \$150 million per year, respectively, for on-farm and water supplier level improvements. The WUE Comprehensive Evaluation estimates do not include potential water use reductions in the Klamath Project or Imperial Valley. Efficiencies calculated for this report are lower than the ROD estimates because rice irrigation systems can only achieve about 60 percent efficiency on an individual field basis and rice acreage is significant in certain hydrologic regions (the ROD assumed that irrigation efficiency improves to an average value of 85% in every hydrologic region). Marginal costs of irrecoverable flow reduction are shown in Figure 2-1.

Placeholder: Figure 2-1 Marginal cost of irrecoverable flow reduction

The cost of achieving irrecoverable flow reductions and water use reductions from canal linings will total about \$4 billion, expressed in 2004 dollars. This includes 620,000 acre-feet per year of irrecoverable flow reduction estimated in the Year Four Report (2006) over 25 years (about \$3.75 billion), plus the cost of 94,000 acre-feet per year of water use reductions resulting from lining the All American and Coachella Branch canals (a total of 714,000 acre-feet per year). It should be noted that costs and flow for each investment level identified in Table 2-2 includes costs and water use reductions of all previous investment levels.

The **Comprehensive Evaluation studies of CALFED Bay Delta Program** estimates show increasing statewide average seasonal application efficiency as a function of annual investment (Figure 2-2).

Placeholder: Figure 2-2 Statewide average on-farm seasonal application efficiency at various levels of investment

California's Major Water Use Efficiency Efforts

Beginning in 2000, the State has implemented several cycles of loan and grant programs for water use efficiency improvements. The funds have been through successive competitive Proposal Solicitation Packages (PSP) for projects on a cost-sharing basis for water use efficiency projects that may not be locally cost-effective. The grant cycles are summarized in Table 2-3 below:

³ The cost estimates are derived from potential on-farm and water supplier efficiency improvements associated with savings in irrecoverable flows. Details of estimates and assumptions are in the CALFED WUE Program Plan (Final Programmatic EIS/EIR Technical Appendix – July 2000).

Table 2-3 Projects Funded Through Water Use Efficiency Grant Cycles

Funding source	Projects funded	State share (In millions)
SB 23	23	\$6.0
2001 Prop 13	5	\$0.5
2002 Prop 13	8	\$0.7
2003 Prop 13	0	\$0
2004 Prop 50 Implementation	11	\$6.1
Non-Implementation	16	\$3.9
2007 Prop 50 Implementation	6	\$6.9
Non-Implementation	15	\$2.1
2008 Prop 50*	Funds on hold	\$15
(Prop 204 funds were not for WUE programs)		

*2008 Proposal Solicitation Package is in progress for \$20.3 million for agricultural water use efficiency projects.

Analysis is underway to quantify water savings from Prop 50 (2004, and 2007) grant cycles. It is anticipated that this analysis will be accomplished upon completion of all projects by 2011-12. These projects had a more defined monitoring and verifications requirements to quantify outcomes and results. One difficulty in such an analysis is that grantees report a real water savings along with applied water reduction figures. Quantification of outcomes from previous grant cycles (SB 23 and Prop 13 cycles) have proved more difficult since those grant cycles did not have extensive monitoring and verification efforts built into the projects.

Major Issues Facing Agricultural Water Use Efficiency

Funding

Funds dedicated to water use efficiency have fallen below estimates of the 2000 CALFED Record of Decision that called for an investment of \$1.5 billion to \$2 billion from 2000-2007. The CALFED Framework for Agreement stated that State and federal governments would fund about 50 percent (25 percent each), with local agencies paying for the remaining 50 percent of CALFED water use efficiency activities.

Although the need is great, small and disadvantaged communities may not be able to apply for State and federal grants since they have limited funds. In addition, such water suppliers rarely have the technical and financial abilities to develop plans or implement expensive water management practices. During the last two Prop 50 WUE grant cycles, DWR has made significant effort, and will continue to do so with the Ag WUE 2008 grant cycle, to provide technical and financial assistance to disadvantaged communities.

For some water suppliers, funding for water use efficiency comes from the ability to transfer water, such as in the Colorado River region. While transfers to urban areas may reduce the

amount of water available to grow crops, they are expected to play a significant role in financing future water use efficiency efforts.

Implementation

Implementation of agricultural water use efficiency depends on many interrelated factors. Farmers strive to optimize agricultural profits per unit of land and water without compromising agricultural economic viability, water quality, or the environment. Success depends not only on availability of funds but also on technical feasibility and cost-effectiveness, availability of technical assistance, and ability and willingness of growers, the irrigation industry, and water suppliers. Other factors such as soils and topography, micro-climate, markets, etc. play important roles as well. Opportunities exist to implement efficiency measures beyond efficient water management practices to provide water quantity, water quality, flow and timing, energy efficiency, and other benefits to the growers and local water suppliers and to provide regional or statewide benefits. Comprehensive implementation of efficiency measures must, to the extent possible, include multi-purpose and multi-benefit projects.

Water Conservation Act of 2009, SB 7x-7, requires agricultural water suppliers to develop and adopt a water management plan with specified components, and implement cost-effective efficient water management practices. The Bill requires agricultural water suppliers to submit their water management plan and report, using a standardized form, on which efficient water management practices have been implemented and are planned to be implemented, an estimate of water use efficiency improvements that have occurred since the last report, and an estimate of water use efficiency improvements estimated to occur five and 10 years in the future. The Department is required, in consultation with the board, the California Bay-Delta Authority or its successor agency, the State Department of Public Health, and the Public Utilities Commission, to develop a single standardized water use reporting form to meet the water use information needs of each agency. The Department of Water Resources is required to submit to the Legislature a report on the agricultural efficient water management practices that have been implemented and are planned to be implemented and an assessment of the manner in which the implementation of those efficient water management practices has affected and will affect agricultural operations, including estimated water use efficiency improvements. Also, the Department is required, in consultation with the Agricultural Water Management Council, academic experts, and other stakeholders, to develop a methodology for quantifying the efficiency of agricultural water, use. Alternative to be assessed, shall include, but not limited to, determination of efficiency levels based on crop type or irrigation system distribution uniformity.

Regulated Deficit Irrigation

Reducing ET requires precise application of water. Stressing crops through regulated deficit irrigation (RDI) is one approach that requires careful scheduling and application of water and may have additional costs and adverse impacts on crop quality or soil salinity. RDI long-term studies are underway and results differ by crop, location, and year.

Water Rights

Many growers and irrigation districts are concerned about existing and potential water use efficiency legislation and believe that implementing efficiency measures could affect their water rights. They believe that conserved water may be used by others, causing a loss of rights to the conserved water. This belief may impede implementation of water use efficiency strategies. For example, the conservation efforts of Imperial Irrigation District and funded by Metropolitan Water District of Southern California has resulted in water being transferred to urban uses.

Climate Change

Climate change has significant impact on amount, availability, and timing of water resources. Changes in snow pack (as estimated to be 25 percent less of Sierra snow pack), rainfall pattern and amount of both impacts State's reservoirs and amount of water needed to sustain current level of agriculture. This change is a major challenge to sustainability of agriculture. Results of climate change model analysis indicate that most likely scenario is reduced snow pack and increased rainfall amount. Also, higher levels of temperature, an important component of evapotranspiration, accompanied with higher levels of green house gases, such as CO₂ which is important component of photosynthesis, more likely will increase water use resulting in increased biomass and yields.

Energy and Water Relationship

Relationship between water use and energy use is a direct and linear one. Generally, a reduction in water use in agriculture, also true for any sector of society, results in proportional reduction in energy use. Less water is used to irrigate, less energy is spent to store, transport, pump, and distribute water. Power plants emit GHGs, such as CO₂, in the course of generating and producing energy. Any reduction in energy use reduces green house gas emissions.

However, relationship between water use efficiency and energy use is complex and needs to be thoroughly studied and understood. Improved agricultural water use efficiency may or may not be a mitigating strategy - to reduce energy use and thus reduce GHGs - because of complex relationship between greenhouse gas emissions, the use of energy, use of natural gas, and the use of fossil fuel. It appears that decreased use of one resource through implementation of efficiency measures, increases use of another resource which may neutral or greatly impact net outcome, and often may have overall adverse effects than intended or desired. Not enough studies and research has been conducted to quantify relationship between water use efficiency and energy use.

On-farm and water supplies water use efficiency improvements often require additional energy. Conversion of furrow irrigation to drip or sprinkler would require significant energy, even though growers and/or water suppliers may pump less water which then may reduce energy use. Yet, the overall result of such efficiency practice may be a net increase of energy use. Water supplier infrastructure improvements and the increasing use of pressurized irrigation systems by growers require additional energy resources such as electricity, gas, and diesel. Pressurized systems also require pipelines, pumps, filters and filtration systems; chemicals for cleaning drip systems; and replacement and disposal of the hardware after their useful life. **Consequently, significant additional energy is required for manufacturing of pipelines, pumps, filters and filtration systems, chemicals, replacement and disposal of the hardware.** Likewise, pressurized irrigation systems will need energy to produce required pressure in the pipelines for irrigation. Such additional energy will significantly increase GHG contributing to climate change. **Within the agricultural setting, net impact of reduced water use and increased water use efficiency on the energy use and consequently on net GHG emissions calls for study and quantification of such impacts.**

Other Implementation Issues

Other water use efficiency implementation issues that need to be evaluated include 1) concerns over groundwater impacts, overdraft, and loss of recharge, 2) increase in the vulnerability of trees and vines to hardening of demand, and 3) unpredictability of changing climate. Climate change is expected to impact water use since rising temperature will result in higher ET and higher crop water use requirements.

Measurement and Evaluation

Lack of data, mainly farm-gate irrigation water delivery data, is an obstacle for assessing irrigation efficiencies and planning further improvement. The State lacks comprehensive statewide data on cropped area under various methods of irrigation, applied water, crop water use, irrigation efficiency, water savings, and the cost of irrigation improvements per unit of saved water. Collection, management and dissemination of data to growers, water suppliers, and water resource planners are necessary for promoting increased water use efficiency. A concern identified by some members of the California Water Plan Advisory Committee is a lack of statewide guidance to assist regions and water suppliers to collect the data needed for future Water Plan Updates in a usable format.

The Independent Panel on the Appropriate Measurement of Agricultural Water Use (www.Calwater.ca.gov) convened by the CBDA made specific recommendations for measurement of water supplier diversions, net groundwater use, crop water consumption, and aggregate farm gate deliveries. In addition, the panel recommended increased efforts to measure water quality, return flows, and stream flow. As a result, AB 1404 - Water Measurement Information - was signed into the Water Code, requiring agricultural water suppliers to submit water use measurement reports to the Department. Agricultural water suppliers supplying 2000 or more acre-feet of surface water annually for agricultural uses or serving 2000 or more acres of agricultural lands are required to submit the report. The law requires these suppliers to submit annually a report that includes aggregated farm-gate delivery data on a monthly or bimonthly basis. Farm-gate delivery data is the volume of water delivered from the supplier's distribution system to its customers, measured at the point where the water is delivered. DWR is in the process of developing the report format and schedule.

Education and Training

Improving agricultural water use efficiency depends on disseminating information on the use, costs, benefits, and impacts of technologies and on providing incentives for implementation. Existing evidence, although limited, indicates a strong response to financial incentives. In addition, while the Water Code provides certain water rights protections and incentives to conserve water, reaffirming and reinforcing such mechanisms could significantly improve results statewide. Education and training programs can emphasize the potential benefits and risks of efficiency improvements; for example, soil sustainability from a salinity stand point, energy impacts and so forth.

Dry-Year Considerations

In dry years, California's water supply is inadequate to meet its current level of use, and agriculture often is faced with a reduction in water deliveries. Growers are compelled to reduce irrigated acreage to cope with the lack of water and implement extraordinary water use efficiency or even land fallowing. While agricultural water suppliers deal in a variety of ways with water shortages and droughts, there is a need for an Agricultural Drought Guidebook.

Recommendations to Achieve More Agricultural Water Use Efficiency

The following recommendations can help facilitate more agricultural water use efficiency:

Funding

1. The State should identify and establish priorities for grant programs and other incentives. This should include a process for quantifying and verifying intended benefits of projects receiving State loans and grants. Priority funding may be for technical, planning and financial assistance to improve water use efficiency including implementation, monitoring, and reporting of certain programs for specific geographic areas of the state, or priority funding for projects that are not only cost-effective efficient water management practices (EWMPs), but also are part of the Integrated Regional Water Management Plans. Likewise, projects that include clear and well defined Targeted Benefits (including water quality, flow and timing, energy conservation, and overall environmental benefits) may be given high priority.
2. The State should cooperate with a broad section of the agricultural community, including representatives of small farms and disadvantaged farmers and communities, to fund research, development, demonstration, monitoring and evaluation projects that improve cost-effective agricultural water use efficiency and support programs that encourage the development of new cost-effective water savings technologies and practices. In the case of RDI, research is needed to evaluate the level of current practices, extent of implementation of these practices, and quantification of RDI benefits and short and long-term impacts of RDI on plant longevity and productivity.
3. State loans and grants should provide ample opportunities for small water suppliers and economically disadvantaged communities, Tribes and not-for-profit community-based organizations to benefit from technical assistance, planning activities, and incentive programs based on environmental justice policies.
4. The State should provide additional funding for long-term evapotranspiration (ET) reduction (regulated deficit irrigation, mulch, alfalfa dry down, etc.) demonstration and research plots and fund other promising programs to reduce ET.

Implementation

5. The Department, in cooperation with the Agricultural Water Management Council, should work to develop legislative requirements for a uniform and comprehensive process for all California water suppliers, enabling them to develop Water Management Plans (WMP) and implement all cost-effective Efficient Water Management Practices.
6. The Department, in cooperation with the Agricultural Water Management Council, should develop Targeted Benefits specific to different hydrologic regions of California. Targeted Benefits include improvements in water quality, flow and timing, and energy conservation.
7. The Agricultural Water Management Council should continue to incorporate Targeted Benefits within the agricultural water management planning and implementation process, where applicable, in addition to quantifying other benefits of improved water efficiency, including water supply, water quality, energy efficiency, and crop yield benefits.
8. The Agricultural Water Management Council, in cooperation with the Department, should revise and expand the existing Efficient Water Management Practices listed in the

Memorandum of Understanding (1999) Regarding Efficient Water Management Practices by Agricultural Water Suppliers in California.

9. The Agricultural Water Management Council should continue to encourage more water suppliers to sign the Memorandum of Understanding to broaden its base of support. The Council should seek the support of the State and local agencies, as articulated in the MOU, for full implementation of efficient water management practices by signatories and encourage the addition of new efficient practices as benefits are identified.
10. The State should clarify policy and improve incentives, assurances, and water rights protections to allay fears over the loss of water rights resulting from improved water use efficiency.
11. Encourage rate structures for billing by volume of delivered water that improve water use efficiency. AWMC's report "Efficient Water Management, Irrigation District Achievements" state that 89 percent of farmers in the irrigation district survey area pay for water based on the volume of water received. AWMC should emphasize the pricing and billing practice as defined in the Ag MOU and provide additional technical assistance to water suppliers in implementing and further improving this practice.
12. The State should verify and clarify in its programs, especially loans and grant programs, that efforts to conserve water do not alter water rights.
13. The Department should fully implement the provisions of SB7x-7 regarding review of agricultural water management plans, prepare required reports to the Legislature, and evaluate and update agricultural efficient water management practices.
14. The Department should develop, in consultation with the board, the California Bay-Delta Authority or its successor agency, the State Department of Public Health, and the Public Utilities Commission, to develop a single standardized water use reporting form to meet the water use information needs of each agency.
15. The Department should develop, in cooperation with States educational institutions, SWRC Board, AWMC, and other stakeholders, a methodology and criteria for evaluation and quantification of agricultural efficiency improvements such as quantification of on-farm irrigation system distribution uniformity improvements. This may be achieved through establishment of Mobile Labs for evaluation of irrigation system distribution uniformity.
16. The Department should develop, in cooperation with SWRC Board and stakeholders, a standard from that agricultural water suppliers use to provide monthly farmgate water deliveries.

Data Measurement and Evaluation

17. The Department should create a statewide system of water use monitoring data available to all users.

18. The State should expand water-efficiency information, evaluation programs, and on-site technical assistance provided through Agricultural Extension Services and other agricultural outreach efforts.

19. The State should improve in-line data collection and dissemination networks to provide farmers with immediate meteorological and hydrological information on climate, soil conditions, and crop water needs.

20. The State should collect, manage and disseminate statewide data on the cropped area under various irrigation methods, amount of water applied, crop water use, and the benefits and costs of water use efficiency measures. Develop statewide guidance to assist regions and water suppliers to collect the type of data needed in a form usable for future Water Plan Updates. DWR should work with the AWMC to develop a database of information from the Water Management Plans on water use-related data, and information generated from implementation of AB 1404. AB 1404 requires water suppliers to report to the Department aggregate farm-gate delivery data on a monthly or bimonthly basis, for dissemination and use in the Water Plan Update. DWR should work with CBDA to implement the recommendations of the Independent Panel on the Appropriate Measurement of Agricultural Water Use.

21. The State should cooperate with the agricultural community to develop methods to quantify water savings and costs associated with hardware upgrades, water management, and ET reduction projects identified in this strategy.

22. The State should incorporate in its definitions of “efficiency measures”, and “cost-effectiveness” ownership and operating costs, including labor, energy, and cost of maintenance.

23. The State should develop performance measures for water use efficiency goals and inform the public and stakeholders of accomplishments toward those goals. These performance measures should be updated to reflect new findings and changing conditions.

24. The Department should establish on-farm irrigation system evaluation program, such as Mobile Labs, statewide. The irrigation system evaluation program provides valuable assistance to growers to further improve the performance of their irrigation systems, and help quantify changes in such performance as a measure of efficiency improvements.

25. The Department should prepare reports on results of efficiency improvements in irrigation systems to the Legislature and public.

Education and Training

26. Expand CIMIS (including use of remote sensing technology, satellite imagery, etc.) mobile laboratory services and other training and education programs to improve distribution uniformity, irrigation scheduling, and on-farm irrigation efficiency, as well as improvements in pumping system efficiencies, remote control technologies and telemetry, canal automations, flexible water delivery systems, and irrigation system design.

27. Based on long-term ET reduction studies and research, DWR should develop informational guidelines that define the crop water consumption reduction practices, identify how they can be implemented for each crop, and estimate the potential crop benefits and impacts, water savings, and costs for growers and water suppliers.

28. Develop community educational and motivational strategies for conservation activities to foster water use efficiency, with the participation of agricultural and water industries and environmental interests. Develop partnerships with State, federal, UC Cooperative Extension Service, farm advisors, irrigation specialists, and State educational and research institutions to provide educational, informational, and training opportunities to growers, water supplier staff, and others on the variety of available water and irrigation management practices, operations, and maintenance techniques.

29. State partnership with other entities. The State should explore and identify innovative technologies and techniques to improve water use efficiency and develop new water use efficiency measures based on the new information. Consider fast-track pilot projects, demonstrations, and model programs exploring state-of-the-art water saving technologies and procedures, and publicize the results widely. Foster closer partnership among growers, water suppliers, irrigation professionals, and manufacturers who play an important role in research, development, manufacturing, distribution, and dissemination of new and innovative irrigation technologies and management practices.

30. Initiate State collaboration with county governments to offer tax credits for installation of more efficient irrigation systems.

31. Incorporate a comprehensive educational, informational, and awareness element regarding sustainability of consumption of local products in the water use efficiency programs for growers, water suppliers, post-harvesting processors, consumers, and others. Encourage reduction of long distance transportation of commodities and importation of commodities and thus, reduce energy use and greenhouse gas emissions.

Dry-Year Considerations

32. The Agricultural Water Management Council, in cooperation with the Department and others, should compile measures currently in use by growers and water suppliers to deal with water shortages and droughts and develop a comprehensive Agricultural Drought Guidebook as a storehouse of information and procedures for drought mitigation, including new and innovative methods.

33. Review and adopt standard water use efficiency approaches to meet water needs during dry years. New approaches should be explored such as alfalfa summer dry-down and regulated deficit irrigation to cope with water shortages.

34. Drought water management should be fully incorporated in Agricultural Water Management Plans.

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